Promoting Safety Culture in Vertical Construction:

An Empirical Framework Tailored to New Zealand.

Natalia Ortega

School Built Environment, Massey University, Albany, New Zealand

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Abstract

While the construction industry contributes to the global Gross Domestic Product (GDP) and employment, it faces persistent challenges in workplace safety, where injury rates have shown a general upward trend, particularly in New Zealand pronounced in vertical construction projects. Safety Culture (SC) is recognised for its relevant role in injury prevention, risk mitigation, and hazard identification, contributing to fewer accidents, and better safety performance. This thesis addresses the urgent need to promote SC in construction projects by developing a practical framework tailored to New Zealand, yet adaptable for global application. The framework is designed to support safety practitioners in implementing safety interventions and facilitating informed decision-making.

This research followed a structured design comprising four distinct phases: Identify, Categorise, Visualise, and Operationalise employing a mixed-methods methodology. The initial phase employed a Modified Delphi study to achieve consensus among a panel of 32 experts regarding the factors that define SC, and factors and tools influencing its promotion, complemented by a comprehensive literature review to provide additional depth. The second phase categorised tools and influential factors identified in Phase 1 using a Causal Loop Diagram (CLD), thematic analysis, syllogistic reasoning, representing relationships and dynamic interactions. Phase 3 involved the development of a prototype framework through a flow-based diagram, accompanied by an informational report integrating Quick Response (QR) codes and video materials for enhanced usability. In Phase 4, the framework was operationalised its usability through case studies focused on vertical construction projects in New Zealand. Methodological triangulation was employed by integrating qualitative and quantitative data, from site visits inductions, interviews and the survey System Usability Scale (SUS). This integration allows cross-case analysis and enables analytic generalisation and demonstrates its potential usability for widespread adoption by safety practitioners.

This research advances the theoretical development of frameworks by introducing a structured and replicable methodological approach through its four distinct phases, making it applicable across various domains. On a practical level, it delivers a practical framework, to promote SC in vertical construction projects tailored to New Zealand, presented as an informational report, serving as a decision-making guide for safety practitioners, providing actionable tools meeting specific project challenges, ultimately enhancing workplace safety, reducing inequalities, and contributing to sustainable economic growth.

While the framework demonstrates potential, limitations include geographic specificity, sectoral focus on vertical construction, and lack of longitudinal validation. Future research should expand the framework’s application across diverse contexts and construction types to ensure broader relevance and adaptability.

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Chapter 1: Introduction

1.1 Research Background

In the international context, the construction sector is a fundamental vehicle for infrastructure development and socio-economic growth globally (Rafindadi et al., 2022; Umeokafor et al., 2022). It serves to produce structures and infrastructure involving housing, bridges, hospitals, and offices (McCarthy, 2013; Nguyen et al., 2017). The construction sector, often referred to as the construction industry, encompasses all activities related to the building and maintenance of structures (McCarthy, 2013). The terms “sector” and “industry” have been used interchangeably, as they both considered broadly describe the area of economic activity involved in construction, as applied in this thesis (Le et al., 2022). Moreover, the sector accounted for 11.9% of the Gross Domestic Product (GDP) in 2013 and 13 % in 2020 globally (Annor et al., 2025; McCarthy, 2013). By providing jobs to approximately 7% of the world’s workforce, the construction sector generates direct and indirect employment opportunities for millions who build, operate, monitor, or maintain these facilities worldwide (Rafindadi et al., 2022). However, 30%-40% of the annual occupational fatalities come from the construction sector, making safety issues a major concern in the sector (Rafindadi et al., 2022; Trueblood & Yohannes, 2024). Safety remains a critical challenge in the construction sector, where inadequate safety practices, limited resources, and economic pressures often lead to inconsistent safety measures, elevated risks, and preventable workplace accidents. (Hasan et al., 2018; Musonda & Okoro, 2021). Technological integration in construction introduces challenges such as skill gaps, uneven adoption rates, and difficulties in accessing information, which poses barriers to utilising advanced safety technologies like automation and safety equipment effectively (Chen & Chang-Richards, 2022; Ramadan et al., 2023). These technologies have the potential to reduce exposure to hazardous tasks (Wadley, 2021). However, despite proactive design efforts to identify and mitigate hazards, accidents still occur during the execution phase, which is the stage where construction activities are carried out on-site and where the plans are implemented on the ground (Harvey et al., 2018; Rafindadi et al., 2022). Common incidents during the execution phase include falls, electrical shocks, and being struck by objects, often resulting from a combination of construction process failures, unsafe site conditions, workers’ actions, and management lapses (Bashir et al., 2011; Rafindadi et al., 2022; Trueblood & Yohannes, 2024). Therefore, reducing on-site accidents remains a critical goal for construction organisations aiming to ensure project success (Mohammadi & Tavakolan, 2020).

In the New Zealand context, these challenges are also represented in its local statistics, with the construction sector, which employs a substantial portion of the national workforce, leading in work-related injury claims and fatalities (Eaqub, 2024; MBIE New Zealand, 2024; PwC New Zealand, 2016).

Over the past decade, work-related injury claims in New Zealand's construction sector have risen sharply, from 26,000 in 2011 to over 33,000 in 2022, with muscular stress from lifting, carrying, or placing objects being the leading cause (WorkSafe New Zealand, 2022c). Notably, 85% of these incidents occurred in vertical construction, which typically involves building multi-level structures (Jayasinghe et al., 2023; Stats New Zealand, 2020; WorkSafe New Zealand, 2022c). A report, published in 2024 about New Zealand's construction sector, presented alarming figures on workplace accidents within New Zealand's building construction sector (Eaqub, 2024). This report noted 22 serious injuries per 1,000 workers, which is 70% higher than the New Zealand average, and 16% higher than the Australian construction sector; thus, this rate underscores the urgent need for safety improvements within the industry (Eaqub, 2024).

Within the sphere of reducing safety incidents, promoting Safety Culture (SC) across the sector has been hailed to potentially help reducing both the frequency and severity of accidents and incidents by addressing unsafe behaviours and the interaction of psychological, behavioural, and organisational factors (Asilian-Mahabadi et al., 2018; Choudhry, 2007b, 2014). The concept of SC gained international relevance particularly after the Chernobyl disaster in 1986 (Seo et al., 2015). The SC concept relates to the set of shared values, expectations, and beliefs that impact a group's health and safety behaviour (Choudhry et al., 2009; Misnan & Mohammed, 2007; Musonda et al., 2021; Sutherland, 2020; Zou, 2011). Acknowledging the industry's complexity, where safety incidents often have health implications as seen in construction environments, this thesis considers health implicitly within the broader concept of SC and consider its development occurs at various organisational levels (Fand & Wu, 2013; Lingard et al., 2014). Schein (2014) highlights that each organisation must implement its own SC programmes tailored to its unique characteristics and constraints, because cultural factors vary significantly across industries, organisations, and subcultures within each organisation. Unlike the organisational level, which places overarching safety policies and values in construction industry, the project level is where these policies interact with site constraints, team dynamics, and operational conditions (Choudhry et al., 2009; Del Puerto et al., 2018; Gao et al., 2015; Lingard et al., 2014; Namian et al., 2022; Zhou et al., 2015). The implementation of any new plan, policy, or tool is influenced by the prevailing SC, which highlights that existing norm, leadership commitment, and worker engagement, playing a crucial role in determining the adoption and prioritisation of safety initiatives over other competing priorities (Abdullah & Wern, 2012; Bahn, 2012; Sukamani et al., 2021). Moreover, promoting SC in the construction sector contributes to achieving the United Nation (UN)'s Sustainable Development Goals, particularly Goal 8, related to decent work and economic growth; and Goal 3, based on good health and well-being (United Nations, 2025). There is a strong consensus on the importance of SC in strongly contributing to reduce workplace accidents and incidents, and therefore, enhancing worker well-being and productivity (Choudhry et al., 2009; Del Puerto et al., 2018; Gao et al., 2015; Lingard et al., 2014; Namian et al., 2022; Zhou et al., 2015). This point of view underscores the interconnection between promoting a safer work environment and fostering sustainable economic growth and decent work opportunities, which also intersects with broader objectives such as sustainable urban development, and responsible production (United Nations, 2025).

1.2 Research Problem

Defining and understanding SC in construction is challenging due to the dynamic nature of the industry, its fragmentation, and the variety of workplace environments that characterise it (Boton & Forgues, 2017; Choudhry et al., 2007b; Hartley & Cheyne, 2009). Various studies have proven the value of SC in injury prevention, for mitigating current and emerging risks, and so hazards can be identified. Establishing positive SC facilitates stakeholders, mainly on-site project managers and safety practitioners, to manage workplace safety (Al-Bayati et al., 2019; Gillen et al., 2004; Lingard et al., 2015, 2019). The number of publications produced by researchers, institutions, and countries, indicates a global consensus on the importance of SC in reducing workplace accidents, improving worker well-being, and fostering organisational productivity and compliance with health and safety (H&S) standards (Choudhry et al., 2007b; Sutherland, 2020; Zou, 2011). A thorough bibliometric analysis by Otitolaiye et al. (2022) reported that despite growing research on the topic, the concept of SC in the construction sector remains ambiguous, indicating a gap between theoretical frameworks and practical implementation (Biggs & Biggs, 2013; Wamuziri, 2006). The abundance of definitions, tools and context-dependent factors adds layers of confusion to its real-world implementation of SC (Sherratt et al., 2011; Szabo et al., 2023), by obstructing the operationalisation of this concept throughout diverse construction project sites (Choudhry et al., 2007b; Hartley & Cheyne, 2009; Sherratt et al., 2025).

Promoting SC in the construction sector has always been challenging, particularly during the execution phase on construction sites (Del Puerto et al., 2018; Machfudiyanto et al., 2020). It is therefore crucial that the promotion of SC is implemented, ensuring that safety practices are integrated into daily operations to address on-site hazards and foster a safer working environment (Abdullah, 2012; Bahn, 2012; Choudhry et al., 2009; Zou, 2010;). Illustrating this, a 2023 survey in New Zealand construction sector revealed a significant decline in the commitment to SC (Rout, 2023). The survey exposed a concerning 10-point decline in the prioritisation of H&S among construction employers since 2021, as well as a significant gap in the adoption of standard safety communication processes and effective personal protective equipment (PPE) training practices. Systemic issues further complicate this, with the industry’s low-margin nature forcing many builders to prioritise cost management over exceeding minimum legal safety requirements (BRANZ, 2024). The predominance of small businesses in the sector, with 95% employing fewer than five workers, exacerbates this issue, as they lack the financial resilience to invest in advanced safety measures (BRANZ, 2024). Additionally, the cautious approach to innovation within the sector restricts the adoption of new technologies and methods that could enhance safety and productivity (BRANZ, 2024). These innovations are vital for advancing the overall health and competitiveness of New Zealand's construction sector (BRANZ, 2024).

While researchers like Al-Bayati et al. (2019), Choudhry et al. (2007a), Misnan et al. (2007), Molenaar et al. (2009), and Vierendeels et al. (2018), have meaningfully contributed to the SC literature by developing frameworks and models, the concept of SC within the construction sector remains ambiguous and fragmented. This constant ambiguity highlights the need for a more detailed and contextually fitted approach (Sherratt et al., 2011; 2025). This approach should address the characteristics and challenges identifiable in the construction sector, including its fragmented nature, the diversity of workplace environments, and the high prevalence of occupational fatalities and injuries. It should also consider the impact of systemic issues such as financial constraints leading to minimum compliance with safety standards and the decline in safety commitment, with gaps in communication processes that contribute to workforce retention challenges and productivity losses (Farmer, 2016; Musonda & Okoro, 2021; Ni et al., 2022). To address these challenges, a framework that aligns theoretical frameworks with practical applications is needed, fostering SC tailored to the construction sector's needs.

1.3 Research Aim and Objectives

The research background and problem statement indicate the need to facilitate stakeholders, mainly on-site project managers and safety practitioners working on-site, managing workplace safety by establishing and maintaining SC in New Zealand vertical construction. The aim of this research is to improve the promotion of SC in vertical construction projects by developing a practical, usable framework tailored to the New Zealand context, but designed for potential global application, to assist stakeholders, particularly on-site project managers and safety practitioners, to adopt safety interventions facilitating the decision-making. Table 1-1 presents the research questions and objectives designed to achieve the research aim.

Table 1-1

Research Objectives and Questions

Phases	Research Objectives	Research Questions

Phase/Objective 1 – Identify	Objective 1: to explore the meaning of SC as well as factors and tools that enhance SC in practice, as perceived by New Zealand construction safety practitioners.	• How do safety practitioners define SC, in the context of construction projects? • What factors do safety practitioners consider in enhancing SC in New Zealand construction sites? • What are the current tools that safety practitioners are considering when promoting SC in New Zealand?
Phase/Objective 2 – Categorise	Objective 2: to categorise the tools described by New Zealand construction safety practitioners and the literature, identifying their relationships with key factors influencing SC.	• What is the relationship between factors and tools regarding SC?
Phase/Objective 3 – Visualise	Objective 3: to design and develop a prototype framework and present it in the format of an informational report that provides a clear roadmap for decision-making to improve SC in New Zealand.	• How can a framework be designed and developed to enhance SC in the New Zealand construction sector? • What key elements could be incorporated into the framework, in the form of an informational report, to ensure its usability?
Phase/Objective 4 – Operationalise	Objective 4: to operationalise the SC framework and evaluate its usability to facilitate its adoption in New Zealand vertical construction projects.	• How practical and usable is the proposed framework for improving decision-making and promoting SC in New Zealand vertical construction projects?

1.4 Thesis Outline

The thesis adheres to the Massey University Graduate Research School's Doctoral Thesis with Publications guidelines, including eight chapters. The thesis outline is designed to demonstrate the connections between the chapters and the corresponding research objectives. Chapters 1 through 3 operate as the introduction, methodology, and literature review. Chapters 4 through 6, formatted as papers for publication, explain how the framework was developed. Chapter 7 is the Informational Report created, which is one of the outcomes of this thesis. Chapter 8 concludes the thesis where the general discussion, limitations, and overall conclusions are presented.

Chapter 1 introduces the research background, problem, aim, objectives, and the outline of the thesis by chapter.

Chapter 2 of the thesis sets out the structure of this study including the methodology employed. The comprehensive methodology is divided into four phases, designed to align with the objectives set out in Chapter 1. It also highlights ethical considerations relevant to this research.

Chapter 3 provides a thorough literature review of SC, examining both global and New Zealand specific studies. It explores influential factors, relevant tools, and existing frameworks. The chapter's findings establish critical research gaps. This chapter aligns with the objectives in Chapter 1.

Chapter 4 details the Modified Delphi study that explored defining and influencing factors of SC through two rounds with a panel of 32 experts from New Zealand. The combination of qualitative and quantitative methods, in the first-round interviews and thematic analysis to analyse the data, and in the second-round surveys with Likert scales, and Cronbach's alpha coefficient and relative importance index (*RII*), to analyse the data, enabled the transparency and robustness achieving consensus on SC. The findings from this chapter identified six defining factors to define SC. Also, six influential factors to promote SC, and, through a Causal Loop Diagram (CLD), their dual nature as facilitators and barriers, addressing part of the first and second research objectives and setting the stage for the next chapter, which explores tools to enhance SC in construction sites and the creation of the framework.

Chapter 5 is presented in two parts: firstly, common tools to promote SC are examined through the same method in Chapter 4, a Modified Delphi study. Secondly, these tools are categorised based on the six influential factors and the CLD presented in Chapter 4, followed by further categorisation process. The first categorisation was done through thematic analysis, and the second through syllogistic reasoning. The first categorisation facilitated classification on how each tool, identified through the literature review and the Modified Delphi study in Phase 1, correlates with the six influential factors outlined in Chapter 4. The syllogistic reasoning presented how the tools, both those captured by the Modified Delphi study and the literature review in Phase 1, are connected in terms of expert consensus and literature review. The categorisation facilitated the development of a framework visualised as a flowchart diagram, supported through an informational report (see Chapter 7), which outlines strategies for promoting SC at vertical construction sites across New Zealand. This chapter achieves part of objectives 1, 2, and 3.

Chapter 6 presents the validation process of the usability framework for future adoption, and its informational report developed in Chapter 5, through four case studies. Four safety practitioners took part in guided site visits inductions, interviews, and the System Usability Scale (SUS) survey for operationalising the usability of the framework in real-world settings. The results demonstrate the framework impacts safety practitioners by simplifying their ability to select the most appropriate safety tools for specific project challenges, so as to promote SC. The key highlights gathered from the site visits inductions, interviews, and SUS survey, were incorporated into the informational report developed (see Chapter 7), serving as illustrative case studies for the framework. This achieves objective 4.

Chapter 7 presents the final informational report, in its original format to preserve its industry relevance and practical focus, based on Chapters 4, 5, and 6. The report sections present a concise overview of the framework, detailed descriptions and videos links of safety tools, and a summary of case study results, summarising their alignment with the research objectives, becoming one of the outcomes of this thesis as a contribution to the industry.

Chapter 8 demonstrates the overall contribution to knowledge provided by the body of research within the thesis, through a synthesis of the work completed. This chapter draws on final overall conclusions and revisits the research objectives. It also outlines theoretical and practical contributions, and limitations, before suggesting opportunities for future research.

The appendices offer comprehensive documentation integral to the research process, encompassing ethical approvals, consent forms, participant information sheets (PIS), invitations, transcript approval requests, survey details, the forms of statements of contribution, and details of calculations of Cronbach's alpha coefficient, *RII* and SUS survey. Additionally, they include an academic paper supporting Chapter 2, presented at a conference, but conference proceeding is in the process to be published. The DRC 16 "Statement of Contribution – Doctorate with Publications/Manuscripts" for each publication is also supplied in the Appendices. These documents collectively ensure the transparency and reproducibility of the research methodologies and findings.

Chapter 2: Methodology

2.1 Research Philosophy

Research involves a careful, systematic process designed to increase knowledge by thoroughly investigating, interpreting, describing, predicting, and explaining a phenomenon (Saunders et al., 2019; Sutrisna, 2009). The process must be, as far as possible, controlled, rigorous, systematic, valid and verifiable, empirical and critical (Brod et al., 2009; Maxwell, 2012; Pruzan, 2016). This chapter outlines the research process used in this project, ensuring that each phase is robust and makes substantial contributions to both academic and industry knowledge (Corbett and Kember, 2018; Hammond, 2022; Saunders et al., 2019). The research process is structured around three fundamental dimensions: ontology, epistemology, and methodology (Corbett & Kember, 2018; Saunders et al., 2019).

Ontology defines the nature of reality and what can be known about it, defining the research by establishing the foundational assumptions about how the world operates (Antwi & Kasim, 2015; Sutrisna, 2009). It determines whether reality is viewed as objective or socially constructed, shaping the research focus, methods, and interpretation of findings (Saunders et al., 2019; Sutrisna, 2009). Philosophical discussions in research often contrast objectivism and constructionism. Objectivism assumes an independent reality that exists regardless of human perception. On the other hand, constructionism assumes that reality is a social construct shaped by human interactions and perceptions, emphasising subjective experiences.

Epistemology defines the nature of knowledge and how it can be conceived shaping the research approach by determining what is considered valid knowledge, the methods used to acquire it, and the relationship between the researcher and what is being studied (Antwi & Kasim, 2015; Saunders et al., 2019; Sutrisna, 2009). The two main paradigms in epistemology are discussed here, namely positivist and interpretivist. Positivist is rooted in the scientific method, emphasising the use of quantifiable data and the pursuit of universal laws. It views knowledge as objective and independent of the researcher, aiming to uncover truths through empirical observation. Positivist paradigm prioritises measurement and objectivity, relying on quantitative methods. Hence, it commonly involves hypothesis testing, ensuring replicability, and striving for generalisable findings, relying on quantitative methods, such as experiments, surveys, and statistical analysis, to uncover universal laws or patterns. On the other hand, interpretivist paradigm prioritises understanding of meanings derived from human actions, emphasising the exploration of phenomena through individuals' perspectives while valuing depth and context over generalisability. Thus, it postulates that reality is interpreted by human perceptions, experiences, and interactions, making the research process inherently intertwined with the researcher.

Interpretivist prioritises exploration of the meaning individuals assign to their experiences, relying on qualitative methods such as interviews, and case studies. Saunders et al. (2019) presented five philosophical stances: positivism, interpretivism, critical realism, pragmatism, and postmodernism. Each philosophical stance represents a distinct worldview or approach to understanding and conducting research, guiding methodological choices, to address complex research problems (see Table 2-1).

Table 2-1

Definitions of Philosophies Stances by Saunders et al. (2019)

Philosophies	Definition
Positivism	It is based on observable phenomena to formulate predictive laws and demands controlled and quantifiable variables. It focuses on objective measurements and quantifiable results.
Interpretivism	It allows for subjective interpretations and focuses on understanding the meanings behind the data, the subjective meanings and interpretations individuals or groups assign to their experiences. It suggests qualitative methods to explore social phenomena in depth.
Pragmatism	It focuses on the practical impact of research outcomes, providing solutions that work in specific situations and supporting the use of multiple methods, which is essential in dynamic environments.
Critical Realism	It recognises a reality independent of human thoughts and beliefs, supporting the notion that empirical data is affected by underlying mechanisms, deeper structures, causes, or processes that influence observable phenomena, but are not directly apparent or measurable. These mechanisms operate in the background and shape the outcomes or behaviours that can be observed. It often uses data triangulation, combining multiple methods or data sources.
Postmodernism	It offers insights for questioning assumptions and the multiplicity of possible interpretations in any situation, focusing more on deconstructing existing narratives rather than providing constructive solutions. It uses qualitative methods that focus on questioning, critical analysis, and exploring multiple perspectives.

Note. Adapted from Saunders, M., Lewis, P., Thornhill, A., & Bristow, A. (2019). Research methods for business students (pp. 128-171).

Methodology defines the methods used to gather and analyse data, being the rationale and strategy that determines which methods to use and how to apply them in a coherent and systematic way (Saunders et al., 2019; Sutrisna, 2009). It reflects why certain methods are deployed, how they align with the research objectives, and how they are influenced by the philosophical stance of the researcher. By considering the interplay between ontological and epistemological assumptions, methodology ensures coherence in linking philosophical foundations to practical methodological approaches. For instance, deductive reasoning that has been considered in line with positivism, emphasise the development and testing of theories derived from existing knowledge, while inductive reasoning considered in line with interpretivism, aim to build knowledge based on observations and data. Methodologically speaking, mixed-methods research refers to combining these approaches, enabling researchers to collect and analyse data while combining strengths of different data collection methods, such as statistical validity and contextual relevance, to address complex research questions.

This research follows the constructionism ontological stance, where the researcher considers that reality is not an objective entity but is instead continuously constructed and reconstructed through social interactions (Antwi & Kasim, 2015; Saunders et al., 2019; Sutrisna, 2009). From this ontological stance, knowledge is seen as fluid and shaped by shared meanings and experiences within specific contexts. Particularly, the concept of SC is viewed as a socially constructed phenomenon, and shaped through interactions, experiences, and perceptions, among individuals and groups, within the construction sector. This aligns with the focus on exploring SC within the context of New Zealand, where the meaning and practices of SC are shaped by cultural, organisational, and industry dynamics.

Following on from the ontological stance, the research is guided by the interpretivism epistemological stance, where the research process is interconnected with the perspectives of participants to understand the subjective meanings they attribute to their actions and environments (Saunders et al., 2019; Tolley et al., 2016). This means exploring how safety practitioners perceive the definition of SC, the factors and tools that influence it, drawing from their experiences and knowledge. Interpretivism stance rejects the notion of a single objective truth and instead emphasises the co-creation of knowledge between the researcher and the participants (Antwi & Kasim, 2015; Saunders et al., 2019; Sutrisna, 2009), aiming to develop an understanding of a particular phenomenon within its social context, rather than producing generalisable findings (Bell et al., 2018; Saunders et al., 2019; Sutrisna, 2009). By prioritising depth and contextual understanding, the interpretivist stance is in line with the exploratory objectives of the research, particularly in defining SC and identifying the factors and tools that influence it (Objective 1); also, to establish relationships between tools and factors (Objective 2) and ensuring the framework's usability and applicability across broader contexts.

To address the complexity of developing a practical and adaptable framework for promoting SC (Objectives 3 and 4), this study employs a mixed-methods. Mixed-methods research ensures a comprehensive understanding of SC by integrating qualitative insights, which capture the perceptions of individual experiences, with quantitative validation, which increases the credibility of findings (Creswell & Creswell, 2017; Saunders et al., 2019). Qualitative methods, such as interviews and case studies, were used to provide rich contextual data on participants' definitions of SC, and the factors and tools influencing its promotion. Quantitative methods, including surveys and statistical analysis, were used to refine and validate these findings. The mixed-methods approach balances the need for depth and co-creation with the need for a practical framework that is evidence-based and widely applicable (Bryman, 2012; Fellows & Liu, 2015; Kraus et al., 2022; Hart, 1998; Maxwell, 2012). This application of mixed-methods enables the systematic exploration, categorisation, visualisation, and operationalisation of SC, ensuring that the framework developed is both contextually relevant to New Zealand and adaptable for global application.

2.2 Research Approach

When exploring frameworks for understanding and conducting research, several influential authors provide valuable guidance, including Bryman (2012), Creswell & Creswell (2017), and Saunders et al. (2019), each offering distinct approaches to research design and methodology:

- Bryman (2012) delves into a comprehensive approach to integrating qualitative and quantitative methods to be suited for studies requiring deep sociological insights.
- Creswell & Creswell (2017) focuses on exploring mixed-methods research, combining statistical analysis with human insights to address research questions comprehensively and emphasising methodological integration.
- Saunders et al. (2019) present a framework known as the "Research Onion," a concept that structures research by peeling back the layers of complexity, providing a clear pathway through which research can be planned and executed, from philosophical to tactical considerations.

On the one hand, Bryman's work presents an in-depth exploration of mixed methodologies and practical guidance within the social sciences; however, due to its specialised focus, it has not been extended across different disciplines and lacks a structured, sequential approach to research design (Bryman, 2012). On the other hand, Creswell's work guides the execution of mixed-methods research (Creswell & Creswell, 2017). However, it presents a less detailed examination of research strategic planning, such as considering the philosophical to the same extent as Saunders presents with the "Research Onion," which layers from philosophical to tactical considerations (Creswell & Creswell, 2017; Saunders et al., 2019). In this research project, Saunders's approach is considered in line with the frameworks of Bryman and Creswell because it provides a structured, sequential framework that aligns well with the aim of the project and its objectives (Bryman, 2012; Creswell & Creswell, 2017). The "Research Onion" facilitates a systematic progression through the layers of research design, starting from philosophical considerations and moving through theoretical development, methodological choices, strategies, time horizons, and data collection and analysis techniques. Given the project's aim to develop a framework for promoting SC tailored to the New Zealand vertical construction sector but adaptable for global application, Saunders's framework ensures coherence across all stages of research.

This thesis, as outlined in the research philosophy, takes the interpretivist stance within the first layer of the "Research Onion" by Saunders et al. (2019), emphasising that reality is socially constructed and prioritising the exploration of the subjective meanings that participants attribute to SC (Saunders et al., 2019).

In research methodology, abduction, deduction, and induction represent three distinct approaches to reasoning and theory development, each with unique characteristics and applications (see Table 2-2).

Table 2-2

Abduction, Deduction, and Induction by Saunders et al. (2019)

Characteristics	**Abductive**	**Deductive**	**Inductive**
Definition	It consists of making and refining hypotheses based on incomplete information.	Follows a logical process where conclusions are formulated based on general principles.	It involves building theories through observations, starting with specific data and moving towards broader generalisations.
Applicability	Permits an iterative approach that can handle the complexities.	This approach is used in testing theories.	It is ideal for exploratory research, especially in cases where existing models do not adequately capture the context.

Strength	A practical approach to refining hypotheses and theories based on emerging data.	Information moves from the general to the specific.	It moves from the specific to the general, forming theories based on observations.

Note. Adapted from Saunders, M., Lewis, P., Thornhill, A., & Bristow, A. (2019). Research methods for business students (pp. 128-171).

The study employs a combination of inductive and deductive reasoning to develop the framework inductively and uses deductive reasoning to refine elements of the framework (Creswell & Creswell, 2017; Partelow, 2023; Saunders et al., 2019). Methodological choices are predominantly qualitative, focusing on in-depth exploration of participants' perceptions, experiences, and knowledge, complemented by quantitative methods to validate findings and ensure wider applicability. Strategies include a variety of methods such as interviews, case studies, and surveys, ensuring robust data collection and analysis while enhancing the potential generalisability of the framework (Fellows & Liu, 2015; Saunders et al., 2019; Yin, 2018). The research adopts a cross-sectional time horizon, which is the timeframe defined to collect the data, targeting data collection in 2023-2024 to capture current practices and perspectives in the New Zealand construction sector related to SC (Saunders et al., 2019). Techniques and procedures for data collection and analysis are outlined in the Research Design section; some of them include thematic analysis, and statistical methods, all tailored to produce actionable insights. The next section provides a systematic explanation of how methods align with each research objective.

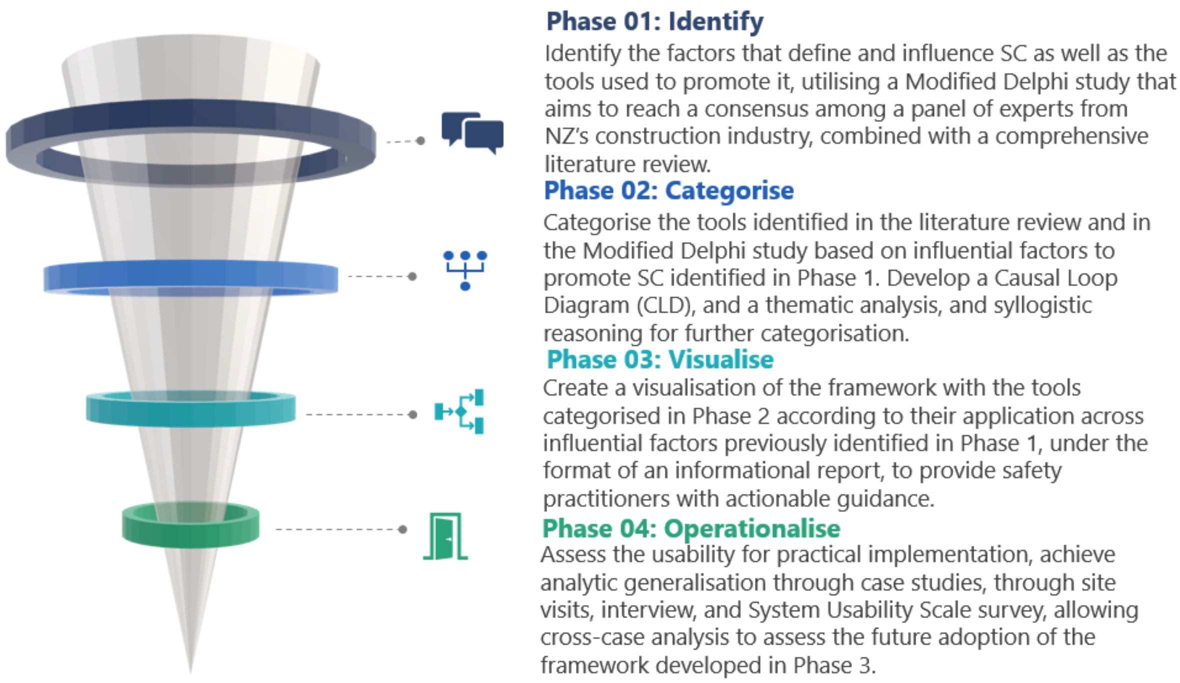
The aim of this research approach is to improve the promotion of SC in construction projects by developing a framework. This framework is designed to be contextually relevant to vertical New Zealand construction sector, while can potentially also be adaptable for global application, supporting safety practitioners in implementing safety interventions and facilitating decision-making processes. Overall, the "Research Onion" offers the flexibility to integrate mixed-methods as outlined by Bryman (2012) and Creswell & Creswell (2017) and emphasises the philosophical and strategic planning necessary to ensure a coherent and rigorous research design (Saunders et al., 2019).

2.3 Research Design

Building on the established philosophical foundation, the Research Design is organised into four key phases: Identify, Categorise, Visualise, and Operationalise. Each phase is systematically aligned with the research objectives and questions in Chapter 1, providing a comprehensive framework for achieving the study's aim. These phases are grounded in a constructionist ontological stance and an interpretivist philosophical approach, incorporating a mixed-methods methodology (Saunders et al.,2019; Sutrisna; 2009).

Figure 2-1

Phases of the Research Project Framework: Identify, Categorise, Visualise, and Operationalise



Note. Phase 1-Identify, Phase 2-Categorise, Phase 3-Visualise, Phase 4-Operationalise.

2.3.1 Phase 1: Identify

The goal in this Phase is to identify the factors that define and influence SC as well as the tools used to promote it, utilising a Modified Delphi study that aims to reach a consensus among a panel of experts from New Zealand's construction sector, combined with a comprehensive literature review.

A Modified Delphi method is recommended for achieving consensus on perceptions, based on the knowledge and experience of a group of experts, regarding concepts in a specific area of study (Brady, 2015; McKay et al., 2022; von der Gracht, 2012). This method, which emphasises interactive feedback and anonymity, combines qualitative and quantitative elements to achieve expert consensus through two rounds of data collection (McKay et al., 2022; Mullen, 2003; von der Gracht, 2012). The traditional Delphi method is exploratory in nature, beginning with open-ended questions to gather unstructured data, reducing the range of responses across multiple iterative rounds (McKay et al., 2022; Mullen, 2003; von der Gracht, 2012). Delphi studies require multiple rounds to refine expert judgment, ensuring progressive consensus-building through iterative feedback loops (Mullen, 2003; von der Gracht, 2012). The consistency of responses across successive iterations, indicating that the group has reached a well-considered and informed position, reinforcing the reliability of the findings, as it demonstrates that expert opinions have converged and are unlikely to change significantly with additional rounds (Mullen, 2003; von der Gracht, 2012). The process can be time-intensive due to the numerous rounds required, often leading to participant fatigue and dropouts (Mullen, 2003; von der Gracht, 2012). To balance methodological rigor with practical constraints such as time and resources, the Modified Delphi method was chosen over the traditional approach. This adaptation limits the process to two rounds, thereby reducing the risk of participant fatigue and dropout (Brady, 2015; McKay et al., 2022; Mullen, 2003; von der Gracht, 2012). By engaging New Zealand construction safety practitioners in two iterative rounds of input and feedback, the Modified Delphi method ensures their perspectives are systematically captured and refined. This approach facilitates the collaborative definition of SC within the context of construction projects, the identification of context-specific factors, and the tools currently employed for SC's promotion, aligning with Objective 1 of this research project.

A Modified Delphi study should involve at least ten experts, known as an "expert panel" (McKay et al., 2022; Mullen, 2003; von der Gracht, 2012). Participant selection for a Modified Delphi study involves recruiting a panel of experts with recognized experience in the field (Mullen, 2003; von der Gracht, 2012). A minimum of three years of professional experience is typically considered a reasonable threshold, as it ensures that participants have acquired sufficient practical knowledge and insights to contribute meaningfully, promoting diversity and informed perspectives within the expert panel (McKay et al., 2022; Mullen, 2003). The selection of experienced participants contributes to the iterative process by providing insights that are grounded in practical knowledge, reducing variability in responses and enhancing the credibility (Mullen, 2003; von der Gracht, 2012). The expert panel may provide feedback, modify, or add elements to the topic in each round (McKay et al., 2022). The data collection, involving qualitative and quantitative data, is through two rounds of individual interviews, seminars, focus groups, and questionnaires (Brady, 2015; McKay et al., 2022; Mullen, 2003; von der Gracht, 2012). Anonymity among panel members prevents dominance by stronger personalities, reducing biases from status or expertise, and encourages diverse perspectives through the interactive consensus process (Fellows & Liu, 2015; Flick, 2018; McKay et al., 2022; Mullen, 2003). Panel selection, in a Delphi study or in a Modified Delphi study, is based on expertise rather than representativeness, relying on a carefully curated panel of experts whose knowledge and experience can be iteratively refined through multiple rounds, reinforcing the need for a structured and purposeful sampling strategy (Mullen, 2003; von der Gracht, 2012). The sample for the expert panel is not intended to reflect the general population but is instead carefully selected based on subject-matter expertise (Elo et al., 2014; Mullen, 2003; von der Gracht, 2012). Purposive sampling, also known as judgmental or selective sampling, is a non-probabilistic technique widely used in qualitative research to ensure the inclusion of knowledgeable individuals who can contribute meaningful insights to the study (Palinkas et al., 2013). Purposive sampling justifies the selection of participants based on their expertise, allowing for the collection of rich, information-dense data through detailed and contextually relevant contributions (Elo et al., 2014; Palinkas et al., 2013; von der Gracht, 2012). Additionally, purposive snowball sampling was employed to further enhance the expert panel by leveraging participant recommendations (Bairagi & Munot, 2019; Elo et al., 2014). This approach facilitated the identification of additional qualified professionals who might not have been initially reachable through conventional databases, ensuring that critical perspectives were not overlooked (Bairagi & Munot, 2019; Elo et al., 2014). By combining purposive and snowball sampling, the study ensured a diverse, credible, and well-informed panel, strengthening the reliability of the consensus-building process.

Modified Delphi method requires at least 75% of the experts from the first round to participate in the second round (Mullen, 2003; von der Gracht, 2012). Furthermore, the theoretical saturation, as aligned with grounded theory principles, is reached when data collection no longer generates new insights relevant to the evolving categories (Guest et al., 2006; Sim et al., 2018, Corbin & Strauss &, 2008; Sutrisna, M., & Setiawan, W., 2016). While most themes typically emerge within the first 12 interviews, saturation is generally solidified around 30 interviews (Creswell, 2018; Guest et al., 2006).

To implement the Modified Delphi method in this study, preparatory activities, such as obtaining ethical approval, defining an expert panel, and securing consent, were undertaken to ensure ethical compliance and the inclusion of a qualified panel of experts (Flick, 2023; McKay et al., 2022; Mullen, 2003; Yin, 2018). Ethical approval was obtained through Massey University's Human Ethics Notification (4000027113) for the period 2023-2025, covering both rounds of the Modified Delphi study, and the case studies later described on this chapter (see Appendix 1). Obtaining ethical approval and informed consent ensures ethical integrity and transparency in research, safeguarding participants' rights, and ensuring the study is performed transparently (Bryman, 2012; Flick, 2023). The panel of experts integrated safety practitioners with at least three years of experience in H&S and Project Management within New Zealand's construction sector, with participants' experience ranging from 3 to 40 years. Particularly, 11 experts had over 20 years of experience, ensuring substantial industry knowledge. The selection of participants aligns with purposive sampling, which aims to include individuals with specific knowledge and experience relevant to the study's objectives (Albrecht, 2011; Mullen, 2003; Yin, 2018). Details about the expert panel are provided in Chapter 4, Table 4-2, 27 out of 32 experts (84.4%) had more than 5 years of experience in the construction industry in New Zealand. Two documents were prepared for the first round: a consent form and a participant information sheet in email format, both of which continued applicable for the second round (see Appendix 2). The detailed consent forms and participant information sheets ensured transparency about the study's data collection and confidentiality measures, fostering trust and compliance with ethical standards (Bryman, 2012; Flick, 2023).

In line with the Modified Delphi study's emphasis on expertise over representativeness, the selection of the expert panel followed a structured and purposeful sampling approach (Mullen, 2003; von der Gracht, 2012). Invitations were initially sent to 217 contacts from Massey University's database and 258 LinkedIn professionals, carefully chosen based on their subject-matter expertise (Elo et al., 2014; Palinkas et al., 2013). To enhance diversity and ensure a broad range of perspectives, purposive snowball sampling was employed, allowing participants to recommend additional qualified professionals who met the expertise criteria but were not initially included (Bairagi & Munot, 2019; Elo et al., 2014). This approach strengthened the credibility and inclusiveness of the expert panel by capturing critical insights from industry specialists beyond conventional databases (Bairagi & Munot, 2019; Elo et al., 2014). To maintain methodological rigor, emails were sent to all 32 participants from the first round, with two reminders included (see Chapter 4, Table 4-2). In the second round, 26 experts (81%) continued their participation (see Chapter 4, Table 4-2), exceeding the methodological requirement that at least 75% of the first-round participants remain engaged, which is essential for ensuring validity in the Modified Delphi study consensus process (Mullen, 2003; von der Gracht, 2012).

Data management was guided by Massey University's Research Data Management Policy, which outlines procedures for storing, retaining, and ensuring the confidentiality of research data for five years. Research data was stored on University-managed infrastructure to ensure security and accessibility, preventing access by individuals outside the research team and maintaining participant confidentiality by ensuring they could not view each other's transcripts. Establishing such processes ensures data protection, confidentiality, and compliance with institutional policies (Flick, 2023; Saunders et al., 2019).

For the first round of data collection, individual interviews were held with 33 experts to ensure a comprehensive range of perspectives and achieve data saturation (Corbin & Strauss, 2008; Fellows & Liu, 2015; Guest et al., 2006; Sim et al., 2018). Although the method requires a minimum of 10 experts, a preliminary analysis of the first 15 interviews indicated that thematic saturation had not yet been reached, as defined by Corbin and Strauss (2008). A total of 33 experts were recruited, surpassing the standard requirements for the Modified Delphi method (Biggs et al., 2013; Mullen, 2003; von der Gracht, 2012). In the first round, 33 individual online interviews were conducted; however, one expert withdrew before approving the transcript due to personal reasons. As a result, 32 participants were validated for this study, exceeding the minimum standard by 22 experts. Furthermore, this sample size also supports the achievement of theoretical saturation, as aligned with grounded theory principles where saturation is typically solidified around 30 interviews, enhancing the credibility of the results. (Guest et al., 2006; Sim et al., 2018; Corbin & Strauss, 2008; Sutrisna & Setiawan, 2016). The panel of experts included Directors, Project Directors, H&S Managers, H&S Advisors, Senior H&S Advisors, Site Managers, Technical Directors, Chartered H&S Professionals, and Principal Engineers (see Chapter 4, Table 4-2). The panel reflects a diverse and well-balanced representation of New Zealand's construction sector. Individual interviews offer depth and detail, allowing for a deep exploration of participants' perceptions based on experiences and knowledge (Williamson, 2018; Yin, 2016). Semi-structured interviews were conducted to ensure flexibility, allowing participants to elaborate on their thoughts without limitations (Bryman, 2012; Fellows & Liu, 2015; Maxwell, 2012; Williamson, 2018). Open-ended questions were chosen because they allow participants to express their thoughts and perceptions freely, which can guide the development of concepts and theories (Corbin & Strauss, 2008; Maxwell, 2012; Williamson, 2018). These interviews involved three open-ended questions focused on the definition of SC, the factors influencing it, and the tools used to promote it on New Zealand construction sites, aimed at gathering insights from the participants (see Chapter 4 and 5).

Pilot tests were conducted for both research instruments in the first round and in the second round. Pilot tests are instrumental in refining data collection instruments, enhancing the validity and reliability (Kim, 2010; Williamson, 2018). The sample size for pilot tests can vary, but it is recommended to be a small percentage of the final sample size, depending on the complexity of the study (Kim, 2010). In the first round, pilot interviews were conducted with five experts, including one industry expert and four academic scholars, the combination allowed for a comprehensive review of the questions, to help reduce errors in data collection that are not related to the sample but instead arise from issues within the questions; these errors could include unclear terms, biased wording, or misunderstandings by respondents (Williamson, 2018; Kim, 2010). Following the pilot interviews, the second question was revised to replace the term "factors" with "barriers, obstacles, and impediments," as these terms were more easily understood by industry professionals.

Prior to the open-ended questions, demographic information was asked, including participants' roles and years of experience, to verify participants with specific knowledge and experience relevant to the study's objectives (see Chapter 4, Table 4-2). While demographic data were collected from participants in the Modified Delphi study, specifically their role and years of experience, to create the panel of experts, that confirmed their suitability and credibility as expert panellists. Categories such as age, gender, or cultural background, were not collected due to ethical considerations and recruitment limitations. The primary focus of the Modified Delphi process was to achieve consensus across a diverse group of experienced safety professionals, rather than to test differences among subgroups; as such, no stratified analysis was conducted. The interviews were conducted within one month

(September 2023). Recording the interviews was done with the participants' informed consent (see Appendix 2), which included authorisation for audio recording to maintain findings with direct quotations (Tong et al., 2007). The interviews were digitally recorded using Microsoft Teams, which includes an automatic transcription tool. After the transcription was generated, it was double-checked for accuracy by comparing it with the original audio recordings before being sent for approval via email to the participants (see Appendix 2). The transcription approval process for each interviewee took maximum 10 days. The interview durations ranged from 7 to 43 minutes, with the majority falling between 14 and 24 minutes, depending on the level of detail and elaboration in participants' responses.

The Modified Delphi study used thematic analysis to analyse the data collected from the first round, to organise and describe qualitative data in rich detail, while also interpreting various aspects of the research topic (Creswell, 2018; Saunders et al., 2019). Thematic analysis was chosen because it is flexible and accessible, as it can be applied to a wide range of qualitative data types such as interviews and surveys (Braun & Clarke, 2006; Roseveare, 2023). Furthermore, it is a systematic method that follows a clear, organised process, including familiarisation with the data, coding, theme generation, and refinement for identifying patterns or themes in qualitative data, which aligns well with the exploratory nature of the research (Braun & Clarke, 2006; Roseveare, 2023). Thematic analysis was utilised to identify key themes from safety practitioners' responses. This involved transcribing digital interview recordings and analysing them with NVivo 14, a software tailored for managing and structuring qualitative data (Galea et al., 2020; Hoover & Koeber, 2009). Adhering to Braun and Clarke's (2022) six-step process, each audio recording was reviewed at least twice to confirm transcript accuracy. Initial codes were then generated to systematically organise data related to the definition of SC, challenges, issues, and tools directly captured by safety practitioners. After completing the coding process, the data synthesis led to the identification of three major clusters: six defining factors (see Chapter 4, Figure 4-1), six factors influencing SC (see Chapter 4, Figure 4-2), and 27 tools used to promote SC on New Zealand construction sites (see Chapter 5, Table 5-3).

For the second round of data collection, an online survey questionnaire was developed based on the findings from the first round, which aligns with the Modified Delphi method, where the second round involves refining and validating insights gained from the first round (Mullen, 2023; Williamson, 2018). Among the 26 experts who continued into the second Modfied Delphi round. As the Modified Delphi process progressed, participant retention remained strong, with 81% of experts continuing into the second round (Mullen, 2003; von der Gracht, 2012). The use of self-administered questionnaires through surveys is appropriate for exploring topics that involve personal experiences, allowing for anonymity, which encourages participants to be honest and provide truthful responses, enabling participants to complete the survey at their convenience, and ensuring that the questions are asked consistently (Fellows & Liu, 2015).

The questionnaire focused on validating the themes and insights identified in the first round, with the Likert scale, providing a structured method for gathering quantitative data on respondents' perspectives (Norman, 2010; Saunders et al., 2019). The survey questionnaire consisted of three clusters of items, each representing a key theme identified through the thematic analysis of the interviews from the first round (see Appendix 2). The first cluster in the survey consists of defining factors, which are core principles critical to define SC; the second cluster consists of influencing factors, which are context-dependent elements that impact the promotion of SC; and the third cluster consists of tools, which are specific strategies or interventions used to promote SC on New Zealand construction sites directly capture by the panel of experts (see Appendix 2).

A pilot test was conducted using a questionnaire administered through the Qualtrics XM online survey platform, which is recognised for creating and distributing surveys. This pilot test was led by two industry experts to assess the functionality and user experience of the survey. By conducting these pilot tests, potential issues can be identified and corrected, improving the refinement of the research instruments' accuracy and reliability (Kim, 2010; Yin, 2018). Based on their comprehensive feedback, minor adjustments were made to improve consistency and clarity across the survey items. Specifically, terminology adjustments were recommended, such as changing "low importance" to "less important" to align more closely with the standard survey language used in research studies (Kim, 2010; Lavrakas, 2008; Yin, 2016).

The level of granularity in a Likert scale refers to the number of response options available and should be selected based on the specific needs of the data analysis (Johnson & Morgan, 2016; Norman, 2010). Granularity influences how responses can differentiate between varying degrees of opinion, ensuring that participants have enough options to capture their perceptions (Johnson & Morgan, 2016). The use of both 4-point (even) and 5-point (odd) Likert scales in this survey ensures clarity and minimise response biases (Johnson & Morgan, 2016; Norman, 2010). For the first cluster, the 4-points scale is particularly useful when the goal is to eliminate indecision and force respondents to take a clear stance, in this study ensuring decisive feedback on the core elements defining SC. In contrast, for the second and third clusters, the 5-point scale includes a neutral midpoint, providing a balanced range for respondents to express varying degrees of agreement or importance, without overwhelming them with excessive options, and without being forced into an extreme position (Johnson & Morgan, 2016). For influencing factors and tools, the 5-point scale allows for more refined responses, reflecting varying levels of importance. These scale choices ensure that each cluster of items captures the level of detail required for the analysis (see Appendix 3).

The first cluster comprised six items related to the defining factors for SC, with a scale ranging from 1 (low important) to 4 (very important). The second cluster contained six items related to the influencing factors, with responses ranging from 1 (low important) to 5 (very important). Lastly, the third cluster included twenty-seven items related to the tools to promote SC with responses ranging from 1 (low important) to 5 (very important). Participants accessed the final survey via unique email links distributed through Qualtrics XM online platform (see Appendix 3). The estimated time to complete the survey was approximately 15 to 20 minutes. The survey was conducted for one month (November 2023). The timeframe for a Modified Delphi study spanned from twelve weeks to up to six months, depending on the complexity of the topic, the number of rounds required, and the availability of participants (Mullen, 2003). The first round was conducted in September 2023, followed by the second round in November 2023, this timeline aligns with the commonly accepted duration for Modified Delphi studies, reinforcing the methodological rigor and feasibility of the process.

To analyse the data from the second round (survey), Cronbach's alpha coefficient was first computed to assess the internal consistency reliability of the Likert-type scales used (Tavakol & Dennick, 2011), followed by the application of the *RII* technique to rank clusters based on expert perceptions (Tarek, 2022; Seidu et al., 2022).

First, calculating Cronbach's alpha coefficient is used when utilising Likert-type scales to evaluate the internal consistency reliability of the measurement scales employed (Tavakol & Dennick, 2011). The data analysis includes a preliminary assessment of the questionnaire's internal consistency using Cronbach's alpha (α), which provides internal consistency reliability on a scale from 0 to 1. A value above 0.6 generally indicates moderate reliability, while values closer to 1 suggest higher internal consistency among the items in the questionnaire (Nwadike & Wilkinson, 2022; Rey-Merchán et al., 2021). The preliminary assessment for each cluster revealed the following Cronbach's alpha values: 0.655 for the first cluster (*N*=6), 0.773 for the second cluster (*N*=6), and 0.958 for the third cluster. The first cluster shows a lower Cronbach's alpha, which, although below the ideal threshold, is still considered acceptable in exploratory research, where the focus is on identifying trends rather than achieving perfect reliability (Nwadike & Wilkinson, 2022; Opoku et al., 2020). The Cronbach's alpha values for the first and second clusters indicate moderate to good internal consistency, particularly for the third cluster, which is consistent with the exploratory nature of the research (Nwadike & Wilkinson, 2022; Opoku et al., 2020). Detailed calculations and results for the Cronbach's alpha are available in Appendix 2, Table 1, 2, and 3.

Following the reliability check, *RII* technique was employed to rank clusters based on expert perceptions (Tarek, 2022; Seidu et al., 2022). The *RII* method assesses the relative significance of various factors within the study, providing a quantitative measure of expert consensus (Tarek, 2022;

Seidu et al., 2022). The *RII* calculation involves assigning numerical values to the ranked positions or ratings provided by participants, followed by computing the average score for each factor (Seidu et al., 2022; Tarek, 2022). This index aids in prioritising factors based on their perceived importance within the context of the study (Rey-Merchán et al., 2021; Tarek, 2022). The *RII* is calculated using the following equation:

$$RII = \frac{Total\ weight\ given\ to\ each\ factor\ by\ the\ respondent}{The\ highest\ weight\ \times\ Total\ number\ of\ respondents} = \frac{W1 + W2 + \ldots + Wn}{A \times N}$$

Where:

• Wn: Weight assigned to each factor by a respondent.

• *A*: The highest possible weight.

• *N*: Total number of respondents.

In the *RII* equation used for this study, "*W*" represents the weight assigned by respondents to each factor, ranging from 1 to 4, or 1 to 5, depending on the Likert scale applied to each cluster. "*A*" is the maximum weight possible (either 4 or 5), and "*N*" is the total number of respondents, which in this case is 26. The *RII* allows for the assignment of numerical values to participants' ratings and calculation of average scores, facilitating the ranking of factors and tools (Rey-Merchán et al., 2021; Tarek, 2022). This approach allowed for a systematic ranking of each cluster based on expert perceptions, providing a clear hierarchy of importance for the six defining factors, the six factors influencing SC, and the twenty-seven tools used to promote SC on New Zealand construction sites. The use of *RII* ensures that the rankings reflect the collective insights and priorities of the experts involved, highlighting the most critical elements within each category (Seidu et al., 2022; Tarek et al., 2022). Data analysis was conducted using SPSS version 29, a comprehensive statistical software package. Detailed calculations for *RII* are available in Appendix 2, Table 4, 5 and 6; and results for *RII* are available in Chapter 4, Table 4-4 for defining factors, Table 4-5 for influential factors, and in Chapter 5, Table 5-4 for tools to promote SC.

To contextualise the findings from the second round of Modified Delphi study and strengthen the theoretical foundation of the study, a comprehensive review was conducted of the existing literature on SC within the construction sector. In this research project, a comprehensive literature review was carried out to identify definitions, factors, tools and frameworks that promote SC (see Chapter 3 and 5). A qualitative review enabled the synthesis of international and local studies, integrating theoretical frameworks and practical applications to bridge the existing gap between theory and practice (Bryman, 2012; Fellows & Liu, 2015). Due to the complex and ambiguous nature of SC within the construction sector, a comprehensive literature review was performed, which aims to summarise, synthesise, and critically evaluate a wide range of sources, providing a detailed understanding of the subject matter (Bryman, 2012; Fellows & Liu, 2015; Kraus et al., 2022; Hart, 1998; Maxwell, 2012). By thematically organising the review into SC challenges, definitions, factors, tools, and frameworks, this method provided a comprehensive understanding of the operational barriers and opportunities for promoting SC (see Chapter 3).

Searches were performed using the Scopus and Google Scholar databases, which are widely recognised for their comprehensive coverage of academic literature (Falagas et al., 2008; Guz & Rushchitsky, 2009), as well as studies, like industry reports, specific to the construction sector and H&S (Bowen, 2009). Keywords used in the search included “safety culture,” “frameworks,” “factors,” “tools,” “construction sector OR industry”, ensuring the inclusion of studies that addressed SC in the construction sector.

Studies were selected based on specific inclusion criteria, including their relevance to construction safety, focus on promoting SC, and connection to the New Zealand context where applicable (Fellows & Liu, 2015). Articles were filtered for peer-reviewed publications, and industry reports were selected by their practical or theoretical contributions to SC within the construction industry (Bryman, 2012; Fellows & Liu, 2015). To conduct this comprehensive literature review, data from journal articles and industry reports were systematically organised to ensure thorough analysis. Relevant sources were first identified using predefined inclusion criteria, focusing on publications related to SC in the construction industry. Following this, thematic analysis was applied to identify recurring patterns and categorise the data into major themes. The themes identified were: safety challenges in the global construction industry, SC definitions, promotion of SC, challenges to promoting SC in New Zealand, tools and frameworks for enhancing SC (see Chapter 3). The data was then synthesised by integrating theoretical insights from academic literature with practical findings from industry reports. The findings from the second round of Modified Delphi study analysis, where expert perceptions were ranked using the *RII*, were subsequently compared against the literature review to validate and refine the emerging framework, ensuring that the framework is both empirically grounded and theoretically informed (Chaudhuri, 2020; Partelow, 2023; Yin, 2018). The results of the Modified Delphi study can be found in Chapter 4, Figure 4-1, Figure 4-2, in Chapter 5, Table 5-4.

2.3.2 Phase 2: Categorise

The goal in this Phase is to categorise and organise the large volumes of data collected during Phase 1. A key tool utilised in this process was the Causal Loop Diagram (CLD), which was selected to visually represent the relationships between three entities, namely SC, its influential factors, and the barriers impacting its implementation (Bala, 2017; Sherwood, 2022; Sterman, 2000). CLDs are qualitative diagrams used to illustrate system dynamics and feedback loops among various factors, highlighting how certain influences can have positive or negative impacts depending on their levels. The CLD illustrates the dual nature of the influencing factors, as they can have either a positive impact or a negative impact depending on whether their level is low or high (Bala, 2017). The CLD was used in this research due to its ability to depict the complex interplay between SC, its influencing factors, and the barriers they encounter (see Chapter 4, Figure 4-3). The “high” and “low” levels used in the CLD are not derived from the raw data. Rather, they serve to illustrate directionality in the feedback loops, for example, how an increase or decrease in a factor's presence or effectiveness may influence SC outcomes. It visually represents how these factors can both positively and negatively impact SC. For instance, high “subcontractor alignment” reduces industry fragmentation, enhancing SC; conversely, low “subcontractor alignment” increases fragmentation, obstructing SC. These directional representations are conceptual, meant to visualise relationships within the system rather than quantify them. This approach aligns with CLD best practices for mapping qualitative dynamics (Sterman, 2000; Bala, 2017).

The CLD was also utilised for validation to address potential biases introduced by the researcher or misinterpretation of data (Cassidy et al., 2022; Meadows & Wright, 2008). By incorporating expert input in the early phases allowed for refining the CLD to ensure it accurately represented the complexities of SC and its influencing factors, further validation with a broader group of experts can be conducted in subsequent phases (Barbrook-Johnson & Penn, 2022). This validation was conducted through a digital interview via Microsoft Teams with one expert, who has over 20 years of experience in H&S within the construction industry. During the interview, the expert reviewed the CLD for coherence and confirmed its completeness, indicating that no adjustments were necessary to align with practical applications and industry realities. The software used to develop the CLD and structure and visualise the system’s dynamic was Vensim, Personal Learning Edition (Barbrook-Johnson & Penn, 2022). The creation of the CLD contributed to developing the framework as it provides a visual representation of the dynamic interactions and feedback loops between SC, its influencing factors, and barriers to its implementation.

When dealing with large volumes of complex data, categorisation is essential for interpretation (Jacobs, 2018; Vergne & Wry, 2014). The six most influential factors impacting SC were identified from data gathered during the Modified Delphi study in Phase 1. The tools, captured from both the Modified Delphi study results and the comprehensive literature review in Phase 1, were categorised under these influential factors (see Chapter 5, Table 5-5) using thematic analysis (Braun & Clarke, 2006; Roseveare, 2023). Thematic analysis provides a systematic approach for categorising and analysing qualitative data (Roseveare, 2023). By identifying, analysing, and reporting patterns or themes, thematic analysis helps break down overwhelming data into meaningful, manageable subdivisions, making it an appropriate method for organising the identified factors and tools in this study (Braun & Clarke, 2006).

The categorisation of the tools was further refined using syllogistic reasoning, a logical approach that helps bring order and clarity to extensive data sets (Sato & Mineshima, 2015; Standford, 2022). This method structures information by establishing logical relationships, often represented by Venn diagrams or matrices (Sato & Mineshima, 2015; Standford, 2022). Syllogistic reasoning, rooted in classical logic, is a deductive approach that links two premises to reach a logically valid conclusion. In the context of this study, syllogistic reasoning was applied not in its strict symbolic form, but as a conceptual method to categorise SC tools based on their source. In this phase, syllogistic reasoning was applied to group the tools based on their origin: those directly captured exclusively by New Zealand experts, those discussed solely in the literature, and those recognised by both groups. This form of reasoning provided a systematic basis for distinguishing tools grounded in practical industry experience from those developed through academic research, enhancing the transparency and interpretability of the framework, and credible classification of tools used to promote SC. A matrix was developed to visually categorise the tools (see Chapter 5, Table 5-5), providing a clear distinction between these categories, thereby enhancing the clarity of the data (Sato & Mineshima, 2015; Standford, 2022).

These three methods, CLD, thematic analysis, and syllogistic reasoning, were applied in a layered and complementary to ensure comprehensive categorisation. The CLD supported the visualisation of relationships and feedback dynamics, thematic analysis grouped tools under influencing factors, and syllogistic reasoning provided logical structuring based on data source. This structure guided the framework's development in a way that is both logical and practitioner-focused.

2.3.3 Phase 3: Visualise

The goal in this Phase is to create a visualisation of the framework. Tools such as diagrams play a crucial role in uncovering themes and interactions that traditional analysis might overlook (Barrett & Sutrisna, 2009; Partelow, 2023; Yin, 2018). These visualisation tools simplify complex data, making them more actionable and comprehensible, thus helping stakeholders understand the complexities inherent to construction safety (McMeekin et al., 2020; Rocco & Plakhotnik, 2009). Detailed reports and white papers also serve as effective tools, offering actionable recommendations tailored to industry needs (Wilkinson, 2022). Therefore, the framework was created as a diagram and displayed under an informational report format, whose primary purpose was to inform and instruct the reader about the usability of the framework (Kabir, 2016; Wilkinson, 2022).

The prototype framework developed in this study is represented through a flow-based diagram that clearly visualises the relationships between the influential factors, barriers, and tools involved in promoting SC. Flowcharts can be effectively employed to structure and visualise the steps of frameworks (Chaudhuri, 2020; Partelow, 2023; Yin, 2018). Starting with the six influential factors identified in Phase 1, it uses arrows to link these factors to their respective barriers, as guided by the CLD, and progresses to show the categorisation of tools, both presented in Phase 2. These tools are visually distinguished by different background colours in the flowchart to highlight their categorisation through thematic analysis and syllogistic reasoning in Phase 2, indicating whether they were identified exclusively by New Zealand experts, discussed in the literature, or recognised by both groups. This visual approach facilitates a clear understanding of how each component contributes to the framework (see Chapter 5, Figure 5-2).

To enhance the accessibility and understanding of the framework, an informational report was created (see Chapter 7). The informational report format was selected for its clarity and structured approach, making it effective for presenting detailed descriptions (Kabir, 2016; Wilkinson, 2022). Also, the informational report was aligned with the need to comprehensively explain the framework's tools, featuring detailed descriptions of the tools, including their purpose, frequency and format of use, engagement strategies, examples, and their potential impact on SC (Kabir, 2016; Wilkinson, 2022). This format allows the inclusion of visual aids, such as Quick Response (QR) codes linked to video descriptions, enhancing accessibility and understanding (Megha & Satishkumar, 2024; Wilkinson, 2022). The QR code allowed readers to easily access the video content, improving accessibility and enabling them to revisit the material as needed (Megha & Satishkumar, 2024), while the video format ensured consistent dissemination of knowledge (Gedera & Zalipour, 2018; Varela & Mejía, 2018). The videos accompanying the framework were created using Pictory AI, based on the tool descriptions provided in Chapter 7 of the report (Pictory, n.d.). These descriptions served as scripts, ensuring consistency between the written and audiovisual materials while enhancing clarity and usability for end users. The informational report facilitates decision-making by offering actionable insights in a user-friendly manner; also, the ability to access supplementary materials, such as videos, directly from the report further supports iterative learning, addressing the practical needs of the industry while enhancing the framework's usability (Sherratt et al., 2025; Wilkinson, 2022).

2.3.4 Phase 4: Operationalise

The goal in this Phase is to assess the usability for practical implementation of the framework. Operationalisation is critical for bridging the gap between theory and practice, transforming theoretical frameworks into practical tools (Yin, 2018). It involves systematically applying the developed framework to collect and analyse data, drawing conclusions based on empirical evidence gathered across various cases to validate its usability (Yin, 2018).

Case studies serve to provide detailed, contextual insights into specific instances of the research subject (Fellows & Liu, 2015; Gray, 2014; Yin, 2018). They help validate theories, test frameworks, or uncover new patterns and relationships (Gray, 2014; Yin, 2018). They often combine multiple data collection methods, such as interviews, observations, surveys, and document reviews, to provide a holistic understanding of the subject (Gray, 2014; Yin, 2018). Multiple case studies, typically involving 3 to 4 cases, are used to enhance the validity of findings by allowing cross-case analysis (Shanks & Bekmamedova, 2018; Yin, 2018). This approach enables researchers to identify recurring patterns, differences, and contextual influences, contributing to a deeper understanding of how the phenomenon operates in diverse settings (Gray, 2014; Yin, 2018). Multiple case studies allow cross-case analysis, which involves systematically comparing and synthesising findings from multiple case studies to identify patterns, themes, and differences; and are integral to generating analytic generalisation, where findings from individual cases inform the development or refinement of broader theoretical models, ensuring applicability beyond the specific cases studied (Shanks & Bekmamedova, 2018; Yin, 2018). Thus, operationalisation relies on case studies to test, refine, and validate theoretical frameworks, ensuring their practical relevance. While this study employed a case study approach to validate the usability and applicability of the developed framework, it did not adopt a fully longitudinal design as suggested by Yin (2016), due to scope of this research. Longitudinal case studies can be valuable for tracking change over time; however, the aim and objectives of this research do not include a longitudinal study. Instead, the study implemented multiple cross-sectional case studies across four vertical construction sites in New Zealand to gather in-depth, context-rich data (Shanks & Bekmamedova, 2018; Yin, 2018). The structured site visits, comprising inductions, semi-structured interviews, and surveys, provided a solid foundation for evaluating the framework's practical relevance and usability at a specific point in time. Therefore, the case study methodology was purposefully focused not to assess behavioural shifts over time, but rather to fully understand the usability of the framework in real-world settings with a variety of stakeholders under diverse conditions. This focused approach allowed the study to meet its usability validation objectives while maintained methodological rigour.

The selection of four case studies aligns with the study's objective of achieving analytic generalisation (Yin, 2018). A checklist, which is a table to systematically organise and collect data during site visits, and a script, which is a document that outlines the key questions, prompts, and topics to be covered during the interview, were developed (see Appendix 3) as part of the structured protocols for case study research (Shanks & Bekmamedova, 2018; Yin, 2018). These tools were designed to ensure that critical information was consistently captured (Yin, 2018).

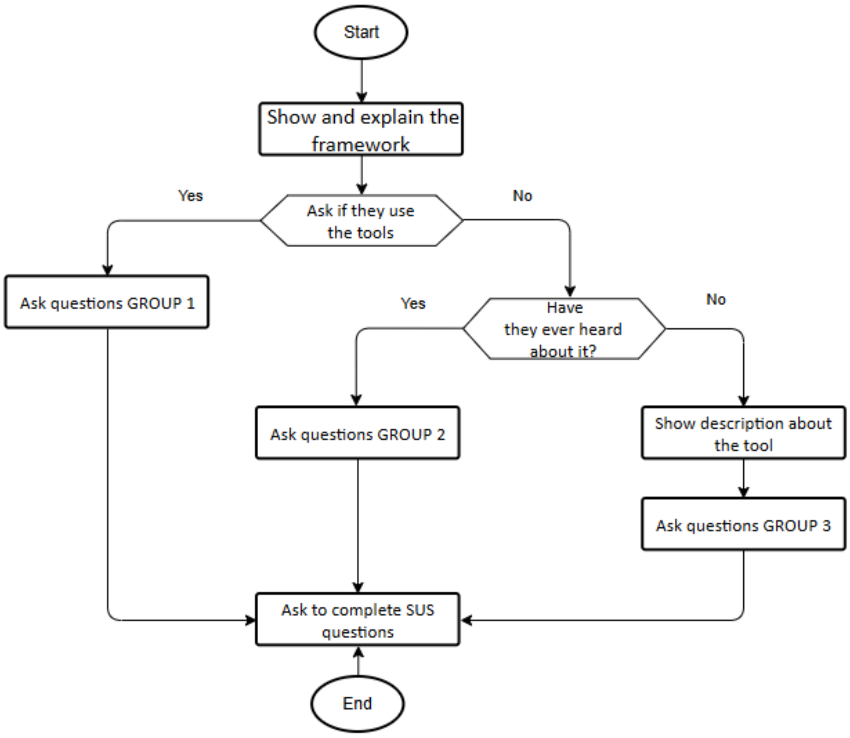
Several evaluation techniques were applied to ensure the validity and reliability of the findings, following the recommendations of Gray (2014) and Yin (2018). Triangulation is particularly valuable in case studies because it enhances the construct validity of the research by integrating multiple data sources, perspectives, or methods (Shanks & Bekmamedova, 2018; Yin, 2018). Methodological triangulation specifically refers to the use of different research methods, such as integrating qualitative and quantitative ones, to study the same phenomenon (Gray, 2014; Yin, 2018). This approach enables a comprehensive understanding by capturing complementary aspects of the research question (Shanks & Bekmamedova, 2018; Yin, 2018). In construction research, triangulation is essential for capturing the complexity of industry-specific challenges and ensuring methodological consistency (Sutrisna & Barrett, 2007). In this research, the case studies encompass site visits to four vertical construction projects from four different companies in New Zealand; these visits comprised of site induction followed by data collection through interviews and a SUS survey with practitioners in charged for those projects (see, Chapter 6, Table 6-2). Thus, methodological triangulation involved combining qualitative data from site visits interviews, and with quantitative SUS survey data, ensuring findings about the framework's usability (Brooke, 1995; Yin, 2018).

Site visits were conducted as part of the data collection process to gather context-rich, firsthand information about the operational environments of construction projects (Fellows & Liu, 2015; Yin, 2018). Site visits are integral to case study research because they provide direct familiarization with the project (Yin, 2018). The site visits allowed the researcher to become familiar with the environment the environment where the SC framework would be applied, capturing essential details about site dynamics, operational challenges, and safety practices (Fellows & Liu, 2015; Yin, 2018). In this research, site visits were used as an induction to facilitate the researcher's familiarisation with each site and served as a foundation for subsequent data collection activities. The site visits chosen for this research focus on vertical construction projects in New Zealand, which are characterised by multi-level structures, the use of heavy machinery, and work in confined spaces and at heights (see Chapter 6). These projects include the construction of residential, commercial, and industrial buildings (Brenner, 2015; Jayasinghe et al., 2023). Vertical construction was selected due to its significant representation within the industry and the high proportion, 85%, of reported H&S incidents in this sector in New Zealand (Stats New Zealand, 2020; WorkSafe New Zealand, 2022c). For example, between October 1, 2022 and September 1, 2023, 518 out of 600 reported construction incidents occurred within the vertical construction sector, highlighting its critical need for safety interventions (Stats New Zealand, 2020; WorkSafe New Zealand, 2022c). To recruit participants, 300 emails were selected and sent from a database compiled during Phase 1, targeting safety practitioners. This approach was designed to ensure adequate representation of vertical construction projects, recognising that response rates are often low due to the demanding schedules and commitments of potential participants (Bryman, 2012). Four positive responses were received from vertical construction projects, from four different companies, involving two Project Managers, one Site Manager, and one H&S Manager (see Chapter 6, Table 6-2). Consent forms and participant information sheets were prepared, distributed, and returned with consent to conduct site visits, participate in interviews, and complete a survey, following the ethical approval (see Appendix 1 and 3). Subsequently, the dates for the site visits were confirmed.

During the four site visits, semi-structured interviews were conducted with the four participants. This approach was employed to assess the informational report developed in Phase 3, which included a visual representation of the framework, detailed descriptions of the tools, and visual aids such as QR codes linked to video explanations. The full informational report, where its structure and content are further detailed, is available in Chapter 7. Semi-structured interviews, widely used in qualitative research, enable participants to elaborate on their experiences and perceptions, providing rich, context-specific insights (Bryman, 2012; Ebneyamini et al., 2018; Fellows & Liu, 2015; Williamson, 2018). An Interview Process Flowchart was developed to guide the interview process, illustrating the decision-making pathway throughout the conversation (see Figure 2-2). The flowchart outlines how the interview progresses based on participants' responses, adapting the questions to their level of familiarity with the tools in the framework. While the interviews followed a predefined structure to validate the framework, focusing on tool usage, benefits, and implementation challenges, they also incorporated exploratory elements, such as detailed follow-up questions. This combination of structure and exploration enabled a deeper understanding of participants' perspectives while ensuring consistency across interviews (Bryman, 2012; Fellows & Liu, 2015; Maxwell, 2012; Williamson, 2018). Three distinct pathways were designed to gather information through targeted questions (see, Chapter 2, Figure 2-2). These pathways align with participants' levels of familiarity and actual usage of the tools within the framework, facilitating a structured data collection approach (Ebneyamini et al., 2018; Partelow, 2023). The first pathway is for those participants who recognised a tool and confirmed its use in a project. They were asked two questions: "Do you know this tool?" and "Are you using it on this project, and why?" This inquiry helped to clarify the reasons for selecting specific tools and their benefits. The second pathway is for those participants who did not initially recognise the tool but did so after viewing a video and were asked: "How do you use this tool?" This question aimed to uncover the practical applications for those less familiar with the tool's name. The third pathway was for those who did not recognise the tool and confirmed non-use after the video; five questions were posed to gauge perceptions about its necessity and implementation challenges in construction: "Why is this tool necessary for improving SC?" "What challenges might arise with its implementation?" "When is the best time to introduce this tool in the project lifecycle?" "Who should lead its implementation?" and "How will its adoption affect daily operations on construction sites?" These questions aimed to deepen understanding of the potential impacts of tool adoption in the construction industry. The questions were revised based on a pilot interview with an expert with more than 20 years of experience, with only minor changes made to the selection of questions and their wording. Engaging a single expert with extensive experience can provide valuable insights for refining research instruments (Kim, 2010; Lavrakas, 2008). The interviews were conducted face-to-face immediately after each of the four site visits, with a total of four interviews, one per site. Each interview was recorded using Microsoft Teams, which also provided automatic transcriptions for accuracy and ease of analysis, which also provided automatic transcriptions. The duration of the interviews ranged from 44 to 70 minutes. The transcriptions were sent to the interviewees for approval with a 10-day review period, during which no withdrawals occurred.

Figure 2-2

Interview Process Flowchart



The data collected through the interviews were analysed using thematic analysis, a method previously outlined in Phase 1 during the first round of the Modified Delphi study, to explore the tool usage, benefits, and implementation challenges (Braun & Clarke, 2006; Roseveare, 2023). Also, a cross-case synthesis data analysis method was used, comparing and integrating findings from the four case studies to gain a more comprehensive understanding of perspectives on the framework to help identify patterns, similarities, and differences across cases, confirming the repeatability and scalability of the results (Gray, 2014; Yin, 2018). Cross-case synthesis emphasises preserving the integrity and complexity of each individual case while analysing interactions and patterns across multiple cases, offering a more holistic understanding of the phenomena under study (Gray, 2014; Yin, 2018). The use of tools such as tables and matrices to organise data from multiple cases, facilitate visual comparisons, and aid in the identification of patterns and trends is commonly used (Yin, 2018). These tools streamline the analysis of case study data by making it easier to observe similarities and differences across cases (Gray, 2014; Yin, 2018). For this research, the cross-case synthesis of interviews involved examining each influential factor and the tools categorised under them (see Chapter 6, Tables 6-3, 6-4, 6-5, 6-6, 6-7, and 6-8). Responses were grouped based on participants' familiarity with and use of the tools. This comprehensive methodological approach allows for the consideration of the framework's applicability across various vertical projects in the New Zealand construction sector, aiming for analytic generalisation based on the insights gained (Gray, 2014; Yin, 2018). Also, the results were included in the informational report as part of the table content as "Case Studies Highlights", serving as feedback from four case studies (see Chapter 7).

A final part of Phase 4 involved the SUS survey (Brooke, 1995; Peres et al., 2013). The SUS survey serves as a tool to quantitatively assess participants' subjective perceptions of the framework's usability. The SUS survey is relevant for evaluating frameworks aimed at guiding decision-making, as it ensures that the assessment identifies usability strengths and areas for improvement (Brooke, 1995; Lewis, 2018). Furthermore, the SUS survey was used by Al-Bayati et al. (2024) to evaluate the perceived usability of an SC framework within the context of the United States construction industry. The SUS survey employs a 10-item, 5-point Likert scale, where responses range from "strongly agree" to "strongly disagree," providing a global view of usability related to a product or service (Brooke, 1995). According to Brooke (1995), who was the creator of SUS survey, the rationale behind using a 5-point Likert scale is rooted in its ability to provide a balance between ease of use for respondents and meaningful discrimination in responses (Brooke, 1995; Peres et al., 2013). The SUS survey includes 10 items, which are phrases or statements in the questionnaire that alternate between positive and negative phrasing (Brooke, 1995). This design balances shortness with comprehensive usability evaluation, minimising respondent fatigue and reducing response bias (Brooke, 1995; Peres et al., 2013).

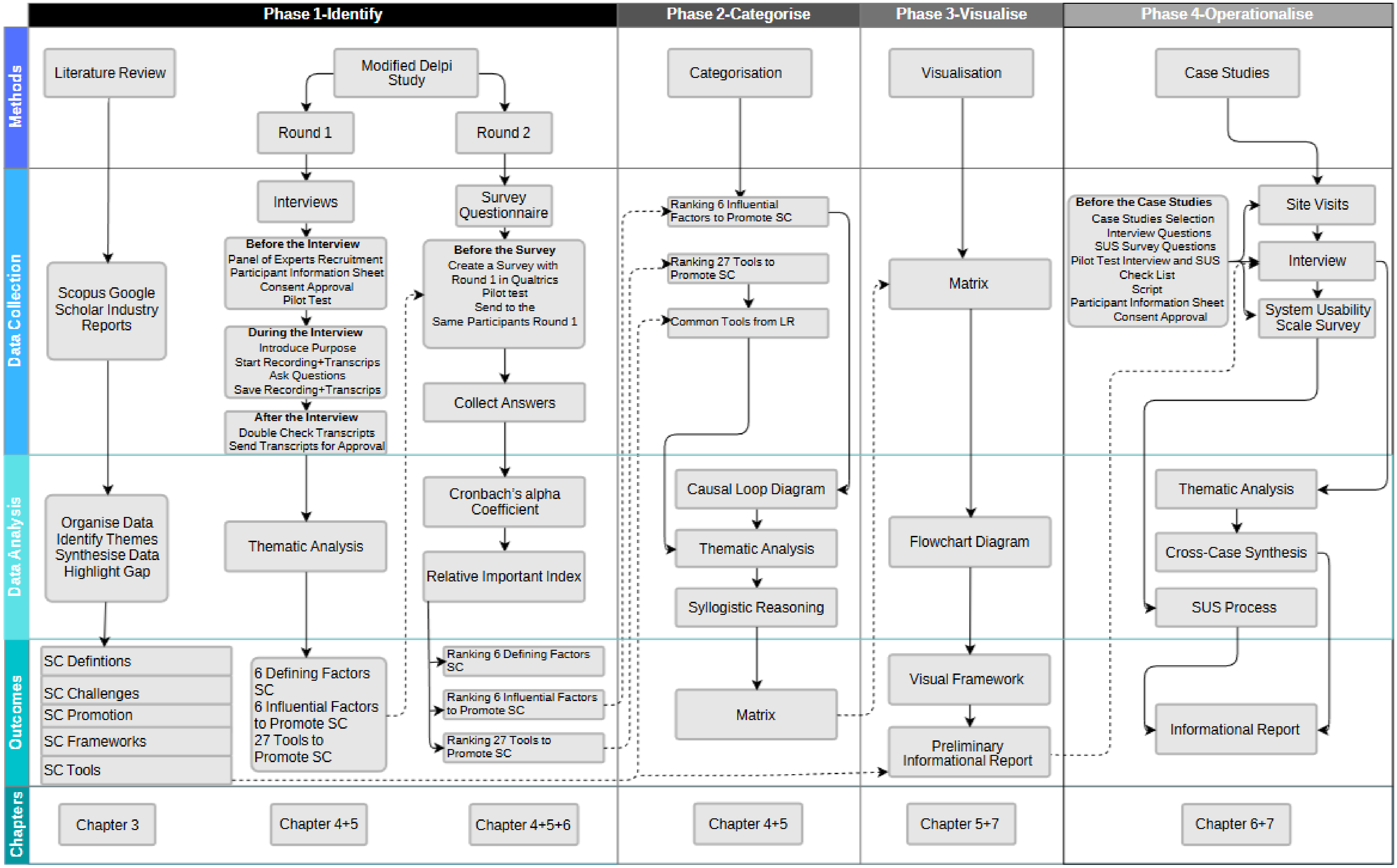
Therefore, the SUS survey was chosen for its efficiency, and adaptability, enabling the collection of quick, actionable feedback without requiring prior hands-on experience with the framework (Al-Bayati et al., 2024; Brooke, 1995; Lewis, 2018; Peres et al., 2013). While the SUS survey is typically recommended for use with 20-30 participants to achieve statistically significant results, smaller sample sizes can still yield valuable insights when the findings are interpreted cautiously (Brooke, 1995; Peres et al., 2013). In this study, responses were collected from the same four participants, who were interviewed during the site visits, providing a preliminary understanding of the framework's usability. The SUS survey was administered in a paper-based format and provided to participants immediately after the interview, taking approximately 10 to 15 minutes to complete, and responses were manually collected before being processed using Microsoft Excel (see Appendix 3, Table 7). Scores were calculated following Brooke's (1995) established process, ensuring consistency and accuracy. The scoring process involved adjusting each response based on the positive or negative framing of the question. For positively framed questions (odd-numbered), 1 was subtracted from the participant's response; for negatively framed questions (even-numbered), the response was subtracted from 5. The adjusted responses were summed across the ten questions, producing a total score between 0 and 40 for each participant. This total was then normalised by multiplying it by 2.5, scaling the score to a range of 0 to 100. The individual SUS scores were averaged to provide a group score, offering a single usability metric that reflects participants' overall perceptions of the framework usability (see Chapter 6, Figure 6-2). A SUS score above 68 is generally considered above average, while a score above 80 indicates excellent usability (Brooke, 1995; Lewis, 2018; Peres et al., 2013). The average SUS score from these four participants was 81.875, suggesting the participants generally found the framework to be user-friendly and satisfactory in terms of integrating the SUS survey, the study ensured a comprehensive usability evaluation, identification of usability challenges, and informed future refinements to enhance the framework's practical value (Al-Bayati et al., 2024; Brooke, 1995; Lewis, 2018). Detailed calculations and results for SUS survey can be found in Appendix 3, Table 7.

The four-phase methodological framework, Phase 1: Identify, Phase 2: Categorise, Phase 3: Visualise, and Phase 4: Operationalise, was structured to ensure that the research outcomes are grounded in data and truly reflect the practical realities faced in the field, making the findings both valid and applicable. These phases establish the steps that are further detailed in Chapters 4, 5, and 6.

A paper supporting aspects of this methodology was presented at the AUBEA 2024 conference, contributing to the academic discussion on SC frameworks. While not identical, this paper aligns with and reinforces key elements of the research approach used in this study. The full paper is available in Appendix 4.

Figure 2-3

Research Diagram Flowchart



Phase 1-Identify
Phase 2-Categorise
Phase 3-Visualise
Phase 4-Operationalise
Methods
Data Collection
Data Analysis
Outcomes
Chapters
Literature Review
Modified Delpi Study
Round 1
Round 2
Categorisation
Visualisation
Case Studies
Interviews
Survey Questionnaire
Scopus Google Scholar Industry Reports
Before the Interview
Panel of Experts Recruitment
Participant Information Sheet
Consent Approval
Pilot Test
During the Interview
Introduce Purpose
Start Recording+Transcrips
Ask Questions
Save Recording+Transcrips
After the Interview
Double Check Transcripts
Send Transcripts for Approval
Before the Survey
Create a Survey with Round 1 in Qualtrics
Pilot test
Send to the Same Participants Round 1
Collect Answers
Ranking 6 Influential Factors to Promote SC
Ranking 27 Tools to Promote SC
Common Tools from LR
Matrix
Before the Case Studies
Case Studies Selection
Interview Questions
SUS Survey Questions
Pilot Test Interview and SUS Check List
Script
Participant Information Sheet
Consent Approval
Site Visits
Interview
System Usability Scale Survey
Organise Data
Identify Themes
Synthesise Data
Highlight Gap
Thematic Analysis
Cronbach's alpha Coefficient
Relative Important Index
Causal Loop Diagram
Thematic Analysis
Syllogistic Reasoning
Flowchart Diagram
Thematic Analysis
Cross-Case Synthesis
SUS Process
SC Defintions
SC Challenges
SC Promotion
SC Frameworks
SC Tools
6 Defining Factors SC
6 Influential Factors to Promote SC
27 Tools to Promote SC
Ranking 6 Defining Factors SC
Ranking 6 Influential Factors to Promote SC
Ranking 27 Tools to Promote SC
Matrix
Visual Framework
Preliminary Informational Report
Informational Report
Chapter 3
Chapter 4+5
Chapter 4+5+6
Chapter 4+5
Chapter 5+7
Chapter 6+7

Chapter 3: Literature Review

3.1 Introduction

This literature review aims to synthesise knowledge about SC within the construction industry, with a particular emphasis on the New Zealand context. A comprehensive literature review was conducted to unravel the complexities of SC in construction, guided by the principles of systematic inquiry, ensuring that the review process is rigorous and comprehensive, and critical synthesis, ensuring that the findings are analytically rich, theoretically grounded, and practically relevant (Bryman, 2012; Kraus et al., 2022; Maxwell, 2012). Comprehensive literature reviews focus on understanding the meaning and context of phenomena, which is crucial when addressing concepts that are subjective and socially constructed. This type of literature emphasises the systematic integration of existing knowledge to identify research gaps and frame objectives. Such reviews contribute to advancing theoretical knowledge while offering actionable insights for practice, by synthesising existing knowledge and re-evaluating theoretical constructs to address emerging complexities in the study of SC (Kraus et al., 2022; Maxwell, 2012). This literature review provides the grounds for developing a comprehensive framework tailored to the construction sector's unique challenges of SC. The scope of this review involves an examination of the challenges to promoting SC alongside an analysis of definitions, factors, and tools that promote SC. Additionally, the review explores various theoretical and conceptual frameworks connected with SC.

The research process employed a systematic methodology, including searches of Scopus and Google Scholar databases and industry reports (Falagas et al., 2008; Guz & Rushchitsky, 2009). Keywords such as "safety culture," "frameworks," "factors," "tools," "construction industry OR construction sector", and "New Zealand" ensured broad coverage of relevant studies, as well as studies, like industry reports, specific to the construction sector (Bowen, 2009). Studies were selected based on their relevance to construction safety and the promotion of SC, with particular attention to theoretical and practical contributions (Kraus et al., 2022).

The review is structured around three core areas:

- Safety challenges and solutions in the international context, with a focus on New Zealand.
- Definitions, factors, and tools for promoting SC in construction.
- Exploration of theoretical and conceptual frameworks related to SC.

3.2 Literature Review

3.2.1 Safety Challenges in the Global Construction Industry

Gross Domestic Product (GDP), which measures the total economic output produced within a country’s borders, serves as an indicator for assessing the economic impact of the construction sector (Samuelson & Nordhaus, 2010). The construction industry contributes to the GDP of many nations, reflecting its vital role in infrastructure development, economic growth, and job creation (McCarthy, 2013; Samuelson & Nordhaus, 2010). By focusing on GDP, the economic contribution of the construction sector can be consistently evaluated and compared across different countries (McCarthy, 2013; Samuelson & Nordhaus, 2010). Globally, the construction sector contributed an average of 11.9% to GDP in 2013 and 13% in 2020, highlighting its role as a driver of economic growth worldwide (Annor et al., 2025; McCarthy, 2013). For instance, Bhutan’s construction sector contributes 38.7% of its GDP, while China’s 29.8% share underscores its emphasis on large-scale infrastructure projects (McCarthy, 2013). Conversely, Nigeria’s construction industry accounts for only 1.6% of GDP, indicating a different stage of economic development (McCarthy, 2013).

In New Zealand, the construction sector impacts the economy, contributing 6.3% to GDP and ranking as the fifth-largest industry, following four other industries that contribute more to GDP: professional, scientific, technical services, and manufacturing, each at 8.2%; owner-occupied property operation at 7.2%; and rental, hiring, and real estate services at 6.9% (BRANZ, 2024; Eaqub, 2024; MBIE New Zealand, 2024). These figures underscore the vital role of the construction sector in New Zealand while highlighting its position relative to other major industries. These variations highlight how the economic impact of the construction sector is influenced by national priorities, available resources, and levels of development (McCarthy, 2013; Samuelson & Nordhaus, 2010; Umeokafor et al., 2022). Understanding the construction sector’s contribution to GDP is relevant for policymakers and industry leaders as it enables them to target investments, and develop strategies to enhance productivity (McCarthy, 2013; Samuelson & Nordhaus, 2010).

The construction sector also plays a critical role in job creation, contributing to employment across various economies (McCarthy, 2013; Umeokafor et al., 2022). According to the International Labour Organisation (2021), the construction sector accounted for 7.7% of global employment (McCarthy, 2013); employment trends in the construction sector from 2012 to 2022 also confirmed an average employment contribution of 7% (Annor et al., 2025). The employment’s impact extends beyond direct employment on construction sites, as the sector supports numerous jobs indirectly through supply chains, material production, and related industries (Le et al., 2022; McCarthy, 2013). For the year ended March 2023, New Zealand’s construction industry employed 308,500 people, representing 10.7% of the total workforce (BRANZ, 2024; Eaqub, 2024). Despite the construction sector’s significant contributions to GDP and employment, it still faces persistent safety challenges, including poor risk management, unrealistic project forecasting, and inadequate communication, which often result in severe safety oversights, costly delays, and accidents (Basar & Basar, 2023; International Labour Organisation, 2021; KPMG, 2023).

In 1998, a report identified key areas for improvement in the United Kingdom's construction industry, highlighting the need for committed leadership, enhanced quality, and a stronger focus on customer satisfaction (Egan, 1998). It emphasised H&S as a critical area requiring urgent attention, pointing out that unsafe practices and poor working conditions negatively impacted productivity and workforce well-being (Egan, 1998). In 2016, another report from United Kingdom outlined systemic challenges such as low productivity, a lack of innovation, and a shrinking workforce in the construction industry (Farmer, 2016). The report called for the adoption of modern methods and technologies to secure the industry's future and underscored that improving H&S was vital for addressing these issues, as better safety standards contributed to workforce retention and project efficiency (Farmer, 2016). By 2021, H&S remained a global concern in the construction industry, the International Labour Organisation (2021) released a report showing that the construction sector continued to record higher rates of workplace injuries and fatalities compared to other industries such as agriculture, forestry, fishing, and manufacturing, which collectively accounted for 63% of all fatal occupational injuries worldwide (International Labour Organisation, 2021). The report highlighted globally the construction industry accounts for 30%-40% of all fatal occupational injuries, reinforcing the urgent need for enhanced SC (International Labour Organisation, 2021). Although these reports span decades, they collectively emphasise the continuing importance of addressing safety concerns to drive sustainable growth and improvement in the construction industry (Egan, 1998; Farmer, 2016; International Labour Organisation, 2021).

Bridging the focus on addressing safety concerns, the "Triple Bottom Line" (TBL) framework introduces a broader perspective by integrating social, environmental, and economic dimensions into sustainable growth strategies (Elkington, 1999). TBL underscores the importance of aligning H&S improvements with broader goals of sustainable development, ensuring that construction practices enhance economic performance, and contribute to social equity and environmental stewardship (Elkington, 1999). Building on this foundation, recent reviews have examined how the economic, environmental, and social pillars of the TBL have been conceptualised and applied in sustainable construction between 1997 and 2021 (Goh et al., 2019). Within the social pillar, where H&S is situated, H&S appears as a critical yet often underrated theme. These studies highlight that while economic and environmental considerations tend to lead, H&S remains inconsistently addressed in both theoretical frameworks and practical applications, signalling a need for better integration of H&S within contemporary sustainability discourse (Elkington, 1999; Goh et al., 2019). TBL approach aligns with global sustainability goals, such as the United Nations' Sustainable Development Goals (SDGs), particularly Goal 8 and Goal 3, which emphasise the promotion of sustained, inclusive economic growth, productive employment, and decent work for all, ensuring healthy lives and promote well-being for all at all ages (United Nations, 2015, Goal 8 and 3). By addressing H&S within the construction sector, organisations contribute to the United Nations Sustainable Development Goal 8 and Goal 3, while aligning with sustainability frameworks such as TBL (Elkington, 1999; United Nations, 2025).

Knowing the critical stages for hazard identification is integral to improving H&S practices in construction, it was found that 42% of hazards can be identified during the design phase of a construction project, while 58% are identified during the execution phase (Hardison & Hallowell, 2019). While improving design practices can help prevent a significant proportion of construction fatalities, a comprehensive approach during the execution phase is essential to reduce accidents and fatalities further (Choudhry & Fang, 2008; Hardison & Hallowell, 2019; Sherratt et al., 2011). Thus, reducing the number of on-site accidents is one of the goals of construction organisations to ensure the success of their projects and align with sustainability principles (Mohammadi & Tavakolan, 2020; Sawacha et al., 1999; Sherratt et al., 2011). Thus, this research project is focused on the execution phase of a construction project.

3.2.2 SC Definitions

A wide range of scholars have contributed to the conceptualisation of SC, reflecting the global importance and multidisciplinary nature of the topic (Choudhry et al., 2007). In this literature review, 40 distinct authors from 18 countries were reviewed. To illustrate the breadth of international engagement, examples include contributions from Australia (Lingard et al., 2010; Sherratt et al., 2013; Szabo et al., 2014), Malaysia (Abdullah & Wern, 2010; Misnan et al., 2008), the United States (Seo et al., 2004; Gillen et al., 2002; Chen et al., 2021; Molenaar et al., 2009), the United Kingdom (Wamuziri, 2006; Elkington, 1996), China (Zhou et al., 2008; Wu et al., 2010; Fang & Wu, 2013), and Hong Kong (Choudhry & Fang, 2008). This diversity underscores the breadth of international perspectives informing the development of SC theory and highlights the wide applicability of SC principles across geographic and industrial contexts.

The foundational works were of Turner (1978), Zohar(1980), and Perrow (1984). These three perspectives collectively underline the need for proactive SC initiatives that address latent risks, anticipate system-level failures, and foster a shared commitment to safety at all organisational levels (Bills et al., 2023; Perrow, 1984; Zohar, 1080). Turner’s Man-Made Disasters (1978), highlighted how organisational and socio-technical factors, such as poor communication, inadequate procedures, and cultural blind spots, can accumulate over time, creating latent conditions for accident (Bills et al., 2023). Similarly, Perrow’s Normal Accidents theory emphasised that in complex and tightly coupled systems, such as large-scale construction projects, failures are not only possible but inevitable, given the interdependencies and time pressures inherent in such environments (Perrow, 1984). Complementing these perspectives, that Zohar introduced the concept of safety climate, focusing on workers' shared perceptions of safety priorities within an organisation (Zohar, 1080). SC concept gained more traction and relevance after the Chernobyl disaster in 1986, an explosion in a nuclear power plant, one of the major safety failures, that marked a pivotal moment in recognising SC's importance within organisational contexts (Seo et al., 2015). The concept of SC emerged to promote safety, focusing on shared values, beliefs, and behaviours that prioritise the prevention of accidents and protecting people and the environment (Seo et al., 2015). SC has emerged as a critical factor in enhancing H&S performance within construction projects and organisations (Abdullah & Wern, 2012; Choudhry & Fang, 2008; Lingard et al., 2014; Sherratt et al., 2011). Given the critical role that SC plays in preventing incidents, SC has been extensively defined (Sherratt et al., 2025). The Advisory Committee on the Safety of Nuclear Installations (ACSNI) defines SC as "the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's H&S management" (Wamuziri, 2006). The definition highlights the multifaceted nature of SC, encompassing both individual and collective dimensions that contribute to an organisation's safety outcomes (Lingard et al., 2014; Wamuziri, 2006).

SC within construction projects is about fostering shared values, attitudes, and behaviours that prioritise safety across all levels of an organisation (Choudhry et al., 2007a; Deepak & Mahesh, 2021). SC encompasses the collective norms and beliefs that guide how individuals and groups approach H&S practices in their daily operations (Choudhry & Fang, 2008; Wu et al., 2017). Leadership plays a crucial role in shaping SC by establishing the values and perceptions that influence safety behaviours and ensuring these are consistently reinforced across various stakeholder levels (Wu et al., 2017). The holistic understanding highlights SC as a dynamic construct that integrates individual and group attitudes with organisational practices to enhance safety outcomes (Fang & Wu, 2013; Choudhry et al., 2007a). By embedding safety into the organisational culture, construction projects can build, promote, and maintain SC that fosters collaboration and accountability, ultimately improving H&S performance (Md & Mahesh, 2021; Wu et al., 2017). SC involves the shared values, beliefs, and behaviours that impact safety practices and decision-making within an organisation (Chen et al., 2017; Musonda et al., 2021). Therefore, investing in promoting SC reduces risks, enhances productivity, and ensures the sustainability of construction organisations (Abdullah & Wern, 2012; Choudhry & Fang, 2008; Lingard et al., 2014; Sherratt et al., 2011).

SC can be understood as a multifaceted construct influenced by national, organisational, and vocational cultures, shaped by intrinsic and extrinsic factors such as values, beliefs, norms, rituals, symbols, and behaviours (Misnan et al., 2008). It is not limited to abstract concepts but is operationalised through practical organisational enablers such as leadership, policies, partnerships, resources, and processes, which play an important role in achieving safety objectives (Mohamed & Chinda, 2011). Further refinement of SC concepts has identified key variables, including organisational commitment to safety, safety incentives, subcontractor involvement, accountability, and measures to discourage unsafe practices, all of which contribute to an organisational SC that enhances safety performance (Molenaar et al., 2009). Expanding SC understanding, the concept of a "Resilient SC" has been introduced to highlight the capacity of SC to withstand, recover from, and adapt to evolving challenges, emphasising the importance of resilience, continuous improvement, and adaptability in sustaining a strong SC (Trinh & Feng, 2020). By synthesising these perspectives, demonstrate that developing SC is about implementing concrete organisational strategies that enhance and maintain SC, ensuring sustained safety performance over time (Misnan et al., 2008; Molenaar et al., 2009; Trinh & Feng, 2020).

SC is widely recognised for its critical role in injury prevention, hazard identification, and risk mitigation, all of which contribute to fostering safer workplaces and reducing accidents (Al-Bayati et al., 2019; Gillen et al., 2004; Lingard et al., 2015, 2019). Despite SC's proven value, defining SC remains a challenge, as it encompasses various interpretations and factors depending on the context (Abdullah & Wern, 2012; Wamuziri, 2013; Zou, 2011). Research highlights the ambiguity surrounding SC within the construction sector, with studies revealing a lack of consensus on what SC precisely entails (Biggs & Biggs, 2013; Wamuziri, 2006; Otitolaiye et al., 2022). While some definitions emphasise shared values, norms, and behaviours, others focus on the role of organisational systems and leadership, resulting in varied and conflicting understandings (Choudhry et al., 2007; Sherratt et al., 2025; Szabo et al., 2023).

SC and safety climate are closely related but distinct concepts, with the former encompassing deeply rooted beliefs and practices, while the latter reflects more immediate perceptions of safety within an organisation (Harvey et al., 2020; Lingard et al., 2019). SC can be understood as a fundamental set of organisational beliefs and assumptions about safety, providing a stable foundation for long-term safety practices (Lingard et al., 2019). In contrast, safety climate serves as a tool to assess and enhance SC by capturing workers' shared perceptions of safety within their current environment (Lingard et al., 2019). Despite these distinctions, some scholars view the two concepts as overlapping, with Meliá (2015), Sizemore (2017), and Wu et al. (2016) often using them interchangeably. However, this PhD research and thesis treats SC and safety climate as separate, in line with Harvey et al. (2020) and Lingard et al. (2019).

Despite SC recognised importance, it remains a complex and often ambiguous concept within the construction sector, characterised by varying definitions and interpretations (Choudhry et al., 2007; Sherratt et al., 2025; Szabo et al., 2023). The persistent ambiguity underscores the need for a structured approach to help construction organisations effectively develop and promote SC, ultimately driving sustainable improvements in H&S performance (Elkington, 1999; Mohammadi & Tavakolan, 2020; Sawacha et al., 1999; Sherratt et al., 2011).

3.2.3 Promotion of SC

The challenge lies not only in the conceptual ambiguity of SC but also in the practical difficulties of promoting SC (Mohammadi & Tavakolan, 2020; Sherratt et al., 2025). Despite the recognised benefits of SC, promoting SC in construction remains a significant challenge, requiring cultivation at different levels, such as organisational and project levels (Choudhry et al., 2009; Sherratt et al., 2025). The effective implementation of any safety initiative, whether a new plan, policy, or tool, is influenced by the existing SC within an organisation or project (Abdullah & Wern, 2012; Bahn, 2012; Choudhry et al., 2009; Del Puerto et al., 2018; Namian et al., 2022; Machfudiyanto et al., 2020). SC challenges are not unique to the construction sector but are also prevalent in high-risk sectors such as healthcare, aviation, and manufacturing, where structured safety interventions and behavioural change mechanisms are essential (Butler et al., 2022; Hulme et al., 2021; Newnam et al., 2021).

Poor safety behaviours, such as neglecting to use personal protective equipment (PPE), bypassing safety measures, and failing to report hazards or participate in safety training, pose challenges to the development of SC and increase the likelihood of incidents on construction sites (Lingard et al., 2014; Biggs et al., 2005). However, a strong SC can effectively reverse poor safety behaviours by fostering accountability, promoting adherence to safety protocols, and empowering workers to prioritise safety in their daily tasks (Biggs et al., 2005; Dulaimi and Chin, 2009; Lingard et al., 2014; Machfudiyanto et al., 2019).

Promoting SC across the construction sector yields significant benefits, including a reduction in the frequency and severity of accidents and incidents (Asilian-Mahabadi et al., 2018; Choudhry et al., 2007a; 2014). Numerous studies highlight strong correlations between SC and improved safety outcomes (Schein, 2014; Sherratt et al., 2025). The relationship between fostering SC and reducing incidents is widely supported in the literature, though most studies highlight strong correlations rather than definitive cause-and-effect relationships (Lingard et al., 2014; Schein, 2014; Sherratt et al., 2025). For instance, Lingard et al. (2014) highlight that leadership plays a focal role in promoting safety values and fostering behaviours that boost safety performance, suggesting a robust link between SC and reduced incidents. Similarly, Biggs et al. (2005) report that leadership initiatives, such as clear communication and collaboration, are correlated with improved safety awareness by enhancing SC.

Dulaimi and Chin (2009) point out the role of leadership commitment in enhancing SC and safety performance, while Machfudiyanto et al. (2019) further focus on the contribution of proactive SC to improved safety. Collectively, these studies demonstrate the impact of SC on safety outcomes.

Understanding SC requires examining its interplay with social and organisational culture in the construction sector (Lingard et al. 2015, Setiawan & Sutrisna, 2010; Sherratt et al., 2025). Social culture encompasses the shared values, beliefs, and norms of the broader society, fostering inclusion, mitigating conflicts, and indirectly enhancing safety by promoting social cohesion within communities (Choi et al., 2015; Setiawan & Sutrisna, 2010). Organisational culture pertains to the specific values, practices, and behaviours within an organisation, shaping project outcomes, employee experiences, and safety practices by addressing cross-cultural differences (Choi et al., 2015; Setiawan & Sutrisna, 2010). Given the multicultural nature of construction workforces, Hofstede's cultural dimensions theory offers a useful lens for understanding how national cultural values, such as power distance, individualism versus collectivism, and uncertainty avoidance (Alsswey et al., 2022). While Hofstede's model was not directly applied in the development of this framework, as the focus was on sector-specific influencing factors and actionable tools identified through empirical methods, its principles remain relevant for interpreting and adapting the framework in future research in culturally diverse or international contexts (Alsswey et al., 2022). SC, a subset of organisational culture, focuses specifically on values, attitudes, and behaviours related to safety. It reflects the organisational commitment to minimising risks and protecting workers, and its development is influenced by both social and organisational culture (Biggs et al., 2005; Lingard et al., 2014). These concepts intersect, as societal norms provide the context for organisational practices, while organisations contribute to social culture through their influence on broader societal interactions, by understanding this interplay is important or fostering a productive, inclusive, safe, and adaptive construction environment (Choi et al., 2015; Setiawan & Sutrisna, 2010). In construction organisations, leadership plays a pivotal role in operationalising organisational culture, and in promoting SC, particularly in the project environments characteristic of the industry (Dulaimi and Chin, 2009).

The complexity of implementing SC remains in its reliance on the characteristics and constraints of each organisation and project (Schein, 2014). SC exists within an organisational and operational hierarchy, and that culture at the project level influences the implementation and sustainability of safety practices (Lingard et al., 2014; Schein, 2014). Unlike the organisational level, which sets overarching safety policies and values, the project level is where these policies interact with specific site constraints, making the project level a critical focal point for understanding how SC is promoted (Fang & Wu, 2013; Lingard et al., 2014). Tailoring safety strategies enables organisations to develop proactive, integrated approaches that promote SC (Schein, 2014; Sherratt et al., 2011). However, promoting SC requires a thorough understanding of organisational and contextual factors that influence SC success (Lingard et al., 2014; Schein, 2014).

Identifying the factors that contribute to both, unsafe and safe practices, is essential for establishing a strong SC (Abdullah & Wern, 2012). Collectively, the factors underscore the multifaceted nature of SC, and the challenges associated with its promotion, emphasising the importance of a comprehensive and tailor-made approach to enhance safety practices and outcomes in the construction sector (Abdullah & Wern, 2012). Since SC develops within a complex and dynamic environment, its formation and sustainability are influenced by multiple interrelated factors (Abdullah & Wern, 2012; Schein, 2014; Wamuziri, 2013).

Technological integration is one factor, that introduces both opportunities and challenges (Chen & Chang-Richards, 2022; Smith & Rybkowski, 2012). While automation and advanced safety equipment can reduce workers' exposure to hazardous tasks, these innovations often require new skills, effective implementation, and adaptation to changing site conditions to avoid creating additional risks (Emuze et al., 2024; Rocheleau et al., 2020; Wadley, 2021). Communication, safety education, and supervision are relevant factors in promoting SC (Lingard et al., 2020; Wu et al., 2016). Effective communication ensures clarity around safety practices, while education and training equip workers with the skills to identify and mitigate risks (Lingard et al., 2020; Wu et al., 2016). Strong leadership further strengthens SC by fostering open communication, encouraging workers to voice safety concerns without fear of retaliation, embarrassment, or negative consequences (Guadix et al., 2017; Kineber et al., 2023). Additionally, the construction sector's subcontracting model is another factor that challenges SC (Fuller et al., 2022; Musonda et al., 2021). The presence of multiple subcontractors with varying safety values and practices in the same projects often leads to coordination difficulties and inconsistent safety standards (Fuller et al., 2022; Musonda et al., 2021). Other factors, such as the uncontrolled and dynamic nature of construction sites and the technical complexity of projects, exacerbate challenges like inconsistent safety practices, difficulty in maintaining oversight, and increased risk of accidents due to rapidly changing conditions and intricate workflows (Fang & Wu, 2013; Orogun & Issa, 2016).

Another factor impacting SC is the analysis of accidents, hazards, and incidents, which provides valuable insights into safety challenges and highlights areas for improvement in safety practices (Machfudiyanto et al., 2019; Schein, 2014; Szabo et al., 2023; Wamuziri, 2006). Fostering a strong SC has been widely linked to improved safety outcomes and a reduction in workplace incidents (Lingard et al., 2014; Schein, 2014; Sherratt et al., 2025). Building on this foundation, organisations can further enhance SC by incorporating targeted safety strategies, which not only reduce accidents but also lead to cost savings, greater efficiency, and improved overall safety performance (Biggs et al., 2005; Dulaimi & Chin, 2009; Machfudiyanto et al., 2019). Globally, 30%-40% of occupational fatalities are attributed to construction, underscoring the persistent challenges in improving safety performance (International Labour Organisation, 2021). Worker behaviour and actions, such as neglecting the use of PPE, combined with environmental hazards like uneven terrain increase the likelihood of incidents such as the risk of trips, slips, and falls (Abdelhamid & Everett, 2000; International Labour Organisation, 2021). Falls alone represent 40% of all fatal injuries in the industry, with ladders and unprotected heights being the most common causes (Trueblood & Yohannes, 2024). Unsafe working conditions, including unguarded edges and improper scaffolding, are exacerbated by management oversights such as failing to enforce operating procedures or provide effective training (International Labour Organisation, 2021; Rafindadi et al., 2022; Trueblood & Yohannes, 2024). For instance, over two decades in the U.S., approximately 10,400 fall-related fatalities occurred, with over 3,120 attributed to insufficient use or inadequate functioning of fall protection equipment, and workers aged 35-54 accounting for 42.4% of fatal injuries, the highest proportion among age groups (Trueblood & Yohannes, 2024). Additionally, roadway incidents involving motorised land vehicles contributed to 13.9% of fatalities, while being struck by objects or equipment accounted for 8.2%, highlighting the diverse and significant safety risks in the US's construction sector (Trueblood & Yohannes, 2024). These findings underscore the interconnectedness of management practices, worker behaviour, and environmental conditions in shaping safety outcomes (International Labour Organisation, 2021; Rafindadi et al., 2022). By incorporating targeted safety strategies, organisations can strengthen SC, which is widely correlated with reducing accidents and improving safety outcomes (Schein, 2014; Sherratt et al., 2025). Although studies emphasise strong correlations rather than definitive cause-and-effect relationships between SC and accident reduction (Lingard et al., 2014; Schein, 2014).

The promotion of SC in the construction sector requires a thorough understanding of the factors specific to the context and project complexity that shape its development (Lingard et al., 2014; Schein, 2014; Sherratt et al., 2011). Addressing the factors to strengthen SC, minimise workplace incidents, and improve safety performance, which in turn enhances project efficiency, lowers costs, and supports the sustainable growth of the construction sector (Lingard et al., 2014; Machfudiyanto et al., 2019; Schein, 2014; Sherratt et al., 2025; Szabo et al., 2023; Wamuziri, 2006).

3.2.4 Challenges to Promoting SC in New Zealand

Although the construction sector in New Zealand plays a vital economic role, the sector faces persistent safety challenges that hinder its growth and sustainability (BDO, 2021; BRANZ, 2024; Deloitte, 2023; Eaqub, 2024; PwC New Zealand, 2016). Various reports and surveys produced by the government, industry associations, and consultancy firms have highlighted how operational inefficiencies and systemic issues within the New Zealand construction sector are deeply intertwined with safety performance, emphasising the critical need for targeted SC strategies to address these challenges and enhance H&S outcomes (BRANZ, 2024; Deloitte, 2023; Eaqub, 2024; NZCBIA, 2024). Overwork and inadequately trained workers face an increased risk of accidents, as the reliance on temporary labour often results in inconsistencies in safety training and adherence to established protocols (BDO, 2021; Deloitte, 2023). Additionally, resource constraints and labour shortages stretch the capacity of existing workers, leading to fatigue and reduced vigilance, which further undermine safety measures (BRANZ, 2024; Deloitte, 2023). Fragmented regulatory compliance and inconsistencies in applying the Building Code exacerbate these issues, creating gaps in safety standards across projects (BRANZ, 2024).

Inefficiencies in procurement practices, which can refer to flaws, delays, or mismanagement, or substandard materials, tools, or equipment, can contribute to safety risks directly affecting worker safety (Mosey, 2009; Deloitte, 2023). Traditional procurement routes often fail to integrate contractor expertise early enough, leading to inefficiencies, design errors, and safety risks (Nibbelink et al., 2017; Rahamni et al., 2015). Early Contractor Involvement (ECI) has significant potential to improve SC by integrating critical safety measures into the design phase, but its effectiveness is often undermined by unclear processes and accountability gaps (Deloitte, 2023; Mosey, 2009; PwC New Zealand, 2016). Without clear ECI practices such as establishing clear contractual frameworks and clearly defined roles, safety considerations are delayed until the construction phase, increasing the likelihood of hazards that could have been mitigated earlier (Mosey, 2009; PwC New Zealand, 2016). Inefficiencies in procurement practices, modularisation and standardisation, can further contribute to safety risks, as substandard materials or tools may be used during installation, directly affecting worker safety (Mosey, 2009; Deloitte, 2023).

Financial constraints represent another challenge to fostering SC in New Zealand's construction sector (Deloitte, 2023; NZCBIA, 2024). Builders often prioritise cost management over safety investments, relying on minimum compliance measures rather than proactive safety initiatives, leaving critical safety improvements unaddressed (NZCBIA, 2024). Additionally, the sector's cautious approach to innovation limits the adoption of advanced safety technologies (NZCBIA, 2024). Moreover, inflationary pressures and supply chain disruptions compound these challenges, as compressed timelines and reduced budgets force contractors to cut corners, often at the expense of safety (BDO, 2021).

Construction industry suicides by year fluctuated from 35 to 65 in New Zealand, experiencing disproportionately high levels of suicide, with rates approximately 1.4 times greater than those of men in other industries (Doran, 2024; Jenkin & Atkinson, 2021; Massey University, 2019). The risk is particularly acute among young men aged 20-24 years, who recorded a rate of 32.94 per 100,000, nearly double that of their peers outside construction (Jenkin & Atkinson, 2021). Māori are also overrepresented, accounting for 21.3% of suicides in construction compared to 16% in other industries (Jenkin & Atkinson, 2021). Beyond suicide, poor mental health and stress are increasingly recognised as critical challenges, extending beyond productivity concerns to serious health and well-being risks (van Heerden et al., 2021; WorkSafe New Zealand, 2024a). Stress within the sector has been closely linked to burnout, absenteeism, and suicidal behaviour, with evidence indicating that diminished well-being also heightens the likelihood of human error, unsafe practices, and workplace accidents (van Heerden et al., 2021).

By embedding SC into both, organisational and project-level practices, the construction sector can lay the foundations to enhance worker well-being, productivity, and overall competitiveness (BRANZ, 2024; NZCBIA, 2024). These interconnected challenges underscore the urgent need for changes to promote SC across the construction sector (BRANZ, 2024; Eaqub, 2024; NZCBIA, 2024). Addressing them through targeted SC strategies is essential to mitigate risks and improve H&S outcomes across the New Zealand construction sector sustainability (BDO, 2021; BRANZ, 2024; Deloitte, 2023; Eaqub, 2024; PwC New Zealand, 2016).

Workplace accidents in New Zealand's building construction sector highlight a critical need for safety improvements, emphasising the role of SC in mitigating risks and preventing incidents (Eaqub, 2024; Rout, 2023). The sector reports 22 severe injuries per 1,000 workers in 2024, a rate 70% higher than the national average across industries and 16% above that of Australia's construction sector (Eaqub, 2024).

Further insights from a survey in 2023, revealed a noticeable decline in H&S prioritisation, stressing the need for a stronger SC within New Zealand's construction sector (Rout, 2023). Among 2,494 employers surveyed, including 390, representing 2% of the total from the construction sector, only 57% of construction employers emphasised H&S as a priority in 2023, a 10-point drop since 2021 (Rout, 2023). Moreover, only 10% of employers fall into the "Care for Others" category, representing mature SC. Meanwhile, 37% remain in the "All Talk, Little Walk" category, indicating gaps between stated intentions and actual safety practices. Engagement in standard H&S practices, such as Toolbox Talks and regular safety meetings, is limited, with only 47% having processes to communicate safety issues, and only 42% holding regular safety meetings. The maturity of safety practices within construction organisations indicates room for improvement (BRANZ, 2024; Eaqub, 2024; NZCBIA, 2024).

The ethnic composition of New Zealand's construction workforce has been shifting since 2018. The proportion of European workers declined from around 77% to 66% by 2022, while Māori representation increased from 12% to 17%, Asian from 9% to 12%, and Pacific peoples from 4% to 6% (MBIE New Zealand, 2024). The growing inclusion of diverse societal groups, including women, who comprise only 15% of the workforce in New Zealand's construction sector, underscores a shift towards greater diversity in the industry (Eaqub, 2024; Hennecke et al, 2021; Rout, 2023). However, despite women experiencing lower rates of workplace injuries compared to men, they are more at risk of specific types of injuries, such as musculoskeletal injuries (Hennecke et al, 2021). The role of SC in achieving inclusive safety practices, emphasising the need for tailored interventions (Eaqub, 2024; Hennecke et al, 2021; Rout, 2023). Another significant challenge in New Zealand's construction sector is addressing the disproportionate impact of workplace injuries and fatalities on Māori and Pasifika workers, who constitute 17% and 6% of the construction workforce, respectively (MBIE New Zealand, 2024). While the injury rates, which are 103 and 100 claims respectively per 1,000 full-time employees, are based on all industries, they highlight a need for targeted safety interventions within construction to mitigate risks for these groups (Hennecke et al., 2021).

Horizontal and vertical construction represent two distinct facets of the construction sector, recognised both globally and within New Zealand (Brenner, 2015; Deloitte, 2023; Jayasinghe et al., 2023). Horizontal construction involves infrastructure projects such as bridges, roads, and highways, emphasising civil engineering. Vertical construction, on the other hand, refers to buildings and other vertical structures, which require considerations specific to architecture and urban development (Brenner, 2015; Jayasinghe et al., 2023). The characteristics of vertical construction contribute to a higher frequency of safety-related incidents. Vertical construction involves high-rise buildings, confined workspaces, structural complexity, and increased reliance on scaffolding, cranes, and temporary supports, which inherently elevate safety risks compared to horizontal projects (Jayasinghe et al., 2023). The structural challenges and sequencing constraints in vertical projects necessitate higher coordination among multiple stakeholders, which, if not managed properly, may contribute to greater safety risks (Jayasinghe et al., 2023). In contrast, horizontal construction projects often take place in open environments with different types of hazards related to traffic management and excavation activities (Jayasinghe et al., 2023). In New Zealand, trends related to vertical and horizontal construction are highlighted in reports such as Workplace Safety and the Future of Work by Hennecke et al. (2021). Incident data from October 1, 2022, to September 1, 2023, reveal that out of 600 reported incidents in the country's construction sector, 518 occurred within the vertical construction sector (Hennecke et al., 2021; WorkSafe New Zealand, 2024c). The difference in accident numbers between vertical and horizontal construction has influenced this research to focus on vertical construction projects as a critical area for promoting SC (WorkSafe New Zealand, 2024c).

Together, these reports highlight a wide range of challenges that hinder safety within New Zealand's construction sector, many of which are intertwined with the need for SC (BDO, 2021; BRANZ, 2024; Deloitte, 2023; Eaqub, 2024; PwC New Zealand, 2016). Overcoming these challenges requires informed safety decisions that prioritise and embed SC into every aspect of the construction sector, specially (Lingard et al., 2014; Schein, 2014; Sherratt et al., 2011).

3.2.5 Tools and Frameworks for Enhancing SC

Tools and frameworks for enhancing SC play a pivotal role in addressing the safety challenges faced by the construction sector, providing structured approaches and practical solutions to promote safer work environments and improve safety performance (Lingard et al. 2014; Misnan & Mohammed, 2007). By consolidating insights from previous studies, this section highlights existing tools and frameworks that have been identified in enhancing SC.

Tools are defined as specific mechanisms or instruments designed to achieve a particular goal, encompassing tangible items, actionable practices, practical applications, or organised initiatives, all of which are tailored to address specific needs or challenges and directly contribute to improving processes and outcomes within their intended context (Misnan & Mohammed, 2007; Schein, 2014; Merriam-Webster, n.d.). In the context of SC in the construction sector, the tools are designed to address specific safety challenges in a construction project (Sherratt et al., 2011; Lingard et al., 2014). The tools can have a direct impact on SC by fostering safer behaviours, enhancing communication, and improving hazard identification, or an indirect impact by creating an environment that supports better safety practices (Biggs et al., 2005; Lingard et al., 2014; Sherratt et al., 2011; Shein, 2014). To navigate the variety of tools available and target interventions to the challenges of SC, the tools were organised by their core functions, ensuring a practical application of tools within the construction sector (Goh & Askar, 2016; Misnan & Mohammed, 2007).

Leadership tools are mechanisms or instruments designed to help leaders foster SC by influencing behaviours, improving communication, and ensuring safety practices are consistently implemented (Indrayana & Pribadi, 2023; Misnan et al., 2008; Romero et al., 2019; Wu et al., 2016). Leaders play a pivotal role in shaping the SC of an organisation, as their behaviours and actions set the tone for safety practices at all levels (Khalid et al., 2021; Lestari et al., 2020). However, a lack of acceptance or commitment to leadership can lead to poor safety behaviours, undermining SC (Khalid et al., 2021; Lestari et al., 2020). Trust and open communication are viewed as operationalised tools in the leadership tools because they are values and also actionable practices that leaders can develop and implement to improve SC outcomes, encouraging transparency, allowing team members to share safety concerns without fear of retaliation, thereby fostering collaboration and empowering workers to engage in safety practices (Bisbey et al., 2019; Karanikas et al., 2022; SiteSafe, 2024). Toolbox Talks, short safety-focused meetings held regularly, reinforce SC by integrating safety discussions into daily routines, promoting active participation, and ensuring safety remains a visible priority (MacCollum, 2007; Sneddon et al., 2006; WorkSafe New Zealand, 2022b). Lean philosophy tools in construction are designed to enhance SC by reducing risks and improving performance by fostering a proactive approach to safety management (Barbosa et al., 2013; Emuze and Mpembe, 2021; Farzad and Cameron, 2019; Plugge et al., 2023; Rubio-Romero et al., 2019). Lean tool like "Last Planner System", improve safety by reducing inefficiencies and optimising processes, embedding SC into workflows through organisation and proactive task management (Barbosa et al., 2013; Bhagwat & Delhi, 2024). Another Lean tool, Poka-yoke systems, rooted in the concept of "mistake-proofing," aims to prevent human errors by designing processes and work environments in a way that eliminates or mitigates potential mistakes before they happen, where leaders encourage teams to integrate mistake-proofing into daily practices (Rubio-Romero et al., 2019). Similarly, lean visual management tools support SC by providing teams with real-time, visually accessible information about safety metrics, potential hazards, and project updates where leaders encourage team engagement with the information presented (Farzad and Cameron, 2019). However, despite the availability of effective tools, the Lean philosophy remains underutilised in the construction sector and has yet to achieve widespread integration (Emuze & Smallwood, 2014; Plugge et al., 2023). The success of technological tools is contingent on addressing common barriers, such as costs, worker resistance, and the need for infrastructure to support these innovations, and leadership promotion by illustrating the benefits (Chen & Chang-Richards, 2022; Ramadan et al., 2023; Rocheleau et al., 2020).

Behavioural tools are designed to influence how safety practices are understood, embraced, and maintained (Bisbey et al., 2019; Machfudiyanto & Latief, 2018). Continuous improvement in safety behaviour, paired with fostering a proactive mindset, significantly enhances safety outcomes on construction sites (Deepak & Mahesh, 2019). For instance, awards and incentive programs recognise and reward safe practices, motivating workers and fostering an environment where safety is prioritised, thereby embedding SC within team dynamics (Abdullah & Wern, 2012; Bao et al., 2024).

Technological tools that enhancing SC by addressing communication gaps, improving hazard recognition, and fostering proactive safety behaviours. For instance, safety applications offer real-time monitoring and hazard reporting via mobile devices, streamlining on-site safety management and enabling immediate communication (Liu et al., 2019; Rey-Merchán et al., 2021). Similarly, real-time safety control using electronic tablets provides immediate data access and incident monitoring, transforming safety management from reactive to proactive and cultivating a preventative safety mindset (Barbosa et al., 2013). Advanced systems like Real-Time Employee Monitoring Technologies (REMTs), and site access control ensure continuous oversight of workers' activities, emphasising accountability, adherence to safety protocols, and risk mitigation, which reinforces SC through vigilance (Nguyen et al., 2017; Wu et al., 2023). Immersive technologies such as virtual reality (VR) and augmented reality (AR) create interactive training environments that simulate realistic hazards in controlled settings, enhancing workers' hazard recognition and compliance with safety practices (Bao et al., 2024; Chen & Chang-Richards, 2022). Additionally, artificial intelligence (AI) augments safety efforts by predicting hazards, automating compliance monitoring, and enabling real-time decision-making, fostering a data-driven approach to safety management that supports the development of SC (Rabbi & Jeelani, 2024; Wu et al., 2022). Together, these technological tools promote behavioural changes and improve organisational safety practice (Chen & Chang-Richards, 2022; Ramadan et al., 2023).

Communications tools aim to address critical communication, cultural, and collaborative challenges within the construction sector, fostering a strong SC by promoting inclusivity, efficiency, and shared accountability (Lingard et al., 2019; Pandit et al., 2018). Language translation ensures clear communication across multicultural teams by converting safety protocols, signs, and technical specifications, which prevents miscommunication and ensures accurate understanding of safety requirements (Carlan et al., 2012; Del Puerto et al., 2018). Digital screens serve as dynamic platforms for real-time communication, displaying health and safety reminders and updates, thereby improving the accessibility of safety information for all workers (MBIE New Zealand, 2024; Tezel et al., 2015). Quick Response (QR) codes provide instant access to detailed safety protocols, project plans, and equipment manuals, fostering a proactive approach to safety management on-site (Chen et al., 2022; Galea et al., 2020). The use of QR codes assumes that site personnel have access to digital devices, whether supplied by the organisation or personally owned. To fully realise the benefits of this tool, organisations must address potential barriers by ensuring all workers have access to compatible devices and providing the necessary support (Chen et al., 2022; Galea et al., 2020). The colour-coded card system is a visual tool designed to simplify role identification, communicate safety messages, and improve clarity and operational efficiency across construction sites (Tezel et al., 2013; 2018). Implemented as physical cards, badges, or labels, these colour-coded markers are integrated into safety gear, equipment, or site signage to indicate roles, responsibilities, or statuses, ensuring instant visual recognition and minimising confusion (Tezel et al., 2018). These tools collectively enhance communication by addressing critical aspects of information delivery and accessibility, which impact in SC (Biggs et al., 2013; Del Puerto et al., 2018). Networking and knowledge sharing platforms, like knowledge-sharing sessions and structured networking activities, encourage collaboration and innovation, enabling professionals to exchange insights on safety practices and challenges, thereby building a culture of shared learning and continuous improvement (Lekchiri & Kamm, 2020; Love & Smith, 2016). Sharing Working Groups refer to collaborative forums where individuals, including contractors, subcontractors, and other stakeholders, come together to discuss work-related safety matters. These groups are typically site-based to address the immediate and practical safety challenges, ensuring that all participants, regardless of their organisational level or timing on the project, have a voice relevant to the project (Jaffe et al., 2016; Md & Mahesh, 2021). Safety Clubs are voluntary groups designed to promote safety awareness and facilitate knowledge sharing among workers and managers. Their aim is to create an inclusive platform where members can share safety experiences and best practices; membership or participation is typically open to anyone interested in contributing to or benefiting from the club's activities (Baiden et al., 2006; Bridges et al., 2020). Collectively, these initiatives foster a culture of collaboration inclusivity (Lingard et al., 2019; Pandit et al., 2018).

Resource allocation tools are needed to support financial commitment and planning to mitigate risks and promote SC (Bokor et al., 2019; Goh & Askar Ali, 2016; Oner & Saritas, 2005; Ramani et al., 2023). Early planning in construction activities for enhancing safety, is being achieved through tools like Discrete Event Simulation, Agent-Based Simulation, and System Dynamics (Bokor et al., 2019). Discrete Event Simulation models systems as sequences of distinct events occurring at specific points in time, helping to identify potential bottlenecks and inefficiencies in construction processes (Bokor et al., 2019). System Dynamics focuses on the behaviour of systems over time, emphasising the relationships and feedback loops between different components, being useful for understanding how various factors, such as workforce levels, safety policies, and incident rates, interact dynamically (Bokor et al., 2019). Agent-Based Modelling simulates the actions and interactions of autonomous agents, which can represent individuals, teams, or equipment in a construction setting, by modelling scenarios where individual actions significantly influence system outcomes (Bokor et al., 2019). By employing these simulation techniques, safety practitioners can predict potential issues, evaluate the effectiveness of safety interventions (Bokor et al., 2019; Ramani et al., 2023). Another tool is the balanced scorecard, a performance management tool that provides a structured approach to measure and improve safety performance by translating organisational goals into actionable metrics across four key perspectives: management, operational, customer, and learning (Kaplan & Norton, 1996). Within the context of SC in construction, the balanced scorecard offers a comprehensive mechanism to align resource allocation with safety objectives, ensuring that safety initiatives are prioritised alongside operational and financial goals (Dulaimi and Chin, 2009; Haseeb et al., 2014; Mohamed, 2003).

Industry fragmentation, involving multiple contractors, subcontractors, and stakeholders with varying standards and practices within a single project, necessitates tools that promote integration, transparency, and accountability among these diverse parties (Gibson, 2015; Nguyen et al., 2017; Shin et al., 2022). Tools like recording systems and documentation mechanisms are used to capture, monitor, and manage safety-related data, ensuring transparency and accountability by documenting routine safety checks, incidents, and compliance with safety protocols (Gibson, 2015; Nguyen et al., 2017; Shin et al., 2022). Regular audits and safety compliance mechanisms ensure that projects adhere to recognised safety standards, which include on-site inspections and documentation reviews, identifying areas for improvement and alignment with regulations (Rabbi & Jeelani, 2024; WorkSafe New Zealand, 2015, 2017a). Tools such as Accident Mapping (Accimap), the Swiss cheese model, causal loop diagrams, the Human Factors Analysis and Classification System, and the Systems-Theoretic Accident Model and Processes analyse complex systems to identify both active and latent failures (Igene & Johnson, 2020; Leveson N, 2004; Salmon et al., 2012). These tools adopt a holistic approach, grounded in systems thinking, to understanding and mitigating risks in construction environments (Boardman & Sauser, 2013; Goh et al., 2010; Zhang et al., 2022). Tools such as induction-prestart meetings and safety committees facilitate open communication and collaboration among contractors, subcontractors, and stakeholders (Harvey et al., 2020; Musonda et al., 2021; Ness, 2012; Rowlinson & Jia, 2015). These tools establish shared safety expectations, distribute responsibilities, and align efforts across fragmented teams (Bahn, 2012; Choudhry & Fang, 2008; Rowlinson & Jia, 2015; Asilian-Mahabadi et al., 2018). Additionally, the Safety Climate Assessment Toolkit (SCAT), a survey-based tool designed to gather insights into employee perceptions of safety-related policies, practices, and procedures, provides a structured way to assess how safety is perceived and prioritised. Similarly, the Safety Training Observation Program (STOP), helps to identify the cause of unsafe behaviours, and the Nordic Occupational Safety Climate Questionnaire is also a survey, that evaluates employees' perceptions across various dimensions of safety, such as management commitment, worker involvement, and communication (Darvishi et al., 2015; Guadix et al., 2017; Kwon et al., 2021; Probst et al., 2019). These tools collectively address the challenges posed by industry fragmentation by fostering integration and aligning safety practices and perceptions across contractors, subcontractors, and workers (Farrell & Sunindijo, 2020; Wu et al., 2016).

A framework serves as a structured representation that connects a series of concepts to facilitate understanding, guide empirical inquiry, and establish a foundation for theoretical or practical advancements (Partelow, 2023; Rocco & Plakhotnik, 2009). Theoretical frameworks provide an overarching explanation of phenomena grounded in established theories, offering a lens through which research questions are examined and interpreted. Conceptual frameworks, on the other hand, focus on the relationships between specific concepts, serving as a guide for organising ideas and identifying variables within a study. Frameworks act as mediators, bridging concepts, theories, and paradigms to organise and communicate knowledge effectively.

There are a variety of frameworks related to SC that are applicable across various contexts (Bisbey et al., 2019; Partelow, 2023; Vierendeels et al., 2018). These include general frameworks, which are broadly applicable across industries and focus on universal aspects of SC, such as safety climate dimensions and risk mitigation (Bisbey et al., 2019; Vierendeels et al., 2018). Specific construction frameworks address challenges and requirements of the construction sector, providing actionable recommendations and strategies for embedding SC into construction practices (Al-Bayati et al., 2019; Misnan and Mohammed, 2007). Additionally, regionally tailored frameworks are designed to meet the specific needs of construction industries in particular countries, focusing on context (Alasamri et al., 2012; Ismail et al., 2010; Machfudiyanto and Latief, 2018).

The general framework by Bisbey et al. (2019) identifies seven enabling factors like leader commitment and prioritisation of safety, policies and resources for safety, group cohesion, psychological safety, safety knowledge, employee sense of control, and individual commitment to safety, which help employees adopt SC norms and values. It also outlines four behavioural enactments, which refers to observable actions or behaviours, like communication and information flow, teamwork and collaboration, incident reporting, and fair rewarding and punishing, that reinforce or revise SC through feedback loops. The framework emphasises SC as a dynamic, socially constructed phenomenon that evolves over time through multilevel influences, such as organisational policies, team behaviours, and individual learning. Similarly, Vierendeels et al. (2018) present the Egg Aggregated Model (TEAM), which integrates safety-related factors like behaviour, technology, training, and procedures into a cyclic framework. This model focuses on continuous feedback between safety dimensions, enabling organisations to assess and improve SC proactively.

Frameworks specific to the construction sector have been presented by (Al-Bayati et al., 2019; Misnan & Mohammed, 2007). For instance, the framework by Misnan and Mohammed (2007) emphasises the critical role of leadership and training in fostering a proactive SC. Leadership is identified as central to influencing worker attitudes and promoting a shared commitment to safety, while training serves as a mechanism to inspire safety as an organisational value. Similarly, Al-Bayati et al. (2019) developed a construction-specific framework that distinguishes between management safety and site safety. The management safety factor reflects the influence of upper management and safety personnel in shaping organisational SC through policies and resource allocation, while the site safety factor captures the safety climate demonstrated at the project level by frontline supervisors and workers. These examples illustrate that SC is integrated into practices at both organisational and site levels (Lingard et al., 2014; Schein, 2014).

In addition, the characteristics of the geographical location can play a role. Example of regional-country specific frameworks developed for Indonesia, Malaysia, and Saudi Arabia are presented in Table 3-1, highlighting differences in their objectives, methodologies, and validation processes.

Table 3-1

Comparative Analysis of Regional SC Frameworks in the Construction Sector

	Alasamri et al. (2012). Saudi Arabia	**Ismail et al. (2010). Malaysia**	**Machfudiyanto and Latief (2018). Indonesia**
Purpose	Enhancing SC by incorporating a unique organisational (top management) component to address specific safety challenges in Saudi Arabia.	Developing a framework for consistently quantifying and analysing SC within Malaysian construction companies.	Integrating policy, institutional factors, and SC development at various organisational levels.
Methodology	Based on literature reviews and adaptations of existing models to fit the Saudi context.	Employs preliminary and main surveys, semi-structured interviews, and expert validation to measure psychological, behavioural, and situational safety factors.	This includes a literature study, deductive analysis, and expert validation to develop and ensure the conceptual framework's appropriateness.
Key Elements	This includes safety climate, safety management systems, safety behaviour, and an additional focus on top management's role.	Psychological factors, behavioural practices, and situational conditions affecting SC.	SC dimensions include cultural behaviour, norms, management, physical culture, and ideology.
Validation/Implementation	The framework was designed as part of ongoing research aimed at improving SC on Saudi construction sites. It has not yet been fully implemented.	The framework was validated through semi-structured interviews with industry experts and safety professionals. It was also tested using a combination of surveys and interviews with	The framework was validated by expert reviews. However, practical implementation data were not explicitly discussed.

		construction organisations in Malaysia.	
Main Outcomes	Integrated psychological (safety climate), behavioural (safety behaviour), situational (safety management system), and organisational factors (top management support).	Identified five critical factors for embedding SC: leadership, organisational commitment, management commitment, safety training, and resource allocation.	Demonstrated that policies and institutional factors are essential for improving SC at national, organisational, and project levels. Provided a structured approach to integrating SC into project processes.

As shown in Table 3-1, while all three frameworks provide structured approaches to defining SC in their local contexts, the degree of validation varies. Some, such as the Malaysian framework by Ismail et al. (2010), underwent empirical testing through interviews and surveys with industry professionals. Others, like those from Saudi Arabia (Alasamri et al., 2012) and Indonesia (Machfudiyanto & Latief, 2018), remain primarily theoretical or were validated only through expert review, without being operationalised in live construction environments. This study adopted multiple cross-sectional case studies across four active vertical construction sites in New Zealand to collect in-depth, context-rich data (Shanks & Bekmamedova, 2018; Yin, 2018). This approach was proven to enable the collection of practical insights through induction, semi-structured interviews, and surveys with key stakeholders (Yin, 2018) in this research.

When selecting a way to validate the usability of a framework, it is essential to consider the specific usability aspects to measure and the context in which the tool will be applied (Partelow, 2023; Rocco & Plakhotnik, 2009). A survey instrument ensures that the assessment identifies the most suitable tools, resulting in reliable and relevant data to guide targeted improvements to the framework's usability (Partelow, 2023). Three questionnaires, namely SART, USE and SUS, have been considered suitable for evaluating usability, each with distinct purposes and characteristics (Partelow, 2023; Rocco & Plakhotnik, 2009). The Situational Awareness Rating Technique (SART) assesses situational awareness across three dimensions, which are attentional demand, supply of attention, and understanding of the situation, using 10 items, with sample sizes of 20-30 participants recommended for robust statistical analysis (Taylor, 2011). The Usefulness, Satisfaction, and Ease of Use (USE) questionnaire evaluates usability, satisfaction, and ease of use through 30 questions divided into four sections: usefulness, ease of use, ease of learning, and satisfaction (Lund, 2001). USE is effective for both small initial tests with 5-10 participants and larger studies for detailed insights (Lund, 2001). Finally, the System Usability Scale survey (SUS) provides a comprehensive usability score through 10 alternating positive and negative items (Brooke, 1995). The SUS survey is valued for its efficiency and versatility, requiring a minimum of 5 participants for initial tests, though 20-30 participants are preferred for meaningful results (Brooke, 1995; Peres et al., 2013). The SUS survey concept was previously discussed in Chapter 2, Section 2.3.4, where the "Operationalise" phase was introduced as a crucial step in the research framework. For instance, Al-Bayati et al. (2024) employed the SUS survey to evaluate a proposed construction SC framework, highlighting its ability to provide quick and reliable usability measurements.

The reviewed frameworks predominantly emphasise theoretical constructs and lack alignment with industry practices by providing specific, tangible tools and strategies that address practical needs (Sherratt, 2011, 2025; Schein, 2014). Sherratt (2025) highlights the importance of pragmatic methodologies to address the fragmented and overly conceptual nature of SC.

This chapter provides a broad theoretical foundation on SC, tools, and influencing factors, drawn from both international and local research. These insights were not only foundational but also directly shaped the development of the data collection instruments and the structuring of the analytical framework. Chapters 4, 5, and 6 were built upon this foundation by integrating phase-specific literature references. This design ensured that the empirical findings remain grounded in the existing body of knowledge, while also reflecting the contextual realities of the New Zealand construction sector.

3.3 Summary

The construction sector plays a pivotal role in economic development, contributing significantly to GDP and employment globally and in New Zealand (McCarthy, 2013; BRANZ, 2024; Eaqub, 2024). However, persistent safety challenges, including high injury rates and fatalities, underscore the urgent need for improved safety practices, emphasised by reports from the United Kingdom and international organisations (Basar & Basar, 2023; Egan, 1998; Farmer, 2016; International Labour Organisation, 2021; KPMG, 2023). Furthermore, frameworks such as the Triple Bottom Line (TBL) highlight the importance of aligning safety improvements with social, environmental, and economic goals, directly supporting the UN's Sustainable Development Goals, particularly Goal 3 (Good Health and Well-being) and Goal 8 (Decent Work and Economic Growth), by promoting safer, healthier, and more equitable workplaces (Elkington, 1999; United Nations, 2025).

Making a turning point after the 1986 Chernobyl disaster, SC was recognised as an essential concept in organisational contexts to prevent accidents and protect people and the environment through shared values, beliefs, and behaviours (Seo et al., 2015). In construction, SC is about fostering shared values and behaviours prioritising safety at all organisational levels (Choudhry et al., 2007a; Deepak & Mahesh, 2021). Leadership is pivotal in shaping SC by reinforcing safety values and perceptions across stakeholders (Wu et al., 2017). By embedding SC into organisational culture, construction projects can promote collaboration and accountability, improving H&S performance (Md & Mahesh, 2021; Wu et al., 2017). SC involves shared norms and practices that influence decision-making and safety outcomes, reducing risks, enhancing productivity, and ensuring organisational sustainability (Chen et al., 2017; Musonda et al., 2021). SC is influenced by national, organisational, and vocational cultures, shaped by intrinsic and extrinsic factors like values, norms, rituals, and behaviours (Misnan et al., 2008). SC is operationalised through leadership, policies, partnerships, resources, and processes that support safety objectives (Mohamed & Chinda, 2011). Variables such as organisational commitment, subcontractor involvement, and measures to discourage unsafe practices further refine SC (Molenaar et al., 2009). These perspectives underline the importance of implementing practical strategies to enhance SC (Misnan et al., 2008; Molenaar et al., 2009; Trinh & Feng, 2020). Despite its proven value, SC remains a complex and ambiguous concept in construction, with varied definitions and interpretations (Abdullah & Wern, 2012; Wamuziri, 2013; Zou, 2011). Given SC's recognised importance and complexity, there is a critical need for a structured approach to help construction organisations effectively develop and promote SC. This would drive sustainable improvements in H&S performance and address the persistent ambiguity surrounding the concept (Elkington, 1999; Mohammadi & Tavakolan, 2020; Sawacha et al., 1999; Sherratt et al., 2011).

Promoting SC in the construction sector presents significant challenges due to its conceptual ambiguity and the practical difficulties of implementation (Mohammadi & Tavakolan, 2020; Sherratt et al., 2025). The promotion of SC significantly reduces the frequency and severity of accidents, with numerous studies linking SC to improved safety performance (Asilian-Mahabadi et al., 2018; Sherratt et al., 2025). Leadership plays a critical role in promoting SC by fostering safety values and behaviours, with strong communication and collaboration contributing to improved safety awareness (Biggs et al., 2005; Dulaimi & Chin, 2009; Lingard et al., 2014). However, the literature often highlights correlations between SC and safety outcomes rather than definitive cause-and-effect relationships (Schein, 2014; Lingard et al., 2014).

SC exists within the broader context of social and organisational cultures, which shape safety practices and outcomes. Social culture promotes inclusion and cohesion, indirectly enhancing safety, while organisational culture directly influences project outcomes and safety behaviours (Choi et al., 2015; Setiawan & Sutrisna, 2010). Promoting SC requires addressing the unique characteristics and constraints of each organisation and project (Schein, 2014). Key factors influencing SC include leadership, technological integration, communication, education, supervision, and subcontracting models (Chen & Chang-Richards, 2022; Lingard et al., 2020). Promoting SC in construction requires a comprehensive understanding of the context-specific factors that shape SC development. By addressing these factors, organisations can strengthen SC, minimise workplace incidents, and improve project outcomes, contributing to the sustainable growth of the construction sector (Lingard et al., 2014; Sherratt et al., 2025; Szabo et al., 2023).

New Zealand's construction sector faces significant safety challenges, including operational inefficiencies, resource constraints, and inconsistent safety standards, which increase accident risks (BDO, 2021; BRANZ, 2024). Reliance on temporary labour, fragmented regulations, and financial constraints hinder proactive safety strategies and the adoption of advanced technologies (NZCBIA, 2024). Diversity adds complexity, with women facing musculoskeletal risks and Māori and Pasifika workers experiencing disproportionately high injury rates (Hennecke et al., 2021; MBIE New Zealand, 2024). Addressing these challenges requires embedding SC across all industry levels to improve safety, productivity, and sustainability (Lingard et al., 2014; Sherratt et al., 2011). Frameworks bridge concepts, theories, and paradigms, facilitating knowledge organisation and communication, providing structured representations to connect concepts, guide research, and support theoretical or practical advancements (Partelow, 2023; Rocco & Plakhotnik, 2009).

Tools in the context of SC in construction are mechanisms or practices designed to address safety challenges, having direct impacts, such as fostering safer behaviours and improving hazard identification, or indirect impacts by creating environments that support better safety practices (Biggs et al., 2005; Lingard et al., 2014; Sherratt et al., 2011). While tools provide actionable strategies to promote SC, their implementation presents several challenges. Leadership tools require strong commitment and trust (Bisbey et al., 2019; Karanikas et al., 2022). Behavioural tools, such as incentives, need careful design to avoid fostering short-term compliance rather than genuine cultural change (Abdullah & Wern, 2012). Technological tools, while transformative, face barriers such as high costs, worker resistance, and insufficient infrastructure, particularly on smaller or resource-constrained projects (Chen & Chang-Richards, 2022; Nguyen et al., 2017). Communication tools must account for language barriers, and access to digital devices, which can vary significantly across diverse construction teams (Chen et al., 2022; Lingard et al., 2019). Similarly, resource allocation tools, such as simulation models, require expertise and data availability, which can limit their applicability (Bokor et al., 2019). Integrative tools face the challenge of industry fragmentation, where coordination across multiple contractors and subcontractors with varying safety standards is complex (Farrell & Sunindijo, 2020; Wu et al., 2016). Addressing these challenges to implement tools requires selecting the right tools, also tailoring their implementation to the specific context, fostering leadership commitment, and ensuring accessibility and inclusivity across the workforce to achieve sustained improvements in SC (Chen & Chang-Richards, 2022; MacCollum, 2007; Sneddon et al., 2006; Ramadan et al., 2023).

Several SC frameworks cater to diverse contexts. General frameworks, like those by Bisbey et al. (2019) and Vierendeels et al. (2018), focus on universal aspects such as leadership, group cohesion, and feedback loops, viewing SC as a dynamic, multilevel construct. Construction-specific frameworks, such as those by Misnan and Mohammed (2007) and Al-Bayati et al. (2019), emphasise leadership and training, integrating SC at both organisational and project levels. Region-specific frameworks address local challenges, such as leadership in Saudi Arabia (Alasamri et al., 2012), SC quantification in Malaysia (Ismail et al., 2010), and policy integration in Indonesia (Machfudiyanto & Latief, 2018). While these frameworks are context-sensitive and validated through expert input, practical implementation often remains limited. While existing frameworks provide theoretical insights, they often lack alignment with practical industry needs. Sherratt (2025) highlights the importance of developing pragmatic methodologies to address fragmented and overly conceptual SC frameworks, ensuring their relevance to real-world construction challenges (Sherratt, 2011, 2025; Schein, 2014).

Chapter 4: Investigating the Factors that Define and Influence SC: Perspectives from Expert Professionals

This chapter is based on the following manuscript, published in the Architecture, Structures and Construction journal.

Ortega, N., Paes, D., Feng, Z., Sutrisna, M.,Wing Yiu, T. (2025). Investigating the Factors that Define and Influence SC: Perspectives from Expert Professionals. *Architecture, Structures and Construction*.

Abstract

Reducing the number of harmed workers in the construction sector has proven to be a challenging task. While promoting a Safety Culture (SC) is crucial for achieving that goal, defining it and pinpointing the key factors that influence it is difficult. SC has been defined in many different ways, and there is no consensus on what it exactly entails. Therefore, this study aims to investigate the factors that define and influence SC in the New Zealand construction sector. This goal was achieved through a Modified Delphi study conducted in two rounds to gather experts' views and reach a consensus. Data collection included in-depth interviews and survey questionnaires. A total of 32 experienced construction safety professionals participated in the first round, and 26 of them continued in the second round. Data were analysed using Thematic Analysis and relative importance index (*RII*). The main findings are twofold. First, they indicate the need for a holistic definition of SC incorporating its various defining factors. Second, they indicate that the top-ranked influencing factors are "Level of Leadership Commitment," followed by "Level of Experience and Mindset," and "Level of Communication." Furthermore, the results show the dual nature of these influencing factors, as they can either facilitate or hinder SC depending on whether their level is low or high. The results of this study offer valuable insights that enable practitioners to assess and promote SC in their organisations.

Keywords: Construction Industry, Safety Culture, Critical Factors, Delphi Study, Safety Experts

4.1 Introduction

Safety is one of the main factors affecting labour productivity in the construction sector (Hasan et al., 2018), and the lack of health and safety (H&S) competencies is one of the reasons for skills shortages in the industry, impacting the retention of young workers (Musonda & Okoro, 2021; Ni et al., 2022). As per Gambatese and Hinze (1999), 42% of hazards can be identified during the design phase of a construction project, while 58% can be identified during the execution phase. Thus, reducing the number of on-site accidents is one of the main goals of construction organisations to ensure the success of construction projects (Mohammadi & Tavakolan, 2020).

Promoting SC across the sector can help reduce both the frequency and severity of accidents and incidents (Asilian-Mahabadi et al., 2018; Choudhry, 2007a, 2014). A positive SC needs to be cultivated at both the organisational and project levels (Choudhry et al., 2009; Del Puerto et al., 2018; Gao et al., 2015; Namian et al., 2022; Zhou et al., 2015). The implementation of any new safety plan, policy, or tool is significantly influenced by the prevailing SC (Abdullah & Wern, 2012; Bahn, 2012; Sukamani et al., 2021).

Nonetheless, promoting SC in the construction industry has always been challenging (Del Puerto et al., 2018; Machfudiyanto et al., 2020), particularly during the execution phase on construction sites (Abdullah & Wern, 2012). Choudhry et al. (2007a), Fang and Wu (2013), Feng (2013), and Hartley and Cheyne (2009) argue that fostering SC at the project level can enhance the safety performance of organisations. However, Schein (2014) highlights that each organisation must implement its own SC programs tailored to its unique characteristics and constraints.

The construction industry is responsible for 30 to 40% of workplace fatalities (Rafindadi et al., 2022). In New Zealand, a report published by Eaqub (2024) provides alarming statistics about workplace accidents. In 2022, the sector employed 200,000 workers and led in work-related injury claims, with over 33,000 cases of muscular stress from lifting, carrying, or placing objects being a primary cause of these claims (Stats New Zealand, 2021; WorkSafe New Zealand, 2022a). This represents a significant increase from the lowest registered number of work-related injury claims, which was 26,000 in 2011 (WorkSafe New Zealand, 2022c). Furthermore, there were 12 fatalities in both 2021 and 2022 (WorkSafe New Zealand, 2022d). Despite the Harm Reduction Action Plan (ACC, 2018), which aims to achieve a sustained reduction in worker harm, reaching this goal has proven challenging. Another recent BRANZ report (2024) highlighted significant systemic challenges that intertwine economic pressures with safety outcomes in New Zealand's construction industry (BRANZ, 2024). Many builders have to juggle between maintaining high-quality standards and managing costs, opting to meet the minimum safety legal requirements due to budget constraints, impacting the overall quality and safety performance of construction projects. Also, there is a need for tailored safety protocols to accommodate physical limitations due to New Zealand's aging workforce. Native-born workers are found to have lower rates of injuries than migrant workers in New Zealand (Rout, 2023). Māori and Pasifika workers experience higher rates of work-related injuries compared to other ethnic groups (Rout, 2023). These multifaceted issues underscore the critical need for a holistic approach to SC to enhance both safety and competitiveness in New Zealand's construction sector.

A thorough bibliometric analysis by Otitolaiye et al. (2022) revealed that despite growing research on the topic, the concept of SC in the construction industry remains ambiguous (Biggs & Biggs, 2013; Wamuziri, 2006). Identifying the factors that define and influence SC is essential for gaining a better understanding of how to effectively promote it (Schein, 2014). Therefore, the objective of this research is to address this gap by investigating and establishing a consensus on (a) the factors that define SC (hereafter referred to as "defining factors") and (b) the factors that influence SC (hereafter referred to as "influencing factors"). By identifying the defining and influencing factors of SC, this study aims to enhance understanding of the concept and offer valuable insights for professionals to promote it within New Zealand's construction sector.

4.2 Background

4.2.1Safety Culture Definitions

The concept of safety culture was first introduced after the Chernobyl disaster in 1986 (Seo et al., 2015). It relates to the set of shared values, expectations, and beliefs that impact a group's health and safety behaviour (Chen et al., 2017; Musonda et al., 2021). The Advisory Committee on the Safety of Nuclear Installations (ACSNI) defines the SC of an organisation as "the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's health and safety management" (Wamuziri, 2006). Wu et al. (2017) defined SC as the shared values, perceptions, and behavioural norms set by leadership and shaped by their actions across various stakeholder levels within construction projects. Choudhry and Fang (2008), Choudhry et al. (2007a), Deepak and Mahesh (2021), and Fang and Wu (2013) defined SC as a blend of safety attitudes, beliefs, values, behaviours, and norms shared by persons and groups in a construction project.

Harvey et al. (2020) and Lingard et al. (2019) provide a distinction between SC and safety climate, stating that while SC covers rooted beliefs and practices, safety climate refers more to perceptions of safety. More specifically, Lingard et al. (2019) defined SC as a fundamental set of beliefs and assumptions regarding safety within an organisation, distinguishing it from safety climate, which they describe as a tool to enhance SC by reflecting workers' shared perceptions of safety in their environment. However, some authors, such as Meliá (2015), Sizemore (2017), and Wu et al. (2016) view the two concepts as similar, often using them interchangeably.

Misnan et al. (2008) defined SC as a hierarchy of national, organisational, and vocational culture manifested by intrinsic and extrinsic factors such as values, beliefs and assumptions, norms, rituals, symbols, and behaviours. Mohamed and Chinda (2011) presented a holistic definition of SC, emphasising the role of various organisational enablers such as leadership, policy and strategy, partnerships and resources, people, and processes. These enablers are essential for ensuring effective operations and achieving safety objectives within an organisation (Mohamed & Chinda, 2011). Similarly, Molenaar et al. (2009) identify five latent variables that define corporate SC, including an organisation's commitment to safety, incentives for safe performance, subcontractor involvement, safety accountability, and disincentives for unsafe behaviours. These authors offered a comprehensive, holistic view for defining and better understanding of SC within organisations. More recently, Trinh and Feng (2020) introduced the concept of Resilient Safety Culture, which refers to an organisational commitment to safety through resilience, continuous improvement, and adaptability.

As evident from the studies above, SC has been defined in various ways. The current definitions in the literature are often vague, and there is no clear consensus on what SC precisely entails, leading to confusion (Abdullah & Wern, 2012; Schein, 2014; Zhou et al., 2015).

4.2.2 Safety Culture Factors

Identifying the factors (see Table 4-1) that contribute to both unsafe and safe practices is essential for establishing a strong SC (Abdullah & Wern, 2012). Hudson (2007) proposed a model based on the Health, Safety, and Environment (HSE) Culture ladder for the continuous advancement of SC and the creation of lasting behavioural change. This model outlines stages progressing from pathological behaviour in a low-information, low-trust, and low-accountability environment to generative behaviour in an environment characterised by high levels of information, trust, and accountability. Fang and Wu (2013) developed a model where the person, the behaviour, and the environment are related, considering external factors and internal psychological factors that impact SC.

In general, communication, safety education and training, and supervision have been identified as key factors in promoting a safe environment (Lingard et al., 2020; Wamuziri, 2013; Wu et al., 2016; Zhang et al., 2020). Other factors related to organisational structure and commitment to safety were also found to influence SC (Brett & Bradley, 2008; Namian et al., 2022, 2024). Furthermore, commitment to safety should be promoted by encouraging the active involvement of all employees rather than being enforced solely through rules and procedures (Fred & Farrell, 2008; Schwatka et al., 2016). Developing an organisational culture that values safety as a core principle is essential (Machfudiyanto & Latief, 2019; Wamuziri, 2013).

One of the factors affecting the successful implementation of H&S promotion programs is the construction sector's subcontracting model (Zou et al., 2007). The contractual model's complexity, combined with the lack of coordination among stakeholders, makes it challenging to implement, manage, and follow up on health and well-being initiatives (Fuller et al., 2022; Namian et al., 2022). Having so many subcontractors on the same job site is a factor that needs to be considered because they may affect each other's SC as they come to the project with their particular beliefs, expectations, safety values, policies, and procedures (Fuller et al., 2022; Musonda et al., 2021). Other aspects unique to the construction sector, such as the environment and the technical complexity of projects, also impact SC (Orogun & Issa, 2016; Trinh & Feng, 2020). The uncertainties of an uncontrolled environment and the overall dynamic nature of the sector affect SC (Fang & Wu, 2013; Orogun & Issa, 2016). In addition, the challenge of addressing differences in risk perception related to workers' ethnicity and cultural background adds complexity to safety promotion (Ricci et al., 2020).

Another factor to consider is leadership from supervisors, who should encourage construction personnel to voice safety concerns without fear of retaliation, consistently reinforce safety reminders on the job (Kineber et al., 2023; Shen et al., 2017), keep workers informed of policies and procedures, provide clear safety guidelines (Kineber et al., 2023; Mazzetti et al., 2020), and provide personalised interventions tailored to individual worker characteristics (Guadix et al., 2017; Lingard et al., 2015; Solomon & Esmaeili, 2021).

Table 4-1

Factors that Affect Safety Practices

Factors	Authors
Environmental factors and individual behavioural factors	Hudson (2007)
Environmental factors and individual psychological factors	Fang and Wu (2013)
Communication, safety education and training, and supervision	Lingard et al. (2020), Wamuziri (2013), Wu et al. (2016), Zhang et al. (2020)
Organisational structure and commitment to safety	Brett & Bradley (2008), Machfudiyanto & Latief (2019), Namian et al. (2022, 2024), Wamuziri (2013)
Commitment to safety	Fred & Farrell (2008), Schwatka et al. (2016)
Subcontracting model	Fuller et al. (2022), Musonda et al. (2021), Zou et al. (2007)
The technical complexity of projects	Orogun & Issa (2016), Trinh & Feng (2020)
The uncertainties of an uncontrolled environment	Fang & Wu (2013), Orogun & Issa (2016)
Differences in risk perception	Ricci et al. (2020)
Leadership from supervisors	Guadix et al. (2017), Kineber et al. (2023), Lingard et al. (2015), Mazzetti et al. (2020), Shen et al. (2017), Solomon & Esmaeili (2021),

Collectively, these factors underscore the multifaceted nature of SC and the challenges associated with its promotion, emphasising the importance of a comprehensive and custom-made approach to enhance safety practices and outcomes in the construction sector (Abdullah & Wern, 2012).

4.3 Methods

This study adopts an exploratory methodology, incorporating both qualitative and quantitative methods. The methods include a Modified Delphi study conducted in two rounds to gather experts' responses through in-depth interviews and survey questionnaires (described in detail in section 4.3.2). Data were analysed using Thematic Analysis and *RII* (described in detail in section 4.3.3).

The Modified Delphi method was considered the most appropriate tool in light of the research aim, as it allows for reaching a consensus on the factors that define SC and those that influence it based on the views and perceptions of experienced construction safety professionals. The Modified Delphi method is an adaptation of the traditional Delphi method, following specific guidelines designed to facilitate consensus-building over two rounds of interaction with at least 10 experts with more than three years of experience in the field (Mullen, 2003). The Delphi method offers several advantages: it maintains the anonymity of panel members to minimise potential bias, accommodates geographically dispersed participants and groups, and enables the collection of diverse insights from numerous experts (Mullen, 2003; von der Gracht, 2012). It involves collecting qualitative and quantitative data through rounds of focus groups, individual meetings, or surveys (either online or in-person), where experts can provide feedback, modify, or add more elements to the topics under discussion (Allison et al., 2017; McKay et al., 2022). While the traditional Delphi method typically involves three or more rounds of interaction (Biggs et al., 2013; Nayak & Jespersen, 2022), the modified version requires only two rounds and a minimum of 10 experts (Linstone & Turoff, 1975; McKay et al., 2022; von der Gracht, 2012). Therefore, adopting a Modified Delphi method shortens the process, ensuring sustained participant involvement (McKay et al., 2022). It should be noted, however, that the modified method requires that 75% of the experts who participate in the first round also join in the second round (Biggs et al., 2013; Mullen, 2003; von der Gracht, 2012).

4.3.1 Participants

In accordance with the guidelines outlined above, the expert panel was composed of professionals with over three years of experience in H&S and Project Management (PM) within the New Zealand construction sector (Mullen, 2003; Nayak & Jespersen, 2022). The recruitment process began by sending invitation emails to 217 industry contacts from the School of Built Environment (Massey University) and 258 cold contacts from LinkedIn, all of whom met the eligibility criteria. Furthermore, the snowball sampling technique was employed to expand the list of prospective participants who also met the inclusion criteria (Lavrakas, 2008).

Ultimately, exceeding the requirements of the Modified Delphi study (Biggs et al., 2013; Mullen, 2003; von der Gracht, 2012), 33 experts were recruited. In the first round, 33 individual online interviews were conducted. However, one expert withdrew before their interview transcript was approved, leaving 32 experts who consented to participate and approved their interview transcripts. Of these, 26 (81%) advanced to the second round, which consisted of an online survey.

On average, the experts had 14 years of professional experience. Experts who did not participate in Round 2 (survey) are marked with an (*) in Table 4-2. All personal information was de-identified. The study plan was reviewed and approved by Massey University's Ethics Committee (Ethics notification number: 4000027113).

Table 4-2

Participants Details

Expert ID#	Role	Years of Experience
1	Director	10
2	Head of HR	6
3*	Quantity Surveyor	16
4	Technical Director – Structural Engineering	20
5	Director	8
6	Business Support Manager	5
7*	Quantity Surveyor	22
8	Regional H&S Manager	3
9*	Site Manager	20
10	National HSEQ Manager	10
11	Principal Engineer	13
12	Project Manager (Civil)	22
13	HSW Manager	10
14	Site Manager	15
15	Senior Project Manager	12
16	Principal Project Manager	10
17	H&S Manager	15
18	Project Director	40
19	CEO	25
20	Senior H&S Advisor	11
21	H&S Manager	7
22*	Chair of H&S Organisation	25
23	HSEQ Advisor	20
24	Risk Manager	10

25	H&S Associate	6
26	Transformation Lead (People) Construction Sector	40
27	Chartered H&S Professional	6
28*	Senior H&S Advisor	5
29	Head of EHS	8
30*	Construction Manager	3
31	CEO	30
32	H&S Innovation Manager	21

4.3.2Data Collection Methods

4.3.2.1 Modified Delphi Method – First Round (Interviews)

Round one consisted of in-depth, semi-structured, online, individual interviews conducted with the panel of experts (Biggs et al., 2013). These interviews consist of semi-structured formal dialogues in which an interviewer asks questions, and the respondent provides answers. They are known as an effective technique for assessing attitudes, subjective experiences, perceptions, and values (Braun & Clarke, 2006; Lavrakas, 2008). The two open-ended questions were designed based on the study's objectives, namely, identifying the factors that define SC and those that influence it.

Pilot interviews were conducted with five experts to detect and resolve potential issues before running the actual interviews (Johanson & Williamson, 2017). The pilot interviews help reduce errors in data collection that are not related to the sample but instead arise from issues within the questions. These errors could include unclear terms, biased wording, or misunderstandings by respondents. By conducting pilot interviews, these potential issues can be identified and corrected, improving the accuracy and reliability of the interview (Lavrakas, 2008).

In summary, the two questions were designed to gather experts' views and perceptions on the factors that define SC and those that influence it, as outlined below:

- Question 1 (defining factors): Based on your experience, how would you define safety culture?
- Question 2 (influencing factors): What are the main barriers, obstacles, or impediments to promoting a safety culture?

After conducting the pilot interviews, the second question was revised to replace the term "factors" with "barriers, obstacles, and impediments," as these terms were found to be more easily understood by industry professionals. Based on the barriers, obstacles, and impediments mentioned, it was possible to identify the influencing factors.

During September 2023, a total of 32 interviews were conducted via Microsoft Teams. With participants' approval, the sessions were recorded and transcribed. By digitally signing the consent form, participants were notified about the confidentiality of the interview and the anonymity of their responses. The duration of the interviews ranged from 7 to 43 minutes, depending on the participant's willingness to share and elaborate on their responses.

4.3.2.2 Modified Delphi Method – Second Round (Survey)

Round two involved an assessment of the importance of the factors identified through the thematic analysis of the interviews (Biggs et al., 2013; Braun & Clarke, 2006). This evaluation was conducted using an online survey questionnaire based on a Likert scale, which allowed experts to rate the importance of the factors (Norman, 2010; Lavrakas, 2008).

The survey questionnaire consisted of two clusters of items. The first cluster comprised six items related to the defining factors. The scale for this cluster ranges from 1 (less important) to 4 (very important). The second cluster comprised six items related to the influencing factors, with responses ranging from 1 (less important) to 5 (very important). In summary, the twelve items were designed to gather experts' assessments of the importance of the defining factors and the influencing factors identified through the thematic analysis of the interviews, as shown in Table 4-3.

Table 4-3

Survey Questionnaire

Cluster 1 (defining factors) Likert scale range: 1 (less important) – 4 (very important)	
a)	*Collaboration and Communication*: open two-way communication and engagement between management and workers, where individuals can express their concerns without fear.
b)	*Leadership and Responsibility*: setting an example while encouraging self-leadership and liability, where individuals take initiative and responsibility for safety matters. Responsibility for safety is shared among everyone in the organisation, including management, workers, and contractors.
c)	*Human-Centred Approach*: behaviours and interactions that promote a sense of belonging and inclusion within the SC.
d)	*Integration and Organisation*: SC, as an inherent part of the organisation, is deeply integrated into its operations, balancing productivity with a focus on the health, well-being, and protection of workers rather than mere compliance with safety regulations.

e)	*Foundational Principles*: commitment, consistency, and continuous improvement in safety practices, exercising a deep sense of care, complying with safety standards and regulations, and exercising individual and collective responsibility.
f)	*Resource Allocation and Prioritisation*: safety is given equal importance alongside other project parameters, such as time, cost, and quality. This involves allocating the necessary resources for safety practitionership and professional development.
Cluster 2 (influencing factors) **Likert scale range: 1 (less important) – 5 (very important)**	
a)	*Client Understanding*: clients lack an understanding of the importance of H&S.
b)	*Communication*: cultural differences and language barriers in the workplace can lead to misunderstandings and a lack of engagement.
c)	*Industry Fragmentation*: aligning safety objectives and setting standardised safety practices across multiple subcontractors is a challenging task.
d)	*Leadership Commitment*: lack of leadership support can hinder the development of a strong SC, underscoring the need for commitment from leadership.
e)	*Experience and Mindset*: inadequate attitudes and beliefs often result in failure to recognise the importance of safety. Lack of proper training exacerbates the problem.
f)	*Resource Allocation*: failure to allocate the necessary funds for safety initiatives results in poor safety performance. Excessive paperwork and high costs exacerbate the problem.

A pilot survey was conducted with two experts, who recommended minor adjustments to ensure consistency across items. Then, the final survey questionnaire was distributed via the online survey platform Qualtrics, and participants accessed it through individual email links. The survey was conducted for approximately one month (November 2023), during which participants received two reminders. A total of 26 experts participated in this round, representing 81% of the first-round sample.

4.3.3 Data Analysis Methods

To manage potential biases that could arise during the Modified Delphi study, several strategies were adopted. First, a diverse panel of 32 experts was selected to ensure a wide range of perspectives. Second, experts were interviewed and completed the survey individually to prevent influence from the views of others (Mullen, 2003; von der Gracht, 2012). Additionally, they were informed about the confidentiality and anonymity of their responses. Finally, the responses were analysed using Thematic Analysis and the *RII*, ensuring consistent and objective interpretation of the data (Braun & Clarke, 2006; Opoku et al., 2020; Seidu et al., 2022; Tarek et al., 2022).

4.3.3.1 Interviews

To analyse the data from round one (interviews), a thematic analysis was conducted following the systematic approach outlined by Braun and Clarke (2006). The data were organised thematically using NVivo version 14, a software application that allows for structuring qualitative, content-rich textual data (Galea et al., 2020). The analysis process began by reading the interview transcripts to gain a deep understanding of the content. Preliminary patterns were noted during this stage. Next, codes were generated by labelling segments of text that were relevant to the study's objectives. These codes were then grouped into broader categories to identify recurring patterns, leading to the definition of initial themes. These themes were subsequently reviewed and refined by merging similar ones. Ultimately, six themes were identified and assigned specific titles.

4.3.3.2 Survey

To analyse the data from round two (survey), the *RII* technique and statistical analyses using the software SPSS version 29 were employed, as follows.

First, Cronbach's alpha (α) was calculated to check the reliability of the questionnaire and results. It is a measure of internal consistency that ranges between 0 and 1. An alpha above 0.6 generally indicates a moderate level of reliability, while values closer to 1 suggest higher internal consistency among the items of a scale (Opoku et al., 2020). Cronbach's α for the first and second clusters of items are 0.655 (N=6) and 0.773 (N=6), respectively, both of which are considered adequate (Opoku et al., 2020).

Second, the *RII*s were calculated. The *RII* is a measure used to assess the relative importance of different factors based on respondents' ratings. It is commonly employed in survey-based research where multiple factors contribute to a broad concept. The indices are calculated by assigning numerical values to participants' ratings and computing the average score for each factor. This allows for ranking and identifying the most crucial factors according to expert perceptions (Seidu et al., 2022; Tarek et al., 2022). As such, the defining factors (the first cluster of items in the questionnaire) and the influencing factors (the second cluster of items in the questionnaire) were ranked based on their *RII*.

The *RII*s are calculated using Equation 1:

$$RII = \frac{Total\ weight\ given\ to\ each\ factor\ by\ the\ respondent}{The\ highest\ weight\ \times\ Total\ number\ of\ respondents} = \frac{W1 + W2 + \ldots + Wn}{A \times N}$$

In Equation 1, "*W*" represents the weight assigned to each factor by the respondents and ranges from 1 to 4 or 1 to 5, corresponding to the Likert scales described in section 4.3.2.2. "*A*" denotes the highest possible weight (i.e., 4 or 5), and "*N*" is the total number of respondents, which is 26.

4.3.3.3 Causal Loop Diagram

Lastly, to depict the relationships between SC, its influencing factors, and their respective barriers, a Causal Loop Diagram (CLD) was created. CLDs are qualitative diagrams widely employed for illustrating systems dynamics and the feedback loops between various factors (Bala, 2017; Sherwood, 2022; Sterman, 2000).

The CLD was submitted for validation to address potential biases introduced by the researcher or misinterpretation of data. This validation was carried out through an interview with one expert, during which questions were posed about the coherence of the diagram and whether any essential elements were missing, highlighting any necessary adjustments (Cassidy et al., 2022; Meadows & Wright, 2008).

4.4 Results

In this section, the results related to the defining factors are derived from the thematic analysis of interview responses to Question 1 (first round) and *RII* analysis of survey responses to the first cluster of six items (second round). In turn, the results related to the influencing factors are derived from the thematic analysis of interview responses to Question 2 (first round) and *RII* analysis of survey responses to the second cluster of six items (second round).

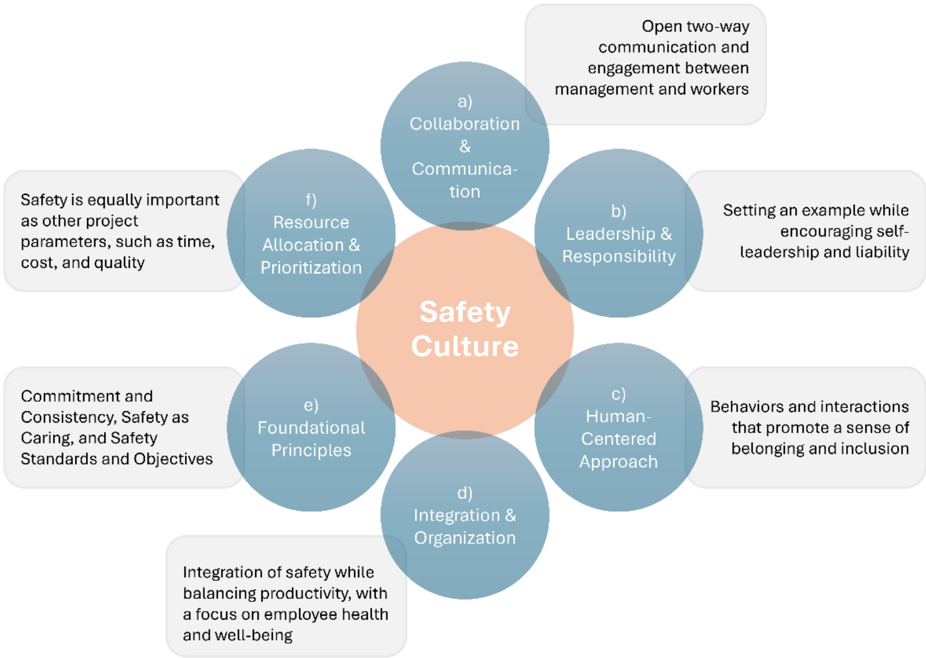
4.4.1 Safety Culture Defining Factors

4.4.1.1 Results of Thematic Analysis (Interviews)

The thematic analysis of interview responses (first round) identified six defining factors (see Figure 4-1).

Figure 4-1

Factors that Define SC



a) Collaboration and Communication

This factor indicates that SC requires open two-way communication and engagement between management and workers, where individuals can express their concerns without fear. Expert ID07 emphasised the need to ensure that everyone is aware of safety requirements and proactively takes measures to ensure safety. ID16 highlighted that SC is a shared attitude that should permeate all levels of an organisation. ID17 stressed the need for safety to be accepted and practiced at every level, with enforcement and promotion by the management team. ID25 discussed the role of relationships and information sharing in shaping SC, with an emphasis on how safety information is communicated.

b) Leadership and Responsibility

This factor indicates that SC involves setting an example while encouraging self-leadership and liability, where individuals take initiative and responsibility for safety matters. Responsibility for safety is shared among everyone in the organisation, including management, workers, and contractors. Expert ID06 discussed the need for building a culture that prioritises the health and well-being of all individuals. ID09 mentioned the influence of rewards and incentives in shaping SC. ID11 highlighted the role of management in promoting safety. ID12, however, emphasised the top-down implementation of SC from top management to workers. At the same time, ID13 underscores the trickle-down effect, where safety-related decisions and policies made by the top management gradually influence employees at lower levels over time. ID15 mentioned the importance of a people-driven SC, which needs to be fostered by project leaders, main contractors, and site leadership.

c)Human-Centred Approach

This factor indicates that SC relies on behaviours and interactions that promote a sense of belonging and inclusion within the SC. The frontline workers are essential to SC, and their understanding and support are crucial. Expert ID26 emphasised the importance of the competence of operators, planners, supervisors, and senior management in building SC. ID28 highlighted the need for engagement and understanding of safety from both top management and workers.

d) Integration and Organisation

This factor indicates that SC is an inherent part of the organisation, deeply integrated into its operations, balancing productivity with a focus on the health, well-being, and protection of workers rather than mere compliance with safety regulations. Expert ID06 pointed out that it takes time to integrate SC into an organisation's ethos. ID11 highlighted the importance of safety networks and acknowledged the omnipresence of risks in every aspect of work. ID31 elaborated on the relationship between organisational culture and safety, emphasising the need for clear values and outcomes, as well as the integration of safety principles into every aspect of the business.

e) Foundational Principles

This factor indicates that SC is based on some underlying principles: Commitment and Consistency (continuous improvement in safety practices), Safety as Caring (exercising a deep sense of care), and Safety Standards and Objectives (complying with safety standards and regulations). ID02 mentioned safety as caring and acknowledged the importance of recognising and complying with safety standards. ID04 stated that safety is a way of life, requiring everyone in the company to follow safety procedures to protect themselves and others. ID08 stressed the importance of ensuring that people go home safely at the end of the day. ID12 underscored the need for education on SC within the company. ID15 highlighted the significance of regular monitoring and inspections, safety software applications (apps), and forum discussions. ID20 emphasised the need for open and respectful communication between workers and management to build trust. ID24 underlined the importance of prioritising safety within an organisation. ID29 defined SC as the day-to-day practices within a business or site. ID32 placed a strong emphasis on prioritising safety.

f) Resource Allocation and Prioritisation

This factor indicates that SC means safety is given equal importance alongside other project parameters, such as time, cost, and quality. This involves allocating the necessary resources for safety leadership and professional development. Expert ID18 emphasised the importance of safety planning and management, stating that safety must be treated with the same level of importance as other project parameters. ID24 mentioned that a good SC involves prioritising safety over profit, with CEOs and managing directors championing safety initiatives. ID26 stressed the importance of integrating risk management into every aspect of the business. ID32 mentioned the importance of tracking safety metrics and performance to highlight safety matters within an organisation. ID31 stated that safety deserves top priority within an organisation.

4.4.1.2 Results of Relative Importance Index Analysis (Survey)

The *RII* analysis of survey responses (second round) found that, among the six defining factors (identified in the first round), “Collaboration and Communication” led with a *RII*=1. The unanimous agreement among all experts (26 out of 26) indicates that “Collaboration and Communication” are essential constituent elements of SC. These are followed by “Leadership and Responsibility” (*RII*=0.97), “Human-Centred Approach” (*RII*=0.94), “Integration and Organisation” (*RII*=0.90), “Foundational Principles’ (*RII*=0.89), and “Resource Allocation and Prioritisation” (*RII*=0.88) (see Table 4-4).

Table 4-4

RII and Ranking of the Factors that Define SC

Factor	1 Less important	2 Slightly important	3 Moderately important	4 Very important	*RII*	Rank
Collaboration and Communication	0	0	0	26	1.00	1
Leadership and Responsibility	0	0	3	23	0.97	2
Human-Centred Approach	0	0	6	20	0.94	3
Integration and Organisation	0	2	6	18	0.90	4
Foundational Principles	0	1	9	16	0.89	5
Resource Allocation and Prioritisation	0	3	6	17	0.88	6

4.4.2SC Influencing Factors

4.4.2.1 Results of Thematic Analysis (Interviews)

The thematic analysis of interview responses (first round) identified six influencing factors. Based on the barriers, obstacles, and impediments mentioned, it was possible to identify these influencing factors. The sunburst diagram in Figure 4-2 depicts these factors along with their related barriers, obstacles, and impediments.

A simple proportion calculation is used to depict each influencing factor in the sunburst diagram based on the *RII* ranking (provided in section 4.4.2.2). By doing so, the size of each slice is proportional to its respective *RII* value. There are six influencing factors that impact SC to varying degrees. The *RII* values for these factors are 0.93, 0.84, 0.82, 0.79, 0.77, and 0.75 (see Section 4.4.2.2). To calculate the size of each slice, the *RII* of each factor is divided by the sum of all *RII* values (4.90), and then a percentage is computed. For example, for the "Level of Leadership Commitment": 0.93/4.90 x 100 = 18.98%. This calculation is repeated for each factor. These percentages provide the size of the slices in the diagram.

Figure 4-2

Factors that Influence SC

The barriers in Figure 4-2 can be seen as contributors or potential underlying causes of their respective factors. For example, within the factor "Level of Communication," there are two barriers: "cultural differences" and "language barriers." The factor "Level of Resource Allocation" encompasses two other barriers, namely, "cost and paperwork" and "financial constraints." As such, cost, paperwork, and financial constraints can all impact the level of resource allocation to safety initiatives, which, in turn, will affect SC.

a) Level of Client Understanding

The data suggest that, from the experts' perspective, the level of client understanding of the importance of H&S, shaped by challenges related to client expectations, is a factor that influences SC. This factor reflects a shared concern among experts regarding clients' lack of understanding and prioritisation of safety in construction projects. Expert ID08 pointed out numerous obstacles on the client side, suggesting that clients may face challenges or resistance in fully embracing SC. ID10 emphasised that some clients prioritise cost over other factors, which can hinder the promotion of SC.

b) Level of Communication

The responses indicate that the level of communication, shaped by cultural differences and language barriers, is another factor affecting SC. When it comes to cultural differences, it is evident that diverse cultural backgrounds can coexist within a workplace. While this can be beneficial, there are also many challenges in ensuring cohesion within the team. Expert ID14 highlighted the impact of cultural differences on SC, while ID19 acknowledged the role of cultural factors in shaping SC within the workplace. ID27 emphasised the challenges in promoting SC due to the diverse nationalities and backgrounds of workers, suggesting the need for tailored strategies based on culture. Also, ID28 pointed out that misunderstandings and lack of communication can be attributed to cultural differences. In turn, language barriers also represent a significant obstacle to achieving SC. ID25 noted that language differences can lead to communication issues, and sometimes, people may confirm or agree to certain information without fully understanding it. ID30 mentioned the presence of language barriers as a potential challenge in SC.

c) Level of Industry Fragmentation

The data suggest that the level of industry fragmentation is also an influencing factor of SC. This factor is, in turn, shaped by challenges related to subcontractor alignment and difficulties in achieving standardisation and consistency in safety practices. The experts pointed out that aligning subcontractor practices with the project's safety goals is essential to overcoming SC challenges. ID08 discussed the particularly significant influence of subcontractor practices on large projects. When these are not strongly aligned with safety principles, it becomes challenging for the primary contractor to ensure and maintain SC. ID15 highlighted the challenge of dealing with subcontractors who are resistant to safety measures despite numerous attempts through toolbox talks and other management strategies. ID17 mentioned that the SC and practices of subcontractors can significantly impact the overall SC on construction sites. ID01 highlighted a common issue where workers are treated as if they were part of a production line or machines rather than as unique individuals. ID05 suggested that safety measures are often implemented because there is a requirement to comply with rules or regulations rather than because people truly care about safety. This suggests that some subcontractors may focus on meeting minimum standards rather than fostering a real culture of safety. ID25 highlighted a challenge where new safety standards may not be effectively communicated to subcontractors, potentially leading to gaps in compliance and understanding.

d) Level of Leadership Commitment

The responses indicate that the level of leadership commitment, shaped by acceptance and commitment issues, is also a factor that influences SC. Expert ID02 highlighted the pivotal role of leadership in promoting SC throughout the organisation. Meanwhile, ID06 emphasised the importance of effective communication and commitment from leadership to employees in achieving a positive SC. ID11 underscored the influence of leadership commitment in creating a workplace environment where safety is deeply integrated into daily operations. ID17 mentioned challenges posed by inconsistency, time constraints, and varying perceptions of SC, emphasising the need for continued leadership commitment to overcome these challenges. ID24 stressed the need for a unified and committed leadership team that values safety as a core aspect of the organisation, not just as a priority but as a way of life.

e) Level of Experience and Mindset

The data suggest that, from the experts' point of view, the level of experience and mindset also influences SC. This factor is shaped by a diverse range of challenges associated with attitudes, behaviours, and driving cultural change within organisations. Expert ID13 discussed the issue of toxic workplace environments that are often portrayed positively. ID14 shared that personal matters and views can act as veils, negatively affecting people's judgment and conduct. Furthermore, ID15 mentioned the issue of workplaces where certain habits, practices, or attitudes have become so established that they are difficult to change or eliminate. In such workplaces, employees may resist change due to familiarity, tradition, or a lack of motivation to adopt new behaviours, making it challenging to implement improvements or adaptations. ID26 commented that safety is often treated as being compartmentalised or isolated from other aspects, thus not fully integrated into the broader organisational culture.

f) Level of Resource Allocation

The responses indicate that the level of resource allocation, shaped by cost, paperwork, and financial constraints, is also a factor that influences SC. Expert ID03 noted that some of the paperwork involved in implementing government-mandated safety measures may be perceived as excessively time-consuming. ID05 mentioned that safety is sometimes viewed as an overhead cost rather than an integral part of the work. Moreover, ID05 discussed the extensive efforts required to implement and document safety measures. ID29 noted the challenge of balancing the perceived cost of safety against operating in an industry with slim profit margins and the tendency to cut expenses. ID12 discussed how allocating funds for safety can sometimes be challenging. ID13 emphasised that when a project falls behind schedule, it can lead to poor decision-making, impacting safety.

4.4.2.2 Results of Thematic Analysis (Interviews)

The *RII* analysis of survey responses (second round) found that, among the six influencing factors (identified in the first round), “Level of Leadership Commitment” was considered the most important one, with a *RII* of 0.93. The vast majority of experts rated this factor as very important. This is followed by “Level of Experience and Mindset” (*RII*=0.84) and “Level of Communication” (*RII*=0.82), which were highly rated factors as well. Although still relevant, “Level of Resource Allocation” (*RII*=0.79), “Level of Industry Fragmentation” (*RII*=0.77), and “Level of Client Understanding” (*RII*=0.75) were considered less important compared to the other factors (see Table 4-5).

Table 4-5

RII and Ranking of the Factors that Influence SC

Factor	1 Less important	2 Slightly important	3 Neutral	4 Moderately important	5 Very important	*RII*	Rank
Level of Leadership Commitment	0	0	3	3	20	0.93	1
Level of Experience and Mindset	0	1	5	8	12	0.84	2
Level of Communication	0	1	5	10	10	0.82	3
Level of Resource Allocation	0	1	5	14	6	0.79	4
Level of Industry Fragmentation	0	1	8	11	6	0.77	5

Level of Client Understanding	1	2	4	14	5	0.75	6

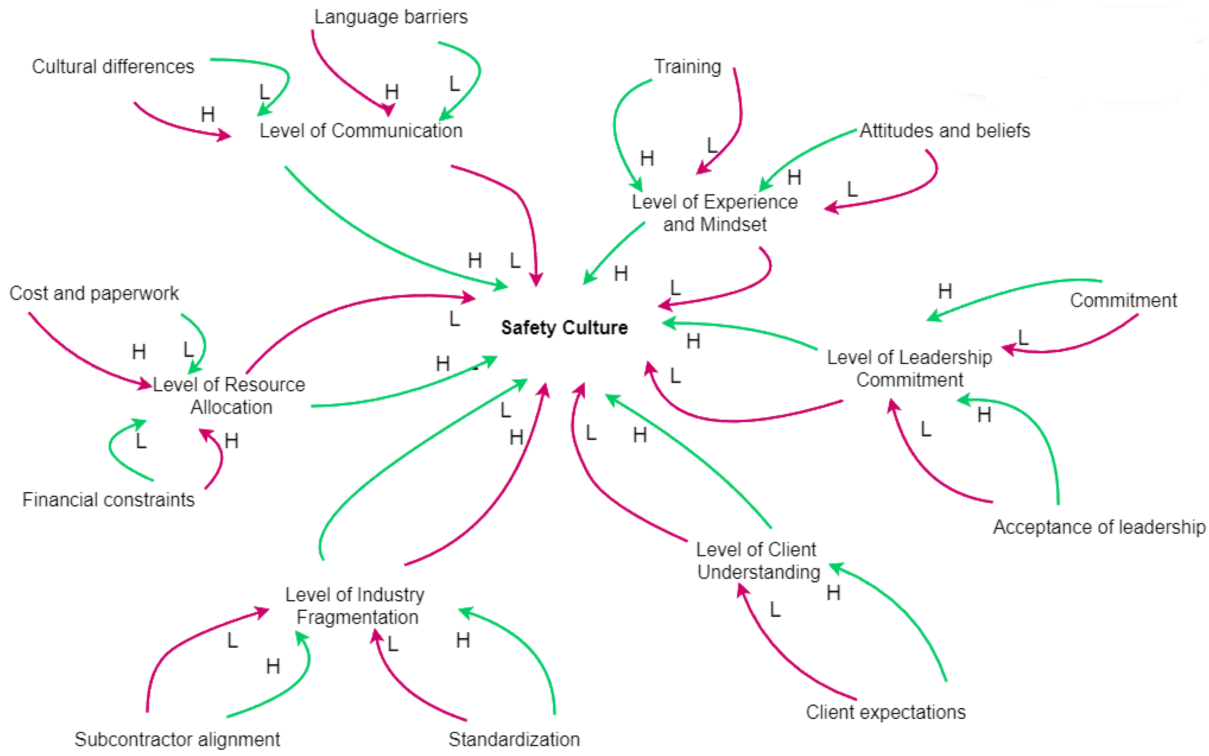
4.4.3 Causal Loop Diagram of SC Influencing Factors

The CLD in Figure 4-3 shows the relationships between SC, its influencing factors, and their respective barriers. The CLD illustrates the dual nature of the influencing factors, as they can have either a positive impact (green arrows) or a negative impact (red arrows) on SC, depending on whether their level is low (L) or high (H) (Bala, 2017; Sherwood, 2022).

For example, as shown by the path with green arrows, a balancing feedback loop is established when the "subcontractor alignment" is high (H) (suggesting greater coordination and agreement among subcontractors), reducing the "Level of Industry Fragmentation" (L), which facilitates SC. However, as shown by the path with red arrows, when the "subcontractor alignment" is low (L) (suggesting less coordination and agreement), the "Level of Industry Fragmentation" increases (H), which hinders SC. Another example is the reinforcing feedback loop created when the "commitment" is high (H), increasing the "Level of Leadership Commitment" (H), which facilitates SC (path with green arrows). In contrast, if "commitment" is seen as low (L), it reduces the "Level of Leadership Commitment" (L), which negatively impacts SC (path with red arrows).

Figure 4-3

Causal Loop Diagram Showing the Relationships Among the Factors that Define and Influence SC



A Project Director with over 20 years of expertise was consulted to validate the CLD. Their feedback suggested that the CLD was practical for managers and supervisors seeking to enhance SC, functioning as a tool for planning preliminary strategies. The expert also highlighted a lack of widespread industry awareness regarding these types of tools, as well as the absence of specific and clear strategies essential for their applicability.

4.5 Discussion

4.5.1 Safety Culture Defining Factors

During the investigation of the factors that define SC, none of the experts were able to provide a clear and holistic definition for it. Instead, they outlined various factors related to, or that make up the concept of SC. This is similar to the scope of SC definitions found in the literature, which are often based on a set of elements or factors encompassing the shared beliefs, values, attitudes, perceptions, and assumptions regarding safety within a group or organisation (e.g., Abdullah & Wern, 2012; Chen et al., 2017; Choudhry et al., 2007a, 2007b; Musonda et al., 2021; Wamuziri, 2006; Zhou et al., 2015).

Based on the consensus achieved through the Modified Delphi study, it appears that the most suitable definition of SC would encompass a specific set of essential factors. The unanimous agreement among all experts indicates that "Collaboration and Communication" are the most essential constituent elements of SC, which underscores their critical role in establishing SC. Equally important are the factors of "Leadership and Responsibility" and "Human-Centred Approach." The factors considered less important but still relevant in defining SC were "Integration and Organisation", "Fundamental Principles", and "Resource Allocation and Prioritisation." The defining factors identified are consistent with previous research, such as that of Mohamed and Chinda (2011), who proposed a holistic perspective on the topic. The authors identified five critical enablers of SC: leadership, policy and strategy, partnerships and resources, people, and processes. Similarly, Molenaar et al. (2009) identified five latent variables describing corporate SC: commitment to safety, incentives for safe performance, subcontractor involvement, field safety accountability, and disincentives for unsafe behaviours. The convergence of these findings highlights the universality and importance of these factors in shaping a holistic definition of SC.

In summary, the findings indicate that the definition of SC is strongly tied to essential factors and should incorporate them. Therefore, SC can be holistically defined as a systemic approach to safety that considers the shared values, expectations, and beliefs influencing a group's health and safety behaviour, where the following elements are present: (a) strong communication and engagement between management and workers; (b) self-leadership and accountability; (c) behaviours and interactions that promote a sense of belonging and inclusion; (d) deep integration of safety into the organisation's operations; (e) continuous improvement in safety practices, a deep sense of care, and compliance with safety standards and regulations; and (f) consideration of safety as equally important as other project parameters.

4.5.2 Safety Culture Influencing Factors

The investigation of the factors that influence SC yielded several insights. Based on the views and perceptions of experienced construction safety professionals, the "Level of Leadership Commitment" is the most important influencing factor, underscoring its critical role in promoting SC. Equally influential are the "Level of Experience and Mindset" and "Level of Communication." Factors considered less important in comparison but still influential in SC include the "Level of Resource Allocation", "Level of Industry Fragmentation", and "Level of Client Understanding."

The results clearly indicate that most experts consider the level of leadership commitment to be crucial. Similar findings have been reported by other researchers, reinforcing the consensus on this factor. Biggs et al. (2005) emphasised the management's pivotal role in Australia; Abdullah and Wern (2012) also highlighted leadership among various factors in Malaysia; Opoku et al. (2020) identified key aspects, with leadership ranking as the top factor in China. This study's findings suggest that New Zealand experts also perceive consistent and unified leadership as essential for fostering SC and ensuring the success of construction projects. This convergence of findings indicates the global importance of the level of leadership commitment as an influencing factor in fostering and promoting SC across different regions and contexts.

The results also suggest potential avenues for improving and promoting SC in construction. To accomplish this, clients may need to develop a deeper understanding of the fundamental importance of H&S, as well as the costs associated with poor safety management (Level of Client Understanding). Recognising and addressing cultural diversity and language barriers is also essential for promoting SC, which makes the development of cultural proficiency skills a potential area of focus (Level of Communication). In New Zealand, this appears particularly crucial for promoting SC, given the country's unique workforce demographics and the higher injury rates observed among migrants, Māori, and Pasifika workers (Rout, 2023). Moreover, ensuring subcontractor alignment and standardised safety practices can help the industry overcome fragmentation issues and foster SC (Level of Industry Fragmentation). As previously mentioned, having a unified and committed leadership team that values safety as a core aspect of their organisational culture is also essential (Level of Leadership Commitment). Providing comprehensive safety training and awareness programs could help address the challenges associated with the "Level of Experience and Mindset" factor. Such initiatives seem particularly urgent in New Zealand, considering the decline in the prioritisation of H&S among New Zealand construction employers (Rout, 2023). Lastly, to overcome the obstacles of the "Level of Resource Allocation" factor, projects must balance costs and financial constraints with the critical importance of safety, considering both the direct and indirect costs of non-compliance, such as lawsuits, fines and penalties, loss of productivity, operational disruptions, and reputation damage. Greater emphasis on this factor is recommended for the New Zealand construction sector, as BRANZ (2024) highlights that many builders are currently facing challenges in maintaining high-quality standards and safety performance while managing costs.

The CLD provided further insights into the relationships between SC, its influencing factors, and their respective barriers. It clearly shows the dual nature of the influencing factors, as they can either facilitate or hinder SC depending on whether their level is low or high. As such, the CLD is instrumental in demonstrating that the identified influencing factors directly impact SC. For example, it shows that when "commitment" (a potential barrier) is high (H), indicating a high commitment to safety in this case, this means an increased "Level of Leadership Commitment" (H), which facilitates SC (path with green arrows in Figure 4-3). In this example, "commitment" refers to the dedication of employees and supervisors toward safety. A common way this commitment is demonstrated is through active employee participation in safety programs, encouraged by supervisors (BRANZ, 2024; Hudson, 2007). Employees might be actively involved in safety training, while supervisors contribute by consistently reminding employees about safety practices and reinforcing the importance of following them. In this scenario, leadership is committed to safety, reflecting the increased "Level of Leadership Commitment" (Kineber et al., 2023; Shen et al., 2017). Ultimately, this supportive leadership helps strengthen SC within the organisation. In contrast, when the commitment to safety is low (L), this means a decreased "Level of Leadership Commitment" (L), which weakens SC (path with red arrows in Figure 4-3), meaning limited implementation of safety practices and poor safety performance (Abdullah & Wern, 2012; Bahn, 2012). This weak SC will perpetuate the frequency and severity of accidents (Asilian-Mahabadi et al., 2018; Choudhry, 2014).

It should be noted that while the CLD can be utilised to plan strategies for promoting SC, this should be done considering the context and specific characteristics of a construction project to ensure that the strategies are tailored appropriately.

4.6 Conclusion

The objective of this research was to identify the factors that define and influence SC, an essential step for gaining a better understanding of how to effectively promote it. An exploratory methodology, incorporating both qualitative and quantitative methods, was adopted. A Modified Delphi study was conducted in two rounds to gather experts' responses. The iteration process in the Modified Delphi study involved two rounds of feedback: interviews followed by a survey. The interview data were analysed using Thematic Analysis to identify themes, while the survey data were processed using the *RII* to rank the themes by importance. Cronbach's alpha was used to assess the reliability of responses and ensure consistency in participant feedback. The combination of these two feedback rounds enabled consensus on the factors that define and influence SC (the primary objective of this study).

The results of this study provide valuable knowledge that enables practitioners to assess and promote SC in their projects. The consensus on the factors that define, and influence SC offers a clearer picture of what it entails, and which variables can impact it. It provides a solid foundation for informed initiatives aimed at promoting SC. In other words, this understanding is expected to facilitate the development of more efficient strategies to promote SC in New Zealand and countries alike. Additionally, the results demonstrate that the influencing factors can act as both facilitators and obstacles, highlighting the complexities involved in creating and promoting SC in construction. As such, the development of SC in New Zealand's construction sector (and likely in other countries with similar characteristics) depends on addressing key factors that significantly influence it. The CLD can serve as a valuable tool for decision-makers to address those factors, offering guidance in planning promotional initiatives.

This study also demonstrated the importance of investigating and accounting for industry-driven perspectives. The identified factors and their interrelationships derive from diverse perspectives and reflect the complex nature of the construction sector. Therefore, a holistic approach is necessary to adequately define SC, incorporating its key elements, such as collaboration and communication, as well as leadership and responsibility. These factors are crucial in establishing SC in the workplace and cultivating a culture focused on safety and well-being. Moreover, while there is consensus on the importance of promoting SC for addressing safety issues in the construction sector, this study found that six influencing factors can act as double-edged swords, either hindering or facilitating SC promotion based on their impact. These findings can guide stakeholders in making informed decisions, understanding the relative importance of various factors, and recognising how each of them can potentially impact SC both positively and negatively.

It should be noted that this study has some limitations. First, all the experts who participated in this study are from New Zealand's construction sector, which reduces the generalisability of the findings and may limit their applicability to this country or similar contexts. Also, although participants were informed about the procedures in place to protect the privacy of their data and responses (with all personal information de-identified), some may have still provided responses influenced by concerns over disclosing sensitive safety-related information. This could have affected the reliability of their responses and, consequently, the study's results. Additionally, relying on a single expert for the CLD validation raises concerns about its coherence, completeness, and applicability.

Future research may explore this topic in other contexts and countries to determine whether SC is defined and influenced similarly to how it is in New Zealand. Future studies could also look into available tools to promote SC or develop new ones that incorporate the defining and influencing factors identified in this study. It is believed that the CLD could be operationalised through an actual tool, which would facilitate its practical application in establishing and promoting SC in the construction sector.

Summary

Chapter 4 has detailed the execution and findings of the Modified Delphi study for the first in-depth question, the defining factors; and the second in-depth question, about the influencing factors, defined on Chapter 3. A Modified Delphi Study relies on a panel of experts, into iteratives 2 rounds. This method enables experts to revise their perceptions based on their knowledge and experience built on the anonymous views of others, leading to a consensus over two rounds. Although the method requires a minimum of 10 participants with 75% retention for the second round, this study interviewed 32 participants in the first round and retained 28, which is 81%, exceeding the methodological requirements for participant numbers and retention, indicating that the participants found the study valuable enough to continue their involvement, and a robust credibility and reliability of the findings (Mullen, 2003). The exploratory methodology combining qualitative, and quantitative methods, in-depth interviews on the first round and survey questionnaire on the second round, facilitated the consensus and understanding of SC. Industry experts provided insights into the challenges in promoting SC, which were analysed using Thematic Analysis to identify the influential factors, and the *RII* to rank them. Furthermore, through a CLD the identification of dual-natured influencing factors, those that can act both as facilitators and obstacles, highlights the dynamics involved in promoting SC, and showing the influencing factors and their respective barriers. This chapter addresses part of the first research objective: to explore the meaning of SC and the factors that enhance it as perceived by New Zealand construction safety practitioners by identifying the six influential factors and their respective barriers. This paper leads to the next chapter where investigating additional tools that integrate the identified six influential factors could further enhance the tools to promote SC in Construction Sites in New Zealand.

Chapter 5: A Framework for Promoting Safety Culture in Construction Sites in New Zealand

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Abstract

Regardless of geographical location, the construction sector is responsible for 30%-40% of workplace fatalities globally. In New Zealand between 2019-2022, injuries in the construction sector rose from 5,301-6,240, with falls from heights being the most frequent cause. Reducing on-site accidents is necessary for the realisation of construction projects, and one proven way to achieve this is by promoting safety culture (SC). However, the fragmented nature of the construction sector makes the implementation of a proactive SC complex, requiring significant financial investment, careful planning, and time. This study hypothesises that a structured framework linking specific SC factors to targeted tools not only can facilitate a clear pathway for site project managers and safety practitioners to identify and implement tools best suited for their specific project challenges but also contributes to optimising resource allocation. The framework was developed with a mixed-methods approach, integrating the tools captured from both the Modified Delphi study and the literature review, and categorising the tools based on influential factors to promote SC in New Zealand. This approach ensures that all potentially useful tools, whether primarily known by industry experts or not, are considered. This organisation aims to improve the traceability of tools, increasing the framework's practical value for daily operations and decision-making. The results highlight a need for greater consideration of tools involving systems thinking approaches, like Systems-Theoretic Accident Model and Processes, the use of advanced technologies for training like virtual reality (VR), and the implementation of survey tools like Nordic Occupational Safety Climate Questionnaire. The framework's emphasis on New Zealand highlights the need to validate the usability before considering its applicability.

Keywords: Safety Culture, Construction sector, Safety Tools, Framework, Delphi Study, Safety Management

5.1 Introduction

The construction sector is known for its organisational complexity and fragmentation, characterised by a predominance of small and medium-sized enterprises (Biggs and Biggs, 2013; Fuller et al., 2022). Due to its characteristics, promoting SC within the construction sector has been challenging, with construction accidents resulting in numerous human tragedies, demoralising workers, disrupting site activities, delaying project progress, and negatively impacting the industry's overall productivity and reputation (Biggs et al., 2005; Wamuziri, 2006). In New Zealand between 2019-2022, there was a notable increase in the number of injuries resulting in more than a week away from work, rising from 5,301-6,240 (WorkSafe New Zealand, 2022c). Falls or releases from heights constituted the most frequent of these injuries (WorkSafe New Zealand, 2015). Fostering and maintaining SC is essential to reducing these injuries, ensuring the well-being of employees, and the overall success of an organisation through its projects (Machfudiyanto et al., 2020).

SC is a critical aspect of any organisation, especially in sectors where human lives are at risk, such as construction and healthcare (Allison et al., 2017; Shen et al., 2007; Wamuziri, 2006). It encompasses the shared values, beliefs, and behaviours regarding safety in the workplace, which employees and management alike hold (Mohamed & Chinda, 2011). A strong SC is typically characterised by open communication about safety concerns, active participation in safety programmes, a commitment to continuous improvement, and the use of tools to prevent hazards (Hon & Liu, 2016; Machfudiyanto & Latief, 2019). In New Zealand, six influential factors to promote SC were identified and ranked from a Modified Delphi study, namely, the Level of Communication, the Level of Leadership Commitment, the Level of Experience and Mindset, the Level of Resource Allocation, the Level of Industry Fragmentation, and the Level of Client Understanding (Ortega et al., 2025). In the context of the construction sector, while these influential factors are crucial, they alone are insufficient to help stakeholders, like on-site project managers and safety practitioners, tackle daily challenges successfully (Sherratt et al., 2025). This is where the necessity of a practical approach becomes evident, and following Sherratt et al. (2025), it is recommended that academia should shift towards more empirical methodologies that are closely aligned with the real-world demands and ensures solutions adaptable to the unique challenges of each construction site. The most relevant tool for synthesising and communicating core concepts in a field, is a framework, because this research tool presents a structured approach to understanding and rendering a research topic (Machfudiyanto & Latief, 2018; Partelow, 2023). A conceptual framework can be presented as a flowchart or diagram, visualising the relationships between key concepts, simplifying complex ideas and highlights how various elements interact (Barrett & Sutrisna, 2009; Partelow, 2023; Vu-Ngoc et al., 2018).

This research aims to develop a framework to facilitate the translation of abstract influential factors into concrete actions, through the identification of tools, providing a clear roadmap for on-site project managers and safety practitioners to adopt safety interventions through the more effective tools facilitating the decision-making. The following objectives were considered to develop the framework:

- Objective 1: to explore the tools that enhance SC in practice, as perceived by New Zealand construction safety practitioners and the literature review.
- Objective 2: to categorise the tools described by New Zealand construction safety practitioners and the literature, identifying their relationships with key factors influencing SC.

- Objective 3: to design and develop a prototype framework and present it in the format of an informational report that provides a clear roadmap for decision-making to improve SC in New Zealand.

5.2 Background

5.2.1 Promoting SC

Promoting SC in the construction sector remains a significant challenge despite its well-documented benefits, requiring efforts at both organisational and project levels (Abdullah & Wern, 2012; Schein, 2014; Wamuziri, 2013). The success of any safety initiative, whether a new plan, policy, or tool, depends on the prevailing SC within an organisation or a project (Abdullah & Wern, 2012; Bahn, 2012; Choudhry et al., 2009; Del Puerto et al., 2018; Namian et al., 2022; Machfudiyanto et al., 2020). Studies consistently highlight the positive correlation between SC and improved safety outcomes, including reductions in the frequency and severity of accidents and incidents (Asilian-Mahabadi et al., 2018; Choudhry et al., 2007a; Choudhry, 2014).

Although many studies establish strong correlations rather than definitive causal links, the literature supports the relationship between fostering SC and reducing incidents (Lingard et al., 2014; Schein, 2014; Sherratt et al., 2025). For example, Lingard et al. (2014) emphasise that leadership plays a pivotal role in embedding safety values and fostering behaviours that enhance safety performance, while Biggs et al. (2005) highlight the importance of leadership initiatives such as clear communication and collaboration in improving safety awareness. Similarly, Dulaimi and Chin (2009) and Machfudiyanto et al. (2019) underscore the role of leadership commitment and proactive SC in achieving better safety outcomes.

Identifying the factors that contribute to both unsafe and safe practices is critical for cultivating a robust SC (Abdullah & Wern, 2012). These factors highlight the multifaceted nature of SC and the challenges associated with its promotion, reinforcing the need for a comprehensive and tailored approach to improving safety practices and outcomes in the construction sector (Abdullah & Wern, 2012; Schein, 2014; Wamuziri, 2013). Moreover, these factors emerge from a complex environment that significantly influences the development and sustainability of SC (Abdullah & Wern, 2012; Schein, 2014; Wamuziri, 2013).

While tools and frameworks for promoting SC have proven effective in various contexts, their success depends on how well they are tailored to the unique characteristics of individual organisations and projects (Lingard et al., 2014; Sherratt et al., 2011). By consolidating insights from previous studies, this section highlights tools and frameworks identified as critical for enhancing SC. Given the large body of research on tools to promote SC, a comprehensive literature review was conducted to identify and categorise these tools (Deepak & Mahesh, 2024; Khalid et al., 2021; Vierendeels et al., 2018). Publications from the Scopus database were selected due to its extensive coverage of peer-reviewed journals and high-quality academic sources (Belter, 2015; Guz & Rushchitsky, 2009). Tools identified in the review were categorised based on their relevance to the main factors for fostering SC (Lingard et al., 2014; Misnan & Mohammed, 2007).

5.2.2 Frameworks relevant to SC

A framework implies connecting a series of concepts to facilitate in understanding processes, structuring ideas, and establishing a basis for practically coordinating activities, this is valuable in project management (Partelow, 2023).

There are a variety of frameworks related to SC, applicable across various contexts. General frameworks that can be adopted in any industry have been developed for example by Bisbey et al. (2019); Vierendeels et al. (2018). Specific to the construction sector have been established for instance by Al-Bayati et al. (2019); Misnan and Mohammed (2007); Molenaar et al. (2009). Additionally, frameworks tailored to countries, like Indonesia, Malaysia, and Saudi Arabia, have been created by Alasamri et al. (2012); Ismail et al. (2010); Machfudiyanto and Latief (2018). These frameworks show diverse approaches tailored to specific regional needs, demonstrating the integration of SC in the construction sector. Each framework uses a combination of literature review, empirical data collection, and expert feedback to address safety challenges faced by workers and management in their respective regions (see Table 5-1).

Table 5-1

Comparative Analysis of Regional SC Frameworks in the Construction Sector

Study	Alasamri et al. (2012), Saudi Arabia	Ismail et al. (2010), Malaysia	Machfudiyanto & Latief (2018), Indonesia
Purpose	To enhance SC by incorporating a unique organisational component, focusing on top management's role in addressing safety challenges in Saudi Arabia.	To develop a framework for consistently quantifying and analysing SC in Malaysian construction companies.	To integrate policies, institutional factors, and SC development across various organisational levels.

Methodology	Conducted a literature review and adapted existing models to the Saudi context, with validation pending.	Utilised preliminary and main surveys, semi-structured interviews, and expert validation to measure psychological, behavioural, and situational safety factors.	Conducted a literature review, deductive analysis, and expert validation to develop and refine the conceptual model.
Key Elements	Focused on safety climate, safety management systems, safety behaviour, and the role of top management.	Examined psychological factors, behavioural practices, and situational conditions influencing SC.	Addressed SC dimensions such as cultural behaviour, norms, management, physical culture, and ideology.
Main Outcomes	Integrated psychological (safety climate), behavioural (safety behaviour), situational (safety management systems), and organisational factors (top management support). Provided a structured approach for integrating SC into organisational processes.	Identified five critical factors for SC: leadership, organisational commitment, management commitment, safety training, and resource allocation. Proposed a consistent and measurable framework for SC improvement in Malaysian construction.	Highlighted the importance of policies and institutional factors in improving SC at national, organisational, and project levels. Demonstrated how policies and institutional support are vital for fostering SC across different levels.

Note: This table has been previously presented in Chapter 3 (Table 3-1). It is included here for reference and support for the paper.

These three frameworks aim to improve SC by focusing on specific and general safety challenges and highlighting the integration of cultural, behavioural, and organisational factors. Each framework is developed and refined using a combination of literature review, empirical research tools like surveys and interviews, and expert validation, ensuring that they are theoretical applicable within their respective contexts.

The Indonesian framework incorporates policy and institutional factors with organisational and project-level SC, addressing the high incidence of construction accidents in Indonesia (Machfudiyanto & Latief, 2018). The Malaysian framework is focused on facilitating professionals' quantifying and analysing SC regularly, with an emphasis on reciprocal trust and communication within construction companies (Ismail et al., 2010). The Saudi framework introduces an additional organisational component, top management, to Choudhry's previous framework, highlighting the role of leadership in fostering a safe working environment (Alasamri et al., 2012; Choudhry et al., 2007). While some frameworks were empirically assessed (Ismail et al., 2010), others remain theoretical or validated only through expert review (Alasamri et al., 2012; Machfudiyanto & Latief, 2018). These frameworks lack of full applicability and have not been fully tested in the field, leaving theory effectiveness in promoting safety culture unverified.

In addition to the regional frameworks developed in Indonesia, Malaysia, and Saudi Arabia, other theoretical perspectives, like the Theory of Planned Behaviour (TPB), have been proposed (Ajzen, 1991). TPB underlines the importance of attitudes, regarding the behaviour that reflects the degree to which a person has a favourable or unfavourable judgment of the behaviour; subjective norms, referring to the perceived social pressure to perform or not perform the behaviour; and perceived behavioural control, which refers to the individual's perceptions of the ease or difficulty of performing the behaviour. These elements are visible in the Malaysian framework, which emphasises attitudes based on trust and communication, as well as in the Saudi framework's focus on leadership attitudes (Alasamri et al., 2012; Ismail et al., 2010). This theory provides a background that supports and extends the practical applications of SC frameworks. While previous studies have explored various frameworks and tools to enhance SC, their effectiveness is often contingent on contextual adaptability and practical implementation. The literature highlights the need for a structured approach that bridges the gap between theoretical constructs and actionable strategies, particularly within the New Zealand construction sector. This study aims to address this gap by developing a framework that systematically translates abstract influential factors into practical tools, thereby facilitating informed decision-making and more effective safety interventions on-site.

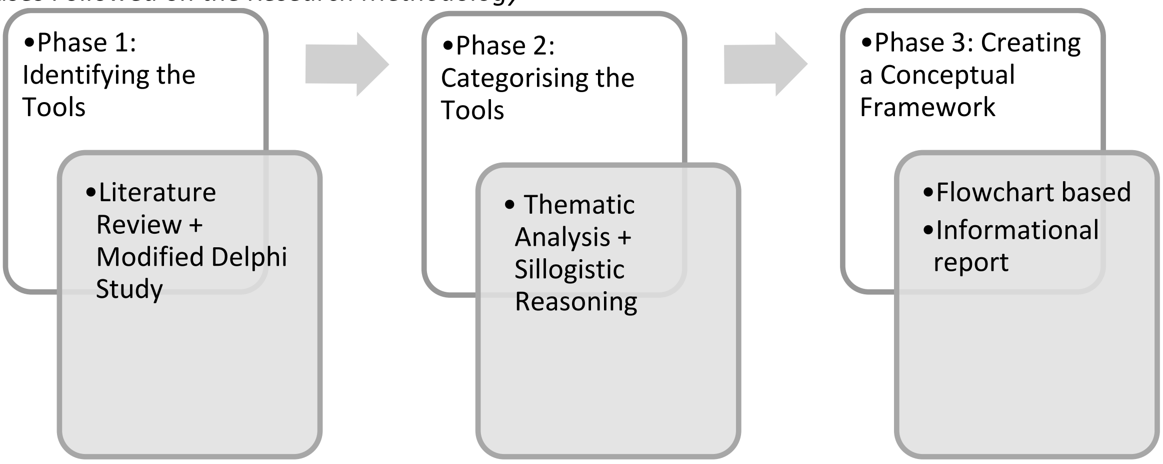
5.3 Research Methodology

The research method adopts a mixed approach, combining inductive and deductive reasoning. Inductive reasoning is used to generate theory from observed patterns, while deductive reasoning refines and tests elements of the framework (Creswell & Creswell, 2017; Partelow, 2023; Saunders et al., 2019). The data collection and analysis method are primarily qualitative, emphasising an in-depth exploration of participants' perceptions, experiences, and knowledge, with quantitative methods incorporated to validate findings and enhance the framework's broader applicability. This approach ensures robust data collection and analysis while increasing the potential of framework's generalisability (Fellows & Liu, 2015; Saunders et al., 2019; Yin, 2018). Grounded in this line of inquiries, the research design is structured into three main phases: Identify, Categorise, and Create.

These 3 phases have been structured within the research methodology to address each objective of the study (see Figure 5-1):

Figure 5-1

Phases Followed on the Research Methodology



5.3.1 Phase 1: Identifying the Tools

To capture the current tools used to promote SC (objective 1), which focuses on identifying the current tools used to promote SC, the study employed two approaches: a comprehensive literature review and a Modified Delphi study. This process allowed to evaluate and validate the tools captured by experts and by the literature review, ensuring their relevance and applicability to on-site safety in New Zealand's construction sector (McKay et al., 2022; Mullen, 2003; von der Gracht, 2012).

5.3.1.1 Comprehensive Literature Review

The first step was a comprehensive literature review, conducted to capture and categorise tools that have been implemented to promote SC. Given the vast number of publications on this topic, the literature review provided a systematic understanding of the current landscape of SC tools and frameworks (Deepak & Mahesh, 2024; Khalid et al., 2021; Vierendeels et al., 2018). The Scopus database, renowned for its extensive coverage of peer-reviewed journals and high-quality academic sources, was used to source relevant publications (Belter, 2015; Guz & Rushchitsky, 2009). Tools identified in the literature were categorised based on their application to the six influential factors for fostering SC in New Zealand's construction sector, previously identified in Chapter 4, ensuring alignment with the framework.

5.3.1.2 Modified Delphi Study

The second step involved seeking consensus among New Zealand safety experts in the construction sector on tools for promoting SC (Mullen, 2003; von der Gracht, 2012). This was achieved through a Modified Delphi method, an iterative process widely used for reaching expert consensus on complex topics (Mullen, 2003; von der Gracht, 2012). The Modified Delphi study was conducted in two rounds, requiring at least 10 experts, who are the "panel of experts", to participate, with a minimum of 75% retention from the first to the second round to ensure validity (Mullen, 2003; von der Gracht, 2012). The Modified Delphi method integrates both qualitative and quantitative elements, utilising structured feedback to explore expert perceptions and refine insights (Mullen, 2003). It emphasises anonymity to avoid bias, interactive feedback to encourage active participation, and systematic data collection to achieve reliable outcomes (Biggs & Biggs, 2013; McKay et al., 2022; Nayak & Jespersen, 2022).

5.3.1.2.1 Participants

This study targeted professionals with over three years of experience in health and safety (H&S) and Project Management (PM) in the construction sector in New Zealand, this was the inclusion criteria. Recruitment began with invitation emails sent to 217 contacts from Massey University's School of Built Environment, and 258 contacts from LinkedIn (Albrecht, 2011), all meeting the inclusion criteria. In addition, snowball sampling technique (Lavrakas, 2008) was also deployed. In the first round, 33 interviews were conducted, but one expert withdrew before transcript approval. Ultimately, 32 experts consented and approved the transcripts (see Table 5-2). Participants were informed about the confidentiality and anonymity of their responses by digitally signing a consent form (see Appendix 2). The experts averaged 14 years of professional experience. Those who did not participate in the second round of the survey are indicated with an asterisk (*) in Table 5-2. To comply with Massey University's Human Ethics (#4000027113) and the Modified Delphi method requirements, all personal information was anonymised. For the second round, an online questionnaire was developed, and invitations were emailed to the same participants from the first round, with two reminder emails sent. Based on prior research (Mullen, 2003; von der Gracht, 2012), dropout rates between rounds were expected to range from 16%-28%. In the second round, 26 experts (81%) continued their participation.

Table 5-2

Panel of Experts

Expert ID#	Role	Years of Experience
1	Director	10

2	Head of HR	6
3*	Quantity Surveyor	16
4	Technical Director – Structural Engineering	20
5	Director	8
6	Business Support Manager	5
7*	Quantity Surveyor	22
8	Regional H&S Manager	3
9*	Site Manager	20
10	National HSEQ Manager	10
11	Principal Engineer	13
12	Project Manager (Civil)	22
13	HSW Manager	10
14	Site Manager	15
15	Senior Project Manager	12
16	Principal Project Manager	10
17	H&S Manager	15
18	Project Director	40
19	CEO	25
20	Senior H&S Advisor	11
21	H&S Manager	7
22*	Chair of H&S Organisation	25
23	HSEQ Advisor	20
24	Risk Manager	10
25	H&S Associate	6
26	Transformation Lead (People) Construction Sector	40
27	Chartered H&S Professional	6
28*	Senior H&S Advisor	5
29	Head of EHS	8
30*	Construction Manager	3
31	CEO	30
32	H&S Innovation Manager	21

Note: This table has been previously presented in Chapter 4 (Table 4-2). It is included here for reference and support for the paper.

5.3.1.2.2 Data Collection

5.3.1.2.2.1 Modified Delphi Method – First Round (Interviews)

In the first round of data collection, individual interviews were conducted with a panel of experts, through open-ended question that was used to gather qualitative data, allowing researchers to explore areas of reality that would otherwise remain inaccessible (Braun & Clarke, 2006; Herring, 2018). In this study, the interview consisted of only one open question (Fellows & Liu, 2015; Yin, 2016), which asked participants to identify the common tools to promote SC. The individual interviews were conducted online via Microsoft Teams, recorded, and transcribed with participants' signed consent (see Appendix 2). Within ten days, transcripts were sent to participants for approval. Interview durations ranged from 7-43 minutes, depending on participants' willingness to share and elaborate on their responses.

5.3.1.2.2.2 Modified Delphi Method – Second Round (Survey)

During the second round of data collection, an online questionnaire was created based on first-round findings, including one question employing a Likert scale (Lavrakas, 2008; Norman, 2010). The Likert response sets can comprise four or more points; while a five-category set is typical, some psychometrics experts suggest utilising response sets with seven, nine, or even eleven points (Lavrakas, 2008). The 5-point scale incorporates a neutral midpoint, offering a balanced range for respondents to indicate their level of agreement or importance (Johnson & Morgan, 2016; Norman, 2010). This design allows for nuanced responses without overwhelming participants with too many choices or pressuring them into selecting extreme positions (Johnson & Morgan, 2016). For this study, a 5-point Likert scale was employed. Participants were asked to rate the level of importance of the tools captured in the first round, with responses ranging from 1 (less important) to 5 (very important). A pilot online questionnaire was conducted with two experts to address eventual issues with the questions (wording, semantics, structure), resulting in minor changes to maintain consistency among items (Williamson, 2018; Kim, 2010). The online questionnaire was then distributed through the Qualtrics platform, and participants could access it via personalised email links. Invitations were emailed to the original participants, followed by two reminder emails to encourage participation (see Appendix 2).

5.3.1.2.3 Data Analysis

5.3.1.2.3.1 Modified Delphi Method – First Round (Interviews)

The data collected in the first round underwent thematic analysis (see Table 5-3), following the steps outlined by Braun and Clarke (2006). The initial coding involved capturing the tools directly mentioned by the participants, while a second grouping was based on the similarity of the tools, which may have been mentioned with different names or abbreviations, such as Apps instead of applications or QR codes instead of Quick Response codes. The data were then organised thematically using NVivo version 14, a software application specifically designed to aid in the structuring of content-rich textual qualitative data (Galea et al., 2020).

5.3.1.2.3.2 Modified Delphi Method – Second Round (Survey)

To analyse the data, first Cronbach's alpha (α) was used to assess the internal consistency and reliability of the questionnaire, ensuring that the data collected from experts were trustworthy, and confirming that the interpretations and conclusions drawn from the data were based on a reliable measurement instrument (Nwadike & Wilkinson, 2022; Rey-Merchán et al., 2021). Cronbach's alpha provides internal consistency reliability on a scale from 0 to 1 (Opoku et al., 2020; Tavakol & Dennick, 2011). A value above 0.6 generally indicates moderate reliability, while values closer to 1 suggest higher internal consistency among the items in the questionnaire (Nwadike & Wilkinson, 2022; Rey-Merchán et al., 2021). The preliminary assessment of the questionnaire's internal consistency yielded a Cronbach's α of 0.958. Then, the use of the relative importance index (*RII*) was considered to quantify the importance of each tool based on the ratings given by the participants. It involves assigning numerical values to responses on Likert-type scales, which are then averaged to determine the overall importance of each tool (see Table 5-4). This enabled a quantifiable analysis of expert opinions (Aziz et al., 2016; Rafeh et al., 2023; Tarek et al., 2022). The *RII* is calculated with the following equation 1 (Aziz et al., 2016):

$$RII = \frac{Total\ weight\ given\ to\ each\ factor\ by\ the\ respondent}{The\ highest\ weight\ \times\ Total\ number\ of\ respondents} = \frac{W1 + W2 + \ldots + Wn}{A \times N}$$

Note: This equation has been previously presented in Chapter 4. It is included here for reference and support for the paper.

The quantitative data collected were analysed using the statistical software SPSS version 29. Detailed calculations of Cronbach's alpha are available in Appendix 2.

5.3.2 Phase 2: Categorising the Tools

To categorise the tools (see Table 5-5) identified from both the literature review and the Modified Delphi study according to the six influential factors for promoting SC in New Zealand, as outlined by Ortega et al. (2025), which were presented in Chapter 4, a thematic analysis was conducted (Braun & Clarke, 2006). This process grouped similar concepts under common themes, leading to the identification of the six influencing factors and associated tools (Braun & Clarke, 2006). Next, the tools were analysed using syllogistic reasoning, usually illustrated with Venn diagrams (Sato & Mineshima, 2015; Standford, 2022). Syllogistic reasoning helps to represent intersections, unions, and differences among a set of elements, facilitating visualisation of how these tools overlap or diverge in terms of expert consensus and the literature (Sato & Mineshima, 2015; Standford, 2022). This helps to establish which tools are only captured by experts, those solely captured in the literature, and those captured from both (see Table 5-5).

5.3.3 Phase 3: Creating a Conceptual Framework

To create a visualisation of the framework (see Figure 5-2) where the tools are categorised according to their application across the influential factors previously identified by Ortega et al. (2025), and presented in Chapter 4, visualisation tools such as diagrams and cognitive maps can be useful (Barrett & Sutrisna, 2009; Partelow, 2023). In this study, a flow-based diagram was adopted (see Figure 5-2) because it consists of a starting point with directional arrows, representing a process, workflow, or sequence of steps in a systematic manner (Barrett & Sutrisna, 2009; Vu-Ngoc et al., 2018). The starting point symbolises the initial stage, while the arrows indicate the flow or progression through subsequent stages, making it easier for stakeholders to understand and follow the intended procedures (Vu-Ngoc et al., 2018).

To improve the accessibility and understanding of the framework, an informational report was developed (see Chapter 7). This format was chosen for its clarity and structured approach, making it well-suited for providing detailed descriptions. The report comprehensively explains the framework's tools, covering their purpose, frequency and format of use, engagement strategies, examples, and potential impact on SC (Kabir, 2016; Wilkinson, 2022). To further enhance accessibility, the report incorporates visual aids such as QR codes linked to video descriptions (Gedera & Zalipour, 2018; Megha & Satishkumar, 2024; Wilkinson, 2022. These QR codes allow readers to easily access video content, enabling them to revisit the material as needed and improving their overall understanding (Megha & Satishkumar, 2024; Wilkinson, 2022). The use of videos ensures consistent dissemination of knowledge, supporting a uniform understanding of the framework's tools (Gedera & Zalipour, 2018; Varela & Mejía, 2018).

5.4 Results

5.4.1 Phase 1: Identifying the Tools

5.4.1.1 Literature Review

Based on the six influential factors that are important for fostering SC in New Zealand identified and ranked in Chapter 4, the identified tools were subsequently categorised. This categorisation assists in recognising how each tool associates with a specific factor. The tools are presented and discussed in relation to each factor, as detailed below:

a) *Level of Leadership Commitment*

Leadership commitment is one of the most influential factors in promoting and maintaining SC within construction projects (Lingard et al., 2014; Schein, 2014). SC thrives when leaders visibly prioritise safety, allocate resources, and influence safety behaviours (Bisbey et al., 2019; Karanikas et al., 2022). However, a lack of acceptance and commitment to leadership can result in poor safety practices (Khalid et al., 2021; Lestari et al., 2020). Trust and open communication are essential leadership strategies for promoting SC (Bisbey et al., 2019; Karanikas et al., 2022). By setting clear expectations, providing consistent feedback, and recognising safety achievements, leaders create an environment where workers feel empowered to share concerns and insights, which is vital for identifying and addressing risks effectively (Bisbey et al., 2019; Karanikas et al., 2022; Pandit et al., 2018; SiteSafe, 2024).

Tools like toolbox talk meetings help ensure consistent safety practices across projects by fostering communication and reinforcing safety standards (MacCollum, 2007; Sneddon et al., 2006; WorkSafe NZ, 2022b). Leadership training programs also play a critical role in developing the skills necessary to influence safety (Bisbey et al., 2019; Lingard et al., 2014). These hands-on programs are tailored for workers and managers, focusing on practical leadership strategies that permeate all levels of the workforce, resulting in fewer incidents and a more committed workforce (Aboagye-Nimo & Raidén, 2019; Gillen et al., 2004; Lekchiri & Kamm, 2020).

Lean construction tools enhance safety by embedding safety principles into workflows (Abu Aisheh et al., 2022; Barbosa et al., 2013; Bashir et al., 2011; Bhagwat & Delhi, 2024; Ng et al., 2012). For instance, Poka-yoke systems, derived from the Japanese concept of "mistake-proofing," minimise human errors and enhance safety by designing processes and tools to prevent mistakes before they occur (Rubio-Romero et al., 2019). Similarly, lean visual management tools provide real-time, visually accessible information, enabling teams to respond quickly to safety issues and improving communication (Barbosa et al., 2013; Farzad & Cameron, 2019). Despite the demonstrated benefits of these tools, Lean philosophy in construction remains underutilised, leaving significant opportunities for broader adoption and integration across the sector (Emuze & Smallwood, 2014; Plugge et al., 2023). Leadership plays a pivotal role in the adoption and consistent use of these tools, ensuring their effective integration into safety practices and fostering accountability and transparency (Emuze & Mpembe, 2021; Plugge et al., 2023).

b) *Level of Experience and Mindset*

The experience and mindset of the workforce are critical factors in promoting SC on construction sites (Bisbey et al., 2019; Machfudiyanto & Latief, 2018). For example, experienced workers bring valuable knowledge about potential hazards due to their familiarity with construction processes (Al-Bayati et al., 2024); however, experience alone is insufficient without the development of an appropriate safety mindset, which is characterised by a proactive approach, continuous learning, and adherence to safety protocols, to ensure a safer work environment (Al-Bayati et al., 2024). Barriers such as lack of training, limited fresh perspectives, and negative attitudes hinder the promotion of SC, emphasising the importance of fostering proactive behaviours (Bisbey et al., 2019; Machfudiyanto & Latief, 2018).

Technological advancements offer tools that significantly enhance site safety and operational efficiency (Chen et al., 2022). Mobile apps, wearable technology, and augmented reality (AR) tools enable real-time hazard identification, safety inspections, and instant reporting (Liu et al., 2019; Rey-Merchán et al., 2021). For instance, mobile apps allow workers to report unsafe conditions and access safety protocols, while smart glasses overlay safety information in a worker's field of vision, reducing response times to hazards (Liu et al., 2017; Rey-Merchán et al., 2021). Real-time safety control using tablets also facilitates immediate access to data and monitoring, shifting safety practices from reactive to preventative (Barbosa et al., 2013; Liu et al., 2019). One of the challenges involved in implementing technology in the construction sector is hindering knowledge of these tools (Chen et al., 2022). The challenge includes high initial costs, training needs for skill development, integration issues with existing systems, security concerns for data protection, and uncertainty about the return on investment, combine with resistance to cultural change within the industry, complex regulatory compliance requirement, impacting the use of tools to promote SC (Chen et al., 2022).

Incentives like safety awards, professional safety diplomas, or small monetary rewards for completing Hazard/Near Miss cards further encourage positive safety behaviours (Gillen et al., 2004; Sherratt et al., 2011). Behaviour-Based Safety (BBS) programs focus on observing and improving individual safety behaviours by identifying at-risk actions, providing feedback, and fostering a culture of prevention and continuous improvement (Choudhry, 2014; Yang et al., 2019). These programs and rewards ensure that safety is both recognised and prioritised (Gillen et al., 2004). Real-time employee monitoring technologies (REMTs) improve safety and productivity by continuously tracking worker locations and activities. Recorded footage from REMTs is used in safety training sessions to provide concrete examples of correct and incorrect behaviours, reinforcing best practices (Johannessen, 2009; Wu et al., 2022; Wu et al., 2023). These technologies foster accountability and help maintain a high standard of safety on construction sites (Wu et al., 2023). Training tools like VR and AR offer immersive experiences that prepare workers for real-life challenges (Bao et al., 2024; Fernández et al., 2021; Newaz et al., 2023). These technologies enhance hazard recognition by providing realistic scenarios that help workers develop intuitive and immediate responses to risks (Bao et al., 2024; Fernández et al., 2021; Newaz et al., 2023). Additionally, artificial intelligence (AI) predicts hazards in real time, further enhancing on-site safety. However, the effectiveness of AI technologies depends on the experience and mindset of their users, emphasising the need for proper training (Chen et al., 2022; Rabbi & Jeelani, 2024).

c) ***Level of Communication***

The level of communication is essential for ensuring that safety practices are implemented and maintained throughout construction projects (Lingard et al., 2014). However, language and cultural barriers often hinder effective communication on construction sites due to the diversity of workers (Biggs et al., 2013; Del Puerto et al., 2018). Social culture, which encompasses shared societal values and norms, fosters inclusion and cohesion within communities, indirectly enhancing safety. Organisational culture, on the other hand, focuses on the specific values and practices within an organisation, shaping safety behaviours by addressing cross-cultural differences (Choi et al., 2015; Setiawan & Sutrisna, 2010). The interplay between these two cultures creates the foundation for fostering a safe, inclusive, and adaptive construction environment (Choi et al., 2015; Del Puerto et al., 2018; Setiawan & Sutrisna, 2010).

To overcome communication barriers, tools such as employing bilingual staff, translating training materials, and conducting customised safety sessions ensure that messages are accessible to all workers (Sukamani et al., 2021). Digital displays improve communication by providing real-time updates, celebrating safety achievements, and ensuring critical safety information is visible and accessible (MBIE, 2024; Tezel et al., 2015; Wadley, 2021). Quick Response (QR) codes enable workers to quickly retrieve safety procedures and project plans with real-time updates on their smartphones or tablets (Chen et al., 2022; Galea et al., 2020). Similarly, colour-coded card systems offer a visual means of quickly identifying critical information to enhance operational efficiency and safety (Tezel et al., 2013, 2015, 2020).

Collaboration tools, such as networking events, sharing working groups, and safety clubs, foster communication and learning by promoting innovation and sharing experiences. These platforms encourage contractors and subcontractors to exchange ideas, solve challenges, and improve project safety outcomes (Lekchiri & Kamm, 2020; Jaffe et al., 2016; Harris et al., 2020). Additionally, cultural integration activities bridge gaps by promoting inclusiveness and understanding, integrating diverse perspectives into the project (Al-Bayati et al., 2018; Tremblay et al., 2023).

d) ***Level of Resource Allocation***

Effective SC requires significant financial investment, detailed planning, comprehensive documentation, and sufficient time to implement safety measures effectively (Lingard et al., 2014; Misnan & Mohammed, 2007). Resource allocation tools are essential for ensuring financial commitments and strategic planning are aligned to mitigate risks and promote SC across all project phases.

Early planning in construction activities is crucial for enhancing safety and can be achieved through simulation-based tools like Discrete Event Simulation (DES), System Dynamics (SD), and Agent-Based Modeling (ABM). Discrete Event Simulation (DES) models systems as sequences of distinct events occurring at specific points in time, helping identify potential bottlenecks and inefficiencies in construction processes (Bokor et al., 2019). System Dynamics (SD), on the other hand, focuses on the behaviour of systems over time, emphasising relationships and feedback loops between different components. This tool is particularly useful for understanding how factors such as workforce levels, safety policies, and incident rates dynamically interact. Meanwhile, Agent-Based Modeling (ABM) simulates the actions and interactions of autonomous agents, such as workers, teams, or equipment, allowing for the analysis of scenarios where individual behaviours significantly impact overall safety performance (Misnan & Mohammed, 2007). Planning tools enable project managers to minimise risks and create safer work environments by identifying potential hazards and integrating safety measures into project schedules (Ramani & Arun Kumar, 2023; Goh & Askar Ali, 2016). Furthermore, the balanced scorecard tool offers a structured framework to measure and improve safety performance systematically (Dulaimi & Chin, 2009). It translates safety goals into actionable metrics across multiple perspectives, including management, operations, customer satisfaction, and organisational learning (Dulaimi & Chin, 2009; Mohamed, 2003).

e) ***Level of Industry Fragmentation***

The involvement of multiple contractors, subcontractors, and stakeholders with diverse standards and practices creates complexities that hinder the uniform implementation of safety measures (Tezel et al., 2013). This fragmentation necessitates standardised tools to establish a cohesive SC across all project participants (Biggs and Biggs, 2013; Fuller et al., 2022).

To address standardisation issues, tools like recording systems are applied to monitor, document, and manage safety-related data (Gibson, 2015; Nguyen et al., 2017). These systems capture information from routine safety checks, incident reports, and other activities, which promote transparency and accountability in safety management (Gibson, 2015; Nguyen et al., 2017; Shin et al., 2022). Another critical tool is regular audits, which are used to evaluate safety practices and compliance with regulations (Rabbi & Jeelani, 2024). Audits involve on-site inspections and documentation reviews that help identify areas for improvement and ensure adherence to recognised safety standards (Rabbi & Jeelani, 2024; WorkSafe New Zealand, 2017a).

Documentation and signing practices also play an essential role in maintaining safety compliance (Tezel et al., 2013, 2015). These tools include maintaining detailed records of safety inspections, incidents, and risk assessments, as well as requiring signed compliance documents to formalise accountability (Tezel et al., 2013; WorkSafe New Zealand, 2015, 2017b). Additionally, Systems Thinking tools are used to analyse complex systems by identifying active and latent failures, providing a holistic view of SC. For example, Accident Mapping (Accimap) analyses contributing factors to accident, while the Swiss Cheese Model illustrates how accidents result from multiple layers of system failures (Boardman & Sauser, 2013). Other tools, such as causal loop diagrams, Human Factors Analysis and Classification System (HFACS), and Systems-Theoretic Accident Model and Processes (STAMP), provide frameworks for understanding and addressing human and system interactions that influence safety (Goh et al., 2010; Leveson, 2004; Zhang et al., 2022).

Induction-prestart meetings are another effective tool to address industry fragmentation (Rowlinson & Jia, 2015). These meetings ensure that all personnel are familiar with site-specific procedures, safety expectations, and risks before starting work, fostering a "safety-first" mindset (Bahn, 2012; Choudhry & Fang, 2008; Rowlinson & Jia, 2015). Additionally, safety committees that include members from both the main contractor and subcontractors enhance collaboration, communication, and coordination on safety matters (Asilian-Mahabadi et al., 2018). These committees ensure shared responsibility and align diverse teams with common safety goals (Asilian-Mahabadi et al., 2018; WorkSafe New Zealand, 2024b).

Finally, tools such as the Safety Climate Assessment Tool (SCAT) and the Nordic Occupational Safety Climate Questionnaire (NOSACQ-50) provide insights into employee perceptions of safety-related policies, practices, and procedures (Darvishi et al., 2015; Probst et al., 2019). Other programs, like the Safety Training Observation Program (STOP), help identify the root causes of unsafe behaviours, enabling targeted interventions to improve safety outcomes (Guadix et al., 2017; Kwon et al., 2021).

f) *Level of Client Understanding*

Keeping stakeholders, such as clients and contractors, well-informed helps them recognise the importance of safety and its impact on overall project outcomes (Misnan & Mohammed, 2007; Lingard et al., 2014). When clients understand the role of SC, they are more likely to prioritise safety considerations during planning and execution, fostering a proactive safety environment throughout the project lifecycle (Lingard et al., 2014).

Tools like planning frameworks and the balanced scorecard provide measurable insights into safety performance and overall project outcomes. Planning frameworks involve structured approaches for organising project activities, allocating resources, and identifying potential safety risks, ensuring safety is integrated into the project workflow (Misnan & Mohammed, 2007). The balanced scorecard, on the other hand, is a strategic performance management tool that tracks key metrics across multiple perspectives like, financial, customer, internal processes, and learning and growth (Dulaimi & Chin, 2009). By incorporating these tools enable stakeholders to align their actions with safety priorities (Haseeb et al., 2014).

5.4.1.2 Modified Delphi Study

5.4.1.2.1 Modified Delphi Method – First Round (Interviews)

In the first round, 32 experts were interviewed about the main tools to promote SC on-site. After analysing their responses with thematic analysis, the 27 tools identified are presented in order of frequency based on how often they were mentioned by the experts (see Table 5-3). Toolbox Talks was the most frequently mentioned, with a total of 17 participants highlighting its importance. Trust-Open Conversations followed, with 12 participants. Other tools were mentioned sporadically by one or two experts, indicating less consensus or a more niche application; these include DuPont Bradley Curve, Scorecard, and Lean Philosophy.

Table 5-3

First Round / Interview – Thematic Analysis Results

Order	Tools/ Themes	Description	Quotes	Mentioned by
1	Toolbox Talks	An effective tool comprising regular discussions where team members share their opinions, experiences, and insights related to Health and Safety, fostering a culture of open communication and shared responsibility.	"The most useful is the toolbox once a day... the toolbox had incredible value..."The toolbox where every morning the supervisor said." (ID03) "The toolbox meetings are generally a perfect on-site tool to communicate expectations and reminders and highlight potential risks." (ID06)	Total 17 IDs: ID01, ID02, ID03, ID05, ID06, ID07, ID08, ID09, ID11, ID12, ID13, ID15, ID18, ID21, ID23, ID25, ID28
2	Trust-Open Conversatio ns	Establishing trust between safety managers and site workers when people can feel psychologically safe to report and speak up.	"We make it an open discussion, and people can raise their concerns." (ID25)	Total 12 IDs: ID05, ID08, ID11, ID13, ID14, ID16, ID17, ID24, ID25, ID28, ID30, ID32
3	Cultural Integration Activities	Breaking down barriers between different worker groups.	"…when new people who come on-site pick up on that culture and it becomes helpful to everybody." (ID10)	Total 11 IDs: ID05, ID10, ID13, D14M, ID18, ID20, ID22, ID24,

				ID28, ID30, ID32
4	Leadership Training	Training that emphasises genuine care for people and strong leadership.	"One-on-one leadership... be there, engage with people, train them, couch them, look after them." (ID10)	Total 8 IDs: ID06, ID08, ID10, ID16, ID20, ID22, ID31, ID32
5	Induction-Prestart Meeting	These meetings involve discussions and communication within the organisation to ensure that safety expectations and practices are clearly conveyed to the site team and subcontractors.	"We talk big about early contractor engagement." (ID26) "…having people inducted into the site through proper procedure." (ID18)	Total 8 IDs: ID01, ID04, ID07, ID14, ID18, ID23, ID24, ID26
6	Awards	Safety awards are tools or programs used to recognise and reward good behaviour and safety practices.	"We often put on barbecues for subcontractors with the best Health and Safety performance, we give away awards for exceptional Health and Safety leadership." (ID15)	Total 7 IDs: ID01, ID05, ID09, ID10, ID15, ID16, ID17
7	Applications (Apps)	Specific software applications or 'apps' designed for Health and Safety quality assurance (e.g., online portals).	"Most apps only work at a compliance level. We used our safety systems." (ID26) "Using technology... text messaging, emailing, apps." ID31	Total 7 IDs: ID04, ID05, ID06, ID14, ID15, ID26, ID31
8	Online Training	Online or digital materials and tools related to Health and	"Online Training on SiteSafe, they have a tonne of material there that any business that wants to get	Total 7 IDs: ID02, ID04, ID16, ID20,

		Safety that are easily accessible for employees.	serious about safety can access usually for free." (ID02)	ID27, ID28, ID30
9	Recording Systems	Tools or software used for documenting and tracking safety-related information, incidents, or compliance with safety measures.	"It's effortlessly easy to record their safety information." (ID21)	Total 6 IDs: ID02, ID05, ID06, ID10, ID15, ID21
10	Language Translation	Providing language translation when communicating safety topics and issues, especially for more impactful hazards.	"It's important to provide the content in their own language, but also in English terms." (ID27)	Total 5 IDs: ID01, ID03, ID14, ID27, ID32
11	Planning	This includes tools such as Last Planner and Risk Planning to ensure everyone understands their dependencies on each other.	"It's collaborative planning, not a telling thing... and using the expertise of people overlapping with each other." (ID18)	Total 4 IDs: ID02, ID14, ID18, ID24
12	Audits	Audits help identify issues, monitor compliance, and improve safety practices.	"Performing safety audits internally." (ID23)	Total 3 IDs: ID05, ID23, ID24
13	Documentation and Signing	Proper documentation and signing of toolbox meeting records.	"Reducing the burden of excessive paperwork that often results in a "paper war." (ID12)	3 IDs: ID12, ID18, ID32

14	Health and Safety Processes	Documenting processes, policies, and values.	"Everyone in the company follows procedures... to protect themselves and others around them." (ID04)	3 IDs: ID18, ID24, ID32
15	Committees for the Main Organisation and Subcontractors	This refers to a group or committee within an organisation that focuses on Health and Safety matters.	"We have regular meetings every week with subcontractors." (ID01) "We have a Health and Safety committee... we meet monthly to discuss major accidents, incidents, and initiatives." (ID15)	3 IDs: ID02, ID05, ID15
16	Working Group	It can involve passionate individuals who may not have Health and Safety as their primary job but are responsible for raising safety concerns and improving safety measures.	"…different nationalities, health safety practitioners together in a working group, it's about engaging them and understanding their challenges." (ID27)	2 IDs: ID07, ID27
17	Lean Philosophy	Adopting a Lean philosophy, as used in other industries like automotive manufacturing (i.e., Lean Construction).	"…lean as a philosophy and a systematic way of working to improve many things, including safety." (ID19)	2 IDs: ID19, ID32
18	Networking and Knowledge Sharing	Networking and seeking knowledge from industry events and other companies.	"Go networking, go to industry events, and find out what others are doing... be open to what other companies have already done." (ID29)	2 IDs: ID15, ID29
19	Safety Club	Promotes safety awareness and engagement among	"Safety Clubs is where we have real conversations about the dangers of construction work." (ID32)	2 IDs: ID09, ID32

		site workers. It includes events like the voice meeting and encourages participation and feedback.		
20	Digital Screen	This could refer to a digital display used to present information.	“We now have a digital screen that shows the entire business when the last day we had a lost time injury.” (ID04)	2 IDs: ID02, ID04
21	QR Codes	QR codes are scannable codes that can link to digital resources or websites to report incidents or raise safety concerns.	“An online portal where they scan QR codes to report on incidents, hazards, and best practices.” (ID16)	2 IDs: ID02, ID16
22	Colour-Coded Card System	Yellow cards may indicate a minor breach that needs discussion with a supervisor, while red cards may indicate more serious violations with potential consequences such as re-induction.	“One of the main contractors runs a red card yellow card system... two yellows red. You're going to be re-inducted." (ID05)	2 IDs: ID05, ID13.
23	Delivery Lead	A leader who champions safety within an organisation or project.	“A delivery lead can work early... setting the contract up to deliver the outcomes that you need.” (ID13)	1 ID: ID13

24	DuPont Bradley Curve	It is used to categorise SC into four key statuses: reactive, dependent, independent, and interdependent.	"I use DuPont Bradley curve that helps define the stages of the safety culture." (ID29)	1 IDs: ID29
25	Scorecard	A system used to track and manage safety performance through a colour-coded card system.	"We have a Scorecard, pretty sophisticated processes in place, ensuring consistency in safety culture." (ID05)	1 ID: ID05
26	First Aid Training	This training enables workers to respond effectively to accidents and injuries.	"First Aid training gives workers the confidence to uphold safety culture." ID30	1 IDs: ID30
27	Visual Indicators	Making safety signs and procedures clearly visible and easily identifiable.	"I believe in visual indicators... something that's clearly visible marked out and delineated." (ID21)	1 IDs: ID21

Note: For detailed descriptions and additional information on each tool, please refer to Chapter 7.

5.4.1.2.2 Modified Delphi Method – Second Round (Survey)

In the second round, the *RII* was calculated, and a ranking of tools is provided based on their *RII* (see Table 5-4). Among the 27 tools, "Trust and Open Conversations" led with *RII*=0.97, followed by "Planning" with *RII*=0.93, and "Leadership Training" with *RII*=0.90. This was emphasised by "Visual Indicators" with *RII*=0.89, alongside "First Aid Training" with *RII*=0.84, and "Toolbox Talks" and "Networking and Knowledge Sharing," both with *RII*=0.81.

Table 5-4

RII and Ranking of the Tools to Promote SC

Tools	1. Less important	2. Slightly important	3. Neutral	4. Moderately important	5. Very important	*RII*	Rank
Trust-Open Conversations	0	0	3	8	115	0.97	1
Planning	0	0	0	36	85	0.93	2
Leadership Training	0	0	9	28	80	0.90	3
Visual Indicators	0	0	9	32	75	0.89	4
First Aid Training	0	2	15	32	60	0.84	5
Toolbox Talks	0	0	24	36	45	0.81	6
Networking and Knowledge Sharing	0	6	3	56	40	0.81	6
Induction-Prestart Meeting	1	4	12	32	55	0.80	7
Recording Systems	0	2	18	48	35	0.79	8
Delivery Lead	1	4	18	24	55	0.78	9
H&S Processes	1	6	9	36	50	0.78	9
Working Group	0	2	21	48	30	0.78	9
Cultural Integration Activities	1	2	21	32	45	0.78	9
Audits	0	2	21	48	30	0.78	9
Language Translation	2	2	21	32	40	0.75	10
Committees for the firm and subcontractors	2	4	15	52	20	0.72	11

Online Training Programme	1	6	24	36	25	0.71	12
Apps	0	4	33	48	5	0.69	13
Awards	0	10	24	40	15	0.68	14
Scorecard	1	8	21	48	10	0.68	14
Lean Philosophy	2	2	33	40	10	0.67	15
DuPont Bradley Curve	4	0	33	28	20	0.65	16
Documentation and Signing	3	12	18	24	25	0.63	17
Digital Screen	1	8	36	32	5	0.63	17
Safety Club	3	8	27	28	15	0.62	18
QR Codes	3	4	36	28	10	0.62	18
Colour-Coded Card System	5	2	39	24	5	0.58	19

Note: See Appendix 2 for detailed *RII* calculation methodology and results.

5.4.2 Phase 2: Categorising the Tools

Firstly, tools captured from the literature review and the Modified Delphi study were categorised through thematic analysis, with each tool being aligned with specific influential factors as outlined by Ortega et al. (2025). Next, through syllogistic reasoning, the tools are organised by whether they were a) directly captured by experts only, b) solely captured in the literature, and c) captured from both.

A total of 39 tools were identified among the experts and literature. The experts captured 21 tools in common with the tools captured in the literature review (see Table 5-5). For instance, tools suggested to enhance SC, such as toolbox talks, are associated with the Level of Leadership Commitment, which was associated as the most critical factor by Ortega et al. (2025). Only 6 tools were captured by experts and not directly captured in the literature, one of these for example is the Dupont Bradley Curve, the first maturity model to assess safety. However, there were 12 tools that the experts did not mention. For example, the literature provided a more comprehensive range of advanced technologies, including simulations, VR, and AR (Chen et al., 2022; Goh & Askar Ali, 2016). Furthermore, the literature review highlighted the importance of system thinking tools; however, it was not a tool brought up by participants. The same occurred with survey tools and safety management programs, like the safety climate assessment toolkit (Darvishi et al., 2015) and the Nordic Occupational Safety Climate questionnaire (Kwon et al., 2021; Schwatka et al., 2016); while the literature review highlighted their importance, none of the participants mentioned them. Both Planning and the Scorecard tools are integral to multiple factors, Level of Client Understanding and Level of Resource Allocation, and are counted only once when assessing their relevance across these areas. These tools are common across the two factors because they foster integration, accountability, and data-driven decisions, all of which are fundamental to cultivating SC.

Table 5-5
Matrix of Tools Categorised According to Influential Factors

Influential factors	Tools from the experts	Common tools (experts and literature)	Tools from the literature
Level of Leadership Commitment	+DuPont Bradley Curve +Delivery Lead	+Trust-Open Conversations +Leadership Training +Toolbox Talks +Lean Philosophy	
Level of Experience and Mindset	+Online Training Programs: Sitesafe + WorkSafe +First Aid Training	+Awards +Applications (Apps)	+Behaviour-Based Safety (BBS) Programs +Real-time Employee-Monitoring Technologies (REMTs), AI-based CCTV Surveillance, Site Access Control +VR for Customised Training +AR for Safety Practices +Real-Time Quality and Safety Control Using Tablets +AI for Safety
Level of Communication	+Safety Club +Visual Indicators	+Networking and Knowledge +Sharing Working Group +Language translation +Digital Screen	

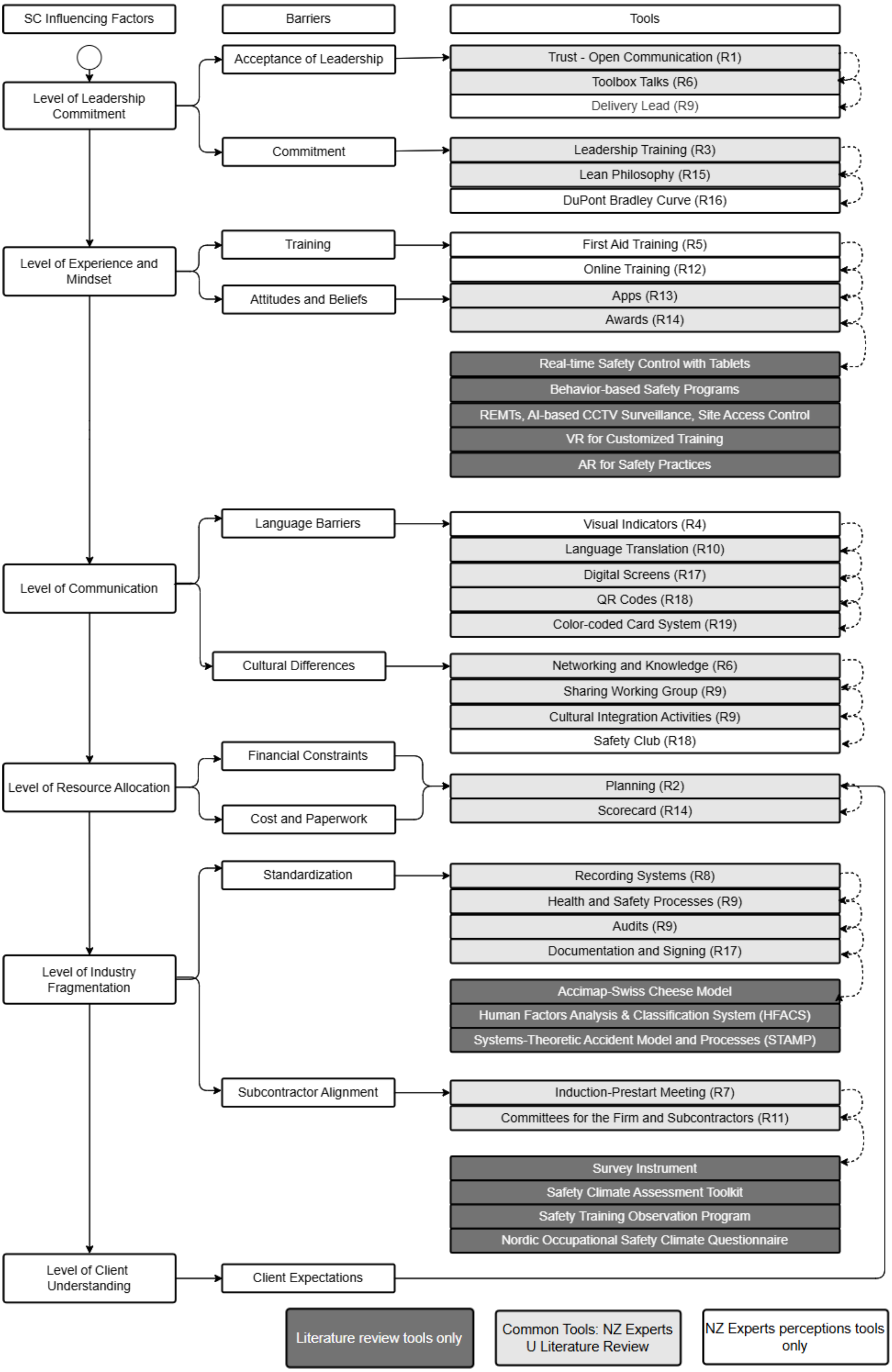
		+QR codes +Cultural Integration Activities +Colour-Coded Card System	
Level of Resource Allocation		+Planning +Scorecard	
Level of Industry Fragmentation		+Induction-Prestart Meeting +Working Group Committees for the Firm and Subcontractors +Recording Systems +Health and Safety Processes +Documentation and Signing +Audits	+Accimap-Swiss Cheese Model +Human Factors Analysis & Classification System (HFACS) +Systems-Theoretic Accident Model and Processes (STAMP) +Safety Climate Assessment Toolkit (SCAT) +Safety Training Observation Program +Nordic Occupational Safety Climate Questionnaire
Level of Client Understanding		+Planning +Scorecard	

5.4.3 Phase 3: Creating a Conceptual Framework

The prototype framework developed (see Figure 5-2) in this study is presented as a flow-based diagram that visually represents the relationships between the six influential factors, barriers, and tools for promoting SC. The diagram begins with the six influential factors identified in Chapter 4, linking each factor to its respective barriers, as outlined in the Causal Loop Diagram presented in Chapter 4. Then progressing to Phase 2, where the tools are categorised and represented in Phase 2, to enhance clarity, the tools are visually differentiated using distinct background colours in the flowchart. These colours indicate whether the tools were directly captured by New Zealand experts, discussed in the literature, or captured by both groups, based on thematic analysis and syllogistic reasoning conducted in Phase 2. This visual representation provides a clear and intuitive understanding of how each component interacts within the framework (see Figure 5-2). For instance, if there is an issue with the "Level of Communication" in the project, associated with language barriers, then safety practitioners could possibly implement tools like Digital Screens, QR codes, and Colour-coded Card System to improve SC.

Figure 5-2

Conceptual Framework of Tools Categorised According to Influential Factors



SC Influencing Factors
Barriers
Tools
Level of Leadership Commitment
Acceptance of Leadership
Trust - Open Communication (R1)
Toolbox Talks (R6)
Delivery Lead (R9)
Commitment
Leadership Training (R3)
Lean Philosophy (R15)
DuPont Bradley Curve (R16)
Level of Experience and Mindset
Training
First Aid Training (R5)
Online Training (R12)
Attitudes and Beliefs
Apps (R13)
Awards (R14)
Real-time Safety Control with Tablets
Behavior-based Safety Programs
REMTs, AI-based CCTV Surveillance, Site Access Control
VR for Customized Training
AR for Safety Practices
Level of Communication
Language Barriers
Visual Indicators (R4)
Language Translation (R10)
Digital Screens (R17)
QR Codes (R18)
Color-coded Card System (R19)
Cultural Differences
Networking and Knowledge (R6)
Sharing Working Group (R9)
Cultural Integration Activities (R9)
Safety Club (R18)
Level of Resource Allocation
Financial Constraints
Cost and Paperwork
Planning (R2)
Scorecard (R14)
Level of Industry Fragmentation
Standardization
Recording Systems (R8)
Health and Safety Processes (R9)
Audits (R9)
Documentation and Signing (R17)
Accimap-Swiss Cheese Model
Human Factors Analysis & Classification System (HFACS)
Systems-Theoretic Accident Model and Processes (STAMP)
Subcontractor Alignment
Induction-Prestart Meeting (R7)
Committees for the Firm and Subcontractors (R11)
Survey Instrument
Safety Climate Assessment Toolkit
Safety Training Observation Program
Nordic Occupational Safety Climate Questionnaire
Level of Client Understanding
Client Expectations
Literature review tools only
Common Tools: NZ Experts U Literature Review
NZ Experts perceptions tools only

To improve the accessibility and understanding of the framework, an informational report was developed (see Chapter 7). This format was chosen for its clarity and structured approach, making it well-suited for providing detailed descriptions (Kabir, 2016; Wilkinson, 2022). The report comprehensively explains the framework's tools, covering their purpose, frequency and format of use, engagement strategies, examples, and potential impact on SC. To further enhance accessibility, the report incorporates visual aids such as QR codes linked to video descriptions (Gedera & Zalipour, 2018; Megha & Satishkumar, 2024; Wilkinson, 2022. These QR codes allow readers to easily access video content, enabling them to revisit the material as needed and improving their overall understanding (Megha & Satishkumar, 2024; Wilkinson, 2022). The use of videos ensures consistent dissemination of knowledge, supporting a uniform understanding of the framework's tools (Gedera & Zalipour, 2018; Varela & Mejía, 2018). The informational report also facilitates decision-making by providing actionable insights in a user-friendly format (Wilkinson, 2022). Additionally, the ability to access supplementary materials, such as videos, directly from the report supports iterative learning and addresses the practical needs of the industry, ultimately promoting the framework's usability (Sherratt et al., 2025; Wilkinson, 2022). The primary purpose of the report is to inform or instruct the reader by clearly detailing the specifics of a situation, with the structure organised first by influential factors, followed by detailed descriptions of tools associated with each factor (Kabir, 2016). Each tool description included a QR code with access to a video explanation. The purpose of the QR code was to enhance accessibility and convenience for the reader, allowing them to review the content as needed (Megha & Satishkumar, 2024). Also, the video format ensured that the dissemination of knowledge was consistent, clear, and engaging, making it more practical and preventing misunderstandings and inconsistencies in how the tools are presented across different interviews. The videos accompanying the framework were created using Pictory AI, a video generation tool that transforms text into engaging visual content (Pictory, n.d.). The script for each video was derived directly from the detailed descriptions provided in Chapter 7 of the report. These descriptions, which outline the purpose, format, and use of each tool, served as the narrative foundation for the video content. This approach ensured consistency between the written report and the audiovisual materials, enhancing the clarity, accessibility, and practical value of the framework for end users.

5.5 Discussion

5.5.1 Phase 1: Identifying Tools

The Modified Delphi method is designed to achieve consensus among experts through iterative rounds, beginning with individual interviews in the first round and followed by a survey questionnaire in the second round (McKay et al., 2022; Mullen, 2003; von der Gracht, 2012). This approach is particularly advantageous as it prevents individual opinions from being influenced by dominant voices, thereby preserving the integrity and independence of each expert's perspective. The evolution of expert opinions from the first to the second round was systematically analysed using statistical measures such as the relative importance index (*RII*). While the first round reflects the individual views, the second round shows how these views converge as participants consider the collective feedback and find areas of agreement and disagreement. For example, some tools that were frequently mentioned in the first round were ranked lower in importance after further consideration, while others rose in importance.

There were minimal changes in the rankings of certain tools observed between the first and second rounds. Leadership Training, which was ranked 4th in the first round and 3rd in the second, maintained a high level of importance, emphasising its critical role in SC. Language Translation and Recording Systems remained stable, with slight or no shifts in rank, demonstrating their continuous value in safety management and communication. Working Groups and Audits experienced little upward progress but stayed close to their initial positions, indicating ongoing recognition of their roles in compliance and collaboration. Committees for the Main Organisation and Subcontractors saw a slight increase in ranking, reflecting consistent acknowledgment of their significance. Trust-Open Conversations also exhibited minimal change, moving from 2nd to 1st place, underscoring its steady importance as a foundational tool for building SC. Lean philosophy was mentioned only by 2 out of 32 experts during the first round of the study. In the second round, it ranked 15th among the tools proposed to promote safety culture. This aligns with observations by Plugge et al. (2023) that Lean philosophy, despite its potential benefits, remains underutilised in the construction sector and has yet to be widely integrated across the industry. These small changes suggest that experts valued these tools from the beginning, with little need for re-evaluation after feedback.

In contrast, significant changes were observed in the rankings of other tools between the first and second rounds. Toolbox Talks, initially ranked 1st, dropped to 6th in the second round, indicating that while initially seen as highly significant, its perceived importance decreased after further consideration. Planning showed a notable rise from 11th to 2nd, highlighting an increasing recognition of proactive safety management. Visual Indicators also experienced significant improvement, climbing from 27th to 4th, reflecting a growing appreciation for enhancing safety communication.

Apps and Awards dropped in significance, with Apps moving from 7th to 13th and Awards falling from 6th to 14th, indicating that after further considerations, these tools were becoming less important than initially thought. The Scorecard tool, ranked 25th in the first round, rose to a joint 14th in the second round, signalling a shift towards recognising its importance in tracking and measuring safety performance. This shift highlights the purpose of the Modified Delphi study: to refine expert opinions through iterative feedback, indicating a consensus that prioritises tools contributing concrete, data-driven insights into SC (von der Gracht, 2012). These shifts highlight a progressing preference for tools with tangible impacts on SC, showing how the Modified Delphi approach facilitated a transition from engagement-focused tools to those that reinforce measurable outcomes.

5.5.2 Phase 2: Categorising the Tools

The thematic categorisation showed a diverse range of tools that correspond to different levels of influence within the SC framework. At the level of Leadership Commitment, tools such as Leadership Training, Toolbox Talks, and DuPont Bradley Curve foster a culture of safety from the top down. At the Level of Experience and Mindset, tools like Behaviour-Based Safety (BBS) Programs and VR for Customised Training improve individual and collective safety awareness and skills.

Tools like Safety Clubs, Networking, and Knowledge Sharing, facilitate safety information at the level of communication and knowledge sharing, because they promote dialogue and learning. Visual indicators and QR codes make safety information accessible on-site, enhancing the visibility of safety protocols and procedures. At the level of Client Understanding, tools boost the client's engagement through Planning and Scorecards by supporting safety practices with reports that align client expectations with the operational realities of safety management.

At the Resource Allocation level, essential tools like Planning and Scorecards ensure that sufficient resources are used, run reports about safety indicators, and evaluate and set measurements to track safety initiatives. At the level of Industry Fragmentation, tools like Induction-Prestart Meetings unify fragmented groups within the industry, from subcontractors to main contractors.

The tools directly captured by the literature review for promoting SC in the construction sector often led to pioneering or less traditionally employed methods within the framework. Tools like the Accimap-Swiss Cheese Model and the Systems-Theoretic Accident Model and Processes (STAMP), which are integral to systems thinking, might be considered by experts if they are facing challenges at the level of Industry fragmentation. Investigating the application of systems thinking in other industries, which has guided teams in identifying safety risks, integrated stakeholders, and supported making decisions to enhance safety (Butler et al., 2022; Hulme et al., 2021; Newnam et al., 2021), requires further exploration among safety experts in the construction sector.

Moreover, the Safety Climate Assessment Toolkit (SCAT), Safety Training Observation Program (STOP), or Nordic Occupational Safety Climate Questionnaire (NOSACQ-50) focus on real-time data utilisation and psychological safety elements, sparking potential consideration from the expert that aligns with modern construction sector challenges and trends. Understanding why experts have not directly captured these survey tools to enhance SC merits additional exploration. As does exploring why experts did not mention VR for Customised Training and AR for Safety Practices, along with Real-time Employee-Monitoring Technologies (REMTs), AI-based CCTV Surveillance, Site Access Control, and AI for Safety, that is, tools that are all emphasised in the literature as significant technological trends. Chen et al. (2022) identified several challenges that hinder the implementation of technology in the construction sector, which may also impact awareness and adoption of tools for promoting SC. These challenges include high initial costs, the need for training to develop relevant skills, integration issues with existing systems, data security concerns, and uncertainty about return on investment. Additionally, resistance to cultural change within the industry and complex regulatory compliance requirements present significant barriers to the effective utilisation of SC tools.

5.5.3 Phase 3: Creating a Conceptual Framework

The third objective of this study was to develop a framework (see Figure 5-2) that categorises tools according to their application across the influential factors presented in Chapter 4. The framework addresses a critical gap in existing SC frameworks by enhancing the traceability and practical application of tools in daily operations and decision-making. Unlike previous frameworks, which primarily focus on integrating cultural, behavioural, and organisational factors, this study explicitly connects influential factors to practical tools, providing a clear pathway for implementation. For instance, the Malaysian framework emphasises quantifying SC but provides minimal guidance on implementing specific tools (Ismail et al., 2010). The Saudi framework highlights the leadership's role but lacks detailed pathways for tool integration (Alasamri et al., 2012). The Indonesian framework focuses on integrating policy and institutional factors but remains centred around addressing national-level safety challenges without practical tool categorisation (Machfudiyanto & Latief, 2018).

The developed framework bridges these gaps by linking tools directly to influential factors, ensuring alignment between daily on-site activities. Furthermore, the framework utilises a mixed-method approach, integrating findings from a Modified Delphi study and a literature review to comprehensively include tools regardless of their level of recognition within the industry. While regional frameworks aim to improve SC through theoretical insights and broad organisational strategies, their practical applicability remains limited. The other frameworks reviewed do not prioritise tool categorisation for practical daily use. Instead, they concentrate on integrating cultural, behavioural, and organisational factors without explicitly linking these to specific tools. The framework developed in this study addresses this limitation by offering pathways for implementation that facilitate decision-making.

Frameworks should ideally present visual tools such as rich picture diagrams, which are crucial for capturing complex interactions and emerging themes, offering a comprehensive view of processes and relationships involved; the visual part of a framework is essential for synthesising and communicating fundamental concepts (Barrett & Sutrisna, 2009; Partelow, 2023). This inspires the framework development in this study, which uses visual representations to clearly outline the relationship between SC influential factors and tools, thus enhancing understanding and facilitating their practical application in improving SC. This structured visual mapping improves traceability and boosts usability among on-site project managers and safety experts. The purpose of the framework is not to identify problems facing practitioners, but rather to promote safety culture by offering a structured and flexible approach to addressing known challenges. It presents a set of tools captured through a panel of expert consensus and literature review, organised according to six influential factors that impact safety culture in New Zealand (Ortega et al, 2025). These influential factors guide users in selecting tools most relevant to the specific safety issues they face. The framework does not recommend the simultaneous use of all tools. Instead, it enables decision-makers to select and prioritise tools based on their project context and available resources. For users unfamiliar with specific tools, the framework is accompanied by an informational report (see Chapter 7), which provides detailed descriptions of each tool, including its purpose, frequency of use, and implementation strategies, including QR codes linking to short explanatory videos that introduce each tool in an accessible and visual format. These resources can be used for individual learning or shared with team members to support consistent understanding and implementation across construction projects.

The integration of the TPB within SC frameworks across different regions, including Indonesia, Malaysia, and Saudi Arabia, throughout different visualisations, provides a theoretical foundation that enhances the understanding and implementation of safety practices (Ismail et al., 2010; Machfudiyanto & Latief, 2018). The developed framework and its visualisation, anticipate behaviour modification by strategically addressing the three TPB factors. TPB's three core components, which are attitudes, subjective norms, and perceived behavioural control, are embedded within the framework to promote safer practices across construction sites. Attitudes toward safety are shaped through tools such as Leadership Training and Awards, which encourage positive perceptions of safety as an essential and valuable part of daily operations. By fostering an environment where safety is consistently prioritised and reinforced by leadership, workers are more likely to adopt favourable attitudes toward safe behaviours. Subjective norms are addressed through the implementation of tools like Toolbox Talks, peer mentoring, and Safety Committees, which establish and reinforce social expectations related to safety. These tools create a culture where safety is viewed as a collective responsibility, increasing the perceived social pressure on workers to adhere to safety standards. Additionally, perceived behavioural control is enhanced through the use of reporting systems, and training programs that equip workers with the necessary knowledge, skills, and resources to perform tasks safely. The framework operationalises TPB by strategically mapping each tool to one or more of these behavioural components, ensuring that safety interventions are not only practical but also grounded in behavioural theory. This integration ensures that the adoption of safety tools is both behaviourally sound and contextually relevant, fostering a robust SC within the New Zealand construction sector.

5.5 Conclusion

This research achieved its aim of developing a comprehensive framework to translate abstract influential factors into actionable strategies for enhancing SC in New Zealand construction sector. By using a mixed-methods research design, this study offers a framework for on-site project managers and safety leaders to implement to promote SC within SC in construction sites in New Zealand.

The objective 1 was accomplished by getting a consensus among New Zealand experts in the construction sector on the tools commonly used to promote SC. This consensus provides a validated foundation of current practices and expert preferences, ensuring that the framework is built on industry expert insights. The objective 2 involved categorising the tools detected in the literature review and the Modified Delphi study, capturing both tools directly recognised in practice and those less explicitly acknowledged. By aligning these tools with the influential factors for promoting SC in New Zealand, as developed in Chapter 4, the study has begun a clear linkage between theoretical and practical tools. Finally, the objective 3 was achieved by creating a visualisation of the framework, which organises the tools according to their application across the identified influential factors. This visualisation assists interpretation, and the informational report facilitates the application of the framework, granting safety leaders to quickly assess which tools are most appropriate for addressing specific characteristics of SC.

However, to support broader adoption, the next essential step is to validate the framework's usability, similar to prior frameworks, and to ensure its full applicability, future implementation through longitudinal studies will be necessary. This underscores the need for future research to focus on operationalising and validating the usability of the framework through case studies, interviews, or surveys. The framework developed has broader implications that could be valuable to the academic community for further refinement and application in different contexts, suggesting its usefulness as a foundational methodological model for global academic research.

In conclusion, this framework acts as a tool for bridging the gap between abstract safety concepts and concrete actions, allowing safety leaders with the knowledge and resources needed to make informed decisions about safety interventions tailored to the unique needs of their projects.

Summary

This chapter aimed to develop a framework for promoting SC, tailored to New Zealand's construction sector where accidents and injuries are prevalent. The fragmented nature of the construction sector presents unique challenges in implementing proactive SC measures, requiring innovative strategies and tools. This chapter aimed to develop a structured framework that connects SC factors to targeted tools, facilitating practical decision-making for safety practitioners. The framework addressed gaps in existing frameworks about SC by focusing on actionable tools and their application to influential SC factors, with the goal of facilitating decision-making to safety practitioners, ultimately enhancing safety practices on construction sites. It was guided by three objectives: (1) achieving consensus among industry experts on SC tools, (2) categorising these tools based on their alignment with influential SC factors, and (3) creating a visual framework to operationalise these insights effectively.

The Phase 1, identifying the tools, involved a comprehensive literature review and a Modified Delphi study with industry experts, capturing both tools directly recognized in practice and those less explicitly acknowledged. This chapter presents the findings of the third question of the Modified Delphi study, which focused on identifying tools to promote SC, and by categorising the tools, a conceptual framework was developed. The study followed the same data collection and analysis methods used for identifying the six influential factors outlined in Chapter 4. A panel of 32 experts participated in the Modified Delphi Study to reach a consensus about the most common tools they use to promote SC within the New Zealand construction sector. A total of 39 tools were identified, with 21 tools appearing in both the literature and Delphi study results, 12 exclusives to the literature, and 6 unique to expert feedback. Tools such as "Trust and Open Conversations" and "Planning," ranked highly, while others like "Apps" and "Awards" ranked lower.

In Phase 2, the tools were categorised under six influential SC factors defined in Chapter 4. The categorisation process was conducted in two main stages: initial categorisation and refined analysis. The initial categorisation identified how each tool, gathered through a comprehensive literature review and the Modified Delphi study, aligns with the six influential factors. Thematic analysis was employed to group the tools, revealing a diverse array of tools corresponding to different levels of influence within the SC framework. This process highlighted gaps between tools commonly cited by experts and those identified in the literature, particularly in areas such as advanced technologies, like VR and AI, systems thinking tools, like STAMP, and survey tools like The Nordic Occupational Safety

Climate Questionnaire. The refined analysis used syllogistic reasoning to represent intersections, unions, and differences among the tools. This approach delineated which tools were exclusively noted by experts, solely highlighted in the literature, or recognised by both. The categorisation provided clear guidance on which tools are most effective and how they correlate with specific influential factors, aiding decision-making for safety practitioners.

In Phase 3, a conceptual framework was created, that involved designing a visual framework to operationalise the identified tools. A flowchart-based representation was used to link tools to their respective SC factors, making it easy for practitioners to navigate and apply. Distinct colours in the diagram differentiated tools identified solely by experts, those from the literature, and those common to both sources. For example, tools like "QR Codes" and "Digital Screens" were mapped to the "Communication" factor to address language barriers and improve real-time safety updates. This visual framework simplifies the application of tools, making it accessible and actionable through the informational report for safety practitioners (see Chapter 7). This standardised presentation guarantees that all users receive the same detailed explanations, enhancing understanding and preventing miscommunication during future implementation.

The framework bridges the gap between theoretical research and practical application, addressing the fragmented nature of New Zealand's construction sector, where accidents and injuries are prevalent. It connects influential SC factors to actionable tools, providing a structured guide for improving safety practices. Tools such as "Trust and Open Conversations" and "Planning" ranked highly, while others like "Apps" and "Awards" ranked lower. The framework emphasises usability, traceability, and adaptability, ensuring that tools can be tailored to specific project contexts. While it is tailored to New Zealand's construction sector, the methodology and structure of the framework offer significant potential for broader application and refinement in other contexts, however, validation and implementation are the next steps for broader adoption. This chapter establishes the framework as a foundational model for academic research, with the potential to be refined and adapted to various contexts. It sets the stage for the next phase, which will focus on validating the framework to ensure its effectiveness and adaptability for broader adoption in enhancing SC on a global scale.

Chapter 6: Operationalising a Safety Culture Framework: Applicability and Practicality in Real-world Settings

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Abstract

Although the construction sector presents substantial safety risks, it plays a pivotal role in global infrastructure development and socio-economic growth, creates significant employment opportunities. New Zealand's construction sector also shows a high incidence of workplace accidents, reporting severe injury rates significantly higher than both the national and international averages. Therefore, this paper aims to validate the usability of the framework previously developed through four case studies. This validation involves operationalising the framework using feedback related to its potential utilisation as a decision-making tool for on-site projects, from project managers and H&S managers in the four case studies. The findings highlight the framework's potential as a methodological model for promoting SC in vertical construction sector, applicable both within New Zealand and internationally. However, the study's country specific focus suggests a need for longitudinal studies to evaluate the framework's sustained impact and practical integration. This research contributes to the academic and practical understanding of constructing safer work environments, emphasising continuous improvement and adaptation of safety practices suitable for various construction settings.

Keywords: Safety Culture, Construction sector, Framework, Case Study, Safety Management

6.1 Introduction

The construction sector is widely recognised as the fundamental vehicle for infrastructure development and socio-economic growth globally (Rafindadi et al., 2022; Umeokafor et al., 2022). It serves to produce structures and infrastructure involving housing, schools, hospitals, and offices. Besides, the construction sector generates direct and indirect employment opportunities for millions who build, operate, monitor, or maintain these facilities worldwide (Rafindadi et al., 2022). However, 30%-40% of occupational fatalities belong to the construction sector (Rafindadi et al., 2022). In New Zealand, a report created by Eaqub (2024) about the construction sector unveiled alarming facts about workplace accidents within New Zealand's building construction sector. It reports 22 severe injuries per 1,000 workers, which is 70% higher than the New Zealand average and 16% higher than the in the Australian construction sector. This rate underscores the urgent need for safety improvements in construction sector in New Zealand.

Despite the valuable role of SC in mitigating risks and preventing injuries, a survey funded by WorkSafe New Zealand highlights a significant erosion in collaborative safety practices within the sector, revealing a decrease in health and safety (H&S) prioritisation in New Zealand since 2021 (Rout, 2023). Between October 1, 2022, and September 1, 2023, incident records show that 518 of the 600 reported cases in New Zealand's construction sector occurred in the vertical construction sector (Hennecke et al., 2021; WorkSafe New Zealand, 2024c). The integration of safety culture (SC) in New Zealand's construction sector is considered necessary to improve the situation but at the same time, its implementation is facing specific challenges.

To tackle these issues, this study intends to operationalise the framework developed by Ortega et al. (2025) to promote SC in construction sites in New Zealand, by validating its usability. Operationalisation involves using the developed framework to collect and analyse data, and then drawing conclusions based on empirical evidence gathered across four cases related to vertical construction to validate the framework's usability for further adoption. This is relevant because it demonstrates how the framework could be used by professionals in construction sites in the real world.

6.2 Background

6.2.1 Safety Culture

Studies have proven the value of SC in injury prevention, mitigating current and emerging risks, identifying hazards, and establishing a positive SC to facilitate workplace safety (Al-Bayati et al., 2019; Gillen et al., 2004; Lingard et al., 2015, 2019). A survey run by Rout (2023a), funded by WorkSafe New Zealand, about H&S in New Zealand, which involved 2,494 employers from different industries including 390 employers from construction, identified there has been a noticeable erosion in the elements that foster a collaborative SC in the construction sector. The survey exposed that the prioritisation of H&S for the construction sector has markedly declined since 2021; there has been a 10-point decline in the emphasis on keeping workers healthy and safe, with only 57% of employers in construction now prioritising these issues. This has also been a downturn in engagement practices, including informal conversations and standard reporting processes in this sector. This shift has been associated with reduced levels of correct personal protective equipment (PPE) usage and training in the sector.

6.2.2 Safety in Construction

The Deloitte (2023) Construction Pulse Check report and the BRANZ (2024) Industry Insights Reports assess the current state and emerging trends in New Zealand's construction sector. The Deloitte (2023) report examines various challenges facing New Zealand's vertical construction sector. Firstly, there is a need for the market to increase resources, to strengthen contractors' concentration based on the size, and complexity, as contractors allocate resources to meet extensive tender requirements instead of enhancing site safety measures. Secondly, there are difficulties in sourcing skilled labour due to the pressure of wage prices and industry fatigue, which affect the overall performance and safety standards on construction sites. The need for improved productivity through modularisation, standardisation, and appropriate project sizing requires adequate procurement practices, potentially leading to inconsistent safety practices as contractors juggle various projects with varying demands. A third challenge is the overruns in budget and schedule, due to issues with the completeness and coordination of design documents, which can compromise safety standards as projects rush to meet deadlines. These challenges indicates that contractors operating under intense cost, time, and labour constraints may deprioritise safety in favour of meeting tender, productivity, or scheduling pressures. Without deliberate strategies and tools to embed safety into everyday decision-making, these structural challenges risk perpetuating inconsistent and inadequate safety practices in vertical construction.

In New Zealand's construction sector, systemic challenges intertwine economic pressures with safety outcomes, as highlighted in a recent BRANZ (2024) report. Builders often face the dual pressures of maintaining high-quality standards while managing costs. This economic constraint frequently leads to prioritising minimum legal requirements, which negatively impacts the quality of construction projects and contributes to inconsistencies in building code applications. These inconsistencies make it difficult for the industry to adapt to market changes or implement new technologies, ultimately compromising safety.

There are also specific issues and trends related to safety in the construction sector covered in the Workplace Safety and the Future of Work in New Zealand report (Hennecke et al., 2021). Of 600 construction incidents reported from October 2022 to September 2023, 518 were in vertical construction. Vertical construction focuses on erecting structures in a vertical orientation, such as skyscrapers, residential buildings, and other multi-story facilities (Brenner, 2015; Jayasinghe et al., 2023). Falls, struck by moving objects, and machinery incidents are the common types of injuries in the vertical construction sector, which continues to report a high number of injuries (Abdelhamid Tariq & Everett John, 2000; Rafindadi et al., 2022). The complexity of vertical construction stems from the multiple layers of logistical coordination required, from deep foundations to high-rise frameworks, demanding planning and safety measures (Brenner, 2015; Jayasinghe et al., 2023). Each phase of building vertically integrates a range of specialised trades and technologies, making communication and project management essential for budget and timely completion (Brenner, 2015).

The health and economic implications of these challenges are significant. The average medical cost of work-related claims lodged with New Zealand's Accident Compensation Corporation (ACC) is

$905.12, with many claims resulting in compensated time off, averaging 6.64 days per claim, which further impacts workplace productivity. Additionally, the demographic shift towards an aging workforce necessitates the development of tailored safety protocols to accommodate physical limitations (Rout, 2023). A notable challenge in New Zealand's construction sector is tackling the disproportionate burden of workplace injuries and fatalities experienced by Māori and Pasifika workers, who represent 17% and 6% of the construction workforce, respectively (MBIE New Zealand, 2024). Although the injury rates, i.e., 03 and 100 claims per 1,000 full-time employees respectively, reflect data from all industries, they underscore the need for targeted safety interventions within the construction sector to better protect these groups (Hennecke et al., 2021).

The implementation of SC into New Zealand's construction sector faces several challenges (Abdullah & Wern, 2012; Choudhry et al., 2007). Despite its critical role in mitigating risks and preventing injuries, collaborative safety practices have eroded in recent years. A WorkSafe New Zealand survey reveals a decrease in the prioritisation of H&S within the industry since 2021 (Rout, 2023).

Further compounding the issue are persistent obstacles such as labour shortages, budget overruns, and a cautious approach to innovation, which hinder both safety improvements and operational efficiency (BRANZ, 2024; Deloitte, 2023). Due to this reported dataset, this research is focused on vertical construction projects (as defined by WorkSafe New Zealand, 2024c). This context highlights the need for a focused SC framework specifically tailored for vertical construction projects to enhance safety, competitiveness, and adaptability in New Zealand's construction sector.

6.2.3 Frameworks

A framework implies connecting a series of concepts to facilitate understanding processes, structuring ideas, and establishing a basis for practically coordinating activities (Partelow, 2023). This is valuable in project management (Partelow, 2023). There are a variety of frameworks related to SC that are applicable across various contexts. General frameworks that can be adopted in any industry have been developed by Bisbey et al. (2019); Vierendeels et al. (2018). Specific to the construction sector have been presented by Al-Bayati et al. (2019); Misnan and Mohammed (2007); Molenaar et al. (2009). Additionally, frameworks tailored to countries such as Indonesia, Malaysia, and Saudi Arabia have been created by Alasamri et al. (2012); Ismail et al. (2010); Machfudiyanto and Latief (2018). Also, the framework developed by Ortega et al. (2025), that was tailored for New Zealand, presented in Chapter 5.

In addition, the country specific frameworks developed in Indonesia, Malaysia, and Saudi Arabia cover theoretical perspectives like the Theory of Planned Behaviour or TPB (Ajzen, 1991). TPB underlines the importance of attitudes regarding the behaviour that reflects the degree to which a person has a favourable or unfavourable judgment of the behaviour; subjective norms refer to the perceived social pressure to perform or not perform the behaviour; and perceived behavioural control refers to the individual's perceptions of the ease or difficulty of performing the behaviour. These elements are visible in the Malaysian framework that emphasises attitudes based on trust and communication, as well as in the Saudi framework's focus on leadership attitudes (Alasamri et al., 2012; Ismail et al., 2010). This theory provides a scene that supports and extends the practical applications of SC frameworks.

When deciding on a survey instrument to validate the usability of a framework, it is relevant to consider the specific aspects of usability to measure, as well as the context in which the tool will be used. There are three suitable questionnaires, namely, the System Usability Scale (SUS), Situational Awareness Rating Technique (SART), and Usefulness, Satisfaction, and Ease of Use (USE), that serve different purposes and are optimised for different types of evaluations (Brooke, 1995; Lund, 2001; Peres et al., 2013; Taylor, 2011). Table 6-1 presents an overview of the survey instruments and their purposes, items, and sample size requirements. The purpose is to clarify why SUS survey was considered more appropriate than the SART and USE questionnaires for assessing the usability of the framework developed in this research.

Table 6-1

Overview of Usability Survey Instruments: Purpose, Questions, and Sample Size

Surveys	Purpose	Questions	Sample Size
SART	This questionnaire is designed to assess situation awareness. It measures the perception, comprehension, and projection of situational elements	It includes 10 items that assess three dimensions of situation awareness: attentional demand, supply of attention, and understanding of the situation.	The SART does not have a widely agreed-upon minimum sample size. However, for meaningful statistical analysis around 20-30 participants are often considered suitable for robust results.

USE	It is focused on evaluating the usability, satisfaction, and ease of use of a system or product, including specific measures of usefulness, ease of use, ease of learning, and satisfaction.	It contains 30 questions, grouped into four sections: Usability, Satisfaction, Ease of Use, and Ease of Learning.	It initial tests can be conducted with as few as 5-10 participants to identify obvious issues.
SUS	It offers a balance of efficiency and effectiveness to obtain a comprehensive usability score.	It consists of 10 questions. These items alternate between positive and negative statements about the system's usability.	While there is no hard rule, a sample size of at least 5 participants is often recommended for preliminary usability studies. However, for meaningful statistical analysis around 20-30 participants are often considered suitable for robust results.

The SUS survey was considered for Usability Testing of the Framework because:

- It measures how users perceive the usability of a system, including interfaces of frameworks meant to guide decision-making l, focusing on elements that are universally considered important across different user interfaces (Peres et al., 2013).
- It is less time-consuming for both participants and researchers, which can facilitate greater response rates and simpler data analysis (Al-Bayati et al., 2024; Lewis, 2018).
- It is recognised and provides a clear, empirical basis for evaluating usability improvements. It was considered to validate another SC framework (Al-Bayati et al., 2024). The study aims to assess the perceived usability of a new framework designed to enhance SC in the construction sector. The SUS survey was chosen specifically because it can provide quick, actionable feedback that is essential for iterative development processes (Al-Bayati et al., 2024; Lewis, 2018).

- The minimum sample size required for usability surveys like the SUS, SART, and USE questionnaires vary depending on several factors, including the objectives of the study, the expected variability of responses, and the desired confidence in the results (Brooke, 1995; Lund, 2001; Taylor, 2011). While there is no hard rule for SUS and SART, a sample size of at least 5 participants is often recommended for preliminary usability studies; however, for meaningful statistical analysis around 20-30 participants are often considered suitable for robust results (Brooke, 1995; Lewis, 2018; Peres et al., 2013).

In conclusion, for general usability assessment of a practical framework in a professional setting, SUS survey stands out for its focused applicability, ease of administration, and breadth of reliability and validity, making it more suitable than other specialised questionnaires like USE or SART.

6.3 Methodology

Case studies are typically used for validation and practical implementation of frameworks (Yin, 2018). In this research, case studies were conducted to assess the usage, practical applications, and end-user knowledge of the tools within the framework, thereby assessing its validity as a roadmap for promoting SC. While this study employed a case study approach to assess the usability and applicability of the developed framework, it did not apply a fully longitudinal design as outlined by Yin (2016), due to in the research scope, aim and objectives. Longitudinal case studies can be valuable for examining changes over time; however, such an approach was not needed in this research. Instead, four cross-sectional case studies were conducted across different active vertical construction sites in New Zealand, enabling the collection of rich, context-specific data (Shanks & Bekmamedova, 2018; Yin, 2018). The structured site visits, which included site inductions, interviews, and SUS survey, offered a robust basis for evaluating the framework's usability relevance at a specific point in time. Accordingly, the case study design was intentionally adapted not to monitor behavioural change, but to test the framework's usability and real-world functionality across diverse stakeholder contexts. This pragmatic approach fulfilled the usability validation objectives while maintaining methodological rigour. The case studies encompass site visits to four construction projects from four different companies specialising in vertical construction. These visits consisted of a site induction followed by data collection through interviews and a SUS survey with the participating project members. The site visits, interviews, and SUS survey were conducted on the same day for the four site visits. The site visits served to familiarise the researcher with the sites and to help refine the interview questions that followed.

6.3.1 Participants

Case studies are recommended for operationalising the practical implementation of a framework, so in this research four case studies on diverse projects from four different companies in vertical construction were selected (Gray, 2018, Yin, 2018). These case studies involved site visits to four different project locations, where the interviews and surveys were conducted to facilitate data collection. An email invite was sent to 280 contacts from 59 companies in New Zealand that were involved in the vertical construction type of projects, resulting in one positive response. The remaining three case studies (see Table 6-2) were secured through snowball sampling (Bairagi & Munot, 2019; Elo et al., 2014). Consent forms and participant information sheets (see Appendix 3) were prepared for signatures from the interviewees (Bryman, 2012).

In this research project, specific details about the company and the project are not disclosed to adhere to confidentiality, and information that could potentially identify the company or project has been generalised or omitted (Fellows & Liu, 2015). For the research findings, specific details about site visits to vertical construction projects from four different companies have been intentionally anonymised to maintain confidentiality ensuring that no sensitive information was disclosed, and only providing findings that focus on the aggregated data and insights gathered from the interviews and surveys conducted. The demographics of the participants identified as Participant 1 (P1) from Case Study 1, Participant 2 (P2) from Case Study 2, Participant 3 (P3) from Case Study 3, and Participant 4 (P4) from Case Study 4 for each respective site visit, are provided in Table 6-2. This approach respects the ethical considerations of the research and aligns with industry standards for protecting sensitive information (Fellows & Liu, 2015).

Table 6-2

Participants Details (Case Studies)

Demographics	**Interviewee Site Visit 1**	**Interviewee Site Visit 2**	**Interviewee Site Visit 3**	**Interviewee Site Visit 4**
Age	31-35	Over 60	36-40	31-35
Educational Level	Bachelor's degree	High school diploma.	High school diploma. Trade qualification.	Bachelor's degree
Position	H&S Manager	Site Manager	Project Manager	Project Manager
Years of experience in the current position	1-5	1-5	1-5	6-10

Total years of experience in related field	6-10	1-5	11-20	11-20
Number of staff typically working on the projects	More than 100 workers	More than 100 workers	Less than 25 workers	More than 100 workers

Note: To maintain confidentiality and adhere to ethical research standards, specific details about the companies and construction projects involved in the site visits have been anonymised.

6.3.2 Data collection

This research involved site visits, where the researcher physically visited the locations and conduct a supervised induction walk around to get familiar with the operational environment. The data collection occurred over one day for each case on four separate days. During the four site visits, the researcher conducted interviews with key stakeholders to understand their perspectives on the framework and gather usability feedback, which included administering a SUS survey (Gray, 2018, Yin, 2018).

6.3.2.1 Interviews

The interview was conducted face-to-face and recorded using Microsoft Teams, which provided automatic transcription. The transcriptions were later sent to the interviewees for approval (see Appendix 3).

The informational report and the visual framework were presented during the interviews to validate the relevance and applicability of the tools (see Chapter 7). Participants were asked to review the tools listed in the report and identify any they were unfamiliar with. In such cases, the embedded QR codes were scanned to activate short videos that visually demonstrated the purpose and application of each tool. This approach helped bridge the gap between conceptual understanding and practical recognition, particularly for tools that participants had not previously encountered in their day-to-day practice. In sum, this strategy about showing the videos provides a standardised presentation of each tool, ensuring that every interviewer receives the same detailed and visual explanation (Gedera & Zalipour, 2018; Varela & Mejía, 2018).

To understand various dimensions of tool usage, a corresponding set of questions to extract valuable data from interviewees was designed, and a protocol was created to run the interviews (see Figure 6-1) with three distinct pathways (Ebneyamini et al., 2018). These pathways correspond with participants' familiarity and use of tools within the framework. Figure 6-1 was refined based on a pilot interview with an expert with more than 20 years of experience, with only minor changes made to the selection of questions and wording of them (Lavrakas, 2008). The framework was presented to all participants in accordance with the interview protocol. Depending on their familiarity with a specific tool within the framework.

- Pathway 1 - Participants who recognised a tool and confirmed its use in a project were asked:

1. “Do you know this tool?”
2. “Are you using it on this project, and why?”

These questions aimed to clarify the reasons for selecting specific tools and their perceived benefits.

- Pathway 2 - For participants who initially did not recognise the tool but did so after watching a video, the following question was asked:

1. “How do you use this tool?”

This question sought to uncover practical applications for those who were less familiar with the tool's name.

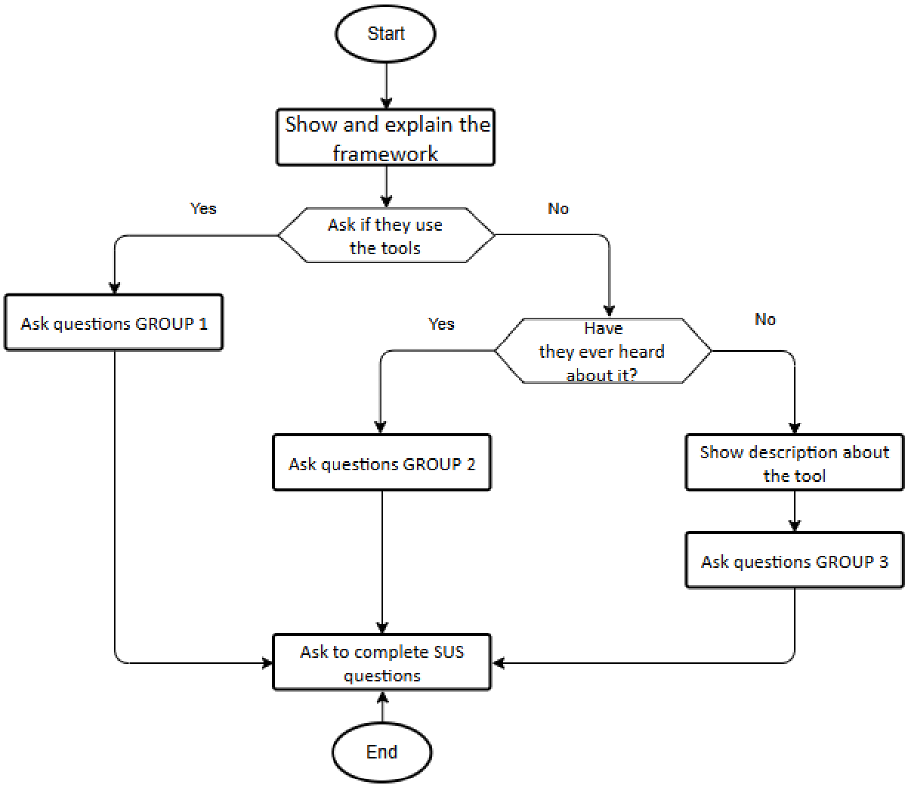
- Pathway 3 - Participants who neither recognised the tool nor confirmed its use after viewing the video were asked five questions to assess perceptions about the tool’s necessity and implementation:

1. “Why is this tool necessary for improving SC?”
2. “What challenges might arise with its implementation?”
3. “When is the best time to introduce this tool in the project lifecycle?”
4. “Who should lead its implementation?”
5. “How will its adoption affect daily operations on construction sites?”

These questions aimed to explore the perceived importance of the tool, identify potential barriers to implementation, and assess its potential impact on construction site operations.

Figure 6-1

Interview Protocol



Note: This figure has been previously presented in Chapter 2 (Figure 2-2). It is included here for reference and support for the paper.

6.3.2.2 SUS Survey

Lastly, a final part of the operationalisation of the framework involved the SUS survey. This questionnaire, with a Likert scale indicating a response ranging from strongly agree to strongly disagree, helps provide a global view of subjective assessments of usability related to a product or service (Brooke, 1995; Lavrakas, 2008). The SUS survey is typically recommended when gathering responses from about 20-30 participants, however, responses from a smaller number of participants, like the four that were collected in this study, still provide valuable information, if the SUS survey is interpreted accordingly. The SUS survey was provided to participants on paper (see Appendix 3), so responses could be collected manually, before the results from these responses were processed using Microsoft Excel. For statements relating to the SUS survey, scoring was calculated following the process defined by Brooke (1995). It is relevant to consider selecting a survey instrument for evaluating the usability of a framework, researchers can ensure that the assessment effectively identifies the most suitable tools. The SUS survey was employed to evaluate the usability of the framework as part of its operationalisation. The SUS survey is a widely used tool consisting of ten items presented on a 5-point Likert scale (see Appendix 3), with responses ranging from "strongly agree" to "strongly disagree" (Brooke, 1995). This design provides a global view of usability related to a product or service while balancing ease of use for respondents with meaningful discrimination in responses (Brooke, 1995; Peres et al., 2013). The alternating positive and negative phrasing of the items ensures a comprehensive usability evaluation while minimising respondent fatigue and reducing response bias (Brooke, 1995; Peres et al., 2013). The 10 SUS statements were:

1. I think that I would like to use this framework frequently.
2. I found the framework unnecessarily complex.
3. I thought the framework was easy to use.
4. I think that I would need the support of a technical person to be able to use the framework.
5. I found the critical factors and tools in this framework were well-integrated.
6. I thought there was too much inconsistency in this framework.
7. I would imagine that most people would learn to use this framework very quickly.
8. I found the framework very cumbersome to use.
9. I felt very confident using the framework.
10. I need to learn a lot of things before I could get going with this framework.

The SUS survey was selected for its practicality and flexibility, enabling the collection of rapid, actionable feedback without requiring users to have prior hands-on experience with the framework (Al-Bayati et al., 2024; Brooke, 1995; Lewis, 2018; Peres et al., 2013). While the SUS is generally recommended for use with 20-30 participants, the responses from four interviewees in this study still offered meaningful insights, though careful consideration is necessary due to the limited sample size.

The rationale for employing the SUS survey in this study lies in its ability to deliver a concise yet robust usability evaluation, ensuring that the framework aligns with user needs and expectations while identifying areas for improvement. The detailed calculation of the SUS survey is presented in Appendix 3, Table 7.

6.3.2 Data analysis

6.3.3.1 Interviews

The data from the interviews was analysed using thematic analysis to identify overarching patterns using NVivo version 14 (Braun & Clarke, 2006; Bryman, 2012; Roseveare, 2023). This approach to data analysis allows for evaluating the framework's relevance across different settings within New Zealand's construction sector, seeking to achieve analytic generalisation from the empirical insights obtained.

A cross-case synthesis method was used, by using matrices and tables as tools to organise data from multiple cases, allowing researchers to visually compare findings and identify patterns (Yin, 2018). These tools help in analysing case study data, making it easier to observe similarities and differences across cases (Gray, 2018, Yin, 2018). They allow for comparing and integrating findings from the four case studies to gain a more comprehensive understanding of perspectives on the framework and identify patterns, similarities, and differences across cases, ensuring the repeatability and scalability of the results (Yin, 2018). The cross-case synthesis for the interviews was conducted by examining each influential factor and the categorised tools. This involved grouping responses based on participants' familiarity with and use of the tools. The results from this synthesis were introduced to refine the report, adding real-world New Zealand cases (Gray, 2018, Yin, 2018).

6.3.3.2 SUS Survey

The data from the SUS survey was analysed following Brooke's process for calculating SUS scores, which involves adjusting each response based on the positive or negative framing of the question (Brooke, 1995). For positively framed questions (odd-numbered), 1 is subtracted from the participant's response; for negatively framed questions (even-numbered), the response is subtracted from 5 (see Appendix 3, Table 7). Then, the responses are summed across the 10 questions for each participant, summing a total score between 0 and 40. To normalise the scores, the total is multiplied by 2.5, scaling it to a range of 0 to 100. After calculating individual SUS scores, an average of these scores is computed to provide the group score. This approach results in a single score that reflects the overall usability perception of the system, where higher scores indicate better perceived usability. Generally, a SUS score above 68 is considered above average, and a score above 80 indicates excellent usability (Lewis, 2018).

6.4 Results

6.4.1 Interviews

In the first site visit induction, it was observed that a variety of safety measures were implemented to ensure worker safety, including the use of PPE and well-marked, safely barricaded access points. On the second site, there were rigorous safety protocols, specifically arranging visit times during worker lunch breaks to minimise disruptions. The third site visit revealed detailed safety practices, notably the provision of additional protective gear such as hearing protection during operations involving heavy machinery. In the fourth site visit induction, while standard safety measures such as the use of PPE and adherence to signage were observed, a minor issue was noted: safety zones were temporarily mislabelled, posing a risk of unauthorised access. This issue was quickly identified and resolved within a minute by correctly positioning the barriers.

During all four site visits, through the interviews, some of the tools promoting SC in the New Zealand construction sector were immediately recognised. However, other tools within the framework required clarification, which was accessed by scanning QR codes embedded in the report that linked to descriptive videos for each tool. After clarification, participants recognised some tools but said that they were using them with specific tweaks or adaptations to better match their project needs. Other tools were not recognised, even after participants were exposed to clarifying audiovisual material from the informational report related to them. Table 6-3 focuses exclusively on the tools that all participants demonstrated consistency in their responses. These are the tools on which all four participants matched either by recognising them initially, recognising them after watching the video, or not recognising them at all.

Table 6-3

Framework Tools Recognised and Not Recognised by all Participants

Tools recognised immediately	
Level of Leadership Commitment • Trust Open Conversations • Toolbox Talks • Leadership Training	**Level of Industry Fragmentation** • Recording Systems • Health and Safety Processes • Audits • Documentation and Signing • Accimap-Swiss Cheese Model
Level of Experience and Mindset • First Aid Training • Applications • Awards	**Level of Resource Allocation** • Induction-Prestart Meeting • Committees for the Firm and Contractors
Level of Communication • Networking and Knowledge • Planning	**Level of Client Understanding** • Planning
Tools recognised after watching the video	
Level of Leadership Commitment • Delivery Lead • Lean Philosophy • DuPont Bradley Curve	**Level of Experience and Mindset** • Behaviour-Based Safety Programs
Tools not recognised after watching the video	
Level of Experience and Mindset • Augmented Reality for Safety Practices • Artificial Intelligence for Safety	**Level of Communication** • Safety Club

The cross-case synthesis for the interviews was conducted by examining each influential factor (see Tables 6-4 to 6-8) and the categorised tools. This involved grouping responses based on participants' familiarity with and use of the tools.

As shown in Table 6-4, when Group 1 discussed the commonly used tools within the context of construction sites, participants expressed varied approaches to fostering trust and open communication. For instance, regarding Trust and Open Conversations, P1 shared their proactive approach: "I'm not afraid to text one of them and say, 'OK, things come wrong'. OK, that's the kind of thing," emphasising a direct and personal method of communication. In contrast, P2 highlighted a more structured approach: "We encourage our subcontractors to discuss anything that they've seen on-site," which suggests a formal encouragement for open dialogue with subcontractors.

The group's responses also showed differing practices around Toolbox Talks, a tool for maintaining regular safety communication. P4 noted, "The importance of weekly Toolbox Talks," suggesting a weekly schedule, whereas P2 stated, "What we do is every second week," indicating a bi-weekly routine. These variations underline the different operational cycle and safety communication strategies employed across construction sites, reflecting tailored approaches.

When Group 2 discussed tools that were initially unfamiliar but later recognised after viewing a video, the participants offered different interpretations of Lean Philosophy in their construction practices. P2 related the concept directly to their workflow, likening it to a production line: "The whole idea of how we build is...it is a production line what we do." This comment reflects an understanding of Lean Philosophy as a systematic approach to construction, emphasising efficiency and continuous flow. Conversely, P3 referred to a specific Lean tool, noting, "Over here, we just call it the last planner." These varying perspectives demonstrate the participants' different levels of familiarity to Lean concepts within their projects.

Table 6-4

Familiarity and Usage of Leadership Commitment Tools

Level of Leadership Commitment tools	Familiar tools, recognised immediately by participants	Unfamiliar with the tool by name but who recognised it after viewing a video	Neither recognised the tool by name nor confirmed its use after watching a video
Trust-Open Conversations	P1, P2, P3, P4		
Toolbox Talks	P1, P2, P3, P4		
Delivery Lead		P1, P2, P3, P4	
Leadership Training	P1, P2, P3, P4		
Lean Philosophy		P1, P2, P3, P4	
Dupont Bradley Curve		P1, P2, P3, P4	

As illustrated in Table 6-5, when asked about the tools commonly from Group 1, participants discussed awards, P1 noted a formal process of awarding workers, saying: "We called it the Hero Observer Award, we have Awards every quarter and then at the end of the year as well." Other participants discussed more ad-hoc awards, or perks for staff. P2 said: "We have a kind of thing. They get Kentucky fried chicken every so often, chocolates for me, and we have a barbecue." P4 echoed this, saying: "If somebody comes and reports a few things, they receive a high-quality pair of safety glasses or, it might be a supermarket voucher." P3 was less clear about the actual awards offered but reiterated: "We really promote positive observations." The participants all use a mix of reward strategies that highlights a flexible yet targeted approach to enhancing safety engagement among workers, supporting a broader strategy of SC.

When discussing tools unrecognised by name until demonstrated through a video by Group 2, participants from the study shared their modified perceptions, especially concerning BBS Programmes. P1 acknowledged a similar practice in their workflow, noting, "We do have something similar where we discuss what each person has accomplished that day, providing feedback directly related to their tasks." P4 referenced a more routine method, stating, "It's essentially our daily patrols of the project." The participant answers indicate that elements of some tools, like BBS Programmes, are integrated through different terminologies.

When Group 3 discussed tools that were initially unfamiliar, such as AI for safety, their responses revealed a range of perspectives. P1 emphasised the value placed on safety by leadership, stating, "It's not like a cost thing for us because the leaders always say that, like, safety does not have a price on it, but it is just making sure that it's kind of fulfilling what you really are." This highlights a commitment to safety irrespective of cost, focused on ensuring tools meet their intended purpose. On the other hand, P2 considered the future implications of adopting such technologies, remarking, "That's the future, right? We're not doing anything like that at this stage, I would imagine at some point, the way the world's going." These comments illustrate differing levels of familiarity and readiness to integrate advanced technologies like AI into safety practices, reflecting an openness to eventual adoption.

Table 6-5

Familiarity and Usage of Experience and Mindset Tools

Level of Experience and Mindset tools	Familiar tools, recognised immediately by participants	Unfamiliar with the tool by name but who recognised it after viewing a video	Neither recognised the tool by name nor confirmed its use after watching a video
First Aid Training	P1, P2, P3, P4		

Online Training	P1, P2*, P3, P4		
Apps	P1, P2, P3, P4		
Awards	P1, P2, P3, P4		
Real-time Safety Control with Tablets	P1, P4	P2, P3	
BBS Programmes		P1, P3, P4	P2
REMTs, AI-based CCTV Surveillance, Site Access Control	P4	P3	P1, P2
VR for customised training	P1, P2		P2. P4
AR for safety practices	P1		P2, P3, P4
AI for Safety			P1, P2, P3, P4

Note. Tools marked with an asterisk (*) indicate they are not currently being used for the project.

As shown in Table 6-6, when responding to inquiries about commonly used tools from Group 1, participants shared various practices reflecting the cultural integration activities employed at their construction sites. For example, P1 described an inclusive and communal approach: "It is basically sitting down with people, sharing food, and then exchanging stuff," which highlights the use of meals as a way to foster team cohesion and cultural exchange. Similarly, P2 illustrated a more event-oriented practice: "When we're on-site, we do the occasional sausage sizzle or roof show," indicating the use of social gatherings and informal events to build a team culture. These responses showcase the range of methods used to integrate and enhance cultural understanding among workers, adapting to the diverse environments of construction sites.

When discussing the unfamiliar tool of a "Safety Club" while asking Group 3 questions, the participants expressed divergent views on its implementation within their respective environments. P2 voiced scepticism about the practicality of a Safety Club, remarking, "We don't have a safety club because. That's just another meeting," indicating a perception that such initiatives might lead to unnecessary redundancy in meetings. Conversely, P3 shared a positive example from their experience, stating, "We've got our internal neighbour; this company has a Safety Association," which suggests that their organisation adopts a structured approach to safety, integrating it into their corporate culture more formally. These contrasting responses highlight the variations community structures are perceived and utilised across different companies.

Table 6-6

Familiarity and Usage of Communication Tools

Level of Communication tools	Familiar tools, recognised immediately by participants	Unfamiliar with the tool by name but who recognised it after viewing a video	Neither recognised the tool by name nor confirmed its use after watching a video
Visual Indicators	P1, P2, P3, P4		
Language Translation	P1, P2, P4		P3
Digital Screens	P2		P1, P3, P4
QR Codes	P1, P2, P4	P3	
Colour-coded Card System	P3	P1, P4	P2
Networking and Knowledge	P1, P2, P3, P4		
Sharing Working Group	P1, P3, P4		P2
Cultural Integration Activities	P1, P2, P3,		P4
Safety Club			P1, P2, P3, P4

As presented in Table 6-7, when asked about the tools commonly used by Group 1, participants showed the importance and relevance of the Planning and Scorecard. P2 noted: “Planning is one of the tools; it is digital.” While both P3 and P4 indicated that planning was important, and named specific applications used to assist with making and managing plans. P3 said: “We are working on the Procore, so that’s definitely planning mainly.” P4 declared: “We’ve changed from traditional planning to Last Planner.” The varied use of tools among participants shows the diversity of approaches required to promote SC.

Table 6-7

Familiarity and Usage of Resource Allocation and Client Understanding Tools

Level of Resource Allocation and Client Understanding tools	Familiar tools, recognised immediately by participants	Unfamiliar with the tool by name but who recognised it after viewing a video	Neither recognised the tool by name nor confirmed its use after watching a video
Planning	P1, P2, P3, P4		
Scorecard	P2, P3, P4	P1	

As exemplified in Table 6-8, when discussing the frequency and practice of external audits in Group 1, participants from different construction sites shared their varying routines. P1 revealed a rigorous approach, stating, “We get an external audit every month,” which suggests a high level of regular scrutiny to ensure compliance and safety standards. On the other hand, P2 indicated a less frequent schedule, noting, “We have an external audit every 3 months.” This variation highlights differing organisational policies and priorities regarding the regularity of audits, reflecting how external audits are tailored to meet the specific governance and risk management needs of each construction site.

When questioned about tools they were initially unfamiliar with but recognised after viewing a video, participants from Group 2 expressed evolved views on the Safety Training Observation Programme. P1 linked their existing practices to the programme, mentioning, “What we have done is actually, and this will kind of tie back to this, we have an award called the Hero Observer.” This indicates an existing reward system tied to safety observations. Conversely, P2 emphasised a more informal, continuous approach to safety vigilance, stating, “For us, it is an everyday responsibility to observe and, if we find something, give feedback immediately, without the specific designation.” This reflects a cultural integration of safety monitoring into daily responsibilities, reflecting the ways organisations can internalise safety observation practices.

When discussing their familiarity with the Nordic Occupational Safety Climate Questionnaire while asking Group 3 questions, the participants shared diverse reactions based on their experiences and perceptions of practicality. P1 raised a concern about the questionnaire’s length, saying, “Well, but the issue is that 50 questions; we call it a 3-minute gap because, after three minutes, your concentration is starting to lapse,” highlighting the potential difficulty in maintaining respondents’ attention due to the questionnaire’s length. P2 expressed scepticism about the likelihood of thorough completion, remarking, “Well, we fear it’s very unlikely that anyone will turn that. Hmm. OK. It doesn’t voice. Let’s see how that works,” indicating doubts about its effectiveness in their environment. Conversely, P3 saw potential value in the tool, stating, “Well, I don’t see why not; it would certainly be a benefit; that would be something we need to be thinking about, something that the H&S team would consider,” suggesting openness to considering its implementation. These varied responses reflect the challenges and considerations involved in adopting these tools within different organisational contexts.

Table 6-8

Familiarity and Usage of Industry Fragmentation Tools

Level of Industry Fragmentation Tools	Familiar tools, recognised immediately by participants	Unfamiliar with the tool by name but who recognised it after viewing a video	Neither recognised the tool by name nor confirmed its use after watching a video
Recording Systems	P1, P2, P3, P4		
H&S Processes	P1, P2, P3, P4		
Audits	P1, P2, P3, P4		
Documentation and Signing	P1, P2, P3, P4		
Accimap-Swiss Cheese Model	P1, P2, P3, P4		
Human Factor Analysis & Classification System (HFACS)	P1, P3, P4	P2	
STAMP			P1, P2, P3, P4
Induction-Prestart Meeting	P1, P2, P3, P4		
Committees for the firm and Subcontractors	P1, P2, P3, P4		
SCAT			P1, P2, P3, P4
Safety Training Observation Programme	P4	P1, P2, P3	

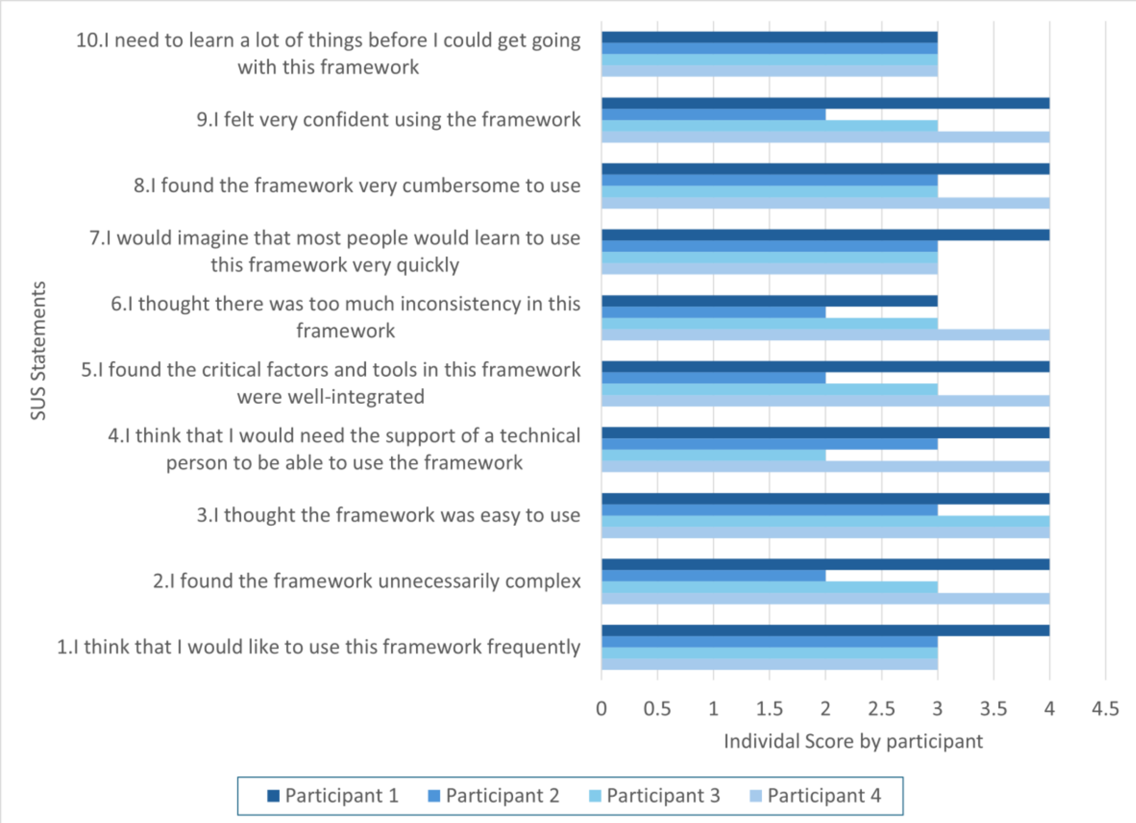
Nordic Occupational Safety Climate Questionnaire			P1, P2, P3, P4

6.4.2 SUS Survey

Figure 6-2 represents the scores for each SUS question, broken down by participant, to provide a clear understanding of how various aspects of the framework were rated. Participant 1 gave the highest scores, while Participant 2 provided the lowest. Positive scores were recorded for statements such as “I thought the framework was easy to use.” For negatively framed statements, such as “I found the framework unnecessarily complex,” scores varied among participants. Question 3, a positively framed item, received favourable ratings, whereas Question 2, a negatively framed item, garnered lower scores. The SUS results for Participant 2 presented different insights into the perception of the framework’s usability, complexity, and practical relevance. Its feedback reflects a moderately positive yet cautious stance. It rated its confidence in using the framework as a 2, indicating low comfort or familiarity. Similarly, it rated the framework as unnecessarily complex (2) and perceived some inconsistency (2), suggesting reservations about its coherence and intuitive design. Despite these concerns, Participant 2 still viewed the framework as generally usable and structured.

Figure 6-2

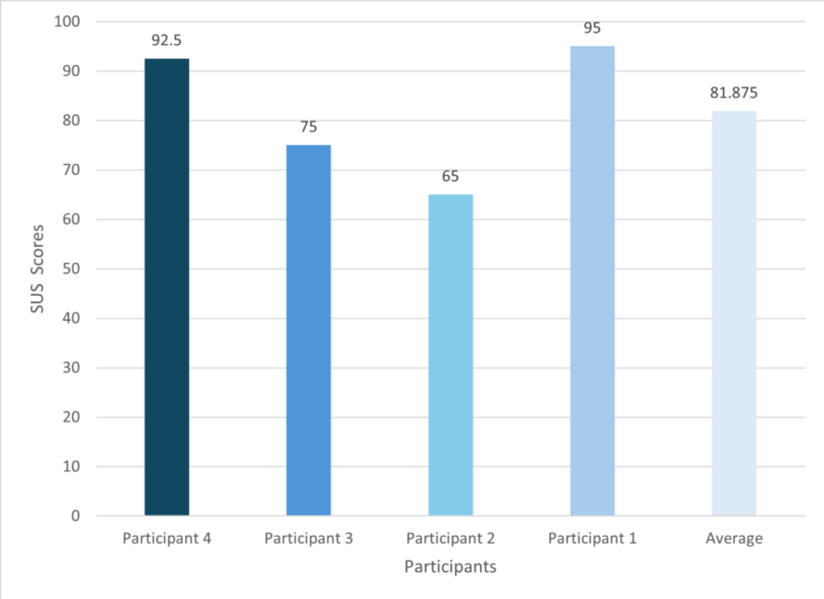
Participant Scores for Each SUS Survey Question



After normalising the scores by multiplying the total by 2.5 to scale them to a range of 0 to 100, the individual SUS scores for the participants ranged from 65 to 95, reflecting varying levels of usability perceptions for the framework (Brooke, 1995; Peres et al., 2013). The highest score was 95, provided by Participant 1, while the lowest score was 65, recorded by Participant 2. The other participants scored 75 and 92.5, respectively, resulting in an average SUS score of 81.875. According to the SUS methodology, scores above 68 are considered above average, and scores above 80 indicate excellent usability (Lewis, 2018). These results suggest that the framework was generally perceived as user-friendly and satisfactory in terms of usability, with some variation in responses pointing to potential areas for refinement (see Figure 6-3).

Figure 6-3

SUS Scores by Participant



Note: See Appendix 3 for detailed calculations and results.

The case studies results were incorporated into the informational report, which is part of the framework, enhancing its applicability and demonstrating its effectiveness in guiding safety interventions (see Chapter 7).

6.5 Discussion

Site visits were conducted as an induction and part of the data collection process to obtain context-rich, firsthand insights into the operational environments of construction projects (Fellows & Liu, 2015; Yin, 2018). These visits are a cornerstone of case study research, as they provide direct observational data (Yin, 2018). During the site visits, the researcher was able to become familiar with the environment where the SC framework is or would be implemented, capturing crucial details about site dynamics, operational challenges, and safety practices (Fellows & Liu, 2015; Yin, 2018). In this study, site visits played a key role in inducting the researcher become familiar with each site, forming a foundation for subsequent data collection activities. The site visits collectively illustrate the dynamic nature of safety management on construction sites. While standard safety measures are widely adopted, site-specific challenges necessitate continuous monitoring and prompt corrective actions. This reinforces the need for adaptable safety frameworks that allow for project-specific modifications while maintaining overarching safety standards. The selected sites focused on vertical construction projects in New Zealand, characterised by multi-level structures, the use of heavy machinery, and work in confined spaces and at heights. These projects included the construction of residential, commercial, and industrial buildings (Brenner, 2015; Jayasinghe et al., 2023).

6.5.1 Interviews

The rapid recognition by all participants highlights the relevance and practicality of the tools (see Table 6-3) within the industry's safety practices, suggesting a strong familiarity and applicability of some tools across various construction settings. For tools that were not familiar, such as Lean Philosophy, the findings highlight a clear gap in awareness despite its recognised importance in enhancing SC from previous research and the literature review. To address this, strategies to increase the likelihood of Lean Philosophy being adopted, including integrating Lean principles into existing training programs, developing on-site workshops, and creating short, accessible video content linked through QR codes, similar to those used during the site visits could be some actions to be considered in the future. The integration of QR codes to access videos streamlined the learning process during site visits, allowing participants to quickly understand unfamiliar tools. This finding informed the inclusion of user-friendly digital resources within the framework to enhance tool adoption. For innovative tools like AI, the lack of familiarity among participants highlights the need for targeted training and awareness programs to bridge this knowledge gap. Similarly, for tools like Safety Clubs, which were perceived as less impactful, strategies such as demonstrating their long-term benefits through case studies and integrating their activities into daily site operations. These strategies have been incorporated into the framework as supporting mechanisms to ensure its successful implementation highlighted with another colour background.

The cross-case synthesis examined each influential factor among the case studies, leading to the development of tailored strategies for promoting under-recognised tools, ensuring that the framework is both comprehensive and adaptable to the unique challenges of the New Zealand construction:

a) Level of Leadership Commitment

In analysing the familiarity and usage of Leadership Commitment tools, Trust-Open Conversations and Toolbox Talks, indicating these tools are well integrated into their operational practices. Conversely, tools like Delivery Lead, Lean Philosophy, and the Dupont Bradley Curve are neither recognised by name nor acknowledged as being used viewing the video.

b) Level of Experience and Mindset

The survey of knowledge and usage of tools revealed a significant variation in the adoption, which correlates closely with their levels of experience and technological readiness. Basic safety training tools like First Aid and Online Training are utilised by most of the participants. However, the adoption of more advanced technological tools such as AI-based CCTV, AR for safety practices, and Real-time Safety Control with Tablets is less uniform. This suggests that while there is broad acknowledgment of traditional safety training, there is caution when integrating new technology, highlighting an area for development.

c) Level of Communication

The participants revealed dynamic communication practices. Tools such as Visual Indicators and Networking and Knowledge Sharing are mentioned across all participants, indicating these are considered central for communication on construction sites. In contrast, the use of more specialised tools like Digital Screens and QR codes shows a divide in use. The Colour-coded Card System and Cultural Integration Activities show a more selective adoption depending on the cultural settings of each site.

d) Level of Resource Allocation and Level of Client Understanding

Level of Resource Allocation and Level of Client Understanding utilise the same foundational tools, Planning and Scorecard. The data reflected unanimous use of both Planning and Scorecard methods among all participants (P1, P2, P3, P4). The consensus on these tools implies a shared identification of their value ensuring transparent communication.

e) Level of Industry Fragmentation

The results demonstrate a high level of uniformity across participants (P1, P2, P3, P4) in the adoption of foundational management systems like Recording Systems, Health and Safety Processes, Audits, and Documentation and Signing. This implies a common recognition of the necessity of set of tools to ensure compliance with industry regulations. Given the high number of incidents in vertical construction, the Accimap-Swiss Cheese Model and the Human Factor Analysis & Classification System (HFACS), despite their widespread adoption, appear insufficient in addressing the frequency of these incidents (Igene & Johnson, 2020; Salmon et al., 2012; WorkSafe New Zealand, 2024c). This situation suggests the need to consider alternative approaches such as the STAMP, which offers a more comprehensive framework for identifying and mitigating systemic risks, or/and the Nordic Occupational Safety Climate Questionnaire which evaluates SC employees' perceptions (Hanell, 1999; Yousefi & Rodriguez Hernandez, 2019).

Tools that all participants recognise indicate a shared understanding of essential safety practices and the broad applicability and strong alignment of the framework with common knowledge and industry standards. Tools that required the video for understanding point to areas where the framework may need additional clarity, explanation, or user training. Understanding why these tools were not recognised helps prioritise actions, such as revising the framework, increasing training, or conducting further research into the perceived barriers to recognition or adoption. The absence of recognition may suggest that these tools are not widely used, well-known, or lacking progress in adopting new methodologies within the industry; it could also indicate that they perceive these tools as less relevant or applicable to their specific roles or contexts.

6.5.2 System Usability Scale

Positive scores on statements such as “I thought the framework was easy to use” highlight the framework’s strengths, suggesting that participants generally found it intuitive and user-friendly. This aligns with the high average SUS score of 81.875. To enhance the learning experience during site visits, the integration of QR codes in the informational report proved instrumental. These codes enabled interviewees to instantly access tutorial videos for unfamiliar tools, streamlining their learning process by allowing them to watch explanations on the spot rather than reading detailed descriptions. This underscores the importance of making resources like QR codes and instructional videos more accessible, ensuring that users can quickly grasp the necessary information. While the scores provide initial evidence of the framework’s usability, the SUS survey is typically recommended for use with 20-30 participants to ensure statistical significance, smaller samples, such as the four participants in this study, can still yield meaningful information (Bangor et al., 2009). A key limitation of this study is the relatively small sample size for usability testing; future research should expand the participant pool to more accurately assess the framework's usability in diverse construction settings. However, the SUS survey demonstrates that even a small number of participants can reveal usability trends and potential improvements, provided that the limitations of the sample size are acknowledged, and future research should aim to expand the sample size to strengthen the reliability of the findings.

The framework was validated through a case study approach that was employed to assess its usability and applicability within real-world conditions (Yin 2016). Due to scope of this research, implementing a fully longitudinal design was needed. Instead, this study adopted a multiple cross-sectional case study design across four active vertical construction sites in New Zealand, enabling the collection of rich, contextual data (Shanks & Bekmamedova, 2018; Yin, 2018). This framework was designed to be responsive and adaptable, incorporating expert feedback and localised data to address specific challenges within the New Zealand vertical construction sector. There is still a significant gap between the perspectives and practices of industry experts and those in academia. This indicates a need for ongoing dialogue and collaboration between these two groups of experts to ensure that theoretical research is effectively translated into practical applications. This framework shows that theoretical research can be translated into practical tools that can have a tangible impact on SC. It provides an initial step to close the gap between academic discourse and industry perspectives, offering hope for a more effective SC in the New Zealand construction sector. The case studies were conducted exclusively with experts from vertical construction projects in New Zealand, its findings may not be entirely generalisable to other regions or sectors like horizontal. Nevertheless, similar studies could be conducted following the same research methodology in other countries or sectors, which are adapted to their specific contexts.

6.6 Conclusion

The study focused on operationalising the usability of the framework to promote SC within New Zealand's vertical construction projects in Chapter 5. Through its practical usability in four case studies, the framework demonstrated its utility in real-world settings, demonstrating effectiveness as a decision-making tool for improving SC on construction sites in New Zealand by helping practitioners select and prioritise relevant tools based on their context and resources. Users are not expected to apply all tools; instead, they can tailor their approach. To support implementation, the accompanying informational report (Chapter 7) provides detailed tool descriptions and QR codes linking to short videos for accessible team learning and consistent use across projects.

However, the study was limited to experts within New Zealand, which may affect the generalisability of the findings to other regions. This highlights the need for future research to further operationalise and validate the framework through additional case studies, interviews, or surveys across diverse contexts. The framework also has broader implications for the academic community, offering a foundational methodological model that could be refined and applied in different international settings.

In conclusion, the results of the usability of the framework confirms that serves as a potential practical tool for translating abstract safety concepts into actionable strategies. It equips safety leaders with the knowledge and resources to make informed decisions about tailored safety interventions that address the unique needs of their projects. The development and implementation of this framework mark a significant advancement in promoting SC within New Zealand's construction sector, with the potential for wider adoption and application globally.

Summary

The study aimed to operationalise the framework through four case studies involving site visits, interviews with safety practitioners, and SUS usability survey assessments. These activities were designed to address the specific needs and challenges of New Zealand’s vertical construction sector. Project managers and H&S managers participated in the study, providing valuable feedback on the framework’s effectiveness. Site visits enabled context-rich induction of the operational environment, shedding light on the dynamics of construction sites and the safety challenges faced by practitioners.

The data collected from the interviews were analysed using thematic analysis and cross-case synthesis, revealing a consistent reliance on traditional safety practices and a cautious approach to adopting new technologies. The analysis highlights the areas of matching among the four participants while also identifying gaps in familiarity or relevance of certain tools. Various tools recognised by all participants into the six influential factors that reflect different aspects of SC. Under the Level of Leadership Commitment, tools such as Trust Open Conversations, Toolbox Talks, and Leadership Training were identified. After participants watched an informational video, further tools were identified across two influential factors of SC. Despite participants viewing an informational video, certain tools remained unrecognised across three influential factors. Tools such as “Trust and Open Conversations” and “Toolbox Talks” were widely recognised and actively used across all sites. However, advanced tools like “AI for Safety” and “Augmented Reality for Safety Practices” were less familiar and often deemed less practical for immediate implementation. QR codes embedded in the framework’s informational report, linking to video explanations for each tool, were instrumental in clarifying unfamiliar tools and underscored the importance of accessible and user-friendly resources.

The usability of the framework was assessed using the SUS survey, a 10-item questionnaire that evaluates effectiveness and ease of use. Despite the small sample size of four participants, the SUS results yielded an average usability score of 81.875, indicating excellent usability. While these scores provide initial evidence of the framework’s practicality, the small sample size limited the statistical significance of the findings. Nevertheless, the study demonstrated that even limited participation can yield meaningful insights, while also highlighting the need for further validation with larger samples.

The findings from this chapter were informed refinements to the framework, incorporating feedback from participants to enhance its usability and relevance, enriching the framework in the informational report by adding a section about case studies, presented in Chapter 7. By including these case studies results, the report provides a theoretical understanding and tangible evidence of how the framework can be successfully implemented, offering readers insightful perspectives and validated the potential usability to enhancing SC within their own project challenges to promote SC. The case studies conducted within New Zealand’s vertical construction sector provided valuable insight into the level of awareness and use of the tools included in the framework. Understanding which tools are least recognised or less commonly applied in the local context helps practitioners avoid introducing unfamiliar or potentially unsuitable tools. Alternatively, if such tools are considered necessary, practitioners can anticipate the need for additional resources and training or follow the implementation examples and guidance provided in the informational report to support their adoption. The framework’s visual representation simplifies navigation and application, enabling practitioners to identify the most appropriate tools for their specific safety needs with ease. To further support implementation, the framework includes an informational report with QR codes linked to video explanations, ensuring consistent, clear, and engaging dissemination of information. This standardised presentation fosters a shared understanding of SC tools and their applications, preventing miscommunication during implementation.

This chapter underscores the framework’s potential to bridge the gap between theoretical research and practical application, addressing the fragmented safety practices within New Zealand’s vertical construction sector. By connecting influential SC factors to actionable tools, the framework provides a structured guide for improving safety practices and fostering a proactive SC. Although specifically designed for New Zealand, the framework's methodology and structure offer significant potential for adaptation and refinement in other contexts. However, further validation and broader implementation are needed to ensure its global applicability.

The chapter concludes by establishing the framework as a foundational model for academic research and practical application. It emphasises the importance of ongoing dialogue and collaboration between industry experts and academia to refine and adapt the framework to diverse contexts. This sets the stage for the next phase of research, which will focus on broader validation and further development to enhance the framework's effectiveness in promoting SC worldwide.

Chapter 7: Informational Report: Tools to Promote Safety Culture Based on Influential Factors in Vertical Construction Sites in New Zealand

7.1 Introduction

This chapter presents an industrial report, mentioned as informational report, comprised of a flow-based visualisation diagram accompanied by an informational report (Kabir, 2016; Gedera, 2018; Megha & Satishkumar, 2024). The informational report is designed for industry purposes, which serves as an application of the framework developed in Chapter 5. The report was instrumental in refining the framework's applicability, as discussed in Chapter 6, where industry feedback was collected through case studies.

The report consolidates the framework's key elements, like the tools' description, and provides practical insights for its potential usability in real-world scenarios. The report sections provide a brief overview of the framework, safety tool descriptions, and case studies results summary, highlighting its alignment with the research objectives. The report bridges the gap between academic research and practical application.

The informational report had the purpose of guiding safety practitioners in making informed decisions while facilitating behavioural changes tailored to specific project needs through case studies (Kabir, 2016; Gedera, 2018; Megha & Satishkumar, 2024).

The report was designed as an informational report format, as an industry report format, to inform and instruct readers effectively, incorporating QR codes linked to video descriptions for enhanced accessibility (Gedera & Zalipour, 2018; Megha & Satishkumar, 2024; Varela & Mejía, 2018). This approach ensured the framework's application was straightforward, promoting user engagement and a deeper understanding (Kabir, 2016).

The report is presented in its original format, which was used to run the case studies, to preserve its industry relevance and practical focus. Note on Formatting:

This content list is part of an informational report intended for sharing with industry leaders. As such, the formatting differs from the standard APA 7 style. The goal here is to prioritize clarity, accessibility, and relevance for a professional audience rather than strict academic citation. This approach allows for more flexible structuring, direct referencing of operational materials, and streamlined presentation of key insights.

7.2 Informational Report

Informational Report
Tools to Promote Safety Culture Based on Influential Factors in Vertical Construction Sites in New Zealand

PhD Candidate: Natalia Ortega

Supervisor team:
DANIEL PAES[1], ZHENAN FENG[1], MONTY SUTRISNA[1], AND TAK WING YIU[2]
[1] SCHOOL OF BUILT ENVIRONMENT, MASSEY UNIVERSITY AUCKLAND, NEW ZEALAND
[2] SCHOOL OF BUILT ENVIRONMENT, UNIVERSITY OF NEW SOUTH WALES, AUSTRALIA
11-2024

TE KUNENGA KI PŪREHUROA MASSEY UNIVERSITY
UNIVERSITY OF NEW ZEALAND

INTRODUCTION

In the pursuit of promoting a safety culture across the New Zealand construction sector, this report presents a unique and comprehensive framework. Developed based on insights from 32 experts across New Zealand and a literature review, this framework not only categorises and prioritises influencing factors and tools crucial for stakeholders' practical application but also fosters decision-making through empirical evidence and systematic analysis.

The development of the framework was guided by a need to present a clear, actionable guide for stakeholders such as project managers and safety practitioners, participating 32 in the first round, and 26 advanced to the second round. This was achieved by incorporating the insights gained from a Modified Delphi study, which served as the empirical backbone for the ranking and categorisation of critical factors and tools. The factors identified through this iterative consensus method were subsequently analysed using relative importance index (*RII*), ensuring reliability in their prioritisation through Cronbach Alpha (McMeekin et al., 2020; Partelow, 2023; Rocco & Plakhotnik, 2009).

Further, the framework is created to subdivision tools into separate categories by a thematic analysis (Braun & Clarke, 2006) was considered to categorise tools based on their alignment with specific influential factors to promote safety culture in the construction sector in New Zealand by Ortega et. al (2025). Next, the tools were analysed using syllogistic reasoning, usually illustrated with Venn diagrams (Sato & Mineshima, 2015). Syllogistic reasoning helps to represent intersections, unions, and differences among a set of elements, facilitating a visual validation of how these tools overlap or diverge in terms of expert consensus and academic literature. This organisation improves the traceability of tools, increasing the framework's practical value for daily operations and decision-making. Each tool reflects its purpose and definition, frequency and format, engagement and participation, and example of case study and its impact on safety culture, making it easier for stakeholders to choose appropriate tools tailored to specific project needs. Each tool presents a link and a QR code to a video, where the explanation is created with visuals to facilitate understanding.

Moreover, the framework provides a clear pathway for Site Project Managers and safety practitioners to identify and implement tools best suited for their specific project challenges about promoting safety culture, thereby optimising outcomes and ensuring safety adherence.

To operationalise the practical usability of the framework, four case studies were conducted across different vertical construction projects from four distinct companies, following Robert K. Yin's recommendation (Yin, 2018). The research focused on vertical construction due to its high incidence rate in workplace injuries, with 518 out of 600 reported incidents in New Zealand's construction sector occurring in this sector from October 1, 2022, to September 1, 2023 (WorkSafe New Zealand, 2024c).

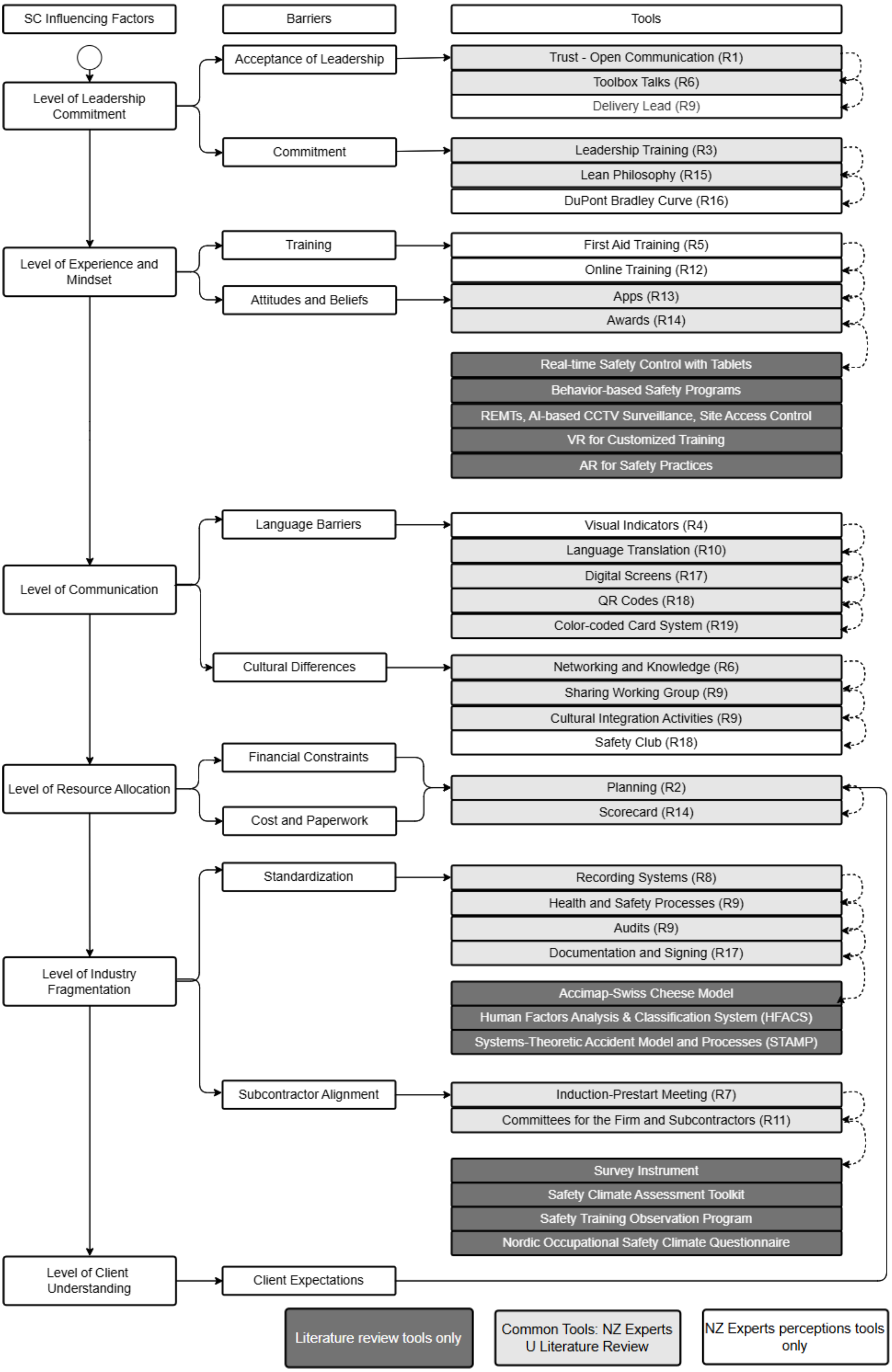
While the absence of longitudinal data is recognised, due to scope and time constraints, the chosen approach allowed the study to meet its usability validation. These studies included site visits, where induction, interviews, and surveys were performed, though specific details were generalised or omitted to maintain confidentiality (Fellows & Liu, 2015).

During the interviews the participants readily recognised the tools promoting safety culture, indicating effective safety practices yet also the need for continuous vigilance. However, some tools required further explanation, facilitated through QR codes linking to videos provided for each tool in this report, which helped clarify their use and integration into workplace practices. After these clarifications, participants acknowledged the utility of some tools, adapting them to fit their project-specific needs, while other tools remained unrecognised, even with additional audiovisual aids.

The range for System Usability Scale (SUS) survey, which is valuable to understand the level of usability, was performed among the 4 same participants. The average SUS score from these four participants was 81.875, scores are 0 to 100 (Brooke, 1995; Peres et al., 2013). The SUS range of scores was the highest score from the interviewee from site visit one at 95, the lowest score from the interviewee from site visit two at 65, and other scores from the interviewee from sites 3 and 4 at 75 and 92.5. This suggests that the participants generally found the framework to be user-friendly and satisfactory in terms of usability.

FRAMEWORK

Figure 1: Conceptual Framework of Tools Categorised According to Influential Factors
Note: This figure has been previously presented in Chapter 5 (Figure 5-2). It is included here for reference to support the informational report.


SC Influencing Factors
Barriers
Tools
Level of Leadership Commitment
Acceptance of Leadership
Trust - Open Communication (R1)
Toolbox Talks (R6)
Delivery Lead (R9)
Commitment
Leadership Training (R3)
Lean Philosophy (R15)
DuPont Bradley Curve (R16)
Level of Experience and Mindset
Training
Attitudes and Beliefs
First Aid Training (R5)
Online Training (R12)
Apps (R13)
Awards (R14)
Real-time Safety Control with Tablets
Behavior-based Safety Programs
REMTs, AI-based CCTV Surveillance, Site Access Control
VR for Customized Training
AR for Safety Practices
Level of Communication
Language Barriers
Visual Indicators (R4)
Language Translation (R10)
Digital Screens (R17)
QR Codes (R18)
Color-coded Card System (R19)
Cultural Differences
Networking and Knowledge (R6)
Sharing Working Group (R9)
Cultural Integration Activities (R9)
Safety Club (R18)
Level of Resource Allocation
Financial Constraints
Cost and Paperwork
Planning (R2)
Scorecard (R14)
Level of Industry Fragmentation
Standardization
Recording Systems (R8)
Health and Safety Processes (R9)
Audits (R9)
Documentation and Signing (R17)
Accimap-Swiss Cheese Model
Human Factors Analysis & Classification System (HFACS)
Systems-Theoretic Accident Model and Processes (STAMP)
Subcontractor Alignment
Induction-Prestart Meeting (R7)
Committees for the Firm and Subcontractors (R11)
Survey Instrument
Safety Climate Assessment Toolkit
Safety Training Observation Program
Nordic Occupational Safety Climate Questionnaire
Level of Client Understanding
Client Expectations
Literature review tools only
Common Tools: NZ Experts U Literature Review
NZ Experts perceptions tools only

LEVEL OF LEADERSHIP COMMITMENT

The level of Leadership Commitment is one of the top influential factors in promoting and maintaining SC within construction projects (Guo et al., 2016; Khalid et al., 2021). When leaders visibly prioritise safety, allocate resources, and influence safety behaviours, whereas lack of commitment and lack of acceptance of the leader leads to poor safety behaviours. (Khalid et al., 2021; Lestari et al., 2020)

TRUST OPEN COMMUNICATION

Purpose and Definition

The concept of trust and open communication is vital and functions as the foundation for a safety culture where team members feel secure expressing concerns and sharing evidence about potential safety issues without fear of revenge.

Frequency and Format

Leaders play a critical role; their contribution to safety training, direct commitment to safety discussions, and regular recognition of safety contributions strengthen trust and show that safety efforts are valued.

Engagement and Participation

Effective communication among project stakeholders depends on the methods employed being tailored to their diverse needs. Regular updates and the use of digital tools can accelerate real-time information contribution and collaboration.

Example of Case Study

Implementing trust, and open communication includes leadership strategies such as setting clear expectations, running consistent feedback, and team-building activities to focus on learning from mistakes and fostering team commitment to safety.

Impact on Safety Culture

Trust and open communication can provide practical insights into creating a more communicative and collaborative, safe environment.

(Bisbey et al., 2019; Karanikas et al., 2022; Pandit et al., 2018; SiteSafe, 2024c; Sydelko et al., 2021)

Video Link

TOOLBOX TALKS

Purpose and Definition

Toolbox Talks are short meetings, 5 to 15 minutes long, held regularly, preferably daily or weekly, on construction sites to discuss workplace safety and project-specific hazards among crew members and supervisors. They help reinforce and ensure ongoing awareness of potential risks on the site.

Frequency and Format

Toolbox Talks are conducted daily or weekly, but the frequency can change depending on the project risks involved. Each session usually lasts 5 to 15 minutes and comprises crew members and supervisors. To increase attendance, these talks are often arranged at the job site before the start of the day of work.

Engagement and Participation

Useful Toolbox Talks foster active contributions from all attendees. This involves not just listening but also talking about experiences, suggestions, and questions. Commitment can be enriched by rotating the responsibility of leading the talks among team members, which can help in speaking and presenting different perspectives.

Example of Case Study

The research by Sneddon et al. (2006) assessed their efficacy in offshore oil platforms. The study emphasised improvements in safety understanding and team unity following regular Toolbox Talks.

Impact on Safety Culture

These Toolbox Talks are not just meetings; they are powerful tools for implanting safety into daily routines. By determining regular communication dedicated to safety and making it a visible priority for both management and staff, they significantly impact the safety culture of the construction site.

(MacCollum, 2007; SiteSafe, 2024c; Sneddon et al., 2006; WorkSafe New Zealand, 2022b)

Video Link

DELIVERY LEAD

Purpose and Definition

The role of a Delivery Lead in construction involves coordinating project delivery features to ensure compliance with safety standards and regulations. The Delivery Lead works closely with project managers and other team members to provide timelines while following safety protocols.

Frequency and Format

For a Delivery Lead, the commitment to safety is not a one-time task but a continuous responsibility throughout the project. This constant commitment ensures the reliability of safety standards and regulations, providing a sense of security to the entire team.

Engagement and Participation

Delivery Leads play a crucial role in promoting safety by ensuring that all processes adhere to recognised safety norms. Their continuous commitment throughout the project is essential for maintaining a high standard of safety in construction projects.

Example of Case Study

During the startup phases of construction projects, they verify that all safety measures are in place as planned to safeguard all workers.

Impact on Safety Culture

Delivery Lead’s responsibilities are connected to maintaining a standard of safety in construction projects.

(Chih et al., 2018; Choudhry & Fang, 2008; Misnan et al., 2008; Romero et al., 2019; Shen et al., 2017; Wu et al., 2016)

Video Link

LEADERSHIP TRAINING

Purpose and Definition

Leadership training in the construction sector is conceived to improve leaders' qualities and effectiveness, concentrating on enhancing safety and project management outcomes. The training aims to teach necessary leadership skills that can influence safety practices and culture on construction sites.

Frequency and Format

The training programs can adapt in frequency and are shaped to the specific demands of the project. They usually include seminars and workshops, on-the-job training sessions that may happen at the start of a project or regularly throughout its lifecycle, and other forms of training.

Engagement and Participation

Leadership training programs are primarily hands-on, including interactive sessions where leaders are challenged to participate in discussions, role-playing, problem-solving, and critical-thinking exercises. These programs are designed to ensure that management can develop their leadership skills in relation to safety management.

Example of Case Study

A leadership training program implemented in a major construction firm. The program included specific modules on safety practitionership. This contained a reduction in accident rates and enriched safety compliance on the job site, indicating the direct impact of leadership training on successful safety outcomes (Wu et al., 2017).

Impact on Safety Culture

Leadership Training has a significant impact on safety culture. Trained leaders are equipped to foster a culture of safety that permeates all levels of the workforce, resulting in fewer incidents and a more committed workforce.

(Lekchiri & Kamm, 2020; Misnan et al., 2008; Wu et al., 2017)

Video Link

LEAN PHILOSOPHY

Purpose and Definition

Lean construction intends to develop the management and operational efficiency of construction projects by removing waste and improving processes. This tool leads to fewer last-minute adjustments and urgent jobs, which are common causes of accidents on construction sites. Thereby optimising overall project delivery in terms of time, cost, and quality. One of the tools is the 5S (sort, set in order, shine, standardise, sustain) system, which is a Lean tool that aims to organise a workplace for efficiency and effectiveness by identifying and storing the items used. By keeping the work environment clean and organised, 5S reduces the chances of accidents caused by slipping on or tripping over items left out of place.

Frequency and Format

Lean tools and practices are typically integrated throughout the project lifecycle. The implementation involves continuous monitoring and adaptation.

Engagement and Participation

Successful lean implementation expects active involvement from all project stakeholders, including managers, workers, and subcontractors, to ensure everyone is aligned with the lean methodology and practices.

Example of Case Study

In a large residential project in Brazil, lean construction was applied using tools like the Last Planner System. (Barbosa et al., 2013)

Impact on Safety Culture

Lean Philosophy promotes proactive hazard identification and fosters collaboration through various tools, such as 5S, embedding continuous learning into site operations. Encourages a behavioural norm where workers self-monitor and share responsibility for safety, reducing siloed thinking and enhancing collective adherence to safe practices.

(Abu Aisheh et al., 2022; Barbosa et al., 2013; Bashir et al., 2011; Bhagwat & Delhi, 2024; Ng et al., 2012)

Video Link

DUPONT BRADLEY CURVE

Purpose and Definition

DuPont Bradley Curve was developed to underscore the progression of safety culture maturity. It shows that the more mature the culture, the more evidence there is of reducing workplace incidents and fostering a shared commitment to safety. The DuPont Bradley Curve describes four stages of safety culture maturity: Reactive, Dependent, Independent, and Interdependent.

Frequency and Format

The application of the Bradley Curve is an ongoing process, implying regular reviews, training, and interventions to cultivate a culture that progressively values safety.

Engagement and Participation

It highlights engagement from top management down to individual workers.

Example of Case Study

METHODS TO IDENTIFY CULTURAL STAGES

DuPont Bradley Curve	Worker compliance level	Injury rates
Phase 1: Reactive Relies entirely on safety managers who make changes only after an incident, OSHA citation or new regulation.	**Level 1: Noncompliant** "I won't do it" • Negative environment • High stress	Fall as you proceed through the phases/levels
Phase 2: Dependent Fewer people are getting hurt, but stress can be high, as workers are complying because they feel they have to, not because they want to.	**Level 2: Compliant** "I must do it" • Neutral environment • High stress	
Phase 3: Independent Culture still has room for improvement as its members tend to have an every-worker-for-him/herself mentality.	**Level 3: Committed and engaged** "I want to do it" • Positive environment • Lower stress	
Phase 4: Interdependent Employees take pride in their work and safety record, and they do not hesitate to look out for each other and remind fellow workers if they see them cutting safety corners.		

Figure 2. Stages of growth within a company culture (Sutherland, 2020).

Impact on Safety Culture

At the interdependent stage, accidents and incidents are markedly reduced due to the higher level of internal motivation.

(Harvey et al., 2019; Indrayana & Pribadi, 2023; Sutherland, 2020)

Video Link

LEVEL OF EXPERIENCE AND MINDSET

The experience and mindset of the workforce play a key role factor in promoting safety; it impacts how safety practices are embraced and maintained. However, lack of training, lack of fresh perspective, and poor attitudes and beliefs are barriers to promoting SC (Bisbey et al., 2019; Machfudiyanto & Latief, 2018). Experienced workers bring knowledge about potential hazards; however, experience is not sufficient without the appropriate mindset (Al-Bayati et al., 2024). Continuous improvement in safety behaviour encouraging a proactive safety mindset brings benefits to construction sites (Deepak & Mahesh, 2019).

FIRST AID TRAINING

Purpose and Definition

First Aid training is designed to equip workers with the expertise to react to injuries and medical emergencies on construction sites. The training covers essential First Aid techniques, including CPR and the use of automated external defibrillators (AEDs). It deals with injuries such as cuts, burns, and fractures at common construction sites.

Frequency and Format

First Aid training courses are offered as one-day sessions that combine theoretical and practical learning. As recommended by health authorities in New Zealand, they need to be refreshed every two years.

Engagement and Participation

Workers are trained to recognise and respond to life-threatening situations and to gain confidence and competence in emergency scenarios.

Example of Case Study

Courses are often tailored to the specific needs of the construction sector.

Impact on Safety Culture

Trained workers are more likely to take instant and effective action in an emergency, lowering the seriousness of injuries.

(SiteSafe, 2024a; St John, 2024)

Video Link

ONLINE TRAINING

Purpose and Definition

Online safety training in New Zealand's construction sector aims to provide flexible education and is delivered through online platforms, making it accessible to workers regardless of their location.

Frequency and Format

The training sessions are available online and can be accessed at any time. These courses combine video tutorials, videos, quizzes, readings, simulations, and interactive assessments.

Engagement and Participation

Engagement in online safety training is facilitated through interactive content and support from tutors available via email or phone.

Example of Case Study

Site Safe and BeSafe are the leading providers of online safety training in New Zealand.

Impact on Safety Culture

The studies highlight that well-designed safety training programs lead to improved safety behaviours and a reduction in accidents.

(Bahn, 2012a; SiteSafe, 2024c)

Video Link

APPLICATIONS (APPS)

Purpose and Definition

Safety applications are designed to enhance site safety and operational efficiency. These tools, such as mobile apps, offer functionalities varying from real-time safety monitoring to efficient data handling.

Frequency and Format

Safety apps are used as needed, often daily, to ensure continuous monitoring and updating of site conditions. They are accessible on standard mobile devices like smartphones, tablets, and smart glasses.

Engagement and Participation

Commitment to these technologies needs training and continuous involvement from all project stakeholders.

Example of Case Study

Construction workers use mobile devices to report hazards in real-time. Safety managers also utilise analytics and monitoring tools to supervise project safety and compliance. Some projects about virtual fences are useful, especially projects that involve dangerous zones.

Impact on Safety Culture

The apps help bridge communication gaps on-site, thereby enhancing overall safety and productivity.

(Liu et al., 2017; Liu et al., 2019; Rey-Merchán et al., 2021)

Video Link

AWARDS

Purpose and Definition

Awards are used as a motivational tool to recognise and reward individuals and teams and aim to highlight best practices and integrated team practices.

Frequency and Format

Safety awards can be daily, like vouchers, weekly, monthly, or annual, giving recognition and often highlighting categories like best safety leader, leadership in safety, and best safety team practice.

Engagement and Participation

It is important to involve subcontractors in safety practices as part of the safety culture, which can be recognised through these awards.

Example of Case Study

Companies that executed specific safety practices observed improvements in their safety performance metrics, which were recognised through awards from daily incentives such as a lunch voucher, or when they do VR training interactions, provide blockchain-based tokens (financial benefits) to incentivise safe conduct and reward individuals who have undergone safety training, diplomas, and gift vouchers.

Impact on Safety Culture

Recognition and incentives are necessary to affect safety culture in the construction sector. (Abdullah & Wern, 2012; Baiden et al., 2006; Bao et al., 2024; Molenaar et al., 2009)

Video Link

REAL-TIME SAFETY CONTROL WITH TABLETS

Purpose and Definition

Real-time safety control with tablets boosts on-site safety management through immediate data access and monitoring. These devices allow monitoring conditions and reporting incidents as they happen, adding dynamic.

Frequency and Format

The use of tablets for safety is becoming part of daily operations on construction sites. Managers and workers use these devices during the working day to access real-time data, run safety checks, and communicate concerns instantly as they arise.

Engagement and Participation

The systems are designed to be user-friendly and easy to integrate into daily tasks.

Example of Case Study

In a construction project in Fortaleza, Brazil, the management team began to use the system to plan and control all services, crews, and machines on tablets. Thus, indicators of quality and safety also became controlled on the system and updated at the end of each service.

Impact on Safety Culture

The implementation of tablets for real-time safety control influences safety culture by facilitating a shift from reactive to preventative safety attitudes.

(Barbosa et al., 2013; Liu et al., 2019)

Video Link

BEHAVIOUR-BASED SAFETY PROGRAMS

Purpose and Definition

Behaviour-Based Safety (BBS) programs in construction are designed to focus on individual safety behaviours and the environmental impacts that affect them. These programs identify and reinforce safe behaviour and encourage safe working habits through continuous observation and feedback.

Frequency and Format

BBS programs typically involve regular observations, which can be daily, weekly, or as needed, depending on the specific practices of a project. Trained observers perform these observations. This process is documented and analysed to detect areas for improvement.

Engagement and Participation

It requires participation from top management down to individual workers. Engagement strategies incorporate training workers to become observers, including employees in developing and upgrading safety protocols, and regular meetings to discuss progress and share feedback.

Example of Case Study

A construction company with projects in Hong Kong implemented a BBS program and saw a significant reduction in the incident rate during the first year.

Impact on Safety Culture

These programs are based on prevention and continuous improvement.

(Choudhry, 2014; Spigener et al., 2022; Yang et al., 2019)

Video Link

REMTs, AI-BASED CCTV SURVEILLANCE, SITE ACCESS CONTROL

Purpose and Definition

Real-Time Employee Monitoring Technologies (REMTs) continuously monitor employees' locations and activities on-site to improve safety and productivity.

AI-based CCTV Surveillance: This technology applies artificial intelligence to analyse video data in real time, detecting safety hazards and unauthorised activities on construction sites.

Site Access Control: Systems designed to manage and monitor access to construction sites, ensuring that only authorised personnel can enter.

Frequency and Format

REMTs and AI-based CCTV operate continuously, providing real-time updates and alerts to site managers and safety personnel.

Site Access Control is implemented throughout the construction project.

Engagement and Participation

REMTs require wearable devices that track location activity and active participation from all employees who are monitored.

AI-based CCTV and Site Access Control are overseen by security personnel who monitor and manage access control systems.

Example of Case Study

In a large construction project in Singapore, a video recording system was installed to capture real-time footage of daily operations. The recorded videos were also used during safety training sessions as concrete examples of correct and incorrect behaviours on site.

Impact on Safety Culture

These technologies, by providing a continuous oversight mechanism, foster a culture of safety.

(Johannessen, 2009; Nguyen et al., 2017; Wu et al., 2022; Wu et al., 2023)

Video Link

VIRTUAL REALITY FOR CUSTOMISED TRAINING

Purpose and Definition

Virtual reality (VR) is used to create learning experiences through interactive simulations that replicate real-world scenarios in a safe and controlled environment. Trainees, where multiple participants can interact, can execute tasks, make decisions, and experience the consequences of their actions in real time.

Frequency and Format

VR training sessions can be scheduled as needed and are conducted using VR headsets and controlled environments. The training modules can be adapted to specific tasks and roles.

Engagement and Participation

VR prepares workers for construction tasks without the risks associated with physical training sites, which significantly enhances learning and retention.

Example of Case Study

VR training for drilling works, meaning the heavy machinery, how to use it, and how to prevent accidents due to these drilling tasks (Fernández et al., 2021).

Impact on Safety Culture

VR training prepares workers for real-life challenges, reducing the possibility of accidents.

(Bao et al., 2024; Chalhoub et al., 2021; Chen & Chang-Richards, 2022; Fernández et al., 2021)

Video Link

AUGMENTED REALITY FOR SAFETY PRACTICES

Purpose and Definition

Augmented reality (AR) integrates digital information with the real world, providing workers with real-time data and visual aids, such as overlaying information on physical objects, which assists in identifying hazards and considering complex structures or machinery without physical risks.

Frequency and Format

AR is employed as needed on construction sites, in training sessions, and in daily operations where safety risk identification is crucial. It can be accessed via mobile devices or wearable AR glasses.

Engagement and Participation

It requires workers' involvement, who interact with the technology to receive real-time information. This interactive approach enhances learning retention and engagement.

Example of Case Study

A notable application of AR for safety is its use in heavy equipment training. By using AR, workers can virtually operate machinery in a controlled environment.

Impact on Safety Culture

It permits more apparent hazard recognition and increases communication among workers.

(Bao et al., 2024; Chalhoub et al., 2021; Chen & Chang-Richards, 2022; Chen et al., 2022; Fernández et al., 2021)

Video Link

ARTIFICIAL INTELLIGENCE FOR SAFETY

Purpose and Definition

Artificial intelligence (AI) for Safety refers to the application of AI technologies to boost safety. These AI systems process large amounts of data to forecast potential hazards in real-time monitoring and automate safety compliance on construction sites.

Frequency and Format

AI technologies are integrated in real-time environments, providing ongoing monitoring and updates. These technologies analyse text, visual, and audio data from construction sites.

Engagement and Participation

Successful implementation of AI for safety requires the participation of data scientists, safety managers, and workers to ensure that the AI systems correctly interpret the site conditions.

Example of Case Study

AI algorithms were able to identify workers not wearing helmets and instantly alert safety managers.

Impact on Safety Culture

AI technologies predict in real-time hazard recognition.

(Chen & Chang-Richards, 2022; Rabbi & Jeelani, 2024; Wu et al., 2022)

Video Link

LEVEL OF COMMUNICATION

The level of communication is a central factor in ensuring that safety practices are implemented and maintained throughout construction projects. The main barriers in construction, due to the diversity of cultures working on site, as well as language and cultural barriers, are impediments to communicating correctly. (Biggs et al., 2013; Del Puerto et al., 2018).

VISUAL INDICATORS

Purpose and Definition

Visual indicators are physical tools used for communication on construction sites. They include signs, labels, and other visual aids, as well as static and mobile safety signs, such as those for smoking areas, material/waste collecting areas, and site warehouses. These indicators are vital in impacting safety by making essential information visible.

Frequency and Format

Visual indicators are a constant feature on sites. They are designed to be well visible to ensure all workers clearly spot them.

Engagement and Participation

They are designed to be interacted with by simply placing them in the line of sight of workers.

Example of Case Study

The main contractor precisely enforced its general practices on the subcontractors by using static and mobile safety signs and visual reminders for an equipment checking system.

Impact on Safety Culture

Visual indicators can be applied to improve communication by preventing accidents on construction sites.

(Bhagwat & Delhi, 2023; Sinha et al., 2021; Tezel et al., 2013)

Video Link

LANGUAGE TRANSLATION

Purpose and Definition

Language translation is essential for ensuring clear communication across multicultural teams. It involves converting signs, safety protocols, and technical specifications from one language to another. This tool is crucial for preventing miscommunication and ensuring that all team members have an accurate understanding of project requirements and safety procedures.

Frequency and Format

Language translation is used as needed through the construction project lifecycle. The format can change from written documents to digital content and training.

Engagement and Participation

Effective translation guarantees that all parties recognise their roles and responsibilities. Engagement involves collaboration between translators, construction managers, and workers.

Example of Case Study

In regions like the Arabic Gulf, they improved safety by translating safety protocols, training materials, and operational commands.

Impact on Safety Culture

This tool is crucial for preventing miscommunication and guaranteeing that all team members understand the safety requirements.

(Carlan et al., 2012; Del Puerto et al., 2018; Fass et al., 2017; Rotimi et al., 2021)

Video Link

DIGITAL SCREEN

Purpose and Definition

Digital screens function as dynamic platforms for communicating critical information, enhancing real-time communication. These screens display health and safety reminders, operational updates, and general communications.

Frequency and Format

Digital screens are versatile, featuring both indoor and outdoor models, making them suitable for any environmental conditions.

Engagement and Participation

These screens facilitate enriched engagement by providing a platform for continuous learning and reminders about safety among all workers.

Example of Case Study

These screens have been helpful by displaying timely updates, celebrating safety achievements, and improving overall communication between teams.

Impact on Safety Culture

Digital screens ensure that critical safety and operational information is continuously accessible and visible.

(MBIE New Zealand, 2024; Tezel et al., 2015; Wadley, 2021)

Video Link

QUICK RESPONSE CODES

Purpose and Definition

Quick Response (QR) codes facilitate fast retrieval of detailed information directly at the job site. These codes can link to digital information such as safety procedures, project plans, and equipment manuals with real-time updates, making information available via smartphones or tablets.

Frequency and Format

QR codes are typically generated and placed on various items like equipment, materials, and project documentation areas. The codes can be both static and dynamic, granting updates without altering the physical code itself.

Engagement and Participation

The use of QR codes requires understanding how to scan and interact with the codes to access the necessary information. Training and implementation practices are essential for maximising the benefits of QR code usage.

Example of Case Study

QR codes are placed on construction equipment to provide direct access to safety guidelines and operational manuals. They are also useful for updating blueprints or construction plans.

Impact on Safety Culture

Integrating QR codes ensures immediate access to safety standards, fostering a culture of safety and accountability across construction sites.

(Chen et al., 2022; Galea et al., 2020)

Video Link

COLOUR-CODED CARD SYSTEM

Purpose and Definition

The colour-coded card system is a visual tool used that utilises different colours to denote various statuses, roles, or safety messages, facilitating a clear communication among workers.

Frequency and Format

Colour-coded cards are integrated into safety gear, equipment labels, and site signage. The format and specific colours used can vary.

Engagement and Participation

Workers and site managers use and recognise standardised colour indicators during their daily tasks. Training is needed to ensure everyone understands the meaning behind each colour code.

Example of Case Study

A colour-coded card system is observed in the use of different coloured hard hats on construction sites, where each colour represents a different role.

Impact on Safety Culture

This helps in fast identification and improves operational efficacy and safety.

(Tezel et al., 2013, 2018, 2020)

Video Link

NETWORKING AND KNOWLEDGE

Purpose and Definition
Networking and knowledge sharing are necessary for fostering collaboration, learning, and innovation, for learning about new trends, and for discussing challenges and solutions in the construction sector.

Frequency and Format
Networking can be done through diverse platforms and events, such as conferences, seminars, trade shows, and online forums or social media groups, where professionals can stay connected and informed.

Engagement and Participation
Professionals' active participation can support discussions, sharing insights, and collaboration activities.

Example of Case Study
Professional associations can host events where members can share best practices, challenges, and innovative solutions.

Impact on Safety Culture
Sharing experiences, challenges, and solutions related to safety promotes a culture of safety. (Lekchiri & Kamm, 2020; Love & Smith, 2016; Oo et al., 2022)

Video Link

SHARING WORKING GROUP

Purpose and Definition

A Sharing Working Group facilitates collaboration and information sharing among main contractors and subcontractors. Members exchange experiences and ideas to improve project outcomes.

Frequency and Format

The format of a Sharing Working Group is often regular meetings where members gather to discuss ongoing issues. These groups may utilise digital platforms for continuous communication and data sharing.

Engagement and Participation

Engagement in a Sharing Working Group requires open communication and the willingness of its members to share constructively.

Example of Case Study

In a large-scale construction project where multiple subcontractors collaborated by participating in these groups by sharing data, they were able to reduce delays and cost overruns.

Impact on Safety Culture

The Sharing Working Group fosters an environment where safety practices, challenges, and innovations are regularly discussed and shared.

(Deepak & Mahesh, 2021; Jaffe et al., 2016; Ness, 2012; Schein, 2014)

Video Link

CULTURAL INTEGRATION ACTIVITIES

Purpose and Definition

Cultural integration activities foster a diverse and inclusive work environment and are designed to bridge cultural gaps, integrating diverse cultural insights into the project.

Frequency and Format

Cultural integration activities can vary in frequency and format, depending on the diversity of the workforce and the project's needs. The most common formats consist of workshops and team-building events that celebrate diverse cultures.

Engagement and Participation

These activities require participation from main contractors to subcontractors, creating an environment where everybody feels valued and willing to share their perspectives and experiences.

Example of Case Study

Managing active cultural differences in U.S. construction workplaces between Hispanic and non-Hispanic highlights the importance of addressing active cultural differences to support accident prevention efforts.

Impact on Safety Culture

Cultural integration activities promote inclusiveness and understanding, which are critical in preventing miscommunication and misunderstandings on site.

(Al-Bayati et al., 2018; Raja et al., 2016; Tremblay et al., 2023)

Video Link

SAFETY CLUB

Purpose and Definition

A Safety Club is an organised group that promotes safety awareness by sharing experiences, learning from incidents, and disseminating best practices.

Frequency and Format

Safety Clubs can meet regularly, such as monthly or quarterly, and are usually held on-site. Members debate recent incidents, ongoing safety challenges, and continuous improvement strategies.

Engagement and Participation

Activities can include hosting guest speakers and giving incentives for active participation and recognition of contributions to safety improvements.

Example of Case Study

The club played a crucial role in reducing incident rates by adopting new technologies, revising safety protocols, and providing a platform for open communication about ideas and safety issues.

Impact on Safety Culture

Safety Clubs operate to enhance safety awareness and practices through collaborative efforts and continuous learning.

(Baiden et al., 2006; Bridges et al., 2020; Harris et al., 2020; Hulme et al., 2021)

Video Link

LEVEL OF RESOURCE ALLOCATION

The level of resource allocation is a critical factor in creating and maintaining SC, and Promoting SC requires significant financial investment, careful planning, documentation, and time (Bevan-Brown, 2006; Bevan & Yung, 2015; Hall et al., 2022; Tezel et al., 2018; Zidane & Andersen, 2018).

PLANNING

Purpose and Definition
Planning ensures that all activities are coordinated, and resources are optimally utilised. It involves setting project objectives, defining the scope, and outlining the steps required to achieve the project goals within the specified time and budget.

Frequency and Format
Planning is an ongoing activity that begins before physical work. The planning process includes various tools and techniques, such as Gantt charts, the Critical Path Method (CPM), and the Program Evaluation and Review Technique (PERT), which help with detailed scheduling and task management.

Engagement and Participation
Effective planning requires the engagement of all project stakeholders, including project managers, engineers, architects, and contractors, to keep the project on track.

Example of Case Study
Planning involves all team members in the planning process, ensuring tasks are clearly described, and deadlines are realistic.

Impact on Safety Culture
Planning the projects can minimise risks and promote a safer work environment by identifying potential hazards and integrating safety measures into the project schedule.

(Goh & Askar, 2016; Oner & Saritas, 2005; Ramani et al., 2023)

Video Link

SCORECARD

Purpose and Definition

The scorecard, specifically the Balanced Scorecard (BSC), is utilised to measure safety culture. It translates safety goals across various perspectives, management, operational, customer, and learning. It shifts focus from solely tracking accidents to promoting proactive safety measures.

Frequency and Format

The Balanced Scorecard is reviewed periodically, monthly, and quarterly to ensure alignment with organisational goals. It includes metrics tracking.

Engagement and Participation

The scorecard requires acceptance and integration into daily management practices.

Example of Case Study

The Balanced Scorecard, which measures safety culture across several construction projects in Singapore, showed a tangible improvement in managing safety performance on sites.

Impact on Safety Culture

The Balanced Scorecard provides a structured approach to measure and improve safety performance.

(Dulaimi & Chin, 2009; Haseeb et al., 2014; Mohamed, 2003; Niu et al., 2019; Trillo-Cabello et al., 2021)

Video Link

LEVEL OF INDUSTRY FRAGMENTATION

The level of industry fragmentation is the factor that presents unique challenges to preserving a consistent SC, as multiple contractors, subcontractors, and stakeholders with a variety of standards and practices in a single project (Aboagye-Nimo & Raidén, 2019; Deepak & Mahesh, 2024; Sizemore, 2017; Wamuziri, 2006).

RECORDING SYSTEMS

Purpose and Definition

Recording systems are applied to monitor, document, and manage safety-related data. These systems capture information from routine safety checks to incident reporting.

Frequency and Format

Recording systems are integrated into daily operations and include a combination of digital tools, video, and software that allow for real-time data entry and access.

Engagement and Participation

Successful implementation of recording systems requires workers to input the data accurately and consistently, which may involve regular training sessions.

Example of Case Study

A construction company implemented this to ensure that workers did not enter restricted zones without proper authorisation and safety gear.

Impact on Safety Culture

Recording systems impact safety culture by promoting transparency and accountability.
(Gibson, 2015; Nguyen et al., 2017; Shin et al., 2022)

Video Link

HEALTH AND SAFETY PROCESSES

Purpose and Definition

Health and Safety Processes in New Zealand are mandated by the Health and Safety at Work Act 2015. The law includes the implementation of comprehensive safety plans and risk assessments.

Frequency and Format

Health and Safety Processes are fundamental to daily operations on construction sites. They are reviewed and updated periodically as needed to respond to new changes in project scope or regulatory requirements.

Engagement and Participation

It requires active participation from management and the workers on the ground.

Example of Case Study

The Health and Safety in Construction program provided by Site Safe New Zealand developed a safety practitionership and a comprehensive understanding of workplace health and safety requirements.

Impact on Safety Culture

The structured approach to health and safety in New Zealand's construction sector intends to construct compliance, awareness, and proactive management of workplace hazards.

(SiteSafe, 2024b; Sizemore, 2017; WorkSafe New Zealand, 2015, 2017b)

Video Link

AUDITS

Purpose and Definition

Audits are processes designed to assess safety practices and compliance with safety regulations to ensure adherence to the Health and Safety at Work Act 2015. Their goal is to identify areas of improvement across construction sites.

Frequency and Format

Safety audits are conducted regularly, depending on the project's scope. These audits involve both on-site inspections and documentation reviews to evaluate compliance with safety standards.

Engagement and Participation

Safety audits expect participation from a range of stakeholders, including external auditors. They involve preparing documentation, facilitating site inspections, and contributing to follow-up actions to address any detected issues.

Example of Case Study

A major commercial building in Wellington underwent a series of safety audits, which helped identify potential hazards with scaffolding setups and electrical installations.

Impact on Safety Culture

Regular safety audits promote continuous improvement and accountability.

(Rabbi & Jeelani, 2024; WorkSafe New Zealand, 2015, 2017a)

Video Link

DOCUMENTATION AND SIGNING

Purpose and Definition

Documentation and Signing are tools for implementing safety compliance, maintaining records of safety practices like safety inspections, incidents, and risk assessments, and signing compliance documents. The purpose is to ensure documented, traceable, and verified information to add accountability and transparency to safety.

Frequency and Format

Documentation and signing are continuous, especially at each critical milestone of the project. Forms, checklists, and digital logs are standard tools used for this purpose.

Engagement and Participation

Engagement with documentation and signing requires training to ensure that personnel are familiar with the documentation procedures.

Example of Case Study

An example of effective implementation of documentation and signing practices can be observed in a large construction project in Auckland. The project utilised a digital documentation system to streamline the process of recording safety inspections and incident reports. All site workers were required to sign digital logs using tablets at the end of each shift, which improved the accuracy of safety records and facilitated real-time safety compliance monitoring.

Impact on Safety Culture

The rigorous application of documentation and signing practices, such as maintaining detailed records and requiring signatures for key safety checks, requires responsibility and compliance.

(Chen et al., 2022; Rabbi & Jeelani, 2024; Tezel et al., 2013; WorkSafe New Zealand, 2015, 2017b)

Video Link

ACCIMAP-SWISS CHEESE MODEL

Purpose and Definition

The AcciMap-Swiss Cheese Model illustrates how accidents happen through multiple layers of defence and provides the root causes of these failures across different organisational levels. This integrated approach helps identify underlying systemic issues and the immediate causes of accidents.

Frequency and Format

This model is recommended for post-incident use, but it can also be used proactively during safety audits to identify potential risks. The analysis involves mapping out events preceding an accident by identifying failures and factors that may have contributed to the event.

Engagement and Participation

This model requires the participation of multiple stakeholders to gather comprehensive data about operational practices that could lead to accidents.

Example of Case Study

This model is valuable in environments like construction where the relations and interaction of different factors can lead to safety incidents.

Impact on Safety Culture

Employing the AcciMap-Swiss Cheese Model provides a deeper understanding of how systemic issues and human errors contribute to accidents.

(Igene & Johnson, 2020; Salmon et al., 2012; Shabani et al., 2024; Underwood & Waterson, 2014)

Video Link

HUMAN FACTORS ANALYSIS & CLASSIFICATION SYSTEM (HFACS)

Purpose and Definition

The Human Factors Analysis & Classification System is a framework for identifying and classifying human errors that lead to accidents and incidents. It analyses accidents and near-misses to conclude underlying human error components and systemic weaknesses that contribute to these events.

Frequency and Format

It is applied as a reactive tool post-incident, but it can also be used proactively during safety audits and risk assessments. The format includes a four-tiered method: Unsafe Acts, Preconditions for Unsafe Acts, Unsafe Supervision, and Organisational Influences that lead to safety failures.

Engagement and Participation

The implementation requires training sessions to educate staff on how to recognise and report the human factors and errors classified under this framework.

Example of Case Study

The application of this framework in construction projects revealed deficiencies in training and supervision, as well as organisational pressures that led to unsafe practices.

Impact on Safety Culture

This framework provides a clear and structured method to analyse and understand the human factors causing accidents.

(Igene & Johnson, 2020; Salmon et al., 2012)

Video Link

SYSTEM-THEORETIC ACCIDENT MODEL AND PROCESSES (STAMP)

Purpose and Definition

The Systems-Theoretic Accident Model and Processes (STAMP) is a safety analysis framework that extends beyond traditional failure models. This tool is designed to understand complex interactions and systemic failures within construction projects. First, it defines the purpose of the analysis. Then, it analyses unsafe control actions like not providing causes hazard, providing causes hazard, providing but too early or too late, stopping too soon, or applying too long; finally, it develops the feedback loop with mitigation strategies.

Frequency and Format

STAMP involves continuous evaluation and updating of safety controls and constraints throughout the project's lifecycle to adapt to new risks and changes in the construction environment. STAMP treats safety as a control problem rather than a failure to comply with norms, focusing on constraints to guide acceptable safety behaviour within the system.

Engagement and Participation

Implementing STAMP requires collaborative efforts to define safety constraints and control structures.

Example of Case Study

Although there are no concrete case studies in the building sector, there are many in other industries that share similarities, like healthcare and aviation.

Impact on Safety Culture

The application of STAMP reveals how systemic issues contribute to accidents.

(Leveson, 2004; Leveson & Thomas, 2018)

Video Link

INDUCTION-PRESTART MEETING

Purpose and Definition

Induction-prestart meetings ensure that all personnel are familiar with procedures, safety expectations, and risks at a construction site before work begins.

Frequency and Format

These meetings are held before a shift starts, when a new subcontractor joins, or when a new member starts. They are brief sessions where safety information is reviewed, and attendance is often mandatory.

Engagement and Participation

Engagement in induction-prestart meetings is critical. They require active participation from everyone and involve presenting safety data, chatting about recent incidents, and reviewing safety milestones.

Example of Case Study

They implemented induction-prestart meetings as part of their safety protocol led to a marked improvement in safety compliance and incident reporting.

Impact on Safety Culture

Induction-prestart meetings significantly foster a routine of safety-first thinking among workers.

(Bahn, 2012a; Choudhry & Fang, 2008; Harvey et al., 2020; Musonda et al., 2021; Ness, 2012; Rowlinson & Jia, 2015)

Video Link

COMMITTEES FOR THE FIRM AND SUBCONTRACTORS

Purpose and Definition

These committees involve attendees from both the main contractor and subcontracting firms to facilitate collaboration, communication, and coordination on safety matters. They address safety issues and share safety practices and challenges.

Frequency and Format

These committees meet regularly, often monthly or quarterly, to discuss recent incidents and update safety protocols. The agenda includes different items to allow open dialogue.

Engagement and Participation

These committees require active participation from representatives of both the firm and subcontractors, ensuring that all parties involved in the construction project are equally committed to maintaining and improving safety standards.

Example of Case Study

Companies with influential safety committees can play a more positive role in the improvement of safety performance than those without.

Impact on Safety Culture

These committees promote a shared responsibility for safety, from the main contract and subcontractors by ensuring safety practices are integrated across all operations.

(Asilian-Mahabadi et al., 2018; Choudhry & Fang, 2008; Wamuziri, 2013; WorkSafe New Zealand, 2024b)

Video Link

SAFETY CLIMATE ASSESSMENT TOOLKIT

Purpose and Definition

The Safety Climate Assessment Toolkit is designed to evaluate and identify perceptions and attitudes toward safety at various organisational levels. It provides insights into how workers value and practice safety on the job site.

Frequency and Format

The toolkit uses standardised questionnaires and surveys to ensure that safety practices are implemented and valued by all employees. It usually runs annually and covers various dimensions of safety climate, including leadership commitment, communication effectiveness, worker involvement, and risk perception.

Engagement and Participation

It requires participation from top management to field workers.

Example of Case Study

A safety climate among Latino construction workers in Colorado and Puerto Rico was studied. This exploratory study analysed responses from 315 workers who completed the safety climate survey. The study revealed that Puerto Rican workers described a more positive safety climate and less of a blame culture for accidents compared to their Colorado colleagues.

Impact on Safety Culture

The Safety Climate Assessment Toolkit brings detailed insights into the actual safety perceptions within an organisation.

(Del Puerto et al., 2018; Probst et al., 2019; Umar, 2020; Wamuziri, 2013; Xia et al., 2023)

Video Link

SAFETY TRAINING OBSERVATION PROGRAM (STOP)

Purpose and Definition

The Safety Training Observation Program, known as STOP, is to identify and mitigate potential safety risks through direct observation and feedback on construction sites. The program focuses on observing workers in action, identifying unsafe behaviours or conditions, and providing immediate feedback. It was developed by Dupont Safety and Environmental Management Services in 1995.

Frequency and Format

STOP is conducted daily or weekly, and trained observers, typically safety officers or supervisors, use checklists or digital tools to record observations and provide feedback to the workers observed.

Engagement and Participation

Observers are trained to supervise unbiased observations and provide constructive feedback to workers.

Example of Case Study

A Petrochemical Construction Company in western Iran, after 12 months of implementing the STOP technique, revealed that 76.78% of total behaviours were unsafe. 54.76% of total unsafe acts at-risk behaviours were related to the fall hazard. The most common cause of unsafe behaviours was habit and the unavailability of safety equipment.

Impact on Safety Culture

It acts as a preventive tool, developing awareness and highlighting safety standards through continuous engagement.

(Darvishi et al., 2015)

Video Link

NORDIC OCCUPATIONAL SAFETY CLIMATE QUESTIONNAIRE

Purpose and Definition

The Nordic Occupational Safety Climate Questionnaire (NOSACQ-50) is a diagnostic tool that measures shared perceptions of safety beliefs and practices across various dimensions. It helps organisations detect areas of strength and improvement in their safety culture.

Frequency and Format

NOSACQ-50 is managed annually or biennially. The questionnaire contains 50 items across seven dimensions, including management safety commitment, worker safety engagement, and risk non-acceptance

Engagement and Participation

It requires active participation from top management to front-line workers.

Example of Case Study

A construction company in Sweden implemented the NOSACQ-50 and detected a significant discrepancy between management’s perception of safety practices and the views of front-line workers.

Impact on Safety Culture

It presents a comprehensive view of the safety environment, assisting directed safety interventions.

(Guadix et al., 2017; Kwon et al., 2021)

Video Link

LEVEL OF RESOURCE ALLOCATION

The level of client understanding is another factor that plays a vital role in shaping the SC of a construction project. Keeping them informed as clients and as contractors would help them understand the importance of safety in impacting the overall project outcome. (Choudhry et al., 2007; Del Puerto et al., 2018; Gao et al., 2015; Namian et al., 2024; Zhou et al., 2015).

PLANNING SCORECARD

CASE STUDIES HIGHLIGHTS

During all four site visits, some safety culture tools commonly used in the New Zealand construction sector were immediately recognised by participants. However, other tools within the framework required additional clarification, which was provided through QR codes embedded in the report, linking to descriptive videos explaining each tool.

After viewing the explanatory material, some participants acknowledged recognising certain tools but noted that they had been modified or adapted to better align with their specific project requirements. However, some tools remained unfamiliar, even after participants accessed the supporting audiovisual content.

Table 1 highlights only those tools where all four participants demonstrated consistent responses, either by immediately recognising the tool, recognising it after clarification, or not recognising it at all. This consistency in responses provides valuable insight into the familiarity and adoption of specific SC tools in construction projects.

Table 1

Framework Tools Recognised and Not Recognised by all Participants

Tools recognised immediately	
Level of Leadership Commitment • Trust Open Conversations • Toolbox Talks • Leadership Training	**Level of Industry Fragmentation** • Recording Systems • Health and Safety Processes • Audits • Documentation and Signing • Accimap-Swiss Cheese Model
Level of Experience and Mindset • First Aid Training • Applications • Awards	**Level of Resource Allocation** • Induction-Prestart Meeting • Committees for the Firm and Contractors
Level of Communication • Networking and Knowledge • Planning	**Level of Client Understanding** • Planning
Tools recognised after watching the video	
Level of Leadership Commitment • Delivery Lead • Lean Philosophy • DuPont Bradley Curve	**Level of Experience and Mindset** • Behaviour-Based Safety Programs
Tools not recognised after watching the video	
Level of Experience and Mindset	**Level of Communication**

• Augmented Reality for Safety Practices • Artificial Intelligence for Safety	• Safety Club

Note: This table has been previously presented in Chapter 6 (Table 6-3). It is included here for reference to support the informational report.

The following section presents the results of the safety culture tools categorised according to influential factors. By aligning tools with these factors, this analysis provides a structured understanding of how different interventions contribute to fostering a positive safety culture in construction. The cross-case synthesis, used to analyse multiple case studies by identifying patterns, similarities, and differences, was conducted by examining each influential factor (see Tables 2 to 6) alongside the categorised safety culture tools. Responses were grouped based on participants' familiarity and use of the tools, providing insights into how different safety practices are implemented on construction sites.

Each tool is examined within the context of its associated influential factor, highlighting its recognition, adaptation, or lack of awareness among participants. By analysing these relationships, this section provides practical insights into the effectiveness of safety culture tools and their potential for improving safety outcomes in construction. This categorisation allows for a clearer interpretation of how tools are perceived and utilised on construction sites, shedding light on which strategies are effectively integrated, which require modifications, and which may need further industry-wide awareness and training.

Level of Leadership Commitment

Some tools were immediately recognised and commonly used by participants. When discussing Trust and Open Conversations, participants had different approaches. One participant (P1) emphasised a direct and informal style, stating: “I’m not afraid to text one of them and say, ‘OK, things come wrong’. OK, that’s the kind of thing.” In contrast, another participant (P2) described a more structured method, saying: “We encourage our subcontractors to discuss anything that they’ve seen on-site.” This distinction highlights how trust and openness are fostered through both direct interpersonal interactions and formalised communication structures across different project teams.

Similarly, participants demonstrated varied approaches to Toolbox Talks, a key tool for regular safety communication. One participant (P4) stressed the importance of conducting weekly Toolbox Talks, while another participant (P2) noted a bi-weekly approach, explaining: “What we do is every second week.” These differing schedules underscore how construction teams adapt safety communication practices to suit their specific project needs, schedules, and workforce dynamics.

Other tools were not immediately recognised but became familiar after participants viewed explanatory material. For example, when discussing Lean Philosophy in construction, participants interpreted the concept differently. One participant (P2) associated it with workflow efficiency, stating: “The whole idea of how we build is... it is a production line what we do.” This suggests an understanding of Lean as a systematic, process-driven approach focused on productivity and efficiency. Meanwhile, another participant (P3) referenced a specific Lean tool, saying: “Over here, we just call it the last planner.” These responses indicate different levels of familiarity and application of Lean principles, emphasising the importance of tailored communication and training when introducing safety and efficiency frameworks.

Table 2

Familiarity and Usage of Leadership Commitment Tools

Level of Leadership Commitment tools	Familiar tools, recognised immediately by participants	Unfamiliar with the tool by name but who recognised it after viewing a video	Neither recognised the tool by name nor confirmed its use after watching a video
Trust-Open Conversations	P1, P2, P3, P4		
Toolbox Talks	P1, P2, P3, P4		
Delivery Lead		P1, P2, P3, P4	
Leadership Training	P1, P2, P3, P4		
Lean Philosophy		P1, P2, P3, P4	
Dupont Bradley Curve		P1, P2, P3, P4	

Note: This table has been previously presented in Chapter 6 (Table 6-4). It is included here for reference to support the informational report.

Level of Experience and Mindset

As illustrated in Table 3, several tools were widely recognised and incorporated into existing practices. When discussing awards as a tool for promoting safety culture, participants described a range of formal and informal recognition systems. One participant (P1) highlighted a structured approach, stating: "We called it the Hero Observer Award, we have awarded every quarter and then at the end of the year as well." Others described more ad-hoc incentives, such as food-based rewards or small gifts, demonstrating a flexible and site-specific approach to reinforcing positive safety behaviours. P2 noted: "They get Kentucky Fried Chicken every so often, chocolates for me, and we have a barbecue." Similarly, P4 described an approach that includes practical incentives, explaining: "If somebody comes and reports a few things, they receive a high-quality pair of safety glasses or a supermarket voucher." These responses illustrate the diverse ways safety engagement is encouraged, reinforcing the broader strategy of fostering a positive and proactive safety culture.

Other tools were not immediately recognised by name but became familiar after video demonstrations. When discussing Behaviour-Based Safety (BBS) Programs, participants recognised similar concepts already embedded in their workflows, albeit under different names. P1 described a comparable practice, stating: "We do have something similar where we discuss what each person has accomplished that day, providing feedback directly related to their tasks.” P4 related the tool to routine safety patrols, saying: “It’s essentially our daily patrols of the project.” These responses indicate that while BBS principles are in use, they may be understood through different terminologies and informal processes across different sites.

Some tools, particularly those related to emerging technologies such as AI for safety, remained largely unfamiliar to participants. Their responses reflected a mix of skepticism, awareness, and future consideration. P1 emphasised the leadership's commitment to safety over cost, stating: “It’s not like a cost thing for us because the leaders always say that safety does not have a price on it, but it is just making sure that it’s fulfilling what you really are.” This perspective underscores the value placed on effective safety tools, provided they serve a clear purpose in improving workplace safety. In contrast, P2 acknowledged AI as a future consideration, remarking: “That’s the future, right? We’re not doing anything like that at this stage, but I imagine at some point, the way the world’s going.” These responses highlight varying levels of familiarity, readiness, and openness to adopting advanced safety technologies, indicating potential barriers and opportunities for future implementation.

Table 3

Participant Familiarity and Usage of Experience and Mindset Tools

Level of Experience and Mindset tools	Familiar tools, recognised immediately by participants	Unfamiliar with the tool by name but who recognised it after viewing a video	Neither recognised the tool by name nor confirmed its use after watching a video
First Aid Training	P1, P2, P3, P4		
Online Training	P1, P2*, P3, P4		
Apps	P1, P2, P3, P4		
Awards	P1, P2, P3, P4		
Real-time Safety Control with Tablets	P1, P4	P2, P3	
Behaviour-Based Safety Programs		P1, P3, P4	P2
REMTs, AI-based CCTV Surveillance, Site Access Control	P4	P3	P1, P2
VR for customised training	P1, P2		P2. P4

AR for safety practices	P1		P2, P3, P4
AI for Safety			P1, P2, P3, P4

Note. Familiar tools, and those are marked with an asterisk (*) who are not using the tools for the project. This table has been previously presented in Chapter 6 (Table 6-5). It is included here for reference to support the informational report.

Level of Communication

As shown in Table 4, participants described various methods of fostering cultural cohesion at their construction sites. One participant (P1) emphasised an inclusive and communal approach, stating: "It is basically sitting down with people, sharing food, and then exchanging stuff." This response suggests that shared meals serve as a tool for team bonding and cultural exchange, reinforcing social connections among workers. Similarly, P2 highlighted a more event-driven practice, explaining: "When we're on-site, we do the occasional sausage sizzle or roof show." These informal gatherings serve as opportunities for team engagement, helping to strengthen workplace relationships and encourage open communication. The variety of responses demonstrates that cultural integration strategies are highly adaptable, shaped by the unique dynamics of each construction site.

In contrast, when discussing the unfamiliar tool of a "Safety Club", participants offered diverging perspectives on its feasibility and value. One participant (P2) expressed scepticism about its practicality, stating: "We don't have a safety club because that's just another meeting." This response suggests that some practitioners may view additional structured safety initiatives as redundant or burdensome, particularly in environments where formal safety discussions already take place. However, P3 provided an alternative perspective, referencing a structured, company-led approach to safety engagement, saying: "We've got our internal neighbour; this company has a Safety Association." This suggests that some organisations incorporate formalised safety associations as part of their overall safety culture strategy, integrating them into corporate frameworks to encourage ongoing engagement.

Table 4

Participant Familiarity and Usage of Communication Tools

Level of Communication tools	Familiar tools, recognised immediately by participants	Unfamiliar with the tool by name but who recognised it after viewing a video	Neither recognised the tool by name nor confirmed its use after watching a video
Visual Indicators	P1, P2, P3, P4		
Language Translation	P1, P2, P4		P3
Digital Screens	P2		P1, P3, P4
QR Codes	P1, P2, P4	P3	

Colour-coded Card System	P3	P1, P4	P2
Networking and Knowledge	P1, P2, P3, P4		
Sharing Working Group	P1, P3, P4		P2
Cultural Integration Activities	P1, P2, P3,		P4
Safety Club			P1, P2, P3, P4

Note: This table has been previously presented in Chapter 6 (Table 6-6). It is included here for reference to support the informational report.

Level of Resource Allocation and Level of Client Understanding

As presented in Table 5, participants described different planning tools that assist with organising and executing safety strategies. P2 emphasised the use of digital planning tools, stating: "Planning is one of the tools; it is digital." This suggests a shift toward technology-driven planning solutions that streamline workflow management. Meanwhile, P3 and P4 also recognised the importance of planning but specified different software applications that align with their project needs. P3 highlighted their use of Procore, explaining: "We are working on the Procore, so that's definitely planning mainly." This reflects the integration of construction management platforms that support real-time collaboration and document tracking. In contrast, P4 noted a transition from traditional planning methods to a more structured and collaborative system, stating: "We've changed from traditional planning to Last Planner."

The variety of responses underscores the flexibility required in planning tools to accommodate different project environments, team structures, and digital capabilities. While all participants agreed on the importance of planning, the choice of tools varied, reflecting the industry's evolving reliance on digital solutions to enhance safety culture and operational efficiency.

Table 5

Participant Familiarity and Usage of Resource Allocation and Client Understanding Tools

Level of Resource Allocation and Client Understanding tools	Familiar tools, recognised immediately by participants	Unfamiliar with the tool by name but who recognised it after viewing a video	Neither recognised the tool by name nor confirmed its use after watching a video
Planning	P1, P2, P3, P4		
Scorecard	P2, P3, P4	P1	

Note: This table has been previously presented in Chapter 6 (Table 6-7). It is included here for reference to support the informational report.

Level of Industry Fragmentation

The responses from participants highlight the diverse approaches to external audits and the varied levels of familiarity with different safety culture tools. While some organisations maintain frequent external evaluations, others adopt a more flexible schedule, demonstrating how audit processes are adapted to fit specific governance and risk management needs. Additionally, participants expressed differing views on safety training programs and assessment tools, reflecting the practical challenges and considerations involved in implementing structured safety initiatives in construction.

As exemplified in Table 6, participants described different frequencies and practices regarding external audits. P1 emphasised a highly structured approach, stating: "We get an external audit every month," suggesting regular external oversight to maintain compliance and enforce safety standards. In contrast, P2 reported a less frequent schedule, explaining: "We have an external audit every three months." These differences highlight how external audits are tailored based on each organisation's policies, priorities, and risk management strategies. The variation suggests that while audits are a key component of maintaining SC, their frequency is context-dependent, influenced by project size, compliance requirements, and organisational safety goals.

When discussing tools that were initially unfamiliar but later recognised through video demonstrations, participants reflected on the Safety Training Observation Programme. P1 related it to an existing safety initiative within their company, stating: "What we have done is actually, and this will kind of tie back to this, we have an award called the Hero Observer." This suggests that elements of the observation-based training program are already integrated into their workplace through recognition-based safety incentives. On the other hand, P2 described a less formal approach, saying: "For us, it is an everyday responsibility to observe and, if we find something, give feedback immediately, without the specific designation." This response highlights how some construction teams internalise safety observation as part of their daily responsibilities, rather than through structured programs. These perspectives demonstrate that while some organisations formalise safety observation and training, others embed it organically into workplace culture, reinforcing the need for tailored implementation strategies.

Participants also had mixed reactions to the Nordic Occupational Safety Climate Questionnaire, reflecting practical challenges and organisational attitudes toward structured assessments. P1 raised concerns about its length and engagement, stating: "Well, but the issue is that 50 questions; we call it a 3-minute gap because, after three minutes, your concentration is starting to lapse." This suggests that long surveys may struggle to maintain respondents' attention, potentially impacting response quality. P2 expressed scepticism about the likelihood of thorough completion, remarking: "Well, we fear it's very unlikely that anyone will turn that. Hmm. OK. It doesn't voice. Let's see how that works." This reflects uncertainty about its practical application within their work environment. In contrast, P3 saw potential value in the tool, stating: "Well, I don't see why not; it would certainly be a benefit; that would be something we need to be thinking about, something that the H&S team would consider." This openness suggests that while some practitioners view structured safety climate assessments as impractical, others recognise their potential benefits for organisational learning and improvement.

These findings highlight that while external audits and safety observation programs are widely acknowledged, their frequency, implementation, and perceived value vary across construction sites. Additionally, the reception of structured assessment tools such as the Nordic Occupational Safety Climate Questionnaire underscores the need for practical, user-friendly approaches to safety evaluations that balance comprehensiveness with usability in high-paced construction environments.

Table 6

Participant Familiarity and Usage of Industry Fragmentation Tools

Level of Industry Fragmentation tools	Familiar tools, recognised immediately by participants	Unfamiliar with the tool by name but who recognised it after viewing a video	Neither recognised the tool by name nor confirmed its use after watching a video
Recording Systems	P1, P2, P3, P4		
H&S Processes	P1, P2, P3, P4		
Audits	P1, P2, P3, P4		
Documentation and Signing	P1, P2, P3, P4		
Accimap-Swiss Cheese Model	P1, P2, P3, P4		
Human Factor Analysis & Classification System (HFACS)	P1, P3, P4	P2	
Systems-Theoretic Accident Model and Processes (STAMP)			P1, P2, P3, P4
Induction-Prestart Meeting	P1, P2, P3, P4		
Committees for the firm and Subcontractors	P1, P2, P3, P4		
Safety Climate Assessment Toolkit			P1, P2, P3, P4
Safety Training Observation Program	P4	P1, P2, P3	
Nordic Occupational Safety Climate Questionnaire			P1, P2, P3, P4

Note: This table has been previously presented in Chapter 6 (Table 6-8). It is included here for reference to support the informational report.

SUS Survey: Evaluating Framework Usability

The System Usability Scale (SUS) survey was conducted to assess how safety practitioners perceived the usability of the proposed safety culture framework. Figure 3 presents the individual scores for each SUS question, broken down by participant, providing insights into how different aspects of the framework were rated. Participant 1 provided the highest scores, while Participant 2 assigned the lowest ratings.

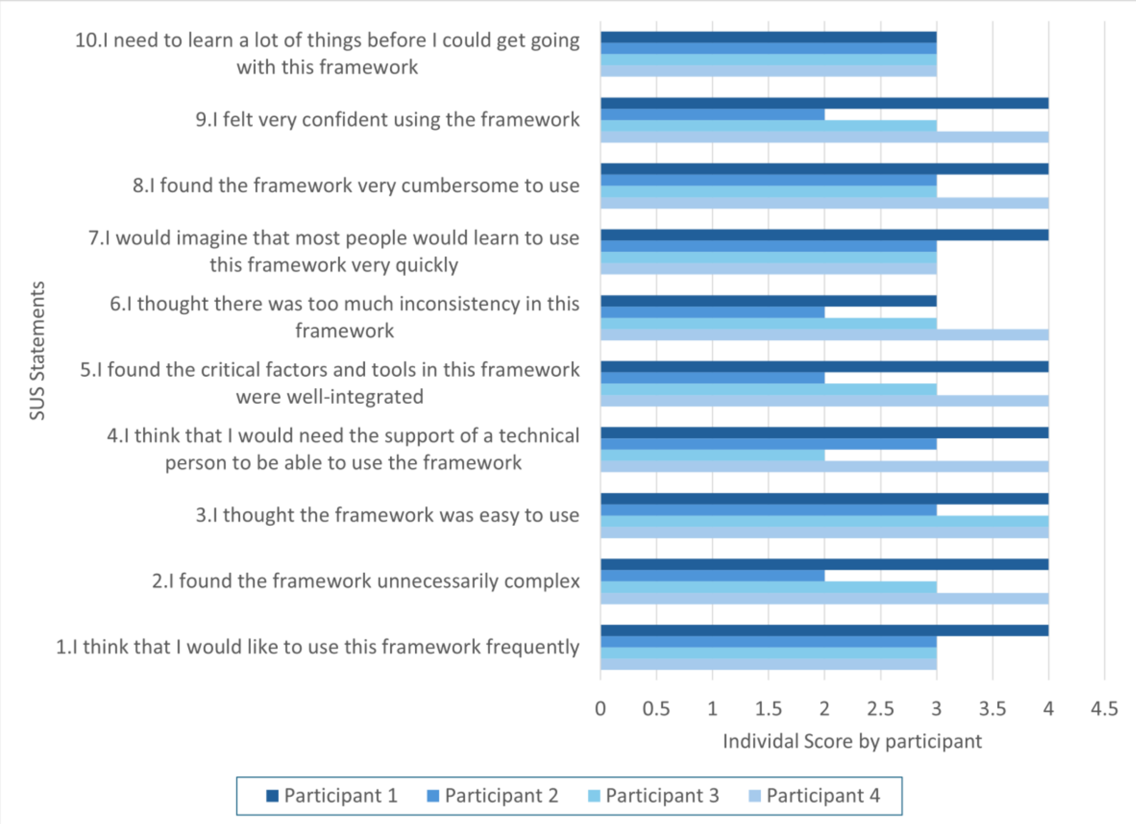
Participants generally responded positively to statements such as “I thought the framework was easy to use,” indicating intuitive usability. However, responses to negatively framed questions, such as “I found the framework unnecessarily complex,” varied across participants. Notably, Question 3, which was positively framed, received favourable ratings, whereas Question 2, a negatively framed item, had lower scores, suggesting that some aspects of the framework may have presented usability challenges for certain users.

After normalising the scores by multiplying the totals by 2.5 (scaling them to a 0-100 range), the individual SUS scores ranged from 65 to 95, reflecting different usability perceptions among participants (Brooke, 1995; Peres et al., 2013). Participant 1 gave the highest score of 95, while Participant 2 recorded the lowest score of 65. The remaining participants scored 75 and 92.5, resulting in an average SUS score of 81.875.

According to SUS methodology, a score above 68 is considered above average, while scores above 80 indicate excellent usability (Lewis, 2018). Based on these results, the framework was generally perceived as user-friendly and effective in supporting safety culture practices in construction. However, variation in responses suggests that some aspects of the framework may require refinement to enhance usability for all users (see Figure 4).

Figure 3

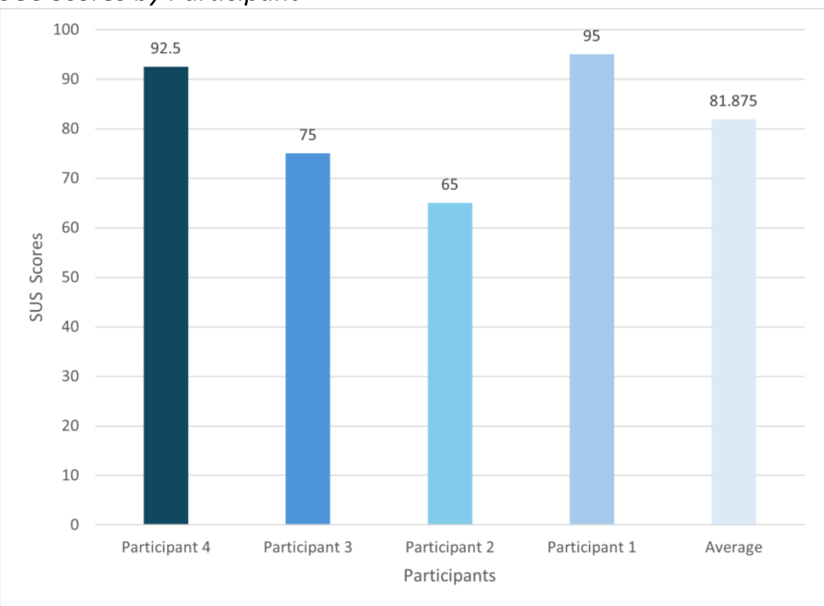
Participant Scores for Each SUS Survey Question



Note: This figure has been previously presented in Chapter 6 (Figure 6-2). It is included here for reference to support the informational report.

Figure 4

SUS Scores by Participant



Note: This figure has been previously presented in Chapter 6 (Figure 6-3). It is included here for reference to support the informational report.

REFERENCES

The references cited in this chapter are not included within the chapter itself, as they are part of the comprehensive reference list at the end of the thesis.

Summary

The informational report developed as a tangible output of this research project, serves to communicate, demonstrate, and apply the findings. Tailored to safety practitioners in the vertical construction sector, the document provides a comprehensive guide to the framework, factors, tools, and case studies from New Zealand aimed at enhancing SC. The structure ensures a holistic approach to understanding and implementing SC improvements, integrating theoretical insights with practical applications.

Chapter 8: Conclusion and Further Research

8.1 Overview of Research Aims and Methodology Recap

The construction sector plays a pivotal role in global infrastructure development and economic growth, contributing an average of 11.9% to the global GDP and employing about 7% of the workforce worldwide (McCarthy, 2013; Rafindadi et al., 2022). Despite its economic importance, the industry is notorious for high occupational fatalities, accounting for 30%-40% of workplace deaths, underscoring the urgent need for enhanced safety measures (Rafindadi et al., 2022; Trueblood & Yohannes, 2024). In New Zealand, the sector contributes approximately 7.2% to the national GDP and employs 8.1% of the workforce, facing similar challenges as its global counterparts in terms of high injury claims and fatalities (Eaqub, 2024; PwC New Zealand, 2016; WorkSafe New Zealand, 2024c). Particularly in New Zealand, where the frequency and severity of workplace incidents remain a critical concern, especially in vertical construction, there is a need for frameworks that can promote SC in Construction sites in New Zealand (Stats New Zealand, 2020; WorkSafe New Zealand, 2022a). Reports in 2024 highlight that severe injuries in New Zealand's building construction sector are significantly higher than the national and Australian averages, signalling critical safety concerns (Eaqub, 2024).

Promoting SC within the construction sector is seen as a strategic response to reducing workplace accidents. Gaining international attention after the Chernobyl disaster in 1986, SC encompasses shared values and beliefs that influence H&S behaviours, with effective implementation recognised as essential at both organisational and project levels (Asilian-Mahabadi et al., 2018; Choudhry et al., 2009; Seo et al., 2015). Moreover, promoting SC aligns with the United Nations' Sustainable Development Goals, particularly Goal 8 and Goal 3, which advocates for safe and sustainable economic growth and decent work, and good health and well-being (United Nations, 2025).

This project aimed to improve the promotion of SC in vertical construction projects by developing a practical, usable framework tailored to New Zealand context, but designed for potential global application, to assist stakeholders, particularly on-site project managers and safety practitioners, to adopt safety interventions facilitating the decision-making. The research methodology was designed to achieve the set objectives defined in Chapter 1, ensuring that by meeting these measurable goals, the overarching research aim was fully realised. The study followed a structured four-phase methodology, integrating mixed-methods. This approach provided a balanced perspective by combining qualitative insights from industry experts with quantitative validation, ensuring both practical relevance and empirical rigor.

8.1.1 Objective 1

The first objective of this study was to explore the meaning of SC as well as factors and tools that enhance SC in practice, as perceived by New Zealand construction safety practitioners. The first objective aligns with Phase 1 of the research design, which centres on identification. This objective has been fully achieved through a structured research design that combined a contextual literature review and a two-round Modified Delphi study with a panel of New Zealand-based construction safety experts. The expert panel comprised professionals with diverse roles in the construction sector, including health and safety managers, site supervisors, project managers, safety consultants, and senior industry professionals involved in safety leadership and policy development. Their expertise spans both frontline safety management and strategic decision-making, ensuring that the findings reflect a comprehensive understanding of SC from different levels of industry practice.

The findings from this study reveal that safety practitioners conceptualise SC through a holistic perspective, by integrating expert consensus from the two-round Modified Delphi study, literature review insights, and empirical validation, this study clarifies the definition of SC as: A holistic approach to defining SC considers shared values, expectations, and beliefs that influence a group's health and safety behaviours and is characterised by the presence of the following defining factors:

a) Collaboration and Communication: open and transparent engagement between management and workers to ensure safety information is shared, understood, and acted upon.

b) Leadership and Responsibility: a clear commitment from leadership to model, enforce, and be accountable for safety culture.

c) Human-Centred Approach: prioritising worker well-being, inclusion, and psychological safety to ensure safety is embedded in all interactions.

d) Integration and Organisation: deep incorporation of safety into an organisation's operational, managerial, and procedural frameworks.

e) Fundamental Principles: compliance with safety standards, ethical decision-making, and a continuous improvement mindset.

f) Resource Allocation and Prioritisation: ensuring adequate investment in safety resources, training, and infrastructure.

Although the expert panel was New Zealand-based, the study findings are not limited to this context. Additionally, the application of a Modified Delphi method, combined with *RII* analysis, which quantifies expert rankings, ensuring that the results accurately reflect collective industry insights, confirms that the identified factors are not solely based on subjective perceptions but reflect a systematically derived industry consensus (Seidu et al., 2022; Tarek et al., 2022). The detailed *RII* calculations and rankings, presented in Appendix 2, further support the robustness of these findings and their potential applicability to broader construction sector contexts.

8.1.1.1 Definition of SC

Existing literature highlights the ambiguity surrounding SC definitions and the need for context-specific understanding (Choudhry et al., 2009; Schein, 2014). SC is inconsistently defined across industries and contexts, leading to challenges in its operationalisation on construction sites (Choudhry & Fang, 2008; Lingard et al., 2014; Sherratt et al., 2011). The lack of consensus necessitated an investigation into how SC is understood and applied in practice (Lingard et al., 2014; Sherratt et al., 2011). This study established a validated, expert-driven definition of SC through the Modified Delphi study, which resulted in consensus on key defining factors. Experts in this study were unable to provide a single, all-encompassing definition of SC. Instead, their responses aligned with the literature, which conceptualises SC as a combination of beliefs, values, attitudes, perceptions, and assumptions regarding safety within a group or organisation (Abdullah & Wern, 2012; Chen et al., 2017; Choudhry et al., 2007a, 2007b; Musonda et al., 2021; Wamuziri, 2006; Zhou et al., 2015). Through a structured Modified Delphi consensus process, a validated definition of SC was established, identifying a set of defining factors that collectively define SC.

The alignment between these results and prior international studies demonstrates that the identified SC factors are transferable across construction industries in other countries (Biggs et al., 2005; Mohamed & Chinda, 2011; Opoku et al., 2020). While the findings reflect country specific and industry-specific insights, the methodological rigor and alignment with global literature suggest that the identified SC factors hold relevance beyond the New Zealand context. For instance, Mohamed and Chinda (2011) identified five critical enablers of SC: leadership, policy and strategy, partnerships and resources, people, and processes, while Molenaar et al. (2009) proposed five latent variables describing corporate SC: commitment to safety, incentives for safe performance, subcontractor involvement, field safety accountability, and disincentives for unsafe behaviours. The convergence between the expert-validated findings of this study and existing literature confirms the universal relevance of these factors in fostering SC across different contexts (Mohamed & Chinda, 2011; Molenaar et al., 2009; Opoku et al., 2020).

The findings confirm that SC is not a singular concept but a holistic construct, encompassing multiple interrelated elements that shape safety attitudes, behaviours, and practices relevant to a wide range of stakeholders responsible for safety leadership, implementation, and continuous improvement in construction settings.

By integrating expert consensus from the two-round Modified Delphi study, literature review insights, this study clarifies the definition of SC as:

A holistic approach to define SC considers shared values, expectations, and beliefs that influence a group's health and safety behaviours and is characterised by the presence of the following defining factors:

a) Collaboration and Communication: open and transparent engagement between management and workers to ensure safety information is shared, understood, and acted upon.

b) Leadership and Responsibility: a clear commitment from leadership to model, enforce, and be accountable for safety culture.

c) Human-Centred Approach: prioritising worker well-being, inclusion, and psychological safety to ensure safety is embedded in all interactions.

d) Integration and Organisation: deep incorporation of safety into an organisation's operational, managerial, and procedural frameworks.

e) Fundamental Principles: compliance with safety standards, ethical decision-making, and a continuous improvement mindset.

f) Resource Allocation and Prioritisation: ensuring adequate investment in safety resources, training, and infrastructure.

Part of the objective was achieved by delivering a comprehensive, structured expert-informed clarification of the definition of SC based on consensus, ensuring its applicability within the New Zealand construction sector while also contributing to the broader international discourse on SC.

8.1.1.2 SC Influencing Factors

This study identified and validated the factors influencing SC, aligning expert perceptions from the Modified Delphi study, with key insights from the literature review. The Delphi study confirmed that SC is shaped by a combination of leadership commitment, workforce mindset, communication, resource allocation, industry fragmentation, and client understanding, each of which is influenced by specific challenges within the construction sector.

The Level of Leadership Commitment emerged as the most influential determinant of SC, reinforcing previous research on leadership's pivotal role in shaping safety outcomes (Biggs et al., 2005; Opoku et al., 2020). Experts (e.g., ID24) emphasised that consistent, proactive, and visible leadership engagement is essential in fostering SC. However, variability in leadership commitment across projects remains a challenge, particularly when operational constraints and competing priorities divert focus from safety initiatives. Some leaders still perceive safety as a compliance-driven requirement rather than an embedded organisational value (ID24), a finding consistent with global literature advocating for a systemic approach to safety leadership (Mohamed & Chinda, 2011; Molenaar et al., 2009).

The Level of Experience and Mindset was identified as another key factor influencing SC. Long-standing workplace habits, resistance to change, and entrenched perceptions of safety as secondary to productivity pose significant barriers to fostering SC (ID15). Cultural inertia in some organisations prevents the adoption of improved safety measures, while internal politics and toxic workplace environments further impede progress (ID13). These findings align with previous studies that underscore the need for cultural transformation strategies to shift deep-rooted attitudes and promote sustained safety improvements (Lingard et al., 2014).

The Level of Communication also emerged as a critical determinant, particularly in culturally diverse construction environments. Experts highlighted that language barriers and differing communication styles contribute to misinterpretations of safety procedures (ID25, ID30). Some workers confirm understanding without full comprehension, increasing the risk of unsafe practices (ID25). Tailored communication strategies, such as visual safety aids and multilingual briefings, are essential in mitigating these challenges (ID28). These findings reinforce existing research on the role of inclusive communication in bridging safety knowledge gaps (Wu et al., 2017).

The Level of Resource Allocation significantly influences SC, with financial constraints, administrative burdens, and project cost considerations affecting the prioritisation of safety initiatives (ID05, ID12, ID29). Some organisations perceive safety as an overhead cost rather than an investment, leading to budgetary trade-offs that undermine SC (ID05). Excessive paperwork and bureaucratic processes further contribute to compliance fatigue, discouraging engagement with safety protocols (ID03, ID05). These challenges highlight the need for a balanced approach to safety investment, aligning with prior research on the economic and operational implications of SC (Fellows & Liu, 2015; Wu et al., 2017).

The Level of Industry Fragmentation was identified as another influencing factor, particularly in relation to subcontractor alignment and safety standardisation. Experts noted inconsistencies in safety expectations across subcontractors, with some failing to integrate site-specific safety protocols (ID08, ID15). Resistance to safety measures from subcontractors who perceive them as restrictive or unnecessary results in fragmented SC across teams (ID17). Additionally, ineffective communication of updated safety standards further contributes to compliance inconsistencies (ID25). These findings align with research emphasising the role of subcontractor integration in maintaining standardised safety practices (Opoku et al., 2020).

Finally, the Level of Client Understanding was found to influence SC, particularly in relation to cost-driven decision-making. Experts reported that some clients prioritise financial constraints over safety, affecting the development of a strong SC within project teams (ID10). A lack of awareness and engagement in safety initiatives by clients creates a disconnect between project safety expectations and actual implementation (ID08). These findings are consistent with previous research indicating that clients who actively enforce high safety standards contribute to more robust SC across construction projects (Biggs et al., 2005; Wu et al., 2017).

By synthesising expert consensus with insights from the literature, this study fully meets the objective of identifying and validating key determinants of SC. The findings provide both theoretical and empirical contributions, demonstrating how leadership, workforce mindset, communication, resource allocation, industry fragmentation, and client understanding collectively shape SC in the construction sector. The *RII* analysis confirms the relative significance of these factors, ensuring that the study's conclusions are quantitatively robust and aligned with practical industry realities (Seidu et al., 2022; Tarek et al., 2022). The detailed *RII* calculations are presented in Appendix 2, further reinforcing the empirical foundation of the findings.

The findings align with international research on SC while contributing New Zealand-specific insights, particularly regarding cultural diversity, language inclusivity, and subcontractor alignment as key challenges in promoting SC. By establishing a validated set of influencing factors based on expert consensus and literature synthesis, the study provides a context-specific yet generalisable understanding of SC determinants. These findings offer a structured framework for future research and industry application, ensuring that SC initiatives are empirically grounded and practically relevant in construction contexts both within and beyond New Zealand.

Establishing a validated set of influencing factors based on expert consensus and literature synthesis meets part of the objective of identifying and validating key factors of promoting SC, ensuring theoretical rigor and practical applicability.

8.1.1.3 Tools to promote SC

This study achieved its objective of identifying and validating tools used to promote SC by establishing expert consensus through the Modified Delphi study. The iterative nature of the process allowed experts to refine their perspectives, leading to a prioritisation of tools with tangible impacts on SC. Also, a literature review was conducted to identify tools that enhance SC, integrating insights from international studies, industry reports, and practical frameworks. The Delphi study findings were then mapped against the literature review to validate and refine the proposed SC framework. The *RII* was applied to quantify expert rankings, ensuring objective prioritisation of tools (Seidu et al., 2022; Tarek et al., 2022).

In the first round, 32 experts were interviewed to identify the primary tools used to promote SC on construction sites. Their responses, analysed using thematic analysis, revealed 27 distinct tools, ranked in order of frequency based on expert mention (see Chapter 5, Table 5-3). The results highlight Toolbox Talks as the most frequently mentioned tool, cited by 17 experts, followed closely by Trust-

Open Conversations, with 12 mentions. Other tools were mentioned less frequently, suggesting that while they contribute to SC, they may have more specialised or niche applications (Fellows & Liu, 2015; Guest et al., 2006; Saunders et al., 2019).

To quantify expert consensus, a *RII* analysis was conducted in the second round, providing an objective ranking of the tools (see Chapter 5, Table 5-4). The highest-ranked tool was Trust-Open Conversations (RII = 0.97), followed by Planning (*RII* = 0.93) and Leadership Training (*RII* = 0.90). The rankings demonstrate that while Toolbox Talks were mentioned most frequently in interviews, experts placed greater importance on open conversations, structured planning, and leadership engagement when directly ranking tools. The complementary use of qualitative thematic analysis and quantitative *RII* ensures that the study's findings are both statistically robust and practically relevant (Seidu et al., 2022; Tarek et al., 2022).

By securing expert consensus on commonly used tools to promote SC in the New Zealand construction sector and validating these findings against international literature. The comparison between expert-derived findings and the literature review ensures that the captured tools are not only relevant within New Zealand but also align with global SC strategies (Lingard et al., 2014; Misnan & Mohammed, 2007; Sherratt et al., 2011). This study provides evidence-based foundation for future industry applications. The integration of *RII* ensures that the tool rankings reflect industry priorities, strengthening the study's empirical robustness.

This study definitively achieves the research objective by delivering an expert consensus, literature-supported for identifying and prioritising tools to promote SC.

By defining SC through expert consensus, identifying key influencing factors, and validating the tools that promote SC, this study not only satisfies the first research objective but also ensures that its findings, while rooted in the New Zealand context, are transferable to broader industry settings through their alignment with international literature.

8.1.2 Objective 2

This study achieved the second research objective to categorise the tools described by New Zealand construction safety practitioners and the literature, identifying their relationships with key factors influencing SC. The second objective aligns with Phase 2 of the research design, which centres on categorisation. A Causal Loop Diagram (CLD) was developed to visualise relationships among safety culture, its influencing factors, and barriers, supporting the framework's conceptual foundation. Then a Thematic Analysis, that enabled systematic coding and organisation of qualitative data from both the literature and Modified Delphi study responses was run (Braun & Clarke, 2006). This process grouped similar concepts under common themes, leading to the identification of the six influencing factors to promote SC in NZ, as outlined in objective 1, and associated tools to promote SC captured by the Modified Delphi study and the literature review. Finally, Syllogistic Reasoning method was applied to categorise tools (Sato & Mineshima, 2015; Stanford, 2022) into three distinct groups: (1) identified solely in literature, (2) captured only by experts, and (3) overlapping both. This strengthened traceability and clarified the origin and relevance of each tool. This structured approach ensures that the findings are empirically validated, theoretically grounded, and practically applicable to industry settings.

8.1.2.1 CLD

The CLD in Chapter 4, Figure 4-3 illustrates the interactions between SC, its influencing factors, and the barriers that impact them. CLDs are widely used in systems dynamics research to represent feedback loops and complex causal relationships (Bala, 2017; Sherwood, 2022; Sterman, 2000). The diagram provides a qualitative representation of how different factors facilitate or hinder SC, depending on their level of implementation.

The CLD visually demonstrates how a high level of subcontractor alignment reduces industry fragmentation, creating a balancing feedback loop that strengthens SC (green arrows in Figure 4-3). Conversely, when subcontractor alignment is low, industry fragmentation increases, forming a reinforcing feedback loop that weakens SC (red arrows). Similarly, higher leadership commitment leads to increased engagement in SC, reinforcing global findings on leadership as a pivotal driver of SC (Abdullah & Wern, 2012; Bahn, 2012; Hudson, 2007).

To validate the accuracy and practical relevance of the CLD, it was reviewed by a Project Director with over 20 years of experience in construction safety. The expert confirmed that the CLD accurately represents real-world industry dynamics and could serve as a strategic tool for managers and supervisors to plan SC interventions. This validation step ensures that the relationships depicted in the CLD are not only theoretically sound but also practically relevant, bridging the gap between academic research and industry application (Cassidy et al., 2022; Meadows & Wright, 2008).

8.1.2.2 Thematic Analysis

Following the CLD validation, the tools identified from both the literature review and the Modified Delphi study were categorised through thematic analysis (Braun & Clarke, 2006). This method allowed the tools to be aligned with specific SC influencing factors identified in Objective 1, ensuring that each tool's role within the SC framework was clearly defined.

A total of 39 tools were identified, with 21 tools common to both expert responses and the literature, 6 identified only by experts, and 12 exclusives to the literature (see Chapter 5, Table 5-5). The classification revealed clear relationships between tools and SC factors, reinforcing the findings from the CLD analysis. For example, tools like Toolbox Talks and Leadership Training were strongly associated with Leadership Commitment, reflecting their role in embedding SC values across teams.

Similarly, Networking, Safety Clubs, and Knowledge Sharing supported Communication and Knowledge Sharing, ensuring that safety-related insights were effectively disseminated across different levels of the workforce.

The categorisation of tools confirmed alignment between expert perspectives and established SC literature, validating the used tools while also identifying underutilised tools that could enhance SC practices.

8.1.2.3 Syllogistic Reasoning

To further explore the relationships amongst tools and SC factors, syllogistic reasoning was employed (Sato & Mineshima, 2015; Stanford, 2022). This method enabled a structured comparison of tools that were:

- Captured by both experts and literature.
- Found only in the literature.
- Captured exclusively by experts.

This analysis provided insights into industry-wide tool adoption trends, highlighting tools that are widely accepted in both literature and practice, as well as those that remain underutilised despite their documented effectiveness. Notably, technological tools such as VR for Customised Training, and AR for Safety Practices, were prominent in the literature but absent in expert responses (Chen et al., 2022; Goh & Askar Ali, 2016). These findings suggest that barriers such as high costs, limited awareness, and industry resistance to digital transformation may be limiting the adoption of advanced SC tools in the New Zealand construction sector (Chen et al., 2022).

The identification of these gaps in tool usage presents key opportunities for future research and industry adoption, particularly in exploring how emerging technologies can be integrated into SC frameworks. The literature emphasises the significance of system-thinking tools such as STAMP and Accimap-Swiss Cheese Models, which, although not mentioned by experts, have been successfully utilised in various industries to identify safety risks and support decision-making. STAMP has been applied in healthcare (Leveson & Thomas, 2018) and aviation (Underwood & Waterson, 2014), while the Swiss Cheese Model has been widely used in the construction sector (Hale et al., 2006), demonstrating its relevance in addressing systemic safety challenges (Butler et al., 2022; Hulme et al., 2021; Newnam et al., 2021). Understanding why these tools were overlooked by industry experts provides an avenue for further investigation.

By applying CLD validation, thematic categorisation, and syllogistic reasoning, this study provides a structured and validated framework for understanding the relationship between SC tools and influencing factors. The combination of expert consensus, literature validation, and analytical methods ensures that the study's findings are empirically and practically relevant. The results confirm that SC tools are not standalone mechanisms but function within an interconnected system, where each tool's effectiveness is influenced by its alignment with key SC factors. The mapping of tools to influencing factors provides a comprehensive and transferable framework that can be applied both within New Zealand and in broader international contexts.

Thus, this research objective was achieved, offering a validated, evidence-based approach to categorising tools to promote SC and understanding their role in shaping SC outcomes. The findings provide critical insights for safety practitioners ensuring that SC interventions are strategically designed, targeted, and effective in improving safety performance.

8.1.3 Objective 3

The third objective was to design and develop a prototype framework and present it in the format of an informational report that provides a clear roadmap for decision-making to improve SC in New Zealand. This objective addresses a critical gap identified in the literature, which highlights that existing frameworks often lack practical applicability and usability, remaining overly theoretical and detached from real-world safety practices (Partelow, 2023; Rocco & Plakhotnik, 2009; Sherratt et al., 2025). The need for a user-friendly framework tailored to New Zealand's specific construction context is underscored by the prevalence of safety incidents in vertical construction projects, where risk exposure is highest (Eaqub, 2024; PwC New Zealand, 2016; WorkSafe New Zealand, 2024c). Furthermore, many existing SC frameworks are either generic or country specific, primarily designed for the US or Europe, reinforcing the need for a New Zealand-specific framework that aligns with local safety challenges and practices (Rocco & Plakhotnik, 2009; Sherratt et al., 2025; Schein, 2014).

The third objective aligns with Phase 3 of the research design, which centres on visualisation. This phase involved developing a framework that integrates the factors and tools identified in Phase 1 and organises them through categorisation in Phase 2. A visual flow-based diagram was created to illustrate the relationships between six influential SC factors, their barriers, and the categorised tools aimed at promoting SC (Barrett & Sutrisna, 2009; Partelow, 2023).

Visualisation tools are essential for synthesising complex information, identifying emergent themes, and structuring decision-making pathways (Barrett & Sutrisna, 2009; Partelow, 2023; Yin, 2018). The conceptual framework is presented as a flow-based diagram, which structures and illustrates the interactions between SC factors, barriers, and tools. Flowcharts are widely recognised for their effectiveness in structuring frameworks, enhancing clarity in decision-making and implementation strategies (Chaudhuri, 2020; Partelow, 2023).

The flow-based diagram in Chapter 5, Figure 5-2, starts with the six influential SC factors identified in Objective 1, linking them to their respective barriers as outlined in the CLD developed in Objective 2. It then progresses to the categorisation of tools, which was also conducted in Objective 2. The tools are visually distinguished using background colours, indicating whether they were captured by New Zealand experts, found in the literature, or captured by both.

This structured visual mapping enhances traceability and usability, making it easier for safety practitioners to identify and implement tools relevant to specific SC challenges. For example, if a project struggles with communication issues due to language barriers, the framework highlights relevant tools such as Digital Screens, QR Codes, and the Colour-Coded Card System, which could enhance SC in that context. By structuring the framework in a visually intuitive format, the study ensures that safety practitioners can quickly assess, interpret, and implement SC tools in real-world scenarios.

To translate the framework into an industry-friendly format, an informational report was developed (see Chapter 7). Informational reports are widely used in industry settings to provide clear, structured guidance on complex issues, ensuring that safety practitioners can apply findings effectively (Kabir, 2016; Wilkinson, 2022). This report format was selected to comprehensively describe the framework's components, offering:

• A structured overview of the framework and its purpose.

• Detailed descriptions of the tools, including their purpose, frequency and format of use, engagement strategies, real-world examples, and potential impact on SC (Wilkinson, 2022).

• Visual aids such as QR codes linking to video explanations, enhancing accessibility and usability (Megha & Satishkumar, 2024). The integration of QR codes allowed practitioners to directly access video content, improving knowledge retention and engagement (Megha & Satishkumar, 2024). The video format ensured consistency in information dissemination, reducing interpretation errors and facilitating ongoing learning (Gedera & Zalipour, 2018; Varela & Mejía, 2018).

• Case studies findings, aligned with Objective 4, validated the usability of the framework across four active vertical construction sites in New Zealand.

By aligning the report's structure with industry needs, the study ensures that the resulting framework is not just an academic construct, but a practical tool designed for real-world application. Thus, the framework was not designed to identify problems for practitioners; rather, it was designed to promote safety culture by supplying structured ways to address active problems through a collection of tools captured in this research.

Thus, this objective was achieved, by structuring a visual representation and industry-driven informational report ensure that safety interventions are strategically designed, targeted, and effective in promoting SC. By bridging theory and practice, the framework enhances decision-making processes, fostering a proactive approach to safety practitioners.

8.1.4 Objective 4

The fourth objective was to operationalise the SC framework and evaluate its usability to facilitate its adoption. The fourth objective aligns with Phase 4 of the research design, which centres on operationalisation. While various frameworks have aimed to define and promote safety culture within their respective national contexts, the extent of their validation differs. For instance, Ismail et al. (2010) empirically tested their Malaysian framework using interviews and surveys, while the frameworks from Saudi Arabia (Alasamri et al., 2012) and Indonesia (Machfudiyanto & Latief, 2018) remained largely theoretical or were only reviewed by experts. This research employed multiple cross-sectional case studies across four active vertical construction sites in New Zealand allowing for rich, contextual insights through inductions, interviews, and surveys, validating the usability of the framework in real-world conditions, addressing the objective. By assessing the usability of the framework in vertical construction projects in New Zealand, this study reduces the gap between theoretical development and practical validation, ensuring its usability (Lingard et al., 2014; Partelow, 2023; Sherratt et al., 2025). Using multiple case studies, generating analytic generalisation, where findings from individual cases contributed to ensuring its applicability beyond the specific cases studied (Gray, 2014; Yin, 2018).

To operationalise the framework, four case studies were conducted within vertical construction projects from four different companies in New Zealand, selected due to the high rate of incidents reported in this sector (Stats New Zealand, 2020; WorkSafe New Zealand, 2022c). A multi-method approach was employed to ensure robust data collection, including:

• Site visits as an induction to safety practices and operational challenges (Fellows & Liu, 2015; Yin, 2018).

• Semi-structured interviews with safety practitioners, project managers, and site managers to validate the informational report and the framework's visual representation (Fellows & Liu, 2015; Guest et al., 2006; Saunders et al., 2019).

• Survey-based usability testing, using the SUS survey, to assess practitioners' perceptions of the framework's usability (Brooke, 1995).

Site visits were used as induction that allows for firsthand data collection. The interviews provided detailed feedback, identifying the tools most frequently used, least recognised, or requiring additional support for implementation. Cross-case synthesis was conducted to compare findings across the four case studies, identifying patterns, variations, and shared insights (Gray, 2014; Yin, 2018). This process enhanced the generalisability of the framework, demonstrating its applicability across different construction sites.

Key findings emerged from the case studies, reinforcing the framework's value:

1. Immediate recognition of core tools: Some tools, such as Toolbox Talks, Leadership Training, and Trust-Open Conversations, were widely recognised and actively used to promote SC. Their inclusion in the framework confirmed alignment with industry practice.

2. Increased adoption through clarification: Tools that were initially unfamiliar became recognised and valued after practitioners viewed QR-linked video explanations, highlighting the importance of clear instructional support like Lean Philosophy.

3. Need for greater awareness of innovative tools: Advanced safety technologies, such as AI-based CCTV, AR for Safety, and Behaviour-Based Safety Programs (BBS), were unfamiliar to participants after watching the explanation video, suggesting the need for additional training and knowledge-sharing initiatives.

To systematically evaluate usability, the SUS survey was employed, a widely recognised tool for assessing users' subjective perceptions of usability (Brooke, 1995). Furthermore, SUS was previously considered to validate the usability of usability of construction safety culture and climate framework developed by Al-Bayati et al. (2024). The same 4 participants from the interviews completed the SUS questionnaire, ensuring that usability feedback was directly linked to their hands-on engagement with the framework.

The SUS analysis followed the established scoring methodology (Brooke, 1995; Peres et al., 2013). The average SUS score was 81.875, indicating that participants found the framework to be highly usable and intuitive (Brooke, 1995; Lewis, 2018). According to usability research, a SUS score above 68 is considered above average, and scores above 80 indicate excellent usability (Brooke, 1995; Lewis, 2018; Peres et al., 2013). The positive usability assessment further validates that the framework is well-designed for future practical adoption in the industry.

The case study results were incorporated into the informational report as part of a newly added section, "Case Study Highlights", providing a structured summary of industry feedback (see Chapter 7).

Thus, this objective was achieved, delivering a robust, evidence-based framework that validated the usability for promoting SC in New Zealand's construction sector.

8.2 Theoretical Contributions

The first theoretical contribution lies in advancing the conceptualisation of SC through the identification and integration of defining factors tailored to New Zealand. The identification and integration of factors to define and promote SC is aligned with a holistic perspective advocated by previous studies, including those by Choudhry et al. (2007), Mohamed and Chinda (2011) and Schein (2014), which highlight the need for understanding SC based on the specific needs of organisations and projects. This approach demonstrates that SC cannot be universally defined or applied; rather, there is a concept to be conceptualised holistically that considers the specific challenges of organisations, projects, and contexts. In the New Zealand context, six factors were identified to promote SC: “Level of Leadership Commitment,” “Level of Experience and Mindset,” “Level of Communication,” “Level of Resource Allocation,” “Level of Industry Fragmentation,” and “Level of Client Understanding”, reflecting specific challenges and priorities of the local construction sector, including high injury rates, fragmented practices, and the need for stronger leadership engagement (BRANZ, 2024; Eaqub, 2024; PwC New Zealand, 2016; Rout, 2023). By focusing on contextually relevant factors, this contribution reduces theoretical ambiguity and offers a clearer, adaptable conceptualisation of SC, particularly suited to the fragmented and dynamic nature of the construction sector. The study enhances theoretical clarity and provides a framework for understanding and improving SC in vertical construction where safety is a critical concern.

The second theoretical contribution of this research resides in the development of a structured and replicable methodology for creating a framework to promote SC. A conference paper on aspects of this methodology was presented, and while not identical, it aligns with key elements of the research approach (see Appendix 4). While this framework is rooted in the New Zealand construction sector, its systematic design process and structured methodology ensure its applicability to broader construction contexts both within and beyond New Zealand. The replicability of this framework is embedded in the systematic steps and reasoning employed in its development, making it adaptable to other sectors facing complex SC challenges, such as healthcare, aviation, and manufacturing, where structured safety interventions and behavioural change mechanisms are similarly required (Butler et al., 2022; Hulme et al., 2021; Newnam et al., 2021). This methodology is organised into four key phases: Identify, Categorise, Visualise, and Operationalise. These phases provide a clear and logical pathway for stakeholders to develop context-specific solutions. The Identify phase focuses on gathering insights through expert consensus and literature reviews to determine the key factors and tools relevant to SC. The Categorise phase organises and structures this data into meaningful clusters, establishing a clear hierarchy of priorities for stakeholders. The Visualise phase utilises tools such as flow-based diagrams and informational report to represent relationships between factors, barriers, and tools, enabling stakeholders to better understand and address complex dynamics and facilitating the access to the description of the tools through QR codes linked to video explanations. Finally, the Operationalise phase bridges theory and practice by assessing the usability of the framework for future adoption in active vertical construction projects. This phase refines the framework’s usability through, induction, interviews and SUS survey results. This phase employs both inductive and deductive reasoning while integrating qualitative and quantitative methods. The use of methodological triangulation ensures the validity and reliability of findings. By focusing on the phases following the research design this approach provides a robust model that other sectors can adopt to address their unique challenges about SC. This methodology transcends the construction sector and offers a transferable methodology for addressing complex, context-specific problems providing an empirical methodology to develop a similar SC promotion framework in other sectors.

The data analysis in this study followed the ethical approval, a structured, multi-phase approach to ensure methodological rigour and validity. Phase 1 employed the Modified Delphi study, incorporating a pilot test for the interview for the first round, a pilot test of the survey, reliability analysis using Cronbach's alpha, and prioritisation through the *RII* for the second round. Phase 2 focused on categorising the findings using a CLD, which was validated by expert review. This was followed by thematic analysis and further refinement through syllogistic reasoning. Phase 3 involved the development of a flowchart-based framework, with colour coding used to visually differentiate tools identified by expert input, literature review, or both, and the creation of an informational report where each tool is described and accompanied by a video link and a QR code to facilitate their understanding and practical application. Phase 4 employed semi-structured interviews and a SUS survey instrument, both previously pilot-tested. Following the implementation of four case studies, although it was not longitudinal, the data were analysed using thematic and cross-case analysis, and the SUS scores were calculated using the standard procedure. This multi-method analytical strategy enhances the transparency and robustness of the research, contributing to the credibility and practical relevance of the findings. Together, these contributions address the core research problem by refining the conceptualisation of SC and providing a robust methodology to develop a practical framework to promote SC in the construction sector tailored to vertical sector in New Zealand. By aligning the theoretical contributions with the research aim and objectives, this study provides a blueprint of a replicable methodology for addressing SC challenges not only in New Zealand's construction sector but also internationally.

8.3 Practical Contributions

Firstly, this study developed a robust SC conceptual framework designed to address the specific needs of New Zealand's construction sector, particularly within the vertical construction sector, which experiences high injury rates (Eaqub, 2024; Rout, 2023). The framework's usability was validated through the SUS survey, which yielded an average score of 81.875, suggesting its accessibility and practical relevance for safety practitioners (Peres et al., 2013). While the framework is tailored to the New Zealand construction context, its structured methodology, systematic categorisation of tools, and decision-making pathways ensure that it is not limited to this specific setting. Instead, it offers a replicable design methodology that can be adapted and implemented in broader industry contexts facing similar SC challenges. The framework approach to linking safety tools with influencing factors provides a general structure that can be modified based on other sectors facing complex SC challenges. Thus, this research reduces the gap between theory and practice, equipping safety practitioners with a validated usability of the framework that enhances decision-making while also providing a methodological foundation adaptable for other industries beyond the construction sector.

Secondly, by incorporating insights from New Zealand safety experts and a thorough literature review, the framework evolved into an informational report presented in Chapter 7 (Kabir, 2016; Wilkinson, 2022). This report serves as a practical guide, equipping safety practitioners with essential tools for informed decision-making that fosters intended behavioural changes to meet specific project needs. Combined with QR codes linked to instructional videos, the framework ensures instant access to critical safety resources, enhancing learning and application on construction sites (Gedera & Zalipour, 2018; Megha & Satishkumar, 2024; Varela & Mejía, 2018). These QR codes allowed practitioners to instantly access tutorial videos for tools they were unfamiliar with, simplifying the learning process by providing on-the-spot explanations instead of requiring them to read lengthy descriptions (Gedera & Zalipour, 2018; Wilkinson, 2022). This approach effectively bridged knowledge gaps in real-world scenarios (Varela & Mejía, 2018; Wilkinson, 2022). Likewise, the use of QR codes and visualisation tools in the report serves as a replicable model for effectively communicating complex concepts in an engaging and user-friendly manner (Gedera & Zalipour, 2018; Varela & Mejía, 2018; Wilkinson, 2022).

Thirdly, the framework demonstrated effectiveness through its usability validation in vertical construction environments via multiple case studies, allowing practitioners to assess its usefulness in improving SC (Lingard et al., 2014; Partelow, 2023; Sherratt et al., 2025). The integration of QR-coded instructional videos enhanced knowledge accessibility, ensuring that both familiar and unfamiliar safety tools could be effectively implemented, addressing workforce diversity and inclusion challenges. Additionally, the SUS survey usability testing, with an average score of 81.875, confirmed its practicality and ease of adoption by safety practitioners, reinforcing its potential to improve labour conditions and productivity (Brooke, 1995; Lewis, 2018). These outcomes have the potential to align with broader objectives of advancing workplace safety, reducing inequalities, and fostering sustainable economic growth, thereby potentially contributing to the principles of the TBL framework and the UN's Sustainable Development Goals, particularly Goal 8, which promotes decent work and economic growth, and Goal 3 which aims to ensure healthy lives and promote well-being for all at all ages (Elkington, 1999; United Nations, 2025). The research background highlights that promoting SC can directly contribute to enhancing labour productivity by minimising downtime caused by accidents and improving workforce efficiency through better safety practices (Eaqub, 2024; Hasan et al., 2018; Rafindadi et al., 2022). By offering a practical and user-friendly approach to promoting SC in construction, the framework could support safety practitioners in developing and implementing strategies that enhance safety while fostering long-term improvements in working conditions and industry sustainability.

Fourthly, an additional practical contribution of this research lies in its potential to support future development of AI-based digital tools and intelligent agents designed to promote SC in the construction industry. The transformative role of generative AI and large language models in construction education, training, and practice is increasingly being recognised in academic research, including recent contributions from New Zealand-based scholars (Jelodar, 2025). OpenAI introduced Operator, an autonomous AI agent capable of navigating web environments, completing tasks such as form-filling and online reservations with minimal user input (OpenAI, 2025). This milestone illustrates how intelligent agents can deliver context-specific guidance and perform operational tasks in real-world settings. The structured and empirically validated nature of the proposed framework, comprising clearly defined factors, practical tools, and implementation pathways, positions it as a strong foundation for integration into AI-driven systems. Although the AI development is beyond the scope of this research, the framework developed in this research holds the potentials to underpin the design of AI agents tailored for construction safety management. These agents could assist project managers, safety officers, and site workers by offering real-time, context-aware safety guidance; promoting consistent use of industry best practices; and enhancing access to safety knowledge across diverse cultural and linguistic settings. This not only extends the usability and reach of the framework but also aligns with current digital transformation trends (Chen et al., 2022; Wadley, 2021).

8.4 Study Limitations

This section outlines the limitations of the thesis and proposes directions for future research to address these constraints.

Firstly, while the framework was designed using a systematic and structured approach, ensuring its potential adaptability beyond the New Zealand context, its validation was conducted exclusively for its usability with construction experts within New Zealand. This geographic limitation means that while the framework is conceptually transferable, its usability in other regions or industries remains untested. Further research is needed to empirically assess its usability in diverse international settings and sectors facing similar SC challenges, such as healthcare, aviation, and manufacturing (Butler et al., 2022; Hulme et al., 2021; Newnam et al., 2021). Testing the framework in different regulatory, cultural, and industry-specific environments will provide stronger evidence for its broader applicability and help refine its usability across various contexts.

Secondly, the study validated the usability of the framework within vertical construction projects, which may not fully capture the distinct safety challenges of horizontal construction sectors. Future studies should validate usability in horizontal construction settings and other infrastructure projects to assess whether sector-specific adjustments are necessary, ensuring its adaptability and comprehensive applicability across the broader construction sector.

Thirdly, this study focused on the immediate validation of usability of the framework through case studies. However, it did not include a longitudinal assessment to measure the long-term impact of the framework on SC improvements over time. Without tracking its implementation across multiple projects and over extended periods, the study cannot fully determine how well the framework sustains safety improvements or adapts to evolving industry challenges. Future research could incorporate longitudinal studies to assess how the framework influences SC development, compliance trends, and organisational safety performance over time.

Fourth, while the validation process included input from four practitioners through site visits and SUS surveys, the relatively small sample size limits the generalisability of the usability findings. Although the SUS is a widely accepted tool, it is typically recommended with 20 to 30 participants to achieve statistical significance (Bangor et al., 2009). While smaller samples can still offer meaningful insights, expanding the participant pool in future studies would strengthen the objectivity and robustness of the findings. Additionally, involving a broader and more diverse group of industry professionals in both the usability testing and the development of the CLD would enhance the framework's applicability and relevance across varied construction contexts. This would also allow for the refinement of the framework to address dynamic, sector-specific safety culture challenges more effectively.

Fifth, while this study focused on the usability and contextual applicability of the framework for promoting SC in vertical construction, it did not directly address broader psychosocial safety issues, including mental health challenges and suicide risk. This limitation is especially relevant given that suicide rates in the New Zealand construction industry range from 35 to 65 per year, with young men and Māori workers disproportionately affected. These issues are closely linked to stress, burnout, and unsafe practices (van Heerden et al., 2021; WorkSafe New Zealand, 2024a). Future development of the framework could involve achieving consensus among specific cultural groups, such as Māori, to ensure its relevance, inclusivity, and cultural appropriateness.

While this study presents a structured and empirically validated framework for promoting SC within the New Zealand construction sector, several limitations highlight opportunities for further refinement and broader validation. Expanding the framework's testing across international settings and diverse construction sectors will provide stronger evidence of its transferability and adaptability beyond its initial scope. Additionally, incorporating longitudinal studies will offer deeper insights into its sustained impact on SC improvements over time. Increasing expert participation in the validation process, particularly in refining the CLD, will enhance the framework's robustness by integrating a broader spectrum of industry perspectives. Addressing these limitations through future research will strengthen the framework.

8.5 Recommendations for Future Research

The research outcome contributes to advancing knowledge and understanding how to promote SC in construction, particularly within New Zealand's vertical construction sector. It provides a structured methodology for evaluating SC interventions, paving the way for further exploration of key decision points in the implementation process. To facilitate wider adoption of the SC framework, future research could conduct longitudinal case studies, which involve tracking the implementation of SC interventions over an extended period across various construction sectors, project types, and organisational structures. These studies would provide valuable insights into how SC frameworks are adopted, sustained, and adapted over time, identifying long-term trends, challenges, and enablers that influence their effectiveness. There are valuable opportunities for future research that build upon the constraints and scope of this study, ensuring that the findings contribute to both theoretical advancements and practical applications in the construction sector. This research addresses current questions and opens new avenues for further investigation. The suggested areas for future work include:

- Exploring the framework's application across different geographical regions could increase the coverage of the framework developed in this PhD research. Extending its reach beyond New Zealand to other countries or even within different sub-sectors of the construction sector would provide further valuable insights into SC in these other locations. Future research could focus on creating specific organisational interventions and evaluating their impact on safety outcomes and decision-making processes within the construction sector in these different countries.
- Adapting the framework for specific cultural contexts within each sector is crucial, for example considering New Zealand's diverse workforce. Native-born workers in New Zealand have lower rates of injuries than migrant workers, and Māori and Pasifika workers experience higher rates of work-related injuries compared to other ethnic groups (Hennecke et al., 2021; Rout, 2023). However, the effectiveness of new technologies in improving safety outcomes may be hindered by challenges such as length, language barriers, and workforce scepticism. Future studies should focus on adapting or redesigning these tools to better accommodate the dynamic and culturally diverse nature of construction sites. Future studies could explore how further cultural consideration of the framework may affect safety outcomes and worker

engagement in a particular cultural group, offering insights into developing strategies that might reduce work-related injuries in a particular cultural group.

- The informational report serves as a strategic tool for identifying gaps in current safety practices and opportunities for stronger collaboration among various construction organisations, including construction firms, government agencies, industry regulators, worker unions, and educational institutions such as universities and technical training providers. The framework's insights into the effectiveness of existing safety initiatives can guide the development of targeted interventions that specifically address persistent safety challenges in the sector. Understanding how various safety-related efforts interconnect and influence the construction sector enables stakeholders to make informed decisions that not only enhance individual and organisational safety practices but also elevate the industry's overall approach to safety. Future research could take the next step by developing specific interventions from different construction organisations based on these insights, evaluating their effectiveness through safety performance metrics such as incident rates, near misses, and compliance improvements before and after framework adoption. A cost-benefit analysis could further strengthen the framework's appeal to decision-makers, providing quantifiable evidence of its economic viability by assessing the financial impact of implementing SC tools against potential reductions in accident costs, project delays, and insurance premiums. This would not only provide a quantifiable measure of the framework's long-term impact but also ensure that SC initiatives are financially justifiable while delivering sustained improvements in workplace safety, organisational culture, and industry-wide safety performance. Additionally, future studies could take the next step by exploring the dynamics of stakeholder decisions and their broader industry implications, further reinforcing the practical applicability and scalability of the framework.
- The research identifies a range of tools with the potential to significantly enhance SC in the construction sector. Emerging technologies like AI, AR and VR offer transformative possibilities but face barriers to adoption, such as cost-effectiveness concerns, operational compatibility issues, and data security challenges (Chen & Chang-Richards, 2022; Ramadan et al., 2023). Aligning these technologies with existing operations and ensuring robust data protection measures are essential steps for successful integration. Similarly, systems thinking tools, such as Accimap, the Swiss Cheese model, and STAMP, provide advanced methodologies for analysing active and latent failures in safety management (Boardman & Sauser, 2013; Leveson, 2004). Although these tools were not widely recognised by New Zealand experts initially, case studies indicate growing interest in their application. Future research could evaluate the

practical benefits of these tools compared to traditional methods, addressing concerns about their complexity and integration into ongoing projects (Salmon et al., 2012). In addition, survey instruments like the Nordic Occupational Safety Climate Questionnaire play a critical role in capturing workers' perceptions about SC (Darvishi et al., 2015; Guadix et al., 2017); research could also focus on identifying barriers to the adoption of these instruments within various organisational contexts and developing strategies to facilitate their implementation.

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Appendices

Appendix 1: Ethical Approval

Gmail

Natalia Ortega <[redacted]>

[HE007] - Human Ethics Notification - 4000027113

humanethics@massey.ac.nz <humanethics@massey.ac.nz> 28 February 2023 at 14:01
To: orteganati@gmail.com, M.Sutrisna@massey.ac.nz
Cc: humanethics@massey.ac.nz

Kia ora,

Link to the application
HoU Review Group

Ethics Notification Number: 4000027113
Project Title: The effectiveness of a Systems Thinking-based method for promoting Safety Culture as a pathway to improve Safety Performance of Construction SMEs

Thank you for your notification which you have assessed as low risk.

Your project has been recorded in our database for inclusion in the Annual Report of the Massey University Human Ethics Committee.

The low risk notification for this project is valid for a maximum of three years.

Please notify me if situations subsequently occur which cause you to reconsider your initial ethical analysis that it is safe to proceed without approval by one of the University's Human Ethics Committees.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named in this document are responsible for the ethical conduct of this research.

If you have any concerns about the conduct of this research that you want to raise with someone other than the researcher(s), please contact Professor Craig Johnson, Director (Research Ethics), email humanethics@massey.ac.nz."

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish require evidence of committee approval (with an approval number), you will have to complete the application form again answering yes to the publication question to provide more information to go before one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

You are reminded that staff researchers and supervisors are fully responsible for ensuring that the information in the low risk notification has met the requirements and guidelines for submission of a low risk notification.

If you wish to print an official copy of this letter:

1. Please login to the RIMS system (https://rme.massey.ac.nz).
2. In the Ethics menu, select Ethics Applications.
3. Using the Advanced option, select Ethics Applications (Area), Application ID (Search On), enter the ethics notification number in the Value area and select Find on the toolbar.
4. With the application the Results Tab, tick the empty box on the far left of the application and select Reports from the toolbar.
5. Select the "Human Ethics - Low Risk Notification Letter" link, this will open the report viewer.
6. Select the application code from the Report Parameters dropdown and submit. You can then select an export option from the top toolbar (Print, Save).

Yours sincerely
Professor Craig Johnson
Chair, Human Ethics Chairs' Committee and
Director (Research Ethics)

Appendix 2: Modified Delphi Study Documentation

Consent Form

MASSEY UNIVERSITY
TE KUNENGA KI PUREHUROA
UNIVERSITY OF NEW ZEALAND

Information sheet:
+The research project aims to promote a Safety Culture among Small and Medium Enterprises (SMEs) within the construction industry by establishing the effectiveness of a Systems Thinking-based method.

Name

Last Name

What is your role/position?

How many years do you have in On-site Construction and Safety?

This was the Ethics Notification Number: 4000027113.
Approximately 20/30 experts on-site Safety and Project Management experts who have worked in the construction industry will be invited to participate in this research project. A 'snowball' method of recruitment is being used. This means that people from my existing networks will be asked to recommend potential participants, and they will also be asked to recommend participants.

+Research approach: The research is being undertaken in two phases.

++Phase 1: involves you having an online interview for around 30 minutes. The aim is not to test your knowledge but rather to gather information about your experiences. With your permission, the interviews will be digitally recorded and typed up. You will be able to review the interview transcript and make changes to it. The interviews will be held in September and 2023.

++Phase 2: involves the participants having another interview for around 30 minutes. The aim is to share the results from the first phase and ask further questions in depth. The interviews will be held in October 2023. Only if it is necessary will another interview be requested.

+Your Rights: You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- Decline to answer any question.
- Withdraw from the study at any stage before my research is submitted for publication.
- Ask for the recorder to be turned off at any time during the interview.
- Be given access to a summary of the project findings when it is concluded.
- If you feel that discussing your experiences will cause you psychological harm or distress, please do not accept this invitation to participate.
- Please let me know if you participate in this research and begin to feel stressed or upset. Your involvement can be stopped at any time.
- You also do not need to talk about anything that makes you feel uncomfortable.

+Data Management: The information obtained from all the participants during this research project will inform the development of my Ph.D.

*To respect our privacy and confidentiality: All details that could identify you or the organization in which you work will be removed from any research publications.

*The Teams Microsoft system will automatically transcribe the interview and double-check by me under a confidentiality agreement.

*The transcripts will be submitted to you to its approval. All material gathered during phases 1 and 2 will be stored in a secure location that I have access only.

*The original data will be kept for five years following the completion of the research in a secure storage room at Massey University (Albay campus).

PHD Student: Natalia Ortega, n.ortega@massey.ac.nz

+Project Contacts:

Monty Sutrisna Head of School of Built Environment School of Built Environment m.sutrisna@massey.ac.nz\

Daniel Paes Lecturer in Digital Built Environment School of Built Environment d.paes@massey.ac.nz

Zhenan Feng Senior Lecturer in Digital Built Environment School of Built Environment z.feng1@massey.ac.nz

Tak Wing (Kenneth) Professor, Construction Management and Property, School of Built Environment, UNSW SYDNEY kenneth.yiu@unsw.edu.au

○ I consent, begin the study

○ I do not consent, I do not wish to participate

>>

Participant Information Sheet

Participant information sheet: Information Research Invitation

The subject of the email: Support for research interviews about Safety Culture

Dear *(Name)*,
You are nominated by *(Name of the contact who nominated)* to participate in this Research Project that intends to promote a Safety Culture among Small and Medium Enterprises (SMEs) within the construction industry by establishing the effectiveness of a Systems Thinking-based method.
You were considered based on your experiences related to Safety during the Construction Project Execution phases. This research is part of my Ph.D. project at Massey University, School of Built Environment.
Thank you for your support, time, and consideration. Approximately 20/30 experts on-site Safety and Project Management experts who have worked in the construction industry will be invited to participate in this research project.
The research is being undertaken in two phases, which require 2 interviews for about 30 minutes each.
Phase 1

- It involves having an online interview for around 30 minutes.
- The aim is not to test your knowledge but rather to gather information about your experiences. With your permission, the interviews will be digitally recorded and typed up. You will be able to review the interview transcript and make changes to it.
- The interviews (online) will be held in September and 2023.

Phase 2

- It involves the participants having another interview for around 30 minutes.
- The aim is to share the results from the first phase and ask further questions in depth.
- The interviews (online) will be held in October 2023.

Only if it is necessary another interview or survey will be requested.
Book time with Natalia Ortega: Safety Culture Research
Why this Research matters
Promoting a Safety Culture (SCU) across the sector can reduce potential disasters, accidents, and incidents. However, one of the main barriers to promoting SCU is the relationship between frontline workers and senior management and the transitory nature of the subcontractor workforce. Thus, one of the main factors to consider in promoting SCU is the management of safety commitment within and among SMEs. Little is known about the construction industry's practice and application of Systems thinking (ST) tools. Evidence suggests that ST-based methods could effectively guide a team in identifying and minimizing safety risks, integrating stakeholders, and making decisions that improve safety. Previous studies also highlight the need and an opportunity for construction disciplines to start exploring ST approaches to address the industry's current safety issues, given its demonstrated potential to do so in other contexts.
Using this information, the project aims, in collaboration with the research participants, to foresee the effectiveness of a Systems Thinking-based method in promoting SCU among construction SMEs. It will involve developing and validating an ST-based method to promote SCU among construction SMEs.

By participating in this research, I also hope you will gain knowledge and insights to help you work with others safely. You will have access to the findings.
Your Rights
You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- Decline to answer any question.

- Withdraw from the study at any stage before my research is submitted for publication.
- Ask for the recorder to be turned off at any time during the interview.
- Be given access a summary of the project findings when it is concluded.
- If you feel that discussing your experiences will cause you psychological harm or distress, please do not accept this invitation to participate.
- Please let me know if you participate in this research and begin to feel stressed or upset. Your involvement can be stopped at any time.
- You also do not need to talk about anything that makes you feel uncomfortable.

Data Management

The information obtained from all the participants during this research project will inform the development of my Ph.D. To respect our privacy and confidentiality:

All details that could identify you or the organization in which you work will be removed from any research publications.

The Teams Microsoft system will automatically transcribe the interview and double-check by me under a confidentiality agreement.

All material gathered during phases 1 and 2 will be stored in a secure location that I have access only.

The original data will be kept for five years following the completion of the research in a secure storage room at Massey University (Albay campus). This was the Ethics Notification Number: 4000027113.

By booking an interview, it will be giving the consent to participate in the Research Study.

Project Contacts

+Natalia Ortega, PhD student, n.ortega@massey.ac.nz

Supervision Team:

+Monty Sutrisna, Head of School of Built Environment School of Built Environment, m.sutrisna@massey.ac.nz.

+Daniel Paes, Lecturer in Digital Built Environment School of Built Environment, d.paes@massey.ac.nz

+Zhenan Feng, Senior Lecturer in Digital Built Environment School of Built Environment, z.feng1@massey.ac.nz

+Tak Wing (Kenneth), Professor, Construction Management and Property, School of Built Environment, UNSW SYDNEY, kenneth.yiu@unsw.edu.au

Please if you know someone who could add value to this research, please feel free to forward this email.

Please, any questions, get in touch with me or my supervisors.

Book time with Natalia Ortega: Safety Culture Research

Yours sincerely

Natalia Ortega

PhD Student

MBA (Thesis, UNLA, ARG)

BBA (Hons., UBA, ARG)

School of Built Environment

College of Sciences

Massey University

T | +64 22 42 227 500

E | N.Ortega@massey.ac.nz

W | www.massey.ac.nz

Second-Round Invitation

Second Round invitation email to answer the survey

Subject: Your Support to the 2nd Round Safety Culture Research

Dear «Name»,

I hope this email finds you well. Following an extensive and meticulous thematic analysis conducted with 32 interview experts based in New Zealand, I am excited to share the preliminary insights that have emerged in this second phase of our inquiry.

You participated in the 1st round of interviews. This 2nd round is about answering survey questions. Your responses will help us unearth the definition, the main barriers, the common tools, the key indicators, and the potential of new tools to promote Safety Culture.

I kindly request you allocate approximately 15 to 20 minutes to complete this survey (click here) before the 20th of November.

Reminder: All details identifying you or the organisation in which you work will be removed from any research publications. This was the Ethics Notification Number: 4000027113.

Thank you for your invaluable support and continued commitment to this research.

Please, if you have any questions, get in touch with me.

Yours sincerely

Natalia Ortega

PhD Student

MBA (Thesis, UNLA, ARG)

BBA (Hons., UBA, ARG)

School of Built Environment

College of Sciences

Massey University

T | +64 22 42 227 500

E |n.ortega@massey.ac.nz

W | www.massey.ac.nz

>>

Transcript Approval Email Template

Dear XXXX (name), Thank you for your time and consideration for participating in this research. I have attached the Transcript of our interview today. *Please feel free to review it by the (day) of (month); if I do not receive any comments by then, automatically, it will be considered approved for this research.* Kind regards.

Second-Round Survey Detail

SC Definition of Safety Culture: These key elements have been discerned through the examination of responses from 32 experts, employing a Thematic analysis approach. How would you rank these elements in terms of importance? (1=Less important - 4=Very important)	1. Less important (1)	2. Slightly important (2)	3. Moderately important (3)	4. Very important (4)
A) Collaboration and Communication: This is about open two-way communication and engagement between management and workers, where individuals can speak up without fear. (1)	○	○	○	○
B) Foundational Principles: This touches on various aspects such as care, adherence to standards, individual and collective responsibility, and the importance of continuous improvement in safety practices. (2)	○	○	○	○
C) Human-Centered Approach: This theme is defined as Human behaviors and interactions because of its strong focus on human behaviors and interactions that foster a sense of inclusion within the safety culture. The frontline workers are key to safety culture, and their understanding and support are crucial. (3)	○	○	○	○
D) Integration and Organization: This theme sees the Safety culture as a fundamental part of an organization's culture, focusing on health, well-being, and protection rather than mere compliance or inspections. Viewing safety culture as an intrinsic part of the organization, integrating with quality, efficiency, and effectiveness requires integration and organization. (4)	○	○	○	○
E) Leadership and Responsibility: This is about leadership playing a pivotal role in setting an example and fostering a safety-first culture. Self-leadership is where Individuals are encouraged to take self-leadership and responsibility in safety matters. It is a shared responsibility involving everyone within the organization, including management, workers, and contractors. (5)	○	○	○	○
F) Resource Allocation and Prioritization: This is about Safety being given equal importance alongside other project parameters such as Time, Cost, and Quality. (6)	○	○	○	○

Barriers **Please rate the level of importance you assign to the following barriers/obstacles/impediments to promote Safety Culture.** *(1=Less important, 5=Very important)*	1. Less important (1)	2. Slightly important (2)	3. Neutral (3)	4. Moderately important (4)	5. Very important (5)
A) Client Understanding: Clients do not comprehend the significance of health and safety. (1)	○	○	○	○	○
B) Communication: Cultural and Language issues: Cultural differences in the workplace can lead to misunderstandings and a lack of engagement. (2)	○	○	○	○	○
C) Leadership commitment: Struggling to gain leadership support and acceptance can hinder the development of a strong safety culture, highlighting the challenge of needing more commitment from leadership. (3)	○	○	○	○	○
D) Experience and Mindset: Neglecting Training and Perspective: Inadequate attitudes and beliefs often lead to a lack of recognition regarding the relevance of safety. Failing to seek new perspectives and neglecting proper training actively exacerbates the problem. (4)	○	○	○	○	○
E) Resource Allocation: Resource allocation issues are exacerbated by the burden of excessive paperwork and high costs, primarily due to the failure to allocate the necessary funds for safety initiatives, resulting in constraints on safety measures. (5)	○	○	○	○	○
F) Industry Fragmentation: Industry fragmentation presents challenges related to subcontractor partnerships and aligning safety objectives, along with the struggle to establish standardized safety practices. (6)	○	○	○	○	○

Tools **Please rate the level of importance you assign to the following Tools to promote Safety Culture.** *(1=Less important, 5=Very important)*	1. Less important (1)	2. Slightly important (2)	3. Neutral (3)	4. Moderately important (4)	5. Very important (5)
Color-Coded Card System (1)	○	○	○	○	○
Language Translation (2)	○	○	○	○	○
Delivery Lead (3)	○	○	○	○	○
Documentation and Signing (4)	○	○	○	○	○
Health and Safety Processes (5)	○	○	○	○	○
Committees for the Firm and Subcontractors (6)	○	○	○	○	○
Induction-Prestart Meeting (7)	○	○	○	○	○
Toolbox Talks (8)	○	○	○	○	○
Working Group (9)	○	○	○	○	○
Cultural integration Activities (10)	○	○	○	○	○
DuPont Bradley Curve (11)	○	○	○	○	○
Lean Philosophy (12)	○	○	○	○	○
Networking and Knowledge Sharing (13)	○	○	○	○	○
Planning (14)	○	○	○	○	○
Awards (15)	○	○	○	○	○
Safety Club (16)	○	○	○	○	○
Audits (17)	○	○	○	○	○
Recording Systems (18)	○	○	○	○	○
Scorecard (19)	○	○	○	○	○
Application (20)	○	○	○	○	○
Digital Screen (21)	○	○	○	○	○
QR Codes (22)	○	○	○	○	○
First Aid Training (23)	○	○	○	○	○
Leadership Training (24)	○	○	○	○	○
Online Training Program (25)	○	○	○	○	○
Trust (26)	○	○	○	○	○
Visual Indicators (27)	○	○	○	○	○
Other:					

Cronbach's alpha (α) Calculation Details

Table 1

Cluster 1: Chronbach's alpha Calculation and Results

Questionn1 (F. frequency; P. percent)	1. Low priority	2. Slightly important	3. Moderately important	4. Very important	Mean	Ʊ (Standard Deviation)
Collaboration and Communication				F.26 - P. 100%	4	4
Foundational Principles		F. 1 - P.3.8%	F. 9 - P.34.6%	F.16 - P.61.5	3.58	4
Human-Centered Approach			F.6 - P.23.1%	F.20 - P. 76.9%	3.77	4
Integration and Organization		F.2 - P.7.7%	F.6 - P.23.1%	F.18 - P.69.2%	3.62	4
Leadership and Responsibility			F.3 - P.11.5%	F.23 - P.88.5%	3.88	4
Resource Allocation and Prioritization		F.3 - P.11.5%	F.6 - P.23.1%	F.17 - P.65.4%	3.54	4
Note: N=26. Decision - weighted average =					22.39	
Cronbach's Alpha is 0.655						

Table 2

Cluster 2: Chronbach's alpha Calculation and Results

Question 2. Influential Factors	Scale Mean	Scale Variance	Corrected Item-Total Correlation	Cronbach 's Alpha
Client Understanding	20.77	7.545	0.655	0.700
Communication	20.42	9.054	0.442	0.759
Leadership Commitment	19.88	9.546	0.487	0.749
Experience and Mindset	20.35	8.635	0.506	0.743
Resource Allocation	20.58	8.814	0.585	0.725
Industry Fragmentation	20.69	9.102	0.457	0.755

Table 3

Cluster 3: Chronbach's alpha Calculation and Results

Question 3. Tools	**Scale Mean**	**Scale Variance**	**Corrected Item-Total Correlation**	**Cronbach 's Alpha**
Color-coded Card System	98.46	165.538	0.695	0.886
Language Translation	97.62	171.606	0.436	0.893
Delivery Lead	97.42	174.654	0.343	0.895
Documentation and Signing	98.19	165.122	0.582	0.889
Health and Safety Processes	97.42	172.814	0.405	0.893
Committees for the Firm and Subcontractors	97.77	172.505	0.444	0.892
Induction-Prestart Meeting	97.35	176.395	0.295	0.896
Toolbox Talks	97.31	170.782	0.701	0.887
Working Group	97.46	176.818	0.418	0.893
Cultural Integration Activities	97.46	169.458	0.572	0.889
DuPont Bradley Curve	98.08	168.714	0.517	0.891
Lean Philosophy	98.00	174.160	0.443	0.892
Networking and Knowledge Sharing	97.31	174.702	0.455	0.892
Planning	96.69	181.022	0.406	0.893
Awards	97.92	174.474	0.448	0.892
Safety Club	98.23	170.345	0.482	0.891
Audits	97.46	178.338	0.346	0.894
Recording Systems	97.38	174.006	0.546	0.890
Scorecard	97.96	173.638	0.461	0.892
Application	97.88	174.746	0.606	0.890
Digital Screen	98.19	172.322	0.582	0.889
QR Codes	98.23	172.665	0.453	0.892
First Aid Training	97.15	174.375	0.481	0.891
Leadership Training	96.85	175.495	0.564	0.890
Online Training Program	97.81	168.722	0.602	0.888
Trust	96.50	184.820	0.120	0.896
Visual Indicators	96.88	181.386	0.246	0.895

***RII* Calculation Details**

Table 4

Cluster 1: RII Calculations and Results

Defining Factors	1. Less important	2. Slightly important	3. Moderately	4. Very important	Total	Total N	A (4*N)	RII	Rank
Collaboration & Communication	0	0	0	104	104	26	104	1	1
Leadership & Responsibility	0	0	9	92	101	26	104	0.97	2
Human-Centered Approach	0	0	18	80	98	26	104	0.94	3
Integration & Organization	0	4	18	72	94	26	104	0.9	4
Foundational Principles	0	2	27	64	93	26	104	0.89	5
Resource Allocation & Prioritization	0	6	18	68	92	26	104	0.88	6

Table 5

Cluster 2: RII Calculations and Results

Influential Factors	1. Less important	2. Slightly important	3. Neutral	4. Moderately important	5. Very important	Total	Total N	A (5*N)	RII	Rank
Leadership Commitment	0	0	9	12	100	121	26	130	0.93	1
Experience & Mindset	0	2	15	32	60	109	26	130	0.84	2
Communication	0	2	15	40	50	107	26	130	0.82	3
Resource Allocation	0	2	15	56	30	103	26	130	0.79	4
Industry Fragmentation	0	2	24	44	33	103	26	130	0.77	5
Client Understanding	1	4	12	56	25	98	26	130	0.75	6

Table 6

Cluster 3: RII Calculations and Results

Tools	1. Low importance	2. Slightly important	3. Neutral	4. Moderately important	5. Very important	Total Number 26	RII	Ranks
Trust	0	0	3	8	115	26	0.97	1
Planning	0	0	0	36	85	26	0.93	2
Leadership Training	0	0	9	28	80	26	0.90	3
Visual Indicators	0	0	9	32	75	26	0.89	4
First Aid Training	0	2	15	32	60	26	0.84	5
Toolbox Talks	0	0	24	36	45	26	0.81	6
Networking and Knowledge	0	6	3	56	40	26	0.81	6
Induction-Prestart Meeting	1	4	12	32	55	26	0.80	7
Recording Systems	0	2	18	48	35	26	0.79	8
Delivery Lead	1	4	18	24	55	26	0.78	9
Health and Safety Processes	1	6	9	36	50	26	0.78	9
Working Group	0	2	21	48	30	26	0.78	9
Cultural Integration Activities	1	2	21	32	45	26	0.78	9
Audits	0	2	21	48	30	26	0.78	9
Language Translation	2	2	21	32	40	26	0.75	10
Committees for the Firm and Subcontractors	2	4	15	52	20	26	0.72	11
Online Training Program	1	6	24	36	25	26	0.71	12
Apps	0	4	33	48	5	26	0.69	13
Awards	0	10	24	40	15	26	0.68	14
Scorecard	1	8	21	48	10	26	0.68	14
Lean Philosophy	2	2	33	40	10	26	0.67	15
DuPont Bradley Curve	4	0	33	28	20	26	0.65	16
Documentation and Signing	3	12	18	24	25	26	0.63	17
Digital Screen	1	8	36	32	5	26	0.63	17
Safety Club	3	8	27	28	15	26	0.62	18
QR Codes	3	4	36	28	10	26	0.62	18
Color-coded Card System	5	2	39	24	5	26	0.58	19

Appendix 3: Case Studies Documents

CONSENT FORM

Project: A framework for assessing tools to promote safety culture on New Zealand construction sites.

You have been provided with project information and the site visit procedure by reading the Participant Information Sheet. This form acknowledges your agreement to participate and your permission for the interview part to be recorded. During the interview, you may ask to stop recording to make comments off the record. Results will not be published in any form that allows the identification of individuals or organisations without permission. You are free to refuse to answer any question and to withdraw your participation at any time without needing to provide any explanation for your decision. In this event, the researcher will destroy all data from any withdrawing participant.

Signature: ________________________ Date: ________________

CONFIDENTIALITY AGREEMENT

I, Natalia Ortega, agree to keep confidential all information concerning the project. I will not retain or copy any information involving the project for any other use than this research's purpose.

Consent Form

Participant Information Sheet

PARTICIPANT INFORMATION SHEET (PIS)

Project: A framework for assessing tools to promote safety culture on New Zealand construction sites.

You have been identified as a key player in the "Project: A Framework for Assessing Tools to Promote Safety Culture on New Zealand Construction Sites" research project. This PIS sets out why we are doing the study, what your participation would involve, what benefits and rights you might have, and what would happen after the study ends.

Regardless of location, the construction sector consistently ranks among the most hazardous industries, responsible for 30 to 40% of workplace fatalities globally. Given that 58% of hazards could be prevented during the execution phase of the construction project, there is an urgent need to assess the tools currently in place and explore new ones that can help overcome these challenges. Reducing on-site accidents is crucial for the success of construction projects, and one proven way to achieve this is by fostering solid Safety. A positive safety culture not only enhances safety performance but also leads to better overall project outcomes. Despite over 30 years of research, there is still no universally accepted definition. The factors that constitute safety culture and the tools to promote it were also frequently debated in the literature. This thesis was undertaken to assess the understanding of safety culture definitions, factors, and tools at on-site building construction sites. This thesis aims to promote safety culture at on-site building construction sites in New Zealand by developing a framework. The research results are expected to provide construction professionals with current practices and a guide to better use and introduction of tools to promote a safety culture based on their daily challenges. The study contributes significantly to the New Zealand construction industry transitioning to the new view 2024-2027 plan, with the vision of "Work is healthy and safe for everyone in New Zealand," and the objective is to uplift health, safety, and well-being maturity and performance.

As a result of the study, a "*A framework for assessing tools to promote safety culture on New Zealand construction sites.*" has been developed. The framework provides detailed guidelines about tools to use and potential tools to be considered on New Zealand construction sites. It is designed to support that all relevant tools promoting safety culture information are collected and considered logically and consistently. The scope of work includes building construction projects that are in the execution phase. The framework consists of six main factors that On-site Managers or Safety experts on-site experience, including (1) Level of Leadership Commitment, (2) Level of Experience and Mindset, (3) Level of Communication, (4) Level of Resource Allocation, (5) Level of Industry Fragmentation, and (6) Level of Customer Understanding. These factors are related to those tools collected from the previous consensus among a group of experts in New Zealand. Information related to other tools in different contexts not considered by New Zealand experts was incorporated into each factor. Additional guidance and a print framework to make decisions on each factor are also provided.

Site visit inductions procedures: The site visit aims to operationalise and refine the developed framework. The invitation will be sent to construction building companies in New Zealand, including on-site project managers and safety experts of a specific project. If you accept the invitation, a copy of the developed framework and an agenda will be sent to you before the site visit. The site visit will take around two hours. All participants will also be sent a poll to select the most suitable time and date. The site visit will include two parts: first, an induction through a site visit, second an interview and a survey. The interview part will be recorded, transcribed, and analysed by the named researchers only, who will safeguard the data. The visit will involve to familiarised about the project. The transcriptions will not be included in the study without your consent. Your identity and company information will not be revealed in the transcripts and analysis except with your and the company's previous permission. Based on the analysis, written reports will be prepared, which may be published in various formats as study findings without mention personal data o company information. The data collected will be destroyed within five years after the completion of this research project.

Participant's Rights: You are under no obligation to accept this invitation. If you decide to participate, you have the right to: • decline to answer any particular question; withdraw from the study (specify timeframe); • ask any questions about the study at any time during participation; • provide information on the understanding that your name will not be used unless you permit the researcher; • be given access to a summary of the project findings when it is concluded. • ask for the recorder to be turned off at any time during the interview, the first site visit.

If you agree to participate in this study, you will be asked to sign the Consent Form. You will be given a copy of the PIS and the Consent Form. This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees, who have approved Human Ethics Notification number 4000027113.

If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please get in touch with Dr. Thushi Jayawardena-Willis, Research Ethics Advisor, telephone +64 6 356 9099 extensions 83904, email "humanethics@massey.ac.New Zealand."

The researchers named in this document are responsible for the ethical conduct of this research.

If any queries arise, please get in touch with the research team:

Natalia Ortega	PhD Candidate, School of Built Environment, College of Science, Massey University, email: n.ortega@massey.ac.nz
Monty Sutrisna	Professor of Construction and Project Management, School of Built Environment, College of Science, Massey University, email: m.sutrisna@massey.ac.nz

Daniel Paes	Senior Lecturer in Digital Built Environment, School of Built Environment, College of Science, Massey University, email: d.paes@massey.ac.nz
Zhenan Feng	Senior Lecturer in Digital Built Environment, School of Built Environment, College of Science, Massey University, email: z.feng1@massey.ac.nz
Tak Wing Yiu	Professor, Construction Management and Property, School of Built Environment, Faculty of Arts, Design & Architecture, 2052, University of New South Wales, SYDNEY, email: kenneth.yiu@unsw.edu.au

Thank you for your time and your kind support!

Hi (Name),

I hope this email finds you well. Thank you again for your time supporting research projects in construction related to safety.

In this opportunity this an extension of the research project you participated last year and this time the activities are as descriptive below.

The procedure will involve a brief site visit to one of your projects, followed by an interview with either the on-site Project Manager or the Health & Safety officer responsible for that project.

I will be presenting a framework designed to promote safety culture, which includes a list of influential factors and corresponding tools that were identified through two rounds of interviews with approximately 30 New Zealand experts plus literature review (tools implemented in other countries with impact on safety culture).

The idea is for you or the person who is in charge of the project to identify the tools you are currently using, the tools you are familiar with but not using at the moment, and those that may be unfamiliar to you. For any unfamiliar tools, I will show you brief videos (approximately 1 minute each) explaining them, followed by a discussion on whether and how these tools could be incorporated into your current practices.

The site visit will not involve any photos or videos. Its sole purpose is to help the researcher gain a better understanding of the project as a whole, enabling the development of more accurate and relevant questions based on the inductions made during the visit.

At the end of the interview, you will receive the report containing the framework and detailed descriptions of each tool (with a QR code with access to the videos).

Please note that this information will remain confidential until the thesis is published.

Kind regards,

Invitation to Perform the Site Visits

Demographics

PhD research project: A framework to promote safety culture

Demographic questions

Participant ID:……..

Age:
☐ Under 25 ☐ 25-30 ☐ 31-35 ☐ 36-40 ☐ 41-45 ☐ 46-50 ☐ 51-55 ☐55-60 ☐ Over 60

What is your education level?
☐ High school diploma ☐ Bachelors degree ☐Master degree ☐PhD degree
☐ Other (specify)………………………………………………………………………………..

What is the job tittle of your current position?...

Please briefly describe your role and responsibilities:
………………………………………………………………………………………..................
………………………………………………………………………………………..................
………………………………………………………………………………………..................
Years of experience in current position:
☐ 1-5 years ☐ 6-10 years ☐ 11-20 years ☐ 21-25 years ☐ Over 25 years
Total years of experience in related field:
☐ 1-5 years ☐ 6-10 years ☐ 11-20 years ☐ 21-25 years ☐ Over 25 years
Number of staff typically working on your projects:
☐ Less than 25 workers ☐ 25-50 workers ☐ 50-100 workers ☐ More than 100 workers

Check-List Site Visits

CHECKLIST SITE VISIT

Project: A framework for assessing tools to promote safety culture on New Zealand construction sites.

Participant #

Actions - Yes/No - Comments

PIS signature + show Consent form signed

Site visit

Read the PIT actions

Open Teams to record + recorder

Show the report

Read script

Ask questions

Show videos

Ask to complete SUS

Thanks!

Script for the Interview

PhD research project: A framework to promote safety culture

Script Site Visits

Today, we are going to review a report based on a research study about tools to promote safety culture on site.

Here is how the previous study was conducted to write this report that I am presenting today:

I conducted interviews with approximately 30 experts.
The first round of questions focused on defining safety culture, identifying factors affecting it, and discussing the tools used to promote it on site.

I analysed the data from the first round to compile a list of tools and factors.

In the second round of interviews, I asked the same group of experts to rank these factors and tools based on their relevance and importance.

Framework Development:

Based on the rankings and data, developed a framework to aid decision-making for on-site Project Manager and Safety Experts.

The framework lists the influential factors with the tools, both those mentioned and ranked by experts and additional ones found in literature.

Explanation:

I am presenting this framework in a printed report, which will also be sent to you in PDF format. Please note that the report is confidential as my thesis has not yet been published.
During our meeting, I will explain the framework and its use: If you encounter a specific issue, you can refer to the framework to see what tools experts typically use to address it.

The idea is you can identify the tools that you are using, tools that you know but you are not using at the moment, and tools that you may be do not know. For the tools that are not familiar to you I will show you brief videos (1 minutes long aprox) explaining each tool, followed by a discussion on whether and how you might consider using these tools based on your current practices.
Discussion of Influential Factors:

The framework highlights six influential factors influencing safety culture as identified and ranked by experts:
Leadership commitment
Experience and mindset
Communication level
Resource allocation
Industry fragmentation
Client understanding

Tool and Barrier Exploration:

For each influential factor we will discuss specific tools and barriers.
You will be asked if you currently use these tools, such as trust and open communication, and to reflect on the effectiveness of these tools in your context.

Feedback Collection:

As we go through the tools related to each factor, you will respond whether you currently use these tools and how they impact your operations.

This structured discussion will help clarify how you can apply the findings from the research to enhance safety culture on your projects.

Questions?

SUS Survey Detail

SUS

Project: A framework for assessing tools to promote safety culture on New Zealand construction sites.

Participant nbr:…

Thank you for participating in our survey. Below you will find a list of 10 statements. For each statement, please select only one option that best reflects your level of agreement or disagreement.

Please follow these steps to complete the survey:

Take your time to thoroughly understand each statement before making your choice.

Choose Only One Option per Statement: For each statement, select one option from the following scale that best describes your opinion:

1 - Strongly Disagree: You completely disagree with the statement.

2 - Disagree: You disagree with the statement but not strongly.

3 - Neutral: You neither agree nor disagree with the statement.

4 - Agree: You agree with the statement but not strongly.

5 - Strongly Agree: You completely agree with the statement.

Do Not Skip Any Questions: It is important that you select an option for every statement to ensure the validity of the survey results.

Review Your Responses: After completing all the questions, review your responses to ensure they accurately reflect your views.

Submit Your Completed Survey: Once you are sure of your answers, submit the survey according to the provided instructions.

SUS Statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I think that I would like to use this framework frequently					
I found the framework unnecessarily complex					
I thought the framework was easy to use					
I think that I would need the support of a technical person to be able to use the framework					
I found the critical factors and tools in this framework were well-integrated					
I thought there was too much inconsistency in this framework					
I would imagine that most people would learn to use this framework very quickly					
I found the framework very cumbersome to use					
I felt very confident using the framework					
I need to learn a lot of things before I could get going with this framework					

Thank you for your time and your kind support!

Table 7

SUS Detail, Calculations and Results

SUS Statements	Participant 4	Participant 3	Participant 2	Participant 1
1.I think that I would like to use this framework frequently	3	3	3	4
2.I found the framework unnecessarily complex	4	3	2	4
3.I thought the framework was easy to use	4	4	3	4
4.I think that I would need the support of a technical person to be able to use the framework	4	2	3	4
5.I found the critical factors and tools in this framework were well-integrated	4	3	2	4
6.I thought there was too much inconsistency in this framework	4	3	2	3
7.I would imagine that most people would learn to use this framework very quickly	3	3	3	4
8.I found the framework very cumbersome to use	4	3	3	4
9.I felt very confident using the framework	4	3	2	4
10.I need to learn a lot of things before I could get going with this framework	3	3	3	3
Total	37	30	26	38
Total x 2.5	92.5	75	65	95
Average	81.875			

Appendix 4 (Conference Paper - AUBEA 2024). Towards a Conceptual Framework to Assess the Understanding of a Relevant Construction Issue: Proposing a Methodological Framework.

This appendix is based on the following manuscript. The manuscript was accepted and presented at the AUBEA 2024 Conference, yet it is pending to be published.

Ortega, N., Paes, D., Feng, Z., Sutrisna, Wing Yiu, T.

Abstract:

This paper develops a methodological framework designed to assess the understanding of a relevant construction issue. The framework development is under an inductive approach and is structured into five key steps, where theory and practical applicability are considered. The first step implies reaching a consensus among experts to establish consensus about the understanding of vital concepts. This consensus-building process ensures that the framework is grounded in practical knowledge from expert perceptions. The second step consists of conducting a systematic literature review. In the third step, a prototype conceptual framework is developed based on the findings from the previous steps by linking the findings. The fourth step focuses on developing case studies to operationalise the prototype framework, allowing for real-world testing and feedback. Finally, the fifth step involves refining the conceptual framework based on feedback and findings from the case study phase. This paper contributes to the field by providing a structured methodology for developing frameworks that enhance the understanding of complex issues in the construction industry.

***Keywords**:* Research Methodology, Safety Culture, Construction Industry, Inductive Approach.

1. Introduction

Regardless of location, the construction sector consistently ranks among the most hazardous industries, responsible for 30 to 40% of workplace fatalities globally (Ni et al., 2022; Rafindadi et al., 2022). The construction industry, while vital to our economy, continues to struggle with high fatality rates and frequent on-site accidents (Harris et al., 2020; Low et al., 2019; Musonda et al., 2021). Reducing on-site accidents is crucial for the success of construction projects, and one proven way to achieve this is by fostering a strong safety culture (Al-Bayati et al., 2024; Deepak & Mahesh, 2021; Raheem & Issa, 2016). A positive safety culture not only improves safety performance but also leads to better overall project outcomes (Choudhry & Fang, 2008; Del Puerto et al., 2018; Gao et al., 2015; Namian et al., 2022). The concept of safety culture, however, is fragmented and often misunderstood (Biggs et al., 2005; Gillen et al., 2004; Schwatka et al., 2016; Sherratt et al., 2011; Umeokafor et al., 2022).

This paper aims to present a methodological framework to create a framework to assess the understanding of a relevant construction issue when the literature is literature overwhelming or the topic is new in the field, based on an inductive approach.

2. Literature Review

Despite over 30 years of research, there is still no universally accepted definition (Bisbey et al., 2019; Schwatka et al., 2016; Umeokafor et al., 2022). The factors that constitute safety culture and the tools to promote it are also frequently debated in the literature (Abdullah & Wern, 2012; Low et al., 2019; Schein, 2004; Tariq Umar, 2020). Running a search only on the Scopus database (TITLE-ABS-KEY ("safety AND culture") AND TITLE-ABS-KEY (construction AND industry OR sector), more than 927 results where 57% are papers, 35%, and 8% are books or books chapters, 14 are related to frameworks, 81 to models, and 10 belong to literature reviews. Although publications started in 1980, considerable growth began after 2004, with more than 10 papers issued that year. The number of publications constantly increases by approximately 10 papers annually, reaching 85 papers by 2020, and this trend has stayed. (Machfudiyanto & Latief, 2019) are the leading authors with more than 16 publications, followed by Latied, AI-Bayati, and Chan, each with more than 10 publications. (Bahn, 2012b; Choudhry et al., 2007; Fang et al., 2006; Feng, 2013; Sherratt et al., 2011) have around 8 papers. Not only is the safety culture literature overwhelming, but the authors themselves acknowledge the need to develop models and frameworks to navigate this issue.

The 14 frameworks (see Table 1) that were identified on Scopus, a search that was previously presented, were using a deductive approach methodology to be developed. This means the research strategy focuses on testing specific hypotheses originating from previous theories (Fellows & Liu, 2015; Partelow, 2023; Sutrisna, 2009). It has a quantitative focus and facilitates the validation or refutation of existing theories (Partelow, 2023). This method is valuable for confirming or challenging founded knowledge (Sutrisna, 2009). Usually, the first phase involves conducting a literature review of existing research to identify knowledge gaps, relevant theories, and existing models and frameworks, followed by asking for perceptions based on their knowledge and experience on the real-world (Fellows & Liu, 2015). For example, (Junjia et al., 2024), developed a risk framework for assembly construction based on structural equation modelling and stakeholder theory. Misnan and Mohammed (2007), developed a conceptual framework for developing safety culture in the construction sector; in this study, a survey-based approach based on a comprehensive literature review was created to discover corporate characteristics that could impact safety culture. It collected data from 3 companies and received 237 responses, but it excluded data from 1 company and 12 outliers, leaving 196 questionnaires for the final analysis.

Table 1. Frameworks list related to safety culture with a deductive approach.

Number	***Title***	***Authors***
1	Assessing the usability of construction safety culture and climate framework: a crucial method for advancing construction safety	(Al-Bayati et al., 2024)
2	Developing a risk framework for assembly construction based on stakeholder theory and structural equation modelling	(Junjia et al., 2024)
3	A 10-phase safety management framework for Construction small and medium-sized enterprises	(Gunduz & Laitinen, 2017)
4	Development of safety culture in the construction industry: a conceptual framework.	(Misnan & Mohammed, 2007)
5	A framework for measuring corporate safety culture and its impact on construction safety performance	(Molenaar et al., 2009)
6	Safety implementation framework for the Pakistani construction industry	(Raheem & Issa, 2016)
7	Safety Management System (SMS) framework development - Mitigating the critical safety factors affecting health and safety performance in construction projects	(Khalid et al., 2021)
8	Construction safety culture and climate: Satisfying the necessity for an industry framework	(Al-Bayati et al., 2019)
9	Developing an assessment framework for evaluating knowledge-based safety culture in construction organisations	(Deepak & Mahesh, 2024)
10	A conceptual framework for the development of construction safety culture in Indonesia	(Adnan & Baharum, 2020)
11	A safety climate framework for improving health and safety in the Indonesian construction industry	(Lestari et al., 2020)
12	A framework of safety culture for the Malaysian construction companies: A methodological development	(Ismail et al., 2010)

13	A proposed framework for measuring maturity of safety practitionership in construction	(Indrayana & Pribadi, 2023)
14	A framework for enhancing and improving the safety culture on Saudi construction sites	(Alasamri et al., 2012)

When concepts are new or when concepts are overloaded with information, the inductive approach is suggested as a research philosophy (Sutrisna, 2009; Yin, 2016). Not only does it emphasise contextual understanding, but its flexibility characterises it. It is commonly used in qualitative research methods. Still, this approach is also considered in exploratory research, where little is known about a topic, or it is not well explained (Yin, 2016). It facilitates the grasping of the meanings, interpretations, and experiences of participants (Yin, 2016). Grounded theory is an example of the inductive approach, where a theory is based on data collected in the field (Sutrisna & Setiawan, 2016). Inductive research results capture the real-world in detailed descriptions, providing a condensed understanding of the research topic (Sutrisna, 2009; Yin, 2016). It is useful in dynamic research environments where flexibility is required (Yin, 2016).

A conceptual framework is a tool in research that provides a structured approach to understanding and interpreting a research issue (Machfudiyanto & Latief, 2018; Partelow, 2023). It guides the research process, and ensures the findings are relevant, grounded in existing knowledge (Misnan & Mohammed, 2007). It contributes to clarifying the scope of the study (Misnan & Mohammed, 2007; Partelow, 2023). It guides researchers in planning new empirical research by showing which relationships and concepts are of relevance to be associated (Partelow, 2023). Furthermore, frameworks can also arise from the bottom up, by gathering and are great tools to synthesise and communicate ideas among academia and industry (Partelow, 2023). A conceptual framework is usually presented as a visual model, like a diagram or flowchart, that shows the relationships between key concepts, factors, and tools, helping to simplify complex ideas and showing how different elements interact (Partelow, 2023). A framework not only guides the selection of appropriate research strategies and data collection tactics, but also suggests how to interpret data, define concepts, and make relationships by considering the context in which the study is conducted (Partelow, 2023). By integrating multiple theories or perspectives, a conceptual framework provides a comprehensive approach to understanding complex issues (Partelow, 2023). It is easy to adapt or refine as new data emerge, letting introduce adjustments to better capture the reality being studied (Misnan & Mohammed, 2007; Partelow, 2023).

3. Proposing a Methodological Framework Following 5 Phases

This paper presents a five-phase methodological framework (see Figure 1) to facilitate the creation of a framework to promote a safety culture based on an inductive approach. This paper offers procedural recommendations, identifies challenges and best practices, and provides each phase with an example to illustrate the methodological framework created.

3.1 Phase 1: Reaching consensus

To achieve consensus of perceptions based on their knowledge and experience of a group of specialists about concepts in a particular area being studied, a Modified Delphi method is recommended. This method is utilised to gather consensus from experts (Fellows & Liu, 2015; McKay et al., 2022; Mullen, 2003). A Modified Delphi study should involve at least 10 experts, which is known as an "expert panel" (Mullen, 2003). This technique is chosen over the traditional Delphi method because it facilitates consensus among geographically distant experts, includes anonymity among panel members, reduces bias, and collects diverse perspectives (Fellows & Liu, 2015; McKay et al., 2022; Mullen, 2003). The traditional Delphi method engages experts to express their perspectives and reach a consensus on different issues through multiple rounds of data collection, analysis, and feedback (McKay et al., 2022; Mullen, 2003; Raheem & Issa, 2016). The Modified Delphi study allows for two iterative rounds of feedback and discussion to reach consensus views, ensuring participant involvement (Biggs et al., 2013; Nayak & Waterson, 2016). The Expert panel may provide feedback, modify, or add elements to the topic in each round (McKay et al., 2022). The data collection, qualitative and quantitative data, is through two rounds of individual interviews, seminars, focus groups, or questionnaires (Brady, 2015; McKay et al., 2022; Mullen, 2003; von der Gracht, 2012). This method requires at least 75% of the experts from the first round to participate in the second round (Mullen, 2003; von der Gracht, 2012).

For the first round, individual interviews are recommended for data collection. The interview suggests being semi-structured, and unstructured with open questions (Williamson, 2018). Open-ended questions can be adapted to gather qualitative data, allowing researchers to explore "areas of reality that would otherwise remain inaccessible, such as people's subjective experiences and attitudes" (Braun & Clarke, 2006; Herring, 2018). Structured interviews involve asking each respondent (Williamson, 2018). Perceptions questions are usually evaluated using a Likert scale to gauge respondents' attitudes or feelings (Williamson, 2018). In contrast, open questions permit respondents to share their answers openly without being confined to predefined categories, offering richer and more detailed responses (Williamson, 2018). Semi-structured interviews, on the other hand, utilise a planned list of questions with prompts, allowing for flexibility in administration to capture participants' perspectives while ensuring relevance to the study (Williamson, 2018). Unstructured interviews are valuable when a researcher cannot anticipate the interviewee's reactions to a new outcome and has no assumptions about its impact (Williamson, 2018). Recording these interviews to support research findings with direct quotations from participants is important, although recording must only be done with the interviewee's permission (Williamson, 2018). Informed consent from the interviewee, including authorisation to record, should be secured before the interview commences (Williamson, 2018).

For the first round the data analysis suggested: The data collected, qualitative data, in the first round underwent thematic analysis, following the phases outlined by Braun and Clarke (2006), which involved acquainted with the data, creating initial codes, finding patterns and themes, evaluating themes, defining and naming themes (Braun & Clarke, 2006).

For the second round, the proposed data collection method is a survey questionnaire based on the results of the first round. Surveys and self-administered questionnaires are appropriate when exploring a topic that includes personal experiences or thoughts; the anonymity provided by a self-administered questionnaire can motivate respondents to offer honest and truthful answers (Williamson, 2018). Additionally, when prioritising participant privacy is essential, demographic information can be collected via a questionnaire before running interviews. This approach can also be helpful in providing feedback during an experiment, for example (Williamson, 2018). Self-administered questionnaires have the advantage of letting respondents reply at their convenience and are less invasive compared to interviews (Williamson, 2018). They also eliminate interviewer bias, ensuring that questions are asked consistently without visual cues influencing responses (Williamson, 2018). Additionally, data from these answers are reasonably simple to gather and analyse (Williamson, 2018). Closed questions can be categorised as either opinion-based or factual (Williamson, 2018). Factual questions that gather concrete and accurate details are direct, offering respondents categories to choose from that accurately reflect their situation (Williamson, 2018). The data collection could be done through an online form questionnaire based on the results of the first round, employing a Likert scale (Lavrakas, 2008). Lavrakas (2008) notes that Likert response sets can comprise four or more points; while a five-category set is typical, some psychometrics experts suggest utilising response sets with seven, nine, or even eleven points (Lavrakas, 2008).

The second-round data analysis suggestion is that the data collected in the second round is quantitative data through the online survey questionnaire. Firstly, computing Cronbach's alpha coefficient is key when using Likert-type scales to assess internal consistency reliability for the scales used (Tavakol & Dennick, 2011). It includes a preliminary assessment of the questionnaire's internal consistency using Cronbach's alpha (α), which provides internal consistency reliability on a scale from

0 to 1. A value above 0.6 generally indicates moderate reliability, while values closer to 1 suggest higher internal consistency among the items in the questionnaire (Rey-Merchán et al., 2021). Secondly, the relative importance index (*RII*) is computed to evaluate the data gathered from the questionnaire following the technique adopted by following the technique adopted by Ng et al. (2005). *RII* serves as a method to evaluate the relative significance of various variables or factors within a study (Seidu et al., 2022). The *RII* calculation involves assigning numerical values to the ranked positions or ratings provided by participants, followed by computing the average score for each factor (Seidu et al., 2022; Tarek et al., 2022). This index aids in prioritising factors based on their perceived importance within the context of the study (Rey-Merchán et al., 2021; Tarek E., 2022). The *RII* is calculated using the equation formula 1:

$$1) \quad RII = \frac{Sumweightinggiventoeachfactorbytherespondent}{Thehighestweightintheresearch \times Totalnumberofresponders} = \frac{W1+W2+\ldots+Wn}{A \times N}$$

Conducting a pilot study for the open questions of the first round and the questionnaire for the second round is essential (Williamson, 2018). This involves testing the questionnaire with the specific type of respondents identified for the study, who can pinpoint any unclear aspects or issues and potentially provide suggestions for better words or phrasing (Williamson, 2018). Additionally, discussing the interpretations of questions with participants can be particularly beneficial (Williamson, 2018).

3.2 Phase 2: Conducting a systematic literature review

The systematic literature review is suggested following the framework recommended the procedure suggested is about screening literature at distinct stages based on PRISMA (preferred reporting items for systematic reviews and meta-analyses) instructions (Arya et al., 2021; Moher et al., 2009; Page et al., 2021). This method ensures the consistent identification and inclusion of references to the study, which aids in examining and selecting relevant articles for review (Arya et al., 2021; Page et al., 2021). The review comprises five stages: defining the research problems, identifying relevant papers, considering the quality of studies, analysing the results, and interpreting the findings. The eligible papers are analysed using a data extraction spreadsheet with the above research aspects and questions developed (Arya et al., 2021).

3.3 Phase 3: Developing a prototype conceptual framework

The initial prototype conceptual framework can be split into two parts, one based on the results of the Modified Delphi study, and another integrating the findings of the systematic literature review, by drawing conclusions about the differences or similarities, the magnitude of those differences, associations, trends, and practical implications (Partelow, 2023). This will contribute to identifying the current state of the experts' perceptions in a specific field topic and the current literature review by understanding and bringing light to where experts are unaware (Partelow, 2023). This will contribute to visualising if experts' perceptions are aligned with the literature or are discrepancies. This could conclude gaps in the literature, trends, opportunities, challenges, or changes in the field that have not been researched yet (Partelow, 2023).

3.4 Phase 4: Operationalising the prototype conceptual framework

Testing the framework in the real-world will contribute to determining if the framework is applicable and practical and how it operates in practice (Yin, 2016). Case studies serve as a valuable research tool for deeply exploring complex subjects, offering detailed, contextual insights (Sutrisna, 2009; Yin, 2018). They are useful for understanding specific cases within their real-world contexts by gathering relevant information (Fellows & Liu, 2015). Case studies are exploratory, which investigate areas with limited information and set the stage for further research; descriptive, which provide a detailed account of a phenomenon without explaining why it occurs; or explanatory, which explains how or why a phenomenon occurs (Yin, 2018). They emphasise the importance of context by understanding the complexities of a situation (Fellows & Liu, 2015). Case studies involve qualitative data like interviews and induction, also could include quantitative data like surveys and numerical data (Fellows & Liu, 2015). In this approach, the case studies are going to be explanatory clarifying causal relationships, which is convenient for complex processes, like mixing Modified Delphi study outcomes with literature review findings and considerate the practical application of a framework (Yin, 2018). Multiple Case Studies, around 2 to 3, needs to be considered because allows cross-case analysis which can lead to a deeper understanding of how the framework works in different environments and can achieve analytic generalisation (Yin, 2018). Site visits are a research and data collection method where researchers physically visit a location where an induction is performed to gather information about the operational environment by observing, which provides firsthand insights, and conduct interviews with key stakeholders to understand their perspective (Yin, 2018). These are often used in fields such as construction, healthcare, and education to gain firsthand insights from the field (Yin, 2018). The data collected is analysed by using, thematic analysis and cross analysis, identifying general patterns, also can be considered narrative analysis for understanding individual experiences (Fellows & Liu, 2015).

3.5 Phase 5: Refining the final conceptual framework

Based on the findings of stage 4, feedback and findings from the case studies enable analytic generalisation, findings from each case study can be applied to refine and adjust the conceptual framework. even if the results do not represent a larger population (Partelow, 2023; Yin, 2018). This process allows for adjustments based on empirical evidence, making the framework more comprehensive (Partelow, 2023).

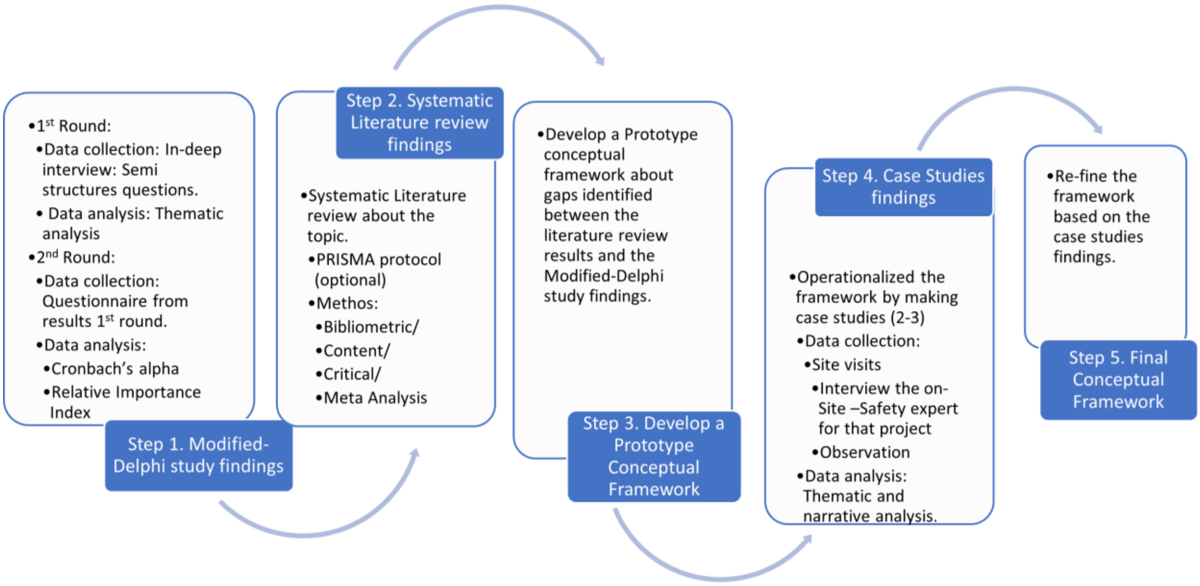

Figure 1. A methodological framework to create a conceptual framework to promote safety culture. (Source: created by the author)

4. Conclusion

In conclusion, this paper has presented a methodological framework designed to develop a framework for weighing the understanding of a relevant construction issue based on an inductive approach. The methodological model is inductive based, as it involves collecting qualitative data, identifying relationships, and developing a framework based on findings. The process starts with open exploration to collect perceptions from experts with open questions and progressively builds towards a conceptual framework, which is characteristic of the inductive approach. Each phase follows from the previous one, building upon the findings in a way that supports inductive research methodology. Thus, it was structured in 5 phases to ensure a comprehensive approach. This approach is suitable for understanding complex construction issues, particularly when there is a need for bridging the gap between theory when is overwhelming, from the Modified Delphi study and literature review, and practice, through real-world refinement. It balances the theoretical with the practical side, making it a valuable tool for academia that leads to better frameworks for the industry. The limitation was the lack of examples of the application of the conceptual framework developed, which opened the door and incentivised researchers to consider when they have to address new knowledge or clarify complex issues with overwhelming literature under specific topics.

Appendix 5: List of Publications

Publications within the thesis

Studies completed during candidature, some of which are reported in this thesis:

Paper	Source	Status	Copyright Transfer Agreement (CTA)
1. Ortega, N., Paes, D., Wing Yiu, T., and Sutrisna, M. 2022. *Understanding the Relevance and Impact of Systems Thinking in the Construction Industry: A Bibliometric Analysis.* [Paper presentation]. The Proceedings of the 45th AUBEA Conference, pp. 123 (Abstract), 23-25 Nov. 2022, Western Sydney University, Australia.	Conference	Published	Yes
2. Ortega, N., Paes, D., Wing Yiu, T., Feng Z., and Sutrisna, M. 2023. *A Systematic Literature Review of the Previous Applications to the STAMP.* [Paper presentation]. Book of Abstracts. 46th AUBEA Conference, pp. 102 (Abstract), 26-28 Nov. 2023, Massey University, New Zealand.	Conference	Published	Yes
3. Ortega, N., Paes, D., Wing Yiu, T., Feng Z., and Sutrisna, M. 2023. *Applying STAMP model through STPA method to facilitate Safety Engineering: A literature review*. [Paper presentation]. The Proceedings of 13th International Conference on Engineering, Project, and Production Management, 2023, Volume 2. pp. 205-217 (paper), 29 Nov-01 Dec. 2023, Massey University, New Zealand.	Conference	Published	Yes
4. Ortega, N., Paes, D., Wing Yiu, T., Feng Z., and Sutrisna, M. 2024. *Investigating the Factors that Define and Influence SC: Perspectives from Expert*	Journal	Published	Yes (by note-Appendix 6)

Professionals. Architecture, Structures and Construction.			
5. Ortega, N., Paes, D., Wing Yiu, T., Feng Z., and Sutrisna, M. 2024. *A Framework for Promoting SC in Construction Sites in New Zealand.*	Journal	Ready to submit	Yes (by note-Appendix 6)
6. Ortega, N., Paes, D., Wing Yiu, T., Feng Z., and Sutrisna, M. 2024. *Towards a Conceptual Framework to Assess the Understanding of a Relevant Construction Issue: Proposing a Methodological Framework*. The Proceedings of the 47th AUBEA Conference. Nov. 2024, Victoria University, Australia.	Conference	In press	Yes (by note-Appendix 6)
7. Ortega, N., Paes, D., Wing Yiu, T., Feng Z., and Sutrisna, M. 2025. *Operationalising a Safety Culture Framework: Applicability and Practicality in Real-world Settings.*	Journal	Ready to submit	Yes (by note-Appendix 6)

Publications and Reports outside the thesis

1. Guan J., Kordestani Ghalenoei N., Mahmoodi M., Ortega N., Ranjan M. 2022. Report: "Lessons Learned from the Impact of Covid-19 – A case study of skill shortage on the construction workforce". International Council for Research and Innovation in Building and Construction Massey Student Chapter.
2. Guan J., Kordestani Ghalenoei N., Mahmoodi M., Ortega N., Ranjan M. 2024. Report: "Work-Life Balance (WLB) of Women Professionals (on-site and off-site) in the New Zealand Construction Industry and Potential Opportunities for Improvement". International Council for Research and Innovation in Building and Construction Massey Student Chapter.
3. Ortega N., Perera J., Galster M., Blincoe K. 2024. Report: "Ensuring Trust and Integrity in Software Systems: Identifying, Integrating, and Measuring Veracity Requirements Technical Debt: A Systematic Literature Review." Veracity Lab. https://veracity.wgtn.ac.nz/wp-content/uploads/2024/07/Literature_Review_Veracity_03072024ON.pdf

Posters outside the thesis

1. Perera J, Culas F, Ortega N, Blincoe K., Tempero E, Yu-Cheng T., Galster M. 2024. Poster: "Veracity Requirements Debt in Software-based Technology: Literature Review (initial analysis) and Real-

World Example”. Veracity Lab. https://veracity.wgtn.ac.nz/wp-content/uploads/2024/06/Judith-Perera.pdf

List of awards

1. Massey University Doctoral Scholarship 2022
2. Massey University Foundation Peer Scholar Award 2023
3. Head of School Postgraduate Excellence Award Cup - School of Built Environment 2022
4. The student investment club 2023 – Leadership Award. School of Business

Appendix 6: Statement of Contribution

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UNIVERSITY OF NEW ZEALAND

GRADUATE RESEARCH SCHOOL

STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Natalia Ortega
Name and title of main supervisor:	Professor Monty Sutrisna
In which chapter is the manuscript/published work?	Chapter 4

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

Literature review, research design, data analysis, drafting and revising the manuscripts. Paper Investigating the Factors that Define and Influence Safety Culture: Perspectives from Expert Professionals. Architecture, Structures and Construction. https://doi.org/10.1007/s44150-025-00130-w

Please select one of the following three options:

- (●) **The manuscript/published work is published or in press**
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Student name:	Natalia Ortega
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Please provide the full reference of the research output:

○ **The manuscript is currently under review for publication**

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Name and title of main supervisor:	Professor Monty Sutrisna
In which chapter is the manuscript/published work?	Chapter 6

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

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Please select one of the following three options:

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  Please provide the full reference of the research output:
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Student name:	Natalia Ortega
Name and title of main supervisor:	Professor Monty Sutrisna
In which chapter is the manuscript/published work?	Appendix 4

Describe the contribution that the student and members of the supervisory team have made to the manuscript/published work:[1]

Literature review, research design, data analysis, drafting and revising the manuscripts, present at AUBEA conference 2024.

Please select one of the following three options:

- (●) **The manuscript/published work is published or in press**
  Please provide the full reference of the research output:
- ( ) **The manuscript is currently under review for publication**
  Please provide the name of the journal:
- ( ) **It is intended that the manuscript will be published, but it has not yet been submitted to a journal**

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