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RESEARCH

Investigating the factors that define and influence safety culture: perspectives from expert professionals

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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 analyzed 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 organizations.

Keywords Construction Industry · Safety Culture · Critical Factors · Delphi Study · Safety Experts

Introduction

Safety is one of the main factors affecting labor productivity in the construction sector [30], 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 [52, 56]. As per Gambatese and Hinze [25], 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 organizations to ensure the success of construction projects [48].

Promoting a Safety Culture (SC) across the sector can help reduce both the frequency and severity of accidents and incidents [4, 14, 17]. A positive SC needs to be cultivated at both the organizational and project levels [16, 19, 26, 54, 86]. The implementation of any new safety plan, policy, or tool is significantly influenced by the prevailing SC [1, 5, 74].

Nonetheless, promoting SC in the construction industry has always been challenging [19, 40], particularly during the execution phase on construction sites [1]. Choudhry et al. [17], Feng [21], Fang and Wu [20], and Hartley and Cheyne [28] argue that fostering SC at the project level can enhance the safety performance of organizations. However, Schein [64] highlights that each organization 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 [61]. In New Zealand (NZ), 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 [72, 80]. This represents a significant increase from the lowest registered number of work-related injury claims, which was

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26,000 in 2011 [81]. Furthermore, there were 12 fatalities in both 2021 and 2022 [82]. Despite the Harm Reduction Action Plan [2], 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 NZ'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 NZ's aging workforce. Native-born workers are found to have lower rates of injuries than migrant workers in NZ [63]. Māori and Pasifika workers experience higher rates of work-related injuries compared to other ethnic groups [63]. These multifaceted issues underscore the critical need for a holistic approach to SC to enhance both safety and competitiveness in NZ's construction sector.

A thorough bibliometric analysis by Otitolaiye et al. [60] revealed that despite growing research on the topic, the concept of SC in the construction industry remains ambiguous [7, 78]. Identifying the factors that define and influence SC is essential for gaining a better understanding of how to effectively promote it [64]. 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 industry.

Background

Safety culture definitions

The concept of Safety Culture was first introduced after the Chernobyl disaster in 1986 [67]. It relates to the set of shared values, expectations, and beliefs that impact a group's health and safety behavior [13, 51]. The Advisory Committee on the Safety of Nuclear Installations (ACSNI) defines the SC of an organization as "the product of individual and group values, attitudes, perceptions, competencies and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management" [78]. Wu et al. [83] defined SC as the shared values, perceptions, and behavioral norms set by leadership and shaped by their actions across various stakeholder levels within construction projects. Fang and Wu [20], Choudhry and Fang [15], Choudhry et al. [17], and Md and Mahesh [43] defined SC as a blend of safety attitudes, beliefs, values, behaviors, and norms shared by persons and groups in a construction project.

Harvey et al. [29] and Lingard et al. [35] 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. [35] defined SC as a fundamental set of beliefs and assumptions regarding safety within an organization, 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 Wu et al. [84], Sizemore [70], and Meliá [45], view the two concepts as similar, often using them interchangeably.

Misnan et al. [46] defined SC as a hierarchy of national, organizational, and vocational culture manifested by intrinsic and extrinsic factors such as values, beliefs and assumptions, norms, rituals, symbols, and behaviors. Mohamed and Chinda [47] presented a holistic definition of SC, emphasizing the role of various organizational 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 organization [47]. Similarly, Molenaar et al. [49] identify five latent variables that define corporate SC, including an organization's commitment to safety, incentives for safe performance, subcontractor involvement, safety accountability, and disincentives for unsafe behaviors. These authors offered a comprehensive, holistic view for defining and better understanding of SC within organizations. More recently, Trinh and Feng [76] introduced the concept of Resilient Safety Culture, which refers to an organizational 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 [1, 64, 86].

Safety culture factors

Identifying the factors (see Table 1) that contribute to both unsafe and safe practices is essential for establishing a strong SC [1]. Hudson [31] proposed a model based on the Health, Safety, and Environment (HSE) Culture ladder for the continuous advancement of SC and the creation of lasting behavioral change. This model outlines stages progressing from pathological behavior in a low-information, low-trust, and low-accountability environment to generative behavior in an environment characterized by high levels of information, trust, and accountability. Fang and Wu [20] developed a model where the person, the behavior,

Table 1 Factors that affect safety practices

Factors	Authors
Environmental factors and individual behavioral factors	Hudson [31]
Environmental factors and individual psychological factors	Fang and Wu [20]
Communication, safety education and training, and supervision	Zhang et al. [85], Wamuziri [79], Wu et al. [84], Lingard et al. [37]
Organizational structure and commitment to safety	Brett & Bradley [11], Wamuziri [79], Machfudiyanto & Latief [39], Namian et al. [54], Namian et al. [53]
Commitment to safety	Fred & Farrell [22], Schwatka et al. [65]
Subcontracting model	Zou et al. [87], Musonda et al. [51], Fuller et al. [23]
The technical complexity of projects	Orogun & Issa [59], Trinh & Feng [76]
The uncertainties of an uncontrolled environment	Fang & Wu [20], Orogun & Issa [59]
Differences in risk perception	Ricci et al. [62]
Leadership from supervisors	Lingard et al. [36], Guadix et al. [27], Shen et al. [68], Mazzetti et al. [41], Solomon & Esmaeili [71], Kineber et al. [33]

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 [37, 79, 84, 85]. Other factors related to organizational structure and commitment to safety were also found to influence SC [11, 53, 54]. Furthermore, commitment to safety should be promoted by encouraging the active involvement of all employees rather than being enforced solely through rules and procedures [22, 65]. Developing an organizational culture that values safety as a core principle is essential [39, 79].

One of the factors affecting the successful implementation of H&S promotion programs is the construction industry's subcontracting model [87]. 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 [23, 54]. 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 [23, 51]. Other aspects unique to the construction sector, such as the environment and the technical complexity of projects, also impact SC [59, 76]. The uncertainties of an uncontrolled environment and the overall dynamic nature of the sector affect SC [20, 59]. In addition, the challenge of addressing differences in risk perception related to workers' ethnicity and cultural background adds complexity to safety promotion [62].

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 [33, 68], keep workers informed of policies and procedures, provide clear safety guidelines [33, 41], and provide personalized interventions tailored to individual worker characteristics [27, 36, 71].

Collectively, these factors underscore the multifaceted nature of SC and the challenges associated with its promotion, emphasizing the importance of a comprehensive and tailored approach to enhance safety practices and outcomes in the construction industry [1].

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 "Data Collection Methods"). Data were analyzed using Thematic Analysis and Relative Importance Index (RII) (described in detail in Section "Data Analysis Methods").

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 [50]. The Delphi method offers several advantages: it maintains the anonymity of panel members to minimize potential bias, accommodates geographically dispersed participants and groups, and enables the collection of diverse insights from numerous experts [50, 77]. 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 [3, 42]. While the traditional Delphi method typically involves three or more rounds of interaction [9, 55], the modified version requires only two rounds and a minimum of 10 experts [38, 42, 77]. Therefore, adopting a modified Delphi method shortens the process, ensuring sustained participant involvement [42]. 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 [9, 50, 77].

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 [50, 55]. 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 [34].

Ultimately, exceeding the requirements of the modified Delphi study [9, 50, 77], 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 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 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

Data collection methods

Modified delphi method – first round (Interviews)

Round one consisted of in-depth, semi-structured, online, individual interviews conducted with the panel of experts [9]. 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 [10, 34]. 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 [32]. 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 [34].

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 min, depending on the participant's willingness to share and elaborate on their responses.

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 [9, 10]. This evaluation was conducted using an online survey questionnaire based on a Likert scale, which allowed experts to rate the importance of the factors [34, 57].

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 3.

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

Table 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 organization, including management, workers, and contractors
c)	*Human-Centered Approach*: behaviors and interactions that promote a sense of belonging and inclusion within the safety culture
d)	*Integration and Organization*: SC, as an inherent part of the organization, 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 Prioritization*: 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
Cluster 2 (influencing factors) Likert scale range: 1 (less important) – 5 (very important)	
a)	*Client Understanding*: clients lack an understanding of the importance of health and safety
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 standardized safety practices across multiple subcontractors is a challenging task
d)	*Leadership Commitment*: lack of leadership support can hinder the development of a strong safety culture, underscoring the need for commitment from leadership
e)	*Experience and Mindset*: inadequate attitudes and beliefs often result in failure to recognize 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

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.

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 [50, 77]. Additionally, they were informed about the confidentiality and anonymity of their responses. Finally, the responses were analyzed using Thematic Analysis and the Relative Importance Index (RII), ensuring consistent and objective interpretation of the data [10, 58, 66, 75].

Interviews

To analyze the data from round one (interviews), a thematic analysis was conducted following the systematic approach outlined by Braun and Clarke [10]. The data were organized thematically using NVivo version 14, a software application that allows for structuring qualitative, content-rich textual data [24]. 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 labeling 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.

Survey

To analyze 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 [58]. 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 [58].

Second, the RIIs 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 [66, 75]. 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 RIIs are calculated using Eq. 1:

$$RII = \frac{Total\ weight\ given\ to\ each\ factor\ by\ there\ spondent}{The\ highest\ weight \times Total\ number\ of\ respondents} = \frac{W1 + W2 + ... + Wn}{A \times N} \quad (1)$$

In Eq. 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 "Modified Delphi method – second round (Survey)". "A" denotes the highest possible weight (i.e., 4 or 5), and "N" is the total number of respondents, which is 26.

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 [6, 69, 73].

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 [12, 44].

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).

Safety culture defining factors

Results of thematic analysis (Interviews)

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

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 emphasized 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 organization. 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.

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 organization, including management, workers, and contractors. Expert ID06 discussed the need for building a culture that prioritizes 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, emphasized 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.

Human-centered approach This factor indicates that SC relies on behaviors and interactions that promote a sense of belonging and inclusion within the safety culture. The frontline workers are essential to SC, and their understanding and support are crucial. Expert ID26 emphasized the importance of the competence of operators, planners, supervisors, and

Fig. 1 Factors that define SC

senior management in building SC. ID28 highlighted the need for engagement and understanding of safety from both top management and workers.

Integration and organization This factor indicates that SC is an inherent part of the organization, 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 organization'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 organizational culture and safety, emphasizing the need for clear values and outcomes, as well as the integration of safety principles into every aspect of the business.

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 recognizing 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 emphasized the need for open and respectful communication between workers and management to build trust. ID24 underlined the importance of prioritizing safety within an organization. ID29 defined SC as the day-to-day practices within a business or site. ID32 placed a strong emphasis on prioritizing safety.

Resource allocation and prioritization 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 emphasized 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 prioritizing 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 organization. ID31 stated that safety deserves top priority within an organization.

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-Centered Approach' (RII = 0.94), 'Integration and Organization' (RII = 0.90), 'Foundational Principles' (RII = 0.89), and 'Resource Allocation and Prioritization' (RII = 0.88) (see Table 4).

Safety culture influencing factors

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 Fig. 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 "Results of Thematic Analysis

Table 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-Centered Approach	0	0	6	20	0.94	3
Integration and Organization	0	2	6	18	0.90	4
Foundational Principles	0	1	9	16	0.89	5
Resource Allocation and Prioritization	0	3	6	17	0.88	6

Fig. 2 Factors that influence SC

(Interviews)"). 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 "Results of Thematic Analysis (Interviews)"). 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': $0.93/4.90 \times 100 = 18.98\%$. This calculation is repeated for each factor. These percentages provide the size of the slices in the diagram.

The barriers in Fig. 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.

Level of client understanding The data suggest that, from the experts' perspective, the level of client understanding of the importance of health and safety, 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 prioritization 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 emphasized that some clients prioritize cost over other factors, which can hinder the promotion of SC.

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 emphasized the challenges in improving 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 a robust 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.

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 standardization 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 a robust 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 safety culture 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.

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 organization. Meanwhile, ID06 emphasized 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, emphasizing 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 organization – not just as a priority but as a way of life.

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, behaviors, and driving cultural change within organizations. 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 behaviors, making it challenging to implement improvements or adaptations. ID26 commented that safety is often treated as being compartmentalized or isolated from other aspects, thus not fully integrated into the broader organizational culture.

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 emphasized that when a project falls behind schedule, it can lead to poor decision-making, impacting safety.

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

Table 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

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 5).

Causal loop diagram of safety culture influencing factors

The CLD in Fig. 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) [6, 69].

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

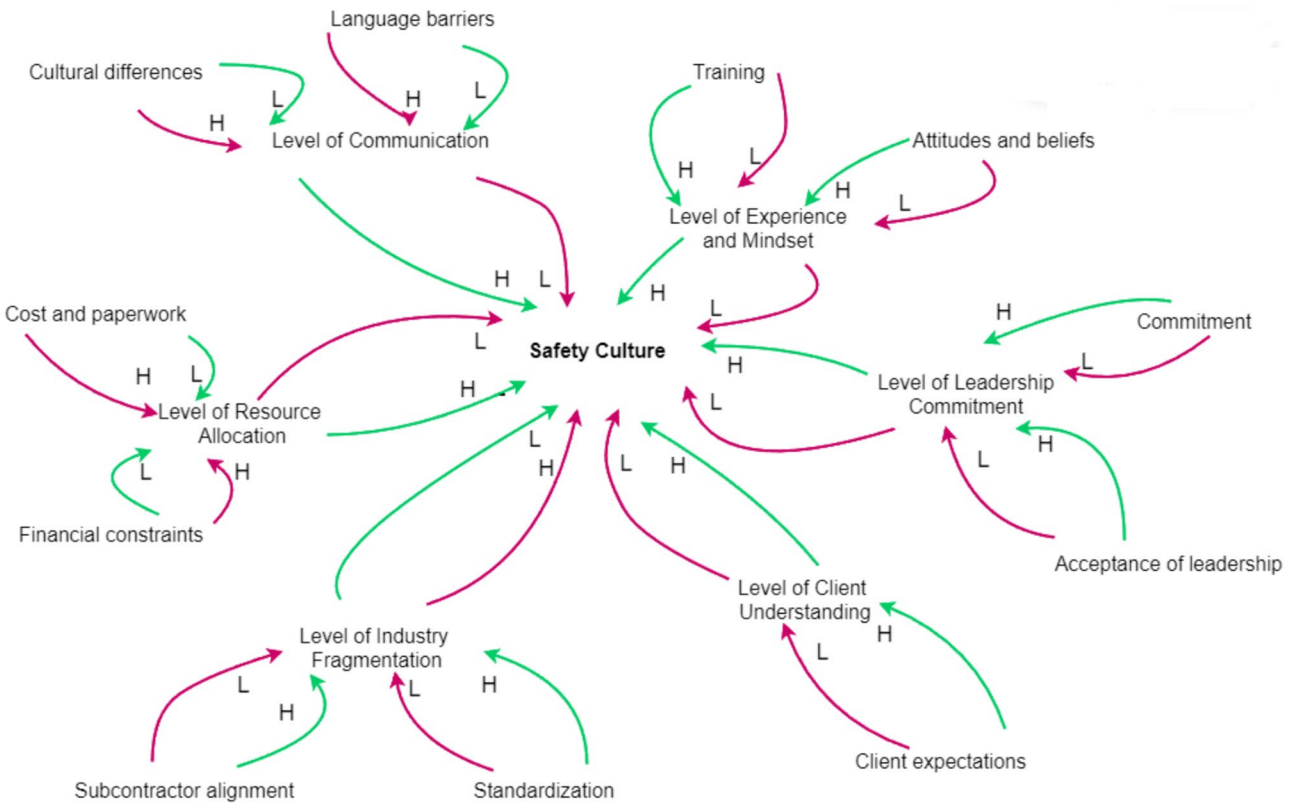

Fig. 3 Causal Loop Diagram showing the relationships among the factors that define and influence SC

'Level of Leadership Commitment' (L), which negatively impacts SC (path with red arrows).

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.

Discussion

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 organization (e.g., [1, 13, 17, 18, 51, 78, 86]).

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-Centered Approach.' The factors considered less important but still relevant in defining SC were 'Integration and Organization', 'Fundamental Principles', and 'Resource Allocation and Prioritization.' The defining factors identified are consistent with previous research, such as that of Mohamed and Chinda [47], 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. [49] identified five latent variables describing corporate SC: commitment to safety, incentives for safe performance, subcontractor involvement, field safety accountability, and disincentives for unsafe behaviors. 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 behavior, where the following elements are present: (a) strong communication and engagement between management and workers; (b) self-leadership and accountability; (c) behaviors and interactions that promote a sense of belonging and inclusion; (d) deep integration of safety into the organization'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.

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. [8] emphasized the management's pivotal role in Australia,Abdullah and Wern [1] also highlighted leadership among various factors in Malaysia,Opoku et al. [58] identified key aspects, with leadership ranking as the top factor in China. This study's findings suggest that NZ 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). Recognizing and addressing cultural diversity and language barriers is also essential for improving SC, which makes the development of cultural proficiency skills a potential area of focus (Level of Communication). In NZ, 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 [63]. Moreover, ensuring subcontractor alignment and standardized safety practices can help the industry overcome fragmentation issues and foster a robust SC (Level of Industry Fragmentation). As previously mentioned, having a unified and committed leadership team that values safety as a core aspect of their organizational 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 NZ, considering the decline in the prioritization of H&S among NZ construction employers [63]. 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 NZ 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 Fig. 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 [31], BRANZ, 2024). 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' [33, 68]. Ultimately, this supportive leadership helps strengthen SC within the organization. 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 Fig. 3), meaning limited implementation of safety practices and poor safety performance [1, 5]. This weak SC will perpetuate the frequency and severity of accidents [4, 14].

It should be noted that while the CLD can be utilized 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.

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 analyzed using Thematic Analysis to identify themes, while the survey data were processed using the Relative Importance Index (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). Typically, a modified Delphi study requires feedback from a minimum of 10 experts across two rounds to achieve saturation. However, in this research, a significantly larger panel of 32 experts participated, providing a robust sample size that greatly exceeded the minimum requirements.

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 recognizing 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 generalizability 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 operationalized through an actual tool or artifact, which would facilitate its practical application in establishing and promoting SC in the construction sector.

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Data availability Anonymized data is provided within the manuscript. All additional data are confidential in nature and may only be provided with restrictions (e.g., anonymized) by the corresponding author upon reasonable request.

Declarations

Ethics approval The study plan was developed in accordance with Massey University's Code of Ethical Conduct for Research, Teaching, and Evaluations Involving Human Participants. It was reviewed and approved by Massey University's Ethics Committee (Ethics notification number: 4000027113).

Consent to participate Participant Consent forms are part of the data collection instruments, and individual forms have been obtained from each participant. The participants digitally signed the form, providing their consent to participate in the study and agreeing to the publication of their anonymized data and responses for research purposes. These forms are not made public as they contain sensitive information, such as participants' names and contact details.

Competing Interests The authors declare no competing interests.

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