MSc Thesis - Construction Management and Engineering
2023-2025

Preventing Escalation:
Early Warning Signals and Anticipation of Creeping Crises in the Initial Stages of Construction Projects

By
José Carlos Galindo Mac-swiney

in partial fulfilment of the requirements for the degree of

Master of Science (MSc)
in Construction Management and Engineering
at the Delft University of Technology.

Green Light Document - Jun 4th, 2025

Student number: 5925711

Graduation Committee:

Chair: Prof. dr. P.W. Chan, TU Delft
First supervisor & mentor: Ir. J.P.G. Ramler, TU Delft
External supervisor: Ir. A.J. Noortman, Witteveen+Bos
External Supervisor: Ir. K. van Hoeij, Witteveen+Bos

I Preface

Hereby, I conclude my master's thesis. This thesis is the closing chapter of my studies at TU Delft and a series of endeavors and decisions taken that guided my path to this point. After six years of continuous employment, putting my professional career on hold for studying a master's degree was not an easy decision, however, as John D. Rockefeller said, “Don’t be afraid to give up the good to go for the great.”

The motivation behind this thesis was laid down on personal experiences. During my professional career, I faced a phenomenon sometimes in which, in the projects, issues kept arising one after another, creating a cascade effect that left teams exhausted, and although some actions were implemented, they often came too late—when the situation had already escalated and it was difficult to regain control. At the beginning I thought it was simply bad luck. I used to ask myself, “Why is this happening on this project? Why are we the unlucky ones?” But over time, I came to understand that the phenomenon I experienced is what is called a crisis.

This thesis focuses on how to deal with crises, specifically on creeping crises that are developed gradually and can lead to a construction disaster. It centers on how engineering consultancy firms can identify and implement early warning systems to manage creeping crises before they escalate. Through close collaboration with Witteveen+Bos, this research was grounded in real-world insights from the engineering and consultancy sector.

I want to thank Arend and Kevin, who, although having busy jobs, were always available to support me, share their insights, give me feedback, and accompany me throughout this process, making it an enriching experience that also showed me a part of how things are done in the Dutch professional environment. Additionally, I owe special thanks to Hans Ramler and Paul Chan for their constant support and mentoring. Both are excellent professionals and educators whose passion for their job inspired me and made this process smoother.

I dedicate this achievement to my parents. Thank you for everything—I admire and love you infinitely. To my family and friends, I extend my sincere gratitude for your constant support and for visiting me, even if we were far away. Seeing you always refueled my spirit and gave me the boost I needed. And finally, a special recognition to my girlfriend and brother, who accompanied me closely during this process.

I really hope that this work will contribute to better project preparedness and resilience in the construction sector.

José Carlos Galindo Mac-swiney

II Abstract

This thesis provides insights and recommendations for the identification and response to creeping crises during the early stages of construction projects, with a special focus on engineering consultancy firms such as Witteveen+Bos. While existing research on crisis management in construction projects focuses on the execution phase, there is still a gap regarding early-stage crises, particularly creeping crises that are crises that develop gradually. These crises are difficult to detect, often going unnoticed until they reach the tipping point, which is the moment the crisis is visible and it has already damaged the outcome of the project. The main research question of this study is: “How can engineering firms identify and implement early warning signals to detect and manage creeping crises in construction projects?" and it is divided into four sub-questions in order to structure the study in a more systematic manner.

To answer the research question and to develop an actionable framework, a qualitative mixed-methods research design is chosen. The research includes a literature review spanning general crisis theories, High Reliability Organizations (HRO), sensemaking, mindfulness, and early warning systems. The second phase involves semi-structured interviews with Witteveen+Bos professionals, where the main objective is to get insights of the most common creeping crises within the organization, barriers to detection, and the existing tools and techniques. The final phase consists of a validation workshop with Witteveen+Bos’ professionals to assess the framework and get a final round of feedback.

After carrying out an analysis, findings reveal six common creeping crisis types: scope creep under stakeholder pressure, effort compensation due to overcommitment, stakeholder misalignment, legal or regulatory infeasibility and obstacles, and external contextual drift. Based on these crises and the barriers encountered, a four-stage Early Warning System (EWS) framework is developed: signal detection, signal interpretation, coordinated response, and learning and system adaptation. This framework integrates HRO principles, mindfulness, and sensemaking mechanisms but is adapted into the engineering context, emphasizing soft skills, technical tools, and qualitative judgment. Additionally, the proposed framework is designed to be flexible and customizable, allowing adaptation to different crises, and project teams, with the option of choosing different tools and techniques, including qualitative mechanisms.

The validation workshop confirmed the relevance and feasability of the framework. The participants reacted positive both verbal and nonverbal, and showed a strong recognition of the findings presented. Although feedback was provided, the four-phase framework was generally well understood as well. Ultimately, this research contributes a practice-oriented model that supports engineering firms in detecting and managing creeping crises proactively, embedding early crisis recognition within professional routines while enabling future integration of tools such as AI or predictive analytics.

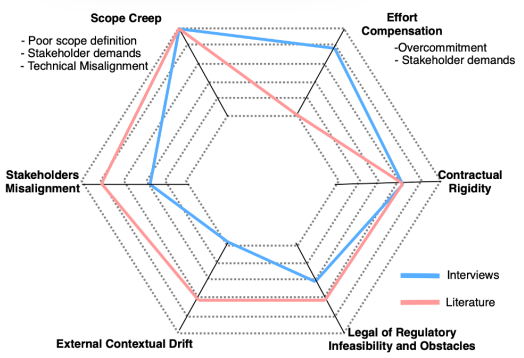
III Executive Summary

This thesis addresses a common but unexplored issue: the identification and response of creeping crises during the early stages of construction projects, particularly seen from the perspective of engineering firms such as Witteveen+Bos. Creeping crises, unlike sudden crises, have the particularity that they evolve gradually through a series of events and are unnoticed or normalized until they reach the tipping point, which is the moment where the crisis is visible but damage has already occurred and the response options are limited. Current literature on crisis management focuses on the execution phase, typically under a contractor's control, leaving an opportunity to explore further the actual situation of engineering firms regarding crisis management and providing an actionable framework that could strengthen resilience within the organizations.

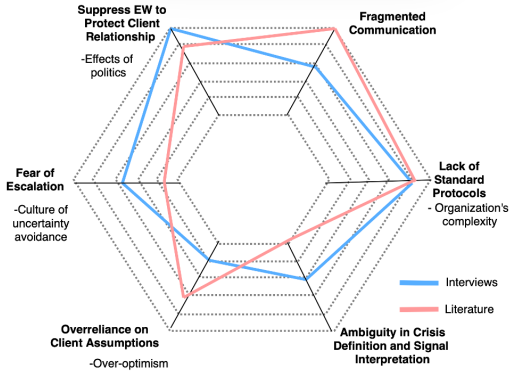
The main research question is*, how can engineering firms identify and implement early warning signals to detect and manage creeping crises in construction projects?* To answer this, the main question has been further broken down into 4 subquestions that allow for t*he detection of* the most common creeping crises in the industry, identification of the barriers that currently exist within the company that do not allow for holistic crisis management, identification of tools and techniques that are already in use and proposed new mechanism implementations, and exploration of the opportunity to develop further the study and position Witteveen+Bos as a leader in the market regarding crisis management. This research follows a qualitative mixed-methods approach that includes three different phases: a literature review, empirical semi-structured interviews, and a validation workshop.

The literature review establishes the conceptual foundations of crisis theory, the distinction and definition between sudden and creeping crises, and a general overview of crises in construction projects. Additionally, it explores models from High Reliability Organizations (HROs), sensemaking, and mindfulness. These theories traditionally are applied to high-risk organizations such as aviation and nuclear power, organizations where small failures are detected before their escalation, and are here adapted to the engineering consultancy context. Furthermore, the literature review go through the different existing tools and techniques for early crisis detection and response, soft skills, and quantitative systems.

The empirical stage of the research relies on semi-tructured interviews with Witteveen+Bos collaborators. Eight interviews were conducted with the objective of getting insights into how creeping crises manifest in projects, what barriers exist in the current working environment, and the current detection and recognition mechanisms. Through a thematic analysis of the transcripts, with the support of the *DelveTool*, and after carrying out an analysis that also integrated the findings from the literature review, several patterns are identified, patterns that would be captured as insights, giving the following results:



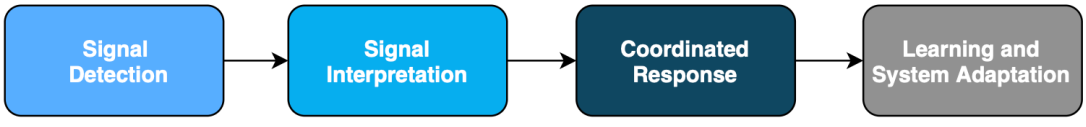
Most Common Creeping Crises



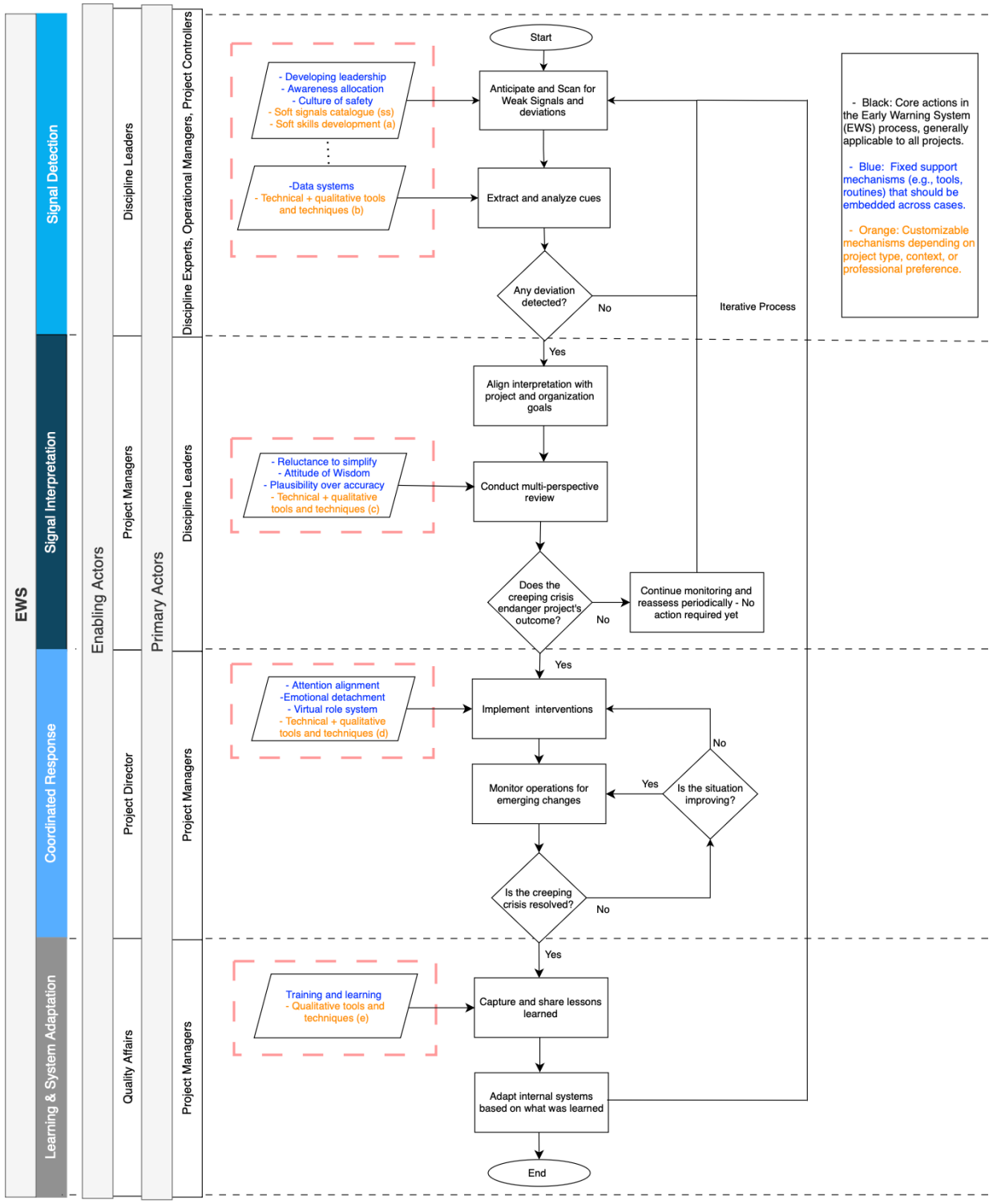
Barriers identified

Furthermore, the analysis allows the identification of the current mechanisms used for the detection and response of crises, as well as the proposition of new or adapted practices to address the most common creeping crises and the barriers encountered. With the insights obtained from Witteveen+Bos professionals, it became evident that engineering firms use a wide range of monitoring tools, dashboards, and project performance indicators; however, these mechanisms are mostly technical, and due to the nature of the identified creeping crises and barriers, there is a clear necessity to develop further rational or qualitative mechanisms.

In response, a four-stage Early Warning System (EWS) framework is developed: Signal Detection, Signal Interpretation, Coordinated Response, and Learning and System Adaptation. Each stage of the framework also specifies both the primary actors that are those directly responsible for carrying out the task, and the enabling actors that, on the other hand, are those who ensure that the organizational environment, resources, and culture are conducive to early warning system functionality. Due to the difficulty of crisis management to follow checklists or rigorous steps, this framework is not intended as a prescriptive or rigid process but rather as a customizable structure that can be adapted to the different creeping crises and project contexts. It integrates HRO principles, mindfulness mechanisms, and sensemaking actions. Additionally, the framework emphasizes professional autonomy and encourages teams to rely on a combination of structured methods and subjective judgment. It can be tailored depending on the tools and techniques already in use or selected by the organization, following Witteveen+Bos culture, where professional freedom and project-specific solutions are valued. By acknowledging the emotional, intuitive, and contextual dimensions of crisis detection, the framework bridges the gap between technical management tools and the human aspects of engineering work.



Four Stage EWS

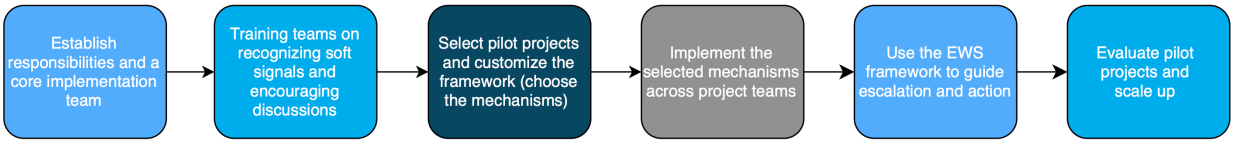


EWS Roadmap

For the validation phase of this thesis, a structure workshop- *The Early Warning Lab*—was held with six Witteveen+Bos professionals. The validation confirmed the relevance of the findings, with participants

recognizing that the proposed framework reflects real-life conditions in ongoing projects. The discussion also led to valuable refinements. Among the recommendations were: the inclusion of real project examples to increase clarity, the formal integration of intuition and tacit knowledge into the detection phase, and the strengthening of the learning stage with specific tools for capturing lessons learned. Participants appreciated the flowchart's adaptability and welcomed its integration into Witteveen+Bos broader organizational systems, though they also stressed the need to ensure cultural buy-in and avoid rigid application.

Regarding the recommendations, this thesis provides with the steps to implement the framework in engineering firms. This stages approach ensures that implementation is both structured and adaptable, promoting long-term adoption and cultural integration.



EWS implementation steps

Overall, this thesis delivers a flexible, actionable, and context-sensitive framework for early crisis detection in construction projects. It contributes both theoretically—by integrating HRO theory, sensemaking, and early warning concepts into a novel setting—and practically, by offering Witteveen+Bos a foundation for institutional learning, proactive crisis mitigation, and future service development in crisis management consultancy. The findings not only strengthen Witteveen+Bos' internal capabilities but also open a path for engineering firms to become trusted advisors in the domain of risk anticipation and resilience.

Contents

IV List of Figures

V List of Tables

VI List of Abbreviations

AEC	Architecture, Engineering, and Construction
BAC	Budget at Completion
BIM	Building Information Modeling
DBFM	Design, Build, Finance, Maintain (contract model)
EAC	Estimate at Completion
EVA	Earned Value Analysis
EV	Earned Value
EW	Early Warning
EWS	Early Warning System
EWN	Early Warning Notice (NEC contract framework)
HREC	Human Research Ethics Committee (TU Delft)
HRO	High Reliability Organization
LC	Lean Construction
LPS	Last Planner System
MFA	Material Flow Analysis
NEC	New Engineering Contract
PLM	Project Leadership Model
PPC	Percent Plan Complete (Last Planner System metric)
RAR	Relational Activation of Resilience
SRQ	Sub-Research Question
S-curve	Schedule-based curve used for progress and cost control
TU Delft	Delft University of Technology

1 INTRODUCTION

1.1 Research Context

The construction industry continues to grow, and projects are becoming increasingly more complex, interdependent, and vulnerable to disruptions that do not strike suddenly but rather build up over time. These so-called creeping crises develop gradually, often unnoticed, until they reach a tipping point. Despite their frequent occurrence, they remain underexplored in academic research; this is due to the difficulty of detecting and recognizing them and also because "crises explode on the scene but usually disappear into the history books after they have been brought under control" (Boin et. al, 2021, p. 3), especially in early project phases where engineering and consultancy firms are involved.

As creeping crises escalate, they can trigger what Weick (1993) calls "cosmology episodes" that are moments where individuals lose control and feel that the system around them is no longer rational. Also, during a crisis, the project's team focuses only on immediate problem-solving and stops looking ahead, akin to a ship in a storm, bailing water instead of steering toward the horizon. These concepts capture the organizational disorientation when early warning signals are missed, making the topic of early warning signals and anticipation of creeping crises in the initial stages of construction projects both urgent and novel.

1.1.2 Crisis Management and its importance

"In highly volatile and uncertain times, organizations are frequently confronted with unexpected events" (Ducheck, 2020, p. 216). A crisis is a type of organizational phenomenon (Alas & Gao, 2012) that "represents an immediate and serious threat to high-priority goals, placing managers under time pressure to find a non-routine solution" (Loosemore, 2000, p. 15). To avoid a disaster, which, according to Loosemore (2000), "is a consequence of a mishandled crisis" (p. 17), organizations need to develop resilience capacity (Lengnick-Hall et al., 2011) and effectively manage crises through crisis management (Alas & Gao, 2012).

Crisis management is crucial for organizational stability and resilience. Ducheck (2020) highlights the importance of developing resilience through crisis management, stating that although "the interest in organizational resilience has steadily grown in recent years" (Ducheck, 2020, p. 215), it remains unclear what organizations actually do and how crisis management is implemented in practice.

One important aspect of crisis management is understanding the type of crises that might arise within an organization. Jarman and Kouzmin (2004) identify two different types of crises. The sudden crisis, which emerges from a single and significant event, such as a natural disaster (Ocal et al., 2006), and the creeping crisis, which develops over time through a series of mutually reinforcing events that collectively escalate into a full-blown crisis. The latter presents greater challenges in recognition due to the lack of clarity regarding its start and end (Boin et al., 2020-2021).

To effectively manage crises, organizations must focus on anticipation capabilities, which form the foundation of crisis management (Ducheck, 2020; Sahin et al., 2015). One of the most critical processes

for anticipation is the establishment of an early warning system (EWS), which "provides some time to take the required precautions against potential crises" (Sahin et al., 2015).

High Reliability Organizations (HROs) lead with the example of industries where crises are not an option and organizations operate in high risk environments. The foundations of their practices lay down in the "collective mindulness" and "sensemaking" where workers are trained to detect and manage early warnings or weak signals of failure before the escalate (Weick & Suitcliffe, 2015). Some industries that are considered as HROs are aircraft carries, electrical power companies, nuclear power, among others (Sutcliffe, 2011; Christianson, 2011). In contraste, construction lacks the stability and feedback loops of HROs, but this gap presents a major opportunity ro strenghten crisis management in the sector.

1.1.3 Crisis Management in Construction

Due to the complexity and uncertainty, without exception, construction projects face challenges that, in most cases, disrupt the initial plans. Construction projects are becoming increasingly complex, and this property makes it difficult to foresee and control its overall behavior (Vidal & Marle, 2008). Crises seem inevitable in construction projects (Hallgren & Wilson, 2008); "they can happen at any time during the project" (Loosemore, 2000, p. 15); therefore, the organizations that participate during the full project cycle need to develop strong crisis management capabilities.

Crises in construction arise from various sources; some researchers, such as Loosemore (1998-2000), have an extensive literature on it; however, there is limited literature on crisis management in the early stages of a project, usually when engineering firms participate. Thus, more attention is needed to understand the crises escalation and how to manage them to strengthen resilience in the industry of consultancy and engineering.

1.1.4 Role of Engineering Firms (Witteveen+Bos)

According to Lee et al. (2020), the three main stakeholders in a construction project are the client, consultant or engineering firm, and contractor. An engineering firm is an organization that provides consultancy, design, engineering, and management (de Graaf, 2016), and their involvement mainly occurs in the early stages of a project; however, in some cases, engineering firms are installed as supervisors during the construction phases.

Wiiteveen + Bos's mission mainly focuses on "providing advice and designs in the fields of water, infrastructure, the environment, and construction" (Witteveen+Bos, 2025). According to Witteveen+Bos (2025), their main scope is to help clients to find solutions to complex challenges. To make it clearer, the following are the roles and scope that Witteveen+Bos (2025) had in some of their most important projects:

- *APMT Container Terminal Rotterdam*: civil engineer design, tender documentation. Supervision during the construction.

- *Afsluitdijk Overhaul:* Planning study, tender support, hydraulic engineering, structural assessments, water safety, ecological design, site supervision, maintenance monitoring, fish migration solutions.
- *EnergieRijk Den Haag:* Energy performance analysis, sustainability consulting, feasibility study, cost-benefit analysis, thermal management, transition path development, environmental impact assessment, system engineering optimization.
- *Room for the River—Avelingen:* Plan development, environmental impact assessment, engineering and design, permits and procedures, tender documents, supervision of works.
- *Fehmarn Belt Fixed Link:* Reference design, construction advisory, immersed tunnel engineering, production process optimization.
- *Oosterweel Connection, Antwerp:* Tunnel engineering, geotechnics, hydraulic engineering, traffic analysis, landscape integration, tunnel safety, civil design.

1.2 Knowledge Gap

Deviating from the project outcome should not be considered normal in construction projects; however, “that state of ambiguity where things do not go according to expectation” (Weick, 1995, p. 91) must be standardized, and the capacity to deal with surprises, which can become a crisis, is what makes organizations resilient (Weick, 1995). Crisis management is an integral component of project construction management; therefore, there is vast literature available. However, there is a lack of research on early-stage crisis management, which includes the most recurrent crisis during the engineering, design, and consultancy phases. This is because the existing literature predominantly focuses on crisis management at the execution phase, where the contractor is the main stakeholder involved. Moreover, few authors categorize crises as sudden crises, which emerge from a single and significant event, and creeping crises, which develop over time through a series of mutually reinforcing events that collectively escalate into a full-blown crisis (Boin, 2021). Sudden crises are the ones that tend to get more attention from the researchers, while creeping crises remain largely overlooked. This creates a significant gap in the literature regarding strategies to detect and manage creeping crises in construction projects, mainly in early phases, before they escalate into full-blown crises. Finally, there is a gap in developing actionable tools and techniques that engineering firms can use in house, within the organization, and can offer as a part of crisis management conslultancy services, techniques that are oriented to early warnings detection.

1.3 Objectives and Research Question

A knowledge gap is identified, and it lies in the lack of research on crisis management in the early stages of a project, specifically addressing creeping crises during the consultancy, design, and engineering phases. This thesis seeks to tackle this literature gap and contribute to the work on crisis management frameworks by generating insights and understanding about the most recurrent crises in the early stages of a project, how to deal with them, and avoid that the creeping crises turn into full-blown crises (Boin, 2020), and what actionable solutions or tools can be offered for effective crisis management by identifying early warnings. Therefore, the main question is:

"How can engineering firms identify and implement early warning signals to detect and manage creeping crises in construction projects?"

This main question has been further broken down into 4 sub-questions to guide the research process and to answer the 5W1H questions (what, why, when, where, who and how (Fauziah et al. 2021). The subquestions are:

Subquestion 1:

What are the most common creeping crises encountered by engineering firms, and what indicators or early warning systems are used to identify them?

The aim of answering this sub-question is to gain insights on what are the most common and recurrent creeping crises in the early stages of a project in which engineering firms participate. By responding to this sub-question, the gap in the current literature is addressed, as the existing literature focuses solely on the execution phase. Also, in this sub-question, the focus is placed on identifying the current crisis management of engineering firms, highlighting the early warning systems.

Subquestion 2:

What challenges do engineering firms face in detecting and responding to creeping crises during the early phase of construction projects?

The aim of answering this sub-question is to identify technical and organizational challenges that engineering firms encounter to detect and respond to crises. These include the crisis recognition and the identification of the moment when the crisis begins without waiting for the tipping point. Additionally, with this sub-question, insights are looked for on how crises are addressed at the moment when these signals appear.

Subquestion 3:

How can engineering firms integrate pre-crisis planning and early warning mechanisms to better anticipate and mitigate potential crises in construction projects?

The aim of answering this sub-question is to tackle the knowledge gap about the tools and methodologies used by engineering firms to both detect early warnings and respond against them. While extensive literature exists on crisis management during the execution phase of construction projects, there is a notable lack of research focused on the early project phases. Additionally, it looks for recommendations to implement or improve early warning systems for creeping crisis preparedness. Different project management tools and, also, insights from HROs like sensemaking and collective mindfulness can serve as a valuable reference.

Subquestion 4:

How can engineering firms position themselves as trusted advisors by offering crisis management consultancy as an added value to their clients?

The aim of answering this sub-question is to get insights about the opportunity to continue with further crisis management research and development of tools and techniques that engineering firms can offer as consultancy services to their clients. Although the development of these specific tools and techniques, that engineering companies might offer to their clients as an added value, are not part of this thesis scope, the willingness to take this research further is.

1.4 Research Design

For this research, a qualitative mixed-methods approach is chosen to acquire more evidence, complement the strengths of different methods, incorporate diverse views, and create novel insights. This qualitative mixed-method is conducted in collaboration with the engineering firm Witteveen+Bos, which is key to the success of this research by providing tools, data, and guidance.

To achieve the objectives, the research is divided into three stages: a literature review, an empirical research stage based on semi-structure interviews, and finally, the validation stage which also substitutes and complements traditional case studies analysis. Figure 1 illustrates the overall research methodology for this study, while figure 2 shows the methodology that will be used to answer each of the sub-questions in order to give a substantiated answer to the main question research.

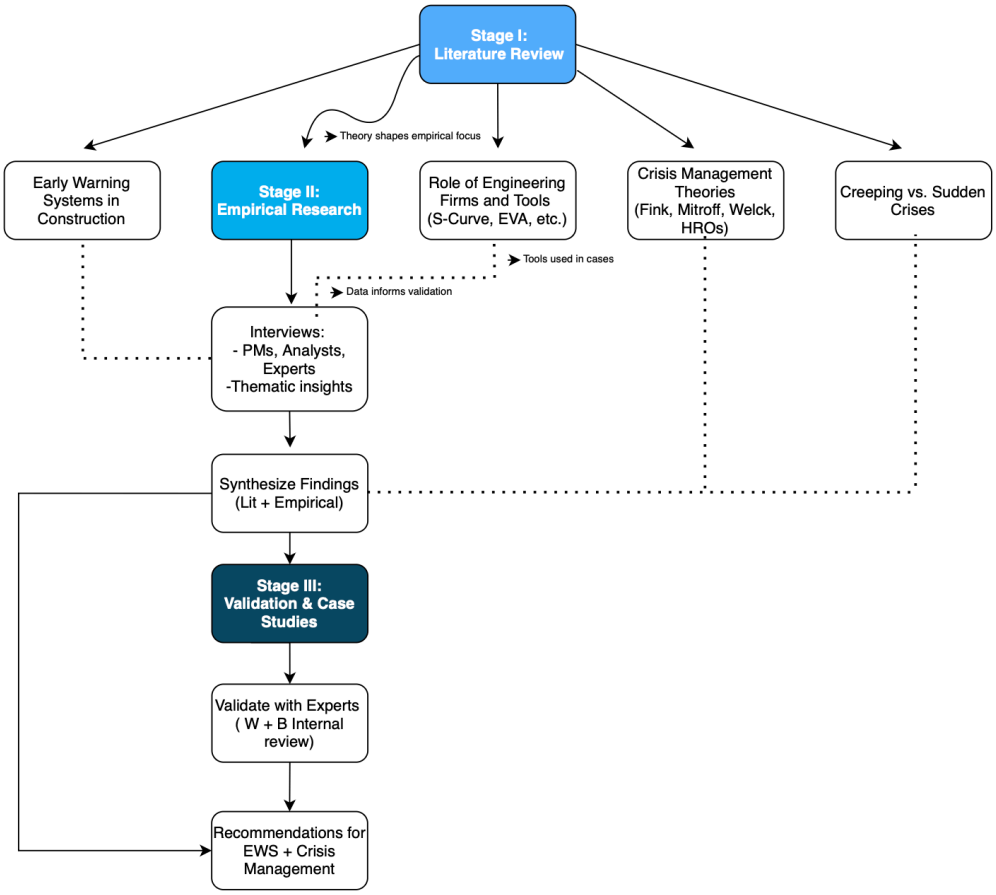


Figure 1 Research Design Overview

Main Question					
How can engineering firms identify and implement early warning signals to detect and manage creeping crises in construction projects?					
Methodology		**SQ1**	**SQ2**	**SQ3**	**SQ4**
Literature Review		What are the most common creeping crises encountered by engineering firms and what indicators or early warning systems are used to identify them?	How can engineering firms integrate pre-crisis planning and early warning mechanisms to better anticipate and mitigate potential crises in construction projects?	What challenges do engineering firms face in detecting and responding to creeping crises during the early phase of construction projects?	How can engineering firms position themselves as trusted advisors by offering crisis management consultancy as an added value to their clients?
Empirical Research	**Interviews**				

Figure 2 Methodology for answering the sub-questions

1.5 Stage I – Literature Review

A literature review is conducted in the existing body of knowledge to examine and identify frameworks that will guide this research. Scientific and academic journals and papers are retrieved from websites such as ResearchGate, ScienceDirect, Scopus, and Elsevier. The keywords used to narrow down the search include creeping crisis, construction crisis, crisis prevention, crisis management, resilience in construction, and crisis early warnings, among others. Printed literature, books, and e-books are reviewed at the TU Delft library, focusing mainly on general crisis theories and management. Additionally, the revision of theses at the TU Delft repository is crucial to ensure that this research builds upon prior academic work and aligns with existing studies within the field.

To provide a structured foundation for this research, the literature review follows a systematic approach, starting with general crisis literature. Boin et al. (2021) and Loosemore (2000) define a crisis and introduce the differentiation between sudden and creeping crises. Additionally, De Sausmarez (2007) distinguishes between endocrisis and exocrisis, which helps to understand the source of the crisis and provides insights on how to manage them.

Next, traditional crisis management frameworks are explored, such as Fink's (1986) four-stage model and Mitroff et al.'s (1988) five-stage crisis management approach. These models also introduce proactive and reactive crisis management approaches, which provide insights into how creeping crises transition into full-blown crises. As an example of successful crisis management in industry, High-Reliability Organizations (HROs) are studied for their ability to maintain operational activity in high-risk environments. The work of Weick & Sutcliffe (2015) is examined in detail, focusing on HRO approaches and the foundational concepts of sensemaking and mindfulness, which provide organizations with principles for crisis management and early crisis recognition.

Finally, the literature review connects general crisis management frameworks with construction crisis theories. Loosemore (1997-2000), as a leading researcher in the field, provides a comprehensive analysis and theoretical framework for both sudden and creeping crises in the construction industry. Through case studies, he analyzes different types of crises, their triggers, and the responses. Additionally, in alignment with the focus of this research, various early warning systems are explored, such as the S-curve (San Cristobal, 2017), the Earned Value Analysis (Zhan et al., 2015), the Project Assessment methods by Williams (2012), and the Last Planner System by Ballard (2000). These frameworks and tools help in detecting early warning signals, assessing risks, and implementing proactive measures in construction project management.

1.6 Stage II – Empirical Research Stage

1.6.1 Semi-structured Interviews

For this stage, semi-structured interviews are carried out to obtain insights from professionals that are directly involved in the early stages of a project, collaborating at Witteveen+Bos, who have experienced firsthand creeping crises in past or current projects and have made use of crisis management practices. Interviews are not limited to project managers; they also include risk analysts, designers, cost estimators, and other specialists whose experience might be helpful for this research.

The interviews' time is one hour. They are conducted under the prior consent of the interviewee, in which an "informed consent" document (appendix 1) is filled out in advance, making sure to give all the necessary information and the purpose of the research to the interviewees. In addition, the interview will be recorded and transcribed. Thematic analysis is used to analyze the data. More details are given in section 3.

As mentioned above, the interviews follow a semi-structured format, which allows for a balance between consistency and flexibility and "are mostly based on open-ended questions that prompt participants to develop their thoughts and ideas in depth" (Karatsareas, 2022, p. 99), and give room for follow-up questions, clarification, and the exploration of unexpected but relevant topics that may emerge during the conversation. The data collected at the interviews contributes to addressing the four sub-questions of the research: sub-questions 1, 2, and 3 are partially tackled by the interviews, while sub-question 4 is addressed entirely at this stage.

1.7 Stage III – Validation

To ensure the credibility and robustness of the research findings and their relevance and usefulness in the organization, Witteveen+Bos, it is included a validation process as the final stage of this research. As emphasized by the American Educational Research Application (1999, p. 9), "validation is the process of accumulating evidence to provide a sound scientific basis for the interpretation of results"; thus, the validation process is crucial in establishing the legitimacy of the research, and also, it can provide feedback for both current findings and future inquiries that support the chapter of recommendations for future research.

In the context of this research, the validation strategy comprises two core components:

Firstly, the triangulation of data sources, which is a cross-verifying system in which the findings from the literature review, semi-structured interviews, and case studies are analyzed and compared to enhance the reliability of the research, looking for similarities and differences across methods.

And secondly, the feedback from practitioners. For this stage, selected professionals from Witteveen+Bos, including some of the ones originally interviewed and preferably people related to risk management, are invited to review the preliminary findings and framework's proposal. Their feedback helps validate the accuracy and practical applicability of the results.

2 LITERATURE REVIEW

2.1 Introduction

To provide a strong theoretical foundation for this research, a systematic literature review was conducted, comprising 45 relevant sources. These comprise scientific journals from academic databases such as ResearchGate, ScienceDirect, Scopus, and Elsevier, as well as published works, books, and master's theses in the TU Delft repository. The keywords used to narrow down the search include creeping crisis, construction crisis, crisis prevention, crisis management, resilience in construction, and crisis early warnings, among others. The review includes diverse fields for a holistic approach toward crisis management, with a special focus on creeping crises and their relevance for engineering firms in the construction sector. Additionally, this literature review also seeks to partially address sub-question 1 and 3 by identifying the most common creeping crisis triggers and exploring existing tools and early warning mechanisms that engineering firms could adopt.

Literature has been carefully selected to cover four main fields important for research: (1) General Theory of Crisis, including sudden and creeping crisis differentiation; (2) Creeping Crisis and Crisis Management frameworks; (3) Crisis Management in Construction, with special emphasis on early project phases, where engineering firms participate; and (4) Early Warning Systems (EWS), including tools and soft skills for early detection and proactive management. Table 1 summarizes the reviewed literature and categorizes it into the six main areas or domains relevant for this thesis.

2.2 General crisis' theory

For Boin et. al. (2021), a crisis "is an empirical phenomenon—a real threat—that has the potential to cause serious damage to critical values or systems" (p. 4). For Loosemore (2000), it represents an "immediate and serious threat to high-priority goals, placing managers under extreme time pressure to find a non-routine solution" (p. 15). And both map the crisis in sudden and creeping crises.
According to Jarman and Kouzmin (2004), there are two different types of crises: The sudden crisis that emerges from a single and significant event, such as a natural disaster (Ocal et al., 2006), which, due to their low likelihood of occurrence but high impact, some of them are considered as Black Swans (Taleb, 2007). And the creeping crisis, also known as a slow-burning crisis (Boin, 2021), develops over time through a series of mutually reinforcing events that collectively escalate into a full-blown crisis.

2.3 Creeping crisis and management

Boin et. al. (2021) defines a creeping crisis as "a threat to widely shared societal values or life-sustaining systems that evolves over time and space" (p. 3), which is foreshadowed by precursor events, which most of the time develop under radar, and, in early phases, when damage potential is building, the precursor events are not easy to detect (Boin, 2020) and could escalate into major crises and deviations (Weick & Sutcliffe, 2015). Creeping crises have an incubation period when warnings are there, but usually, very little attention is paid to the triggers, which is considered a mistake (De Sausmarez, 2007), because when a creeping crisis turns into a full- blown crisis, to what is called a tipping point (Boin, 2020), it creates a

negative loop, and teams focus on immediate solutions rather than addressing the root cause to prevent them (Boin, 2020).

Domain	Author	Main Contribution	Intended Application
General Crisis Theory	Boin et al. (2020, 2021)	Differentiates between sudden and creeping crises.	Provide foundamental understanding of creeping crises and what triggers them.
	Sausmaez (2007)	Distinguishes between internal and external crises within an organization.	Helps to differentiate type of crises and which ones can be controlled by an organization.
	Fink (1986), Mitroff, I. I., Shrivastava, P., & Udwadia, F. E. (1988).	Present clear steps on how to deal with crises.	Help to manage crisis and present procedures for dealing crises in early stages.
Creeping Crises	Boin (2020, 2021)	Defines creeping crises as slow-burning crises that develop unnoticed until escalation, emphasizes precursor events and tipping points in crisis escalation.	Helps identify creeping crisis, recognizing early signs before they escalate.
	Vince (2022)	Shows how creeping crises are overshadowed by urgent crises.	Demonstrates how urgent crises shift attention away from creeping crises, useful for risk prioritization. And why creeping crises go unnoticed.
High-Reliability Organizations (HROs) & Crisis Prevention	Weick & Sutcliffe (2011, 2015)	Introduces HRO, and their principles: mindfulness, preoccupation with failure, resilience. Emphasizes weak signal detection and adaptive crisis response.	Establishes the importance of risk anticipation and resilience in crisis. The principles can be adapted to construction projects.
	Christianson (2011)	Examines HRO practices in industries like aviation and power grids. Emphasizes anticipation and resilience.	Helps in designing early warning systems for construction project management, focusing on error detection and mitigation.
Sensemaking & Mindfulness	Weick (1995)	Defines sensemaking as a process for interpreting crises and highlights the role of leaders.	Highlights the imporance of leadership perception and decision-making in handling crises.
	Weick & Sutcliffe (2015)	Mindful organizing reduces oversimplification and helps organizations detect early weak signals of failure early.	Encourages proactive crisis management by reducing reliance on oversimplifications.
Crisis Management	Loosemore (1997-2000)	Big picture of crisis management in construction with case studies.	Explains construction crises, their triggers, and case studies to improve preparedness.

in Construction	Vincent (2017)	Identifies poor planning, time pressure, and lack of defined scope as triggers for crises.	Provides insights into early risk identification and crisis management in construction.
	Halgren et al. (2007)	Ranks different crisis triggers in construction, including accidents, client delays, and subcontractor compliance issues.	Supports risk ranking and crisis prevention strategies for construction projects.
Frameworks and tools	San Cristobal (2017)	Introduces the S-curve as a tool for comparing performance.	Supports PM in detecting deviations.
	William et al. (2012)	Develops project assessment methods as a structured process for evaluating project risks and crises.	Supports structured project reviews to detect potential failures and improve decision-making.
	Dimitrov (2024)	Analize different Early Warning tools and techniques for their potential use at the design stage in Dutch infrastructure projects.	Evaluates the applicability of various early warning tools and techniques in the design stage of Dutch infrastructure projects to enhance proactive risk mitigation.
	Zhan et al. (2019)	Defines Earned Value Analysis (EVA) as a way to measure project performance based on cost and schedule metrics.	Assists in monitoring project progress and identifying potential risks.
	Ballard (2000)	Last planner system and lean construction improve plan reliability and project adaptability. Reduces disruptions.	Provides process-based strategies to improve project execution and reduce crisis potential.
	Teo et al. (2017), Loosemore and Teo (2000), Winch and Hajikazemi (2025)	Identify communication, leadership and resilience as the main soft skills for crisis management.	Provides insights into the role of communication, leadership, and resilience in crisis management, supporting the development of effective crisis-handling strategies in construction projects.

Table 1 Literature Review Overview

According to De Sausmarez (2007), a creeping crisis has two distinct origins within organizations. The exocrises , which are externally triggered events (De Sausmarez, 2007), such as economic downturns and regulatory changes. And, on the contrary, the endocrises that originate from within the organization itself and are deeply embedded in the organization's structure and processes (Pauchant & Mitroff, 1992), such as ethical lapses, leadership failures, or operational efficiencies, are also called internal weaknesses. The presence of precursor events within an organization that remain unnoticed or underestimated is a defining characteristic of a creeping crisis (Boin, 2018), and organizations must build resilience (Weick & Sutcliffe, 2015) and "establish a powerful emergency and crisis organization" by providing tools to deal with crises (Kaschner, 2020, p. 45), also called "crisis management".

It is essential to explore the frameworks that guide organizations to respond to creeping endocrises. Fink (1986) introduced the four-stage model of crisis management. The prodomal stage covers the period between the first signs and the tipping point, when the precursor events happen, and when the warning signs are present, but often ignored or underestimated (Fink, 1986). The acute stage marks the actual crisis event, after the tipping point, when the creeping crisis turns into a full-blown crisis (Boin, 2020), and immediate action to mitigate damage is required (Fink, 1986). The chronic stage, where organizations start experiencing the repercussion of the crisis (Fink, 1986), e.g., reputational damage or financial strain. Lastly, the resolution stage is reached when normal operations resume. Mitroff et al. (1988), continuing with Fink's crisis management framework, identify five main stages, which are signal detection, also known as early warnings, and according to Mitroff et al. (1988), "organizations often fail to detect weak signals because they do not have proper mechanisms in place" (p. 102), prevention and preparation, containment, in which emergency responses are involved, recovery, and learning and adaptation. (Mitroff et al., 1988). Mitroff et al. (1988) also introduce the proactive and reactive model (figure 3); however, subsequent researchers explored the topic in greater depth, such as Loosemore and Hughes (2002), that highlight that the proactive crisis management approach identifies potential crises before they occur, and the reactive crisis management approach focuses on bringing an affected organization out of the crisis and stabilizing it.

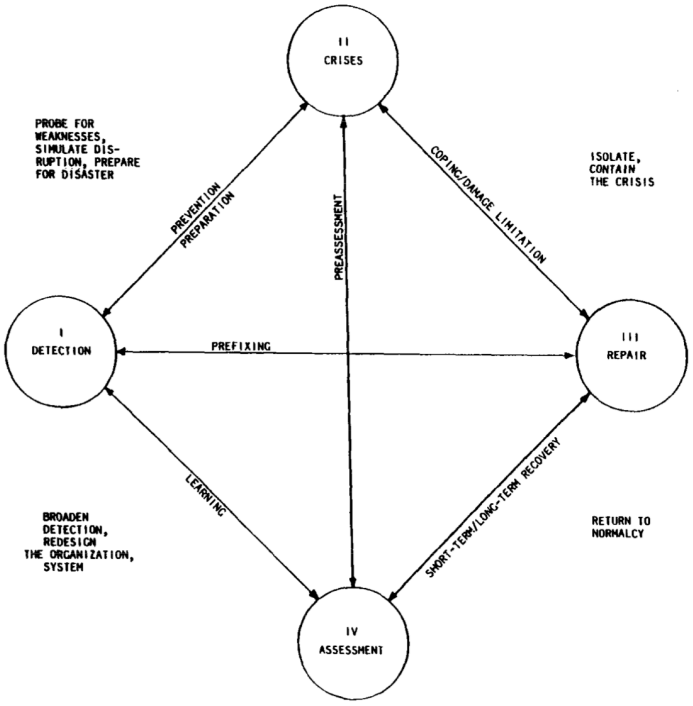


Figure 3 A preventative model of cris is management (Mitroff et al., 1988, p.102)

To effectively address creeping crises, it is essential to explore how organizations can develop resilience and adaptability for avoiding unexpected failures that can lead to major crises if not managed properly (Weick & Sutcliffe, 2015). Christianson et al. (2011) identifies them as High Reliability Organizations (HROs). These organizations have the potential for catastrophic failure, have a commitment to safety at the highest level, recognize weak signals of failure, and can "adapt before a crisis fully develops" (Weick

& Sutcliffe, 2015, p. 94). “The HROs paradigm was developed by a group of researchers at the University of California, Berkeley, to capture observed commonalities of operations among aircraft carriers, air traffic control, and nuclear power” (Sutcliffe, 2011, p. 134), and subsequently, other researchers such as Christianson (2011) added other organizations like electrical power grids and wildland firefighting to the HROs.

2.4 High Reliability Organizations

HROs, as described above, are organizations that operate in high-risk environments, and their main driver is the “collective mindfulness, in which all workers look for, and report, small problems before they pose a substantial risk to the organization” (Veazie et al., 2019, p. 1). Weick & Sutcliffe (2015) state that HROs have developed a sophisticated mechanism to detect and manage potential crises before they escalate and turn into a full-blown crisis, fundamentally what this research refers to as creeping crises, and given that they develop gradually and often go unnoticed until they reach a tipping point (Boin, 2021), the principles of HROs are valuable and can be adapted in any other type of organization.

According to Sutcliffe (2011), HROs follow five principles (figure 4). The first principle is preoccupation with failure, which is a “mindset in which workers look for errors rather than assuming what is in front of them is correct” (Paine et al., 2017, p. 171), a chronic wariness of the possibility of unexpected events (Sutcliffe, 2011) that aligns with the signal detection proposed by Mitroff et al. (1988) and the prodomal stage proposed by Fink (1986). The second principle is reluctance to simplify interpretations, which its definition provided by Sutcliffe (2011) is a “deliberately questioning assumptions and received wisdom to create a complete and more nuanced picture of current situations” (p. 139), helping HROs to uncover blind spots and detect changing demands (Weick et al., 1999). The third principle is sensitivity to operations, which means “creating and maintaining an integrated big picture of the current situation through ongoing attention to real-time information” (Sutcliffe, 2011, p. 140). By monitoring the information, small adjustments can be made and “there are opportunities to stop mistakes and errors from lining up in such a way the grow into a bigger crisis” (Reason, 1997, p. 10). The fourth principle is commitment to resilience. “Resilience has been broadly defined as the ability to bounce back or to overcome adversity” (McCubbin, 2001), and for Sutcliffe (2011), it’s “the capability to contain and bounce back from mishaps that have already occurred, before they worsen and cause more serious harm” (p. 139), a principle that aligns with the containment stage proposed by Mitroff et al. (1988) and the Acute stage proposed by Flnk (1986). Lastly, the fifth principle is the deference to expertise, in which “people are aware of each other’s unique skills and knowledge and when problems arise take advantage of the unique skills of their colleagues” (Sutcliffe, 2011, p. 139). HROs empower individuals with the most experience and knowledge to take critical decisions (Weick & Sutcliffe, 2001), regardless of authority or rank (Sutcliffe, 2011).

In line with the growing interest in operationalizing HRO principles across sectors, several implementation frameworks have emerged. Veazie et al. (2019) identify five frameworks that, apart from the principles, are considered common strategies that organizations develop in order to become HROs. These common implementation strategies are shown in Figure 4.

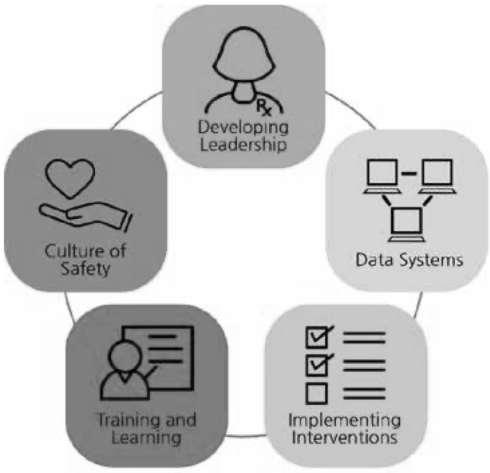


Figure 4 Common HRO implementation strategies (Veazie, 2019).

Adittionally, a critical aspect of HROs that differentiates them from other organizations, is their emphasis on sensemaking and mindfulness, concepts developed mainly by Weick (1995, 2015), however, HROs initiatives can be adapted into other organizations, but is a "costly process that involves organizing people, processes", and, resources (Veazie et al., 2019, p. 5).

2.5 Sensemaking and Minfulness

According to Weick (1995), "sensemaking is the process through which individuals and organizations interpret and give meaning to ambiguous or uncertain situations" (p. 6) to develop informed responses. In this process, as Allard Poesi (2005) describes, "sensemaking activities involve the construction and bracketing of cues to be interpreted, linking them to a previous frame of reference that summarizes past experiences, and revising the interpretations that have thus developed as a result of actions, interactions, and their consequences" (p. 169).

Weick (1993) identifies four resilience concepts that help organizations to adapt to difficulties, detect anomalies, and maintain an organization's functionality under pressure. These are (1) improvisation and bricolage—the ability to combine knowledge and available resources and tools; (2) virtual role systems—individuals can assume multiple roles if necessary; (3) An attitude of wisdom—balancing confidence in knowledge with humility and openness to new information; and (4) Respectful interaction—effective communication based on trust and mutual respect.

Afterwards, in his work Sensemaking in organizations, Weick (1995) adds and further elaborates the seven properties of sensemaking that guide organizations to interpret uncertain situations. These properties are intertwined and affect each other (Eriksson, 2009).

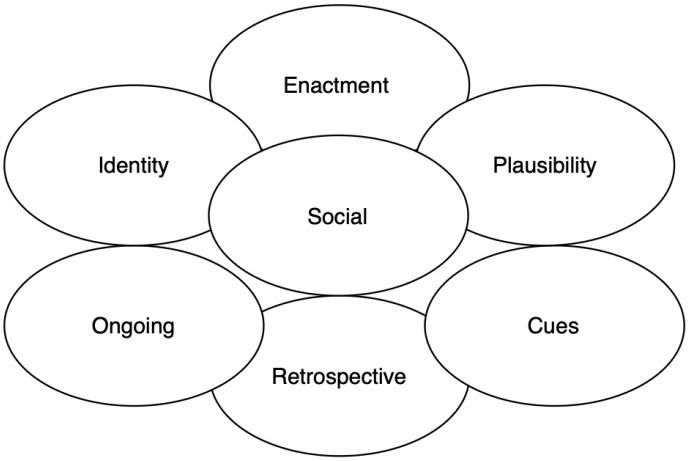


Figure 5 The seven properties of sensemaking (Eriksson, 2009).

Similarly, mindfulness, which is a qualitative technique that encourages high levels of alertness to a task (Weick & Sutcliffe, 2006), helps organizations by developing an infrastructure that makes them more adaptable to uncertainty and helps them remain vigilant to early warning signs and adapt their strategies dynamically in response to evolving threats (Weick & Sutcliffe, 2015). Brown & Ryan (2003) define it as the "state of being attentive to and aware of what is taking place in the present" (p. 822).

Mindfulness can be achieved through mechanisms such as awareness allocation, emotional detachment, and attention alignment (Wang et al., 2021). Figure 6 summarizes the collective mindfulness mechanisms in organizational resilience.

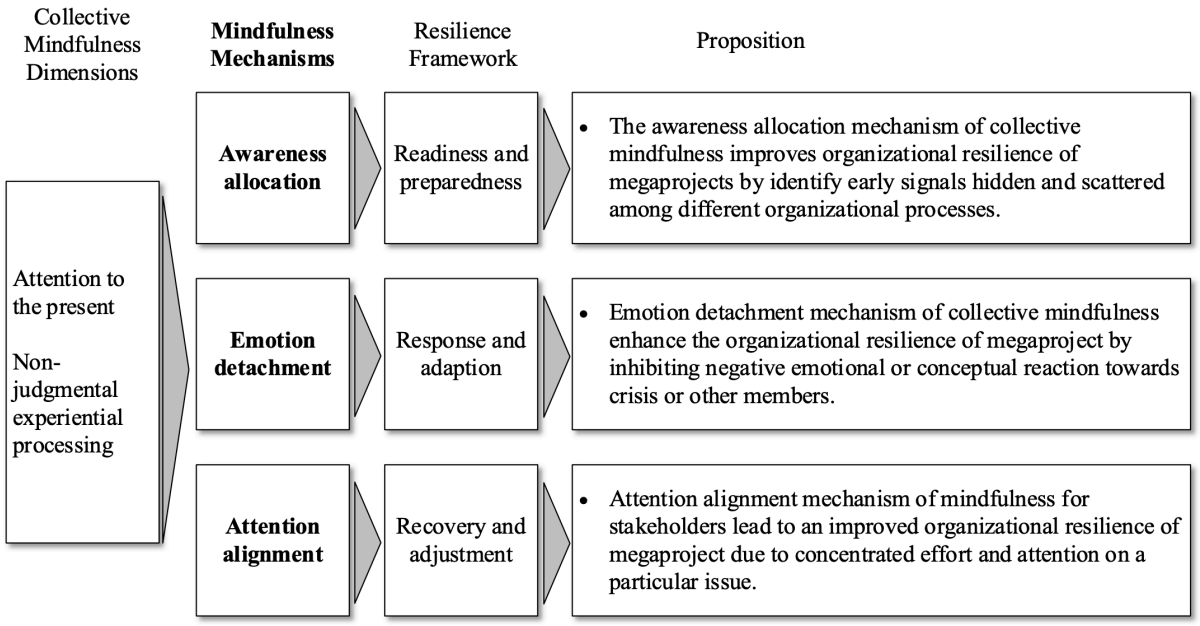


Figure 6 The summarized collective mindfulness mechanisms in organizational resilience (Wang et al., 2021).

Both sensemaking and mindfulness are particularly relevant in the context of creeping crises. As Boin (2021) highlights, creeping crises develop over time through a series of mutually reinforcing events, so, through the application of these frameworks, organizations can enhance their capacity to identify early warnings and contain them before they turn into a full-blown crisis.

2.6 Crisis Management in Construction

Crises seem inevitable in construction projets (Hallgren & Wilson, 2008), consequently, "companies that deal in projects on an ongoing basis thus must learn to deal with crises on a regular basis" (Hallgren & Wilson, 2008, p. 830). Dr. Martin Loosemore, who from 1997 to 2000 contributed extensively to the literature on the subject, defines a crisis as "an immediate and serious threat to high-priority goals, placing managers under extreme time pressure to find a non-routine solution" (Loosemore, 2000, p. 15), and "if the threat is not managed properly, it can lead to a construction disaster" (Loosemore, 2000, p. 39). In contrast with Fink's (1986) four-stage model and Mitroff et al.'s (1988) five-stage crisis management approach, Loosemore (2000) recognizes seven distinct phases in crisis management that are detection, diagnosis, decision-making, implementation, feedback, recovery, and learning. Subsequently, Ringoir (2017) simplified these seven phases into five, which are analyze and prioritize, reorganize, recover internal relations, recover external relations, and evaluate and learn.

Crises in construction arise from a variety of sources. For Loosemore (2000), "many construction problems arise from unresolved conflicts in design" (p. 18) and inadequate and poor communication among stakeholders (Loosemore & Hughes, 2002). For Ringoir (2017), some of the crisis triggers found in his research are bad planning due to time pressure and the lack of a defined scope, which usually aligns to misalignments and can create a cascade effect. Moreover, Hallgren & Wilson (2007) identify accidents as the most common source of crises. Additionally, Hallgren & Wilson (2007) rank different events that trigger crises, which are included, but not limited to, under-estimate discovery, client delay, negotiation dilemma, taxation issues, and slow subcontractor compliance. Hallgren & Wilson (2007) state that a crisis can be prevented by applying increased awareness, and "the only exception might be a natural disaster" (p. 831). Finally, other authors, such as Ocal et al. (2006), identify other sources of crises but primarily focus on external triggers, referred to as exocrises (De Sausmarez, 2007), for example, government policies, unstable market conditions, and lack of financial support.

"A crisis can happen at any time of the project" (Loosemore, 2000, p. 15), yet there is limited literature on crisis management in the early stages of a project, usually when engineering firms participate. Most research and crisis management frameworks focus on the execution phase, typically when crises pop up, and do not delve into early phases, when, on occasion, damage potential is building (Boin, 2020). Nevertheless, several researchers agree that the design and engineering phase is crucial to reduce risk and prevent crises from escalating. Loosemore (2000) emphasizes that "many construction problems arise from unresolved conflicts in design; therefore, better design management could contribute significantly to reducing the crisis proneness of construction projects" (p. 18). Love et al. (2022) highlight that typical contributors to disasters in the construction projects are engineering errors and violations of standards and regulations. Likewise, Alves (2021) identifies the design and technical factors, such as engineering

miscalculations and inadequate specifications, as critical contributors to project vulnerabilities. Lefar et al. (2023) see as the main crisis triggers in engineering firms the non-permanent and unqualified workforce, and the non-compliance with work schedule. And finally, a little more general, that can be applicable in other type of organizations, Williams et al. (2012) identifies as crisis triggers, a poor project definition, the deterioration of relations between the participants, and vague or evasive answers to critical questions.

Table 2 presents the five most recurrent types of crises identified in construction projects, with a focus on early stages of a project.

#	Type of Crisis	Main Sources
1	Poor Scope Definition	Loosemore (2000); Ringoir (2017); Dimitrov (2024); Nader (2023).
2	Contractual Rigidity	Hallgren & Wilson (2007); Loosemore (2000); Ringoir (2017); Nader (2023).
3	Stakeholder Misalignment	Loosemore (2000); Ringoir (2017); Lefar et al. (2023); Williams et al. (2012).
4	Legal and Regulatory Obstacles	Hallgren & Wilson (2007); Loosemore (2000); Dimitrov (2024); Nader (2023).
5	Resource Overstretch and Unrealistic Planning	Lefar et al. (2023); Ringoir (2017); Dimitrov (2024); Love et al. (2022); Alves (2021).

Table 2 Types of Crises Encountered in the Literature Review

Prior to their actual occurrence, all crises send out a repeated train of early warning signals. If these signals can be picked up, amplified, and acted upon, then many crises can be averted before they happen (Mitroff et al., 2000), and the escalation might be interrupted, avoiding them to turn into full-blown crises (Boin, 2021).

2.7 Early Warning System (EWS), Frameworks and Tools

Klepo and Radujkovic (2019) define early warning systems (EWS) "as any initiative that focuses on systematic data collection, analysis, and/or formulation of recommendations, including risk assessment and information sharing" (p. 533). Mitroff et al. (2000) divided the data collection and analysis into four categories: internal technical signals, which are detected inside the organization by remote sensing devices; internal people signals, which are detected inside the organizations by people; external technical signals, which are detected outside the organization by remote sensing devices; and external people signals, which are detected by people.

EWS became popular in the military, economy, IT industry, medicine, communications, and, to a certain extent, construction (Klepo and Radujkovic, 2019). The principles of EWS align closely with the principles of HRO, in which sensemaking and mindfulness are the foundations, and the objective is to remain vigilant of signals that can generate a crisis (Weick & Sutcliffe, 2015).

Klepo and Radujkovic (2019) emphasize that although "there are many theoretical models and practical tools, which can be put under the early warning category" (p. 533), none of them present a holistic solution applicable in construction projects; however, the ones included in Table 3, are widely utilized for monitoring projects and might be adapted as an EWS.

Author, year	Early warning system or tool
Pinto and Slevin (1992)	Project Implementation Profile
Fleming and Koppelman (1998)	CAP – Control account plan
Mavrotas, Caloghirou, and Koune (2005)	S curves
Spjelkavik, Andersen, Onsoyen, Fagerhaug, and Marheim (2008)	*Project health* check tool
Williams, Klakegg, Walker, Andersen, and Magnussen (2012)	Project assessment methods Phase-door models
K. Wang, Zhang, X. Wang, and Yu (2009)	Early warning system related to safety in mountain highway construction
Abdul-Rahman, Wang, and Muhammad (2011)	Earned value analysis
H. S. Lee, K. P. Lee, Park, Baek, and S. Lee (2011)	Real-time location-based construction labour safety management system
Azeem, Hosny, and Ibrahim (2014)	Deterministic models of time forecasting on construction projects: EV (Earned Value); ES (Earned Schedule) Probabilistic models of time forecast on construction projects: KFFM (Kalman Filter Forecasting Model)
Vondruska (2014)	Early warning system in detection of construction projects crises
Skibniewski (2014)	IT applications for construction safety
Lowe (2016)	Maturity models DICE (Boston Consulting group) Stakeholder analysis Simple questions and surveys Retrospective and lessons learned Causes and effects diagrams Burn down charts Earned value management Critical path method planning

Table 3 Early warning systems or tools in project management (Klepo and Radijkovic, 2019)

"Managers commonly use the S-curve for project control as it provides the basis for forecasting cash flows" (San Cristobal, 2017, p. 757); additionally, the S-curve can be used for several purposes, mainly for the current performance status, which can be used as an EWS " (San Cristobal, 2017), in which the actual progress is compared with the planned progress.

The project assessment method, developed by Williams et al. (2012), is a structured process used to evaluate a project's progress, risk, and potential crisis that helps the project manager to make informed decisions. These assessments are generally performed as part of stage-gate procedures and anchored in established governance frameworks (Williams et al., 2012). A stage-gate is a process in which "the entrance of each stage is a gate; these gates control the process" (Cooper, 1990, p. 46), and in each gate there are defined a set of exit criteria and an output to continue with the next step (Cooper, 1990). Williams et al. (2012) identify five stages in the assessment, which are initial review and justification,

stakeholder and risk assessment, formal review and decision gates, monitoring execution and identifying deviations, and final review and knowledge transfer.

"Earne Value Analysis (EVA) is a way to measure the amount of work actually performed on a project" (Zhan et al., 2019, p. 46), but it relies on a key measure known as earn value (EV) which measure in time units vs money units (Ballesteros-Pérez & Elamrousy, 2018), "is the cost originally budgeted to accomplish the work that has been completed as of the analysis date" (Zhan et al., 2019, p. 46). Figure 7 shows the three values obtained with the analysis, in which ETC stands for estimate to complete, BAC for budget at completion, and EAC for estimate at completion.

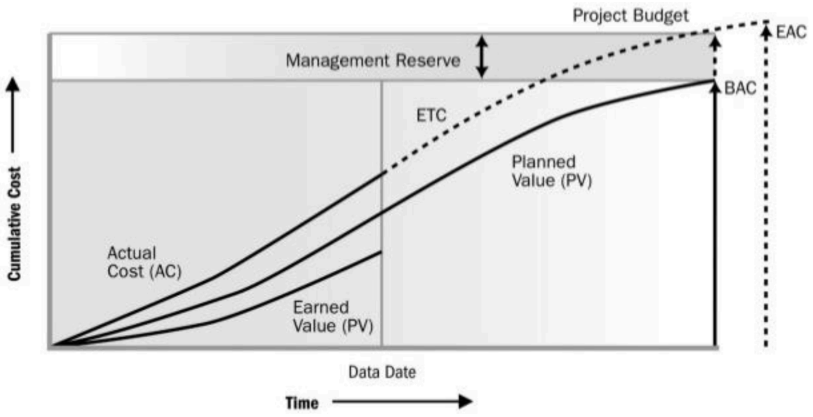


Figure 7 EVM standard curves (Zhan et al., 2019).

Construction projects employ the Last Planner System (LPS) to manage uncertainty and reduce variations (Hamzeh, 2011). It can be applicable in AEC organizations, which stands for Architecture, Engineering, and Construction, to maintain consistency in production flow (Hamzeh et al., 2007). The LPS system allows organizations to early identify and minimize deviations (Hamzeh et al., 2012). Usually these deviations are identified by analyzing the percentage of assignments completed (PPC), which is a key metric of the LPS (Ballard, 2000), "that is the number of planned activities completed, divided by the total number of planned activities" (Ballard, 2000, p. 14). PPC is calculated at the end of the week and it's positively linked to productivity (Liu et al. 2010). There is not a universally acceptable PPC; however, both high PPC and low PPC can be considered as an early warning of deviations: "PPC could be 100%, productivity excellent, and a project still be falling apart on schedule" (Power & Taylor, 2019, p. 133).

Finally, Dimitrov (2024), in his master's thesis, provides some recommendations to designers on how to manage the EWS effectively to avoid schedule delays. Dimitrov (2024) identifies slow client decision-making, high levels of design errors, unsatisfactory quality of reports, and continued attempts to redesign projects as the most recurrent EWS that might influence a project. The study concludes by recommending different tools for early detection of signals and enhances the leverage of advanced technologies such as BIM, AI, and virtual reality.

One practical example of an effective EWS in construction is the Early Warning Notice (EWN). This procedure was developed by the British Institution of Civil Engineers and is currently used in the New Engineering Contract (NEC) framework. The EWN consists of a series of procedures in which the stakeholders, such as contractors, subcontractors, clients, and consultants, work together to detect early signs. According to Hide (2024), the main focus of the EWN is the prevention, and it is not blame-oriented. This EWS consists of four different stages. The first one is the notification, in which stakeholders notify in writing as soon as possible any issue that could affect the project's cost, schedule, or quality (Smith, 2023). The second one is the Early Warning Meetings, in which the issue is discussed jointly. The third one is the register, in which the project manager is responsible for maintaining and issuing the early warning register within one week of each meeting (Hide, 2024). And lastly, the fourth stage, that is, the ongoing review, where the early warnings are discussed at regular intervals until resolved (Hide, 2024). British companies highlight the efficiency of this EWN due to its transparency, and according to Hide (2014), it is proven to enable faster and smarter decisions within the projects. On the other hand, Smith (2023) recognizes as pitfalls the administrative burden that can emerge in large and complex projects due to the sheer volume of early warnings submitted.

In addition to technical and structured tools and systems, several researchers, such as Haji-Kazemi (2015), emphasize the role of human intuition and gut feeling as an EWS. Haji-Kazemi (2015) argues that it is necessary to develop instinctive perceptions, usually the result of experience, to enhance the comprehensiveness and responsiveness of EWS in engineering projects.

Furthermore, in her PhD thesis, "The Early Warning Procedure in Projects," Haji-Kazemi (2015) identifies the most common barriers to detecting EW signals in projects. Figure 8 illustrates the aspects that lead to a lack of detection and effective response to EW signals. "The elements in the inner circle are influenced by elements mentioned in the outer circle, and they altogether alter the final EW response" (Kaji-Kazemi, 2015, p.130).

Figure 8 Most common barriers to detecting EW signals in projects (Haji-Kazemi, 2015)

2.8 Soft Signals and Early Recognition of Crises

In accordance with Haji-Kazemi, the major challenge for project managers in crisis management is the identification of early warning signals. “Although it is not a proven fact that identification of EW signals is a guarantee against project failure, there are a number of resources that consider paying attention to these signals and attempting to respond to them as a contribution to project success” (Haji-Kazemi, 2015, p. 3).

Scholars such as Weick and Sutcliffe (2015) emphasize that the difficulty for the recognition of early warnings relies on the fact that they are not easily quantifiable; however, it is crucial to timely detect and intervene before it is too late. (Boin et al., 2021).

For Vaughan (1996), soft signals can manifest as a “background noise” (p. 482), and relating them to human dimensions, he gives as an example repeated ambiguities, silence during key discussions, rework loops, or vague stakeholder directives. For Haji Kazemi (2015) and Weick (1995), soft signals differ from hard data and often reside in informal conversations, delayed actions, body language, or patterns of subtle resistance.

In line with this, previous TU Delft master’s theses have also explored early-stage vulnerabilities. For instance, Dimitrov (2024) delves into the triggers that can cause schedule delays in infrastructure projects. Dimitrov (2024), in his master's thesis, conducted interviews with professionals and developed a list of the 25 most common early signals, ranking them by frequency of mention in interviews. The top five early warning signals included in Dimitrov (2024) results are slow decisions by clients, a large number of change requests, unclear scope definition, a high turnover rate of people, and a lack of detailed specifications in contracts.

These insights reaffirm that early warning signals are not always dramatic or sudden but often unfold incrementally through patterns of behavior, communication lapses, or managerial hesitation.

2.9 Soft Skills in Crisis Management

According to Di Loreto et al. (2012), in the field of crisis management, a combination of technical skills and soft skills is required. The term soft skills describes a set of skills that are not purely cognitive or technical (Hurrel, 2016) and are developed by education (Warin, 2017) and experience. The soft skills identified by researchers on crisis management are resilience (Teo et al., 2017), leadership (Olsen et al., 2023) (Winch and Hajikazemi, 2025) and effective communication (Vondrunska, 2014; Loosemore and Teo, 2000).

“Resilience may be framed as the capacity to bounce back to a state of normality” (Holling, 1973, p. 223), or “as an emergent property, when an organization learns to adjust adversity” (Teo et al., 2017, p. 121). For Teo et al. (2017), both resilience and leadership play an important role in crisis management;

therefore, the Relational Activation of Resilience (RAR) model is proposed (Figue 9), which "takes a social constructionist perspective of leadership" (p. 123) and explores how a discursive leadership orientation can contribute to the communicative perspective of resilience (Teo et al. 2017). Through relational networks, that is, trust, communication, and collaboration, leaders seek sensemaking to identify EWS and guide teams to activate resilience during crises (Teo et al. 2017).

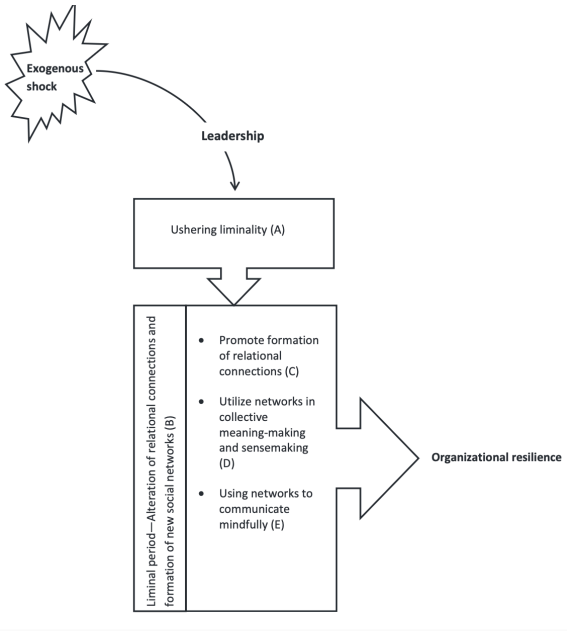


Figure 9 Relational Activation of Resilience model (Teo et al., 2017).

Vodrunska (2014) identifies effective communication as an important tool for crisis management on construction projects, which are linked directly to strategic planning. For Loosemore and Teo (2000), effective communication is particularly important in crisis situations, both horizontal and vertical, and internal and external. Loosemore and Teo (2000) give as an example a well-established procedure that several companies apply for tracking design faults in which work-improvement teams highlight potential problems and together discuss solutions and improvements. However, they identify as a limitation the activities of "whistle-blowers" (Loosemore and Teo, 2000), which might generate conflicts within the organization. Kamau (2024) highlights that effective communication strategies significantly improve crisis management in construction by implementing structured reporting mechanisms that ensure that the early warning signals are escalated quickly to decision-makers.

Pederizini (2017) highlights leadership as a crucial part of sensemaking and defines it as "the capacity to influence others" (p. 8). Winch and Hajikazemi (2025) state that EWS are often detected by those who are not in the position to authorize changes or take decisions; therefore, leaders must create environments where teams feel safe reporting EWS, and this can directly contribute and improve crisis detection. This aligns with the practical wisdom model, which is shown in figure 10, and highlights the importance of experience, intuition, and values for recognizing EWS and making decisions (Winch and Hajikazemi, 2025).

Dumas and Beinecke (2018) state that organizations and their leaders should “move from hierarchical leader-centric management to one that is more open and participative” (p. 873).

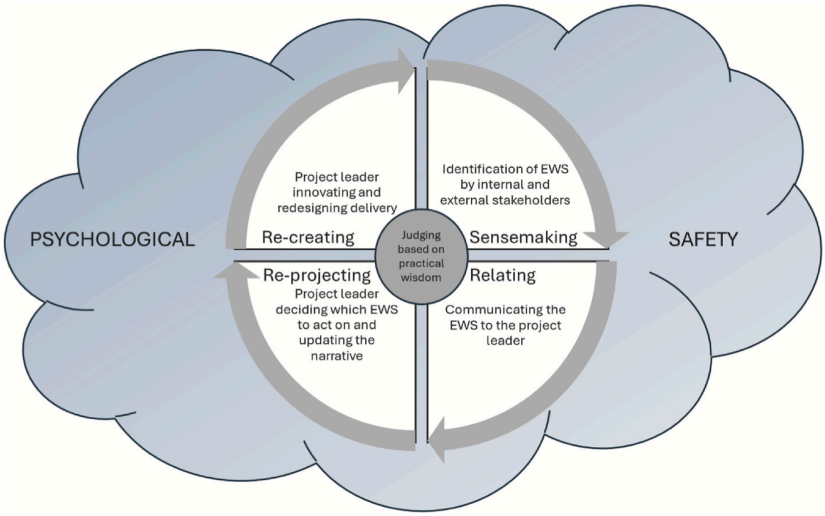


Figure 10 Practical wisdom as applied to EWS (Winch and Hajikazemi, 2025).Practical wisdom as applied to EWS (Winch and Hajikazemi, 2025).

Addittionally, Winch and Hajikazemi (2025) introduce the project leadership model (PLM) as a potential contribution to the EWS framework. The PLM offers a structured way to address EWS through five key leadership practices, which are sensemaking, relating, judging, projecting, and creating (Winch and Hajikazemi, 2025).

2.10 Conclusions

The literature review has provided a solid foundation for the domains listed in Table 1, highlighted the complexities of crisis management—particularly creeping crises in the context of construction and engineering—and validated the existence of a relevant knowledge gap.

The literature review has partially addressed two sub-questions, they will be fully addressed in conjunction with the other research methods applied later in the study. Boin (2021) explains the nature of a creeping crisis and highlights the importance of tackling them due to the fact that usually the precursor event go unnoticed. Loosemore (1997-2000), Hallgren & Wilson (2007), Williams et al. (2012), Ringoir (2017), and, Love et al. (2022), identify as trigger events of a crisis in early stages of a project the following: unresolved conflicts in design, innadecuate communication between stakeholders, lack of defined scope, under-estimate discovery, client delays, negotiation dilemmas, engineering errors, violations of standards and regulations, deterioration of relations between participants, vague answers to critical questions, lack of financial support, among others. Nevertheless, these are trigger events but not crises, so further research with other methods, case studies and interviews, is necessary to fully answer

sub-question 1: *What are the most common creeping crises encountered by engineering firms, and what indicators or early warning systems are used to identify them?.*

Regarding the indicators or EWS that are used to identify creeping crises by engineering firms, Klepo and Radujkovic (2019) present a list of the most used EWS in project management, in which are included the S-curve (San Cristobal, 2017), the Earned Value Analysis (Zhan et al., 2015), and the Project Assessment methods by Williams (2012), however, there is still a knowledge gap as there is no evidence or information on how these tools can be used or adapted in the early stages of a project where engineering companies are involved.

Furthermore, the review has shed light on subquestion 3: *How can engineering firms integrate pre-crisis planning and early warning mechanisms to better anticipate and mitigate potential crises in construction projects? .* Mitroff et al. (1988) argue that "organizations often fail to detect weak signals because they do not have proper mechanisms in place" (p. 104), while Weick & Sutcliffe (2015) introduce High Reliability Organizations (HROs), which are studied for their ability to maintain operational activity in high-risk environments. The findings reveal that sensemaking and mindfulness help HROs to detect weak signals and to respond before a crisis escalates. By combining project management tools and techniques, sensemaking and mindfulness, and soft skills, it might be possible that companies better anticipate and mitigate potential crises; however, there is a need for a more holistic approach to integrating pre-crisis planning and early warning mechanisms in construction projects

3 EMPIRICAL STAGE

3.1 Introduction

To complement the findings obtained from section 2, the literature review stage, and to explore how creeping crises manifest in practice, this chapter presents the empirical phase of the research. The empirical investigation focuses on capturing insights from professionals in engineering consultancy firms, specifically, for this research, those collaborating at Witteveen+Bos. The objectives of this empirical phase are both to enrich the conceptual understanding of creeping crisis with real-world insights and recent experiences at Witteveen+Bos and to identify and assess the mechanisms already in use or required for early detection and response to creeping crises.

As explained in section 1, a qualitative approach was adopted, using semi-structured interviews as the main data collection method. This choice responds to the exploratory nature of the topic (Creswell and Poth, 2017), which is characterized by ambiguity and subjectivity, since creeping crises develop gradually, and it is difficult to handle them in a standardized way, due to their recognition often depending on individual perception and informal communication that may not be considered systematic.

This chapter is structured as follows: (1) the criteria behind the selection of the interviewees and (2) the design of the interview guide, questions, and steps to follow in order to get as much valuable data as possible. (3) The thematic findings are presented in order to find similarities and to structure the data obtained. (4) The results of this section, which includes a short reflection, highlight how the sub-questions were addressed through the findings.

3.2 Semi-structured Interviews

3.2.1 Goal and Selection Criteria

In this next stage, semi-structured interviews are conducted with professionals. The main goal of this phase is to partially address sub-questions 1, 2, and 3, which will be entirely addressed with the other methods included in this research, and to completely tackle sub-question 4, which, due to the nature of the sub-question and its focus on future scenarios, can only be tackled through the perspectives and forward-looking opinions of professionals. Additionally, the semi-structured interviews seek to validate or contrast findings from the literature review and gather insights that may inform the subsequent phases.

The selection of the professionals that will participate in interviews is made based on the following criteria: (1) Professionals that are directly involved in the early stages of a project, which include feasibility studies, concept design, tender documents, or the planning phase, also have familiarity with uncertainties and decision-making processes. (2) Those who have firsthand experience with project disruptions that escalated gradually or have knowledge in the fields of crisis management and/or risk management. (3)

That use tools or methods for monitoring and forecasting the project progress or the organization performance. Interviews are not limited to project managers; to ensure that this research adopts a holistic perspective, other key actors are also interviewed. The three professional roles and profiles included are: (1) Core project roles: Project Managers, Construction Managers, Contract Managers. (2) Risk & quality-focused roles: Risk Analysts, Risk Managers, Quality Assurance Managers. (3) Technical specialists: cost estimators, scheduling engineers, and designers.

All the interviews are conducted under the prior consent of the interviewee and in compliance with the TuDelft HREC procedures, in which an "informed consent" document is filled out in advance, making sure to give all the necessary information and the purpose of the research to the interviewees.

Position	*Years of Experience*	*Type of projects*
Project Manager	13+	Infrastructure
Tender Manager	5+	Bridge / tunnels
Contract Manager	17+	Flood risk prevention
Project Control	2+	Infrastructure
Project Control	5+	Infrastructure
Project Manager	15+	Urban development

Table 4 List of interviewees

3.2.2 Interview Design

The interviews are designed in a semi-structured way. These types of interviews do not necessarily follow a pre-set order in covering the topics, allow participants to develop their thoughts and ideas in depth (Karatsareas, 2022), and give room for follow-up questions, clarification, and the exploration of unexpected but relevant topics that may emerge during the conversation. Additionally, according to Karatsareas (2022), semi-structured interviews can also bring to light entirely new information to the established knowledge. This is particularly valuable at this stage of the research, as most of the questions are exploratory in nature and aim to uncover insights that may not yet be reflected in the literature.

The duration of each interview is 1 hour (60 minutes). They are carried out either in person or via Microsoft Teams; it depends on the availability and location of the interviewee. The interviews are recorded and transcribed. The interview transcripts are analyzed using thematic analysis, which is a method "for analyzing qualitative data that involves searching for recurring ideas" or patterns in a data set (Riger & Sigurvinsdottir, 2016). Figure 11 shows the interview design, in which the time and output of each phase of other interview are included.

For answering Subquestion 1 (What are the most common creeping crises encountered by engineering firms, and what indicators or early warning systems are used to identify them?):

- What are the most common creeping crises encountered in your projects?
- Can you share examples of creeping crises that escalated over time?
- What early signals were present in that case? Did you detect them? Did you ignore them? When was the tipping point?

For answering Subquestion 2 (What challenges do engineering firms face in detecting and responding to creeping crises during the early phase of construction projects?):

- What are the main challenges that Witteveen+Bos faces in detecting creeping crises?
- Are there any barriers (cultural, organizational, or technical) that prevent crisis detection?
- How does your department handle crisis signals?

For answering Subquestion 3 (How can engineering firms integrate pre-crisis planning and early warning mechanisms to better anticipate and mitigate potential crises in construction projects?):

- How do you think Witteveen+Bos can better integrate early warning mechanisms?
- Do you use specific tools/methods for crisis detection (e.g. project monitoring software, risk analysis)?
- What strategies could improve crisis preparedness in the early stage of a project?

For answering Subquestion 4 (How can engineering firms position themselves as trusted advisors by offering crisis management consultancy as an added value to theirclients?)

- Do you see demand for consultancy services focused on crisis prevention and management? This information would be valuable for further research; however, the topic would not be studied in depth.
- What capabilities or expertise do you think engineering firms would need to offer such services credibly and effectively?

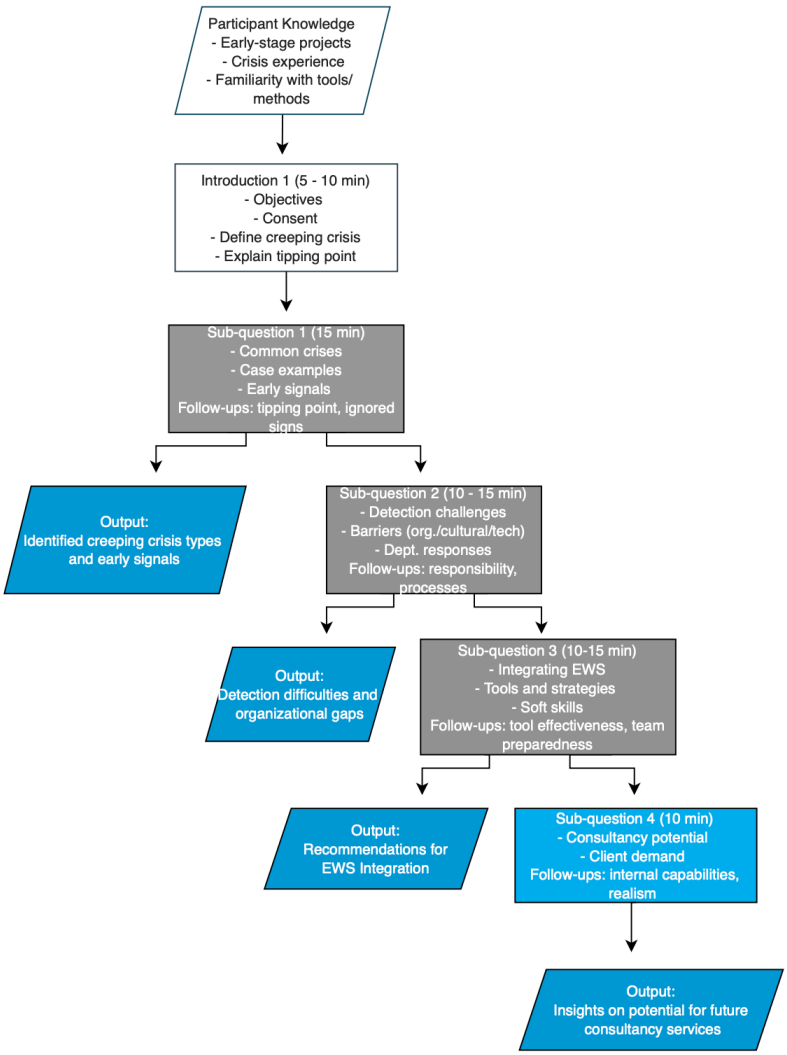


Figure 11 Interview design

3.2.3 Interview's Thematic Analysis

This chapter presents the findings from the eight semi-structured interviews conducted with professionals at Witteveen+Bos. As mentioned in section 1, the analysis follows Braun and Clarke's (2006) six-phase framework for thematic analysis, facilitated by the DelveTool software, which was useful for organizing and interpreting qualitative data in a structured manner. Figure 12 shows the six-phase framework followed fort he analysis.

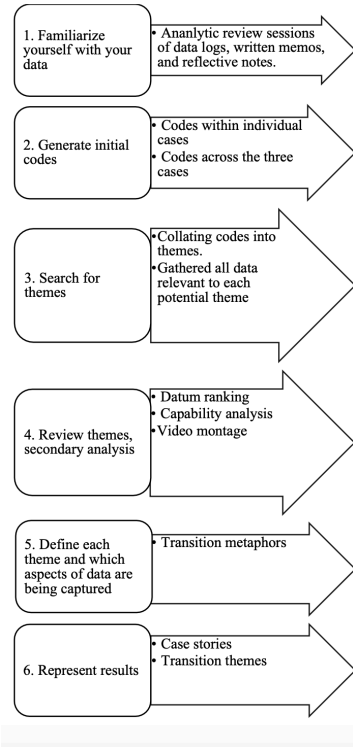


Figure 12 Thematic analysis model with stages (Braun and Clarke's, 2006)

Phase 1: Familiarize yourself with your data.

Firstly, the recordings of the eight interviews were transcribed with the Microsoft Teams tool and then fixed manually to maintain accuracy and avoid mistakes and typos. The transcripts were saved in .docx format and uploaded into DelveTool with both the corresponding interviewee's and company's anonymized names. A first reading was conducted without any coding, focusing on generating reflective memos and notes that capture initial impressions and help revisit the interview to recall the context and the important aspects of each one. Below are some examples:

"Mentions tension between collaboration and financial reality"
"Repeated reference to scope deviation"
"Legal feasibility issues ignored"

Phase 2: Generate Initial Codes

In phase 2, using DelveTool's code panel, codes were assigned line by line. A total of 39 initial codes were created. Each code was color-tagged, and each code reflects patterns on ideas, concerns, or behaviors by the interviewees.

According to Braun and Clarke (2006), the recommendation is to carry out the open coding phase at two levels. (1) The semantic coding that is explicit content, in the case of this research, is when the interviewee

responds literally to the question, giving insights that can directly be used as information. (2) Latent coding that is going deeper, trying to read between lines and look beyond the literal words.

The coding process was guided by the four subquestions and some of the crucial concepts found at the literature review stage. Some examples of the 39 codes include:

"Stakeholder pressure"
"Unclear scope boundaries"
"Legal feasibility misjudged"
"Overcommitment to client satisfaction"
"Internal silence culture"
"Fear of escalation"

Phase 3: Search for themes

At this phase, the transition from the initial analysis and coding is carried out. The analysis proceeded to a higher level, where the codes are merged into thematic categories. The thematic categories are done through a comparative method where the codes are combined depending on their similarities (Braun and Clarke, 2006).

For this phase 3, "it may be helpful to use visual representations to help you sort the different codes into themes" (p. 19), such as mind maps (Braun and Clarke, 2006). A full version of the mind map resulting from this analysis is included in appendix 2, which was used to cluster the codes and align them with the themes developed in DelveTool. Several illustrative coding paths are showed in table 5.

Theme:	**Grouped codes:**	**Key insights:**
Financial creep and stakeholder demands	"scope change", "stakeholder demands", "budget stretch", "fixed price conflict", "unbudgeted word" "just a small change"	These codes together highlight he issue of expanding project demands, usually by the client, without financial adjustment. This theme appeared in all the interviews.
Delayed recognition and crisis escalation	"ignored soft signal", "silence culture", "escalation hesitation", "no formal trigger", "too late to act"	Delay of raising concerns despite awarness of risks, often due to political or relational factors.
Fragmented communication and reporting culture	"lack of internal feedback, "client shielding", "info silos", "vertical disconnection"	Communication breakdowns within teams. Weak reporting lines amplify risk.
Technical-contractual missalagnment	"contract doesn't reflect technical reality", "design surprises", "legal deasibility misjudged"	Misalignment between contractual documents and technical realities discovered during project execution.

Lack of Early Warning Infrastructure	"No technica EWS", "reactive monitoring", "hours tracked post-deviation"	Absence of proactive tools for crisis detection, existing used reactively after problmes arise.
Organizational Overcommitment	"overdelivery", "internal enthusiasm", "hidden effort", "non-billiable time"	Teams voluntarily do more work than contracted, creating hidden labor crises.
Design Uncertainty and Technical Misalignment	"design surprises", "interdependent risks", "scope underesrimated"	Unexpected technical complexity emerges during design/execution, clashing with contract limits.
Stakeholder Misalignment	"conflict goals", "multiple authorities", changing priorities", "interference"	Different stakeholders such as municipalities, provinces, and interest gropus, pull the project in conflicting directions.

Table 5 First Themes List

Phase 4: Review themes, secondary analysis

In this phase, the initially identified themes were evaluated to look for coherency, distinctiveness, and empirical robustness. This assessment involved returning to the full set of transcripts, already charged in DelveTool, and the main objective is to identify "candidate themes that are not really themes", themes that might collapse into each other, separate themes that might form one, and other themes that might need to be broken down into separate themes" (Braun and Clarke, 2006, p. 20). This phase is an iterative process because themes were continuously modified and redefined. Table 6 shows the final theme list after the iterative technical review.

Theme:	**Grouped codes:**	**Key insights:**
Scope creep and stakeholder pressure	"scope change", "stakeholder demands", "budget stretch", "fixed price conflict", "unbudgeted word"	These codes together highlight he issue of expanding project demands, usually by the client, without financial adjustment. This theme appeared in all the interviews.
Delayed recognition and crisis escalation	"ignored soft signal", "silence culture", "escalation hesitation", "no formal trigger", "too late to act"	Delay of raising concerns despite awarness of risks, often due to political or relational factors
Fragmented communication and reporting culture.	"lack of internal feedback, "client shielding", "info silos", "vertical disconnection"	Communication breakdowns within teams. Weak reporting lines amplify risk.
Technical-contractual missalagnment	"contract doesn't reflect technical reality", "design surprises", "legal deasibility misjudged"	Misalignment between contractual documents and technical realities discovered during project execution.
Lack of Early Warning Infrastructure	"No 47echnica EWS", "reactive monitoring", "hours tracked post-deviation"	Absence of proactive tools for crisis detection, existing used reactively after problmes arise

Table 6 Final Themes List

Phase 5: Define each theme and which aspects of data are being captured.

In the fifth phase proposed by Braun and Clarke (2006), the final themes are clearly defined and conceptually anchored to both the empirical data and the research sub-question of the thesis.

Financial Creep due to Stakeholder Demands

This theme refers to and encapsulates how incremental client demands, usually outside the original contract, increase the project's scope and generate an issue in which the effort put into the project is not aligned neither with the contract budget nor the bills sent to the client. Notably, these pressures and requests often arise from a mix of stakeholder demands, primarily the client, but not exclusively, and an internal overcommitment by teams seeking to avoid arguments and maintain strong client relationships.

This is the most consistently cited situation across the interviews. Participants identified these situations as common both within the organization and in projects. Below are some examples where financial creep emerged due to stakeholder demands and Witteveen+Bos overcommitment:

— Interviewee 1
"You write a tender and try to think of everything, but during the process, a lot of things change. For example, a stakeholder suddenly wants something extra. We tend to say yes… and in the end, the hours go up, but it's not always paid.
— Interviewee 2
"We have forms to track scope changes, but people forget to use them or think 'this is too small'. But those small things add up."
— Interviewee 3
"You just keep going. We often do way more than what's in the contract because it feels like the right thing to do. But at the end, the project is in the red."
— Interviewee 4
"Sometimes you only notice later that your team has spent 20 extra hours that weren't in the plan. But by then, it's already too late to claim them."
"For example, a stakeholder suddenly wants something extra. We tend to say yes… and in the end, the hours go up, but it's not always paid"

Delayed Recognition and Crisis Escalation

In this theme is reflected how some early warning signals of legal, technical, or strategic infeasibility are often identified but not escalated. Some reasons for this are interpersonal caution, internal power dynamics, or reluctance to challenge clients. Similar to theme one, to maintain a good relationship with stakeholders, Witteveen+Bos tries to accommodate evolving demands even when the possibility of continuing with that specific proposal is really low, working on solutions that most likely will have a big change.

With this theme, it is possible to analyze how creeping crises develop during the prodomal phase (Flink, 1986), when it's possible to recognize signals but are dismissed. Also, it represents some barriers to raising red flags. Below are some quotes from the interview where this theme was identified:

— *Interviewee 1*
"We already knew it wasn't legally feasible. But we tried to find alternatives anyway. We should have hit the brakes earlier, but we didn't… We stayed in this 'collaboration mode' for too long, and it ended up costing us a lot."
— *Interviewee 2*
"You know early on that the legal framework is fragile. But you don't want to be the one that says 'stop.' You just keep going, hoping it will fix itself with new insights or stakeholder changes."
— *Interviewee 3*
*"*Sometimes we continue working on solutions even when we know the original idea isn't realistic. It's politically possible."
— *Interviewee 4*
"It's hard to challenge a client when they're emotionally attached to a concept. Even if you see trouble ahead, you try to make it work. The problem is we only escalate once it's too late."

Fragmented Communication and Reporting Culture

This theme captures both internal and external communication breakdowns that prevent timely escalation of risks. It highlights disconnections between hierarchical and vertical layers within the organization and the lack of standard and shared reporting mechanisms. Early signals may be identified by members of the teams but remain localized due to unclear procedures and standard project documentation to follow up on issues. This fragmentation is amplified in projects in which several stakeholders are involved.

In opinion to the interviewees, there is a communication gap, sometimes because of the suppression of early warning signals in favor of client or coworker relations, and sometimes because there is not a clear and standard procedure for reporting early warning signals; every manager has their own way based on their experience. Some quotes that illustrate this theme are:

— *Interviewee 1*
"We were trying to keep the client happy, to maintain good collaboration… But deep down, we already knew it wasn't going to work."
— *Interviewee 2*
"There's no structured way to recognize early warning signs… It's based on experience, not protocol."
— *Interviewee 3*
"We, as project management advisors, each use different tools and methods. Everyone has their own Power BI dashboard or Excel sheet to monitor finance and planning."
— *Interviewee 3*

"We lack unambiguous project management tools. Everyone does it their own way. That makes early detection inconsistent."

Technical Contractual Misalignment

This theme describes how initial project assumptions often clash with contractual constraints. According to the interviewees, contracts are often signed before having the full information of the project; therefore, new information emerges, such as unforeseen site conditions, stakeholder demands, regulatory changes, etc. The result is a latent tension that gradually escalates and generates issues that can turn into a creeping crisis.

Several participants noted that once these new realities arise, it is difficult to manage them because of the commitment with the stakeholders and the resource limitations. An example of the quotes where this theme is identified are:

— *Interviewee 1*
"At the start, we try to accommodate them, saying, 'Yeah, we can still do this, we can still add that.' But eventually, it becomes unmanageable and financially unviable for us."
— *Interviewee 1*
"Initially, we identified two critical structures… but after analyzing the area further, we discovered it wasn't two, but four… That added a whole layer of complexity and became a major issue."
— *Interviewee 1*
"According to the contract, we were only responsible of two items, right? But then there's also this general clause that says something like, 'You have to do everything necessary to complete the assignment.'"
— *Interviewee 3*
"The planning is very strict. So they begin execution before the validated final design is ready. That's the root of the crisis here."

Lack of Early Warning Infrastructure

This theme refers to the lack of standardized procedures within the organization for early warning systems. While there is a consistency in the use of monitoring tools across the organization to detect deviations, such as s-curves, dashboards, and early value analysus (EVA), every manager, based on their experience and intuition, chooses which tool or technique to use and how to interpret signals.

This autonomy allows for flexibility, but it also leads to inconsistencies. Some managers rely on the financial aspect while others prioritize planning deviations or qualitative indicators, such as client behavior, stakeholders attitude, or team morale. Although many projects include both quantitative and qualitative monitoring elements, there is not a standardized approach, and the crisis management and EWS frameworks must be more developed within the organization. Some quotes that illustrate this theme are:

— Interviewee 1

"By the time we know something is wrong, we've already lost money."

— Interviewee 5

"There is no formal strategy for identifying early warning signals. It's more implicit than explicit. Sure, we have tools like risk registers and financial dashboards. But there's no proven strategy—no structured approach—for recognizing when a crisis is emerging."

— Interviewee 4

"We, as project management advisors, each use different tools and methods. Everyone has their own Power BI dashboard or Excel sheet to monitor finance and planning. Project managers often say, "My project is unique, so I'll do it my own way'."

— Interviewee 1

"What I'm doing now is very much based on heart. I look at burn rate and earned value to see if we're on track. But sometimes the most serious issues aren't financial. If collaboration with the client isn't going well, that doesn't show up on a dashboard."

Thematic Linkage to Subquestions

Theme	*Sub-question(s) Addressed*
Scope Creep and Stakeholder Pressure	SQ1
Delayes Recognition and Crisis Escalation	SQ2
Fragmented Communication and Reporting Culture	SQ2 and SQ3
Technical Contractual misalignment	SQ1 and SQ2
Lack of Early Warning Infrastructure	SQ2, SQ3 and SQ4

Table 7 Final Themes Linked to Sub-Questions

3.2.4 Findings

Phase 6: Represent Results

Following the analysis of the transcripts, in phase 6 the results are presented to respond partially to the 4 sub-questions of this research. Each sub-section presented below addresses one of the sub-questions , drawing on thematic codes, recurring patterns, and direct quotations and insights from the interviewees.

A key initial finding was that the concept of "creeping crisis" remains ambiguous among professionals, since there is a general hesitation as to when to call a situation a crisis, when to call it an issue, and when to call it a normal challenge that arises in the industry. Several interviewees showed unsureness in labeling specific events as crises, often using phrases like"*"I don't know if this would count as a crisis," "maybe I'd*

call this a mini-crisis," or *"this is more of an issue than a real crisis."* This indicates a general discrepancy in how project risks and escalation moments are conceptualized across the organization.

Common crises encountered by engineering firms.

A list of over 20 common creeping crises was the outcome after the analysis of SQ1; however, to narrow down the list and focus on the most relevant ones, a filtering process was carried out based on the frequency that each creeping crisis was mentioned in the interviews. Figure 13 shows the 6 most common crises encountered.

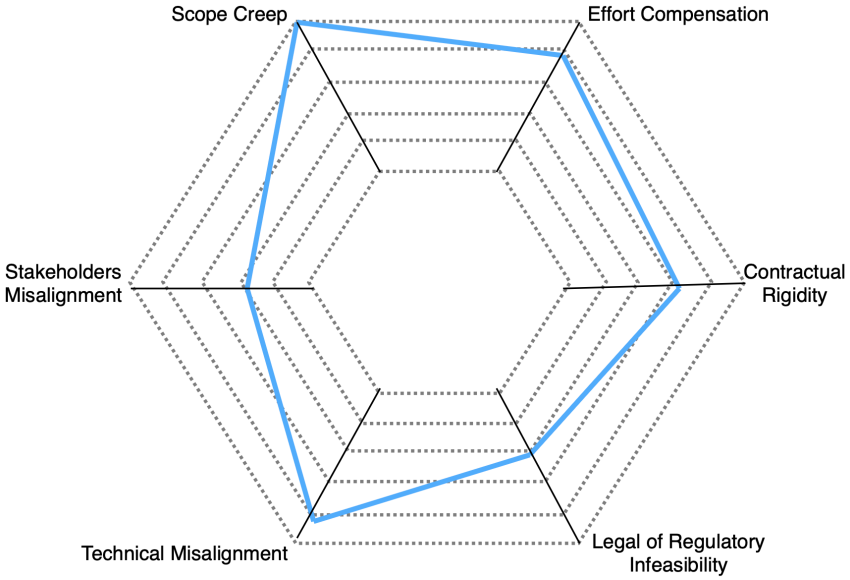


Figure 13 Most common creeping crises encounterd in Witteveen+Bos

1) Scope Creep: Gradual, often informal expansion of project scope due to client requests, without formal contract updates or change orders presented. This creeping crisis can generate financial stress and conflicts with the client (full-blown crisis).

Indicators and EWS to identify them:

(1) Effort and planning Tracking Tools: Dashboards (Power BI), reports, and schedules that show resources spent over planning.

(2) Observation (soft signals): The client repeatedly asking for "small extras" and showing signs of misunderstanding of what is and is not included within the scope. Additionally, the procrastination of the client to revise the financial request is a clear sign that later on a financial crisis may surge.

2) **Effort Compensation:** Teams invest more effort than budgeted or billed. This can be the result of organizational overcommitment or low performance and can generate financial stress and conflicts within the organization.

Indicators and EWS to identify them:

(1) Effort and planning Tracking Tools: Dashboards (Power BI), reports, and schedules that show resources spent over planning. Additionally, monitoring project management tools are used, such as S-curve and EVA.

(2) End-of-Phase Evaluations: Deviations are identified during formal evaluation moments, usually at follow-up meetings and after the completion of project phases.

3) **Contractual Rigidity:** This creeping crisis refers to a situation in which a project contract is too inflexible to adapt to changes, while the project itself is constantly evolving and still surrounded by many uncertainties. This mismatch puts Witteveen+Bos at a disadvantage, potentially causing financial stress, conflicts with the client, uncompensated scope extensions, and a noticeable decline in team morale.

Indicators and EWS to identify them:

(1) Detailed Revision of Contract : Ambiguous vocabulary such as “do everything necessary to complete the assignment” is a red light and puts Witteveen+Bos at a big disadvantage. Additionally, the lack of a change mechanism becomes particularly risky and lets it be known that there is no room to present any change.

4) **Legal or Regulatory Infeasibility:** This creeping crisis occurs when a project design or proposal does not completely meet required standards to get the construction permits, or worse, it is late found to be incompatible with legal frameworks.

Rather than addressing these signals proactively, professionals stay in a collaborative mode, continuing working to maintain a good relationship with the client and hoping for regulatory adjustments, however, this creeping crisis can generate major project delay (that sometimes can be attributed to Witteveen+Bos), legal conflict and rework

Indicators and EWS to identify them:

(1) Stakeholder Feedback Loop: Misalignment with legal frameworks is revealed through stakeholder feedback, in which regular sessions are organized mainly with authorities to check and follow up on feasibilities. Feedback is received, usually informally.

(2) Internal Doubts (soft signals): Signals are verbalized and discussed in follow-up meetings.

5) **Technical Missalignment:** Actual technical conditions, such as soil conditions, and environmental factors, differ from early assumptions; therefore, technical complexities are multiplied, and interdependencies increase. If this type of creeping crisis is unaddressed and escalates, it can generate financial issues and a major design problem, which most of the time is absorbed and must be fixed by Witteveen+Bos.

Indicators and EWS to identify them:

(1) Design Reviews / Site Data: New findings during design development.

(2) No Preemptive Buffer or Scope Margin: Crisis builds from a rigid budget where there is no room for technical surprises.

(3) Vague or Contradictory Tender Documents: The documents provided for the tender show uncertainties and are open to interpretation.

6) **Stakeholder Misalignment:** The creeping crisis emerges when multiple stakeholders, such as provinces, municipalities, clients, and interest groups, are involved in a project and have diverging priorities, responsibilities, or expectations that are not clearly aligned at project initiation. Over time, these misalignments tend to gradually escalate, resulting in repeated design changes and political tension that can delay the project and disrupt the original planning.

Indicators and EWS to identify them:

(1) Political Pressure (soft signal): Politically driven stakeholder demands, such as deadlines for public events, often lack justification and are a clear signal that “Everyone has their own opinion, their own area of responsibility…”

(2) Stakeholder mapping tools: The stakeholder map analyzed at the beginning of the project helps to identify possible stakeholder deviation by identifying if their power and interest remain consistent.

Challenges encountered to detect and response to creeping crisis.

Interviews uncovered a series of organizational challenges that make difficult the early detection and escalation on time of creeping crises.

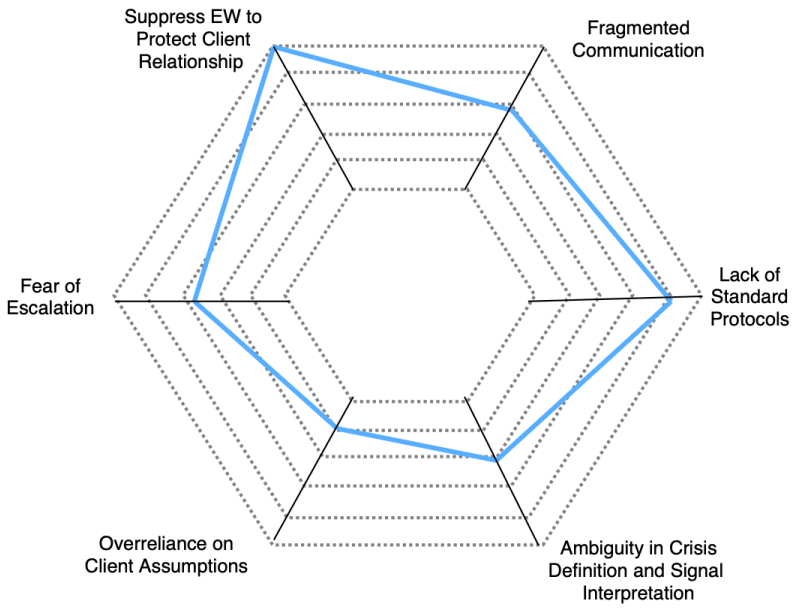


Figure 14 Challenges encounterd in Witteveen+Bos for crisis detection

1) **Suppress EW to Protect Client Relationship:** This was the most universally cited challenge. Professionals find it difficult, or sometimes prefer not to escalate EWS to avoid damaging the relationship with the client. The result is that creeping crises are not addressed in a "collaborative manner" until formal intervention becomes unavoidable.

2) **Fragmented Communication:** Some professionals pointed out communication breakdowns and a lack of a clear "shared reporting line" both with the client and vertically in the organization.

3) **Lack of Standard Protocols:** No shared method exists in the organization for detecting, documenting, and managing EWS. Some interviewees pointed it out as an advantage because "everyone does it their own way" and depends on the experience, while others recognized it as a barrier.

4) **Ambiguity in Crisis Definition and Signal Interpretation:** There is not a shared understanding about what constitutes a crisis and how to recognize it. Teams find it challenging to distinguish between issues that require escalation and those that are routine tasks for engineers.

5) **Overreliance on Client Assumptions:** Refers to a situation in which project teams move forward based on informal expectations expressed by the client; professionals trust that the client will resolve the issues later at that time, especially regarding budget approvals.

6) **Fear of Escalation:** This challenge reflects an internalized hesitation to be perceived as negative or alarmist. Apart from that, in smaller numbers, some professionals are hesitant to escalate issues with their superiors to prevent their work from not being beingseen as incompetent.

Proposed early warning mechanisms to improve signal detection and response.

In direct response to the crises identified and challenges, interviewees shared practical ideas and proposals to improve the recognition, anticipation, and mitigation of potential creeping crises. Some proposed tools mentioned are already in use, such as the monitoring dashboards and the traditional project management tools like S-curve and EVA; nevertheless, interviewees see the opportunity to further develop these tools and standardize their use across all the teams. On the other hand, several additional suggestions were made that can contribute to a more proactive crisis management approach. Table 8 presents the results with the proposed tools and techniques.

Implementation Strategy	Status	Inteview's Insights
Monitoring Tools	Existing (improvement)	Weekly hours tracking, EVA, S-curve, and burn rate; but limited to review metrics. Need enhacement to standardize and to include soft indicators.
Lessons Learned Sessions	Existing (improvement)	"We do it, but not structurally". Need 56echnica document EW and reflect on what worked/failed. Also do not wait until the end of the project (project gates)
Knowledge Sharing Sessions	Existing (improvement)	"Spread knowledge and experiences"; "not structurally done across projects". There's a need for more organized, frequent cross-project learning.
Reverse Mentoring	Proposal	Learning should focus on "cultural and personal experience" not rigid checklists.Younger or less senior employees share knowledge with more experienced colleagues.
Soft Signal Registration Tools	Proposal	No system for flagging non-financial issues eary (e.g. tensions, client dissatisfaction)."Would be valuable to monitor soft indicators"
Structured Stakeholder Monitoring	Partially Existing	Stakeholders analysis occurs at the beginning and monitoring occurs informally. Issues like shifting demands, political motivation, and hidden expectations are detected too late.
Culture of Psychological Safety	Partially Existing	"Don't be afraid to start difficult conversations"; "No-blame, no-shame culture" is desired but not consistently.
Strenghtening Soft Skills Capabalities	Partially Existing	Soft skills like communication, emphaty, leadership, and priority alignment were mentioned repeatedly as essential but improvement is necessary.

Table 8 Porposed improvements to tools and techniques)

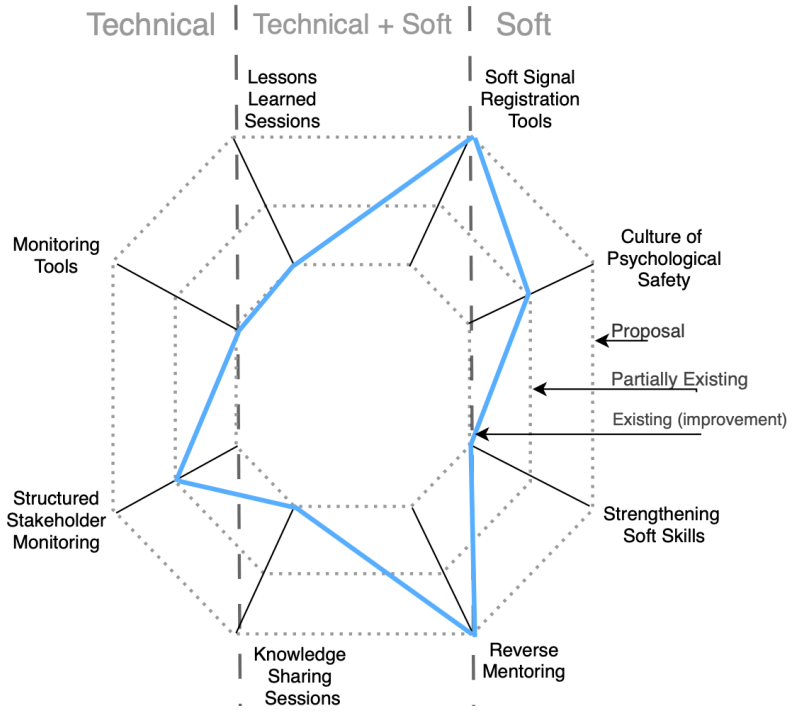


Figure 15 Tools and Techniques identified

According to technica implementation maturity (new proposal, partially existing, and existing-improvement) and strategic nature (technical, technical + soft, and soft), the eight suggested or current implementation techniques for implementing the EWS approach are illustrated in figure 15. Notably, the professionals are soft-skill oriented. The eight interviewees mentioned soft skills as the foundation for detecting and managing EWS, proposing practices like psychological safety, where the trust and confidence are present to raise concerns before their escalation, and reverse monitoring that empowers junior employees to freely share knowledge and observations with senior managers in order to create a feedback loop and promote continuous learning across different hierarchical levels .

Likewise, as shown in figure 15, some technical implementations are proposed, or professionals believe their improvement or further development may directly improve EWS detection and response. For instance, monitoring tools such as S-curve, EVA, or PPC are already in use; however, interviewees highlight the necessity of standardization.

To address this gap, several professionals suggested combining the 57echnica land current-use monitoring tools with qualitative input, such as soft-signal observations or deviation in stakeholder engagement, to create hybrid tools in which quantitative and qualitative data and hard and soft skills are integrated into a more holistic early warning system.

Professionals' perception of crisis management within Witteveen+Bos

Interviewees consider that Witteveen+Bos already possesses strong foundations in crisis management and early warning recognition. When asked to have professionals score Witteveen+Bos performance in crisis management, all eight interviewees gave positive ratings, resulting in an average score of 7.5 (see figure 16), which reflects a generally positive perception of Witteveen+Bos' capabilities and current performance.

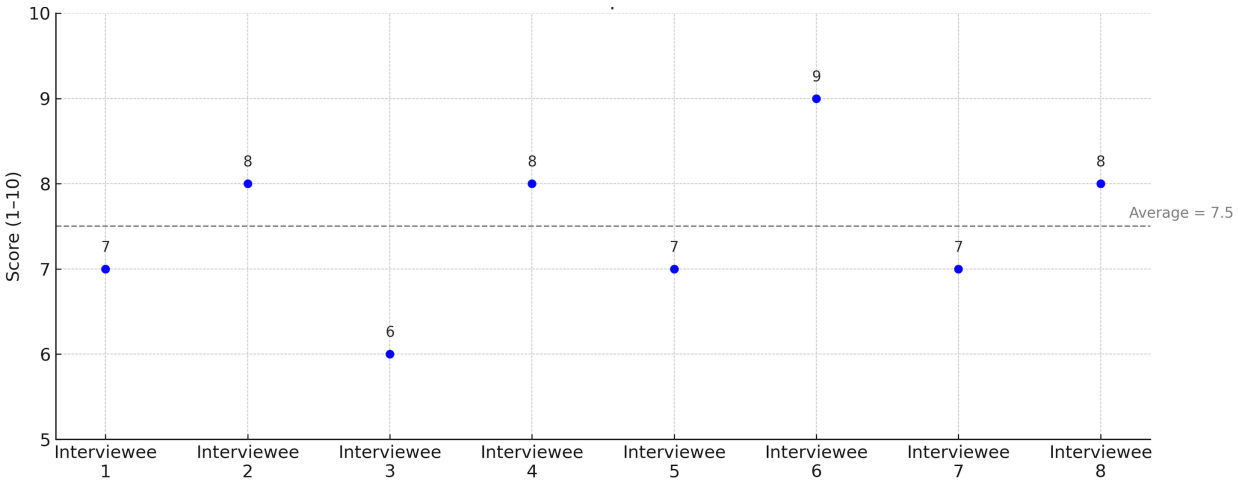


Figure 16 Witteveen+Bos Crisis management scoring

Seeing crisis management consultancy services as an opportunity

However, every interviewee agreed that before offering crisis management consultancy to external parties, Witteveen+Bos must first strengthen its internal structure and crisis management processes. 5 out of 8 professionals do not see it as necessary for Witteveen+Bos to formalize crisis consultancy as an additional service to offer as an added value, since it is something Witteveen+Bos should always do but internally. On the other hand, 3 out of 8 professionals see external consultancy as an opportunity; however, they consider it necessary to first improve internal processes. In this view, external consultancy is a possibility and also a natural evolution of internal excellence. Figure 17 shows the proposed roadmap for launching external consultancy, outlining a three-stage maturity path.

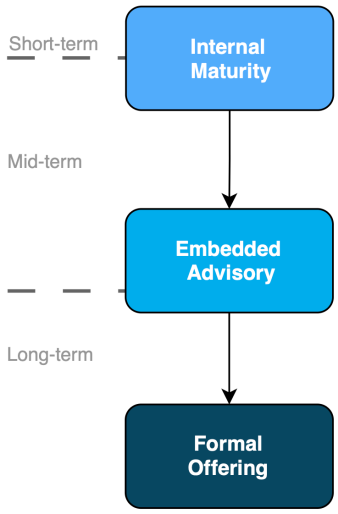


Figure 17 Proposed roadmap for launching external consultancy

Internal Maturity: This is achieved by following the implementation and improvement of strategies proposed in SQ2, such as soft signal registration tools and the improvements of monitoring tools. These implementations are considered short- to medium-term actions.

Embedded Advisory: This is achieved by applying its internal EWS within existing client projects and sharing systems and knowledge with stakeholders. In this mid- to large-term phase, the collaboration by both parties, Witteveen+Bos and its clients, is essential.

Formal Offering: This phase involves structuring and marketing Witteveen+Bos' crisis anticipation expertise as a dedicated consultancy service. This is achieved in the long term after the internal maturity and embedded advisory because such services can only be credible once internal practices are robust and proven.

3.3 Conclusion

The thematic analysis carried out, following the six-phase framework proposed by Braun and Clarke (2006), in the eight semi-structured interviews provided an in-depth understanding of current Witteveen+Bos insights and standing regarding EWS and the opportunity for improvement for enhancing resilience within the company.

Key findings demonstrate that there is general hesitation as to when to call a situation a crisis, and although the concept of creeping crisis was broadly understood, several professionals showed unsureness in labeling events.

The four sub-questions were addressed and partially responded. Participants identified different creeping crises, such as scope creep, legal infeasibility, and stakeholder misalignment—each often triggered by a

mix of internal overcommitments and evolving client demands. Challenges to detecting early warning signals include fear of escalation, fragmented communication, and the absence of standard or formalized early warning tools and techniques. To address these, professionals proposed improvements to existing monitoring systems and the addition of tools that are mostly oriented towards soft skills. Finally, while Witteveen+Bos is seen as having a strong foundation in crisis management, interviewees agreed that formalizing external consultancy services could be a possibility, but just after strengthening internal systems and proving their effectiveness.

MSc Thesis - Construction Management and Engineering
2023-2025

4 ANALYSIS & RESULTS

4.1 Introduction

In this chapter an analysis is carried out in order to present how creeping crises can be better detected, interpreted, and managed at the early stages of a project through the implementation of EWS. For this analysis, the input of the previous phases, literature review findings, and empirical findings from semi-structured interviews are the main source of data.

Literature Review Findings: The information around crisis management, creeping crises, EWS, HRO principles and implementations, mindfulness, sensemaking, and soft skills.

Empirical Findings from Semi-structured Interviews: Insights and results from the thematic analysis of the eight semi-structured interviews with professionals of Witteveen+Bos.

The goal of this analysis is to translate theoretical concepts into actionable tools and behavior that may be applicable within the engineering context. This ensures that the EWS framework, the output of this research, does not remain abstract by proposing practical feasibility.

The analysis is structured in four main parts:

Section	Focus
4.2 Understanding and classifying creeping crises in engineering projects	Defines what constitutes a creeping crisis, based on literature and interviews. Identify the most common types of creeping crises in Witteveen+Bos, along with the soft signals associated with each.
4.3 Translating high reliability principles, mindfulness, and sensemaking in engineering context.	Analyse how HRO principles and implementations, sensemaking, and mindfulness can be adapted into the engineering context, focusing on early crisis detection.
4.4 Mapping creeping crises types to EWS functions and implementing mechanisms	Connect the identified creeping crises to specific EWS stages. Show which tools and techniques (mechanisms) support each stage, along with the main actors for each stage.
4.5 Overcoming barriers for effective EWS implementation	Links the identified barriers to the proposed tools and techniques and show how these mechanisms may help to mitigate the barriers that obsruct early crisis detection and management.

Table 9 Four stages of the analysis

4.2 Understanding and Classifying Creeping Crises in Engineering Projects

The first step for this holistic analysis is to define what a creeping crisis is. As mentioned in section XXX, it was observed at the interviews that professionals found the concept of creeping crisis ambiguous, since there was a general hesitation as to when to call a situation a crisis.

The following section analyzes the definitions obtained through the literature review and interviews and creates a definition that will be consistently applied during the validation and case studies phase.

In traditional crisis literature, a crisis is characterized as disruptive, time-sensitive, high-impact, high-priority, and unexpected (Loosemore, 2000; Ducheck, 2020; Hallgren and Wilson, 2007). The definitions included in section XXX reflect characteristics such as urgency, threat, and deviation from routine problem-solving capacity. These characteristics were present in the interviews as well: “We had to stop the entire process and redesign under pressure… that was definitely a crisis moment.” “When the project was blocked for legal reasons, that was the tipping point—it has to be solved immediately, or we would lose months.”

Regarding creeping crises, the main characteristics are developing over time, a series of mutually reinforced events, turning into a full-blown crisis, being unrecognized, and being gradual (Boin et al., 2020-2021; Kovacs, 2013). Interviewees described and mentioned similar patterns. “I am not sure I would call it a crisis; it just kept getting more complex.” “It was not a single event … more like a slow pressure building up.” “It was a crisis, but we did not treat it like one until it was too late.”

Proposed definition:

Crisis: A crisis in engineering projects is a high-impact disruption that can deviate from the core objectives of a project and requires urgent and non-routine effort and attention from the project team under conditions of uncertainty, stress, and pressure.

In simpler terms, or how it is explained to people interested in this research, it is when an event jeopardizes the outcome of the project, and overcoming it requires significant attention from the project manager and key members of the project team, interrupting the normal flow and activities of the project. There is no looking ahead; instead, teams must only act as troubleshooters.

Creeping crisis: A creeping crisis in engineering projects is a gradually developing condition that emerges from low-visibility interconnected events that initially appear manageable or insignificant, but as time goes by, they turn into a full-blown crisis.

In ther words, it is a problem that grows in the background and is often unnoticed, unmanaged, or normalized until it is too big to ignore, and at that point it turns into a crisis and disrupts the initial plans.

Figure 18 summarizes the progression from routine issue to creeping crisis and full blow crisis, as supported by literature (Fink, 1986; Boin et al., 2020) and inteview findings.

Figure 18 Progression from routine issue to creeping crisis and full blow

Most Common Creeping Crisis Types Identified:

From the synthesis of the data obtained through the literature and the thematic analysis of the interviews, six core types of creeping crisis have been identified as most relevant within Witteveen+Bos.

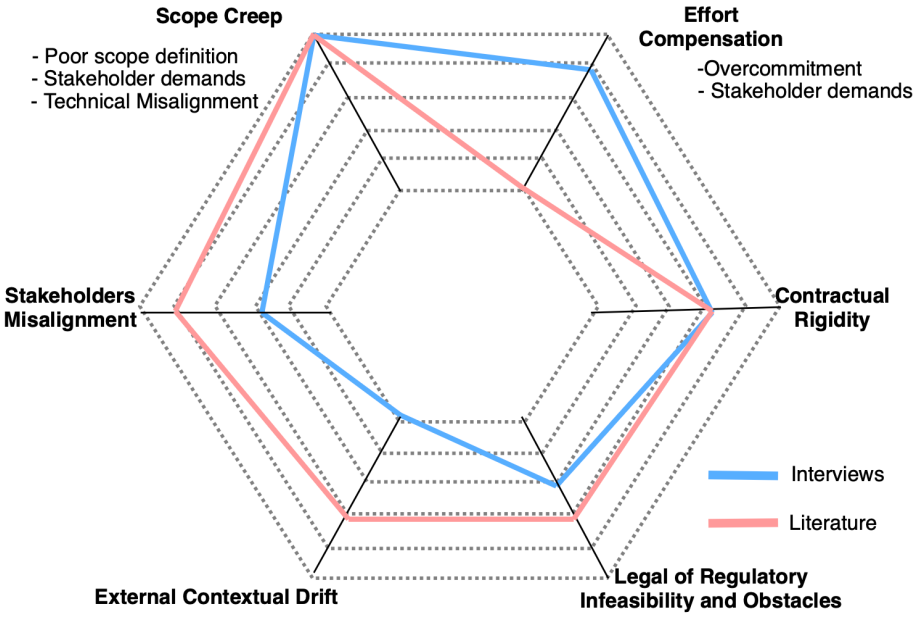


Figure 19 Most common types of creeping crises identified

Figure 19 presents these creeping crisis types, highlighting their perception and relevance according to both the literature review and the results of the thematic analysis of the interviews. This comparative analysis ensures that the analyzed crises are relevant and have a presence in both academic research and professional experiences. The six identified creeping crisis types are :

Scope Creep: Mostly driven by poor scope definition and stakeholder demands. It is characterized by silent or informal expansion of project scope without a formal procedure to update the contract price. This is the most recurring creeping crisis mentioned both by professionals and in the literature.

Effort Compensation: Usually produced by the project team's overcommitment. Project teams invest more effort than budgeted and billed. This is because teams may feel pressure to maintain client satisfaction or just because of personal commitment. This crisis was highly mentioned in the interviews, but it is not included in the literature.

Contractual Rigidity: This crisis involves situations in which contracts are inflexible and put engineering firms in an unfavorable position. This type of crisis was mentioned by several professionals, and it is included in the existing literature.

Legal or Regulatory Infeasibility and Obstacles: Due to the nature of the work performed by engineering firms, this is a recurrent crisis in which the planned project faces barriers due to legal constraints, regulatory requirements, or permitting procedures that were not recognized earlier. This creeping crisis is mostly recognized in the literature; however, four interviewed professionals recognized it as a crisis as well.

External Contextual Drift: Captures the influence of external factors and environmental changes, such as political decisions, regulatory amendments, or economic instability. This crisis type was predominantly identified in the literature review, in which several authors recognize external factors as the most threatening ones.

Stakeholder Misalignment: The creeping crisis emerges when multiple stakeholders, such as provinces, municipalities, clients, and interest groups, are involved in a project and have diverging priorities, responsibilities, or expectations that are not clearly aligned at project initiation. This crisis was mostly identified in the literature; nevertheless, it was mentioned by three professionals during the interviews.

Soft Signals by Creeping Crisis Type

From the synthesis of the data obtained through the literature and the thematic analysis of the interviews, soft signals are identified for each of the six most common types of creeping crises in engineering firms explained in section XXX. The following tables present the soft signals for each creeping crisis.

Creeping Crisis Type	Soft Signal	Source(s)
Scope Creep	V*ague or frequently changing client requirement*	Literature, Interviews
	"Just a small change" attitude becomes frequent	Literature, Interviews
	Design freeze is constantly postponed	Interviews
	Project team unsure about final scope	Literature
	Project manager avoiding scope diffusion fue to fear of future changes	Lterature

Effort Compensation	No discussions around re-scoping even when everyone is overloaded	Literature, Interviews
	Repeated phrases like “we will fix it later” or “just deliver something for now”	Literature, Interviews
	Team members working extra hours	Interviews
	Monitoring tools show deviation, but team claims “it is under control”	Interviews
	Visible signs of fatigue or burnout	Literature
Contractual Rigidity	Repeated references to the contract to avoid resolving issues informally	Literature, Interviews
	Decision-making slows because every action requires	Literature, Interviews
	Contract language is ambiguous, giving room to reinterpretations	Literature
Legal or Regulatory Infeasibility and Obstacles	Silence or avoidance in meetings when legal implications are raised	Literature, Interviews
	Permits “expected soon” but timeline keeps sliding	Interviews
	Overconfidence in permit acquisition despite unclear regulatory context	Interviews
	Overreliance on client assumptions	Literature
External Contextual Drift	“We will deal with the municipañity later” attitude	Interviews
	Regional elections approaching	Literature
	Market volatily in key materials	Literature
	Cultural differences in international projects are unacknowledged	Literature
Stakeholder Misalignment	Parallel converstions without centralized updates	Interviews
	Key stakeholders absent from critical meetings	Literature
	High turnover rate of stakeholders, lack of stability	Literature
	Same things come up again and again in meetings	Literature
	Blaming during review or coordination sessions	Literature

Table 10 Soft signals by creeping crisis type

4.3 Translating High Reliability Principles, Mindfulness, and Sensemaking in Engineering Context.

High Reliability Organizations (HROs) cultivate what Weick and Sutcliffe (2015) describe as a state of collective mindfulness, where all team members are aware and scanning for signs of failures, small deviations, and uncertainties from their normal operational environment. While HRO principles originate from organizations that operate in high-risk environments, such as nuclear power and aviation (Veazie et al., 2019) (Sutcliffe, 2011), their 5 principles, explained in section 2.4, can be adapted in the context of construction and engineering.

An analysis is carried out to assess how HRO principles can be operationalized in the context of engineering and consultancy organizations like Witteveen+Bos, with a specific focus on the three principles that are directly related to the detection and recognition of creeping crises that can also support the development of an EWS.

These are (1) preoccupation with failure—constant vigilance toward small, weak signals of possible small errors that might indicate a possible future problem (2) Reluctance to simplify interpretations—actively resisting the urge to reduce complex situations into oversimplified explanations, encouraging multiple viewpoints to create a complete picture of the situation. (3) Sensitivity to operations—maintaining real-time awareness of the current conditions of a system (Weick and Sutcliffe 2015). Table 10.

Complementing these three HRO principles, this analysis also incorporates the five common HRO implementation strategies proposed by Veazie et al. (2019): leadership commitment, safety culture, learning and training, implementing interventions, and data systems. Table 11 shows the adaptation of the aforementioned implementation strategies within the engineering and consultancy context.

While mindfulness and sensemaking originate as conceptual approaches from high-reliability studies and are essential in the HRO frameworks and principles (Weick & Sutcliffe, 2015; Weick, 1993; Kleint et al., 2006), this research proposes an engineering-adapted operationalization. Instead of treating these concepts as abstract cultural goals, they are translated into specific project management behavior, processes, tools, techniques, and communication structures. Therefore, proposed definitions in the context of engineering and consultancy are

Proposed definitions (engineering context):

Mindfulness refers to a structured set of project management behaviors and team practices in which attention to small deviations, the monitoring of risks, and the encouragement of early tension recognition are promoted within the organization, maintaining a shared awareness.

Sensemaking: It is a collective process in which project teams interpret ambiguous or incomplete information, align different technical and stakeholder perspectives, and document the rationale behind the decisions taken for learning, especially under situations of uncertainty.

HRO Principles	*Engineering-Focused EWS adaptation*	*Observed Gaps / Improvement Needs*
Preoccupation with Failure	Systematic reporting and review of near misses and eary deviations. Technial + soft signals	No formal mechanism to record soft signals. Risk perception depends on experience.
Reluctance to Simplify	Structured stakeholder analysis and recognition of complex socio-technical interdependencies.	Lack of structured reflection moments; critical review of assumptions is ad hoc.
Sensitivity to Operations	Real-time project monitoring and deviation across all levels (frontline to leadership)	Missing shared operational overview, front-line awarness is not always escalated.

Table 11 HROs principles related and adapted to construction and engineering firms

Common HROs Implementation Strategies	*Engineering-Focused EWS adaptation*	*Observed Gaps / Improvement Needs*
Developing Leadership	Empower leadership to look for an environment where early warnings can be voiced by all team levels.	No structured process exists for jr to sr feedback; knowledge sharing is mostly informal.
Culture of Safety	Promote psychological safety, normalize and enhance discussions about risks and tensions.	Fear of escalation, especially toward clients or higher management (to avoid arguments).
Training and Learning	Conduct EWS training, standardize lessons learned and enhance knowledge sharing.	Lessons learned are conducted sporadically, crisis training is not standardized.
Implementing interventions	Focused respond ptotocols for weak signals.	No clear escalation protocol for early signals; responses are reactive rather than proactive.
Data Systems	Integrate EWS into digital project control tools, both technical and soft-signal tracking.	Existing dashboard focus on finances and progress, soft signals and qualitative deviations are not integrated or tracked.

Table 12 Five common HROs implementations adapted to engineering firms

Mindfulness Mechanism	*Engineering-Focused EWS adaptation*	*Observed Gaps / Improvement Needs*
Awarness Allocation	Distribute EWS monitoring responsabilities across different roles in the organization.	EWS monitoring often falls on the project manager alone; lack of shared accountability.
Emotional Detachment	Train teams to manage crises calmy, focusing on the problem. There is no time to blame people.	Emotional reactions to emerging crises are common; fear of escalation and blame culture are still present.
Attention Alignment	Define clear protocols for EWS escalation.	Lack of dedicated response structures for early warly warnings; escalation processes are not well defined.

Table 13 Mindfulness mechanism adapted to construction and engineering firms

Sensemaking Concept	*Engineering-Focused EWS adaptation*	*Observed Gaps / Improvement Needs*

Improvisation and Bricolage	Develop innovative methods for detecting EWS by integrating insights from stakeholders across roles and levels of expertise.	Teams tend to stay with disciplinary silos; limited use of creative or collaborative framing.
Virtual Role Systems	Assign back-up roles and promote signal reporting.	Role flexibility is low; early warnings often ignored if outside someones core task or confort zone.
Attitude of Wisdom	Senior staff actively support upward knowledge flow from junior colleagues.	Juniors often hesitate to escalate; upward feedback is sporadic and lacks formal encouragement.
Identity Construction	Align project goals with broader organizational identity to avoid conflicting responses.	Project teams sometimes operate in isolation from organizational strategy or societal mission.
Plausibility over accuracy	Prioritize interpretations that are coherent and actionable, even if not perfectrly accurate.	Teams hesitate to act without "perfect data"; ambiguity often causes paralysis rather than action. Necessary to learn how to "read the air"
Cue extraction	Expand the EWS to social and political signals. Don't focus only on technical aspects.	Soft signals are rarely logged or formalized.
Retrospection	Use post-incident review and lessons learned for future experiences.	Retrospectives happen late or inconsistently; lessons learned often do not feedback into EWS design.

Table 14 Sensemaking concepts adapted to construction and engineering firms

For this first stage of the analysis, the insights presented in the tables 10, 11, 12, and 13 are synthesized into a coherent engineering framework that categorizes them into four stages depending on their primary function within the EWS process. To ensure a holistic approach to recognizing and responding to signals of creeping crises , the four stages integrate selected HRO principles, and implementations sensemaking concepts, and mindfulness mechanisms; all of these elements will be referred to collectively as "concepts for the purpose of this classification". Figure 20 shows how these concepts are categorized in each stage depending on their intended contribution.

(1) Signal detection: This category focuses on scanning the environment and performance of the project to identify deviations, anomalies, and weak signals before they escalate and are easily recognized as what is referred to as "the tipping point". The concepts that belong to this category are preoccupation with failure, culture of safety, data systems, awareness allocation, cue extraction, and developing leadership.

(2) Signal Interpretation: After the signal detection, this dimension ensures that the signals are interpreted with appropriate depth and perspective, acknowledging uncertainty and risks, and resisting premature simplification. Additionally, it promotes a balanced and informed understanding to guide the response. The concepts that belong to this category are reluctance to simplify, attitude of wisdom, identity construction, and plausibility over accuracy.

(3) Coordinated Response: This dimension enables fast and effective responses to EWS to avoid escalation. The concepts that belong to this category are sensitivity to operations, implementing interventions, attention alignment, and virtual role systems.

(4) Learning and System Adaptation: Focused on long-term resilience, this dimension emphasizes reflective learning through lessons learned and the use of resources to improve future EWS performance by adaptability. The concepts that belong to this category are training and learning, emotional detachment, improvisation and bricolage, and retrospection.

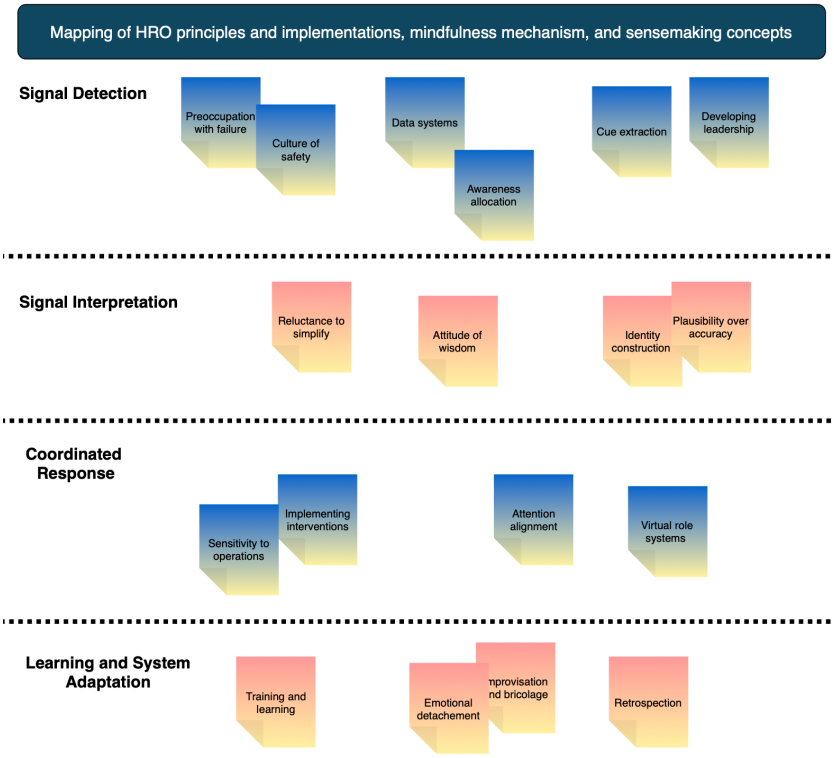


Figure 20 Maping HRO principles, mindfulness, and sensemaking concepts

4.4 Mapping Creeping Crises Types to EWS Functions and Implementing Mechanisms

This section bridges the gap between the identified six most recurrent creeping in engineering firms and the proposed EWS. This section provides a structured mapping of the types of creeping crises, the stages of the EWS process, the main actors, and the tools and techniques that can be implemented for each detected crisis to strengthen early detection, interpretation, coordinated response, and learning and system adaptation.

The mapping is structured and presented by two main elements (representation):

The General EWS Process Flowchart, Figure 21:

Figure 21 presents the flowchart (roadmap) illustrating the four proposed phases analyzed in section 4.3: signal detection, signal interpretation, coordinated response, and learning & system adaptation, which together represent the stages of the EWS proposed for engineering firms. The flowchart integrates the engineering-adapted principles from HROs, sensemaking, and mindfulness.

Furthermore, figure 15 shows who the actors are in each of the stages of the roadmap. Actors are divided into two categories. Primary actors are those directly responsible for carrying out the task, and enabling actors are those who ensure that the organizational environment, resources, and culture are conducive to early warning system functionality.

Due to the complexity of crisis management and its intuitive nature, the intention of this flowchart is not to be treated as a checklist that must be followed rigidly, but rather it offers a flexible and customizable framework that may be adapted to each specific creeping crisis, project, team, and context. Emphasizing interpretation, judgment, and collective experience as core parts of the framework are elements that extend beyond quantitative and traditional engineering-oriented tools. Designed to accommodate both existing and new tools and techniques, this framework allows organizations to adapt the tools and techniques that they already use while also being open to the integration of new ones considered valuable by project teams.

The primary objective of the proposed framework is not to enforce rigid standardization, but rather to contribute to the development of organizational learning and reinforce alignment with project culture of organizations. The EWS is intended to support a mindset oriented toward the early recognition of weak signals, deliberate and context-aware response, and systematic post-crisis reflection.

Creeping Crises Types and Corresponding Tools and Techniques Table, Table 14:

A table in which specific tools and techniques are proposed for the six most recurrent creeping crises identified (scope creep, effort compensation, contractual rigidity, stakeholder misalignment, external contextual drift, and legal and regulatory infeasibility). These tools and techniques are the result of a synthesis of three sources: (1) the thematic analysis carried out on the conducted interviews, (2) information gathered from the literature review, and (3) the author's own reflections and proposals. The integration of these three sources ensures that the proposed framework is evidence-based yet pragmatic and innovative.

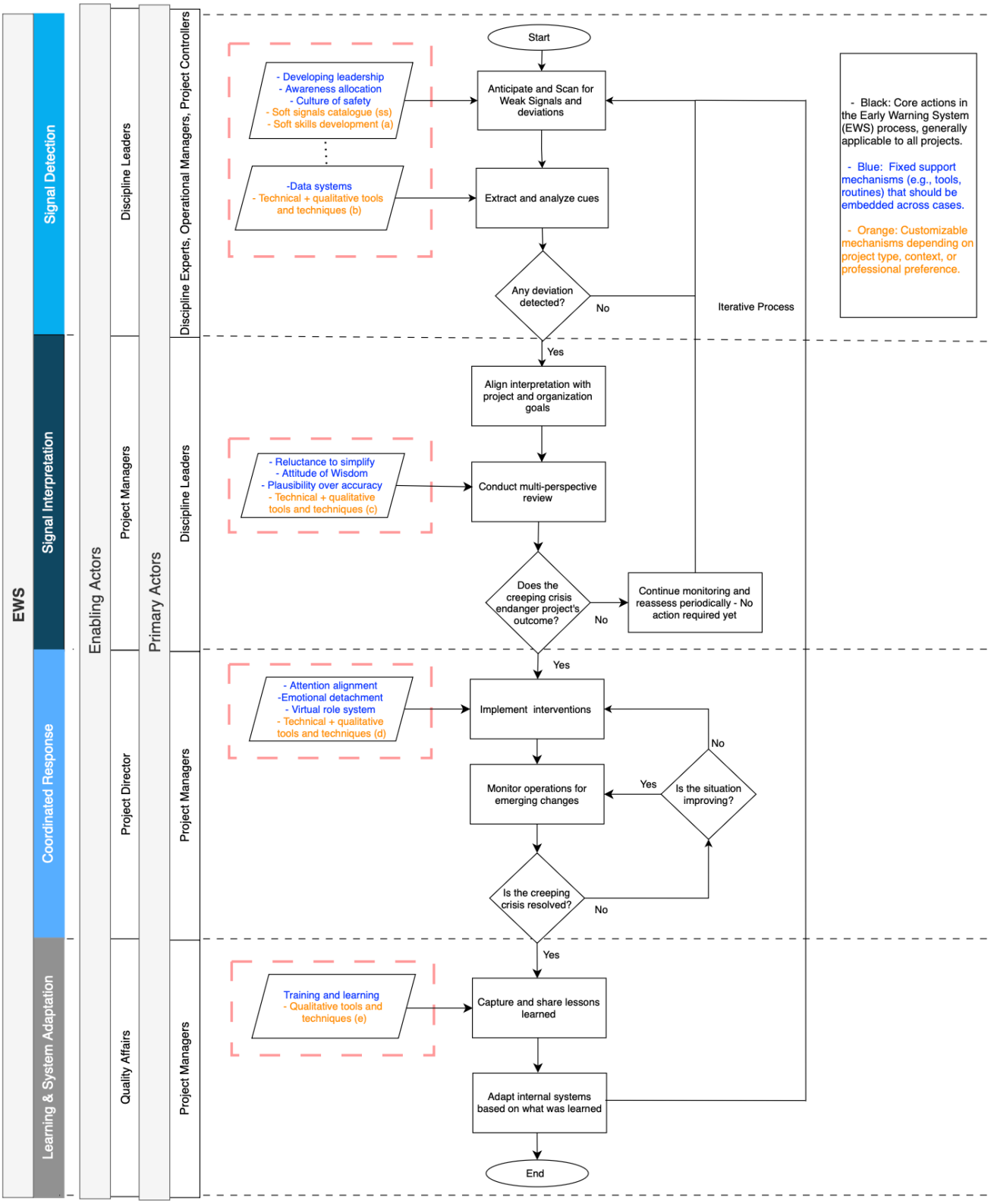


Figure 21General EWS process flowchart

Type of creeping crisis	(a) Signal Detection Soft Skills Development	(b)Signal Detection Tools and Techniques	(c)Signal Interpretation Tools and Techniques	(d)Coordinated Response. Tools and Techniques	(e)Training and Learning Tools and Techniques
Scope Creep	Assertive communication, negotiation skills, psychological safety promotion	Stakeholder expectation tracking system, Target Value Delivery (LC), structured scope monitoring (control budget allocation), EVA, s-curve, LC weekly meetings, soft signal registration mechanism, project assessment	Multi-stakeholder review sessions, cross-functional reflection rounds, past project consultation	Agile scope management interventions, scope renegotiation, LC weekly meetings	Lessons learned sessions, negotiation training, knowledge sharing sessions
Effort Compensation	Assertive communication, workload awareness discusion, psychological safety promotion, emphaty in leadership	Burn rate monitoring, EVA, s-curve, resource allocation dashboards, PPC (LC), job stress survey, soft signal registration mechanism	Effort compensation reviews, resource allocation validation meetings, past project consultation	Resource reallocation strategies, stress relief programs, scope renegotiation	Lessons learned sessions, stress management training, burnout prevention programs, knowledge sharing sessions
Contractual Rigidity	Conflict resolution facilitation, adaptive leadership, negotiation skills	Contract deviation logs, contract risk heatmaps	Legal consultation, contract flexibility assessments, cross-functional reflection rounds, past project consultation	Adaptive contract response protocols	Contract management training, knowledge sharing sessions
Stakeholder Misalignment	Interpersonal negotiation, cultural competence, empathy and trust-building conversations	Stakeholder expectation tracking system, structured stakeholder monitoring, RACI matrix updates, LC weekly meetings, soft signal registration mechanism, project assessment	Collaborative sensemaking workshops, Multi-stakeholder review sessions, past project consultation	Conflict mediation interventions, alignment workshops, LC weekly meetings	Lessons learned sessions, stakeholder engagement training,trust-building exercises, knowledge sharing sessions

External Contextual Drift	Environmental scanning awareness, political acumen, strategic questioning, resilience	Political and financial environment monitoring	Trend analysis, political risk discussions, economic feasibility evaluations, past project consultation	Political strategy adaptations, flexible scenario responses	Lessons learned sessions, external engagement strategy sessions, knowledge sharing sessions
Legal and Regulatory Infeasibility	Assertive communication, collaborative Problem solving	Permit compliance tracking tools, regulatory milestone monitoring, checklist audits, soft signal registration mechanism	Permit issue resolution meetings, joint legal-regulatory reviews, past project consultation	Regulatory escalation pathways, adaptive solution protocols	Regulatory compliance training, permit process learning loops, knowledge sharing sessions

Table 15 Creeping Crises Types and Corresponding Tools and Techniques

Mapping Creeping Crisis Types to Tools, Skills, and Cognitive Mechanisms

This section presents the results of a mapping process that links each of the six identified creeping crises types in section 4.2 to specific categories of intervention. The categories are soft: soft skills, technical tools and techniques, and qualitative and learning tools (cognitive mechanisms).

Soft skills refer to interpersonal and behavioral competencies that support leadership, communication, and team cohesion during uncertainty and crises. As mentioned in section 2.9, these are not purely cognitive or technical (Hurrel, 2016) but are shaped by education and experience (Warin, 2017). In the context of this research, they include assertive communication, leadership, empathy, and others.

Technical Tools and Techniques: These are quantitative mechanisms to monitor performance, progress, and deviations. In the context of this research, they include systems like EVA, S-Curve, and tracking dashboards. They are often digital mechanisms, and an often update and continue learning is important.

Qualitative and Learning Tools (Cognitive Mechanisms): This category integrates mindfulness and sensemaking, as well as tools like lessons learned, reflections, and workshops. These cognitive tools support Witteveen+Bos in "remaining vigilant to early warning signs and adapting strategies dynamically" (Weick and Sutcliffe, 2015).

This classification was based on patterns observed during interviews and supported by literature insights. For each crisis type, the dominant mechanisms used (or required) for detection and response were identified and assigned to one or more of the categories above. This approach allows organizations to understand which types of tools and capabilities are most relevant to each crisis type, and where current detection and response strategies may need reinforcement.
Figures 22 and 23 summarize the distribution of these intervention categories:

- Figure 22 shows how each of the six crisis types maps to the three intervention categories.
- Figure 23 presents the overall presence and frequency of each intervention category across all crises, offering a strategic overview of which areas require the most attention.

These figures help engineering firms assess their current practices and highlight the importance of investing in qualitative and learning-oriented approaches to strengthen early warning capabilities and proactively manage creeping crises.

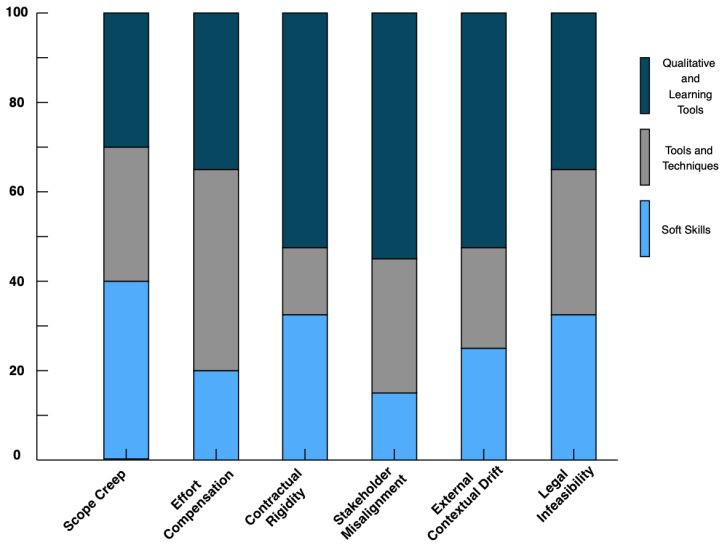


Figure 22 Distribution of intervention categories across each of the six identified creeping crisis types

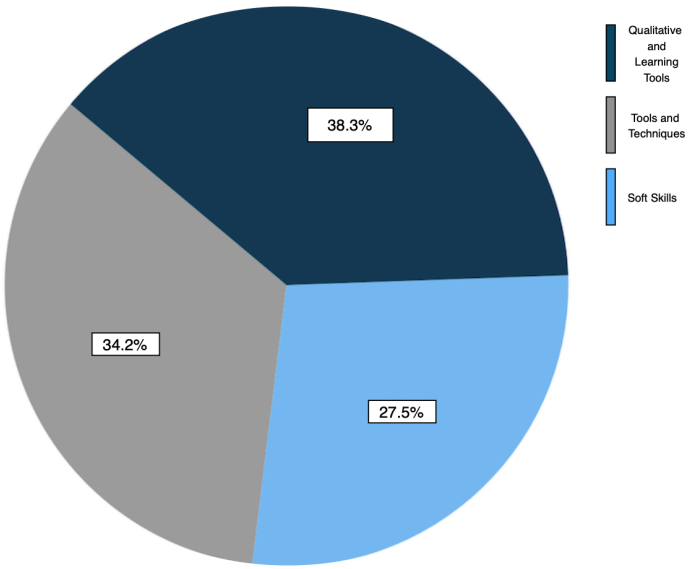


Figure 23 Overall prescence of each category across all crisis types

4.5 Overcoming Barriers for EWS Implementation

One of the critical findings from both the literature review and the thematic analysis carried out on the interviews at Witteveen+Bos is that early detection and response to creeping crises are often hindered by organizational behaviors or barriers. These barriers impede the normal flow of creeping crises management and allow the escalation of them. This section analyzes how the tools, techniques, and soft skills development can directly address the key barriers encountered.

Figure 24 presents the barriers encountered, highlighting their perception and relevance according to both the literature review and the result of the thematic analysis of the interviews. This comparative analysis ensures that the analyzed crises are relevant and have a presence in both academic research and professional experiences. The six identified barriers are:

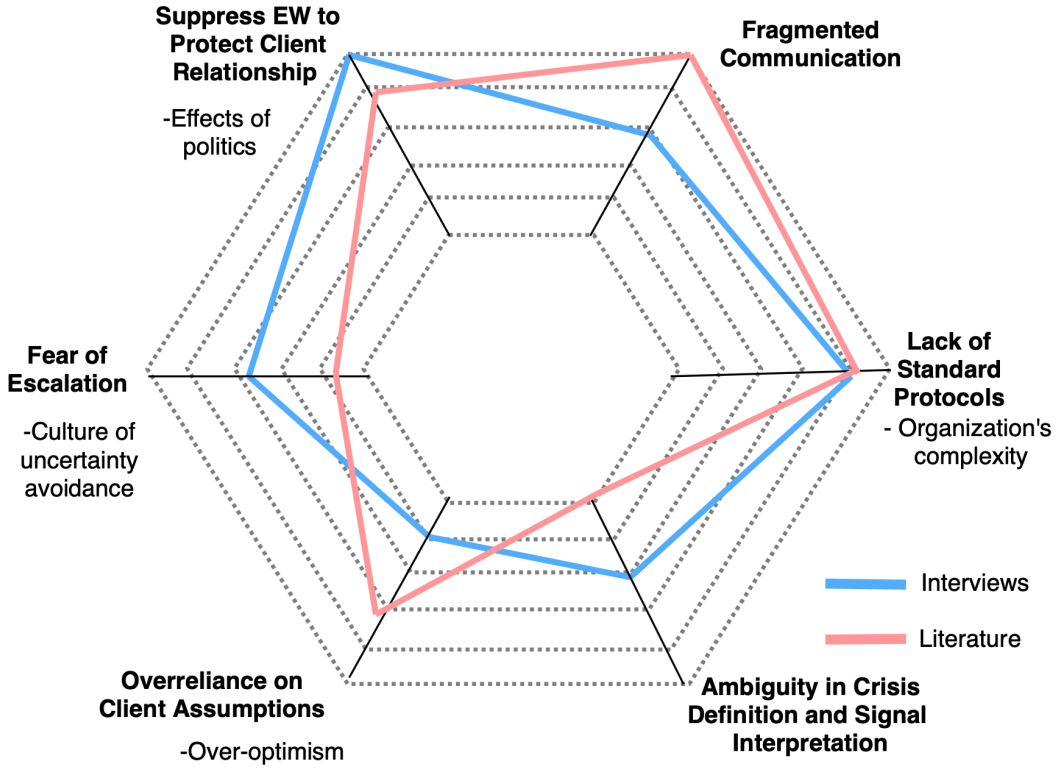


Figure 24 Most common barries for the EWS detection identified

Suppress EW Signals to Protect Client Relationship (Effects of Politics): This barrier refers to the intentional withholding of EW signals to avoid damaging the relationship with the client and avoid arguments in order to "make them happy" and smooth the project life cycle. Both interviews and literature research confirm that this is one of the strongest barriers in the process.

Fragmented Communication: This barrier refers to the disconnection between different departments, disciplines, or stakeholders involved within a project, showing communication deficiencies both horizontally and vertically. This barrier was mostly identified in the literature review; however, it was also mentioned by six professionals.

Lack of Standard Protocols (Organization's Complexity): Refers to the lack of clear organizational procedures, templates, or governance mechanisms to handle EW signals. This means that even if EW signals are detected, there is not a clear procedure of what to do. This barrier was relevant both in the literature review and the interviews.

Ambiguity in Crisis Definition and Signal Interpretation: This barrier relates to the unclear definition of what constitutes a crisis. Professionals hesitate on when to call a situation a crisis. Without shared understanding, signals must be misjudged as irrelevant. This barrier was solely mentioned at the interviews but was not found in the literature review.

Overreliance on Client Assumption (Over-optimism): This barrier refers to the tendency to trust client input and decisions without sufficient critical assessment; also, it creates an over-optimism that may lead to a false sense of safety regarding project feasibility and risks. This barrier was mostly mentioned during the interviews; however, it was found in the literature as well as over-optimism.

Fear of escalation (culture of uncertainty avoidance): Describes the reluctance of individuals to report bad news or potential threats due to their fear of blame and the necessity to show their project as successful. This barrier was mostly mentioned at the interviews.

To translate these findings into practical, actionable strategies, figure 25 presents an integrated visualization of proposed mitigation mechanisms across three dimensions: (1) HRO principles, mindfulness, and sensemaking mechanisms. (2) Soft skills development. (3) Practical tools and techniques.

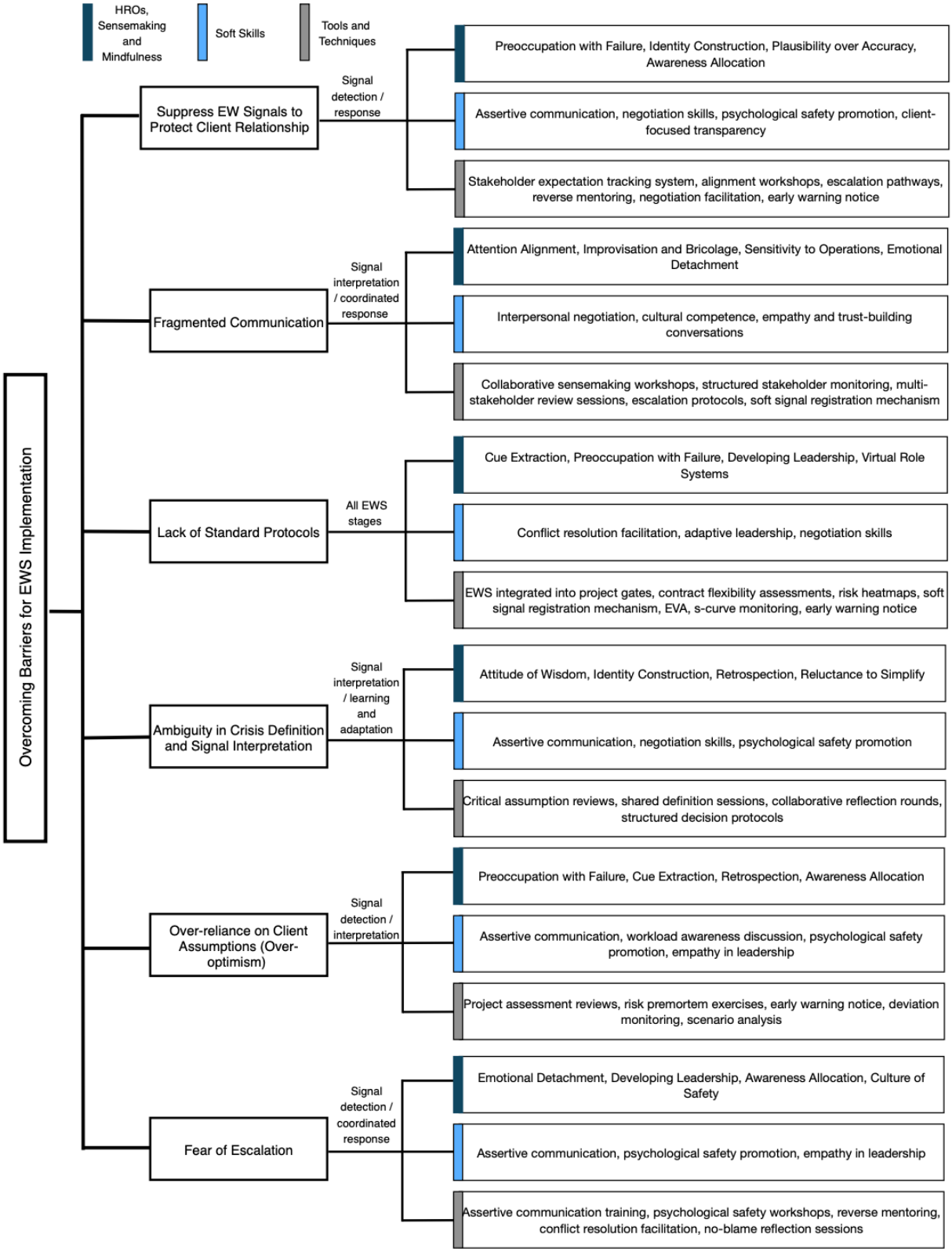


Figure 25 Integrated visualization of proposed mitigation mechanisms to overcome barriers

4.6 Conclusion

This chapter analyzes the most common creeping crises in engineering firms and how these crises can be detected and managed through structured EWS. By synthesizing insights from both the literature review and the thematic analysis of the interviews with professionals of Witteveen+Bos, six recurrent creeping crises identified were (1) scope creep, (2) effort compensation, (3) contractual rigidity, (4) stakeholder misalignments, (5) external contextual drift, and (6) legal and regulatory infeasibility.

To address these crises, the analysis operationalized HRO principles and sensemaking and mindfulness concepts into actionable behaviors, tools, techniques, and mechanisms, making them engineering-actionable and avoiding the subjectiveness. The analysis demonstrates that the integration of these principles and concepts helps foster the cultural and procedural conditions necessary for early detection and intervention of EW signals; additionally, it proposes the foundations for a organization to become high reliable.

One key contribution of this phase is the mapping of creeping crisis types to the stages of EWS, stages that were proposed through the literature review findings, which are signal detection, signal interpretation, coordinated response, and learning and adaptation. The flowchart and the list of tools and techniques provide Witteveen+Bos with a structured framework and procedure, moving beyond theory to practical application. This flowchart can be adapted to any creeping crisis; however, the tools and techniques depend on the type of crisis.

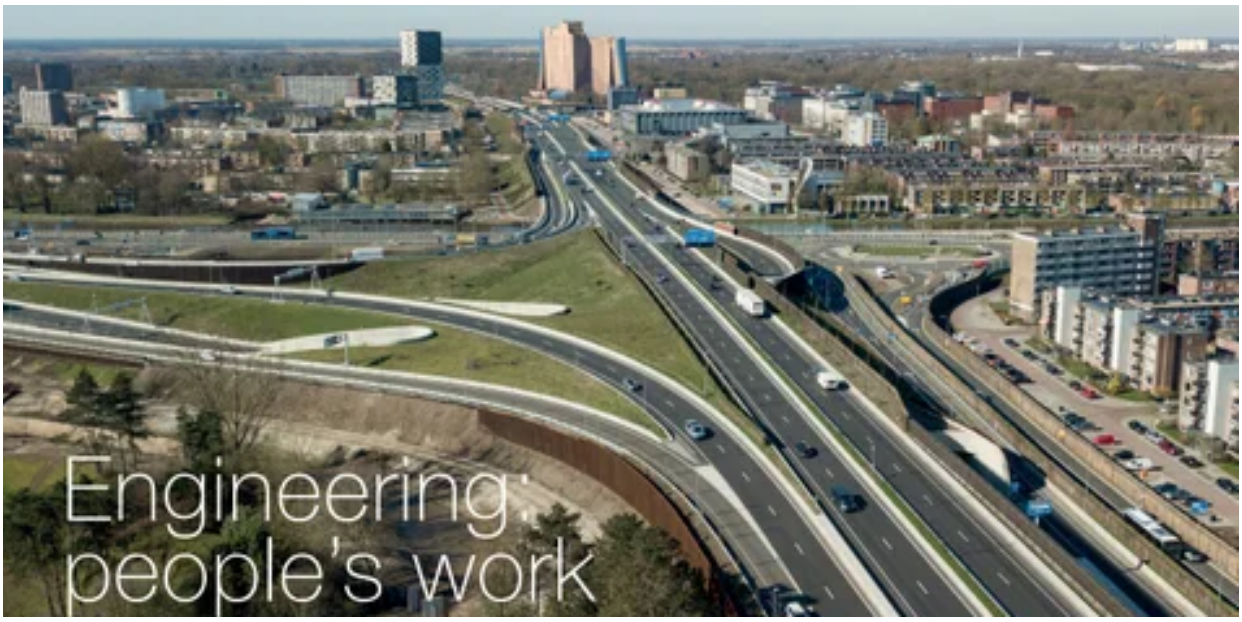
By visualizing the proposed implementations, and together with the figures, engineering firms can clearly identify where current strengths lie and where critical gaps remain. After the analysis, it can be concluded that special attention is necessary in the three types of intervention categories; nevertheless, the qualitative and learning tools, such as sensemaking, mindfulness, and shared knowledge, are the categories that require reinforcement and development from engineering firms, moving beyond traditional project control in the human and cultural dimensions of reliability.

Additionally, this analysis addressed the main challenges and barriers present both in the literature review and in the interviews; six challenges were outlined: (1) suppression of signals to protect client relationships, (2) fragmented communication, (3) lack of standard protocols, (4) ambiguity in crisis definitions, (5) overreliance on optimistic assumptions, and (6) fear of escalation due to cultural norms. The analysis highlighted that overcoming these barriers requires not only technical and procedural improvements but also significant investment in soft skills.

Three sub-questions were addressed and fully answered during this analysis. However, due to the nature of this research, the results may evolve slightly after the validation phase, where feedback from professionals is gathered.

MSc Thesis - Construction Management and Engineering
2023-2025

5 VALIDATION



5.1 Introduction

The practical relevance, credibility, and robustness of the research is validated through a final stage that incorporates the organization or a validation workshop in collaboration with Witteveen+Bos professionals. As mentioned in section 1.7, the American Educational Research Application (1999, p. 9) states that "validation is the process of gathering evidence to support a solid scientific understanding of the results"; therefore, this validation workshop is essential for making sure the research can be useful, relevant, and capable of contributing both to organizational practice and to the crisis management body of knowledge.

Unlike conventional validation processes, a validation workshop is proposed in order to be aligned with the validation strategies in qualitative research. Creswell and Poth (2017) highlight the importance of "collaborating with participants" and "enabling external audits" as key strategies for an accurate and holistic validation in qualitative research. Furthermore, validation workshops serve as a platform for peer debriefing, and it is highly recommended by several scholars for enhancing the dependability and confirmability of qualitative research (Creswee and Poth, 2017).

The main purpose of the workshop is to validate the EWS framework proposed in this thesis by engaging experienced professionals, some of whom are already interviewed with an understanding of the subject, and some other new participants to provide fresh and independent perspectives. Rather than solely reviewing conclusions, participants are invited to critically assess, refine, and contextualize the framework based on their experience and current projects in which a crisis has had presence.

The workshop, titled "The Early Warning Lab", is design as a collaborative setting where professionals will: (1) reflect and give feedback of the creeping creses detected both from the literature review and the interviews. (2) Evaluate the soft skills, tools, techniques, and mechanisms proposed for ES detection and respond. (3) Provide feedback on their relevance, applicability, and determine if they have potential for organizational integration. (4) Identify implementation barriers or additional mechanisms that must be included.

5.2 Validation Design

The duration of the "Early Warning Lab" workshop is approximately 1.5 hours. Professionals from all locations can participate through Microsoft Teams. The online format also facilitates flexible scheduling and enables session recording for later transcription and analysis.

The selection of the professionals that participate in the "Early Warning Lab" is based on the following criteria: (1) Half of the participants should have been involved at the interview stage; thus, they are familiar with the subject and may expect to see some of their insights synthesized in the proposed framework. (2) The other half should not have been involved at the interview stage and are not familiar with the research content. Therefore, they can provide fresh perspectives and help assess the framework's clarity from the eyes of professionals encountering it for the first time.

The three professional roles and profiles included are: (1) Core project roles: Project Managers, Construction Managers, Contract Managers. (2) Risk & quality-focused roles: Risk Analysts, Risk Managers, Quality Assurance Managers. (3) Technical specialists: cost estimators, scheduling engineers, and designers. Table 15 enlists the participants of the workshop, highlighting their position and years of experience.

Position	*Years of Experience*	*Type of projects*
Project Manager	+15	Infrastructure
Project Control	+2	Infrastructure
Project Control	+5	Infrastructure
Project Manager	+10	Urban development
Contract Manager	17+	Flood risk prevention
Project Control	+5	Urban development

Table 16 List of participants in the workshop

The "Early Warning Lab" consists of three key phases. The Framing and Introduction, in which a short presentation of the topic and the EWS framework is carried out in order to provide the participants with the necessary background, clarify the purpose of the workshop, and ensure that the participants get familiarized with key concepts, such as creeping crisis. The second phase, EWS Frame Evaluation and Tool Mapping, where the framework is evaluated together using a sample example of a crisis. Finally, the group reflection and feedback discussion, in which the main objective is to get final recommendations from the professionals to refine the framework and identify missing elements. Figure 26 shows a summary of the three workshop phases, showing their structure, time allocation, and key activities.

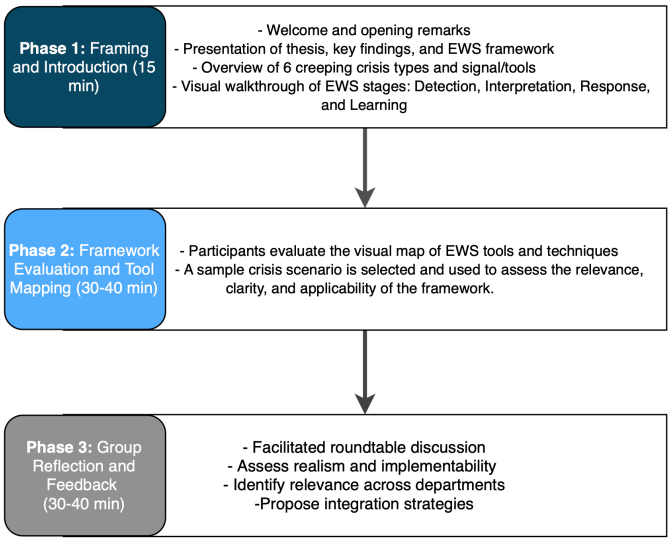


Figure 26 Validation workshop phases

5.3 Results

This section presents the main insights from the “Early Warning Lab” workshop, organized across 3 core validation criteria. (1) Relevance: Do the results and framework reflect a real situation from practice? (2) Clarity and Feasibility: Is the framework understandable, and is the implementation possible? (3) Cultural Fit: Does the framework align with the organizational behavior of Witteveen+Bos?

Relevance

Participants agreed that the research aligns closely with real issues experienced. The six identified creeping crises and the barriers resonate strongly with attendees, and they confirmed the accuracy of the findings. Additionally, while discussing the crisis types and the barriers, participants exchanged knowing glances, and some even looked at each other smiling, suggesting that they have experienced those situations while working at Witteveen+Bos.

The distinction between creeping crisis and sudden crisis, and the proposed definitions during the presentation, were well understood too; however, terms such as “normal flow” and “initial plans” were the subject of discussion, with one participant noting the complexity of identifying deviations since project trajectories are rarely linear and changes happen every time. So the recommendation was to make as agile as possible the framework for giving room to adaptation.

Overall, participants agreed that the framework focuses on the right crisis phenomena and addresses highly relevant dynamics, since crises have a presence in several projects, and at this moment there is not a standardized procedure within Witteveen+Bos.

Clarity and Feasibility

The participants generally found the results and the framework understandable and intuitive. The four stages were seen as logically sequenced and feasible to implement. One participant said, “The flowchart makes sense; crisis management cannot be seen as a checklist, but having structure may help.”

The scope creep walkthrough used as an example for the analysis of the framework was appreciated and seen as a good example; nevertheless, participants suggested the addition of real crises (case studies) for a better understanding and clarity improvement. Additionally, it was suggested to standardize the instructions of the flowchart, making all of them verbs and actions rather than concepts.

The inclusion of optional inputs (tools and techniques) was noted as a strength, as it allows for contextual customization and ensures that Witteveen+Bos can adapt the available procedures within the framework. One participant asked whether intuition or experience could be formally part of the toolset, and the response was that yes, subjective judgment is intentionally incorporated into the framework as a necessary input for the detection and interpretation stages.

For the last stage of the framework (Learning and Adaptation Systems), it was recommended to strengthen this phase by providing concrete tools to capture lessons learned. Furthermore, the discussion brought to light the urgent necessity to implement lessons learned procedures, since it was mentioned that "after a project ends, we move on quickly—there's rarely a moment to reflect," suggesting that rarely this practice occurs.

Regarding feasibility, participants felt the framework could realistically be implemented at Witteveen+Bos, especially if supported with training materials, examples, and a phased introduction. The only concern is the economic feasibility of training teams and implementing new tools and techniques.

Cultural Fit

The framework was seen as a good cultural fit with Witteveen+Bos 's working style, but some organizational tensions were identified. For example, several participants mentioned that although there is a necessity to escalate early warnings with the client, the suppression to maintain a good relationship with them is real, and even if the framework is implemented in Witteveen+Bos, that barrier could prevail; thus, the company is characterized by a strong client-oriented mindset.

5.4 Conclusion

The validation workshop confirmed the relevance, clarity, and applicability of the proposed EWS framework. Participants confirmed that the identified creeping crises and barriers reflect the reality of the company. Their reactions, both verbal and nonverbal, showed a strong recognition of the findings presented during the presentation phase.

On the other hand, the four-phase framework was generally well understood; the participants highlighted a clear interest in adopting the framework and developing it further. Additionally, the analysis of the roadmap with a crisis example gave room for constructive feedback.

In sum, the validation workshop achieved its purpose: it confirmed the credibility and applicability of the research results while also generating valuable recommendations for refinement.

MSc Thesis - Construction Management and Engineering
2023-2025

6 CONCLUSIONS, DISCUSSION, AND, RECOMMENDATIONS

6.1 Conclusion

This thesis has explored the complexities of detecting and responding to creeping crises before their escalation. The study focuses on engineering firms, specifically on Witteveen+Bos, which plays a crucial role at the early stage of a construction project, most of the time during the exploratory phase. By investigating how early warning signals can be recognized and managed, this study contributes to the existing project management literature, addressing the knowledge gap detected. The main research question of this thesis was

"How can engineering firms identify and implement early warning signals to detect and manage creeping crises in construction projects?"

To answer this overreaching question, the research was structured around four sub-questions. Each one of the sub-questions has been examined through a combination of qualitative research methods that includes literature review, semi-structured interviews, and a validation workshop. This chapter provides an integrated reflection of each of the sub-questions, a holistic conclusion and response to the main question, and recommendations to engineering firms.

Sub-question 1: *What are the most common creeping crises encountered by engineering firms, and what indicators or early warning systems are used to identify them?*

Through a literature review and a thematic analysis carried out on the transcripts of the semistructured interviews, six recurrent types of creeping crises were identified: (1) Scope Creep, (2) Effort Compensations, (3) Contractual Rigidity, (4) Legal or Regulatory Infeasibility and Obstacles, (5) External Contextual Drift, and (6) Stakeholder Misalignment.

These crises share several key characteristics. They fulfill the defining characteristics of creeping crises; usually they grow in the background and are unnoticed, unmanaged, or normalized until they are too big to ignore. They are not primarily technical in nature but rather relationally oriented, emerging from stakeholder management, communication breakdowns, and contractual and regulatory issues, and they are difficult to detect through conventional risk management frameworks.

From a detection standpoint, early warning systems currently used across engineering firms vary between teams and collaborators. Different monitoring and engineering-oriented tools were identified, such as dashboards, S-curves, and EVA; however, the data showed a lack of standardization across the company, often depending on the experience and intuition of each professional, and an opportunity to strengthen qualitative tools.

Sub-question 2: *What challenges do engineering firms face in detecting and responding to creeping crises during the early phase of construction projects?*

The second sub-question focused on finding barriers—technical, organizational, and cultural—that limit the effective early detection and response to creeping crises. Based on both literature review and thematic analysis of the semi-structured interviews, six recurring challenges were identified: (1) Suppress EW to Protect Client Relationship, (2) Fragmented Communication, (3) Lack of Standard Protocols, (4) Ambiguity in Crisis Definition, (5) Overreliance on Client Assumption, and (6) Fear of Escalation.

These findings suggest that most of the biggest challenges are not technical or engineering oriented; that, similar to the crises encountered, they are relationally oriented; and that the cultural and organizational behaviors are the ones that discourage proactive engagement with emerging risk. Thus, the capacity to detect and respond to crises is constrained by informal cultures of risk communication and lack of psychological safety.

These challenges show that without changes and improvements in communication practices, trust structures, and standardization of crisis management protocols, even the most advanced monitoring engineering tools and techniques will be underutilized.

Sub-question 3: *How can engineering firms integrate pre-crisis planning and early warning mechanisms to better anticipate and mitigate potential crises in construction projects?*

For responsing sub-question 3, this research assessed how Witteveen+Bos can evolve from technically oriented monitoring practices to a more holistic pre-crisis planning strategy for better detection and response. The results the literature review and the thematic analysis suggest that the integration of early warning mechanisms requires three critical shifts:

Combining technical tools and techniques, qualitative tools, and soft skills: Traditional monitoring, like S-curve, financial dashboards, or EVA, must be complemented by structured soft signal detection practices. Additionally, as mentioned before, due to the relationally oriented creeping crisis types and encountered barriers, soft skills also play a crucial role in strengthening early warning capacity. In particular, assertive communication and negotiation skills appear as the two most essential competencies to manage crises before their escalation.

Embedding High Reliability Organization (HRO) principles: Although every industry is different and has its own complexities, principles and best practices from other high-risk industries may contribute to engineering firms enhancing resilience. Principles from HROs, such as “preoccupation with failure” and “sensitivity to operations,” can guide teams to remain alert to weak signals. In the context of engineering firms, this translates into continuous reflection and learning, team-level sensemaking, and active scenario thinking, always being prepared for unexpected situations.

Sub-question 4: *How can engineering firms position themselves as trusted advisors by offering crisis management consultancy as an added value to their clients?*

While not a primary focus of the thesis, this sub-question explored the opportunity for Witteveen+Bos to offer crisis management consultancy services to external parties. This sub-question was addressed exclusively through the semi-structured interviews, in which professionals rated Witteveen+Bos with an overall score of 7.5 regarding crisis management performance—uncovering the belief that, although the company is currently managing crises at an acceptable level, there is room for improvement, especially in detecting EWS.

A three-stage roadmap was proposed, and the time between each stage depends on reaching internal excellence before involving external parties. The three stages are (1) *Internal Maturity*: Establish robust EWS procedures by combining technical tools and techniques, qualitative tools, and soft skills. (2) Embedded Advisory: Apply the company's knowledge and enhance the use of EWS within ongoing projects where different stakeholders collaborate, actively engaging them in the process and demonstrating the expertise that Witteveen+Bos possesses. (3) *Formal Offering:* Only after internal success and after proving that EWS provides an added value can consultancy services be offered to external parties.

Returning to the main research question—"How can engineering firms identify and implement early warning signals to detect and manage creeping crises in construction projects?" - This thesis concludes that the response is to develop an integrated Early Warning System (EWS) framework. This framework combines technical tools and techniques, soft skills, and qualitative and learning mechanisms. The proposed framework must be capable of detecting both quantitative deviations, such as budget and time overruns, and qualitative deviations, like stakeholder tensions, internal silence, or "gut feelings. Equally crucial is the interpretation of ambiguous signals through sensemaking and cross-functional dialogue. Additionally, the system must enable timely responses through clearly defined escalation pathways and flexible adjustments, and finally, the learning and adaptation part is imperative for this framework by embedding feedback mechanisms.

Finally, the insights derived from the case of Witteveen+Bos suggest that engineering firms already possess several of the necessary components for detecting and responding to creeping crises—primarily engineering and monitoring oriented—but require strategic alignment, standardization, and cultural reinforcement to implement EWS effectively and to transform early detection from an individual skill into an organizational capability.

6.2 Recommentations

6.2.1 General Recommendations

The findings and conclusion of this research highlight the need for Witteveen+Bos to adopt a more systematic, anticipatory approach to crisis management. Creeping crises by their nature are difficult to detect and most of the time normalized, being fully recognized only in retrospect. For that reason, their impact can be as severe as sudden crises if not managed appropriately, with the difference that most likely the creeping crises appear not only in one singular project but across multiple of them.

To address these challenges, this chapter summarizes and gives punctual recommendations to Witteveen+Bos. These are derived from a synthesis of the literature review, thematic analysis of the semi-structured interviews, adaptation to HRO, sensemaking, and mindfulness.

Institutionalizing an Early Warning System (EWS) Framework

Formalize the Four-Phase EWS Model Across Projects

Witteveen+Bos should implement and standardize the four-phase EWS framework (roadmap) developed in this thesis—signal detection, signal interpretation, coordinated response, and learning and system adaptation—as a project formal governance tool. It is important to first have a full understanding of it and customize its application based on the available resources (tools) and the specific projects.

Integrate EWS into digital monitoring systems.

Currently, most professionals use digital monitoring tools like digital dashboards, EVA, and S-curves for performance and deviation tracking. Nevertheless, these tools are focused only on the technical and quantitative metrics. Witteveen+Bos should expand these platforms to include fields for soft signal documentation and issue logging—even before quantitative deviations occur.

Standardize Early Warning Indicators Across Projects

The thematic analysis of the semi-structured interviews revealed that signal detection relies on the experience and knowledge of the project team. To improve consistency, a standardized set of early indicators should be developed and constantly reviewed during the monitoring routines. Examples include scope changes requested outside the original scope, unusual emotional tension or stress within the team, and repeated quality issues in design iterations.

Develop a Soft Signal Registration Tool.

Introduce a digital or analog registration mechanism where team members can report soft signals or concerns without needing a full analysis. These logs should be reviewed together and should be given the same importance as the technically oriented issues (revision in every following-up meeting).

Create Dedicated Escalation Protocols

Currently, there is not a standard response procedure or path once a signal is detected. Each project should define the path to follow and make sure that is clear for every project member.

Strengthening Soft Skills and Behavioral Competencies

Embed Soft Skills in Project Culture

Witteveen+Bos should integrate soft skills development into its project management training, particularly assertive communication, empathy, trust building, and negotiation. It is important to position the negotiation skill as necessary to deal with stakeholders, since most directly influences the firm's ability to manage scope changes and align stakeholders. These can be taught through scenario-based role-play training, reverse mentoring sessions, cross-functional stakeholder simulations, and others.

Establish Psychological Safety as a Norm

A recurring barrier in this study is the fear of escalation and the avoidance of being "the bearer of the bad news," leading to signal suppression. Management should clearly communicate that early warnings, rather than being failures, are signs of high-functioning teams, giving the necessary openness to the collaborators to feel free to notify as soon as a deviation is detected.

Operationalizing HROs, Sensemaking, and Mindfulness

Translate HRO Principles into Actionable, Engineering-Oriented Protocols

Three HRO principles are especially applicable to the detection of early warning signals of creeping crises: preoccupation with failure, reluctance to simplify, and sensitivity to operations. These principles should be embedded into Witteveen+Bos routines through constant deviation scans in project teams, regular assumption-checking workshops, and real-time project visuals shared across teams. The recommendation is that key indicators may be seen by all members of the teams, regardless of hierarchy.

Additionally, Witteveen+Bos should go through and analyze the practices that HROs, such as aviation and nuclear energy, employ in order to try to adapt the best practices within the organization, aiming to strengthen resilience.

Implement Collective Mindfulness Mechanisms

For Witteveen+Bos, collective mindfulness is about the development of a culture in which teams remain alert to early anomalies. To promote the mindfulness culture, Witteveen+Bos should implement specific practices, such as pause-and-reflect moments during transitions (project gates) and attention allocation to distribute signal detection roles among team members.

Additionally, cue extraction practices are highly recommended. Witteveen+Bos should train teams to identify and log social and political signals alongside technical ones; this is to create resilience against potential external shocks.

Promote Structured Sensemaking Moments

Sensemaking is essential when signals are ambiguous or conflicting. Witteveen+Bos should train teams to collectively construct meaning to signals and formalize the use of structured sensemaking moments, especially in key and complex stages of a project or when early signals appear but they are still unclear and weak. These structured moments should include discussions of team members from different disciplines to improve signal interpretation and workshops in which alternative scenarios are explored.

For enhancing sensemaking, an immediate actionable recommendation that Witteveen+Bos should implement is the inclusion of “What Are We Seeing?” sessions.

Description: Add a fixed agenda point during weekly team meetings for discussing weak signals, anomalies, or interpersonal tensions observed during the week.

Accountability: Project leads ensure the session is held and documented; team members are expected to contribute observations.

6.2.2 Recommentations for Implementation (Steps)

For adopting the framework and moving from theory to practice, this section provides with the steps to implement the framework in engineering firms. Figure 27 shows the main steps.

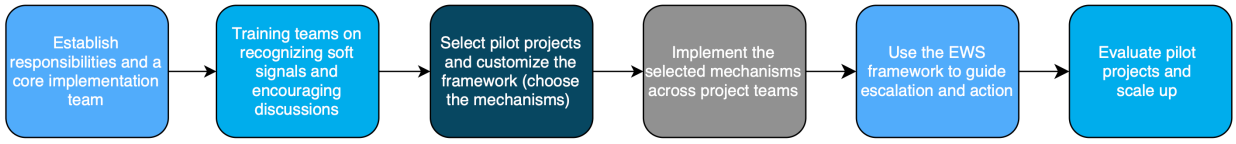


Figure 27 Implementation steps

Step 1: Establish responsibilities and a core implementation team: The first step is to assign a core implementation team that is responsible for implementing and following up on the EWS. This team could include members from project management, risk management, and organizational development.

Step 2: Training teams on recognizing soft signals and encouraging discussions: The second step is to organize workshops and trainings to introduce the concept of creeping crises, focusing on the recognition of soft signals. The recognition of soft signals is essential for the beginning of the implementation since it changes the mindset of project teams to be aware of them. Training should promote open discussion and strengthen the culture of organizations to be “preoccupied with failure.”

Step 3: Select pilot projects and customize the framework (choose the mechanisms): The third step is to choose a few projects that are both complex and have a high probability of facing creeping crises. Allow teams to select the customizable mechanisms, tools, and techniques, depending on their context, availability, and preferences. Addittionally, a training of the tools and techniques is necessary before their implementation.

Step 4: Implement the selected mechanisms across project teams. Project teams begin implementing the chosen tools and techniques, while company governance supports the process by fostering a culture of early detection, adapting existing mechanisms to it, and implementing new ones (the ones chosen during step 3). This includes enabling qualitative tools, which are key to strengthening the EWS.

Step 5: The fifth step is to use the EWS framework to guide escalation and action. Empower teams to take action based on interpretation of early signals using the structural framework and decision-making protocols. Foster a culture of psychological safety.

Step 6: Evaluate projects and scale up. Conduct retrospective evaluations to evaluate the EWS. The sixth step is to scale the EWS to other business units and adopt it as part of the organization's culture.

6.3 Confrontation with Literature and Discussion

This research directly contributes to the literature on crisis management in construction; it addresses an undeveloped domain: the detection and response to creeping crises at the early stages of construction projects. While most crisis research focuses on sudden, high-impact events (Loosemore, 2000; Fink, 1986; Mitroff et al., 1988), this study reinforces and complements the growing study of creeping crises—slow-developing threats that accumulate over time and remain unaddressed until tipping points are reached (Boin et al., 2021; Weick & Sutcliffe, 2015)—by going beyond the definition and offering a practical framework.

By conducting the research with a qualitative mixed method combining literature insights, empirical findings from the interviews, and validation workshops, this study identifies six common crisis types and barriers for early detection and response. These findings extend the work of Halgren et al. (2007) and Vincent (2017), who rank the crisis triggers encountered during the project execution and see the crises as project-specific disruptions and not as the result of organizational systemic patterns. Additionally, the findings reveal that although different monitoring tools and techniques are already in use, there is a lack of a standard procedure for detection and response, in line with Klepo and Radujkovic (2019), who noted

that while many EWS tools exist, none of them offer a holistic solution that could be applicable in real-life projects.

One central theoretical contribution of this study is the adaptation of HRO principles, mindfulness, and sensemaking into a single EWS framework. Although these concepts originate in high-risk industries such as nuclear power and aviation, and the efficacy has been tested, so far, no studies have been found in which these concepts were adapted into the construction (engineering consultancy) context. This research adapts them for construction project-based environments where decentralized decision-making and relational complexity dominate. As Weick and Sutcliffe (1995, 2015) emphasize, mindfulness and sensemaking are crucial for early signal detection and response and strengthen an organization's resilience. This study validates those concepts in the engineering consultancy industry, translating them into a framework with concrete actions and a set of tools and techniques that can be customizable and applied to a wide range of situations.

This research also reveals novel insights from critical findings. Among the various insights, two stand out due to their relevance and originality. The first one is the overcommitment, which is an identified creeping crisis type. It would be valuable to further explore and check whether it is a recurring crisis in other organizations, engineering firms, or only in Witteveen+Bos. The second one is the ambiguity in crisis definition and signal interpretation as a barrier for detecting and responding to crises. This barrier shows that although crisis management is a well-developed subject of project management, professionals still face uncertainty in recognizing what constitutes a crisis. This insight calls for a general further development of the topic and its inclusion as a core element of project management training, potentially together with traditional modules such as risk and change management.

The study confirms the results of Haji-Kazemi (2015), who emphasizes the role of intuition (gut feelings) and informal judgment in crisis detection. After carrying out the analysis and developing the framework, the results showed that a significant part of the EWS should be primarily oriented toward qualitative strategies, enhancing soft signals, and implementing mechanisms that support subjective implementation.

Ultimately, this thesis demonstrates that addressing creeping crises demands a flexible and iterative approach, in line with Weick's (1993) view that crisis management often unfolds through improvisation and adaptation rather than through fixed procedures.

6.4 Study Limitations

While this study proposes a practical and conceptual contribution to the understanding and management of creeping crises in engineering consultancy firms, some limitations are identified and must be acknowledged:

Limited Project Documentation: At the beginning, this study pretended to carry out a case study phase where data would be collected through a deep revision of past project documents (e.g., performance reports and progress reports); however, due to the nature of the main research topic, the confidentiality, and the language of the documents, the study focused mostly on indirect sources of data, such as interviews and workshops with experts.

Framework Maturity: The proposed EWS is conceptual and has not yet been tested in a pilot project. Although the framework and recommendations were validated by professionals during the workshop, their practical feasibility, long-term adoption, and financial implications (return on investment) are still untested.

Qualitative Emphasis: The study relies heavily on qualitative methods. Although the literature review, interviews, and thematic analysis allow for a rich understanding of the current situation and provide nuanced insights, they may be subject to interpretation, and the data may vary depending on the personal perspective and knowledge. Quantitative data could increase the credibility of this study.

6.5 Recommendations for Further Research

For expanding and strengthening the findings of this thesis, the following studies are recommended for future research:

Pilot Implementation and Monitoring: Future research should focus on implementing: The proposed framework of this research is in an infrastructure project. This would enable iterative refinement and getting insights into the differences encountered after the development of the framework and recommendations of this study.

Integration of AI and Predictive Tools: Exploring the use of AI tools to support early warning efforts may prove valuable. While this study focused on qualitative indicators and professional judgment, predictive technologies could complement those efforts by identifying patterns that are harder to detect manually.

Crisis Situations Beyond Organizational Control: Finally, future research could look into how creeping crises evolve when they are caused by external factors—such as political decisions, third-party delays, or public resistance. In such cases, Witteveen+Bos may have little control over outcomes, which raises questions about how an internal framework can remain useful when influence is limited.

7 References

Alas, R., & Gao, J. (2012). Introduction to crisis management. In R. Alas & J. Gao (Eds.), Crisis management in Chinese organizations (pp. 1-15). Palgrave Macmillan. https://doi.org/10.1057/9780230363168_1

Allard-Poesi, F. (2005). The paradox of sensemaking in organizational analysis. Organization, 12(2), 169-196. https://doi.org/10.1177/1350508405051187

Alves, J. L., Ferreira, E. A., & Nadae, J. de. (2021). Crisis and risks in engineering project management: A review. Brazilian Journal of Operations & Production Management, 18 (4), 1-17. https://doi.org/10.14488/BJOPM.2021.026

American Educational Research Association. (1999). Standards for Educational and Psychological Testing. American Educational Research Association.

Ballard, G. (2000). The Last Planner system of production control [Doctoral dissertation, University of Birmingham]. University of Birmingham Institutional Repository.

Ballesteros-Pérez, P., & Elamrousy, K. M. (2018). On the limitations of the earned value management technique to anticipate project delays. In M. Abdul-Malak, H. Khoury, A. Singh, & S. Yazdani (Eds.), Responsible design and delivery of the constructed project (pp. XX-XX). ISEC Press.

Boin, A. (2018). The transboundary crisis: Why we are unprepared and the road ahead. Journal of Contingencies and Crisis Management, 26 (1), 1-5. https://doi.org/10.1111/1468-5973.12241

Boin, A., Ekengren, M., & Rhinard, M. (Eds.). (2021). Understanding the creeping crisis. Springer. https://doi.org/10.1007/978-3-030-70691-3

Boin, A., Ekengren, M., & Rhinard, M. (2020). Hiding in plain sight: Conceptualizing the creeping crisis. Risk, Hazards & Crisis in Public Policy, 11 (2), 116-138. https://doi.org/10.1002/rhc3.12193

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. Journal of Personality and Social Psychology, 84 (4), 822-848. https://doi.org/10.1037/0022-3514.84.4.822

Christianson, M. K., Sutcliffe, K. M., Miller, M. A., & Iwashyna, T. J. (2011). Becoming a high reliability organization. Critical Care, 15*(6), 314. https://doi.org/10.1186/cc10360

Cooper, R. G. (1990). Stage-gate systems: A new tool for managing new products. Business Horizons, 33 (3), 44-54. https://doi.org/10.1016/0007-6813(90)90040-I

Creswell, J. W., & Plano Clark, V. L. (2017). Designing and Conducting Mixed Methods Research (3rd ed.). SAGE Publications.

Creswell, J. W., & Poth, C. N. (2017). Qualitative Inquiry and Research Design: Choosing Among Five Approaches (4th ed.). SAGE Publications.

De Sausmarez, N. (2007). Crisis management, tourism, and sustainability: The role of indicators. Journal of Sustainable Tourism, 15 (6), 700-714. https://doi.org/10.2167/jost653.0

de Graaf, R., Voordijk, H., & van den Heuvel, L. (2016). Implementing systems engineering in civil engineering consulting firm: An evaluation. Systems Engineering, 19 (2), 131-144. https://doi.org/10.1002/sys.21336

Di Loreto, I., Mora, S., & Divitini, M. (2012). Collaborative serious games for crisis management: An overview. In 2012 IEEE 21st International Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises (pp. 352-357). IEEE. https://doi.org/10.1109/WETICE.2012.25

Dimitrov, I. (2024). Early warning signals: A strategy for reducing schedule delays in infrastructure projects during the design phase [Master's thesis, Delft University of Technology]. Delft University of Technology Repository.

Duchek, S. (2020). Organizational resilience: A capability-based conceptualization. Business Research, 13, 215-246. https://doi.org/10.1007/s40685-019-0085-7

Eriksson, E. (2009). Making sense of usability: Organizational change and sensemaking when introducing user-centred systems design in public authorities [Licentiate thesis, Uppsala University]. Department of Information Technology, Uppsala University. http://www.it.uu.se/

Fauziah, Y., Putri, E. Y., Susmita, A., Rosdiana, D., Isniah, S., & Purba, H. H. (2021). A systematic literature review of 5W1H in manufacturing and services industries. In Proceedings of the 3rd Mercu Buana Conference on Industrial Engineering (MBCIE 2021) (pp. 220-228).

Fink, S. (1986). Crisis management: Planning for the inevitable. AMACOM.

Haji-Kazemi, S. (2015). The early warning procedure in projects: Foundations, approaches and challenges (Doctoral dissertation). Norwegian University of Science and Technology, Faculty of Engineering Science and Technology, Department of Production and Quality Engineering. https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/283959

Hällgren, M., & Wilson, T. L. (2008). The nature and management of crises in construction projects: Projects-as-practice observations. International Journal of Project Management, 26 (8), 830-838. https://doi.org/10.1016/j.ijproman.2007.10.005

Hamzeh, F. R. (2011). The lean journey: Implementing the Last Planner® System in construction. In Proceedings of the 19th Annual Conference of the International Group for Lean Construction (IGLC-19).

Hamzeh, F., Ballard, G., & Tommelein, I. D. (2012). Rethinking lookahead planning to optimize construction workflow. Lean Construction Journal, 2012, 15-34.

Hamzeh, F. R., Tommelein, I. D., Ballard, G., & Kaminsky, P. (2007). Logistics centers to support project-based production in the construction industry. In Proceedings of the 15th Annual Conference of the International Group for Lean Construction (IGLC 15) (pp. 181-191).

Hide, G. (2024.). ECC Section 15 - Early Warnings - NEC Guidance Note. GMH Planning. https://gmhplanning.co.uk/nec-guidance-notes/nec-ecc-clause-16-early-warnings/

Holling, C. S. (1973). Resilience and stability of ecological systems. Annual Review of Ecology and Systematics, 4, 1-23.

Hurrell, S. A. (2016). Rethinking the soft skills deficit blame game: Employers, skills withdrawal, and the reporting of soft skills gaps. Human Relations, 69 (3), 605-628. https://doi.org/10.1177/0018726715591636

Jason, L. A., & Glenwick, D. S. (Eds.). (2016). Methodological approaches to community-based research: Qualitative, quantitative, and mixed methods. Oxford University Press.

Jarman, A. M., & Kouzmin, A. (2004). Exploring the links between leadership and strategic management: The role of crisis management. Journal of Management Development, 23 (1), 120-137. https://doi.org/10.1108/02621710410517252

Kamau, M. N. (2024). Management of project alliancing and performance of building construction projects. IR Library, Kenyatta University.

Karatsareas, P. (2022). Semi-structured interviews. In Research methods in language attitudes (pp. 99-113), https://doi.org/10.1017/9781108867788.010.

Kaschner, D. (2020). Building organizational resilience: A study of crisis management capabilities in high reliability organizations. Journal of Business Continuity & Emergency Planning, 14 (1), 45-58.

Klepo, M. S., & Radujković, M. (2019). Early warning system in managing water infrastructure projects. Journal of Civil Engineering and Management, 25 (6), 1-14. https://doi.org/10.3846/jcem.2019.10404

Kovács, O. (2013). Black swans or creeping normalcy? - An attempt to a holistic crisis analysis. Eastern Journal of European Studies, 4 (1), 127-146. Retrieved from https://ejes.uaic.ro/articles/EJES2013_0401_KOV.pdf

Lee, Z. P., Rahman, R. A., & Doh, S. I. (2020). Key drivers for adopting design-build: A comparative study between project stakeholders. Physics and Chemistry of the Earth, 120, 102945. https://doi.org/10.1016/j.pce.2020.102945

Lengnick-Hall, C. A., Beck, T. E., & Lengnick-Hall, M. L. (2011). Developing a capacity for organizational resilience through strategic human resource management. Human Resource Management Review, 21 (3), 243-255. https://doi.org/10.1016/j.hrmr.2010.07.001

Li, Y., Sun, Y., & Jin, J. (2021). The impact of COVID-19 and the 2008 financial crisis on stock markets in emerging economies. Finance Research Letters, 42, 101923. https://doi.org/10.1016/j.frl.2021.101923

Liu, M., Ballard, G., & Ibbs, W. (2010). Work flow variation and labor productivity: Case study. Journal of Management in Engineering, 27 (4), 236-242. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000056

Loosemore, M. (1998). Organisational behaviour during a construction crisis. International Journal of Project Management, 16 (2), 115-121. https://doi.org/10.1016/S0263-7863(97)00039-9

Loosemore, M. (1999). A grounded theory of construction crisis management. Construction Management and Economics, 17 (1), 9-19.

Loosemore, M. (2000). Crisis management in construction projects. American Society of Civil Engineers (ASCE).

Loosemore, M., & Hughes, W. (2002). Reactive crisis management in construction projects-Patterns of communication and behaviour. Journal of Contingencies and Crisis Management, 10 (2), 83-95. https://doi.org/10.1111/1468-5973.00065

Loosemore, M., & Teo, M. M. M. (2000). Crisis preparedness of construction companies. Journal of Construction Engineering and Management, 126 (5), 414-419.

Love, P. E. D., Matthews, J., Sing, M. C. P., Porter, S. R., & Fang, W. (2022). State of science: Why does rework occur in construction? What are its consequences? And what can be done to mitigate its occurrence? Engineering, 21, 74-88. https://doi.org/10.1016/j.eng.2022.05.010

Mazzoleni, S., Turchetti, G., & Ambrosino, N. (2020). The COVID-19 outbreak: From "black swan" to global challenges and opportunities. Pulmonology, 26 (3), 117-118. https://doi.org/10.1016/j.pulmoe.2020.03.002

McCubbin, L. D. (2001). Challenges to the definition of resilience. Journal of Community Psychology, 29 (2), 145-153. https://doi.org/10.1002/1520-6629(200103)29:2<145::AID-JCOP1001>3.0.CO;2-2

Mitroff, I. I., Shrivastava, P., & Udwadia, F. E. (1988). Effective crisis management. The Academy of Management Executive, 2 (4), 283-292. https://doi.org/10.1016/0040-1625(88)90075-3

Ocal, A., Topkaya, B., & Ozden, A. T. (2006). The 1999 Marmara earthquake: A review of epidemiologic findings and community disaster preparedness. Disasters, 30 (4), 475-487. https://doi.org/10.1111/j.0361-3666.2006.00332.x

Olsen, M., Oskarsson, P.-A., Hallberg, N., Granåsen, M., & Nordström, J. (2025). Exploring collaborative crisis management: A model of essential capabilities. Swedish Defence Research Agency.

Paine, L. (2017). What a real preoccupation with failure could look like. Quality Management in Health Care, 26 (4), 1-5.

Pauchant, T. C., & Mitroff, I. I. (1992). Transforming the crisis-prone organization: Preventing individual, organizational, and environmental tragedies. Jossey-Bass.

Pederezini, G. D. A. (2017). The senior management sensemaking paradox. Journal of Strategy and Management, 10 (3), 360-371. https://doi.org/10.1108/JSMA-01-2016-0007

Power, W., & Taylor, D. (2019). Last Planner® System and Percent Plan Complete: An examination of trade contractor performance. https://doi.org/10.60164/a9d8g5a9b

Reason, J. (1997). Managing the risks of organizational accidents. Ashgate.

Rehman, A. U., & Karimullah, S. (2023). The global financial crisis of 2008: Causes, consequences, and policy responses. Journal of Economic Perspectives, 37(1), 45-68. https://doi.org/10.1257/jep.37.1.45

Ringoir, V. (2017). Assessing how recovery interventions by public project managers in the crisis of a Dutch large construction project contribute to a successful recovery outcome [Master's thesis, Delft University of Technology]. Delft University of Technology.

Sahin, S., Ulubeyli, S., & Kazaza, A. (2015). Innovative crisis management in construction: Approaches and the process. Procedia - Social and Behavioral Sciences, 195, 2298-2305. https://doi.org/10.1016/j.sbspro.2015.06.181

San Cristóbal, J. R. (2017). The S-curve envelope as a tool for monitoring and control of projects. Procedia Computer Science, 121, 756-761. https://doi.org/10.1016/j.procs.2017.11.097

Sanae, M., & Abderrahman, A. (2025). The impact of leadership on project success in industrial companies. Multidisciplinary Science Journal.

Smith, T. (2023). Early Warning Notice contract procedure: Improving its use on large infrastructure projects. Crossrail Learning Legacy. https://learninglegacy.crossrail.co.uk/documents/early-warning-notice-contract-procedure-improving-its-use-on-large-infrastructure-projects/

Sutcliffe, K. M. (2011). High reliability organizations (HROs): Toward a better understanding of resilience. Annual Review of Organizational Psychology and Organizational Behavior, 8 (1), 20-40. https://doi.org/10.1016/j.bpa.2011.03.001

Taleb, N. N. (2007). The Black Swan: The impact of the highly improbable. Random House.

Teo, W. L., Lee, M., & Lim, W.-S. (2017). The relational activation of resilience model: How leadership activates resilience in an organizational crisis. Journal of Contingencies and Crisis Management, 25(3), 136-147. https://doi.org/10.1111/1468-5973.12179

Vaughan, D. (1996). The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA. Chicago, IL: University of Chicago Press.

Veazie, S., Peterson, K., & Bourne, D. (2019). Evidence brief: Implementation of high reliability organization principles (VA ESP Project No. 09-199). U.S. Department of Veterans Affairs, Veterans Health Administration, Health Services Research and Development Service, Evidence Synthesis Program. https://www.hsrd.research.va.gov/publications/esp/reports.cfm

Vidal, L.-A., & Marle, F. (2008). Understanding project complexity: Implications on project management. *Kybernetes, 37(8), 1094-1110. https://doi.org/10.1108/03684920810884928

Vince, J. (2023). A creeping crisis when an urgent crisis arises: The reprioritization of plastic pollution issues during COVID-19. Politics & Policy, 51(1), 26-40. https://doi.org/10.1111/polp.12512

Wang, L., Müller, R., Zhu, F., & Yang, X. (2021). Collective Mindfulness: The Key to Organizational Resilience in Megaprojects. Project Management Journal, 52(6), 592-606. https://doi.org/10.1177/87569728211044908

Weick, K. E. (1995). Sensemaking in organizations. SAGE Publications.

Weick, K. E. (1993). The collapse of sensemaking in organizations: The Mann Gulch disaster. Administrative Science Quarterly, 38(4), 628-652. https://doi.org/10.2307/2393339

Weick, K. E., & Sutcliffe, K. M. (2015). Managing the unexpected: Sustained performance in a complex world (2nd ed.). Wiley.

Weick, K. E., Sutcliffe, K. M., & Obstfeld, D. (1999). Organizing for high reliability: Processes of collective mindfulness. In B. M. Staw & L. L. Cummings (Eds.), Research in organizational behavior (pp. 81-123). JAI Press.

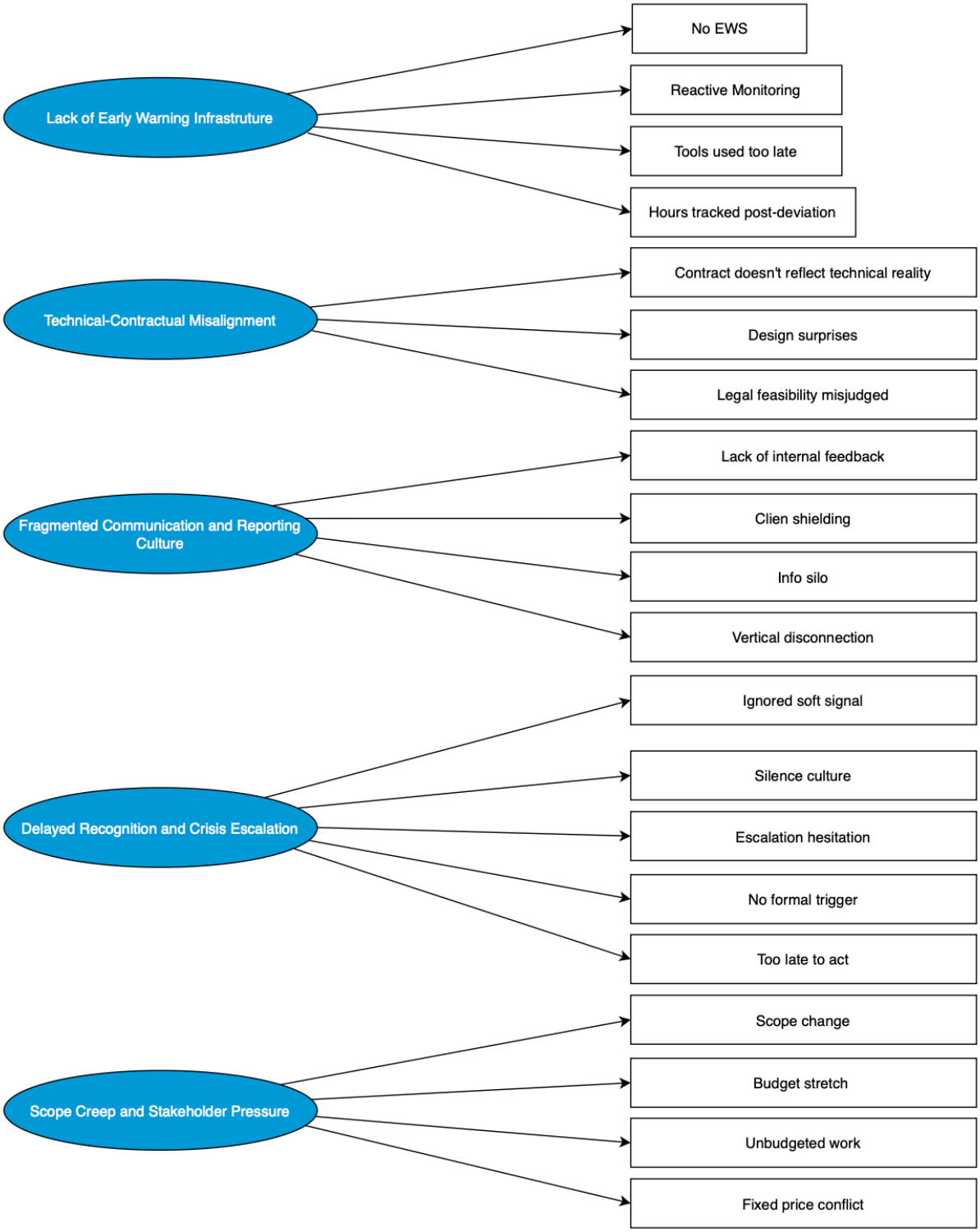
Williams, T., Klakegg, O. J., Walker, D. H. T., Andersen, B., & Magnussen, O. M. (2012). Identifying and acting on early warning signs in complex projects. Project Management Journal, 43(2), 37-53. https://doi.org/10.1002/pmj.21259

Winch, G. M., & Hajikazemi, S. (2025). Practical wisdom for leading projects: The case of early warning signs. Project Leadership and Society, 5, 100173. https://doi.org/10.1016/j.plas.2024.100173

Yin, R. K. (2014). Case Study Research Design and Methods (5th ed.). Thousand Oaks, CA: Sage.Canadian Journal of Program Evaluation, 30(1), 108-110. https://doi.org/10.3138/cjpe.30.1.108

Zhan, Z., Wang, C., Yap, J. B. H., Samsudin, S., & Abdul-Rahman, H. (2019). Earned value analysis, implementation barriers, and maturity level in oil & gas production. The South African Journal of Industrial Engineering, 30(4), 44-59. https://doi.org/10.7166/30-4-2030

Appendix 1 – Thematic Analysis (List of Codes)



Appendix 2 – Interview Invitation and Informed Consent

Dear participant,

Thank you for agreeing to participate in this interview as part of my MSc thesis research at TU Delft, conducted in collaboration with Witteveen + Bos. The purpose of the interview is to gather insights on how engineering firms detect and manage creeping crises in the early stages of construction projects.

What is a Creeping Crisis?

A creeping crisis refers to a situation that develops gradually over time through a series of small, often overlooked warning signs. Unlike sudden crises, creeping crises are difficult to detect in their early stages because they lack a clear starting point, but if ignored, they can escalate into major problems that disrupt project outcomes and organizational stability.

Interview Format and Duration

The interview will follow a semi-structured format and is expected to last approximately 60 minutes. With your consent, it will be recorded and later transcribed for analysis. All information will be treated confidentially and anonymized in the final thesis.

Interview Questions

Below are the questions that will guide our conversation:

Introduction: 10 min

Module 1: 15 min

- What are the most common creeping crises encountered in your projects?
- Can you share examples of creeping crises that escalated over time?
- What early signals were present in that case? Did you detect them? Did you ignore them? When was the tipping point?

Module 2: 15 min

- What are the main challenges that W+B faces in detecting creeping crises?
- Are there any barriers (cultural, organizational, or technical) that prevent crisis detection?
- How does your department handle crisis signals?

Module 3: 15 min

- How do you think W+B can better integrate early warning mechanisms?
- Do you use specific tools/methods for crisis detection (e.g. project monitoring software, risk analysis)?
- What strategies could improve crisis preparedness in the early stage of a project? Soft skills?

Module 4: 10 min

- Do you see demand for consultancy services focused on crisis prevention and management?
- What capabilities or expertise do you think engineering firms would need to offer such services credibly and effectively?

Please feel free to reflect on these questions ahead of our interview. Your insights will be incredibly valuable to this research, and I truly appreciate your time and participation.

Best regards,
José Carlos Galindo Mac-swiney
MSc Candidate, TU Delft

Deventer, NL. March, 20th, 2025

Participation Information Sheet (PIS)

Early Warning Systems for Creeping Crises in Engineering Firms: A Case Study Approach

- **Researcher:** José Carlos Galindo Mac-swiney
- **Affiliation:** Delft University of Technology (TU Delft) and Witteveen + Bos
- **Supervisor(s):** Hans Ramler (TU Delft), Paul Chan (TU Delft), Arend Jan Noortman (W+B), Kevin van Hoeij (W+B)

You are invited to participate in a research study investigating how engineering firms can identify and implement early warning systems to detect and manage creeping crises in construction projects. The study aims to provide practical insights and recommendations for improving crisis management during the early stages of a project.

If you agree to participate, you will be asked to take part in an **interview** (approximately **60 minutes**) where we will discuss:
✓ Your experience in engineering projects and crisis management.
✓ How crises emerge and are identified in your organization.
✓ The tools and strategies used for early warnings and crisis prevention.

Your participation is **completely voluntary**, and you can withdraw at any time without consequences.

- The interview will be **audio-recorded** (with your permission) and later transcribed for analysis.
- Your responses will be **confidential** unless you provide explicit consent to be identified.
- All data will be **anonymized and securely stored** following **GDPR regulations**.
- Data will be stored on a **TU Delft secure server** and retained for **5 years**, after which it will be deleted.

There are no **physical or psychological risks** associated with this study. The main risk is the potential identification of sensitive information. However, all data will be de-identified to protect your privacy.

By participating, you will contribute to **academic research** and **practical improvements** in crisis management strategies for engineering firms.

✓ You may **refuse to answer any question** or withdraw from the study at any time.
✓ You can request access to your data and, if necessary, request deletion.
✓ You can choose whether your responses can be used as **anonymous quotes** in research publications.

Deventer, NL. March, 20th, 2025

Informed Consent Form (ICF)

I, the undersigned, have read and understood the information provided about the research study "Early Warning Systems for Creeping Crises in Engineering Firms" conducted by José Carlos Galindo Mac-swiney from TU Delft and Witteveen + Bos. I have been given the opportunity to ask questions and have received satisfactory answers.

Please indicate your agreement with the following statements by ticking the appropriate boxes:

Statement	Yes	No
I confirm that I have read and understood the Participant Information Sheet.	☐	☐
I voluntarily agree to participate in this study.	☐	☐
I understand that I can withdraw at any time without giving a reason.	☐	☐
I agree for my interview to be audio-recorded for research purposes.	☐	☐
I understand that my responses will be anonymized in publications unless I explicitly agree otherwise.	☐	☐
I agree that anonymous quotes from my interview may be used in research publications.	☐	☐
I understand that my data will be securely stored for research purposes and will follow GDPR compliance.	☐	☐
I would like to receive a summary of the research findings after the study is completed.	☐	☐

Participant Signature:
Date: _____

Signature: _____

Researcher Signature:
Date: 25 Mar 2025

Signature: _____