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Organizational Culture in Systems Engineering Adoption

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ORGANIZATIONAL CULTURE IN SYSTEMS ENGINEERING ADOPTION

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ABSTRACT

While Systems Engineering adoption within the construction industry has increased over the past decades in response to growing complexity, stakeholder diversity and lifecycle performance needs, the successful implementation of it remains inconsistent. Despite its theoretical maturity and proven benefits in multiple sectors, there are several factors that could counteract the outcome. Literature suggests that one of the most critical yet underexplored determinants of adoption is organizational culture. This thesis therefore investigates *how organizational culture influences the successful adoption of Systems Engineering practices in construction projects.*

The graduation project addresses this research question using two methods: literature review and semi-structured interviews. Initially, the extensive literature review was performed to create the foundation for understanding theories related to organizational culture and systems engineering. Then to collect as many contributing factors to successive outcomes but also cultural enablers and constraints and their field of impact offering a comprehensive overview. This study supports that successful SE adoption should be monitored across four interrelated dimensions: lifecycle-wide application of SE processes, effective execution of core technical practices (requirements management and verification & validation), organizational embedding, and realization of tangible and perceived benefits. The literature review was followed by empirical research focused on the large-scale IJmuiden Ver Alpha onshore substation project. Semi-structured interviews with professionals helped identify the underlying beliefs, norms, and patterns that individuals perceive within their organization, while also capturing their practical insights into strategies for improving how systems engineering is enacted. Based on this synthesis, multi-level improvement strategies are proposed, addressing leadership alignment, strategic embedding, competence development, motivation, and the cultivation of supportive and learning-oriented cultural attributes.

In addition, the theoretical and empirical findings were synthesized into the development of a framework in the form of a Causal Loop Diagram that models the dynamic interdependencies between organizational culture and systems engineering adoption. It illustrates reinforcing and balancing feedback loops that explain how cultural conditions can either strengthen or weaken the institutionalization of systems engineering. The resulting framework highlights both the academic and practical relevance of the study by offering a systemic perspective on where organizations should intervene, identifying key leverage points for action while encouraging continuous monitoring of system behavior over time. The framework is expected to support systems engineering adoption in organizations by emphasizing that successful implementation requires not only technical and procedural capabilities, but also cultural awareness and transformation.

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LIST OF ABBREVIATIONS

The following list of abbreviations is used throughout the document.

(CLD): Causal Loop Diagram
(CVF): Competing Values Framework
(IPT): Integrated Product Teams
(OC): Organizational Culture
(OPM3): Organizational Project Management Maturity Model
(PG): Project Governance
(RA): Requirement Analysis
(SA): Systems Analysis
(SD): Systems Dynamics
(SE): Systems Engineering
(TA): Thematic Analysis
(V&V): Verification and Validation

1. Introduction

System Engineering is an interdisciplinary approach that enables the realization of successful systems by identifying stakeholder needs, translating them into formal requirements and guiding the design & development process to deliver integrated solutions (Incose, 2023). It provides structured methods to address complexity and align stakeholder needs with system capabilities. The purpose of SE is to ensure that the right system is developed efficiently, operates as intended in its environment and continues to meet user needs over time. It is especially valuable in reducing project risk, improving quality while ensuring traceability and validation throughout the development process (Incose, 2023). The Dutch guideline Leidraad voor Systems Engineering (2013), highlights SE's growing importance in the public and private sector to improve collaboration, quality assurance and lifecycle performance. For over than twenty years Rijkswaterstaat and other public clients has been developing SE in partnership with the market and knowledge institutes to make infrastructure projects more manageable and transparent. According to Watson (2019), SE principles are not specific to any single system type or life cycle phase but rather offer universal guidance for making informed decisions in complex environments. In practice, SE is increasingly supported by digital tools such as Relatics, which enable systematic information management for interface control and requirement tracking. Despite its theoretical maturity, it often faces implementation challenges in practice, as organizations may adopt the language of systems thinking without fully embedding its methods into their processes. These challenges are frequently compounded by organizational culture, which can either support or hinder the integration of principles (Kossiakoff et al., 2011).

The purpose of this chapter is to provide background information about the rationale behind this graduation project. In the following sections the problem statement, the main research question and sub-questions, the research objectives and thesis outline are elaborated respectively.

1.1 Problem Statement

Modern construction projects are increasingly complex, involving multiple disciplines, numerous stakeholders and demanding performance, sustainability and lifecycle requirements (Cusumano et al., 2024). In this context, the adoption of SE practices offers considerable potential. Several studies have demonstrated that applying a systems engineering approach enhances requirement traceability, interdisciplinary integration and the overall project effectiveness & outcome. However, while SE has been successfully embraced in sectors such as aerospace and defense, its adoption in the construction industry remains limited and inconsistent.

A key reason for this inconsistency lies in the OC within which SE practices are introduced. Studies have shown that various factors influence the performance of systems engineers, with one of the most critical being the organizational context in which they operate. Yet, few studies have explored how OC, governance, structure and workforce composition affect the effectiveness of SE (Hutchison et al., 2019). Because SE requires a shift from solution-driven to integrated, function-oriented and lifecycle-based thinking, organizations must undergo substantial cultural transformation to support its principles (Buck et al., 2013). Moreover, differences in organizational structure and culture significantly influence how development and operational information flows from designers to the overall design process. Large system development projects are often socially, technically and culturally diverse and this complexity increases further when multiple companies are involved. In such settings, determining what

information to share and how to share it becomes increasingly challenging. Therefore, systems engineers must understand how organizational structure and culture shape the flow of system-related information (Watson, 2019).

Research also indicates that these organizational transitions are frequently met with internal resistance, particularly when SE practices are perceived as disruptive to existing roles, responsibilities and way of working. Implementing SE therefore requires transformation not only in processes and roles but also in organizational structures and cultural dimensions (Bretz et al., 2019). Many failures in SE result from overlooked warnings, incorrect unit conversions, or simple lapses in attention. This raises the question of what kind of project culture could significantly enhance attentiveness to the numerous small but important everyday details (Greene, 2013). The implementation of SE within contracting organizations varies considerably across disciplines and operational divisions, resulting in multiple interpretations of what SE entails in practice. Successful implementation can occur only when the key factors influencing this success are clearly identified and managed. However, these critical success factors for SE adoption in the civil construction industry remain poorly understood. Furthermore, management approaches that succeed in one project may not be effective in another due to the unique characteristics of each construction project. These variations are often influenced by organizational culture, as differences in shared values, communication norms and attitudes toward collaboration strongly affect how SE principles are interpreted and applied across projects (Van den Houdt & Vrancken, 2013).

Despite the recognized importance of culture, the relationship between OC and SE adoption remains insufficiently explored within the construction industry and needs further investigation. Consequently, the purpose of this graduation project is to propose an integrated framework that addresses this gap for improving SE successful implementation.

1.2 Research Main Question & Sub-questions

Based on the problem statement, the main research question of this graduation project is shaped as follows:

MRQ: *How does organizational culture influence the successful adoption of Systems Engineering practices in construction projects?*

Meanwhile, to answer the main research question, the following sub-questions need to be addressed first:

RSQ1: *What constitutes successful adoption of Systems Engineering in the context of construction projects?*

The aim of this sub-question is to identify and define the key criteria, contributing factors and dimensions that characterize successful implementation of SE practices in construction projects based on literature.

RSQ2: *What types of organizational culture are most relevant to the adoption of Systems Engineering practices?*

The aim of this sub-question is to identify, describe and understand the specific types of OC that are most influential and mainly positive in enabling the adoption of SE practices as identified in the literature.

RSQ3: *What organizational culture factors, identified from empirical findings, enable or constrain the adoption of Systems Engineering practices?*

This sub-question aims to identify the internal conditions within the organization, the perceptions of "how work is done" (e.g. leadership, collaboration, culture, mindset) that support or limit SE practices as established within the project context.

RSQ4: *Which improvement strategies contribute to the successful implementation of Systems Engineering in the construction project as retrieved from empirical findings and literature?*

The aim of this last sub-question is to identify practical improvement strategies that strengthen the OC in ways that support a more effective implementation of SE in the construction project but also the organization. It focuses on translating cultural insights into actionable recommendations for internal practice.

1.3 Research Objectives

This graduation project has three main objectives that are elaborated in *Table 1*. All together guide the investigation of OC and its influence on SE implementation. The objectives progress from establishing a theoretical foundation, through empirical exploration of SE practice in a complex construction context, to the synthesis of theoretical and empirical findings into a conceptual framework in the form of a Causal Loop Diagram. Below the table summarizes the research objectives, their corresponding goals and the methods applied to address each one of them.

Table 1: Research objectives

Objective	Goal	Method
1. Theoretical foundation	• Review existing literature to define key concepts related to SE and OC. • Explore the successful dimensions that contribute to SE implementation. • Identify the cultural profiles (CVF) that support SE adoption.	• Desk research (literature review)
2. Empirical exploration on SE	• Empirically identify how SE is implemented in a highly complex construction project and capture common organizational and cultural patterns. • Gain in-depth insights from professionals regarding organizational culture, managerial practices and their influence on SE adoption and effectiveness.	• Case study research • Semi-structured interviews
3. Synthesis and framework development	• Synthesize findings from theory and practice developing a conceptual framework in the form of CLD. • Map them with CVF types as a base to identify the OC conditions under which are likely to arise. • Develop the Causal Loop Diagram to show the interdependencies between the variables. • Provide practical recommendations for improving SE implementation in the construction industry.	• Single-case analysis • Synthesis between literature & empirical findings

1.4 Thesis Outline

To reach these objectives, the graduation project is divided into three phases as illustrated in *Figure 1*. In the start of this graduation project (Phase I), a literature review is conducted on SE and OC to fulfill the first research objectives, as presented in *Table 1* and to provide an answer to the first and second sub-questions (Chapter 2 & 3). In addition, this desk research places particular emphasis on establishing foundational knowledge about SE and identifying the key parameters that lead to the successful implementation of it in the construction industry, along with the cultural frameworks applicable in the context of this thesis and the cultural types to address the literature based sub-questions.

In Phase II, semi-structured interviews were conducted with professionals involved in the selected case study in collaboration with WSP Nederland (Chapter 4). These interviews aimed to verify and expand the findings from the literature review by identifying additional organizational, cultural traits and strategies related to SE processes and retrieved from the daily workflows of professionals. The collected insights provide input for answering sub-questions 3 & 4 (Chapter 5). In addition, the findings from both literature and practice were synthesized to develop a framework, in the form of CLD that links OC and SE interdependencies as an observable tool to address the main research question (Chapter 6).

The combined findings from Phase I (Theory) and Phase II (Practice) form the basis for the final conclusions and recommendations presented in Phase III (Conclusion). Chapter 7 presents the validation feedback following from Chapter 8 & 9 presenting the discussion on relevant topics, the limitations of the study, the recommendations for future research and conclusions. The project is concluded with a personal reflection on the research process.

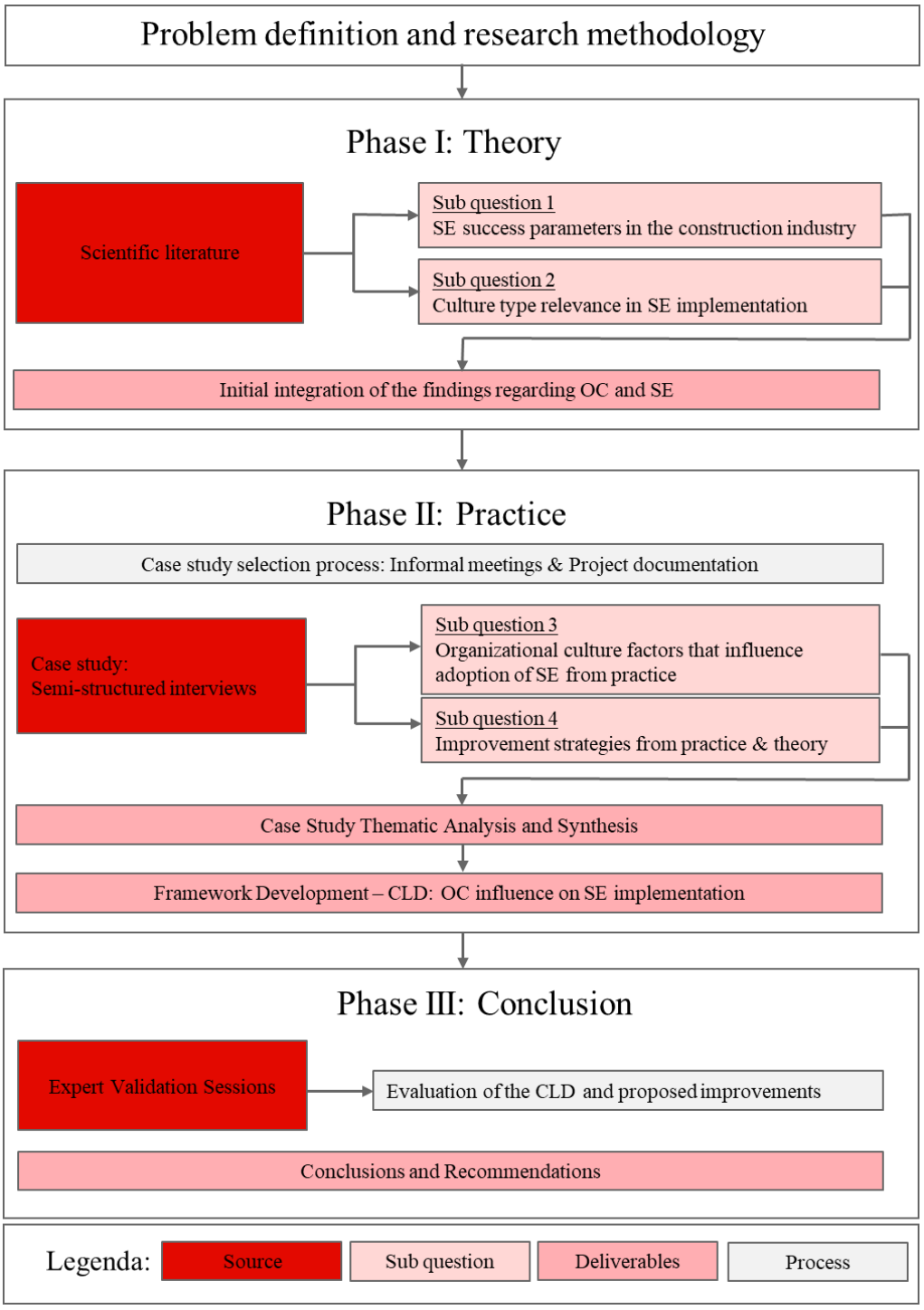

Figure 1: Schematic overview of the research approach

2. Literature Review: Part A

Chapter 2 lays the theoretical foundation of this research by examining the key concepts and principles that underpin the adoption of SE within the construction industry. This part of the literature review focuses specifically on the SE domain, exploring how it is defined and how its main processes are structured. Section 2.1 introduces the fundamental definitions of SE, followed in Section 2.2 by an overview of the processes that guide the system's life cycle. Section 2.3 discusses the intended goals and added value of SE, while Section 2.4 examines its role in enhancing integration within civil engineering projects. Emphasis is placed on the Dutch context in Section 2.5, where SE has become increasingly embedded in infrastructure development. Finally, Section 2.6 & 2.7 explore how the management, organizational environment and broader project context influence SE implementation. Together, these sections establish the essential background needed for addressing the first sub-question, introduced in Section 2.8, which seeks to identify and define the indicators and dimensions that characterize the successful implementation of SE practices in construction projects based on the existing literature.

2.1 What is System Engineering?

Our world, and the systems developed within it, are becoming increasingly complex and interconnected. SE offers an integrative framework that enables teams to collaborate effectively in managing this complexity and in delivering successful outcomes. Grounded in systems thinking, it emphasizes awareness of wholes and the relationships among their constituent parts. The central aim is to ensure that all elements function together in pursuit of the system's objectives (Incose, 2023). However, due to its wide range of applications, the scope and paradigms of SE are not easily identified, which often results in ambiguity and differing interpretations of its universal definition and related concepts. Consequently, the understanding of SE may vary across fields and domains of application (Hossain, 2018). There are numerous definitions in literature; however, some have become widely cited and authoritative such as:

The International Council of System Engineering (Incose, 2023) that defines as follows:

"System Engineering is a transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods."

The Department of Defense USA (Office of the Deputy Director for Engineering, 2022) defines system engineering as follows:

"System engineering is a methodical and disciplined approach for the specification, design, development, realization, technical management, operations, and retirement of a system. A system is an aggregation of system elements and enabling system elements to achieve a given purpose or provide a needed capability."

Wikipedia defines Systems Engineering as:

"An interdisciplinary field of engineering and engineering management that focuses on how to design, integrate, and manage complex systems over their life cycles. At its core, systems engineering utilizes systems thinking principles to organize this body of knowledge."

The interpretation of SE varies according to an individual's disciplinary background and professional experience (Blanchard, 2016). Despite the variations, most definitions of it converge on a few key elements: it is interdisciplinary, top-down and life-cycle oriented, it is requirements-driven and integration-focused. In addition, SE carries the responsibility of delivering systems that are *fit for purpose*, meaning that, systems that successfully achieve their intended objectives, remain resilient under real-world operating conditions, and limit unintended outcomes, adverse effects, or unforeseen consequences (Incose, 2023).

2.2 System Engineering processes

In the context of increased globalization, international standards have become crucial in enabling trade and ensuring that products and services meet accepted requirements for performance and safety. More organizations are adopting these standards and guidelines (Xue & Esteban, 2017). One of the most widely applied is the ISO/IEC/IEEE 15288, which provides a common framework of process descriptions for the life cycle of human-made systems. In this context, a process can be understood as a structured set of activities and tasks carried out to achieve specific outcomes for a defined purpose. Within SE, life cycle processes function as key enablers, supporting the management of system solutions across all project stages.

This standard outline a set of processes and associated terminology from an engineering perspective (NEN, 2015). In total, thirty processes are defined and grouped into four categories:

- Agreement processes
- Organizational project-enabling processes
- Technical processes
- Project processes

These processes can be applied simultaneously, repeatedly and recursively throughout the system's life cycle, but must be tailored to the specific context of the industry in which they are used (Van den Houdt & Vrancken, 2013). Collectively, these processes have been found to provide the foundation needed to successfully implement SE, by ensuring a structured, integrated and systematic approach to the development and management of complex systems.

The SE life cycle is composed of several critical phases that guide a project from its initial conception through to completion and eventual retirement. Each stage plays a key role in ensuring that the final system fulfills its intended purpose. Within this framework, the sequential approach emphasizes an ordered progression of activities, organized into linear stages where each step depends on the outputs of the previous one. Originally visualized by Forsberg and Mooz in the mid-1990s and first formally illustrated in 2005, the Vee-model has since become one of the most cited representations of the SE life cycle.

The Vee-model, named after its characteristic V-shape, serves as a widely used conceptual framework for explaining and visualizing the complete development and realization of a system. It highlights the application of SE principles across all stages of the life cycle (Van Son, 2013). A particular strength of this approach lies in its ability to align development and testing activities, ensuring that each specification corresponds directly with a matching validation activity (Incose, 2023).

Moreover, the model emphasizes the importance of continuous stakeholder validation, the early definition of verification plans during requirements development and the ongoing assessment of risks and opportunities throughout the project.

The model further illustrates how a system design is progressively decomposed into smaller subsystem and component designs. These components are then manufactured or procured, integrated into subsystems, and ultimately assembled into the final product. At each level of decomposition, verification and validation activities are performed to confirm that the elements meet their defined requirements. While the conceptual V provides valuable insight into the Systems Engineering methodology, moving from top-down design to bottom-up integration, its use in practice can present challenges. When employed to represent the specific details of a project, whether during planning, execution or retrospective review, the diagram can quickly become overcrowded, making it difficult to interpret effectively (Sutherland et al., 2015).

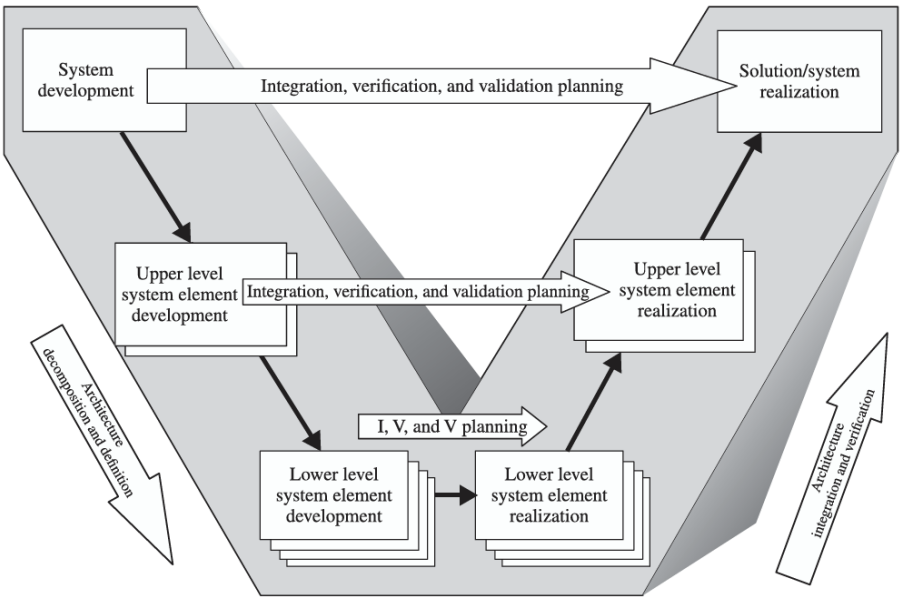

Figure 2: The simplified SE Vee model (Fosberg et al., 2005)

In the civil construction industry, the primary SE processes are represented through a V-model, as illustrated in *Figure 2*, which outlines the system life cycle across six distinct phases. Within this framework, Requirement Analysis and Verification & Validation are recognized as the two core activities of SE in this sector.

During the RA phase, the client translates its needs into specific client requirements, which the contractor then uses to develop an optimal solution to the problem at hand. To fully benefit from the application of SE, a high degree of design freedom is essential. This degree of freedom largely depends on the extent to which the client's requirements are defined in terms of functionality. However, client requirements are often incomplete, inconsistent or ambiguous. Therefore, further analysis by the contractor is necessary to refine these high-level requirements into SMART (Specific, Measurable, Acceptable, Realistic and Time-bound) requirements (Slegers et al., 2012). The decomposed requirements must always be traceable to the original high-level requirements and aligned between client and contractor in order to avoid unintended outcomes.

Although the terms verification and validation appear frequently, they are often used in place for one another, with little clarity about their specific context. As a result, the concepts are sometimes applied to convey very different intentions, leading to frequent misunderstandings of their true meaning (Ryan & Wheatcraft, 2017). The definitions according to ISO/IEC 15288 (2015), are provided as follows:

- Validation: *"confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled [ISO 9000: 2000] NOTE Validation in a system life cycle context is the set of activities ensuring and gaining confidence that a system is able to accomplish its intended use, goals and objectives."*
- Verification: *"confirmation, through the provision of objective evidence, that specified requirements have been fulfilled [ISO 9000: 2000] NOTE Verification in a system life cycle context is a set of activities that compares a product of the system life cycle against the required characteristics for that product. This may include, but is not limited to, specified requirements, design description and the system itself."*

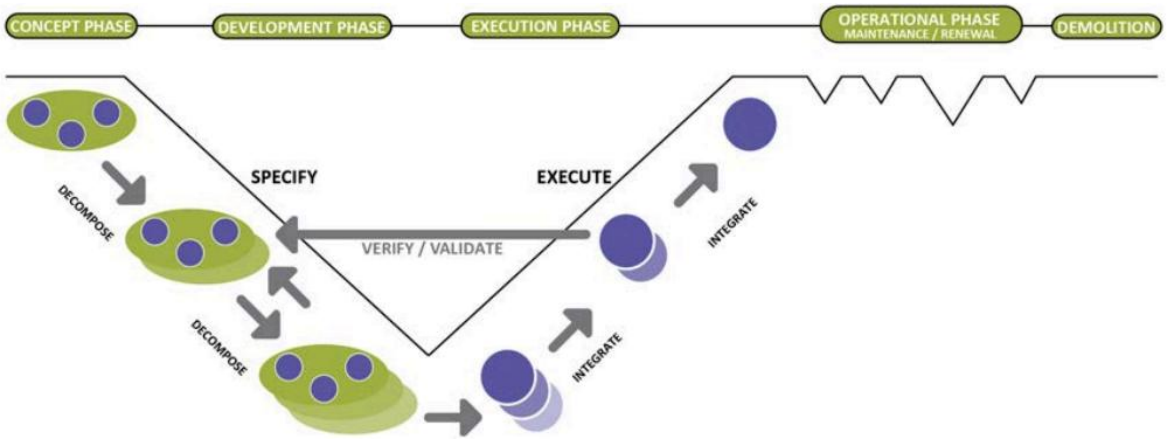

Figure 3: The V-model and life cycle of a civil construction project (Van den Houdt, 2013)

2.3 Intended goal of System Engineering

The primary aim of SE is to ensure that the right product or service is conceived, developed, produced, supported and eventually retired within agreed budget and schedule constraints. Achieving this requires more than just technical design; it depends on building a shared understanding of the system's current state and a common vision of its future, while translating stakeholder needs, expectations and constraints into a viable solution (Incose, 2023). This role becomes especially critical in complex environments, where systems are composed of many interdependent components or subsystems that may be managed separately, increasing both risks and challenges.

Over time, SE has also become more flexible and efficient by adding new methods, such as agile approaches, modeling languages like Systems Modeling Language (SysML) and Model-Based Systems Engineering (MBSE). These tools help teams handle complexity, share a common vision and design systems more effectively. Since the introduction of SE, it has been the focus of extensive research and scholarly discussion across various organizations.

Among these efforts, a 2001 study by the INCOSE Systems Engineering Center of Excellence (SECOE), involving practitioners, managers and executives, revealed a measurable link between the level of SE investment and overall program performance. The data showed that optimum SE is around 15%-20%, and so that increasing the level and quality of SE has positive effect on cost compliance and schedule overruns while improving quality. On the contrary, insufficient or low-quality SE effort can diminish project effectiveness; is also true (Honour, 2004). Even the very good results further research was made to qualify the Return on Investment (ROI) of SE activities on overall project cost and schedule (Honour, 2010).

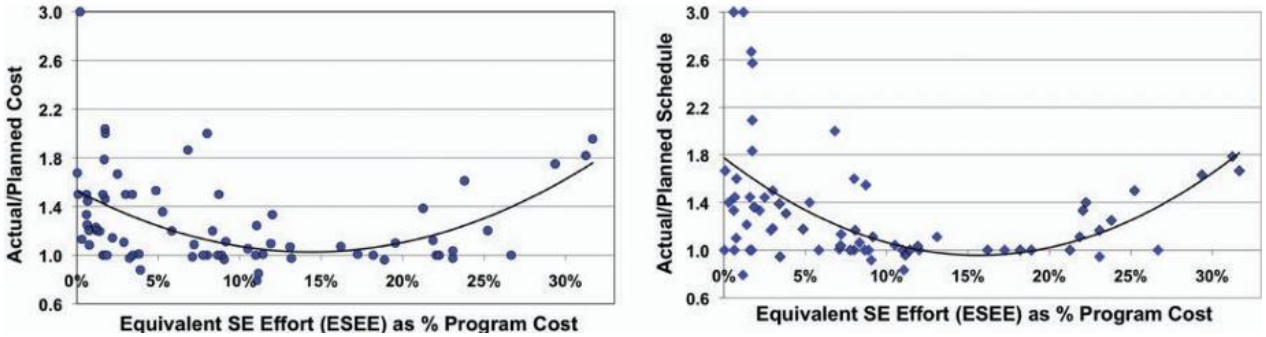

Figure 4: Cost and schedule overruns correlated with SE efforts (Honour, 2010)

The *Figure 4* above compares the total SE effort with project compliance and schedule performance. In both cases, the data indicates that increasing SE effort is positively associated with improved outcomes up to an optimum level. Above this threshold, however, the return on SE investment diminishes, as excessive expenditure on SE activities can lead to inefficiencies and unnecessary processes. Empirical results demonstrate that SE effort exerts a statistically significant and quantifiable influence on project success, with correlation factors reported as high as 80%. The optimal range of SE effort is identified between 10% and 14% of total project cost, at which point cost and schedule overruns are minimized (Incose, 2023).

2.4 Principles in construction industry

The past decade, practice and literature have shown an increasing interest in SE in the civil engineering & construction industry. It has been mentioned and discussed in conferences, academic journals, in professional magazines but also in guidelines and handbooks (De Graaf et al., 2017). Construction projects are becoming increasingly ambitious, not only in terms of their physical size but also in the complexity of structures, the variety of materials used and the growing integration of advanced technologies. Modern buildings often incorporate intelligent systems for security, safety, communications, comfort and entertainment, making them far more technologically sophisticated than in the past (Emes et al., 2012).

Whereas structures were once the vision of a single architect, today's projects require large teams of specialists working collaboratively to develop optimal solutions. At the same time, the number and influence of stakeholders, as well as the volume of project requirements, continue to expand. In this context, delivering projects on time, within budget and in line with client specifications calls for a structured and alternative approach. As Augenbroe (2011) observes, a persistent disconnect exists between client demand and design supply, stemming from the absence of a formal basis to express expectations and verify their fulfillment.

To bridge this gap, scholars argue that adopting SE principles provides a structured and integrative framework to manage complexity and improve outcomes in modern infrastructure projects (Emes et al., 2012). Various guidebooks have contributed to the evolution of SE, and most important, to the formulation of these principles that support successful collaboration and strengthen its adoption within the construction sector. These principles mentioned from Buck et al. (2013) provide a shared language for stakeholders, foster trust and transparency and help to align technical, organizational and cultural dimensions of projects.

- **Giving the customer's needs a central position**

The emphasis shifts from purely technical solutions to understanding and addressing stakeholder needs throughout the system's entire life cycle.

- **Granting room for design freedom**

A clearly defined problem still requires space for multiple potential solutions. Providing design freedom allows market parties to apply creativity more effectively.

- **Systems thinking**

Projects are viewed as interconnected systems within larger systems, considering lifespan and the involvement of all parties in the value chain.

- **Achieving transparency**

SE enables transparent decision-making by ensuring information is traceable and project processes can be demonstrated clearly across the full life cycle.

- **Improving efficiency**

Using appropriate SE methods and reusing existing knowledge and technologies helps minimize risks and reduce failure costs over the system's life cycle.

- **Adding value**

The focus is on solutions that maximize stakeholder value by considering the entire life cycle and making decisions that benefit long-term outcomes.

- **Smart systems for organizing and accessing information**

SE ensures that all relevant information remains available throughout the life cycle by supporting structured documentation and digital tools such as BIM.

- **Focus on attitude and behavior**

Soft skills, such as asking critical questions, creative thinking and active collaboration, are essential for achieving high-quality results alongside technical competence.

The need for SE has become even more evident as the scale of civil engineering projects continues to increase under growing demands for efficiency, safety and sustainability. These pressures, when combined with the involvement of multiple stakeholders, highlight the importance of standardization, technology and supporting tools to enhance organizational performance. It is clear that an integrated and holistic approach is essential for capturing the multifaceted nature of contemporary construction systems and effectively addressing the interdependencies among their many components.

2.5 The Dutch context

The SE methodology is rapidly growing also within the Dutch civil engineering sector. It was first introduced into the Dutch infrastructure sector in the early 2000s. SE caught the interest of the four main principals and an introduction of SE in the Dutch civil sector was made. Rijkswaterstaat, ProRail, Bouwend Nederland, NLingenieurs joined forces resulting in a guideline in 2007, the so-called *'Leidraad voor Systems Engineering binnen de GWW-sector'*, which provided mainly an introduction and explanation of the theory of SE (Van Son, 2013). Priority was to develop a common language for SE throughout the civil engineering sector. A second version of the guideline appeared two years later in 2009, the theory from the first guideline was made practical for application and control of the SE techniques. The, up to now, final guide, *version 3*, was drafted in 2013 and discusses the experiences and problems of the recent years, the current situation and the goals and challenges for the future (Buck et al., 2013). Public clients initiated a shift from the solution-oriented to the problem-oriented approach and SE quickly became part of contractual requirements in large infrastructure projects such as highways, tunnels and waterworks (Van den Houdt & Vrancken, 2013). However, while SE became common in large-scale projects commissioned by Rijkswaterstaat, its uptake in small and medium-sized projects remained limited, and questions have persisted about the cultural fit and proportionality of the method in Dutch practice (Ran, 2018).

2.6 Management and organization of Systems Engineering

Implementing SE necessitates the effective coordination of both technical and managerial processes. As Kossiakoff et al. (2011) emphasize, the management of systems derives from traditional management principles while incorporating specialized system management practices that ensure integration across the system's life cycle. SE managers play a critical leadership role in guiding and overseeing the implementation of SE activities, ensuring that technical and organizational objectives remain aligned throughout project development. There is, however, no universal approach to defining the precise nature of SE management, as it must be tailored to the specific context, complexity and stakeholder environment of each project. The effectiveness of SE management depends largely on the competence, experience and authority of the SE managers themselves, who are responsible not for performing every SE task personally, but for coordinating multidisciplinary teams and maintaining system-level coherence (Van den Houdt & Vrancken, 2013). Furthermore, organizational alignment and culture play a decisive role in supporting SE effectiveness, as demonstrated by Hutchison et al. (2019), who found that alignment between organizational structure, culture and workforce competencies significantly enhances systems engineering outcomes within project teams.

At the **executive level**, senior management must have a clear vision for SE and include it within the organization's strategic objectives. This vision should be effectively communicated and supported through adequate resources, leadership commitment and governance structures. Managerial endorsement from the top down is essential, as it ensures that SE principles are institutionalized within the company's culture and processes (Kossiakoff et al., 2011). Organizations must therefore establish clear roles and responsibilities, promote informed leadership that understands the value of SE, maintain transparent communication channels across all stakeholders, and incorporate mechanisms for continuous feedback and improvement (Van den Houdt & Vrancken, 2013).

At the **project level**, project managers are responsible for translating the organization's SE vision into actionable practices. They play a role similar to senior executives in ensuring that SE principles are properly implemented within project teams. SE managers should be empowered with sufficient authority to make binding decisions, ensuring that SE processes are effectively integrated into project execution and lifecycle management (Kossiakoff et al., 2011).

At the **individual level**, effective SE implementation relies on the competence, motivation and readiness of personnel. Hutchison et al. (2019) emphasize that individual systems engineers' effectiveness is strongly influenced by OC, structure and alignment. Therefore, organizations must provide appropriate training, tools and documentation to foster SE capabilities, while also promoting awareness of the personal and professional benefits of adopting SE practices. Employees' prior experiences, combined with ongoing development opportunities, shape their overall competency and ability to contribute to SE success.

Ultimately, achieving successful SE implementation requires a systemically aligned organization, one in which leadership, project management and individuals operate cohesively under a shared vision and culture that values integration, collaboration and continuous improvement (Hutchison et al., 2019).

2.7 Project context of Systems Engineering

The project context represents the overall project environment, shaped by numerous external factors that are unique and evolve throughout the project's life cycle due to changing stakeholders, agreements and characteristics (Emmitt, 2010). In SE, this context is viewed as the system's environment, where interactions between the system and its surroundings form the foundation of system requirements (Kossiakoff et al., 2011). Contextual factors therefore have a significant impact on the effectiveness of SE activities. As noted by Sage and Armstrong (2000), designing an appropriate SE process at the project's outset can help prevent later failures. However, since no single SE approach fits all situations, successful implementation requires a clear understanding of the specific project context and its dynamics.

The main project context related variables as identified in the literature are:

• Project arrangements:

Hamilton (2004) emphasizes that project procedures and agreements play a crucial role in effective project management, particularly for stakeholders with limited understanding of project operations, such as subcontractors or junior staff. The experience of other SE managers can support the establishment of procedures based on best practices. Effective procedures should empower the SE or project manager while maintaining an appropriate balance between control and flexibility. Key contextual factors influencing project arrangements include working procedures, formal and informal agreements and the clarity of project goals.

• Project team:

Project team composition significantly influences the effectiveness of the SE process (Sage & Armstrong, 2000). The success of SE relies on the collective contribution of all team members, with trust playing a key role in their willingness to engage in SE activities. Differences in expertise and experience among individuals can shape diverse perspectives and solution approaches, which tend to increase with larger and more complex projects. Consequently, systems engineers require strong leadership, communication and conflict management skills to

coordinate multidisciplinary teams effectively (Slegers et al., 2012).

• Working environment:

The effectiveness of project and process management can be hindered by various contextual pressures, including strategic demands, competition and organizational tensions (Bosch-Rekveldt et al., 2011). Pheng & Chuan (2006) highlight that job happiness significantly influences decision-making and overall performance. Key factors contributing to job happiness include job satisfaction, security, working hours and functional fulfillment.

• Resource availability:

The availability of resources such as time, budget, personnel and expertise significantly affects the implementation of SE. In the civil construction industry, limited profit margins often result in minimal allocation of funds or time for secondary processes like SE. Consequently, SE activities may be rushed entirely in time-constrained projects. The success of SE depends on the availability of qualified systems engineers, when such expertise is lacking, project managers may assume this role, with outcomes influenced by their level of SE knowledge.

• Client:

The client represents a key external factor influencing project success, as contractors typically have limited control over client selection (Emmitt, 2010). Effective SE requires strong collaboration and trust between client and contractor throughout the project life cycle. The client's experience, expertise and understanding of SE significantly affect this cooperation and the overall project outcome (Buck et al., 2009). Experienced clients, such as ProRail & RWS, tend to facilitate more effective SE implementation, whereas clients with limited SE knowledge may hinder process efficiency.

• Contractual arrangements:

In civil construction, contractors are increasingly responsible for broader project phases, including design, financing and maintenance, leading to the use of integrated contract types. The extent of contractor involvement depends on the client's procurement strategy and the project's characteristics. Clients like Rijkswaterstaat, often adopt integrated contracts where SE is central. Conversely, smaller clients such as municipalities and water boards typically use traditional contracts, where SE application remains limited.

• Stakeholders:

All construction projects involve stakeholders whose interests and influence can significantly affect project outcomes (Olander et Landin, 2005). Effective stakeholder management, including early identification and analysis, is essential for the successful application. Stakeholder relations are often shaped by media attention and political factors, as civil projects typically operate within socially and politically sensitive environments.

• Project task:

The complexity, size and methodology of a project significantly influence its context (Bosch-Rekveldt et al., 2011). Projects may also be interconnected with larger programs or systems, contributing to broader organizational or societal objectives (Evaristo & Van Fenema, 1999).

• Industry standards and legislation:

The formal application of SE is guided by international standards such as ISO 15288, which define processes for quality, risk and project management. Project performance is often evaluated using frameworks like the Capability Maturity Model Integration (CMMI). Contractors are typically required to comply with these standards, which may evolve into regulatory requirements. Therefore, SE practices in construction must align with international standards while remaining adaptable to change.

2.8 Factors affecting the implementation of SE

SE encompasses a broad set of principles and processes as mentioned earlier. Although SE can be viewed as a profession, a process, or a mindset, its definitions converge on achieving a coherent, effective system that meets stakeholder needs. In practice, SE is structured around several process groups that operate iteratively throughout the system life cycle, with particular emphasis in the construction sector on project and technical processes and especially in RA and V&V. The factors influencing these processes play a critical role in determining the quality and success of SE implementation. *Table 2* below summarizes the key factors identified in the literature, organized according to the SE activities to which they relate.

Table 2: Potential factors affecting the implementation of SE as proposed by Van den Houdt (2013)

General	Inclusion of all SE process groups Extent to which SE is applied and aligned across all life-cycle phases Degree of SE standardization Consistency between SE theory and its practical application
Requirements Analysis	Up to date requirements Harmonization of requirements between client and contractor Functionality of requirements Completeness and level of detail of requirements Smart formulation of requirements Including later life-cycle phases in the requirement analysis Linking interfaces to the requirements
Verification and Validation	Linking V&V activities to the requirements Maintaining V&V throughout the entire project life cycle Joint V&V collaboration between client and contractor Uniformity and standardization of V&V methods Consensus on V&V plans and procedures

Except for the technical processes successful implementation depends on effective management and organizational support. SE managers play a central role in guiding SE activities throughout the project life cycle, yet their influence is shaped by broader organizational structures, the available resources and the level of support from both project leadership and higher management.

Because SE involves multiple disciplines, its effectiveness relies on clear roles, sufficient authority, appropriate tools and structured communication across the organization. The table below summarizes the key management and organization related factors identified in the literature, grouped according to strategic, structural, cultural, human, resource, result-based and interface dimensions that influence SE adoption.

Table 3:Potential factors affecting the implementation of SE on organizational level as proposed by Van den Houdt (2013)

Strategy	Clarity and availability of the organisation's SE-related mission, vision, and objectives Commitment and support from senior management Degree of shared understanding and alignment regarding SE
Structure	Clear definition of SE-related roles and responsibilities Proper balance between project management, SE, and process management Effective collaboration between supporting processes Inclusion of supporting process roles within the project management team Coordination across interdisciplinary teams
Culture	Support provided by the project management team Degree of support for SE among individual project staff Recognition of the learning process by project employees
People	Presence and availability of the SE manager Capabilities and expertise of SE managers Extent of authority held by the SE manager within the project SE related skills and competencies of project employees Previous individual experience with SE
Resources	Resources accessible for applying SE within the project Resources available to support SE development Degree of managerial support offered by the SE manager Availability and quality of SE tools and methodologies within the organisation Availability and quality of SE training materials and documentation Access to knowledge management tools Alignment of knowledge management tools across disciplines, projects, and stakeholders Awareness and practical usability of knowledge management tools
Results	Tangible benefits resulting from the use of SE Perceived benefits of applying SE Extent of evaluation and feedback related to SE within projects
Interfaces	Ongoing identification of interfaces Keeping interface definitions current and accessible Routine, scheduled interface meetings with all relevant stakeholders

Determining success of SE is multifaceted topic. To assess that project context has its own influence with the most relevant variables and associated factors already identified, given the broad and often unlimited nature of project contexts. *Table 4* below summarizes the key project-related and environmental factors that most likely affect SE application.

Table 4: Potential factors affecting the implementation of SE related to project context as proposed by Van den Houdt (2013)

Project	Degree of flexibility in project arrangements Composition and structure of the project team Employee satisfaction and internal work pressure Scope and complexity of the project task Type and structure of contract arrangements
Environment	Client's overall SE capabilities, experience, and expertise SE skills and expertise of subcontractors and suppliers Relevant industry standards and regulatory requirements Level of trust in the client relationship

2.9 Defining successful adoption of Systems Engineering in construction projects

While a substantial body of literature discusses factors that influence the implementation of SE, fewer studies explicitly define what constitutes successful adoption of SE, particularly within the construction sector. Rather than presenting success as a single outcome or performance metric, literature predominantly conceptualizes successful SE adoption as a multidimensional condition that reflects how comprehensively, consistently and effectively SE principles are applied in practice, as well as the extent to which they are embedded within organizational routines and generate value for projects.

Based on established SE standards, guidebooks, maturity models and empirical studies, successful adoption of SE in construction projects can be characterized through four interrelated dimensions:

(1) lifecycle-wide application of SE processes,

(2) effective execution of core SE technical practices,

(3) organizational institutionalization of SE, and

(4) realization of measurable benefits and learning.

Lifecycle-wide and consistent application of SE

A fundamental characteristic of successful SE adoption is the consistent application of SE across the project life cycle. The ISO/IEC/IEEE 15288 standard defines SE as a collection of life-cycle processes intended to support the definition, control, assessment and improvement of systems throughout their entire life span (ISO/IEC/IEEE 15288, 2015). Successful implementation therefore requires that SE is not limited to early design stages, but remains active and aligned across subsequent phases, including realization, verification, validation, operation and transition.

Several authors emphasize that SE processes should be applied in an integrated and coherent manner rather than selectively or informally. Van den Houdt & Vrancken (2013) argue that excluding specific SE process groups undermines the integrative nature of SE and limits its effectiveness in complex construction projects. Similarly, Kossiakoff et al. (2011) note that fragmented or inconsistent application of SE principles often leads to reduced traceability, weak coordination and loss of system-level oversight. As such, lifecycle-wide and standardized use of SE processes is a core indicator of successful adoption.

Effective execution of core SE technical practices

Beyond lifecycle coverage, successful adoption of SE is reflected in the quality with which its core technical practices are executed. In the construction context, requirements management and V&V are consistently identified as central SE activities. Successful adoption is evidenced by requirements that are complete, up to date, traceable and harmonized between client and contractor, as well as by explicit consideration of downstream life-cycle phases during requirements development (Slegers et al., 2012; Ryan & Wheatcraft, 2017). For V&V, success is reflected in the existence of planned and continuous related activities, standardized methods and collaboration between key stakeholders throughout the project life cycle. Effective interface management further contributes to successful adoption by ensuring that system boundaries, interactions and dependencies are clearly identified, documented and coordinated.

Organizational embedding of SE

Successful adoption of SE also requires that SE is not dependent on individual efforts alone but is institutionally embedded within the organization. Literature indicates that this embedding is reflected in the presence of a clear SE mission, vision and objectives, well-defined SE-related roles and responsibilities and structured coordination across interdisciplinary teams. Moreover, when SE is embedded in organizational routines, such as governance structures, decision-making processes and project coordination mechanisms, it becomes part of normal project practice rather than an additional or optional activity. The existence of structured evaluation and feedback mechanisms related to SE further indicates that SE is recognized as an integral component of organizational performance. In construction projects, where temporary organizations and multiple firms are involved, organizational embedding is particularly important to ensure continuity of SE practices across disciplines and project phases (Emes et al., 2012).

Realization of benefits and evidence of effectiveness

Finally, successful adoption of SE is justified by the realization of both tangible and perceived benefits. Honour (2010) provides empirical evidence that appropriate levels of SE effort are positively correlated with improved cost, schedule and technical performance across large engineering programs. This work demonstrates that SE success can be evaluated not only retrospectively but also through measurable performance indicators.

Literature emphasizes that SE adoption should contribute to improved traceability, enhanced coordination, reduced rework and more effective decision-making across the project lifecycle. In addition to tangible outcomes, perceived benefits among project participants are important indicators of success, as they influence continued engagement with SE practices. Continuous evaluation, reflection and learning from SE application further signal that SE is not only implemented but actively used to improve project performance over time.

2.10 Conclusions

This chapter provided the theoretical foundations required to understand how SE functions and which conditions shape its adoption in the construction industry and in order to answer the first sub question. The review showed that SE is a structured, life-cycle-oriented approach designed to manage complexity by integrating requirements management, verification and validation and interdisciplinary coordination. Within construction, SE is increasingly promoted to enhance transparency, reduce failure costs and improve alignment between client and contractor. However, its application remains inconsistent due to sector-specific constraints such as fragmented project structures, limited standardization and differentiation in cultural readiness.

RSQ1: *What constitutes successful adoption of Systems Engineering in the context of construction projects?*

Adapting SE successfully within the construction industry requires a multifaceted approach. Integrating SE into construction projects remains challenging and has not yet been fully explored across all identified factors. Based on the findings, it indicates that successful adoption cannot be reduced to the presence of enabling conditions alone. Instead, successful SE adoption is reflected across four interrelated dimensions. First, lifecycle-wide and consistent application of SE

requires that it must be applied consistently across all project phases, supported by comprehensive process coverage, an appropriate level of standardization and alignment between SE theory and its practical application. Second, success depends on the effective execution of core SE technical practices, which in construction projects is primarily reflected in the quality of requirements management and verification & validation activities. This requires complete and up-to-date requirements, harmonization between client and contractor and clear traceability through the systematic linking of requirements, interfaces and V&V activities. Third, SE must be institutionally embedded within the organization, such that its application does not depend on individual initiative but is supported through senior management commitment, clearly defined roles and responsibilities, effective interdisciplinary coordination, sufficient authority of the SE manager and active support from project staff. Finally, successful SE adoption is evidenced by the realization of tangible and perceived benefits, supported by evaluation and feedback mechanisms and the recognition of learning processes that enable continuous improvement within the organization.

3. Literature Review: Part B

This chapter further explores literature findings but focuses now on OC. Drawing from established frameworks such as Schein's three levels of culture and the CVF (Section 3.1 & 3.2) the chapter identifies the cultural profiles and behavioral patterns that enable or hinder SE integration (Section 3.5) The insights from this chapter aim to address the second sub-question of this graduation project by aligning organizational culture dimensions that are most relevant to SE adoption (Section 3.6). It will also create the cultural foundation for interpreting the empirical findings in later sections and for understanding how OC shapes SE performance within construction projects.

3.1 Understanding Organizational Culture

Although it may appear simplistic, the recognition that OC exists was the outcome of many years of inquiry and theoretical debate (Bellot, 2011). Culture itself is an abstraction, yet the forces it generates within social and organizational contexts are highly influential. As Schein (2010) argues, without understanding these cultural forces, organizations risk becoming subject to them rather than managing them effectively. Since the 1980s, OC has been a central theme of discussion among researchers and practitioners, giving rise to a substantial body of studies across various sectors (Arditi et al., 2017). While values and underlying assumptions are widely regarded as fundamental components of culture, some scholars suggest that differences across organizations are more evident in work practices than in shared values (Nguyen & Watanabe, 2017).

Moreover, once an OC is firmly established and consistently upheld, it can significantly reduce uncertainty within the workplace and so enhance both organizational performance and employee satisfaction. Some definitions to OC as identified in the literature such as S. P. Robbins describe OC as the system of meanings that are assumed by the members of an organization; it distinguishes that organization from other organizations; this system of common beliefs is a set of basic characteristics appreciated by the organization. In addition, A. Brown conceptualizes OC as the pattern of beliefs, values and learned ways of coping with experience that have developed during the course of an organization's history and which tend to be manifested in its material arrangements and in the behaviors of its members (Szczepańska & Kosiorek, 2017).

Many researchers though rely on the definition presented by seminal author Edgar Schein (2010), who describes OC as *"a pattern of basic assumptions invented, discovered, or developed by a given group as it learns to cope with its problems of external adaptation and internal integration that has worked well enough to be considered valid and to be taught to new members as the correct way to perceive, think and feel in relation to these problems."* Schein further conceptualizes OC at three levels *(Figure 5).* The most visible are artifacts, including language, objects, behaviors and rituals, which serve as surface indicators of deeper cultural patterns. The second level is values, reflecting the stated ideals, aspirations and justifications that guide organizational action. At the deepest level lie basic underlying assumptions: the unconscious, taken-for-granted beliefs and perceptions that represent the core of culture itself (Kennedy et al., 2020). Importantly, Schein (1985) emphasized that a strong OC emerges when explicit values and implicit assumptions are aligned.

He also noted that multiple subcultures often coexist within organizations, such as managerial, group and worker cultures, each shaped by different professional, geographic or hierarchical experiences. Nevertheless, an integrative OC develops when the organization possesses a substantial shared history that unites these diverse elements into a coherent whole.

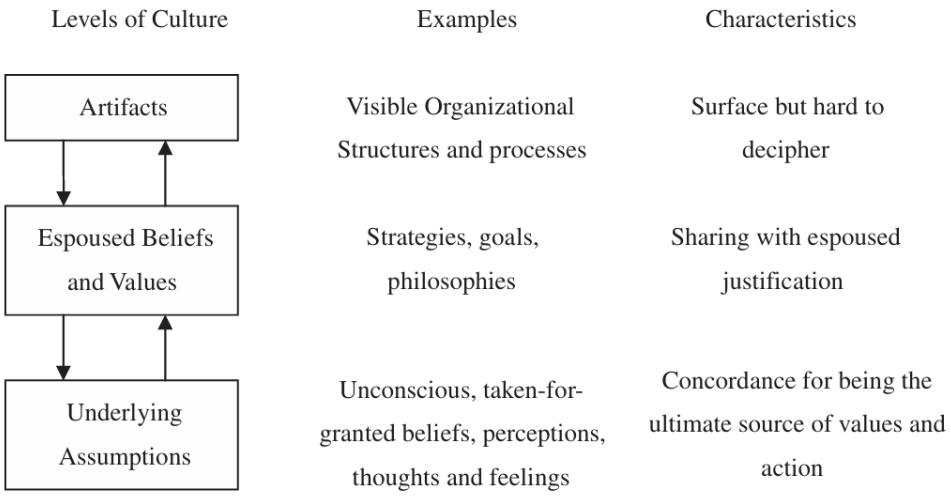

Figure 5: Organizational culture framework (Schein, 2010)

3.2 Competing Values Framework

The CVF is one of the most influential and extensively used models around OC research. Compared with other models and scales, the CVF and its matched scale OCAI are very convenient for practical operations too (Yu & Wu, 2009). It was illustrated by Kim S. Cameron and Robert E. Quinn and has been used by hundreds of organizations over twenty-five years to understand and describe key cultural attributes that relate to organization success (Hutschison et al., 2019). CVF evaluates OC along two key dimensions: flexibility versus control and internal versus external. In *Figure 6* below, the four effectiveness criteria models in the CVF are also called four organizational culture types:

- The clan culture is characterized by shared values, collective goals, a strong sense of community and mutual support among members. It emphasizes employee involvement, collaboration and empowerment. Ouchi & Wilkins (1985) describe this type of culture as one that develops under specific conditions, such as a long organizational history, stable membership, the absence of external institutional alternatives and frequent, meaningful interactions among members.
- The adhocracy culture functions as a flexible, project-based system that forms and dissolves as tasks arise and conclude. It thrives in dynamic environments where innovation and adaptability are essential. This type of culture is commonly observed in industries such as film production, management consulting, aerospace and software development (Yu & Wu, 2009).

- The market culture is oriented towards external relationships and competitiveness rather than internal cohesion. Its primary objective is to achieve profitability and success through market competition. This concept stems from Ouchi's (1985) research on the market control system, which emphasizes performance outcomes and measurable results.
- The hierarchy culture is defined by formal structures, standardized procedures, clear authority lines and strict control mechanisms. Responsibilities are well delineated, ensuring order and consistency in operations.

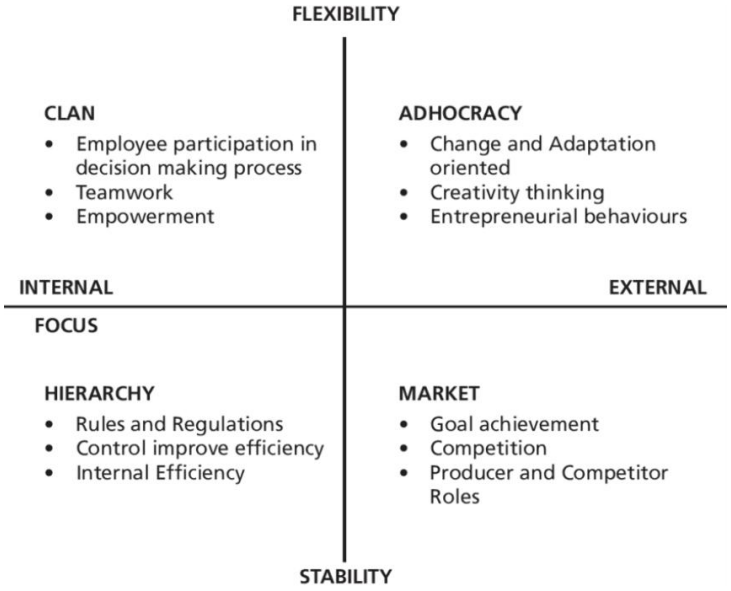

Figure 6: Competing Values Framework retrieved from Cameron and Quinn (2011)

It is important to emphasize that the names of these quadrants were not chosen randomly; instead, they are grounded in academic literature that traces how various organizational values have historically aligned with different types of organizations (Cameron & Quinn, 2011). These categories do not imply that one culture is inherently superior to another, but each type may be particularly well-suited to specific kinds of organizational tasks or contexts. CVF can be used to identify key approaches to organizational design, life cycle development stages, organizational quality, theories of effectiveness, leadership roles and management skills. As Cameron & Quinn (2011) mentioned, understanding OC is vital and considered as the single largest factor inhibiting organizational improvement and change.

3.3 Coexistence of Organizational Culture types in the CVF

From its original formulation, the CVF explicitly acknowledges that the core dimensions of organizational effectiveness, flexibility versus control and internal versus external orientation, represent tensions that organizations must manage simultaneously rather than resolve through exclusive choices (Quinn & Rohrbaugh, 1983). Building on this logic, Cameron & Quinn (2011) emphasize that organizations rarely exhibit a pure culture type. Therefore, they are best understood through culture profiles in which all four CVF culture types may be present to varying degrees, with one or more types typically dominating depending on context and strategic demands. Empirical applications of the CVF further support this assumption by demonstrating that organizational effectiveness depends on the simultaneous enactment of competing value orientations.

Denison et al. (1995) show that high effectiveness in leadership for example requires the capacity to perform roles from all four and continues about behavioral complexity as the ability to enact multiple roles, even when those roles are contradictory. This coexistence is not viewed as a deficiency but as a reflection of complexity, where effectiveness depends on the capacity to balance competing values. Studies applying the CVF in hybrid organizational forms, such as social enterprises, argue that multiple culture types can and do coexist within the same organization, reflecting the need to balance competing values and address the inherent tensions created by dual missions and diverse stakeholder demands (Shin & Park 2019). Accordingly, OC is understood as a combination of different cultural orientations that operate together, where culture types are emphasized or blended depending on organizational needs and circumstances.

3.4 Organizational culture profiles among networks of organizations

The selection of the CVF as the baseline framework for analyzing OC in this thesis is supported by prior SE research that explicitly employs CVF to examine the relationship between these two. Hutchison et al. use the CVF as one of the two primary organizational assessment methods in the Helix project to investigate how OC influences the effectiveness of systems engineers and the development of organizational systems engineering capability. The authors argue that there is a significant gap in existing research regarding the influence of OC, governance and structure on SE performance, and they adopt the CVF specifically because it provides a theoretically grounded and empirically validated way to characterize OC across multiple dimensions. Furthermore, CVF is used in the study to capture the organization as a profile of coexisting value orientations, rather than as a single dominant type, allowing the authors to examine alignment and misalignment across different organizational actors, including systems engineers, peers, managers and leaders (Hutchison et al., 2019). Consistent with this approach, the present thesis uses the CVF not to label the organization with a specific culture type, but to relate the characteristic attributes of the CVF culture types to empirical data.

3.5 Cultural enablers and inhibitors of SE

Understanding the cultural context in which SE practices are introduced is critical to their successful implementation. In engineering organizations, OC is influenced by legacy processes, corporate heritage, customer demands, nature of product/systems delivered and geographic location (Valerdi, 2008). A subset of these areas is an important enabler of technologies, that is, absorptive capacity. This is a unique characteristic that describes an organization's ability to value, assimilate and apply new knowledge (Cohen & Levinthal 1990). SE researchers and practitioners must pay close attention to the cultural environment into which their methods are introduced, recognizing that cultural incompatibility can significantly hinder adoption.

Table 5: Cultural attributes for the adoption of SE according to literature

Author(s) & Year	Enablers	Inhibitors
Valerdi, R., (2008)	• Compatibility with organizational culture, fit with existing norms and practices • Peer support networks-peer guidance and mentoring sustain adoption	• Cultural misfit, SE not aligned with existing practices • Excessive bureaucracy, multi-level decision-making slows adoption • Lack of leadership support/advocacy • Resistance to change • Insufficient incentives
Bretz, M., Kayser, S., & Lindemann, U. (2019)	• Top-down and bottom-up involvement-leadership and employee participation • Change management focus-explicit attention to cultural change • Holistic mindset-systems thinking vs. siloed thinking	• Silo-thinking • Weak cooperation culture • Pronounced specialization • Cultural resistance to change • Reward systems misaligned with SE
Buck, P., van der Linde, P., Nijpels, E., Verhagen, M., Siertsema, T., & Dronkers, J. H. (2013)	• Management involvement and belief in SE • Role models and sharing experiences • Soft skills: openness, cooperation, curiosity, reflection • Trust and respect in collaboration • Learning culture: lessons learned, best practices • Space for experimentation and gradual change • Staff development, peer coaching	• Treating SE as a project-only tool (not organizational) • Assuming SE introduction is “free” (no investment in change) • Closed communication/siloed teams • Rewarding short-term fixes over collaboration
Koolmanojwong , S., & Lane, J. A. (2013)	• Decision-making authority - empowered teams • Skilled/motivated personnel (“best people”) • Team cohesion and trust • Colocation of teams-better collaboration • Business process reengineering willingness	• Lack of authority to decide • Conflicting stakeholders • Non-co-located subcontractors/developers • Personnel turnover (knowledge loss) • Poor personnel capability • Lack of communication across teams • Too many subcontractors/stakeholders (coordination complexity)
Hutchison, N., Walker, M., Lane, J. A., & Honour, E. (2019)	• Generative culture: psychological safety, cognitive diversity, agility • Consistent cultural alignment across engineers, peers, leadership	• Strict hierarchy/overly formal culture • Market-dominant culture: competitive, results-only focus • Non-generative behaviors, resistance, conformity • Complacency & groupthink • Misaligned cultural perceptions across groups
Greene, M. (2013)	• Establishing a “culture of SE” distinct from other engineering • Managing cultural mixes (gender, nationality, discipline etc.) • Positive culture evolution - solution-oriented culture • Tools for culture handling (cross-cultural practices, high-performance team culture) • "Feminizing" communication-listening, inclusiveness, collaboration	• Culture conflicts (managerial vs. engineering, professional/national clashes) • Power imbalance cultures (managerial urgency overriding engineers) • Neglecting cultural training/education in SE • Problem cultures, perpetuating flaws instead of solving them

3.6 Mapping cultural enablers to the CVF

Across literature, several consistent cultural enablers of SE adoption emerge, regardless of organizational or sectoral context. Foremost is leadership commitment and advocacy, as visible managerial support legitimizes SE and provides the resources and coordination necessary for its institutionalization (Buck et al., 2013). Closely related is a culture of collaboration and integration, where teamwork, open communication and trust enable cross-disciplinary processes such as requirements management and interface coordination (Koolmanojwong & Lane, 2013). A strong learning and adaptability orientation also facilitates SE uptake by promoting reflection, experimentation and incremental improvement rather than rigid compliance (Greene, 2013). Successful adoption further depends on actively and consciously plan change management and cultural awareness, acknowledging SE as a sociotechnical transformation rather than a purely procedural shift (Bretz et al., 2019). Empowering skilled personnel to make decisions, while aligning SE methods with existing norms and values, enhances ownership and reduces perceptions of bureaucracy (Valerdi, 2008). Finally, fostering psychological safety and trust creates an environment in which individuals can challenge assumptions, share lessons learned and sustain collaborative problem-solving (Hutchison et al., 2019). Together, these enablers represent the cultural foundation upon which effective SE implementation rests.

Table 6: Mapping SE enablers with CVF types

SE enabler	Clan	Adhocracy	Hierarchy	Market
Cultural compatibility	✓			
Leadership and participation			✓	✓
Change management and mindset		✓		
Management commitment and role modeling			✓	
Collaboration and soft skills	✓			
Learning and development culture	✓	✓		
Empowerment and team dynamics	✓			✓
Process flexibility and innovation		✓		✓
Generative culture and psychological safety	✓	✓		
Cultural integration and evolution	✓	✓		

As can be seen from the *Table 6* above, adhocracy and clan are the main culture profiles that enhance SE adoption. The innovative nature of an adhocracy fosters a focus on new technologies that can enhance its dynamic capabilities for capitalizing on new opportunities (Cao et al., 2025). This emphasis on innovation is critical for the success of SE, as it generates new ideas in unpredictable environments and helps overcome resistance to change in that field. Employees are more likely to engage in mentoring because they view it as valuable for both their career development and the organization's overall effectiveness (Nallaiahgari & Rajagopal, 2025). On the other hand, clan leads to a strong sense of community and shared purpose. Fostering that culture is important for an organization aiming to pursue SE, as it involves redefining value propositions and requires the engagement of the entire organization. This culture can create a friendly and supportive work environment in which different teams and departments can collaborate effectively. Studies support that clan types of culture, characterized by a "family-like environment" emphasizing mentoring, collaboration and collective effort, are positively associated with quality outcomes. In contrast, market-oriented cultures, which are typically results-driven and centered on competition, achievement and task completion, more common in

construction projects, show a negative relationship with quality performance. Nguyen & Watanabe (2017) recommended a shift in the dominant culture in construction projects from a market orientation toward a clan orientation. They further argue that project cultures should be deliberately structured to align organizational goals with the individual objectives of project participants.

3.7 Conclusions

This chapter provided an in-depth exploration of OC and its relevance to SE adoption. Rather than functioning as a neutral backdrop, culture actively influences behaviors, priorities and decision-making patterns that directly affect the integration of SE principles within organizations. The analysis highlights that visible practices related to SE adoption are rooted in deeper values and taken-for-granted assumptions about collaboration, control, learning and responsibility.

RSQ2: *What types of organizational culture are most relevant to the adoption of Systems Engineering practices?*

By introducing the CVF, the literature supports that OC is best understood as a configuration of coexisting value orientations rather than a single dominant type. This perspective is particularly relevant for construction projects, where multiple professional subcultures and organizational actors interact within temporary and highly interdependent settings. The literature shows that tensions between flexibility and control, as well as between internal integration and external performance pressures, are inherent to such environments and shape how SE practices are enacted.

Across studies, adhocracy and clan cultures emerge as the most supportive culture types for SE adoption. An adhocracy-oriented culture, characterized by flexibility, innovation and openness to change, aligns with the exploratory and integrative nature of SE and supports the introduction of new ways of working, tools and coordination mechanisms. Complementing this, a clan-oriented culture fosters collaboration, trust and shared responsibility, which are essential for cross-disciplinary integration and collective ownership of system-level outcomes in construction projects.

Overall, literature indicates that successful SE adoption is most likely in organizations that exhibit a balanced cultural profile, in which competing value orientations are consciously managed. While adhocracy and clan values provide critical support elements of control and performance orientation remain necessary for coordination and delivery. It is therefore up to the organization to actively balance these competing characteristics in response to project context, rather than relying on a single cultural orientation.

4. Empirical Data Collection

This chapter presents the empirical data collection approach used to examine how OC influences SE implementation within IJVA project. It will first address the selection process of the case study and the context of the selected one but also the relevance with the research objectives (Section 4.2). Then the qualitative method design is presented, with explicit overview of the participant recruitment and the interview process for the semi-structured interviews in Section 4.3 - 4.5. Thematic Analysis for interpretation of the results and academic rigor is addressed in Section 4.6. This empirical evidence directly contributes to answering the third and fourth sub-questions related to how culture currently manifests in the project and how it influences the effectiveness of SE processes but also improvements strategies to further support implementation.

4.1 Introduction to WSP in Nederland

WSP is a globally operating consultancy and engineering organization founded in 1959 and headquartered in Montreal, Canada. The firm applies multidisciplinary expertise to address contemporary societal and environmental challenges. Its activities are centered around the development of sustainable, resilient and technology-driven solutions, with specific emphasis on future-proof construction, climate adaptation, the energy transition and digitalization. WSP's mission reflects an ambition to contribute positively to global well-being by shaping a sustainable built environment and enabling communities to thrive in a rapidly changing world.

Recognized as one of the world's leading professional services firms, WSP integrates engineering, advisory, and scientific capabilities across a broad international network. The organization operates in more than 50 countries and employs approximately 75,000 professionals, referred to internally as "Visioneers". Within the Netherlands, WSP comprises a workforce of over 500 employees, distributed across nine office locations. The Dutch operations focus on the sectors of Transport & Infrastructure, Property & Buildings, Earth & Environment, Water and Power & Energy, areas in which innovation and interdisciplinary collaboration are central to service delivery. In line with its Future Ready initiative, WSP continuously invests in expertise and knowledge that anticipate long-term societal trends, reinforcing its role in advancing sustainable development at both national and international levels.

4.2 Case Study Selection

Case selection constitutes one of the most fundamental tasks in case study research. By choosing cases, the researcher not only defines the empirical focus but also implicitly sets the research agenda. In this sense, the processes of selection and analysis are deeply important and greater than comparative research (Seawright & Gerring, 2008). It is considered appropriate when the study focuses on a contemporary phenomenon beyond the researcher's control, is primarily exploratory in nature and seeks to answer *"how"* and *"why"* questions (Yin, 2009).

Most case studies aim to shed light on phenomena that extend beyond the boundaries of the individual case. Even when the generalizations that emerge are modest or tentative (Gerring, 2004), the selected case is asked to serve as more than itself, it is expected to act as a representative of a broader population. In this respect, case study must be sufficiently rich, illustrative and analytically significant to illuminate dimensions of the larger phenomenon under investigation. In this sense, a good fit for the research procedure is hard to find.

The process of selecting a suitable case study was informed by both academic methodological guidance and internal discussions within WSP. Literature emphasizes that the quality and contribution of a case study strongly depend on the rigor and rationale used in case selection (Yin, 2018). Therefore, specific criteria were established to ensure that the chosen case would effectively address the research purpose and provide valuable empirical insights. The following principles were derived from methodological literature:

- **Relevance to research objectives**: Cases should directly address the phenomenon under study and enough to illuminate the broader phenomenon being studied, not trivial. The chosen cases should contribute to analytic generalization, not statistical generalization (Yin, 2018).
- **Information richness**: A case must provide multiple sources of data and sufficient such as administrative documentation, reports, archival records such as organizational charts and personnel and financial records or any information relevant to the investigations. (Friedman et Sage, 2004).
- **Variety across contexts**: Each case is treated as a quasi-experiment. Some are chosen to confirm patterns, others to disconfirm or extend them and diversity across key dimensions allowing for both literal and theoretical replication (Darke et al, 1998).
- **Comparability and analytical generalization**: While cases may differ, they must still be comparable enough to allow for meaningful cross-case analysis (Gerring, 2007).
- **Feasibility of access**: Practical considerations such as time, resources and permissions affect the suitability of cases (Darke et al., 1998).
- **Outcome variance**: Including cases that are confirming and disconfirming as it is mentioned by Shakir (2002) that will help identify enabling and constraining factors.

To complement the selection principles drawn from the literature, a series of internal meetings was held with WSP project managers. These managers operated at a similar hierarchical level, with only minor differences in their professional background and experience. This consistency was intended to enhance the validity of the initial inputs by ensuring that the evaluation of potential cases reflected comparable managerial perspectives. Through these discussions, practical considerations emerged, which influenced the choice of projects:

- **Internal accessibility of data**: Cases were limited to projects where documentation and internal reports were available, even if primarily in Dutch.
- **Stakeholder willingness & confidentiality:** Priority was given to projects in which internal teams and contractors demonstrated a willingness to provide input, engage in interviews or discussions, and give access to shared documentation.
- **Alignment with SE practice**: The case had to reflect practical implementation of SE methods within WSP, fully integrated from the beginning.
- **Organizational relevance**: Cases needed to represent the types of work central to WSP's portfolio, ensuring that findings would be meaningful for internal practices.
- **Use of Relatics**: Projects employing Relatics, the primary platform used by WSP to support systems engineering information management, were favored to ensure consistency with current organizational workflows.

- **Feasibility under constraints**: Given the number of potential projects within the company and the limited time available, particularly because of the repeated meetings required with project managers, a decision on case selection had to be made within a reasonable timeframe.

Through an iterative assessment process based on these criteria, several candidate projects were reviewed. Projects with insufficient data availability, lack of SE integration or limited relevance to the research focus were excluded early in the evaluation. This systematic refinement ultimately led to the selection of a single case study that sufficiently met both the theoretical requirements and the practical feasibility conditions for this research. The most relevant case to collect empirical data for this graduation study is *2GW Landstation IJmuiden Ver Alpha (IJVA).*

Figure 7: Visualized overview of the onshore substation (Windpowernl, 2024)

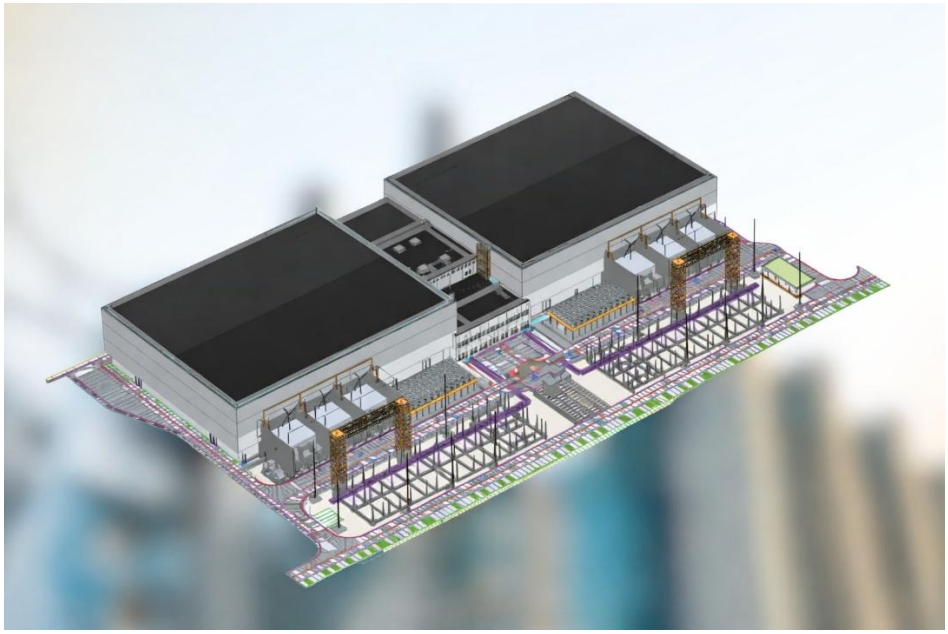

Figure 8: 2GW Landstation model (De Kok Staalbouw, 2023)

Project overview

The European energy transition represents one of the defining challenges of the 21st century. The overall objective is to make Europe the world's first climate-neutral continent by 2050. To achieve both rising energy demand and net-zero commitments, member states must accelerate the deployment of renewable energy sources. Among these, offshore wind energy from the North Sea will play a key role. In response to these strategic aims, the European Union has established ambitious capacity targets: a minimum of 60 GW of offshore wind by 2030 and 300 GW by 2050. To support this expansion, the Netherlands and Germany will jointly implement 14 high-voltage direct current (HVDC) offshore grid-connection systems, each with a transmission capacity of 2GW, to be delivered by 2032, seven in each country. Each 2GW system can transmit an amount of renewable electricity comparable to the output of two conventional coal-fired power stations, while simultaneously reducing spatial and environmental impact due to higher transmission efficiency per system. Within this broader infrastructure program, five onshore substations will be constructed to facilitate the eventual connection of offshore wind farms to the continental electricity grid. This research focuses specifically on the IJVA currently under development in the municipality of Borsele in the province of Zeeland.

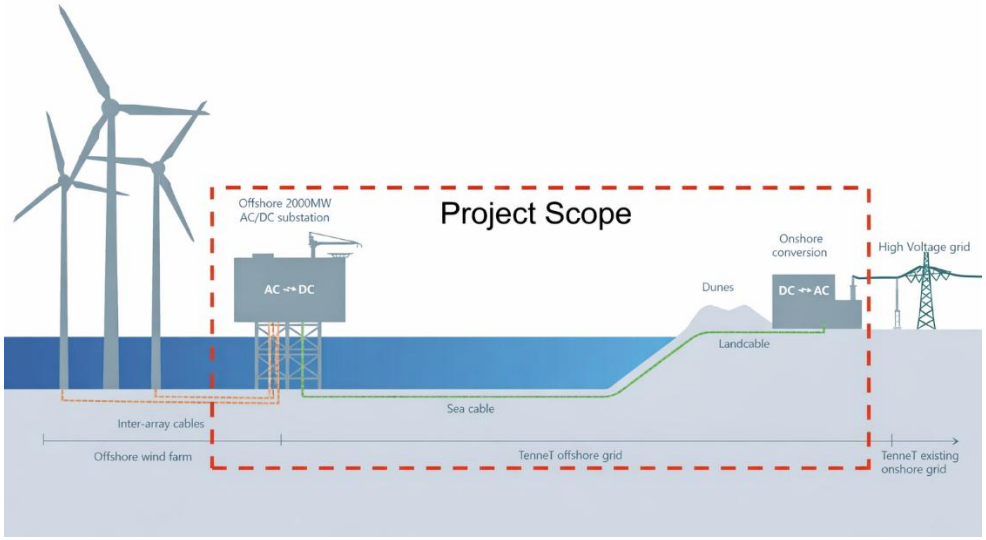

Figure 9: Scope of a Grid Connection System (Alefragkis & Kabul, 2022)

WSP's scope of work encompasses both civil and architectural elements, with key responsibilities allocated across the Definitive Design (DO) and Final Design (UO) phases. The DO phase involves the development of concrete and steel structures, architectural layouts and mechanical components, while the execution design phase focuses on structural detailing, architectural fit-out and the coordination of construction activities to ensure design integrity and alignment with project specifications.

The project currently involves a multidisciplinary team of approximately 45 WSP professionals, with peak involvement reaching around 78 team members. The team consists of both full-time and part-time contributors and is structured across three main business units: Property & Buildings, Power & Energy and Project Management. This diverse composition requires a high degree of coordination and knowledge integration across disciplines. At the same time, OC is increasingly recognized as a critical factor influencing construction project performance and collaboration. Culture is embedded in construction projects at multiple levels, organizational, project, safety and national and influences coordination, communication and collective decision-

making (Li, 2022). Cultural differences have been shown to affect essential performance dimensions such as schedule adherence, safety outcomes and quality management, highlighting culture's central role in shaping project success (Arditi et al., 2017). Because SE requires cross-disciplinary integration, transparency and a shared understanding of requirements, the cultural conditions in which SE is introduced become critical determinants of its success (Hutchison et al., 2019).

In addition, the selected case study represents a large-scale, highly complex project characterized by significant systems complexity, numerous stakeholders and extensive interface management requirements and conditions under which SE is theoretically expected to deliver the greatest added value (Emes et al., 2012). This project therefore provides an appropriate context to examine cultural enablers such as innovation orientation, collaboration, a learning culture and psychological safety, particularly in an environment where SE processes are intensive and essential. Literature indicates that such settings often reveal cultural tensions, including those between innovation and control, hierarchy and flexibility, and traditional engineering practices versus SE-driven integration approaches (Bretz et al., 2019). Consequently, this case enables a detailed investigation into how cultural attributes manifest in practice and how they influence the effectiveness of SE implementation.

4.3 Qualitative research methodology & design

Qualitative research methods, when applied rigorously, enable researchers to engage directly with the inherent complexity of human interactions and organizational processes. In many cases, they provide the most appropriate means of understanding the human and organizational drivers that shape design and development activities (Szajnfarber & Gralla, 2017). Qualitative research includes a broad range of approaches and techniques aimed at exploring individuals‘ experiences, beliefs and perceptions within a given context. Rather than focusing on numerical measurement, this research design emphasizes descriptive data, allowing issues to be examined from the participants' own perspectives. As a result, the researcher must interpret the meanings that participants assign to their behaviors, experiences and interactions. According to Silverman (2016), qualitative research is particularly valuable in settings where open-ended data are required to capture nuanced and context-specific insights. Furthermore, qualitative research designs are especially effective for synthesizing diverse viewpoints, as they facilitate the collection of rich and detailed data across a broad and varied group of participants (Alamri, 2019).

Qualitative interviews can be classified in several ways, with contemporary methodological literature commonly distinguishing between unstructured, semi-structured and structured interview formats (DiCicco-Bloom & Crabtree, 2006). In this research the focus was on semi-structured interviews that often being used as the primary data collection method in qualitative research and are usually planned in advance, taking place at a specified time and location separate from participants' routine activities. This interview format is guided by a predefined set of open-ended questions, while allowing additional questions to emerge naturally through the interaction between the interviewer and the participants. They carried out as a single session per participant and lasted between 40 minutes to 1 hour. Individual in-depth interviews enable the researcher to explore personal experiences, perceptions and social dynamics in considerable depth (DiCicco-Bloom & Crabtree, 2006).

Within the field of SE, limited attention has traditionally been given to the application of qualitative research methods and relatively few studies have made systematic use of such approaches. Only in recent years have qualitative and mixed-methods studies begun to gain visibility within SE research. As noted by Szajnfarber & Gralla (2017), while many aspects of complex system development and acquisition can be measured and analyzed quantitatively, critical elements related to behavior and social interactions often resist quantification. Gaining a deeper understanding of how technical and organizational systems interact therefore requires qualitative inquiry, particularly through in-depth interviews and interpretive analysis. Qualitative methods offer the ability to uncover underlying motivations, informal processes and social dynamics that shape system outcomes. In this way, they do not replace traditional analytical techniques but rather support them by providing explanatory depth in areas where key drivers and uncertainties cannot be adequately captured through numerical or probabilistic approaches.

The research design in *Figure 10* illustrates the process from qualitative data collection to the generation of research findings through thematic analysis. The study begins with qualitative data collection using interviews, which are audio or video recorded and subsequently transcribed to ensure accurate representation of participants' responses. The transcribed data are then analyzed using TA, following a multi-step process. TA is a widely applied method for the analysis of qualitative data, valued for its ability to provide a systematic yet flexible approach to identifying, examining and reporting meaningful patterns or themes within a dataset. Building on the well-established six-phase framework originally proposed by Braun & Clarke in 2006, TA has been extensively adopted across a range of disciplines. The approach places strong emphasis on researcher reflexivity, encouraging continuous critical reflection on how interpretations are shaped throughout the analytical process. In line with its methodology, TA is characterized by high flexibility in application and an active, reflexive role of the researcher *(Table 7)*. In addition, it underscores the importance of theoretical transparency and so enhancing credibility and trustworthiness of qualitative research findings (Ahmed et al., 2025). The final stage involves interpreting the identified themes by linking them to existing literature and aligning the results with the study's sub-questions. Through this process, raw qualitative data are transformed into meaningful insights that contribute directly to answering the research objectives.

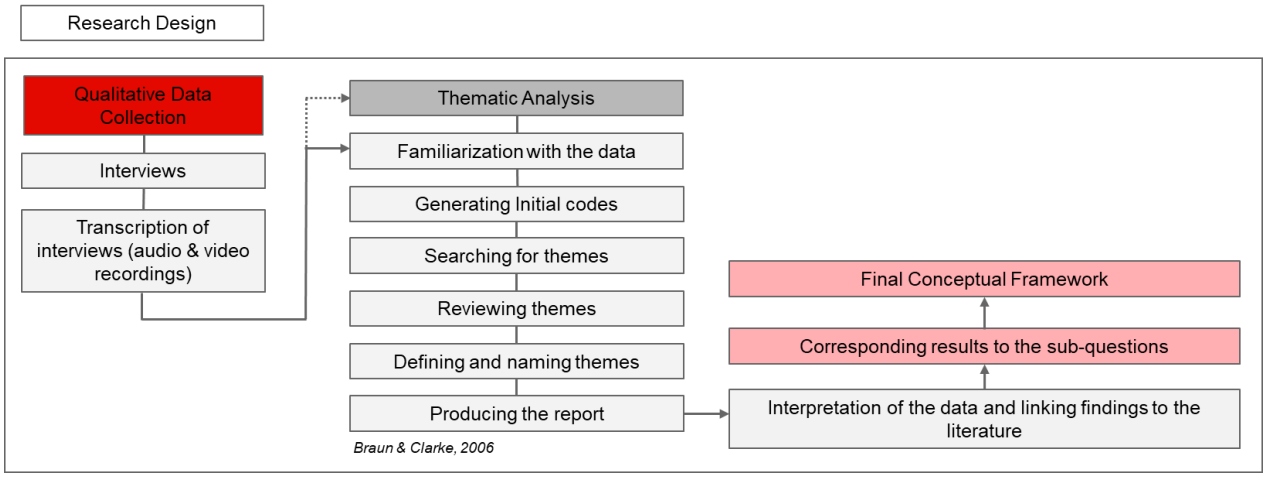

Figure 10: Research design

Table 7: Characteristics of Thematic Analysis (Ahmed et al., 2025)

Feature / Method	Thematic Analysis (TA)
Main goal	Identify and interpret patterns/themes in data
Philosophical foundation	Theoretically flexible (realist or constructivist)
Focus of analysis	Meaning, context, and interpretation
Sample size	Flexible
Researcher role	Active and reflexive
Theory development	Not necessary or central
Use of coding	Codes evolve into themes
Flexibility of application	High – across disciplines and paradigms
Depth of interpretation	Moderate to high (depends on reflexivity)
Tools used	Manually or software

Drawing from *Table 7,* TA offers a theoretically flexible and accessible approach, ideal for researchers aiming to identify patterns of meaning without being constrained by specific epistemological commitments. More specifically, TA can be conducted within both realist and constructionist paradigms, although the outcome and focus will be different for each. The question of epistemology is usually determined when a research project is being conceptualized, although epistemology may also rise again during analysis, when the research focus may shift to an interest in different aspects of the data. The purpose of addressing this continuum is to conceptualize theoretically how the researcher understands their data and the way in which the reader should interpret the findings (Byrne, 2022).

In this study, the focus is on constructionist perspective where meaning and experience are socially produced and reproduced, rather than inhering within individuals. Therefore, TA conducted within this framework cannot and does not seek to focus on motivation or individual psychologies, but instead seeks to theorize the sociocultural contexts, and structural conditions, that enable the individual accounts that are provided (Braun & Clarke, 2006). By adopting a constructionist epistemology, the researcher acknowledges the importance of recurrence in the data while emphasizing meaning and meaningfulness as the central criteria guiding the coding process. This approach is appropriate for this research because the study seeks to understand how SE practices are interpreted, framed and positioned within the organizational culture of the case study. Rather than treating participants' statements as direct reflections of an objective reality, the analysis focuses on how shared meanings, professional norms and underlying beliefs influence how SE is understood.

4.4 Participant recruitment

Purposive sampling is widely recognized as a key strategy in qualitative research due to its capacity to generate rich, contextually grounded insights. This approach involves the careful selection of participants, cases or events based on their relevance to the research objectives and their ability to inform the phenomenon under investigation. Sampling decisions are a fundamental component of any empirical study, and in qualitative research, participant selection should be closely integrated with the overall research design. Accordingly, the rationale for sample selection must be consistent with the study's ontological, epistemological and axiological foundations, ensuring alignment with the overarching research aims (Campbell et al., 2020).

Qualitative studies typically rely on relatively small, purposively selected samples, as the primary objective is to achieve depth of understanding rather than broad generalizability. This strategy enables the researcher to explore complex issues in detail and to capture nuanced perspectives that contribute to a deeper interpretation of the research topic (Palinkas et al., 2015).

In addition, it is important to include participants with diverse backgrounds and roles in order to capture a broad range of experiences and perspectives relevant to the phenomenon under study. Purposive recruitment is inherently flexible, allowing researchers to adapt and refine participant selection as data collection progresses and as emerging insights highlight the relevance of additional viewpoints. The definition of the study population is therefore closely linked to the research design, as the research questions determine the most appropriate target group. As the process develops iterative refinement is allowed, participants may identify other relevant actors whose inclusion could further enrich the understanding of the topic.

Participants selected for recruitment were required to have active or prior involvement in the IJVA project. This criterion ensured that interviewees could draw concrete, project related experiences across different phases of the project. All participants were expected to apply SE processes either as a primary or complementary component of their professional role. Priority was given to individuals involved in activities such as requirements management, interface coordination, verification and validation or other SE-related decision-making processes, as these functions are central to the operationalization of SE within construction projects. In addition, participants were selected to represent a range of professional roles and disciplinary backgrounds within WSP and the broader project organization, including systems engineers, project managers, discipline leads and design engineers (Palinkas et al., 2015).

This criterion was essential for capturing variation in perspectives, as OC is experienced differently depending on hierarchical position, professional specialization and level of involvement in decision-making processes. Including participants from multiple roles enabled the study to examine how SE is interpreted, enacted and valued across different organizational layers. Lastly, participants were required to possess sufficient professional experience to reflect critically on organizational practices related to SE. Although no strict minimum number of years of experience was defined, emphasis was placed on selecting individuals with substantial involvement in SE-related tasks and processes (Campbell et al., 2020). This level of experience enabled more informed and reflective discussions on cultural enablers, sources of resistance, dynamics and behavioral changes associated with the adoption of SE.

Table 8: Interviewee overview

Interview ID	Role of Employee	Interview Format
SE-01	Structural Engineer	Online
AL-02	Architectural Lead	In-person
IC-03	Interface Coordinator	In-person
PM-04	Project Manager	Online
PM-05	Project Manager	Online
SE-06	System Engineer	In-person
DL-07	Design Lead Engineer	In-person
DL-08	Design Lead Engineer	Online
SE-09	Site Engineer	Online

Invitations to participate in semi-structured interviews were distributed to a purposively selected group of professionals, as presented in *Table 8*. In total, nine professionals were invited and all accepted the invitation to participate in the study, resulting in a response rate of 100%. All interviewees expressed willingness to share their experiences and perspectives on the use of SE within the project and acknowledged the importance of reflecting on current practices, including the identification of bottlenecks encountered in this complex case study that stem from organizational and cultural characteristics. The aim was to assemble a diverse group of engineers and project professionals across different levels of seniority and disciplinary backgrounds in order to examine how SE is interpreted within the project.

Table 9 presents the analytical perspectives applied in this study and explains the rationale for including each perspective in the analysis. Collectively, these perspectives capture how SE is implemented, interpreted, coordinated, governed and adapted in practice, highlighting the influence of OC across both technical and managerial domains.

Table 9: Criteria for participant selection

Analytical Perspective	Reasoning
Technical Perspective Requirements translation	To capture diverse viewpoints on how requirements are interpreted, negotiated, and embedded into design work. It reveals how cultural factors such as communication styles, disciplinary silos, and attitudes toward documentation influence the translation of formal requirements into practical design outcomes.
Interface Management	To understand the process of coordinating external interfaces, including managing dependencies between parties and ensuring interface requirements are aligned and communicated.
Governance and control	To understand how organizational culture is reflected in decision-making structures, authority distribution, and control mechanisms. It reveals how cultural attitudes toward hierarchy, accountability, and risk shape managerial oversight and influence the extent to which formal processes are supported or constrained in practice.
SE implementation	It provides the most direct insight into how SE is implemented, recognized and sustained, and how culture affects acceptance but also leadership support and resistance to change shape whether prescribed practices are embraced, adapted, or bypassed.
Technical Integration	To investigate how output from different engineering disciplines are combined into a single, coherent system that satisfies SE requirements. This process requires continuous coordination, alignment of assumptions, and resolution of interdependencies between disciplines. It reveals how organizational culture supports or hinders collective responsibility for system-level coherence and cross-disciplinary alignment.
Learning and adaptation	To retrieve how SE requirements and verification intent are interpreted, adapted, and made workable during execution, where constraints (time, sequencing, constructability, deviations) often require practical judgment and feedback to design/SE teams.

Qualitative research does not aim to produce statistically generalizable findings. Instead, the adequacy of the sample size is assessed through the concept of saturation. Saturation is reached when additional data collection no longer generates new insights or meaningful variation relevant to the research questions. At this stage, further interviews tend to confirm existing patterns rather than contribute new information, indicating that the key concepts have been sufficiently explored (Bouncken et al., 2025). In this single case study, saturation was indicated when interviews across different professional roles repeatedly highlighted similar organizational norms. Regardless of role or seniority, participants consistently referred to shared perceptions of SE, completeness or not of its practices and the level of organizational support provided. The recurring bottlenecks discussed by participants consistently pointed to underlying cultural factors, indicating that the key themes had been sufficiently captured within this case and that thematic saturation had been reached.

4.5 Interview Guide

To enhance the reliability and consistency of the interviews, a structured interview approach was adopted in which specific questions were aligned with predefined participant groups based on their roles and responsibilities. The interview process was designed to enable the collection of data that are relevant to individual, project and organizational level, while ensuring that interview questions were tailored to each level of responsibility and different hierarchical levels within the project.

The interviews conducted in this study were semi-structured in nature. An interview guide consisting of 12 core questions was developed to provide direction to the discussions while allowing flexibility for probing and follow-up questions where relevant (McGrath et al., 2019). This approach enabled participants to elaborate on their experiences and perspectives and so on ensuring that comparable data were collected across interviews. By structuring the interviews in this way, the volume of data could be effectively managed and systematically analyzed, supporting the generation of interpretable and consistent findings across different organizational levels (Palinkas et al., 2015). In addition, the use of semi-structured interviews allowed participants to share narratives and experiences related to significant events in their everyday work. These narratives support enable participants to reflect on actions and changes after they have occurred. This approach is particularly valuable for examining OC, as it reveals how cultural patterns are understood, enacted and reflected upon by organizational members over time (Armenakis et al., 2011).

Accordingly, it was beneficial for this research to design interview questions that enabled participants to reflect on OC and the characteristics associated with the CVF as revealed from SE related activities. The questions were structured to indirectly capture underlying attitudes, beliefs, values and norms as perceived through participants' everyday engagement with SE practices each one from his own role. The interview focused on identifying challenges, cultural tensions and observable shifts in ways of working that influence the effectiveness of SE adoption. Overall, the primary objective was to identify areas for improvement and insights that could inform strategies for enhancing cultural alignment and organizational performance more effectively within the project but also for the organization.

The interview guide began with two background questions (Questions 1–2), followed by ten primarily open-ended questions (Questions 3–12) designed to encourage detailed responses rather than simple yes-or-no answers. Prior to addressing the main interview topics, it is beneficial to begin with simple introductory questions to facilitate a smooth transition into the discussion and to help put the interviewee at ease, particularly when the interview guide has not been shared in advance as in this case (McGrath et al., 2019). The initial questions were intended to gather contextual information about the participants, specifically their role within the project and their experience with SE. Taking into consideration that the company has been active in the Dutch market for approximately five years, this background information was particularly relevant for interpreting the results, as it provided context regarding varying levels of familiarity with the practices and the ongoing development of SE within the organization.

To continue with, rather than asking directly about OC, these questions focused on everyday SE related activities through which cultural characteristics can become visible. Questions concerning collaboration, communication and the ease of asking for support (Questions 3–4) were included to capture cultural attributes related to feeling comfort and safe, which are central to clan and adhocracy-oriented cultures. Questions addressing clarity of roles and responsibilities (Question 5) aimed to reveal how structures and control are experienced in practice.

Questions related to the use of SE tools and documentation (Questions 6–7) were designed to uncover shared values regarding formalization standardization and perceptions of usefulness of SE practices, thereby indicating whether SE is culturally legitimized or not. Time pressure and decision-making autonomy (Questions 8–9) were included to examine how competing priorities, control mechanisms and flexibility influence SE application, highlighting tensions between contradicting cultural profiles. Finally, (Questions 10–11) questions addressing leadership support, motivation and improvement actions explicitly aimed to identify cultural enablers, resistance mechanisms and opportunities for change, directly informing the development of improvement strategies. Participants were encouraged to suggest potential improvement actions based on their practical experience, thereby supporting the identification of culturally informed strategies for enhancing SE adoption. And finally, the last interview question (Question 12) served as a closing prompt, was included to allow professionals to raise issues or insights not covered by the interview guide, a practice that is widely recommended in qualitative interviewing to capture perspectives, not only the researcher's framework and enhance the completeness of the data (Patton, 2015).

4.6 Interview Coding Process

This Section describes the structured approach used to analyze the qualitative data collected through interviews. TA is a qualitative method used to systematically identify, analyze and report patterns or themes within a dataset. As it is applied to open-ended interview data, TA allows for an in-depth exploration of contextual meanings, experiences and perceptions that are often not accessible through quantitative analysis (Castleberry & Nolen, 2018). Furthermore, the interpretive nature of the method requires careful and transparent application to ensure the credibility and trustworthiness of the findings. TA was guided by the framework proposed by Braun & Clarke, which provides a structured six-phase process for coding and theme development as it maintains analytical flexibility and emphasizes reflexivity throughout the analysis. Even though the six phases of TA are presented in a logical sequence, the analytical process should not be understood as strictly linear. Instead, the analysis is inherently iterative and reflexive, requiring the researcher to move back and forth multiple times between phases as insights develop (Braun & Clarke, 2020).

- **Phase one: Familiarization with the data**

The first phase of TA involved familiarization with the dataset, a foundational step common to many forms of qualitative analysis. It requires thorough engagement with the data through repeated reading and close examination in order to develop an in-depth understanding of its content and context. This phase is essential for identifying material that may be relevant to the research questions and for ensuring that all parts of the dataset receive equal attention, rather than selectively focusing on isolated segments (Braun & Clarke 2006).

During the interview process, observational notes were taken to capture initial impressions and contextual details. All interviews were audio-recorded or audio–video recorded using a smartphone or Microsoft Teams, depending on the interview format. Following each interview, the recordings were transcribed as soon as possible to support early immersion in the data. An initial transcription was generated using Microsoft Word's built-in transcription tool; however, these first drafts were found to lack sufficient clarity and accuracy due to mispronunciations, filler words and the non-linear nature of spoken conversation. To ensure that each recording was reviewed in full and the transcripts were manually corrected (Byrne, 2022). This process involved correcting misrecognized words, restructuring interrupted phrasing and removing irrelevant filler expressions, while carefully preserving the original meaning and intent of participants' responses. Once transcription of all interviews was completed, each transcript was read multiple times to achieve deep familiarity with the dataset.

- **Phase two: Generating initial codes**

The second phase of the TA involved generating initial codes to systematically organize and make sense of the qualitative data. According to Braun & Clarke, coding refers to the process of identifying and labelling features of the data that are relevant to the research questions in a meaningful and systematic way. During this phase, the dataset was examined in detail, and segments of text that captured important or recurring ideas were assigned to codes. Coding was conducted across the entire dataset to ensure that all potentially relevant data were considered, rather than focusing only on particularly vivid or prominent passages (Byrne, 2022).

To support this process, the initial codes were systematically organized into thematic maps from an early stage of the analysis. This structuring was applied to create a clear and consistent overview of the emerging topics and to support a focused understanding of the data as coding progressed. The initial codes are presented below in three figures, each illustrating a different context as outlined in the description.

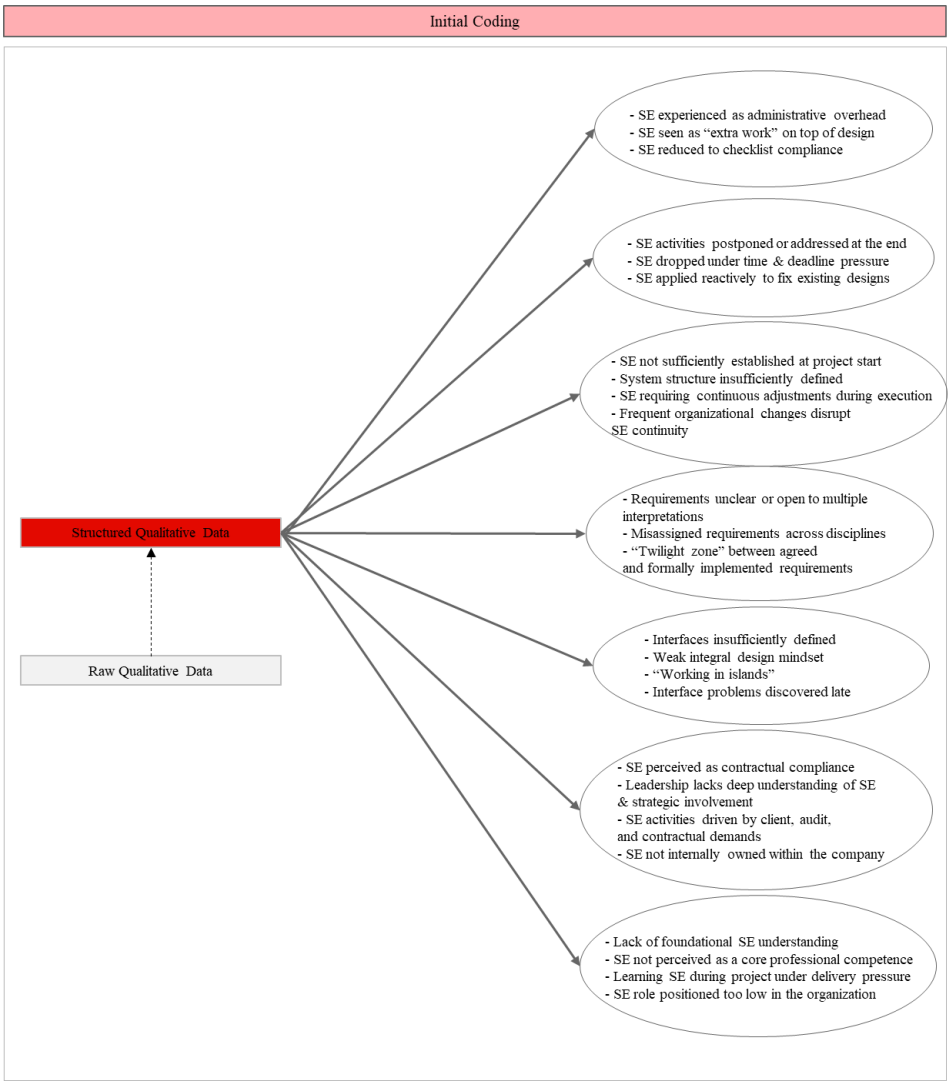

Figure 11: Initial codes related to cultural constraints

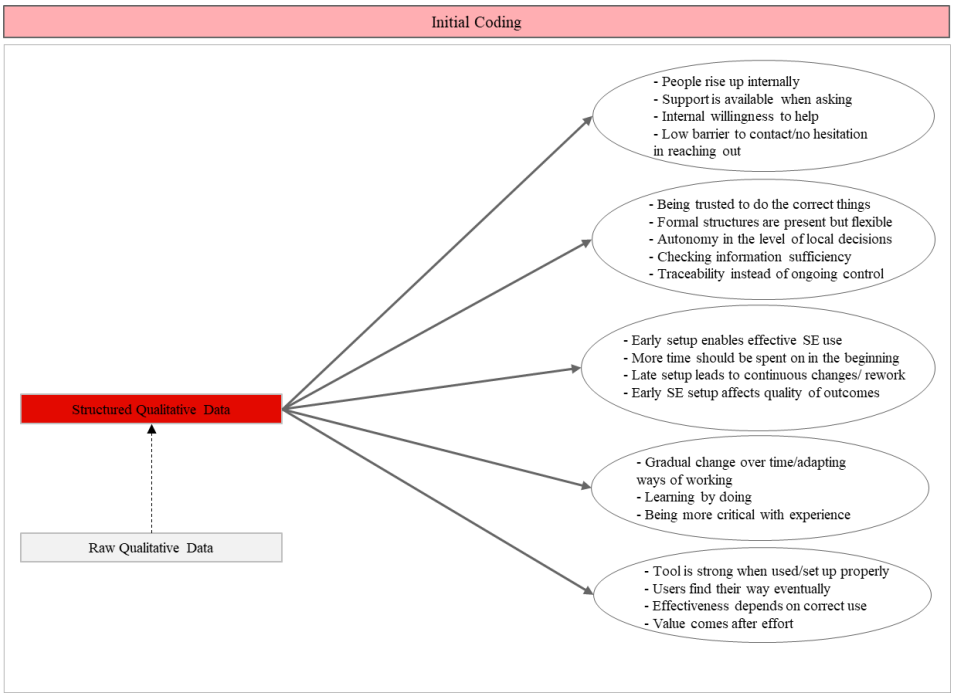

Figure 12: Initial codes related to cultural enablers

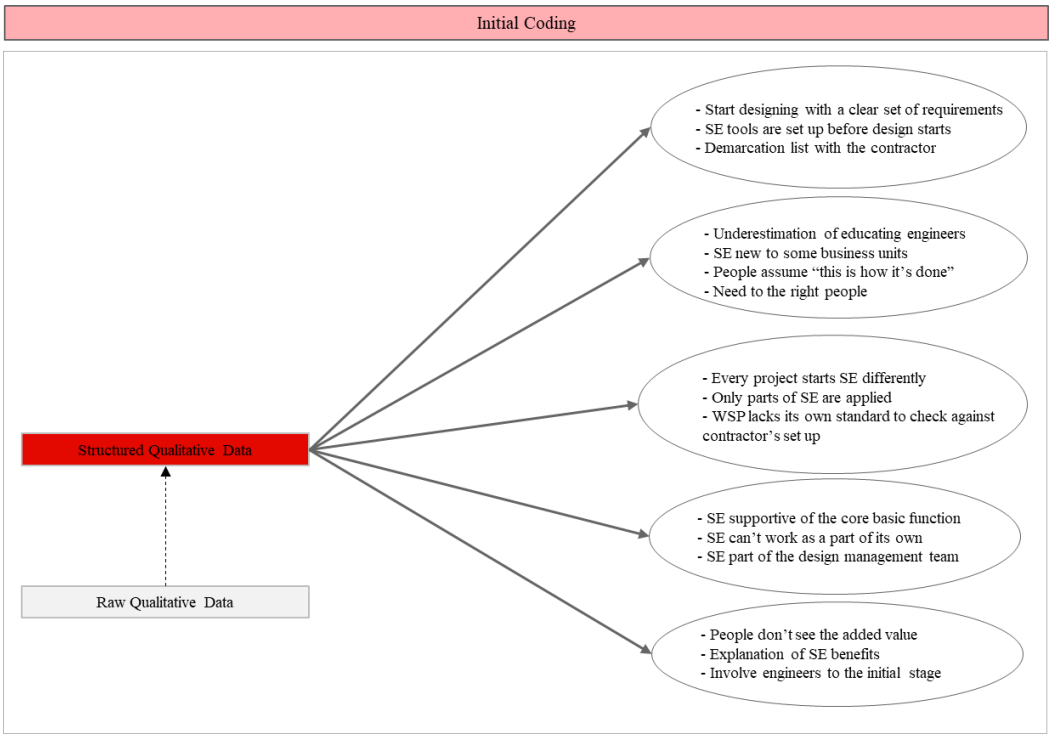

Figure 13: Initial codes related to implementation strategies

The initial coding followed an inductive and deductive approach. The codes emerged inductively from the interview data with focus to remain grounded in participants' accounts and avoiding the imposition of predefined theoretical categories. In parallel, the coding was theoretically sensitized by the research questions and the study's focus on OC. The initial codes primarily informed research sub-question 3 by identifying organizational culture factors influencing SE adoption, while a subset of codes captured forward-looking signals that were carried into later analysis phases to inform research sub-question 4. Coding and analysis rarely fall cleanly into one of these approaches and, more often than not, use a combination of both (Byrne, 2022).

- **Phase three: Generating themes**

In the next phase of TA, attention moved from the examination of individual coded data segments to the identification of broader patterns of meaning across the dataset. During this stage, the coded data are systematically reviewed to explore how related codes can be grouped together based on shared significance, enabling the development of initial themes and sub-themes that capture aggregated meanings within the data (Byrne, 2022). This process requires both analytical judgment and interpretive skill, as themes are developed based on their relevance to the research focus instead of their frequency alone. In this research, a thematic map was used to visually organize the process between codes, categories and themes. This supported the analytical process by enabling the researcher to assess the internal coherence of each theme and to ensure that themes were clearly distinguishable from one another.

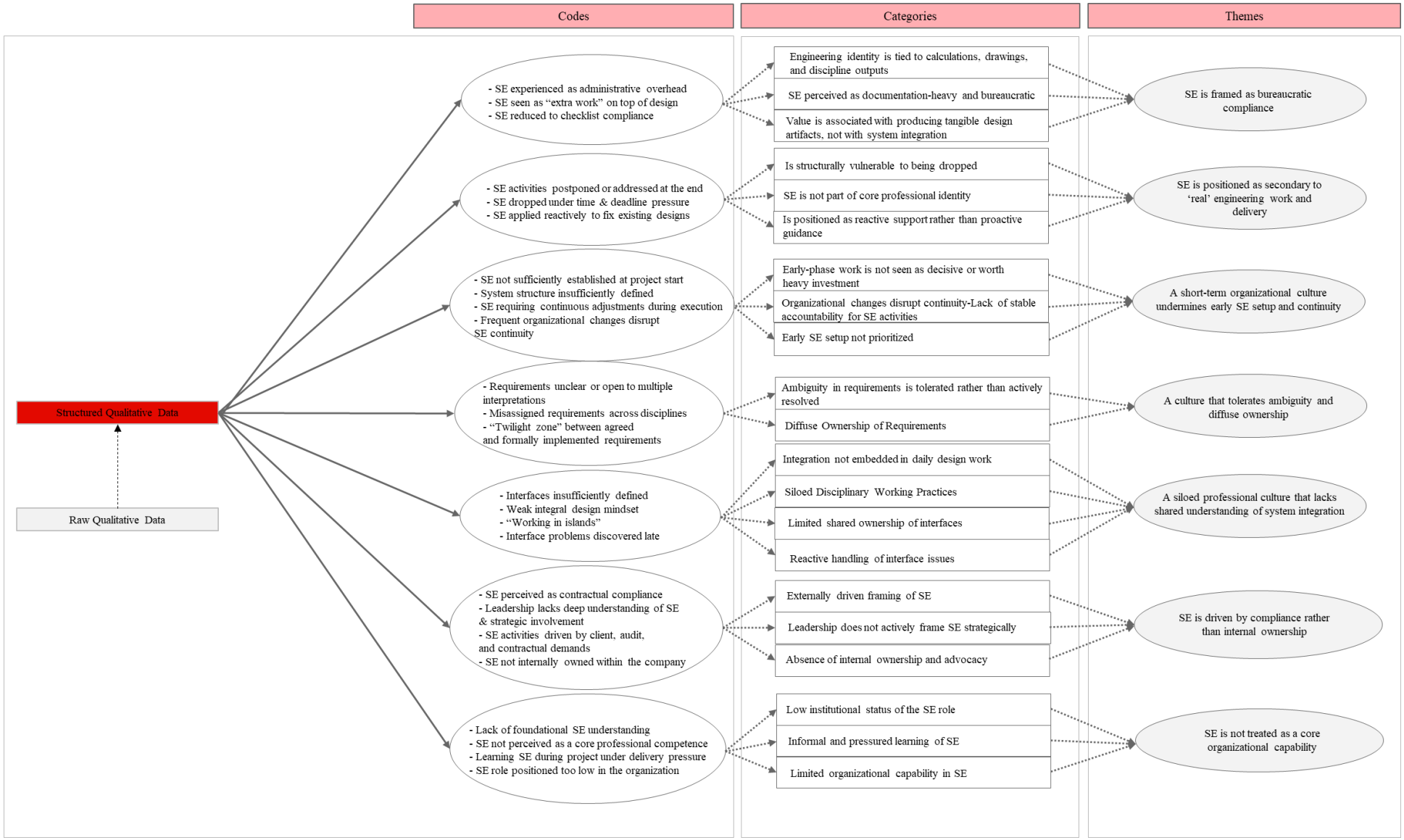

Figure 14:Coding process of the qualitative data referring to cultural constraints

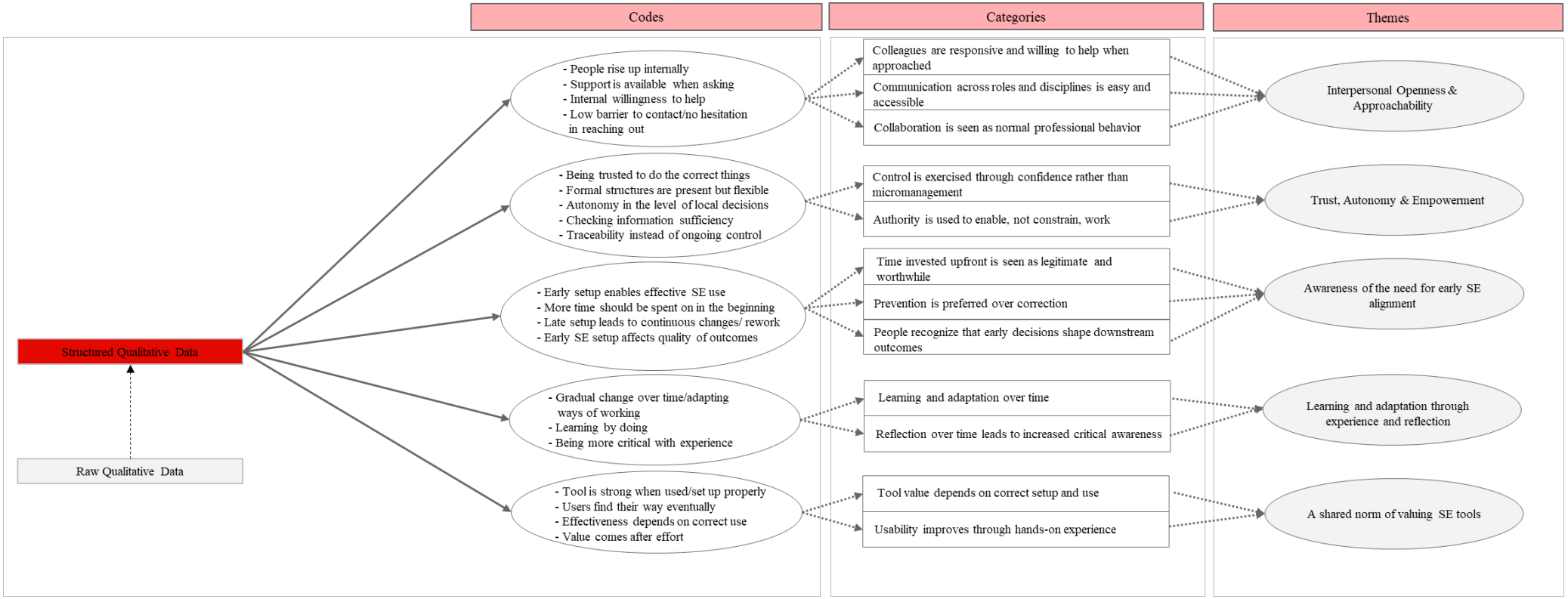

Figure 15: Coding process of the qualitative data referring to cultural enablers

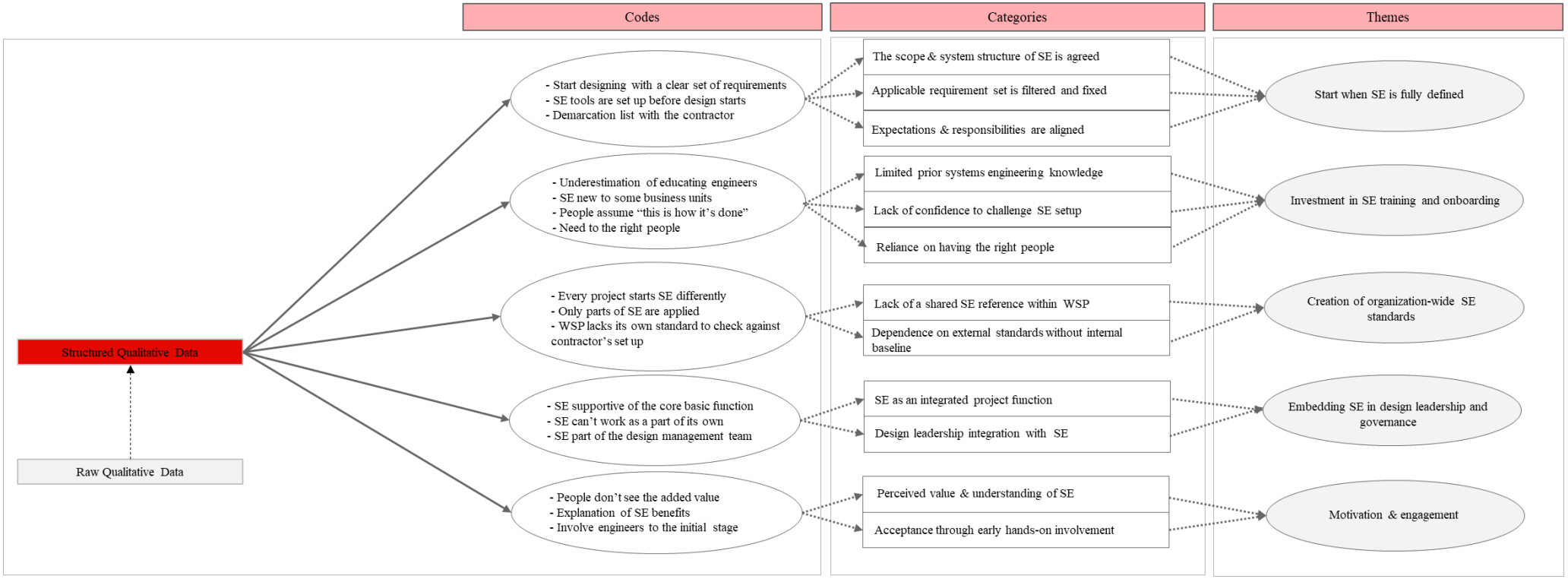

Figure 16: Coding process of the qualitative data referring to improvement strategies

Theme development is inherently iterative. Initial groupings may be revised, merged or refined as the analysis progresses and as the researcher critically evaluates the emerging thematic structure. Throughout this phase, reflexivity plays an important role, as researchers must remain aware of how their assumptions and theoretical perspectives may influence the organization and interpretation of the data. Maintaining clear documentation of analytical decisions supports transparency and methodological rigor (Ahmed et al., 2025). This phase serves as a crucial bridge between the coded dataset and the final analytical narrative. The resulting themes form the foundation for interpretation, ensuring that the analysis remains grounded in the data while providing a coherent and meaningful response to the research questions.

- **Phase four: Reviewing themes**

This phase is focused on reviewing the initially developed themes to assess their coherence, internal consistency, and alignment with the overall qualitative dataset. This phase involved a process of moving back and forth between the candidate themes, the associated coded data extracts, and the full set of interview transcripts to evaluate whether each theme captured a meaningful and shared pattern of meaning across participants. In line with reflexive TA this review emphasized the researcher's active interpretive role in questioning, refining and reshaping themes rather than treating them as fixed outcomes (Byrne, 2022). During this process, themes that lacked sufficient empirical support or displayed substantial overlap were modified, merged or removed to improve analytical clarity. This iterative refinement is also consistent with Saldaña's emphasis on second-cycle analytic work, where codes and categories are revisited, reorganized and refined to strengthen the coherence and credibility of the developing analysis (Saldaña, 2021).

- **Phase five: Defining and naming themes**

The last phase involved the final refinement and naming of the themes to clearly define the analytical focus and contribution to the research questions. Each theme was examined very carefully to identify its central concept and to determine that specific aspect of participants' experiences captured. Really important was to develop clear definitions that specify the boundaries of each theme and to ensure that themes were distinct from one another while remaining grounded in the qualitative data. This process resulted in a set of themes that directly address the research sub-questions. The key themes namely are below:

- T1: SE is framed as bureaucratic compliance
- T2: SE is positioned as secondary to "real" engineering work and delivery
- T3: Short-term and reactive organizational culture
- T4: Ambiguity and diffuse ownership are tolerated
- T5: A siloed professional culture
- T6: SE is driven by compliance rather than internal ownership
- T7: SE is not treated as a core organizational capability
- T8: Interpersonal openness & approachability
- T9: Trust, autonomy & empowerment
- T10: Awareness of the need for early SE alignment
- T11: Learning and adaptation through experience and reflection
- T12: A shared norm of valuing SE tools
- T13: Start when SE is fully defined
- T14: Investment in SE training and onboarding
- T15: Creation of organization-wide SE standards
- T16: Embedding SE in design leadership and governance
- T17: Motivation & engagement

4.7 Ethical and confidential considerations

Ethical considerations were considered throughout all the stages of this qualitative case-study to ensure protection and rights of participants. Participation was voluntary and all interviewees were fully informed about the purpose of the research, the process that would be followed and the use of the collected data prior to providing written informed consent. Participants were assured that they could withdraw from the study at any time, without consequences. To protect anonymity and confidentiality, personal identifiers were removed from transcripts so individually could not be identified and interview data were stored securely while accessed only by the researcher (Arifin, 2018). Given the in-depth and reflective nature of qualitative interviews, particular care was taken to conduct interviews respectfully and professionally, ensuring that participants were feeling comfortable sharing their experiences openly. In addition, ethical principles were applied to balance potential risks with the anticipated benefits of the research and to ensure responsible use of sensitive organizational insights and information. All the required ethical approvals for this study were obtained in accordance with TU Delft regulations. As part of this process, both the Data Management Plan and the Human Research Ethics Checklist were submitted through Lab Servant, TU Delft's laboratory safety and ethics management system, to ensure compliance with institutional ethical and safety standards (TU Delft, 2024). Prior to participation, all interviewees received detailed information about the topic of the study and were provided with an informed consent form, which was signed before the interviews took place. By signing the form, participants formally consented to the collection, processing and analysis of the data gathered during the interviews.

5. Results from interviews

This chapter presents the results of the qualitative interview analysis, focusing on the findings related to the third and fourth research sub-questions. The results are derived from an in-depth TA of the interview data and represent analytically constructed conclusions rather than isolated statements from individual participants. In addressing the third sub-question, the chapter identifies and explains key OC factors that enable or constrain the adoption of SE practices, as reflected in the experiences and perspectives of the interviewees. These findings are presented through a set of clearly defined themes that capture recurring patterns across the data. Building on these insights, the fourth sub-question is addressed by examining how the identified themes & literature findings are being translated into potential improvement strategies for supporting further SE adoption.

5.1 SE is framed as bureaucratic compliance

The interviews reveal a professional culture in which engineering work is mainly associated with discipline-specific design activities, while traceability and documentation are commonly perceived as administrative obligations. Within this context, SE is frequently experienced as additional workload and reduced to checklist compliance rather than being recognized as an integral part of their design process. As IC-03 stated, *"In between for everyone, it's just extra work, frustration, administration and a lot of hours."* Similarly, AL-02 noted that *"It felt like at some point I'm consumed by admin and systems engineering and lacking time for the actual design."*

Importantly, this perception does not indicate a rejection of administrative or coordination activities as inherently useless. Interviewees acknowledged that these activities are necessary but emphasized that they are often implemented or communicated in a way that limits their value for design outcomes. When SE is experienced primarily as a heavy documentation process and detached from daily engineering problem solving, it becomes perceived as administrative burden rather than as support for enhanced quality.

This framing is further reinforced by how engineers culturally define value in their work. SE-01 explained that *"They feel like as long as I have this bucket of requirements, I will get a good design, which isn't the case. That kind also didn't make me interested in the depth of the requirements, and it was just more a checklist of I have to do all these things and then I'm done."* This statement illustrates that value is predominantly associated with producing tangible design outputs, while activities related to system integration, requirements reasoning & traceability are viewed as secondary or instrumental rather than value-creating in their own end.

Several interviewees also indicated that SE activities are deprioritized under time pressure because they are not perceived as part of *"real engineering work."* SE-06 remarked*, "Let's be honest about that there's a lot of administration and that's why for a big part of our design it is not perceived as useful,"* while also adding, *"It is important, but we didn't see the benefits; we mostly see it as a downside."* Lastly PM-04 mentioned that *"People don't see the added value of system engineering in the design process. Therefore, they see it as administrative baggage…"* This reflects a tension between project environments that tend to be driven by speed and SE's emphasis on quality and long-term integration. In such contexts, SE practices are more likely to be overlooked when deadlines are tight.

SE-01 also observed that engineers typically focus first on calculations and design tasks, while SE is addressed afterward or omitted if time was intensified. Likewise, IC-03 described resistance to SE as stemming from the perception that it is *"something extra for them"* rather than an embedded component of design work. All these statements support a cultural framing in which SE is treated as a bureaucratic compliance rather than as legitimate engineering work that inhibits its integration into the core design process and its recognition as a value-adding practice.

5.2 SE is positioned as secondary to 'real' engineering work and delivery

Across the interviews, SE was consistently positioned as secondary to what participants described as *"real"* engineering work, which was primarily associated with producing design outputs and meeting delivery milestones. Several interviewees explicitly stated that SE activities were postponed until after core design tasks were completed. SE-01 explained that engineers *"we're talking about engineers, they focus on that, the work, the calculation that is being done and the design that is being made is done well and that is the focus point number one and afterwards when that's finished, they will look at the requirements."* This indicates that SE is not integrated into the design process but addressed at the end. Similarly, SE-06 noted that in practice *"we were already sometimes finished with the work package before we actually defined our work package within Relatics"*, confirming that SE was applied after design decisions had already been made.

Time pressure further reinforced this hierarchy. SE-01 stated that *"one of the first things that falls off the list whenever tough deadlines and time pressure is present"* is SE, because engineers prioritize the design over verification and traceability. This statement demonstrates that under schedule pressure, SE is treated as lower priority rather than essential.

Therefore, SE was often applied reactively instead of proactively. The DL-08 reflected *"We didn't take enough time at the beginning to set it up in the right way and as a result it kept dragging."*, this supports that SE being used as a corrective mechanism instead of a proactive one. SE-06 described his present role as *"putting a bandage on our design"* by retrospectively improving things something that illustrates how SE was used to repair gaps and fix errors rather than guide early decision-making.

These practices reveal an implicit professional norm in which visible progress, such as drawings issued, calculations completed and deadlines met, is valued more highly than reflective activities such as early-stage requirements analysis and alignment. Because SE does not immediately produce tangible design artifacts, it is not recognized as part of engineers' core professional identity and is therefore postponed, minimized or applied only when problems emerge.

5.3 A short-term and reactive organizational culture

The interviews indicate that SE was not sufficiently established at the start of the project, which had lasting consequences throughout the design and execution phases. Several participants emphasized that insufficient time and attention were given to setting up SE structures, requirements allocation and system breakdowns before design activities began. The IC-03 explicitly reflected that *"If things have been agreed and aligned in the beginning, then you would see less and less problems as the project progresses, but now we need to change things during execution."* Similarly, the AL-02 noted that the team *"should have spent a lot more time in the beginning on the systems engineering to get the system in place and the object tree and the*

responsibilities," indicating that foundational SE decisions were underdeveloped when design work began. This late introduction reduced the effectiveness of SE and required continuous adjustments, as Relatics and associated structures had to be repeatedly modified instead of providing a stable framework for design. In addition, PM-04 mentioned that *"what we didn't do was in the beginning at a good demarcation list with the contractor, what they would do for system engineering and what we would do as engineers for system engineering."* continue saying *"and we needed to check, confirm, do the smart analysis, connect the requirements & objects."*

Organizational instability further disrupted SE continuity. Frequent changes in roles, responsibilities and organizational structure meant that ownership of any kind of SE activities was repeatedly redefined. DL-07 reported that the organizational diagram changed *"8–9 times over the last two years,"* with people frequently joining and leaving, which disrupted responsibility allocation and stability. Collectively, these findings point to a short-term, adaptive OC in which early-phase systems work is not seen as decisive or worth substantial upfront investment. So, the project relied on reactive acts to emerging problems, undermining the continuity and the potential benefits of SE and the ability to function as a stable and value-adding practice across all the project phases.

5.4 Ambiguity and diffuse ownership are tolerated

Several participants described the initial set of requirements as unclear or problematic yet accepted as a given input to work with. SE-01 noted that at project start *"we got a list of requirements that was badly translated from Dutch to English,"* which resulted in *"a lot of haze and vagueness because nobody or a lot of people really knew what the requirements meant or when they had to be applied."* Despite ongoing discussions about unclear or not smart requirements, he observed that *"nothing was done with that,"* indicating that ambiguity persisted rather than being systematically addressed. Similarly, AL-02 explained that the team *"lose so much time on discussing requirements that are not clear requirements,"* adding that many could be *"interpreted in multiple ways,"* further reinforcing what previously mentioned.

In addition to unclear requirements, ownership of requirements was diffused across disciplines. AL-02 described how *"a lot of requirements [were] being assigned to architecture and then you look at them and they are requirements for the civil designer or for the terrain,"* leading to repeated coordination efforts and inefficiencies. This lack of clarity was echoed by DL-08, who stated that a major struggle was determining responsibility: *"Is it architectural that has to verify these requirements or is it structural, is it terrain or is it someone else?"* As a result, engineers frequently had to negotiate responsibility informally rather than working from a clearly defined allocation.

Finally, several interviewees pointed to an intermediate state between agreed requirements and formally implemented ones, which further reinforced uncertainty. The DL-08 described a *"Twilight Zone where you don't know what kind of requirements you really have to work with,"* explaining that although requirements were discussed and partially agreed with the client, they were not updated in the SE system until formal contractual sign-off. Consequently, teams continued working with the full set of requirements, even when parts were known to be inapplicable. Taking together, these findings indicate a project culture in which unclear and misassigned requirements were accepted conditions of work and responsibility for resolving them was fragmented.

5.5 A siloed professional culture

The interviews consistently show that interface management was undermined by a siloed way of working in which disciplines prioritized their own scope and deliverables over integrated design outcomes. Several participants explicitly described a lack of integral design thinking. The IC-03 observed that *"people are working on their own islands and they don't see the design as an integral design,"* explaining that disciplines tend to focus on "my own design" and only collaborate when explicitly asked. This fragmented approach meant that interfaces were not collectively addressed but treated as secondary coordination issues. Similarly, the AL-02 noted that *"the way we work a lot in islands"* results in teams *"running with their own problems, having their own deadlines not aligned,"* reinforcing disciplinary boundaries rather than shared responsibility for system integration. PM-04 mentioned that *"system engineering is not that integrated yet within design processes."* Lastly, DL-08 said that *"in the first working packages of IJVA, we didn't saw that integration to be fully fulfilled and there was a lot of hand-picking work."*

As a consequence, interfaces were often insufficiently defined during design and only surfaced later during construction. IC-03 stated that *"if the disciplines don't talk to each other, in the construction phase it is impossible,"* noting that problems emerged because alignment did not occur early. This was echoed by the SE-09, who described interfaces as *"not well defined"* and *"not known by parties,"* emphasizing that unresolved interfaces *"are coming onto my desk… that is way too late in your design stage."*

These accounts indicate that integration was not seen as shared design work but as an complementary task delegated to interface coordinators or systems engineers. As SE-06 noted, that *"interface management is pushed by the systems engineers, and it was not really owned by the teams"* yet in practice it was pushed onto the SE function rather than embedded in everyday design activities. In addition, he continued by saying that *"Everybody in the project is actually a systems engineer, just a guy who's holding the title… this is a really wrong thought that a lot of people apply."* Culturally, this reflects a professional environment in which disciplinary autonomy and individual deliverables are valued more than shared ownership. This siloed culture limits proactive interface management by discouraging early engagement and allowing problems to accumulate until they manifest as costly rework during later project phases like execution stage.

5.6 A compliance-driven culture prevents internal ownership

The interviews indicate that SE was largely perceived as an externally imposed activity rather than an internally valued practice, which limited its ownership within the project organization. Several participants explicitly linked SE activities to client, contractual and audit demands. The DL-08 openly stated that at the start of the project he had *"zero"* experience with SE and as a result, responsibility for SE was largely managed through contractual and administrative channels rather than strategically embedded in design leadership. SE-06 emphasized this contractual framing by explaining that, from the contractor's perspective, *"systems engineering is managing the contract,"* and that the project was considered finished once *"obligations within the contract are ended,"* regardless of broader system performance. This orientation was echoed by DL-07, who noted that SE reports were written primarily for *"the client and the auditor,"* and that the logic behind verification was *"not technical, but purely administrative."*

Collectively, these statements point to a culture in which SE is framed as a means of demonstrating contractual compliance rather than as a strategic and value-adding practice internally in WSP. Because SE is not actively framed by leadership, it is not internally owned by project teams and remains associated with external control and accountability. This inhibits effective SE adoption by the organization's ability to develop and internalize its own standards and practices for proactively meeting client requirements.

5.7 SE is treated as a core organizational capability

The interviews indicate that SE was not treated as a core professional competence within the organization, but as a secondary skill that individuals were expected to acquire while delivering the project. Several interviewees mentioned that there was lack of foundational SE knowledge across roles, including leadership positions. The DL-08 explicitly stated that at the start *"I was totally not aware of anything with system engineering"* which made it difficult to meaningfully guide teams in how and why SE should be applied. DL-07 mentioned *"I'm not really supporting it I'm using it. SE is not motivating many people."* Similarly, other participants described limited prior exposure to SE concepts, often referencing only fragmented or outdated training. As a result, the purpose and value of SE were not widely understood. SE-06 observed that at the start *"nobody really understood what the idea was behind doing systems engineering,"* while SE-01 noted that engineers *"don't know why they're doing it"* and that *"there is no support essentially for them to understand it."*

Rather than being supported through structured training or formal capability development, learning SE was largely expected to occur on the job and under delivery pressure. The DL-08 reflected that he had to make *"quick learnings"* before starting the project and that, in practice, *"everyone had to learn it by themselves."* This expectation was supported by project conditions, with DL-07 noting that when *"pressure to deliver"* increased, teams tended to prioritize output and *"just do",* leaving little space for reflective learning. Moreover, the organizational positioning of the SE role limited its influence. DL-07 argued that the system engineer *"should be part of the design management team."* and continued *"To say it very bluntly, the system engineer as we have positioned them in the organization are actually too low, they expected more like a BIM coordinator level, but I think actually it should be higher*."

In summary, these data indicate that SE was not treated as a core professional competence but as a secondary skill to be acquired informally under delivery pressure, resulting in limited shared understanding of its purpose and value across roles, including leadership. At the same time, the relatively low organizational positioning of the system engineer role constrained its authority and influence.

5.8 Interpersonal openness & approachability

In contrast to the inhibitors identified earlier, the interviews also revealed a trust-based and collaborative culture that enables informal coordination across roles and disciplines. Several participants emphasized that interpersonal barriers to asking questions were low or non-existing and that reaching out for clarification or support was generally easy. IC-03 stated that *"approaching is not a problem,"* explaining that when something was unclear, could simply ask colleagues and, if needed, follow up. Similarly, SE-01 noted that when issues being encountered, he could *"always send a question"* and would *"very often get a response and advice on how to proceed."*

This openness was also supported by SE-09, who stated that *"I can call everyone and I can ask all the questions I want to ask,"* highlighting a climate in which communication is accessible.

Beyond openness, there was a willingness to support colleagues, even when issues fell outside formal role boundaries. IC-03 described actively helping systems engineers explaining that she preferred to speak up *"instead of saying nothing and just let it go."* In addition, SE-01 similarly observed that *"internally we have pretty good collaboration. When asking for support like internally people really rise up to the task."* Across interviews, collaboration was described as normal professional behavior rather than as an exception. Even when teams were distributed across organizations and locations, participants emphasized a shared willingness to cooperate, with the SE-09 noting that collaboration across companies was *"really good"* and that difficulties were related to logistics rather than unwillingness. All these suggest that low interpersonal barriers and a willingness to support one another function as a cultural enabler for informal coordination in SE work.

5.9 Trust, autonomy & empowerment

Across the interviews, a trust-based approach to authority and decision-making emerged as a cultural enabler for SE practice. Although participants acknowledged that formal structures and approval chains existed, they simultaneously emphasized a working context in which engineers were trusted to act autonomously within those structures. This was reflected in statements such as SE-01's statement that he had *"free rein"* and that his lead engineer trusted him *"with system engineering to do the correct things,"* indicating confidence in individual professional judgment. Similarly, was described from SE-09 where decisions were characterized as *"really open to my interpretation"* and *"up to my discretion,"* suggesting that engineers were empowered to make local SE-related decisions when needed. Importantly, this autonomy was not described as unchecked. Accountability was maintained through confirmation and traceability, as illustrated by the IC-03's remark that she would *"only close it when I have the confirmation that the information is sufficient."* Likewise, SE-06 explained that while technical decisions could be challenged, *"at a certain point you have to trust the decision that is made and just make it traceable,"* highlighting that alignment with SE principles was ensured through transparency and documentation rather than continuous managerial control. Thus, it indicates a culture in which trust enables autonomy, while quality and alignment are safeguarded.

5.10 Awareness of the need for early SE alignment

The interviews indicate a shared recognition that early investment in SE is critical for its effectiveness and for overall project outcomes. SE-06 explicitly stated that *"systems engineering can be applied very well but only if you start with systems engineering very early in the project,"* emphasizing that SE *"can't be picked up later on."* This view was reinforced by AL-02, who reflected on the project retrospectively, describing a key lesson learned: *"we should have spent a lot more time in the beginning on the systems engineering to get the system in place."* He further linked early investment directly to outcome quality, noting that "if you don't spend the time in the forehand, you'll also not get that quality product out of it." Similarly, DL-07 emphasized the importance of upfront SE setup prior to design activities, stating that *"Relatics is very useful if the project is set up in the right way in the beginning and you really have to do that prior to start designing, because otherwise you keep on altering the whole set of it."* These statements demonstrate an explicit awareness among participants that early SE work shapes downstream

outcomes and that time invested upfront is not wasted effort but a necessary condition for preventing later rework and achieving better outcomes.

5.11 Learning and adaptation through experience and reflection

The interviews indicate that learning and adaptation in relation to SE developed gradually over time and were shaped by experience and reflection. DL-07 described how practices evolved during the project, noting that *"over the months, years that has been changed and adopted,"* and that through this process he was eventually able to *"find my way,"* suggesting a learning curve rather than immediate mastery. This reflective learning is further illustrated by DL-08, who stated, *"If I should do now the same job, I think I would be more critical on certain aspects,"* indicating that experience led to increased awareness and more informed judgment. In addition, DL-07 explicitly recognized the importance of early involvement, explaining that he *"wasn't aware of the impact"* at the time and that *"if I had come half a year earlier, I should have stepped into there… to really spend time on having all these requirements assigned to the right design discipline."* Lastly AL-02 said *"Looking back, I would have pushed back earlier and said: let's stop here and sort things out first."* Together, these statements show that understanding of SE did not emerge as a one-off event but developed through reflection on past actions and adaptation over time.

5.12 A shared norm of valuing SE tools

Through the interviews, several participants expressed a generally positive orientation toward the use of SE tools, particularly Relatics, when these tools were properly set up and used as intended. DL-08 emphasized the value of Relatics for project oversight and efficiency. He stated that *"Relatics is very useful if the project is set up in the right way in the beginning and you really have to do that prior to start designing"* highlighting the importance of early and correct configuration. This positive assessment was continued by practitioners working closer to interfaces and day-to-day coordination. The IC-03 reported having *"nothing to say against Relatics,"* characterizing it as *"a nice tool"* and emphasizing its usability by describing it as *"straightforward."* and further remarked that *"it's not complicated… you'll find your way eventually,"* suggesting that, from a user perspective, the tool is accessible and learnable in practice.

From the SE-06 roles reinforced this conditional but positive view by stating that *"Relatics is very strong if it is used properly,"* while also acknowledging that *"it takes a bit of investment… before it becomes valuable."* This framing presents tool acceptance as tied to initial effort and learning, rather than inherent complexity. Participants generally perceive Relatics positively, acceptance is not unconditional, but is grounded in the experience that, when properly configured and invested in, such tools meaningfully support SE work rather than hinder it.

5.13 Start when SE is fully defined

Interviewees consistently indicated that design activities started while key elements of SE were still unclear or incomplete. Several participants described that design begun without a clearly filtered and applicable requirement set. DL-08 noted that *"we worked more than half a year based on the full set of requirements"*, while PM-04 acknowledged that the team *"designed first and then checked whether the requirements matched,"* referring to this as *"a reverse engineering method."* In addition, SE tools were not fully set up before design began. PM-08 emphasized that

"Relatics is very useful if the project is set up in the right way in the beginning," while IC-03 stated that projects should ensure *"the tools are already set up"* before starting, rather than fixing them during execution. Furthermore, responsibilities between the contractor and WSP were not clearly demarcated at the outset which contributed to ongoing confusion about roles and scope.

5.14 Investment in role-specific SE training and onboarding

Interviewees consistently emphasized that limited prior experience with SE reduced confidence and effectiveness in its application, underscoring the need for targeted training and onboarding. PM-04 acknowledged that *"we underestimated the importance of educating our engineers for system engineering"* and further noted that, within certain business units, *"system engineering was not part of the normal design work, so that's quite new"*. This indicates that engineers entered the project with varying levels of familiarity with SE, depending on their organizational background. From a designer's perspective, AL-02 similarly reflected that *"if you never did systems engineering before, you think: this is probably the way it's done"*, suggesting that a lack of foundational knowledge limited the ability to critically assess or challenge how SE was implemented. In addition, IC-03 highlighted the importance of *"finding the right people"* for SE-related roles, implying that effective application depends not only on tools and processes but also on having appropriately trained and positioned personnel. Thus, it is important to invest in SE training and structured onboarding to build competence, confidence and consistent application across roles and business units.

5.15 Creation of organization-wide SE standards

Interviewees explicitly highlighted the absence of a shared and consistent approach to SE within WSP, pointing to the need for organization-wide standards. PM-04 emphasized that while *"there's not one way to work with system engineering,"* WSP currently lacks a common reference, stating: *"We don't have that description, like how do we work with system engineering? What's our WSP standard in that way?"* He further explained that this results in inconsistency across projects, as *"in every project we start new, we do it in a new way."* From a similar perspective, PM-05 described the current practice as fragmented, noting that *"how we're doing it within WSP is on the fly,"* where *"we're just doing parts of it and we try to connect dots, but in the end it's not a coherent practice."* From the DL-08 point of view is argued that WSP should develop its own standards even for projects executed under contractors, stating that although *"the contractor is setting up everything,"* WSP still needs internal standards to *"really check whether what the contractor has set up complies to our standards."* Together, these statements demonstrate that SE within WSP is applied inconsistently across projects and contexts, directly supporting the need for the creation of WSP wide standards.

5.16 Embedding SE in design leadership and governance

Interviewees emphasized that SE should not function as a separate or isolated activity within projects but should be integrated into core project and design leadership structures. SE-06 explicitly stated that SE *"should be really supportive of the core basic functions in the normal project"* and warned that *"it will go wrong if you will see systems engineering as a part of the project that's on its own."* This highlights that SE loses effectiveness when it is treated as an independent line of work and not as an integral part of how projects are managed and designed.

DL-07 reinforced this view by stating: *"I think the system engineer there should be also part of the design management team."* Together, these statements indicate that effective application of SE requires it to be embedded within design leadership and governance structures, instead of positioned alongside or outside them.

5.17 Motivation & engagement

Interviewees consistently indicated that motivation and engagement with SE are strongly influenced by whether engineers understand its value and are involved from the start. Several participants noted that when the benefits of SE are not visible, it is perceived as burden and not as support for design work. IC-03 explicitly stated that *"the organization needs to find a way to show with tangible examples how system engineering benefits the design and the project"*. Similarly, PM-04 reflected that *"People don't see the added value of system engineering in the design process"*, highlighting indicating that limited understanding of its purpose negatively affects motivation. SE-01 stressed the importance of early and active involvement, stating: *"Tell us what you think about it. To have their [engineers] inputs… at least like from the start, just these are the requirements we're going to work with if you have any doubts, you can just share them."* This indicates that engineers are more motivated to engage with SE when they are invited to contribute early instead of being confronted later with fixed requirements and procedures. Overall, these statements show that early hands-on involvement and tangible benefits are key conditions for motivation and engagement with SE.

5.18 Conclusions

This chapter presented the analysis of the empirical findings derived from semi-structured interviews, revealing how SE is perceived and experienced in practice within the studied organizational context. The results demonstrate that SE adoption is shaped not only by formal processes and tools but to a large extent by underlying OC factors that influence priorities, behaviors and decision-making in the project. Together, these insights show that organizational culture plays a critical role in determining how, when and to what extent SE is applied in practice. Building on these findings, the following sections explicitly address research sub question 3 by synthesizing the identified cultural enablers and constraints and their impact on SE adoption, and research sub-question 4 by translating these insights into multi-level improvement strategies that support more effectively SE adoption.

RSQ3: *What organizational culture factors, identified from empirical findings, enable or constrain the adoption of Systems Engineering practices?*

To answer this the interview data were synthesized into a set of core OC factors that shape how SE is understood and valued in practice. Drawing on established definitions of organizational culture as shared meanings, norms, professional identities and leadership framings, the factors presented below capture repeated cultural patterns rather than isolated practices or structural conditions. Each factor reflects a collectively held interpretation of *"how work is done"* and indicates whether it enables or constrains the adoption of SE. *Table 10* summarizes these factors, their impact on SE adoption refers to the practical consequences of each one of them, with references to the empirical sections that support each factor. Specifically, *"impact"* describes what a given perception or cultural condition causes in practice, in terms of how SE is used,

when it is applied, the quality of its execution and the extent to which it supports integration of the system as a whole.

Table 10: Summary of the cultural enablers & constraints derived from empirical findings

Influence type	OC factor	Impact on SE adoption	Supporting Section
Constrains	SE perceived as bureaucratic compliance	Limited contribution to system-level decisions and integration	5.1
	SE positioned as secondary to "real" engineering work & delivery	Applied late or inconsistently, reducing its influence on design quality	5.1 & 5.2
	Short-term and reactive organizational culture	Delayed detection of errors and fragmented lifecycle alignment	5.3
	Ambiguity and diffuse ownership are tolerated	Requirements are managed inconsistently, reducing clarity, traceability and accountability	5.4
	Siloed professional culture	Undermines effective integral thinking and interface management	5.5
	SE framed as contractual compliance	Undermines organizational learning and internal capability development	5.6
	SE not treated as a core organizational capability	Weakens strategic positioning of SE and constrains its authority within project governance structures	5.7
Enablers	Interpersonal openness & approachability	Facilitates informal coordination,supporting day-to-day SE work	5.8
	Trust autonomy & empowerment	Encourages local SE initiative and transparency	5.9
	Awareness of the need for early alignment	Strengths requirements definition, roles & responsibilities and helps prevents rework	5.10
	Learning and adaptation through experience and reflection	Improves performance over time, increasing consistency and quality across projects	5.11
	A shared norm of valuing SE tools	Improves oversight and traceability on information management	5.12

RSQ4: *Which improvement strategies contribute to the successful implementation of Systems Engineering in the construction project as retrieved from the empirical findings and literature?*

This section addresses the last sub-question by translating the insights from the literature review (Chapters 2 & 3) and the empirical findings (Chapter 5) into actionable recommendations. The focus now is toward practical strategies that can strengthen SE implementation in practice.

Both the literature and the empirical results indicate that successful SE adoption depends on alignment across multiple organizational layers. Prior research emphasizes the importance of strategic commitment, project-level governance and individual competence and motivation in enabling SE effectiveness. The empirical findings from the case study confirm this perspective, showing that challenges related to unclear ownership, late SE involvement, limited authority and low confidence in SE practices manifest differently across organizational levels but are closely interconnected.

Accordingly, the identified improvement strategies are structured across three levels: executive, project and individual. This structure reflects both the theoretical understanding of SE as a socio-technical system and the empirical observation that cultural and organizational conditions must be aligned across levels to support effective adoption. *Table 11* presents these synthesized findings organized by level to provide a clear and actionable overview for construction projects.

Table 11: Multi-level improvement strategies for the successful implementation of SE

[1] Executive level strategic ownership and capability building	[1.1] Have a clear vision and include it in the organization's strategic objectives	[1.2] Establish organization-wide SE standards A shared internal baseline that defines common processes & expectations	[1.3] Invest in SE training and onboarding Across all business units: foundational knowledge	[1.4] Elevate the SE role in the organization As a critical and valued function within the organization with sufficient visibility & authority
[2] Project level early setup, integration, and delivery alignment	[2.1] Invest in the proper setup of SE before project start Allocating sufficient time and resources (project team)	[2.2] Start when SE is defined by the project team Start only after SE scope, responsibilities, requirements, and system structure are agreed among all parties	[2.3] Embed SE into design leadership & governance Sufficient authority to influence early decisions and enable proactive system-level guidance	[2.4] Strong leadership support Actively support and protect SE even under time pressure, Person that values/emphasizes the importance of it
[3] Individual level competence, motivation, and readiness	[3.1] Strengthen motivation by making SE benefits visible Successful implementation examples, demonstrating how SE prevents rework, showing how it contributes to improved project outcomes	[3.2] Build *"systems thinking identity"* Encourage individuals across all disciplines to see system integration thinking as part of their professional engineering responsibility	[3.3] Build SE competence and confidence early involvement Critically assess decisions and assumptions Feeling that their opinions are valued and taken into account	

The table is intended primarily for organizational and project decision-makers involved in the implementation of SE, such as executives, senior system engineers and project leaders, as it clarifies where responsibility and intervention are required at different organizational levels. At the same time, it is purposefully structured to remain accessible to practitioners and individual engineers, making explicit how organizational expectations translate into project practices and individual behaviors.

The table should be read vertically, from top to bottom, reflecting the layered nature of organizational change required for successful SE adoption. Each row represents a distinct organizational level starting from the executive level that forms the foundation by setting strategic direction, providing legitimacy while creating the conditions under which SE can succeed through vision, standards and resources available. The project level translates this strategic intent into practice through embedding SE into early project setup, governance and leadership, ensuring that systems thinking is actively applied in day-to-day decision-making. Finally, the individual level captures the role of professionals themselves, emphasizing competence, motivation and readiness to engage with SE principles in their daily work. Importantly, the table illustrates a mutual dependence between levels: while organizations must actively inspire, support and enable their employees, individuals must also recognize their own responsibility in adopting a systems-thinking mindset and contributing proactively to integration efforts. In summary, it is fair to argue that the primary effort should be made at the executive level, as this level establishes the enabling conditions for all subsequent actions, however, executive initiatives alone are insufficient, as their impact only becomes visible when they are translated into concrete project practices and internalized by individuals.

6. Development of the Causal Loop Diagram

This chapter presents the development of the CLD, which is used to illustrate the dynamic relationships between OC and the adoption of SE in construction projects. Building on the empirical findings from Chapter 5 and insights from the literature review, the CLD translates key factors identified into a system-based representation. By capturing feedback mechanisms and non-linear interactions, the diagram moves beyond the linear explanation of SE adoption and highlights how reinforcing and balancing loops shape implementation outcomes over time (Section 6.5 – 6.7). Lastly, the next section interprets the diagram in terms of its practical application within the organization (Section 6.8) and the intended uses of the proposed CLD as identified in the literature are presented (Section 6.10).

6.1 Systems thinking

Systems thinking is a scientific approach concerned with organizing logic and integrating multiple disciplines in order to understand patterns, relationships but also interactions in complex problems. Often it is referred to as systemic or holistic thinking and it emphasizes the analysis of connections between elements that may initially appear independent. Instead of focusing on isolated components, systems thinking seeks to understand how interactions and interdependencies shape overall system behavior (Haraldsson, 2004).

Within this perspective, system thinking encompasses two closely related concepts: System Analysis and System Dynamics. SA focuses on identifying and understanding organizational structures and causal relationships within a system. It involves decomposing a problem into its constituent elements and reassembling them to reveal feedback relationships and underlying structures. A key activity within SA is group modelling, in which a shared mental model of the problem is developed. CLDs are commonly used in this context to visualize causal relationships that characterize the system. SD extends this understanding by examining how systems respond dynamically to changes over time, both internal and external. While SA supports the development of conceptual models, SD builds on previously developed mental models by translating them into formal, often mathematical, representations that enable the analysis of dynamic behavior, uncertainty and potential future outcomes (Haraldsson, 2004).

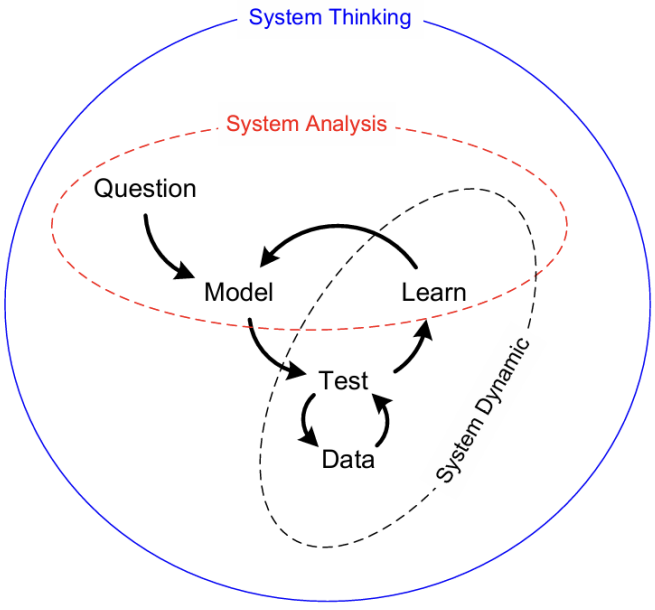

Figure 17: Function of a system through systems thinking (Haraldsson, 2004)

6.2 Objective of the CLD

Within the scope of this study developing a CLD was selected to capture and explain the mechanisms through which OC influences the successful adoption of SE in construction projects and thus answering the main research question.

The development of the CLD builds upon the concept of **influence diagrams**, which are designed to capture people's perceptions of cause–effect relationships within a system. In this context, an influence diagram represents key variables of the system using words or phrases, while arrows indicate the mechanisms through which a change in one variable affects another. Such diagrams aim to represent how participants explain why certain conditions evolve over time. Compared with conventional mind-mapping techniques, the construction of influence diagrams requires a more disciplined approach in defining variables and causal connections, while still allowing flexibility in expressing relationships and ideas (Proust & Newell, 2020).

Building on this approach, CLDs are used to support understanding of the actions and mechanisms that drive system behavior by making causal relationships, feedback processes and resulting behavioral patterns explicit (Cassidy et al., 2022). They enable the identification of reinforcing and constraining dynamics, as well as effects and unintended consequences of actions within the system. In system dynamics usage, the term feedback refers to situations where there are causal loops.

Consequently, the CLD serves two main purposes in this research. First, it functions as an **analytical tool** that helps identify and explain the systemic relationships linking specific cultural attributes, SE practices and adoption outcomes (Littlejohns et al., 2021). These mechanisms interact through reinforcing and balancing feedback loops that either support or constrain the effective implementation of SE over time. Second, it acts as a **communication tool** that visualizes the structure of the problem in a clear and transparent way, enabling a shared understanding of the complex dynamics involved in SE adoption within construction projects.

All models, either conceptual or mathematical, inherently reflect a systems thinking perspective, as they are built upon specific assumptions and causal logics. A model is effective only when this underlying reasoning is clearly communicated and shared among stakeholders. The CLDs are developed mainly using a qualitative approach such as literature review, observations and interviews. In the context of this research, relationships are based on these resources, and such clarity is essential and described further in *Section 6.4*.

Finally, through this representation, the CLD aims to provide the foundation for explaining that disrupting or amplifying feedback loops can be effective leverage points in systems change where organizational interventions, such as leadership actions, governance structures or learning processes may strengthen the successful adoption of SE.

6.3 Integration of Organizational Culture - CVF Perspective

Before identifying and operationalizing the variables used in the CLD, this section briefly explains the conceptual integration-mapping between OC and CVF as visualized in *Figure 18*. It uses the CVF as an interpretive lens to relate organizational culture orientations (Clan, Adhocracy, Market, Hierarchy) to the cultural conditions that influence SE implementation. Importantly, the CVF is not applied as a classificatory tool: the organization is not labelled as one single culture type. Instead, it supports interpretation of coexisting and sometimes competing cultural patterns, treating OC as a dynamic influence rather than a fixed organizational attribute.

Within the dotted cultural boundary, the ovals represent cultural enablers and constraints identified through both the literature and the empirical findings. The arrows indicate dominant cultural alignments, meaning that certain cultural orientations are more likely to be associated with specific enablers or constraints. These alignments are not deterministic and should not be interpreted as direct causality. They indicate tendencies observed across the theoretical and empirical material. For example, Clan culture tends to align with trust, open communication and peer support, whereas Market culture is more strongly associated with short-term performance pressures and weak cross functional cooperation. It can also be noticed that many constraints align with Market and Hierarchy cultures because the same characteristics that make these cultures effective for control and performance can also constrain SE when they dominate or are unbalanced. These cultures are not inherently negative, but they can enable SE while also carry specific risks.

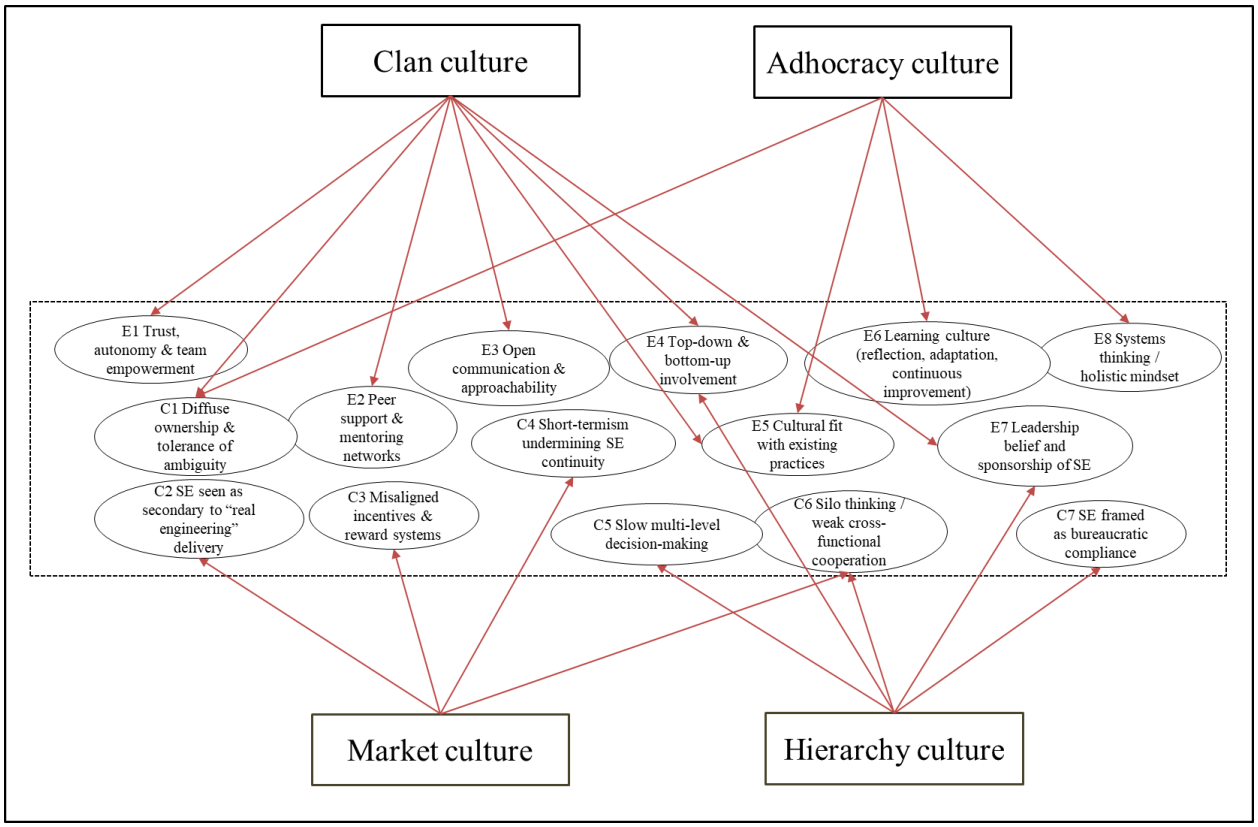

Figure 18: Mapping organizational culture factors to CVF

This conceptual integration provides the starting point for the CLD developed in the following sections. Rather than being modelled as fixed variables, OC orientations function as contextual conditions that give rise to specific enablers and constraints. These factors are subsequently operationalized as dynamic variables in the CLD to examine how cultural influences unfold over time through feedback mechanisms.

6.4 Identification of CLD variables

To visualize and study the complex behavior of OC variables, a CLD was developed using the software "Vensim® PLE". The software is designed to support the simulation and analysis of complex dynamic systems by modeling system behavior over time. It represents interdependencies through feedback loops and causal relationships, enabling a structured examination of interactions among variables. In addition, it facilitates the visualization of model

behavior, allowing analysts to explore how variables evolve under different conditions. Through simulation, it supports the identification of leverage points and contributes to the optimization of system performance. Furthermore, its graphical and analytical capabilities enhance the effective communication of insights derived from system dynamics models (Ventana Systems, Inc.).

Identifying the key elements-variables is a critical step in the development of CLD. In this study, a set of 16 variables was selected to capture the core dynamics of the system. The selection was guided by established modeling principles and refined through repeated review and critical reconsideration to ensure conceptual clarity & relevance. All variables were defined as observable or measurable parameters capable of changing over time. In addition, variables were formulated in a neutral manner and, where it was possible, expressed in their positive form instead of negative. Where relevant, a distinction was made between perceived and actual conditions, recognizing that these may differ in practice and may influence system behavior in different ways. The outcome of interest was explicitly included among the selected variables to ensure that the model remained focused on the purpose of the analysis.

Furthermore, each variable was clearly defined to support a shared understanding of the concept it represents and to provide a consistent basis for subsequent causal modeling (De Pinho, 2015).

OC acts as the stimulus and starting point for the CLD, as it shapes the norms, priorities and values through which SE is enacted in daily project work. Rather than influencing SE adoption through a single direct effect, OC primarily affects adoption indirectly by shaping recurring SE practices. These practices, in turn, determine SE adoption outcomes, including the consistency, quality and sustainability of SE applications. Structuring the CLD as shown in *Figure 19* therefore clarifies the mechanisms through which culture influences SE adoption and supports a coherent interpretation of both the literature and the empirical findings from a systems perspective.

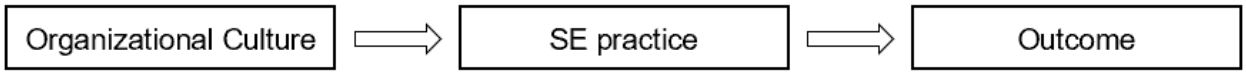

Figure 19: Conceptual logic behind the development of CLD

Organizational Culture Variables

OC influences SE by shaping the behavioral and organizational context within which SE is enacted. Specifically, culture affects what individuals feel safe to question, what leaders prioritize and reward, if adaptation and reflection are encouraged or blame is assigned and whether work is organized collaboratively or within professional silos. Through these mechanisms, culture shapes everyday routines, coordination patterns and decision-making processes. The literature review and empirical analysis identified a broad range of OC attributes influencing the adoption of SE. However, a CLD cannot meaningfully represent a long list of static attributes, it must model a small number of dynamic mechanisms.

These attributes do not operate independently in practice. Multiple attributes tend to shape similar patterns of behavior. Consequently, the identified cultural attributes were grouped into a smaller set of higher-level cultural variables that capture the dominant positive (enabling) and negative (constraining) cultural mechanisms.

The final set of variables included in the CLD are listed below:

- Psychological Safety & Trust
- Leadership Commitment to SE
- Reflection & Adaptation Orientation
- Systems Thinking Mindset
- Compliance-Driven Culture
- Siloed Professional Culture
- Short-Term Delivery Focus

SE Practice Variables

Moving on to the next step, *Table 12* translates a broad set of detailed factors influencing adoption, identified in the literature, into a smaller number of aggregated variables. The right-hand column ("contributing factors") contains the more detailed elements reported in prior research, but modelling each element as a separate variable would make the CLD overly complex and analytically weak. So, these detailed factors were clustered into five practice mechanisms that represent *how* and *when* SE is enacted rather than whether it formally exists: requirements development and alignment practice, cross-disciplinary coordination and interface management, SE role clarity and governance in practice and practical use of SE methods, tools and knowledge.

These variables were selected because they are (i) repeatedly emphasized in the literature as central to effective SE application and (ii) strongly reflected in the empirical findings. In general, interviewees mentioned challenges and enablers related to the early setup and continuity of SE, noting that insufficient early establishment led to reactive adjustments across project phases. They also reported recurring issues with requirements ownership and clarity, including fragmented responsibility and misallocation to disciplines, which weakened consistent requirements analysis. Furthermore, interviews highlighted siloed working practices and late discovery of interfaces, reflecting limitations in cross-disciplinary coordination and interface management. In addition, the interviews indicated that SE roles were often positioned too low within the organizational structure, limiting authority and influence in decision-making. Finally, perceptions of SE tools and methods were described as conditional: tools were viewed positively when configured early and supported through training and learning, but their value was reduced when introduced late or treated as compliance-oriented outputs. Taking these into consideration, *Table 12* below presents the selected variables.

Table 12: SE practice variables included in the CLD and their contributing factors

SE Practice Variable	Contributing Factors
Requirements Development & Alignment Practice	• Up-to-date requirements • Completeness and level of detail of requirements • Smart formulation of requirements • Harmonization of requirements between client and contractor • Inclusion of later life-cycle phases in requirement analysis • Linking interfaces to the requirements
Cross-disciplinary Coordination & Interface Management	• Coordination across interdisciplinary teams • Effective collaboration between supporting processes • Ongoing identification of interfaces • Keeping interface definitions current and accessible • Routine, scheduled interface meetings with relevant stakeholders
SE Role Clarity & Governance in Practice	• Clear definition of SE-related roles and responsibilities • Presence and availability of the SE manager • Extent of authority held by the SE manager within the project • Proper balance between project management, SE, and process management • Degree of managerial support offered by the SE manager
Practical Use of SE Methods, Tools & Knowledge	• Availability and quality of SE tools and methodologies • Awareness and practical usability of knowledge management tools • Alignment of knowledge management tools across disciplines, projects, and stakeholders • Availability and quality of SE training materials and documentation • Access to knowledge management tools

Outcome Variables

The outcome layer represents the dimensions of successful adoption as defined in the context of this research. The analysis of these variables has been presented in *Section 2.9* of the literature chapter. More specifically, successful adoption is characterized by lifecycle-wide application of SE, execution quality of core SE practices, organizational embedding, the realization of perceived and tangible value and realized learning from SE applications. More explicitly, the extent to which SE is applied across all project phases, how well requirements, V&V and interface management perform, the extent to which SE is institutionalized beyond individuals, the benefits stakeholders believe and observe SE delivers and lastly the degree to which SE use leads to reflection and capability improvement respectively. In the CLD, these outcomes capture the progressive effects of SE practices and provide the basis for feedback mechanisms that influence both future practices and cultural conditions.

6.5 Causal Relationships and Directionality

Once the key variables have been identified, the next step is to establish the causal relationships between them by specifying how one variable influence another. In systems thinking, these relationships are represented as directional links and are assigned either a positive or negative polarity to indicate the nature of the influence.

A positive (+) link is used when two variables move in the same direction and that is an increase in one variable leads to an increase in the other or a decrease in one leads to a decrease in the other. Conversely, a negative (–) link is used when variables move in opposite directions, meaning that an increase in one variable leads to a decrease in the other and vice versa (Lannon, 2012).

To construct the diagram, one variable is selected as a starting point, and its relationship with other variables is examined in pairs. This is not necessary to establish relationships between every possible pair of variables but only the meaningful and relevant causal connections should be included. Related variables are connected using influence arrows, which are drawn from the variable exerting influence on the variable being influenced (De Pinho, 2015). If two variables influence each other, the arrow should reflect the stronger of the two influences, as arrows are drawn in only one direction. Each causal link should represent a direct relationship and should not imply effects that occur indirectly through another variable.

When defining causal relationships, it is important to consider not only immediate effects but also long-term impacts and potential unintended consequences. Where possible, decisions about directionality and polarity should be informed by empirical evidence, as the ones retrieved from interviews (De Pinho, 2015).

Before presenting the directionality, it is important to note that although the conceptual structure of the model distinguishes culture, practice and outcomes, variables within the same layer, they do not exist independently. Culture is not a flat set of parallel attributes, it is a system of mutually reinforcing and constraining beliefs and behaviors. In a CLD, it is therefore both appropriate and necessary to represent intra and cross layer causal relationships when one cultural attribute enables or constrains another. These links stay in line with the conceptual logic as they show how different cultural attributes influence each other and gradually reinforce a consistent pattern of behavior over time.

The following figures illustrates how cultural enablers and constraints (variables) influence variables related to practice and outcome attributes.

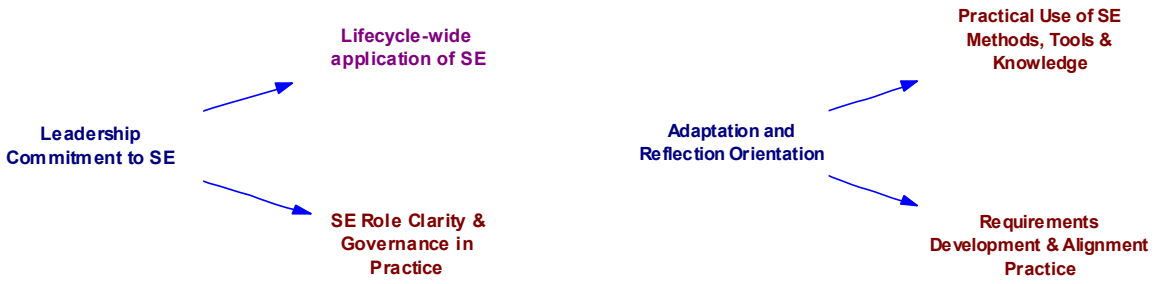

Figure 20: Leadership commitment and reflective cultures causal relationships (Vensim software)

Lifecycle-wide application requires early investment and sustained attention across project phases. Leadership commitment is the requirement, on project level but also higher management, that supports allocation of resources, setting expectations, enabling conditions but also protecting SE activities when they fall under time pressure and deadlines. Adding to that clear SE roles and governance require explicit authority, accountability and decision rights. Leadership commitment formalizes these structures, enabling also system engineers to shape decisions rather than serving only as a procedural role.

A reflective and adaptive culture encourages the use of SE methods and tools for sensemaking and improvement rather than compliance. Learning creates feedback that deepens method use over time or the implementation of new procedures as it increases. Developing high-quality requirements requires time to discuss, refine and reconsider assumptions. This type of culture supports this by emphasizing understanding and awareness rather than early closure of requirements.

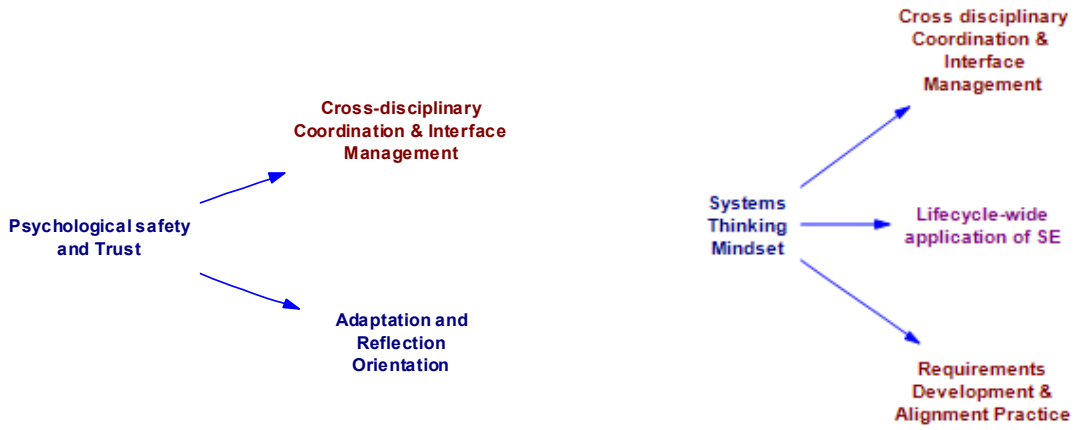

Figure 21: Safety, trust and systems thinking causal relationships (Vensim software)

Psychological safety and trust reduce the interpersonal risk associated with admitting uncertainty, discussing errors and questioning assumptions. As a result, individuals and teams are more willing to engage openly in reflection and learning, which supports continuous improvement and adaptation to SE practices. At the same time, trust enables open communication across disciplinary boundaries and encourages individuals to raise interface concerns without fear of negative consequences. This promotes proactive cross-disciplinary engagement, early identification of issues strengthening coordination and interface management across teams.

A system thinking mindset shapes how individuals perceive and manage complexity by emphasizing interdependencies and behavior across the whole system. As this mindset strengthens, it encourages planning across the full system lifecycle rather than focusing on isolated project phases, so supporting the integrated nature of SE. In addition, system thinking gives attention to interactions between subsystems and disciplines, increasing the need for active cross-disciplinary coordination and conscious interface management. This integrative perspective also influences requirements practices by framing requirements as expressions of overall system intent instead of solo specifications, which supports alignment across stakeholders preventing errors in the later stages.

Figure 22: Siloed and short-term cultures causal relationships (Vensim software)

Siloed cultures reinforce functional boundaries and local optimization, discouraging communication and shared ownership of interfaces across disciplines. In addition, requirements alignment depends on shared understanding and open communication across functions. Silos inhibit discussion and integration of differing perspectives, leading to misassigned or incomplete requirements.

Short-term delivery pressure prioritizes immediate milestones and visible outputs, reducing willingness to invest in planning activities whose benefits can arise later in the lifecycle of the project. When projects are driven by short-term culture, time pressure reduces opportunities for thorough requirements analysis and stakeholder discussion at the extent that should be done. This often results in requirements being finalized or treated as settled before they are fully understood or agreed upon, leading to differing interpretations and unresolved ambiguities.

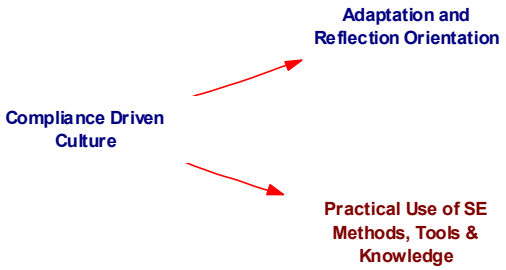

Figure 23: Compliance driven culture causal relationships (Vensim software)

Compliance-driven culture focuses strongly on following predefined processes and standards, especially if perceived as contractual compliance and results driven. In these settings, questioning existing practices, trying alternative approaches or assessing critically on how work is done is often discouraged. It weakens learning and reflection, which are essential while at the same time, SE methods and tools tend to be used mainly to meet audit or formal review requirements rather than to support analysis and decisions that are based on ownership and awareness.

The following figures illustrates how SE practice variables interact with the rest of the variables in the system.

Figure 24: Interface & requirement practices causal relationships (Vensim software)

Effective coordination and interface management positively influence the execution quality of core SE practices. This is self-explanatory but also when there are no boundaries between disciplines focusing on integral thinking, uncertainty is reduced and resolution of interface issues prevent conflicts at a later stage preventing rework but also better quality of verification processes that leads to the overall quality increase.

On the right hand side simirarly this relationship illustrates that clear, agreed and well-structured requirements with early harmonization between the client and contractor reduce variation in interpretation and expectations. Professsionals are now working with defined sets and stable intent reducing time consuming in later stages.

Figure 25: SE authority and procedures causal relationships (Vensim software)

Role clarity and governance establish authority given, responsibilities and established procedures that make SE less dependent on individual initiative. When accountability become clearer, SE becomes institutionalized in *"how work is done",* increasing organizational embedding beyond single projects or team individuals. It should be noted that, in this case, the directionality could also operate the other way around. It is likely that the organizational embedding of SE enables the establishment of clear roles, appropriate authority and visibility. In this situation, instead of the project manager being solely responsible for the division of roles, the organization would define and institutionalize these responsibilities.

When SE methods/tools are used as support in decisions and mechanisms (e.g. trade-off, risk reasoning, traceability, continuity) they increase analytical depth and consistency. This improves how well core SE practices are performed (not just if deliverables exist), raising execution quality.

While the five outcome dimensions are treated as equally important indicators of successful SE adoption, the CLD distinguishes their functional role within the dynamic process through which adoption develops over time. Perceived and tangible value typically emerges after increased quality of SE practices and consistent application across the whole lifecycle of the project where their effects can become visible in the outcomes. Realized learning can happen once SE has been executed multiple times and effective processes have been identified. Organizational embedding of SE develops through repeated application to be gradually translated into stable structures and routines. By doing this distinction it is clarified how the outcome variables interact within the CLD.

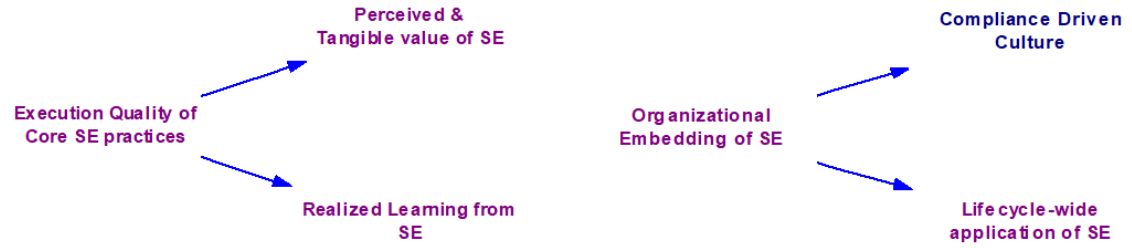

Figure 26: Execution quality and organizational embedding causal relationships (Vensim software)

Execution quality reduces failures that stakeholders notice (e.g. late interface clashes, poorly defined requirements, verification report gaps) and improves outcomes they care about (predictability & fewer changes). This increases both perceived value and tangible value (reduced rework, time & resources). Adding to that better execution quality creates clearer feedback that consequences are more observable, making it easier to identify lessons learned and capture best practices while translating experience into learning.

When SE is embedded in structures within the organization (e.g. implementation plan on the strategic & operational level as objective), its application becomes systematic rather than optional. This increases the likelihood that SE is applied across all phases because it is part of normal workflow of people and accountability is divided and it is not dependent on personal motivation or project context. On the other hand, if organization is only oriented toward market and hierarchical culture types, the embedding procedures are not flexible, leaving no space for meaningful performance and support result-focused procedures. In this scope, SE is institutionalized primarily as a mechanism for meeting contractual obligations and performance

milestones, which are important, but should not be the only focus of an organization.

Figure 27: Lifecycle application and value causal relationships (Vensim software)

Applying SE across the lifecycle in a consistent manner increases opportunities for SE to prevent & manage downstream effects (requirement changes, verification readiness). Broader application makes benefits more visible and measurable across phases, increasing tangible value. The way that this in turn supports leadership commitment is closely related to the benefits that become visible in practice, on project level and it is referring to prevent also resistance in new ways of working.

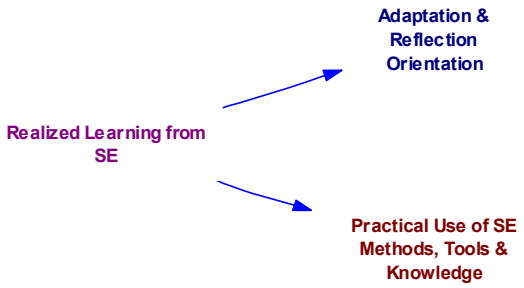

Figure 28: Realized learning causal relationships (Vensim software)

SE creates real insights that when understood through lessons learned, they can evolve over the time to a culture that respects adaptation in different contexts but also willingness to continuous improvement as a natural way of working. Realized learning can also increase the use of standardized procedures and templates that can be operationalized in a different way in next project while also leaving the space for innovation, new tools and technologies as emergent for better application.

6.6 Complete Causal Loop Diagram

No CLD should be regarded as a definitive or final representation. The process of identifying feedback loops may alter the researcher's understanding of the system in ways that necessitate revisions to the variables and causal relationships included in the model. CLDs function both as analytical instruments and as communication tools, supporting the examination of complex situations and the sharing of insights with others. As feedback is gathered from additional stakeholders, this process may further prompt refinement and restructuring of the diagram. Like the real-world systems they seek to represent, causal maps are inherently dynamic and adaptable. Regularly revising and revising the CLD supports a progressively deeper and more accurate understanding of the system's complexity and the issues under investigation (De Pinho, 2015).

Causal Loop Diagram

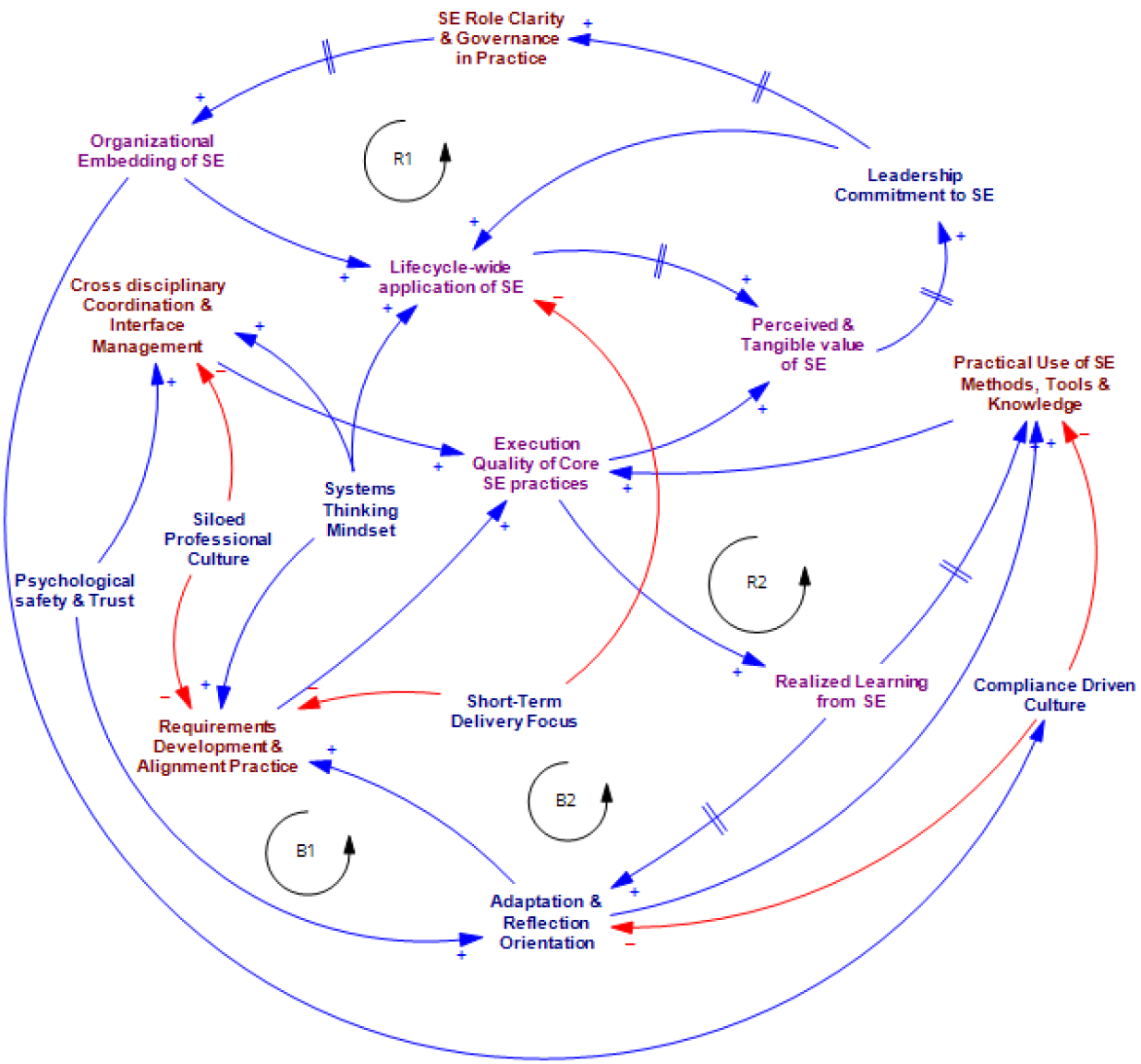

Figure 29: Complete causal loop diagram (Vensim Software)

The transformation of the interrelationship diagrams into CLD is a systematic and iterative process. For the developer of the model, the primary objective is to allow CLD to emerge from the relationships itself, rather than from pre-existing assumptions or implicit mental models about how the system functions. This approach supports the exploration of the dynamic relationships that characterize the system under study. The aim is to develop a diagram that communicates a coherent narrative of a complex reality, achieving a balance between explanatory clarity and appropriate model simplicity (De Pinho, 2015).

Table 13: Legend for CLD symbols

Symbol	Meaning
	Arrow: Indicates the assumed direction of causality and influence. The blue color shows enabling or reinforcing causal relationships that support the effective adoption and maturation of SE.
	Arrow: Indicates the assumed direction of causality and influence. The red color shows constraining or inhibiting causal relationships that undermine or limit effective SE adoption.
+	Polarity indicates positive causal relationship: an increase in the source variable leads to an increase in the target variable (or a decrease leads to a decrease).
—	Polarity indicates negative causal relationship: an increase in the source variable leads to a decrease in the target variable (or vice versa).
‖	The double short lines on an arrow indicate a time delay in the causal relationship, meaning that the effect does not occur immediately but unfolds over time, reflecting gradual organizational processes.
R (e.g., R1, R2)	Reinforcing feedback loop represents a self-amplifying dynamic that strengthens change over time.
B (e.g., B1, B2)	Balancing feedback loop represents a self-regulating dynamic that counteracts change and constrains the development over time.
	Counter-clockwise orientation of feedback loop arrows.
Purple lettering	Variables shown in purple represent SE adoption outcomes, also referred to as successful dimensions.
Maroon lettering	Variables that represent SE practices as enacted in practice. These variables form the mechanism layer through which organizational culture affects adoption outcomes.
Blue lettering	Variables that represent organizational culture factors. These variables are treated as starting conditions in the model and influence how SE is approached and enacted within the organization.

It can be observed that there are several points of *"delays"* in the CLD. All systems exhibit some form of delay, which may vary in duration from seconds to days, centuries or even millions of years. These delays are responsible for causing fluctuations in system behavior. A delay occurs when the response or action between two components within a system proceeds significantly more slowly than other processes in the system (Haraldsson, 2004). A delay is placed between leadership commitment to SE and SE role clarity & governance in practice, as it does not immediately happen. These changes require formal decisions and organizational alignment but also the gradual establishment of new routines. Similarly, even once roles and governance are defined, organizational embedding of SE happens only after repeated enactment across multiple projects and that will take time.

Furthermore, lifecycle-wide application does not immediately lead to perceived & tangible value, meaning that even if SE is successfully embedded in all the phases within a project, reduced rework, cost overruns, fewer interface conflicts etc., can become visible only over time and often retrospectively. Interviewees described value recognition as emerging after issues have been raised, avoided or not and comparisons with previous projects become possible. This explains better the perceived value, that is related to people, how they experience and *"evaluate"* SE.

In addition, realized learning from SE application feeds back an adaptive and reflective orientation only after repeated exposure to lessons learned is reinforced only once value has been established and interpreted within the organization. Shifts in OC toward sustained feedback and continuous learning need time to gradually change and it is not an immediate act. The same thinking goes for the practical use of SE meaning that realized learning doesn't directly explain it. It rather needs time, with enabling from organization, that existing procedures can be adjusted, the tools can be updated and new templates can emerge after multiple lessons learned. Finally, representing these relationships with delays therefore reflects the complex nature of SE adoption and cultural change, where improvements or not emerge gradually. It is important to mention that these delays can be unfold over extended periods that in this study often spanning multiple project phases and according to each case, it can be several months or years.

6.7 Identification of Feedback Loops

Feedback loops represent circular causal relationships between variables. The types of feedback loops can be divided into reinforcing loops and balancing loops. Reinforcing feedback loops occur when changes in one variable lead to changes in other variables in the same direction, causing the initial change to intensify over time. It should be noted that not all causal linkages in a CLD necessarily form part of a feedback loop (De Pinho, 2015). Feedback loops are identified only when variables are connected in a closed, circular sequence, such that causal influence flows continuously through the loop and returns to the starting variable. In identifying feedback loops, the direction and polarity of causal links must be examined carefully. Reinforcing loops occur when all causal relationships within the loop are positive, or when the loop contains an even number of negative links. Although there is no fixed starting point, and any variable may be used as a conceptual entry point for analysis, in this study, the loop is activated from the cultural attributes to guide the analytical narrative. For example, increases in leadership commitment support clearer SE roles and responsibilities within the project. This, in turn, contributes to stronger organizational embedding and broader lifecycle-wide application of SE, which further increases the perceived and tangible value of SE, thereby reinforcing leadership commitment and initial improvement *(Figure 30).*

This is also the case for the *right side of the figure,* where a stronger learning and reflection orientation (culture) encourages the practical use of methods, tools and knowledge. Increased use of these methods improves the execution quality of core SE practices, generating clearer feedback and experience from SE applications. This leads to greater realized learning, which further reinforces the organization's learning leading to cultural shift over time, strengthening the overall cycle. In that case, it can also be that statements may express the same intention but describe the process in a different way (Haraldsson, 2004). Sometimes the impact of one factor over another is not immediate and takes a while to be realized, generating delays in the system behavior and making predictions difficult (Crabolu et al., 2023). That are the delays are

presented earlier and can be further noticed in these loops.

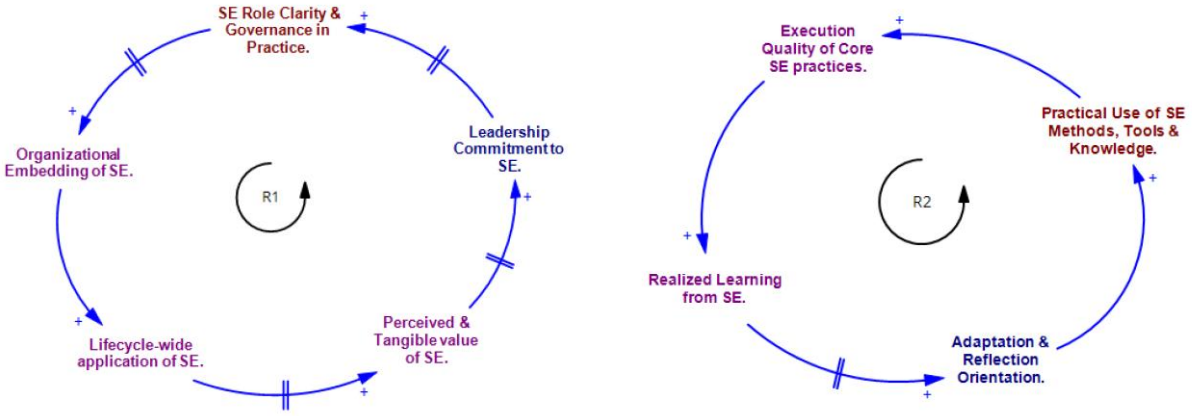

Figure 30: Core reinforcing feedback loops (R1 and R2) in the CLD

In contrast, balancing loops arise when a loop contains an odd number of negative links, causing the effects within the loop to counteract change and promote stability (De Pinho, 2015). For instance, two balancing loops are presented in *Figure 31*. Organizational embedding includes the formal institutionalization of SE through strategic structures, templates, definitions of success and tailored processes, which are essential for achieving consistency and scalability across projects. However, this embedding can be accompanied by increased formalization and standardization. When this emphasizes procedural compliance over decision support and problem-solving value, practitioners may experience perceptions of bureaucratic burden, leading to a shift from substantive engagement with SE methods toward a more compliance driven behavior. In that case over time, success is measured by conformity to processes rather than by learning or system performance. Compliance driven culture diminishes the practical use of methods activating the balancing feedback that moderates further growth in the whole cycle. The practical use of SE methods positively contributes to the execution quality of core SE practices, which in turn enhances the perceived and tangible value of SE. Over time, this strengthens leadership commitment and supports clearer SE roles and governance, as well as greater organizational embedding of SE. However, as compliance-driven tendencies persist, the initial causality counteracts the reinforcing effects, ultimately stabilizing the system and limiting further improvement.

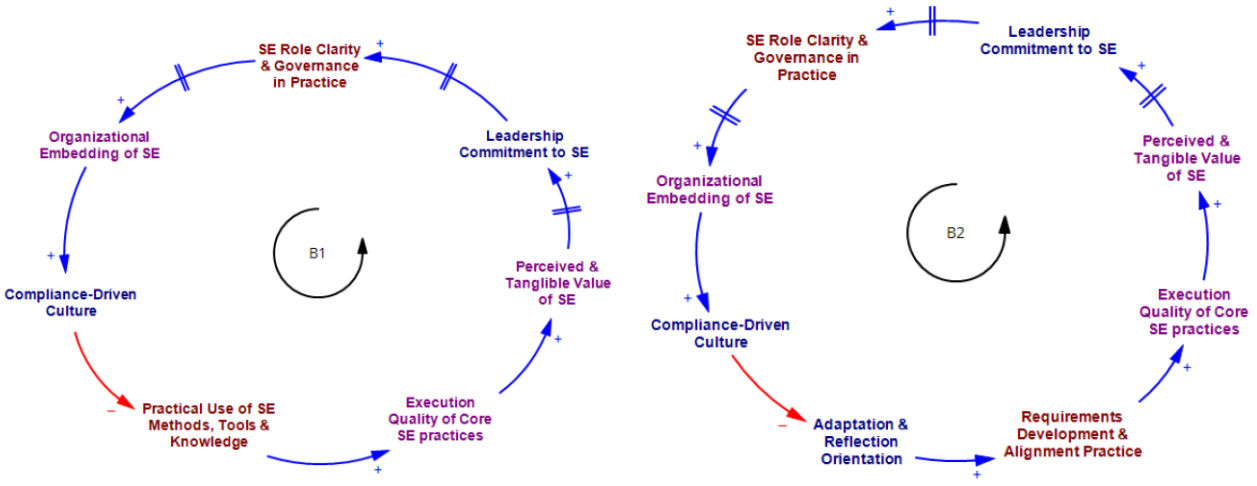

Figure 31: Balancing loop (B1 and B2) in the CLD

The same case is experienced on the right cycle, almost the same variables are involved but this time the relationship between compliance driven culture limits reflection and learning behavior and act as the counteracting dynamic for the rest.

6.8 Translating CLD into practical recommendations

The final step in the modeling process is implementation. At this stage, the value of the CLD no longer lies only in its analytical function, but in its ability to support action. The insights generated through the model must therefore be translated into practical recommendations that can be understood and applied by the intended users of the study, many of whom are not modelers themselves. In this sense, implementation is not a purely technical continuation of model development, but a communicative and interpretive process through which the findings are made meaningful for decision-making and organizational practice. The first step in this process is **the interpretation of the causal relationships** represented in the model and the rationale behind them, ensuring that users share a common understanding of how different variables influence one another. This requires dialogue and reflection, particularly when the model is communicated to managers, policy makers or practitioners who must relate the insights to their own organizational context (Luna-Reyes & Andersen, 2003). Although CLD can serve as a communication tool that is accessible and understandable to a wide range of stakeholders, its practical value emerges primarily for those responsible for taking decisions toward the successful implementation of SE inside the company.

More explicitly, the CLD except for presenting which variables are important also **shows where to intervene first**, which actions should be bundled together, and which constraints may weaken implementation if they are not addressed. This can be achieved by **focusing on the loops** identified in the model. Not all variables possess equal influence in system's behavior. Within the loops, attention should be directed toward **the most effective intervention points**, so practitioners should first look for variables that appear in multiple feedback loops or connect different parts of the system. Such variables influence several causal relationships simultaneously, meaning that improvements in these areas can impact multiple feedback mechanisms at once. Then practitioners should focus on **assessing how these leverage points can be actively strengthened** through concrete actions. These variables should be better treated as foundation conditions:

- *Leadership commitment to SE* is a key intervention point because it activates Reinforcing Loop 1 and part of Balancing Loops 1&2. In this case strengthening that variable is recommended at both organizational and project levels. At the organizational level, higher management should actively sponsor the SE initiative, ensuring continuous enablement, prioritization and visible support for its implementation. At the project level, project leaders should integrate SE into project governance by ensuring that SE processes are applied and that key decisions are made in accordance with SE principles.
- *Organizational Embedding of SE* is an important structural variable (Reinforcing Loop 1 & part of Balancing Loops 1&2) that influences whether SE practices become part of normal project work. Making it an integral part of business processes and project approach, by establishing standardized operating methods and support cultural change where necessary.

Once these variables are addressed, they create the necessary conditions for improvements in more operational variables. These variables should therefore be treated as development variables, which are expected to improve gradually once the foundational conditions have been established.

- *Execution Quality of Core SE Practices* is a central leverage point because it plays a key role in Reinforcing Loop R2 and in both balancing loops, B1 & B2. The processes should be clearly described and documented tailored to each project needs. Furthermore, the quality of implementation should be monitored using clearly defined success criteria and Key Performance Indicators (KPIs).
- *Realized Learning from SE* is the main variable that should be addressed in Reinforcing Loop 2. This can be strengthened by actively collecting and implementing lessons learned after each project, where teams share their experiences and analyze them for recurring patterns. In this way, new projects can immediately benefit from these insights, further strengthening the reinforcing dynamics of the loop.

Then attention should also be given to **variables that exert a negative influence** within the system. These variables do not necessarily represent starting points for change, but rather conditions that can weaken or delay implementation if left unaddressed. In order to do that practitioners should find specific actions to mitigate those that undermine it so that reinforcing loops can develop without being counteracted by balancing pressures. In this case:

- *Compliance-Driven culture* activates Balancing Loops 1&2. This can be mitigated by finding an appropriate balance between flexibility and formality in the application of SE. Practitioners should emphasize SE as a problem-solving approach that supports better project outcomes. Increasing awareness among project teams about the practical benefits gained from applying SE correctly is therefore essential.

After the implementation of the interventions, practitioners should **monitor the behavior of the system**. In practice, the most effective way to observe these effects is through **pilot or ongoing projects**. Following each intervention, practitioners should observe intermediate behavioral changes that occur within the system. These changes are most likely to emerge in practice-level variables such as requirements alignment, traceability, role clarity, and the practical use of tools and methods. Such variables can provide early signals of whether the interventions are influencing the feedback loops identified in the causal loop diagram. Given that system behavior unfolds over time, **the effects of interventions typically emerge gradually rather than immediately**. Therefore, practitioners should evaluate system responses across multiple project cycles or decision points to capture their full impact. If observed outcomes diverge from the expected system behavior, the **CLD should be revisited and updated accordingly**. This iterative process reflects the principles of systems thinking, where models are continuously refined based on feedback from real-world interventions. In this sense, CLDs should be treated as living models that evolve alongside the implementation of SE within the organization.

6.9 Identifying Complexity

It is important to focus on dynamic complexity rather than detailed complexity. When building the mental model and defining a system, it must be given careful consideration to the appropriate level of detail. Generalization is often essential for understanding complex systems. As *Figure 32* illustrates below, increasing the number of components in our mental model initially improves our understanding of the system. However, once too many elements are added, both

our comprehension and performance begin to decline because the system becomes overly complex. This happens because our capacity to understand the overall dynamics of the problem diminishes as more and more variables are introduced.

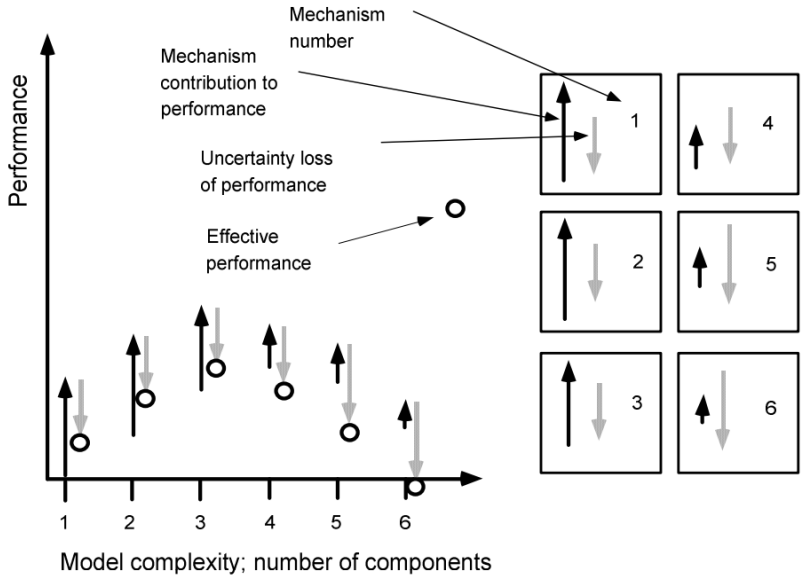

Figure 32: Relationship between model complexity and performance (Haraldsson, 2004)

When developing mental models, the objective is not to represent reality in its entirety within a single model, as such a model would be as complex as reality itself. Instead, the purpose is to represent selected aspects of reality in a way that enables a basic understanding of the complex problem at hand. As shown in *Figure 32*, there is a point at which understanding of the system reaches its maximum relative to the level of complexity included in the model. Beyond this point, additional detail does not enhance insight and should therefore be avoided. This point represents the appropriate level of detail that a model should contain when seeking to understand the system effectively (Haraldsson, 2004). Finally, it is important to observe how systems are integrated into other systems. Variables that have been chosen are in fact sub-systems themselves and their components also sub-systems and etc. It can be concluded that the larger the number of variables considered, the greater the complexity and uncertainty around these variables.

6.10 Intended Uses of CLD

Drawing on the literature, the following applications synthesize these uses and should be adapted to the specific organizational context, demonstrating how CLDs can support deeper understanding and decision-making:

1. **Illustrate complexity and build a shared understanding:** As mentioned earlier the CLD can be used to make explicit how cultural patterns interact with SE practices (requirements, interfaces, verification) through reinforcing and balancing feedback loops, thereby helping teams understand why issues persist and treat them as systems and sub-systems.
2. **Identify leverage points for cultural and process change:** By tracing which variables sit at the center of multiple loops, the CLD helps identify high impact intervention points That means identifying places where small changes can produce significant improvements (Littlejohns et al., 2021).

3. **Inform internal policy and practice:** The CLD can be useful in both policy instrument evaluations and policy design, by mapping the multiple causal chains affecting complex issues and accordingly can guide organizational design by linking each measure to the loops it is intended to weaken or strengthen (Crabolu et al., 2023).
4. **Support evaluation of systems changes over time:** The CLD can be reused as an evaluation tool to assess whether interventions are shifting behavior in the intended direction and to detect unintended consequences.
5. **Enhance stakeholder participation and alignment:** The CLD can serve as a facilitation artifact in group model building (GMB) sessions involving systems engineers, project management, the business development unit and organizational leadership, supporting the alignment of interpretations of SE-related problems, conflicting assumptions and the identification of feasible actions. This process enables reflection on this initial CLD and supports its repeating refinement into revised models. Barbrook-Johnson & Penn (2022) mentioned that once an initial version of the core system structure and its surrounding variables has been developed, it should be subjected to extensive critique, feedback and reflection.
6. **Provide a basis for future system dynamics modelling:** If the organization wants to quantify scenarios, the CLD can be translated into a stock-and-flow model to test "what-if" scenarios (e.g. increased training investment, earlier integration, governance changes) before implementation (Littlejohns et al., 2021). While many of the variables can be quantified using relatively direct indicators, others may need to be disaggregated into more specific variables and subsequently operationalized through suitable indicators for modelling purposes. Additionally, certain variables, such as systems thinking mindset or psychological safety & trust, that are more abstract cannot be measured directly. In these cases, proxy measures can be employed as is an indirect indicator used to approximate the corresponding concept.

7. Validation of CLD

The developed CLD must be validated to reduce the risk of unconscious bias introduced by the researcher during the model development process or through potential misinterpretation of the data. This chapter presents the findings of these sessions introduced in Chapter 6. The purpose of the validation was to assess the comprehensibility and practical applicability of the CLD. Section 7.1 & 7.2 describes the method and the professionals involved while Section 7.3 the execution part of the validation session. Based on feedback received from the experts, the analysis and the feedback regarding the validity of the proposed CLD are drawn in Section 7.4. In section 7.5 the overall conclusions about CLD are presented.

7.1 Validation method

The approach selected on the validation process was informed by approaches described specific in the literature on CLD validation. Burns and Musa (2001) suggest that CLD models cannot be perfectly validated. It may be impossible to create a perfect model that is perfectly valid. It is argued that all models are, in a sense, wrong because there could always exist a counter example to which the model did not conform to completely.

In this research, the disconfirmatory assessment interview approach was selected as the most appropriate. These sessions provide a formal method for working with stakeholders to validate model structure and behavior. When the purpose of the interviews is model assessment as in this case, it is mentioned that individual interviews better support the explication and capture of divergent critical thinking as they avoid both anchoring and group confidentiality concerns. This method involves the presentation of key model features showing structure and behavior alongside textual descriptions or narratives, describing structural assumptions and the elicitation of participants' input for what needs to be changed in the model (Tomoaia-Cotisel et al., 2022). An outcome of this should always be improvements in the model to strengthen user confidence by giving concrete suggestions for how to improve the current version of it.

The validation was conducted one-to-one session lasting approximately 60 to 75 minutes (Tobin et al., 2022). Each session was recorded and later transcribed. The transcripts were subsequently analyzed through summarizing and loose coding, which involved capturing the main ideas expressed by participants and assigning simple thematic labels to relevant parts of the interviews *(Section 7.4)* (Andersen et al., 2012). Conducting the sessions individually ensured that participants could express their perspectives freely and in depth, as each expert reflected from a different angle. This approach allowed for detailed discussion of the framework components and the causal relationships included.

7.2 Experts recruitment

Literature suggests that the number of experts selected for validation depends on several factors, including the ease of access to suitable participants, the availability of individuals with relevant expertise and the objectives of the evaluation process. In addition, the number of experts should reflect the level of expertise required and the diversity of knowledge needed to assess the subject under investigation. It is recommended to select an odd number of experts greater than or equal to three who possess solid knowledge of the topic, proven experience and the ability to apply evaluation criteria objectively (Pino et al., 2023).

In order to make it as beneficial as possible an expert group of senior professionals internally from WSP was identified to validate the proposed CLD. Due to the limited availability of suitable participants and after internal discussions, a total number of three experts were selected for the validation process. This was particularly important given that, at the beginning of this thesis, such expertise was not widely available within the organization, as SE practices were still in the early stages of development and formalization.

There was explicit focus on expertise, including individuals involved in the strategic, operational, and infrastructural implementation of SE across the organization. More specifically, the first expert held a dual role as Lead Systems Engineer and Process Manager, providing insights from a strategic perspective, including defining objectives, governance structures, and performance indicators, as well as supporting the long-term organizational adoption of SE. The second expert works as a Lead Systems Engineer across multiple projects, responsible for requirements analysis and verification activities. In addition, this role includes establishing onboarding processes and tailoring SE practices to the scale and complexity of different projects. The third expert represents the operational perspective as a Lead Systems Engineer, working on pilot project where SE practices are actively implemented. This role involves capturing lessons learned from project experience, knowledge management & addressing culture into multidisciplinary environments. Their direct engagement in shaping and formalizing ways of working in combination with their active involvement in the implementation of SE was intentionally considered to ensure that the feedback would be relevant but as grounded as possible in practical experience.

7.3 Validation sessions guide

Prior to the validation session, all participants were provided with a structured 7-minute PowerPoint presentation outlining the theoretical foundation and the conceptual idea behind the structuring of the CLD. More explicitly, the presentation included an explanation of the assumptions underlying the diagram, the purpose of the CLD and the variables incorporated in the model. Furthermore, participants were informed about the interpretive nature of the interview results and the thematic analysis conducted beforehand. Finally, the objectives and expectations for the upcoming validation session were presented. This preparatory material was distributed in advance to support participants' understanding of the CLD, acknowledging the complexity of the model and the need for constructive feedback (Andersen et al., 2012).

The agenda of the expert sessions was divided in 4 parts. The first part of the sessions began with an opportunity for participants to ask questions regarding the material distributed prior to the meeting, ensuring clarity and addressing any potential uncertainties. A brief introduction to the previously shared material was also provided to help participants become familiar with the context and feel comfortable with the discussion.

The next part focused on reflections regarding the cultural attributes included in the model, particularly whether these attributes were considered influential in shaping how SE is perceived and applied in practice, and whether similar patterns had been observed within the organization. Particular attention was given to specific variables, including psychological safety and trust, leadership commitment, siloed professional culture and compliance driven culture, as these were identified as highly influential parameters to be considered in the model.

The third part of the discussion acknowledged that it was not feasible to reflect in depth on all variables and the multiple dynamics within the system. Consequently, the discussion shifted toward a more explicit focus on the feedback loops and the causal relationships included within them, both reinforcing and balancing. The focus was on examining the directionality of the relationships, the existence of these loops in practice and the circumstances under which they occur. The respondents continuously encouraged to express model problems and areas of improvement that may not have been initially included. Participants were invited to share the contexts in which these relationships are most applicable by drawing on their own experiences and providing targeted examples of how these dynamics are reflected in practice within the ongoing efforts of the company to embed SE efficiently and consistently. This step aimed to verify the existing causal relationships, identify any missing variables and detect potential misinterpretations. Clarifications were sought throughout the discussion to ensure that the feedback provided by the experts was clearly understood by both the participants and the researcher (Burns & Musa, 2001).

The final part of the discussion focused on the delay signs incorporated in the model. Emphasis was placed on the understanding that changes in organizational culture require time to emerge, and that the implementation of SE must reach a certain level of maturity before its effects become visible. Participants reflected on the steps taken over the past months and during this research, noting that several observed delays could be attributed to factors such as the need for enablement from higher management and the recognition of continuous learning as an essential component.

7.4 Feedback & Analysis

Organizational culture reflection

The starting point was to understand if culture was recognized as important within the organization. It was mentioned that *"culture and safety are preconditions for successful adoption"*, emphasizing that an open culture must be encouraged in which knowledge sharing and admitting mistakes are valued. Colleagues need to feel safe sharing lessons without blame, fostering a culture of continuous learning. In addition, culture was recognized as part of the identified challenges related to organizational change. It was mentioned that *"building support and overcoming resistance"* to change is essential, while also addressing resistance through purposeful and targeted actions. It was further supported by the fact that although SE was, in some cases, considered familiar and positive experiences were shared, particularly at a higher level, many engineers perceived SE as external to their core professional role. Statements such as *"I'm just an engineer"* confirmed the limited integration of SE into everyday practice and professional identity. Anchoring SE in the OC was therefore described as a key objective. The aim is for *SE "to become a natural part of how WSP works",* meaning that employees no longer perceive it as an additional procedure and newcomers are automatically introduced to the SE approach as part of standard onboarding. It was indicated that this cultural anchoring is stimulated by sharing success stories to make the added value of SE visible, as well as through individual incentives, such as recognizing and rewarding effective SE application further confirming the improvement strategies *Table 11* that has been developed.

In addition, several suggestions were made for improving the CLD, which are listed below:

[1] Leadership commitment to Siloed professional culture

Explicit attention was given to the siloed professional culture with professionals confirming the existence of it within the organization. The relationship between leadership commitment to SE and the increase of siloed professional culture was discussed, stating that leadership, in terms of higher management, *"has an exemplary role in demonstrating how SE should be applied"*. According to this view, leadership must provide clear direction that SE is to be used across projects. They must enable the appropriate departments to perform SE and establish the right KPIs to support it. In addition, it was emphasized that *"siloed professional culture is often rooted in project leadership"*. Many project managers have many years of experience in the industry and can be difficult to influence. As a result, *"SE does not always fit naturally within their existing worldview"* and was described as a key source of siloed professional culture, influencing the teams working under them.

[2] Leadership commitment to Organizational Embedding of SE

It was suggested that leadership commitment should first translate into organizational embedding, rather than directly into clarity in SE roles and governance structures. According to this view, embedding SE at the organizational level requires having the right people, the right tools and a clear mandate. Only once these foundational elements are in place can more formal role clarity and governance structures can emerge meaningfully. That was further supported by referring to current experience within a self-governing team. In such a setting, "*formal role definitions are not strictly established, team operates as a loose network of professionals"*, learning from each other and enabling good ideas through available provided tools (from management) when possible. In this context, hierarchical governance is limited and managers primarily provide the *"orders and necessary resources"*, while the team governs itself.

[3] Realized learning to Organizational Embedding of SE

Next, the realized learning of SE is typically split into two dimensions, what the project team can learn for future work and what the organization as a whole can learn. This suggestion was based on that *"if learning is not taken up by the organization, then the next project team will have to learn the same lessons again"*. In that case, the organization remains stuck in a loop of *"everlasting learning"*, where knowledge is not structurally embedded and each team starts from scratch. Learning should become part of onboarding as a newcomer should quickly become highly knowledgeable as that person has access to everything the organization has already learned. It was mentioned that *"each time learning is realized, the bar should be raised, setting a new standard for the organization"* continuing that "*once learning is recognized as effective, it should be embedded in the organization"*. On the other hand, realized learning can indicate new procedures, guidelines or specific tools to improve performance in future projects, so the practical use of it. Learning may evolve over time through new reflections and experiences, leading to updated practices and renewed embedding so further supporting that *"onboarding is different over time as the organization incorporates new insights"*. Participants noted that this procedure is time-consuming and may take up to one and a half years to achieve a sufficient level of competence, ensure a certain degree of quality, and establish best practices that can effectively serve the majority of clients.

[4] Organizational embedding to Compliance-driven culture to Practical use of methods, tools & knowledge

Participants referred to that as a *"results-driven culture",* explaining that as *"basically, it doesn't really matter what kind of result, as long as we earn money by doing it. It doesn't really matter in which way."* It was agreed that in a purely result-driven organization, the practical use of SE can suffer confirming the dynamic between these two. When the focus is primarily on making money, adherence to rules may be reduced if those rules are perceived as costly. In that case, the practical application of SE is negatively affected. At the same time, if SE is embedded too strictly, leaving no flexibility and relying only on rules rather than on the expertise of the people involved, this may create resistance. It was mentioned that *"when people feel constrained by excessive rules, they may shift toward a results-driven mindset"*. The importance of maintaining a balance between uniformity and flexibility, noting that a standardized approach for consistency but also sufficient flexibility for customer-specific requirements is supported. Overall, these comments confirm the dynamic influence of organizational embedding of SE on the increase of compliance-driven culture under the conditions abovementioned.

[5] Practical use of methods, tools & knowledge to Execution quality of core SE practices

Furthermore, a parameter for consideration was mentioned regarding this causality. The relationship is strongly influenced by the organization's maturity level. It was mentioned that in contexts where *"SE is applied without standardized procedures or established knowledge management set up and lack of own tools",* execution quality becomes inconsistent. Conversely, increasing standardization and specialization but also the reuse of knowledge contributes positively to execution quality. This suggests that while the causal direction is valid, its strength is based upon organizational maturity and embedding. Adding to that it was clarified that even when knowledge exists within the team *"insufficient organizational enablement and the absence of a clear implementation timeline limit the realization of SE goals".* This was described as *"delaying the whole circle",* supporting the idea that organizational embedding and leadership commitment are critical enablers for improving the practical use of methods.

[6] Execution quality of core SE practices to Realized learning of SE

From a learning perspective, early reflection and review of requirements were considered essential to ensure quality from the start. Contracts need careful interpretation to clarify expectations and determine which SE activities, such as functional breakdown structures or hierarchical requirement analyses, are required. SE should be tailored to the size and complexity of each project, often formalized through the development of different SE management plans.

7.5 Conclusions

The validation sessions yielded constructive suggestions for the proposed CLD, which was perceived as a meaningful and coherent conceptual representation of the dynamics influencing SE adoption within the organization. While the diagram was regarded as a valuable strategic communication tool for illustrating how improvements in one domain may positively or not influence others, caution was expressed regarding its direct use for operational decision-making due to the inherent complexity and multiple interdependencies involved. Finally, it was acknowledged by both the participants and the researcher that additional variables could further increase the complexity of the model as deeper levels of analysis could be explored within each variable.

8. Discussion

In this chapter, some theories that have been identified in the whole procedure of this thesis that lie outside the scope of this graduation project, yet influence OC and SE in organizations, are further elaborated. Section 8.1 contains findings from literature regarding OC change and a proposed approach for managing these transitions. Then Section 8.2 further explores the relevance of project governance with SE. A short analysis about maturity level of organization is further discussed in Section 8.3. Finally, Section 8.4 examines the need for proportional implementation of SE according to project scale.

8.1 Organizational culture change

Cultural change is regarded as a main form of organizational transformation and is typically characterized as radical or second-order change. Literature describes it as a process that reshapes how organizational members perceive, interpret and act within their work environment. For such change to be effective, it must fundamentally transform the underlying assumptions that guide how the organization interacts with its external environment and how it operates internally. In order to change these core assumptions substantial shifts are required in the organization's philosophy and values, but also in the structures and organizational arrangements that influence and regulate members' behaviors (Somerville, 2008). Adding to that researchers have drawn conclusions emphasizing that transforming OC is extremely difficult, particularly in well-established and mature organizations. Cultural change is also considered costly and is often described as one of the most challenging aspects of broader organizational transformation. Furthermore, it is not a single, isolated shift but rather a series of numerous changes, some of them significant while others smaller.

Schein (1999b) acknowledged that changing an organization's culture is a time-consuming process. However, he argued that it can be effectively managed if its underlying dynamics are properly understood. He outlined a structured approach for evolving OC, which involves first clarifying the purpose of the intended change. A group of organizational members should then be brought together to diagnose the existing culture, including an examination of visible artifacts within the organization.

Next, the group should seek to understand the reasoning behind these artifacts and identify the core values they reflect. Building on this analysis, attention should shift to uncovering the deeper underlying assumptions embedded within the culture. The change process can then be initiated by defining the desired outcomes and new ways of working. This includes identifying aspects of the current culture that may constrain the change, as well as those that could support it. Finally, specific attitudes that need to shift in order to achieve the intended results should be clearly addressed.

8.2 Project governance and SE

SE appears as an emerging approach in complex project environments that shifts governance from a project-oriented focus to a more system-based perspective, increasing that way the likelihood of achieving holistic success. It does mean that PG needs a wider perspective that extends beyond the project team and continues after the project's timeframe.

Locatelli et al. (2014) support focusing on governance and complexity that when project failures are due to uncertainty in the way projects must be governed, scope ambiguity, technical complexity and involvement of a large number of partners with different cultures and diverse ways of working. It is though possible to improve project performance with a better PG and a better definition of the responsibilities of the key stakeholders involved. More specifically, he describes what is known as the "control versus commitment dilemma". When a project organization applies strong centralized control, project partners tend to lose their sense of ownership and day-to-day commitment. They feel they lack the autonomy to make decisions and begin to see their role as merely executing tasks that have been assigned to. Commitment is essential for project success, which means an effective balance must be found between managerial control and individual freedom. Under collaboration with multiple organizations and sub-contractors, it is not feasible to manage every phase and individual component through a rigid hierarchical structure. And that is because partners have specialized expertise that is critical for project execution, they play an active role in decision-making processes, which further adds to the complexity of project delivery.

The main SE elements that Locatelli et al., (2014) mentioned that there are several elements that can transform and improve PG in complex project environments. SE tools and practices support PG in managing uncertainty and complexity by enhancing flexibility, reliability in planning and control. Flexible planning allows adjustments during execution, while governance relies on mutual adaptation among actors and effective management of relationships across system boundaries. A systems thinking perspective links multiple disciplines and stakeholders, ensuring that each subsystem is designed in alignment with the overall system and that interfaces and interactions are properly coordinated, particularly when different organizations are involved. This multidisciplinary coordination is operationalized through Integrated Product Teams (IPTs), which oversee lifecycle activities from concept to decommissioning and improve governance through open approach and modular design and further reduce interface complexity. Next system integration process facilitates the governance of multiple IPTs. Governance is further strengthened through a systems approach, which ensures that critical aspects on proper information flows and interfaces are included.

In addition modeling, simulation and trade-off analyses provide structured decision support. SE requirement management tools also contribute to improved governance of subcontractors, as their network capabilities facilitate effective sharing of requirements and information across geographically dispersed teams. This enhances the ability of program managers and systems engineers to handle the project's complexity. Close early integration between PM and SE further improves estimation accuracy, ensures complete and consistent requirements and supports the establishment of well-defined agreements with subcontractors. *Figure 33* below presents the kind of interdependencies between these elements that collectively lead to the overall support of PG.

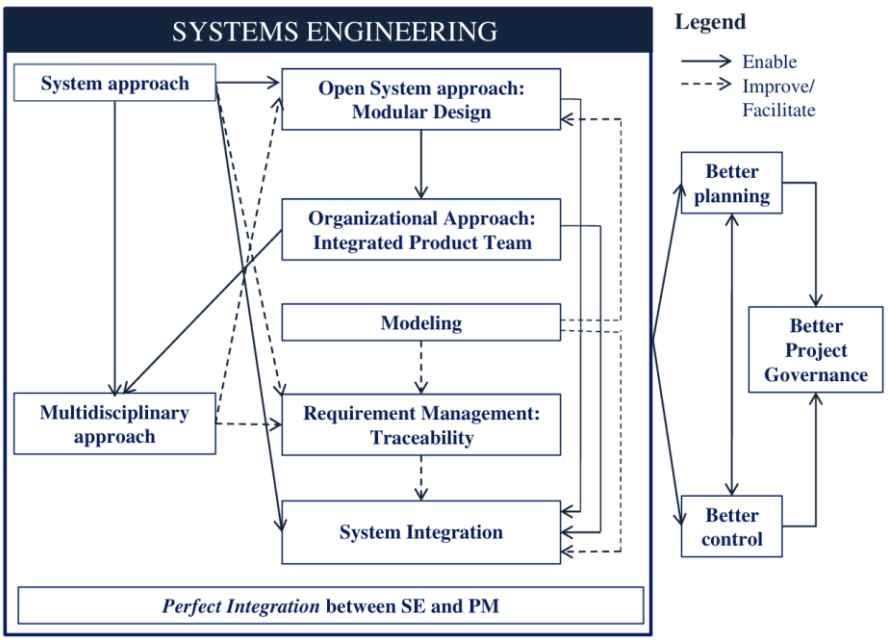

Figure 33: Systems Engineering and Project Governance (Locatelli et al., 2014)

8.3 Maturity Model for successful adoption

The literature indicates that a mature managerial culture is a key factor for the effective application of SE principles. However, there is a lack of comprehensive empirical studies that directly test this assumption. By employing established standards such as the Organizational Project Management Maturity Model (OPM3) to assess organizational maturity, it would be possible to examine the correlation between that and the outcome of adopting SE (Locatelli et al., 2014). The model is structured around three key components: knowledge, assessment and improvement. The knowledge element provides organizations with insight into recognized best practices and the various stages of maturity. The assessment component evaluates the organization's existing level of maturity, while the improvement component uses the assessment results to design strategies aimed at strengthening project management capability. In addition, OPM3 emphasizes continuous evaluation of maturity across two primary dimensions. The one dimension concerns management domains, including projects, programs, portfolios and organizational processes. The other one dimension relates to maturity stages. Here standardization, measurement, control and continuous improvement are included. Organizational progress in enhancing management capabilities is monitored across these two dimensions.

It can be applied across different types of organizations and is capable of evaluating not only individual projects or programs, but also their collective performance within an entire project portfolio. It is quite flexible as it can be adapted to organizations of varying types, sizes and levels of complexity. Furthermore, it offers a comprehensive description of management processes that influence the organization's governance framework, as well as an outline of processes that promote continuous self-improvement (Bakhirkin, 2025).

8.4 Tailoring SE to project scale

While SE has been institutionalized in large-scale infrastructure projects, small and medium-sized construction projects often struggle to adopt SE practices in a proportionate, meaningful way (Incose, 2023). Blanchard (2016) emphasizes that the degree of SE implementation must be tailored to project scale, applying overly formal methods to small or medium projects can lead to inefficiencies or resistance, while insufficient structure in large projects may result in coordination failures. Literature consistently indicates that the frequency and formality of SE adoption tend to increase with project scale and complexity, whereas smaller projects often apply SE principles in a more simplified or informal manner. Large-scale engineering projects are widely recognized as socio-technical systems that involves numerous interdependencies between technological and organizational subsystems. In such environments, the integration of diverse subsystems and disciplines within such projects demands holistic, system-oriented management approaches.

Literature highlights that SE roles and responsibilities vary according to project size and complexity, with larger projects typically requiring dedicated systems engineers and more formalized processes while in smaller one's project manager may perform these practices. Similarly, the Buck et al. (2013) notes that the level of detail and effort invested in SE should be proportional to the project's size, complexity and related risks. Large and complex projects demand more comprehensive SE documentation, coordination and verification activities, while smaller and low-risk projects can effectively apply SE principles in a simplified or "light" form. Adding to these findings, Cusumano et al. (2024) observe that SE adoption within the construction industry has primarily occurred in large-scale infrastructure projects, where increasing project size, technological integration and demanding requirements make systematic approaches essential. In contrast, smaller building projects tend to rely more on technical expertise and informal coordination, viewing SE as an added workload rather than a standard management practice.

The inefficiency of a uniform implementation model is also emphasized by Elm & Goldenson (2012), who argue that a one-size-fits-all approach can have negative results. Many existing project management and engineering frameworks have been designed primarily for large-scale projects and are not well adapted to the constraints and realities of smaller projects (Laporte et al., 2015). Small projects typically operate under tighter budgets, shorter timelines and limited personnel resources, making comprehensive SE frameworks excessively impractical. In this context, the adoption of simplified or lightweight processes enhances acceptance among project teams and helps ensure that the intended benefits of SE are not undermined by resistance or misalignment with project scale (Laporte et al., 2015). Taken together, the literature demonstrates that project scale is a critical factor influencing how SE is integrated into project workflows. Understanding the proportionality between project characteristics and SE application is therefore essential for identifying the conditions under which SE adoption can be most efficient.

9. Limitations, Conclusions & Recommendations

In this final chapter, the graduation project is concluded by first outlining its limitations in Section 9.1, followed by with the overall conclusions presented in Section 9.2 and finally by recommendations for future research and reflection in Section 9.3 and 9.4 respectively.

9.1 Limitations

The methodology used in this graduation project provided valuable insights into the dynamics that interact between OC and SE. However, it is not free from limitations which are listed below:

- The findings of this study are context-dependent and shaped by the characteristics of a large, multidisciplinary energy infrastructure project. As such, they may not directly transfer to smaller or less complex projects. During the initial case-selection discussions within WSP, preliminary conversations with professionals involved in smaller-scale projects indicated that perceptions and practices of SE differed when project complexity was lower.
- The empirical data were collected exclusively from participants working internally within WSP and specifically on the IJVA project. While this approach provided in-depth insights, it limits representation of the broader organizational culture across WSP. OC is a sensitive and context-dependent concept so the cultural factors identified in this study may have differed if another project or business unit had been examined.
- The findings of this study reflect the project context at the specific time of data collection, but the dynamic nature of culture may evolve over time and in a different phase of the whole lifecycle.
- The selected case study operates as a consortium involving multiple companies. As a result, SE practices were not shaped solely by WSP's internal culture but were also influenced by inter-organizational agreements and contractual arrangements. These contractual structures introduced constraints that may have affected how SE was implemented and perceived and may bias the results.
- The validation focus group was conducted exclusively with employees of WSP. This decision was made to ensure consistency, as the empirical data and interpretations were based solely on WSP participants' perspectives. Involving external consortium partners at the validation stage could have introduced viewpoints not represented in the original data, potentially limiting the coherence and internal validity of the findings.
- A key limitation of modelling approaches such as CLDs is their tendency to simplify the complex interconnections that happen in reality. Given the research topic, it can be understood that this system is obviously more complex than it is assumed in the model and there are many more contributing factors for each variable included. As a result, the CLD should be interpreted as a conceptual abstraction rather than a complete representation of reality. It enables though the reduction of complexity in a way that facilitates understanding and analysis, which might otherwise not have happened. The purpose of complexity informed approaches is not to generate perfectly comprehensive answers to complex problems, but rather to avoid conclusions that are fundamentally misleading (Crabolu et al., 2023).

- The proposed CLD was not tested in practice to confirm its effectiveness. It was developed through the integration of professionals interviewed and relevant literature and consequently validated by an expert panel. Due to that, it cannot be conclusively argued that CLD will be effectively implemented in practical scenarios.

9.2 Conclusions

This graduation project focused on understanding the interdependencies between OC and the adoption of SE within an evolving organization. The study intends to deepen the understanding surrounding the cultural dynamics that shape SE practices and to develop a framework thereby contributing to an organization's efforts of implementing SE in an efficient way. Based on this objective, the main research question was formulated as follows: How does organizational culture influence the successful adoption of Systems Engineering practices in construction projects?

In order to address the main research question above, 4 research sub-questions were formulated and the research was designed to address them as outlined in *Figure 1*. Initially, a literature review was conducted to identify the indicators of successful SE adoption within the construction industry, as well as the key contributing factors and core dimensions influencing its implementation. This exploration was used as the benchmark for the development of the CLD, on which the *RSQ1* was formulated as follows: What constitutes successful adoption of Systems Engineering in the context of construction projects?

The literature review emphasizes that successful adoption of SE cannot be reduced to a single performance outcome or isolated success factor. Instead, it is conceptualized as a multidimensional condition. First, successful SE adoption requires lifecycle-wide and consistent application of SE processes. According to ISO/IEC/IEEE 15288 (2015), SE encompasses life-cycle processes that support system definition, realization, verification, validation, operation and transition. In the construction context, limiting SE to early design phases undermines its integrative function. Studies by Van den Houdt & Vrancken (2013) and Kossiakoff et al. (2011) emphasize that fragmented or selective application reduces traceability, weakens coordination but also compromises system-level oversight. Second, successful adoption depends on the effective execution of core SE technical practices, particularly requirements management and verification & validation (V&V). Literature highlights that requirements must be complete, up to date, traceable and aligned between client and contractor (Slegers et al., 2012; Ryan & Wheatcraft, 2017). Similarly, V&V activities must be systematically planned, continuously performed and clearly linked to system requirements. Effective interface management further strengthens integration and reduces ambiguity in complex and multidisciplinary projects.

In addition, SE must be organizationally embedded rather than individually driven. In the context of this thesis, institutionalization is reflected in the presence of a clear SE vision and objectives, defined roles and responsibilities, interdisciplinary coordination structures and governance mechanisms that integrate SE into routine project management (Kossiakoff et al., 2011; Emes et al., 2012). Without senior management commitment and structural alignment, SE risks remaining a compliance-oriented activity rather than a core organizational capability. Last but not least, the realization of tangible and perceived benefits. As Honour (2010) empirically demonstrates that appropriate levels of SE effort correlate positively with improved cost, schedule and technical performance. Beyond measurable performance improvements, literature

also emphasizes enhanced traceability, reduced rework, improved coordination and strengthened decision-making as indicators of effectiveness. Continuous evaluation, organizational learning and lessons learned further signal that SE is not only implemented but actively used to improve project outcomes.

Then, the literature review shifted the focus on the identification of different types of OC that may arise within an organization and identifying which cultural characteristics are most likely to appear for the effective implementation of SE in order to address *RSQ2*. Within this lens, foundational theories were explored, including Schein's (2010) three-level model of OC and the CVF by Cameron & Quinn (2011). These frameworks were used, first, to understand how observable practices, espoused values and underlying assumptions shape organizational behavior and second to identify the different cultural orientations that an organization may appear. Adding to that the literature research continued on cultural enablers and inhibitors of SE adoption was reviewed presented in *Table 5* (e.g. Buck et al., 2013; Bretz et al., 2019; Hutchison et al., 2019). This time drawing from the CVF model (clan, adhocracy, market, hierarchy) the cultural factors were mapped. Through this process, it became evident that adhocracy and clan cultures emerge as the most supportive orientations for SE adoption, as they promote innovation, flexibility, collaboration and shared responsibility. However, elements of hierarchy and market culture remain necessary to ensure coordination and performance control. Therefore, successful SE adoption is most likely in organizations that consciously balance these competing cultural characteristics in response to project demands and organization's objectives.

In order to address the research sub-questions *RSQ3* and *RSQ4*, several interviews were conducted with professionals working in WSP. The concluding remarks for these two sub-questions are drawn in *Section 5.18*.

Empirical Data Collection	
Cultural Enablers	**Cultural Constrains**
Interpersonal openness & approachability	SE perceived as bureaucratic compliance
Trust autonomy & empowerment	SE positioned as secondary to "real" engineering work & delivery
Awareness of the need for early alignment	Short-term and reactive organizational culture
Learning and adaptation through experience and reflection	Ambiguity and diffuse ownership are tolerated
A shared norm of valuing SE tools	Siloed professional culture
	SE framed as contractual compliance
	SE not treated as a core organizational capability

Figure 34: Cultural factors identified in empirical data collection

Figure 34 summarizes all cultural factors identified during the empirical data collection phase. Several of these factors had already been identified in the literature review and were subsequently confirmed and further elaborated by professionals during the interviews. It is also important to note that although many of the cited studies in the literature review were published approximately a decade ago, the cultural factors identified, both positively and negatively influencing SE adoption, remain highly relevant in modern organizational contexts.

The fourth sub-question aimed to translate the identified cultural enablers and constraints into actionable improvement strategies. Building on the empirical themes presented in *Figure 16*, representing the last part of the TA and integrating insights from the literature review, *Table 11* presents a structured overview of multi-level strategies to enhance the successful implementation of SE. In order to do that it requires interventions across three organizational levels executive, project and individual. Starting from the executive level, improvement strategies focus on strategic ownership and capability building. This is translated into establishing a clear organizational vision for SE, embedding SE within strategic objectives, developing organization-wide SE standards, investing in training and onboarding across business units and elevating the SE role and ensuring sufficient visibility and authority within the organization. At the project level, strategies emphasize early setup, integration and delivery alignment. Here the actions include allocating sufficient time and resources for SE before project start, ensuring SE scope and responsibilities are clearly defined, embedding SE within design leadership and governance structures and providing strong leadership support to protect and prioritize SE under time and performance pressures. Lastly, the individual level suggests focusing on competence, motivation and readiness. This involves making SE benefits visible to strengthen engagement, fostering a system-thinking mindset across disciplines and departments and building SE confidence through early involvement, empowerment but also recognition of professional contributions.

Since all four research sub-questions have been addressed, the main research question can now be answered through the proposed framework, presented in the form of a Causal Loop Diagram.

MQR: *How does organizational culture influence the successful adoption of Systems Engineering practices in construction projects?*

The proposed CLD can be used by the organization as a foundation to acknowledge and observe the dynamics between OC and SE but also the underlining factors that can influence successful implementation, as discussed in Chapter 6. The influence of OC emerged as critical for shaping how SE is enacted in practice. It is not direct in terms of procedural and technical processes but is systemic and context dependent. Successful adoption goes beyond principles and guidelines. It requires lifecycle-oriented thinking, early alignment, interdisciplinary integration, governance clarity and continuous validation and learning. In this sense, success is characterized by deep organizational embedding rather than surface-level compliance. However, the realization of these characteristics depends mainly on the surrounding cultural environment.

Adding to that, OC can shape adoption through several “mediating mechanisms” meaning that leadership culture can determine whether SE is framed as a strategic capability internally or as a contractual obligation. When leadership supports short-term delivery pressure, SE tends to be perceived as bureaucratic documentation, limiting internal ownership and proactive application. Conversely, when leadership promotes long-term orientation, integration through all the phases, trust and shared responsibility, SE is more likely to be understood as a value-adding approach. In addition, cultural norms regarding collaboration but also professional identity strongly influence interdisciplinary integration. A siloed professional culture, in which disciplines prioritize their own expertise over the whole system alignment, weakens requirements management and interface control. In contrast, cultures characterized by openness, trust and shared understanding supports communication, understanding and systems thinking. It is important to mention that organization’s learning orientation affects whether SE evolves into a continuous improvement

capability. Cultures that encourage reflection, feedback and lessons learned strengthen the effective use of SE practices that can be unfolded over time. Where learning is limited and SE is treated as a secondary competence, its potential benefits cannot be fully realized.

The CLD illustrates that these influences do not operate solely. Multiple interacting dynamics contribute simultaneously, making SE adoption a complex and evolving phenomenon rather than a linear implementation process. In the context of complex construction environments, the presence of multiple stakeholders further intensifies this, as different organizational subcultures intersect and shape how SE is perceived. In conclusion, OC shapes the conditions under which SE can either succeed or struggle. Therefore, the success of SE is strongly dependent on the cultural environment in which the organization operates.

9.3 Recommendations

A number of recommendations can be drawn from this graduation thesis, which are listed below:

- **Cross-scale project comparison:** Future research could investigate whether the identified OC-SE dynamics also appear in small and medium scale construction projects, where project complexity, structures and availability of resources are typically less extensive. Such studies could examine whether similar cultural perceptions and reinforcing or constraining mechanisms emerge in these contexts and if differences are observed, how and why these dynamics vary across project scales.
- **Intra-organizational comparison across departments:** This recommendation could further explore the maturity of each department internally regarding the application of SE. Departments operating in different construction domains, such as energy infrastructure, water management, transport and building projects, can develop different subcultures, expertise and operational processes that could influence the cultural mechanisms identified in this study. Comparative research could examine whether the reinforcing and constraining dynamics between OC and SE adoption remain consistent or whether different cultural configurations are required to support SE effectiveness in varying industry contexts.
- **Quantitative methods:** This research is limited to qualitative conceptualization. The development of survey could support not only to better understand the cultural orientation within an organization towards SE but will also validate and statistically test the relationships between cultural variables, SE maturity and project performance outcomes while also providing evidence-based insights to support the ongoing effort at strategic, operational and infrastructural level within organizations such as WSP. It can also help in indicating possible hidden variables in that way.
- **System dynamics simulation modeling:** The translation of CLD into a stock-and-flow diagram to represent systems in greater structural detail. The diagram could be transformed into an equation-based model in order to run simulations. These simulations can be used to generate system behavior over time and allow for the analysis and comparison of different simulation runs. Using system dynamics software (e.g. Vensim or similar tools), researchers could simulate different scenarios to explore time delays and long-term consequences of cultural and policy changes on SE adoption. It would deepen understanding of dynamic complexity and provide predictive insights into the evolution of SE performance.

- **Role of middle management in SE embedding:** It is recommended to conduct research to investigate the role of project leaders as key intermediaries between executive strategic level and individual practice, as highlighted in *Table 11*. Research could analyze how these actors translate cultural values, the vision of the higher management and interpret expectations into a project context environment.
- **Cultural alignment between client and contractor:** The investigation of the cultural orientations between these two, how cultural differences between clients and contractors can affect SE application, expectations and decision boundaries from each one's perspective.

9.4 Reflection

During my studies, I had the opportunity to delve into a variety of subjects. In parallel, I gained experience at WSP in Netherlands, the consulting engineering firm, both of which led to this graduation topic. I explored theories for organizational culture and system engineering. In this final section, I would like to reflect back on this challenging yet amazing journey both contributing to my academic and professional development.

My interest in SE was sparked during the first months of my employment at WSP. I became involved in tasks related to Relatics, particularly the restructuring of Interface Queries (IFQs), which was my first exposure to interface management. Working with this tool allowed me to experience firsthand the integrative nature of SE and understand how multiple disciplines can effectively coordinate, not only internally but also with external stakeholders, to achieve alignment and coherence within complex projects. Very early on, I began to recognize the importance of embedding SE from the outset of a project, from personnel capabilities to strategic and operational objectives.

Although SE has been known and discussed for several years, I realized that it remains underutilized within organizations. Even when experienced professionals are familiar with its concepts, translating the full systems-thinking mindset into daily practice remains challenging. This realization played a significant role in shaping my academic curiosity.

During the initial phase of defining my research scope, I explored several directions and had the opportunity to engage in discussions with colleagues across different business units within WSP. These conversations helped me understand diverse perspectives, particularly regarding project scale and how SE is perceived and applied in smaller versus larger projects. Although my research focus eventually shifted toward organizational culture, the insights I gained into how people work across different project contexts, their challenges or not, their understanding of SE and the people involved each time proved valuable.

The progress of this research greatly benefited from the strong support it received within WSP, especially as SE has recently become a topic of strategic importance at higher management levels. Many professionals within the organization recognized the relevance of the subject and were willing to contribute through interviews and validation sessions. I was particularly appreciative of the openness with which participants discussed sensitive cultural aspects of the organization. This willingness to engage in honest dialogue allowed the research process to unfold smoothly and successfully. The enthusiasm shown by colleagues not only reinforced the practical importance of the topic but also motivated me further in potentially pursuing a career path within SE.

This graduation research also became a personal journey of growth. Pursuing an MSc in Construction Management & Engineering provided me with the theoretical foundation, but this project allowed me to truly apply and test my project management skills. I learned to independently structure and execute a research project from start to finish from defining the scope, setting milestones and managing deadlines to maintain quality standards and aligning the expectations of various stakeholders. At the same time, I became more aware of my own communication style and improved my ability to engage with professionals at different organizational levels.

The graduation process is inherently demanding and characterized by continuous ups and downs, at least in my experience. Reflecting on the journey and the final outcome, I'm personally very pleased with the result achieved, particularly considering the complexity of the topic and the conditions under which the research was conducted. Overall, this experience pushed me beyond my limits and has been deeply rewarding, strengthening my confidence about my future path.

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APPENDIX A: CLD with markings for changes

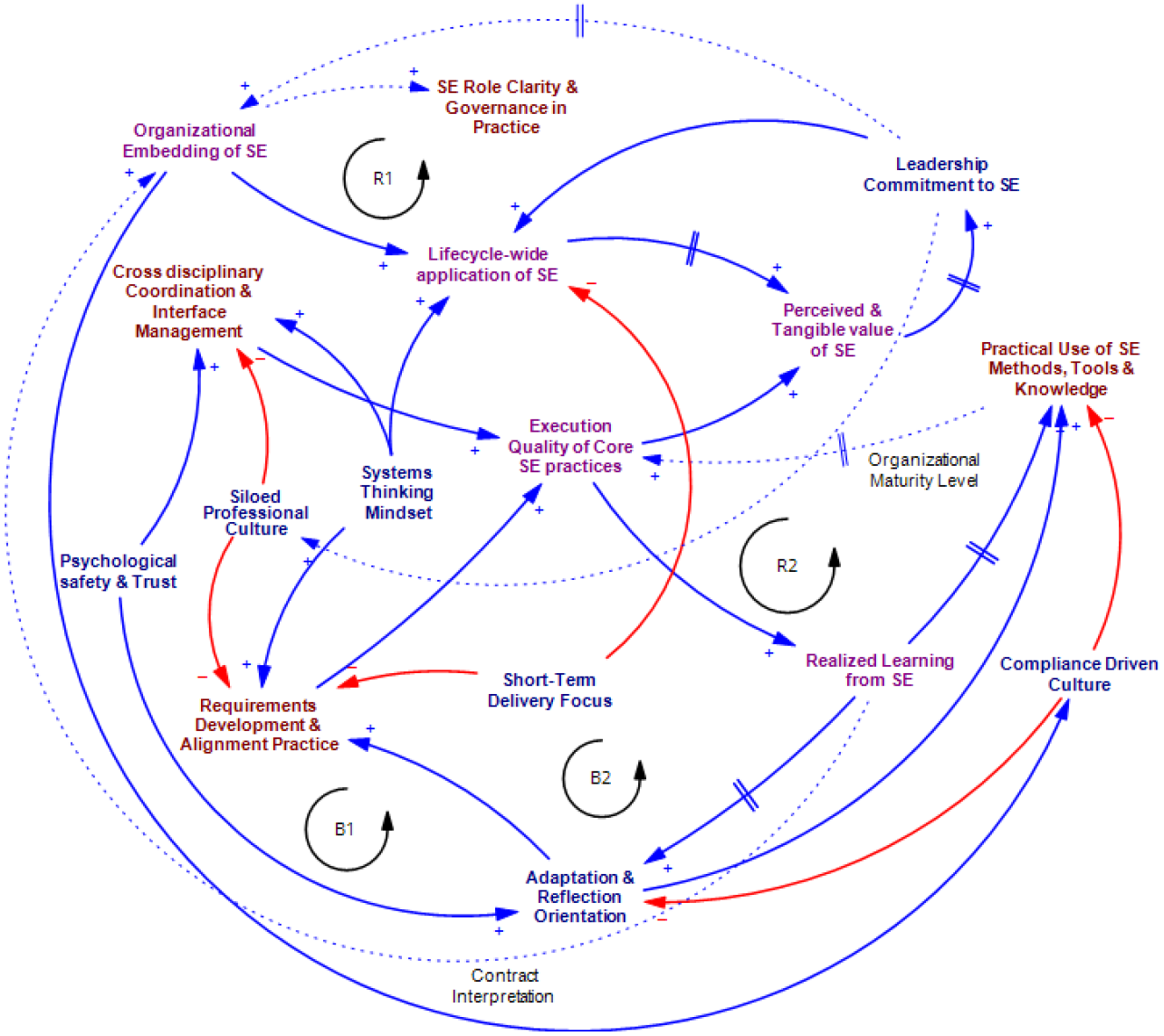

Figure 35: Updated CLD after the validation process

The proposed modifications are shown using dashed lines, and the additional comments integrated during the validation session are displayed within the diagram.