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Exploring Safety Management Measures and Factors in Construction: A Qualitative Study

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Abstract

This study employed a qualitative research method to explore the safety management measures and influencing factors at construction sites through in-depth interviews with practitioners at various levels of the construction industry. The study found that safety management measures mainly include three levels: technical engineering measures, management control measures, and personal protection measures. Their actual effects are jointly influenced by factors at the organizational, group, and individual levels. Safety investment, leadership commitment, and subcontract management model at the organizational level, safety culture and manager leadership at the group level, and safety knowledge and risk perception ability at the individual level all have a significant impact on the effectiveness of safety management. The study specifically highlighted that group factors play a key mediating role in safety management, conveying organizational policies and guiding individual behaviour. Based on this, the study recommends building a multi-level, integrated safety protection system and implementing differentiated safety management strategies to improve the effectiveness of construction safety management.

Keywords: Building safety; safety management measures; group dynamics; qualitative research

1. Introduction

As a pillar of the national economy, the construction industry's safety and production conditions have always attracted considerable attention. However, the construction industry has long been a sector with a high incidence of accidents and prominent safety risks. According to statistics from the International Labor Organization (ILO), construction workers account for only 7% of the global workforce, yet fatalities from accidents account for 30-40% of all occupational fatalities (Ahmad et al., 2025). In China, the safety and production situation in the construction industry is equally severe. Despite government regulatory agencies continuously strengthening safety oversight, accidents still occur, seriously endangering the lives of workers and social stability. A recent notice issued by the State Council's Work Safety Commission Office specifically emphasized the need to "resolutely curb construction accidents and strictly investigate rushing deadlines, rushing schedules, and reckless construction practices," (The State Council Work Safety Commission Office, 2025) reflecting the ongoing challenges facing construction safety management.

The occurrence of construction safety accidents is often not accidental, but the result of the combined effects of management system defects and human factors. Existing studies have shown that more than 80% of construction accidents are directly or indirectly related to unsafe human behaviour (KAO, 2020). However, traditional construction safety research mainly uses quantitative methods. Although it can reveal the correlation between variables, it is difficult to deeply explain the implementation process of construction safety management measures in actual work and the multiple influences they are subject to. In addition, existing research pays relatively little attention to group interaction processes and organizational culture factors in safety management. Various forces within the group can have a significant impact on individuals, providing new ideas for optimizing and improving the unsafe behaviors of construction managers (Li, 2016).

This study employed a qualitative research method, gathering the experiences and perspectives of practitioners at different levels of the construction industry through in-depth interviews. The study examined safety management measures and their influencing factors in the construction industry. The study focused on three questions: First, what are the key safety management measures implemented on construction sites, and what is their actual effectiveness? Second, what factors influence the effective implementation of these safety management measures? Third, how do these factors interact to influence construction safety performance jointly? By answering these questions, this study aims to provide deeper theoretical insights and practical guidance for construction safety management, contributing to the continuous improvement of safety performance in the construction industry.

2. Literature Review

2.1 Research on Building Safety Management Measures

Traditional safety management measures mainly focus on three levels: technical engineering, management control, and personal protection. Technical engineering measures focus on eliminating or controlling sources of danger through inherent safety design, such as the support design of deep foundation pits, stability calculations of scaffolding, and safety protection of temporary power systems (Dewlaney & Hallowell, 2012). Management control measures constitute the core of safety management, covering the establishment of a safety responsibility system, the investigation and management of hidden dangers, safety education and training, and the formulation and practice of emergency response plans (Yang et al., 2023). Personal protection measures emphasize equipping workers with and supervising their correct use of personal protective equipment (PPE) (Nikulin & Romanov, 2017).

Relying solely on the measures above is often insufficient to cope with the complex and dynamic nature of construction sites. Therefore, researchers have begun exploring more systematic management models. For example, the concept of modular management has been introduced, breaking down complex construction safety management systems into relatively independent yet interrelated functional modules, such as construction safety plans, safety warnings, accident handling, accident analysis, and safety measures. This reduces management complexity and improves the efficiency of specialized handling. At the same time, Zhao (2018) indicates that companies need to balance guaranteed safety costs (such as investment in education and training, and safety facility costs) with loss-making safety costs (such as direct and indirect losses caused by accidents), optimizing total safety costs and improving safety performance through scientific and rational proactive investment. With technological advances, artificial intelligence methods such as deep learning have begun to be applied to the field of construction safety (Chakkravarthy, 2019). For example, image recognition is used to automatically monitor unsafe behaviours of on-site personnel (such as not wearing hard hats)

(Liu et al., 2021), and sensor data is used to predict equipment risk status, providing new technical means for preventing safety accidents (Zhang et al., 2017).

2.2 Factors Affecting Safety Management in Construction

A single factor does not determine the effectiveness of construction safety management; rather, it is related to multiple factors, including organizational, group, and individual factors. Reason (1998) argues that underlying organizational deficiencies interact with local workplace conditions, ultimately leading to accidents. At the organizational level, the adequacy and sustainability of safety investment is the foundation, including financial and resource support for safety facilities, education and training, and staffing (Feng, 2013). Insufficient investment directly restricts the effectiveness of management measures. In addition, the fundamental importance that senior management attaches to safety, as reflected in their resource allocation decisions and the signals conveyed by their daily words and actions, is also related to the safety atmosphere of the organization (Flin & Yule, 2004). Since the construction industry typically employs a tiered subcontracting model, the general contractor's control over the subcontracting team's safety is often weakened. There is a significant difference between the subcontractor's own management level and willingness to invest in safety, which can easily lead to management loopholes (Song, 2013). In addition, unreasonable pressure to complete the construction period will force the site to simplify safety procedures, resulting in an increased risk of cross-operation, which is a significant inducement to accidents (Chen et al., 2023; Han et al., 2014).

While organizational factors lay the environmental foundation, a growing body of research emphasizes that group-level factors play a crucial mediating role. At the group level, safety climate has been shown to influence employee safety behavior significantly (Abeje & Luo, 2023; Al-Bayati, 2021; He et al., 2020; Liu et al., 2015). Zohar defines safety climate as the "molar and unified set of cognitions (held by workers) regarding the safety aspects of their organization." (Zohar, 1980) These perceptions and beliefs can be influenced by the attitudes, values, opinions, and actions of other workers in an organization, and can change over time and in response to circumstances. Supervisors and peer norms mediate the relationship between macro-organizational procedures and micro-individual compliance. When group dynamics align with safety goals, they amplify organizational intent; however, when they diverge, they create a distinct local climate that often overrides formal rules (Griffin & Neal, 2000; Lingard et al., 2019). Positive group safety norms can create intense conformity pressure, guiding individuals to adhere to safety procedures. Conversely, negative "shortcut" thinking can foster unsafe behaviour. Managerial safety leadership can help shape safety culture (Ciekanowski et al., 2025) and buffer frontline workers against organizational pressures to rush (Al-Bayati, 2021). The quality of safety communication, including the clarity and timeliness of information dissemination, as well as the availability of feedback channels, directly impacts the efficiency of hazard detection and risk control (Hong & Cho, 2023). Government safety regulatory policies, the scientific nature of the standards system, and the strictness of its implementation constitute the external environment that influences all market participants (Gao et al., 2019; Umeokafor et al., 2022). This highlights that the group is not merely a collection of individuals but a distinct structural layer that processes organizational inputs and shapes individual outputs.

Ultimately, these macro and meso-level forces converge at the individual level, where safety outcomes are realized. Construction workers' safety knowledge and operational skills form the foundation of safe behaviour (Alshammari et al., 2025). However, Endsley (1995)'s discussion of situational awareness and Bhandari et al. (2020)'s research on construction hazard recognition show that knowledge alone is insufficient. Workers' safety attitudes and risk perceptions significantly influence their decision-making tendencies when faced with risks, which are deeply shaped by their experience, personality, and perception of the severity of consequences (Renn, 1998; Wang et al., 2016; Xia et al., 2017). Recent research has increasingly focused on psychological factors, such as resilience, work stress, and role ambiguity. These factors are closely related to safety performance, as they influence workers' attention, judgment, and decision-making (Tong et al., 2023). Fang et al. (2016) suggest that unsafe behaviours among construction workers result from the interaction between their cognitive processes and the external environment.

Currently, most quantitative studies explore the influence of different factors at a single level, such as using SEM to investigate the relationship between safety atmosphere, safety behavior, safety performance and safety outcomes (Amirah et al., 2024; He et al., 2020; Lyu et al., 2018; Zahoor et al., 2017). However, there is little research on the relationships between organizations, groups, and individuals at the macro level. By employing a qualitative method, this study aims to move beyond mere correlation to explore the mechanisms of influence, providing a nuanced understanding of how safety management measures are actually experienced, interpreted, and modified by practitioners at the organizational, group, and individual levels.

3. Method

This study employed a qualitative research design, collecting data through in-depth semi-structured interviews. The aim is to explore safety management practices and their influencing factors in the construction industry. Qualitative research methods are particularly well-suited for exploratory research, as they enable an understanding of social phenomena in natural contexts, capture participants' experiences and perspectives, and generate a deeper understanding of complex phenomena. Compared to quantitative research, qualitative methods provide richer and more contextualized data, helping to uncover the complex interactions and underlying mechanisms in construction safety management.

3.1 Participants

Drawing on the sampling strategy used in a study of construction workers in Bangladesh, this study employed purposive sampling to select participants who could provide rich, relevant information in response to the research questions. Access was gained through the researcher's professional network and site-level gatekeepers who facilitated introductions to diverse project teams. To ensure the richness and representativeness of the information, clear inclusion and exclusion criteria were established. The inclusion criteria included: (1) having worked in the construction industry for at least one year; (2) currently holding a specific position in a project under construction; and (3) voluntarily participating in the research and signing an informed consent form. The exclusion criteria included: (1) temporary or short-term workers (working for less than three months); and (2) non-frontline personnel such as administrative staff.

The study was conducted in strict compliance with ethical standards and received formal approval from the Institutional Review Board (IRB) of Gonzaga University prior to data collection. All participants received written research briefing before the interview, clearly outlining the research objectives, data usage, confidentiality measures, and withdrawal rights. The informed consent process employed a double confirmation mechanism: first, researchers verbally explained the research details, followed by participants signing a written consent form. To protect participant privacy, all identifiable information was anonymized, and interview recordings and text data were stored in an encrypted format. Specifically, digital data was stored on secure, air-gapped drives with limited access permissions, and a strict data retention schedule was established to ensure the permanent deletion of raw audio files after analysis.

Finally, we recruited 32 participants from various construction projects in Shenzhen. Shenzhen was selected as the primary study location because its rapid urbanization and high density of complex infrastructure projects make it a representative microcosm of the challenges facing the modern Chinese construction industry. By focusing on this high-activity region, the study captures the intensity of safety management issues in fast-paced development environments, enhancing the transferability of findings to similar urban contexts. Participants included project managers, safety supervisors, team leaders, and frontline workers, ensuring a diverse range of perspectives and experiences.

Table 1. Basic information of participants

Category	Sub-category	Project Managers (n=6)	Safety Supervisors (n=8)	Team Leaders (n=8)	Workers (n=10)
Age	-	35-52	28-45	30-48	22-28
Education	Higher Education	6	7	2	0
	Vocational/High School	0	1	5	5
	Junior High or Below	0	0	1	5
Household Registration	Outside Guangdong Province	0	2	3	7
	Guangdong Province (excluding Shenzhen City)	2	4	3	2
	Shenzhen City	4	2	2	1
Firm Size	Large (State-owned)	4	5	4	4
	Medium (Private)	2	3	4	6
Project Types	Commercial Building	2	4	3	3
	Residential Building	2	3	3	5
	Public Building	2	1	2	2
Avg. Experience	Years	12.5	7.5	6.5	4.3

All participants come from construction companies with active projects, including commercial, residential, and public buildings. Table 1 provides a breakdown of participant demographics to facilitate an assessment of transferability (The detailed information could be found in Appendix 2). Participants' years of experience range from 2 to 25 years, ensuring they possess extensive industry knowledge and can offer valuable insights.

3.2 Data Collection and Analysis

Data collection was conducted through semi-structured in-depth interviews, using a pre-designed interview outline as a guide while maintaining sufficient flexibility to explore new topics that emerged during the interview process. The interviews were conducted by a researcher with a background in construction management, possessing five years of experience in construction project management and familiarity with the interview research process. To minimize research bias, the research team conducted regular reflective discussions, documenting and reviewing presuppositions and concepts that could potentially influence data collection and analysis.

The researcher's positionality as an "insider" significantly shaped the data collection process. On the one hand, the shared technical vocabulary and understanding of site hierarchies enabled immediate rapport with Project Managers and Safety Supervisors, facilitating a deep dive into complex technical measures such as BIM and deep foundation pit designs. However, this proximity also presented a risk of "taken-for-granted" assumptions where both the interviewer and the participant might bypass the underlying social drivers of safety violations.

Given the interviewer's management background, there was a risk that frontline workers might view the interaction as a performance assessment or feel compelled to provide correct answers rather than honest ones. To address this, the researcher adopted a "learner" stance during interviews with workers, deliberately asking for explanations of basic tasks to dismantle the image of a corporate authority figure. The researchers emphasized their role as independent academic observers to identify management biases among interviewees (e.g., a greater focus on "compliance" than on "employee well-being"). Besides, the interviewer maintained a reflexive journal during data collection and analysis, documenting moments where personal assumptions or insider knowledge might have influenced question framing or interpretation. These reflections were discussed in weekly debriefs with the his supervisor to ensure interpretive transparency.

The interview outlines mainly included the following aspects: (1) the participants' work background and experience; (2) the safety management measures implemented in their projects; (3) the effectiveness of these measures and implementation challenges; (4) factors affecting safety management; and (5) safety suggestions and improvement ideas.

The interviews were conducted between March and June 2025, each lasting between 45 and 90 minutes. With the participants' consent, the interviews were fully audio-recorded. Interviews with workers were conducted in a safe area on-site, allowing them to express their views more freely in a familiar environment. Additionally, we collected safety documents and records from the project to enhance the accuracy of the interview data.

Interview recordings were transcribed verbatim and analysed using a thematic analysis approach. The analysis followed the six steps: familiarization with the data, generating initial codes, generating themes, reviewing themes, defining and naming themes, and writing the report (Braun & Clarke, 2006). Manual coding was used. The coding process was performed by two independent researchers, who achieved coding consistency through continuous comparison and discussion. The calculated Cohen's kappa was 0.87, indicating good coding reliability. No new theme emerged in the interview data after the 28th interviewee, therefore, this study reached data saturation at the 28th interviewee.

Based on the literature review, broad categories such as "organizational factors," "group factors," and "individual factors" were pre-defined, but specific codes within each category were extracted inductively from the data. The analysis followed a rigorous code-to-theme development process. Initial codes captured specific behaviors or conditions (e.g., "veteran workers take the lead"), which were then grouped into categories (e.g., "Safety Culture"), and finally aggregated into overarching themes (e.g., "Group Factors"). The coding framework is shown in Appendix 3 and 4. To maintain the rigor of the analysis, the viewpoints of participants that contradicted the mainstream view were retained. Handling discrepant cases involves three main steps. The first step is identifying data that contradicts the dominant trends or initial assumptions. Then, it is analyzed to understand why the discrepancy exists. The final step is adjusting the coding framework to accommodate these cases.

4. Findings

4.1 Safety Management Measures For Construction Sites

4.1.1 Technical Engineering Measures

Interviews revealed that construction sites generally employ a variety of technical and engineering measures to ensure safety. These measures primarily target high-risk operations and hazards on the construction site, eliminating or controlling risks through engineering and technical means. A project manager explained:

> *"For hazardous and major projects such as deep foundation pits, high formwork, and large machinery and equipment, we adhere to the principle of 'technology first.' We must develop specific construction plans, organize expert reviews, and strictly adhere to these plans to ensure the project's success. This forms the technical foundation for ensuring safety." (P01, Project Manager, 12 years of experience)*

Safety protection facilities are a core component of technical engineering measures, including edge protection, opening protection, and scaffolding protection. However, interviews also revealed significant variations in the actual application of these facilities. One safety supervisor noted:

> *"In theory, all high-altitude work areas should be equipped with guardrails and safety nets, but in practice, they are often temporarily removed due to construction progress and work handovers. Ideally, 'every hole must be covered, every edge must have a guardrail,' but in reality, lack of protection often occurs." (S04, Safety Supervisor, 8 years of experience)*

Regarding temporary power systems, interviews revealed that despite a comprehensive set of safety regulations, violations remain common. An electrical engineer commented:

> *"The biggest concerns with temporary power systems are 'one switch for multiple machines' and 'random wiring'. We utilize the TN-S grounding protection system and a three-level distribution system with two-level protection; however, teams often run wires privately to save time. Now, we've installed insulating brackets and protective covers in key areas, and the situation has improved." (S06, Safety Supervisor, 6 years of experience)*

It's worth noting that there are significant disparities in the implementation of technical and engineering measures across projects. Some well-managed projects are beginning to incorporate intelligent technologies to enhance safety, such as monitoring and alarm systems and BIM. However, the application of these technologies is still in its early stages and is primarily concentrated in large-scale projects.

4.1.2 Management Control Measures

The safety responsibility system is the foundational framework for safety management. "From project managers to frontline workers, every position has clear safety responsibilities." (Interviewee P02, Project Chief Engineer, 15 years of experience) Hazard detection and management are key components of daily safety management. However, one safety supervisor pointed out issues with the quality of hazard detection:

> *"We conduct daily safety inspections and weekly comprehensive inspections, but sometimes these are superficial, mostly detecting superficial issues like 'insufficient fire extinguisher pressure,' and failing to delve into systemic risks." (S02, Safety Supervisor, 10 years of experience)*

Furthermore, current safety training suffers from a pronounced tendency toward formalism. "The third-level safety training is often simply a 'sign-and-done' exercise, leaving workers with limited real input. This is especially true for subcontractors, as training time is severely compressed, significantly reducing effectiveness." (T03, Team Leader, 7 years of experience)

Notably, several interviewees raised criticisms of subcontractor management. Due to the widespread use of a tiered subcontracting model in the construction industry, general contractors have limited influence over the safety management of their subcontractors. "Ideally, all subcontractors should be included in a unified safety management system. However, in reality, professional and labour subcontractors each have their own management practices, making complete unification difficult. Especially for small subcontractors, insufficient safety investment is common." (P03, Project Manager, 11 years of experience)

4.1.3 Personal Protective Measures

Personal protective equipment (PPE) is the last line of defence for workers. Although PPE is widely available on construction sites, its use is suboptimal. "Some workers find safety belts cumbersome and don't wear them when working at height. Some don't wear helmets or fasten their straps in hot weather." (S07, Safety Supervisor, 3 years of experience) The effectiveness of personal protective measures depends not only on the quality of the equipment but also on workers' willingness and ability to use them correctly. A rebar worker explained:

> *"It's not that we don't want to be safe, but sometimes it's inconvenient. For example, wearing a hard hat can be very uncomfortable in the summer, and not wearing goggles when sanding can make it difficult to see. If the equipment were more user-friendly, we would be more willing to use it." (W04, rebar worker, 5 years of experience)*

Attitudes towards personal protective measures vary significantly across different types of work. For example, workers in high-risk occupations generally place greater emphasis on personal protection, while those in low-risk occupations are more likely to ignore protective requirements. This suggests that personal protective measures need to be designed and managed differently based on the specific characteristics of the job.

4.2 Factors Affecting Building Safety Management

4.2.1 Organizational Factors

Organizational factors are macroeconomic factors that influence construction safety management, providing resource support and institutional safeguards. Interviews revealed that safety investment is the most fundamental factor. "Reasonable safety measures account for approximately 2%-3% of the total project cost, but actual investment is often insufficient. Some projects maliciously underbid bids, resulting in 'cutting corners' on safety after construction begins." (P04, Project Manager, 9 years of experience)

Leaders' commitment to safety also impacts organizational safety. "If project managers truly prioritize safety, address it at every regular meeting and conduct on-site safety inspections, the safety landscape of the entire project will be completely different. Conversely, if leaders only focus on progress and not safety, the safety officer's words carry little weight." (S01, Safety Supervisor, 12 years of experience)

Furthermore, several interviewees noted that unreasonable construction schedules can directly lead to the sacrifice of safety measures. One production manager admitted, "Ownerships often demand early delivery, forcing us to rush construction. And when we rush, safety procedures are streamlined." (P06, Project Manager, 10 years of experience)

4.2.2 Group Factors

Group factors reflect the impact of the interactive patterns of the work environment on safety behaviour. Interviews revealed that safety culture is the most significant factor influencing the organization's performance. "In some carpentry groups, veteran workers take the lead in wearing safety belts, and new workers follow suit. In other masonry groups, anyone wearing a hard hat is mocked as 'cowardly.' This group atmosphere has a greater impact than rules and regulations." (S03, Safety Supervisor, 7 years of experience) Group factors influence individual behaviour through invisible pressure. "I actually knew that safety belts should be worn when working at heights, but the veteran workers didn't use them. As a newcomer, I would have seemed out of place if I had used one. But I gradually got used to it." (W02, Concrete Worker, 2 years of experience) This finding aligns with research from a group dynamics perspective, which suggests that groups can influence unsafe behaviours among construction managers through safety behaviour facilitation and safety behaviour convergence (Wang et al., 2021).

Additionally, manager safety leadership also influences safety culture. As managers noted, "Morning shift meetings require more than just reading a script for safety briefings; they must be written in language workers can understand and contextualized to the specific tasks of the day. Hidden dangers must be pointed out immediately, but a simple fine shouldn't be enough; the reasons for the danger must be explained." (T05, Team Leader, 8 years of experience) "I require managers to adhere to the 'three ones': a safety check on the first day of the day on site, a safety discussion at the first weekly production meeting, and a safety review at the first monthly scheduling meeting. If you stick to this, workers will naturally take it seriously." (P01, Project Manager, 12 years of experience)

Group factors can be both obstacles and enablers of safety management. Positive group norms and a safety culture can significantly enhance the effectiveness of safety management measures, suggesting that we should prioritize interventions at the group level, rather than focusing solely on the individual or organizational level.

4.2.3 Individual Factors

Individual factors refer to micro-conditions that influence construction safety management, encompassing the attributes and status of individual workers. Safety knowledge and skills are the most fundamental factors in ensuring a safe environment. A safety supervisor noted, "Worker mobility is high these days, and many newly arrived migrant workers lack basic safety knowledge. They don't know where the risks lie, let alone how to prevent them. In this situation, avoiding accidents is luck; accidents are inevitable." (S08, Safety Supervisor, 2 years of experience) This safety knowledge is influenced by work experience. On the one hand, experienced workers are generally more aware of operational risks. "Scaffolding may seem simple, but it actually presents many hidden dangers. For example, if the distance between the uprights is too large or there are too few sweeping poles, it may not be immediately noticeable, but it could lead to collapse. Experienced workers can spot these problems, but novices won't." (W07, Scaffolder, 8 years of experience) On the other hand, they are also more likely to take risks due to overconfidence. "Experienced workers sometimes rely on their experience to 'take shortcuts,' skipping safety steps. New workers, while cautious, often struggle to accurately assess risks. So, it's not true that more experience equals safety." (T07, Team Leader, 9 years of experience). It means that experience improves hazard identification but can negatively impact compliance due to shortcut-taking. Furthermore, experiencing real-world cases can also enhance workers' safety awareness. "At first, I thought safety was just about meeting inspections, but after witnessing a fall accident, I truly understood that safety is for my own benefit. Now, I not only pay attention to safety myself, but I also frequently remind my fellow workers." (W05, Welder, 6 years of experience)

5. Discussion

The effectiveness of construction safety management is influenced by three primary factors: organization, group, and individual. These factors do not exist in isolation. Organizational factors provide the necessary resource support and institutional framework for safety management, including fundamental conditions such as safety investment guarantees, leadership commitment, and subcontract management models. Group factors shape specific behavioural norms and interaction patterns on the construction site, influencing individual behavioural choices through group safety culture, informal norms, and the role model of managers. Individual factors determine the ultimate effectiveness of safety management. Workers' safety knowledge, risk perception, and psychological characteristics directly influence their compliance with safety regulations and the quality of their safe behaviour.

The group plays a key mediating role. Research has shown that organizational safety policies often require modification by the group before they can effectively influence individual safety behaviours. This confirms the safety climate theory proposed by Zohar, where the enacted safety climate at the group level serves as the true predictor of injury, often bridging the gap between abstract organizational policy and concrete individual action. For example, if an organization's safety investment policy is actively interpreted and reinforced at the team level, it can more effectively change workers' safety attitudes and behaviours. Conversely, even if an organization has a comprehensive safety system, if it is resisted or passively addressed at the group level, it will have little impact on the individual level. These findings echo group dynamics theory, indicating that group norms, group motivation, and group cohesion can indeed have a profound effect on construction workers' safety behaviors through the promotion and convergence of safety behaviors. Research has also observed a degree of compensatory effect between factors at different levels. When deficiencies exist at one level, strengths at other levels can partially compensate for them. For example, even when organizational safety investment is insufficient, strong group norms and a positive safety culture can still maintain a basic level of safety performance. Conversely, when individual safety knowledge is inadequate, effective organizational supervision and group guidance can also prevent accidents to a certain extent. This compensatory effect explains why there are significant differences in safety performance between different projects under similar organizational conditions. It also suggests that we should adopt a systematic approach in safety management and pay attention to the synergy between factors at all levels.

In the practice of building safety management, it is necessary not only to improve safety technology and engineering measures, but also to simultaneously improve management control measures and personal protection measures, and establish a multi-level, integrated safety protection system. The study particularly emphasizes the positive role of group dynamics. By cultivating a positive group safety culture, establishing effective safety communication mechanisms, and enhancing managers' safety leadership, the positive impact of group dynamics on safety behaviour can be fully leveraged. In addition, safety management should adopt a differentiated strategy and design intervention measures based on the characteristics of factors at different levels. For organizations, the focus is on ensuring safety investment and leadership commitment; for groups, the focus is on establishing positive group norms and fostering a safety culture; for individuals, the focus is on enhancing safety knowledge, skills, and risk perception. This differentiated strategy can improve the accuracy and effectiveness of safety management.

Based on the synergistic effects identified in this study, safety management should shift from traditional administrative directives to more targeted, priority-based interventions. At the organizational level, given the weakened binding force of general contractors on multi-level subcontractors, safety performance clauses must be deeply embedded in subcontracting agreements. This should be reinforced through the establishment of dedicated "safety deposits" and mandatory safety resource allocation ratios. Corresponding evaluation indicators should shift from outcome-based to process-based indicators, such as the subcontractor's safety investment ratio (safety expenditure/total contract amount) and hazard rectification rate, thereby compelling subcontractors to move from passive compliance to proactive prevention.

At the group level, it is recommended to institutionalize the behaviors mentioned in the interviews, such as "daily first-day safety inspections, weekly production meeting safety discussions, and monthly scheduling meeting safety debriefings," as a hard indicator for measuring the performance of project management. To reverse the negative informal norm of "not being ashamed of violations" in some work teams, the intervention should focus on establishing mutual safety assistance within the team, using the example of senior workers who take the lead in implementing safety standards to create a positive influence. The effectiveness of such interventions can be dynamically assessed through the frequency of on-site inspections by management and the number of proactive reports of near-miss incidents within the work team.

At the individual level, research has found that insufficient PPE compliance is a core contributing factor to violations, highlighting a lack of comfort. Therefore, interventions should not be limited to increasing penalties but should prioritize upgrading the usability of protective equipment, such as introducing ergonomically designed PPE like ventilated helmets (Weaver III et al., 2024) and anti-fog goggles (Sood et al., 2025). Simultaneously, differentiated training should be implemented to address the varying risk perceptions across different occupations. Key indicators for evaluating this level should include the pass rate of random PPE inspections and post-training risk perception scores, ensuring individuals shift from "I have to be safe" to "I want to be safe" driven by both physiological comfort and psychological awareness.

6. Conclusion

This study employed qualitative research methods to explore safety management measures and their influencing factors through in-depth interviews in the construction sector. The study found that construction safety management measures can be categorized into three levels: technical and engineering measures, management and control measures, and personal protective measures. Their effectiveness is influenced by organizational, group, and individual factors. The study demonstrates that group factors play a key mediating role in safety management, translating organizational policies into individual behaviours. This finding enriches the theoretical perspective on construction safety management.

The study also has limitations. First, the sample size primarily came from construction projects in a single Chinese city, and the generalizability of the findings requires further verification. Future research could expand the sample size to encompass more regions and types of construction projects. Second, this study primarily employed qualitative research methods, with data sources limited to the experiences and perspectives of participants gathered through in-depth interviews. While this approach helps in understanding complex phenomena, it cannot directly observe the actual effectiveness of safety management. The study's conclusions lack direct verification with quantitative or observational evidence, thus failing to employ triangulation methods to provide more comprehensive evidence. Future research could combine quantitative and observation to provide more comprehensive evidence. Finally, the study focused on static factors in safety management, with relatively insufficient attention paid to the dynamic evolution of safety. Future research could adopt a longitudinal design to explore the dynamic development patterns of construction safety management.

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Appendix 1. Interview Protocol

Pre-Interview Instructions:

Hello, thank you for participating in this research interview on construction safety management. I am XXX from XX University. This interview aims to understand the implementation status of safety management measures at construction sites and their influencing factors. The interview content will be strictly confidential and used solely for academic research purposes. The interview is expected to last 45-90 minutes. Please inform us if you need a break or to end the interview. Do you agree to have this interview recorded?

1. Background Information

1.1 Please briefly introduce your professional background and responsibilities in the current project.

1.2 How long have you worked in your current position? How long have you worked in the construction industry in total?

1.3 What types and scales of projects have you participated in?

2. Safety Management Practices

2.1 Please describe the main safety management measures currently implemented in your project.

2.2 What challenges have been encountered in the actual implementation of these measures? Can you provide examples?

2.3 Which measures do you think are most effective? Which are less effective? What are the reasons?

2.4 Please discuss how safety training was conducted in the project? How effective was the training?

3. Influencing Factors

3.1 In your opinion, what factors most affect the effectiveness of on-site safety management?

3.2 When safety requirements conflict with construction schedules and costs, how are they typically balanced?

3.3 What are the differences in attitudes towards safety management among personnel at different levels (managers, team leaders, workers)?

3.4 Please share a successful or unsuccessful safety management case study from your own experience.

4. Improvement Suggestions

4.1.Based on your experience, what is the most important area for improvement in the current safety management system?

4.2.How do you think the relationship between regulatory requirements and actual construction conditions should be balanced?

4.3.What specific suggestions do you have for improving building safety performance?

Our interview is coming to an end. Is there anything else you'd like to add? Thank you again for your participation and support. If you are interested in the research results, we would be happy to share the summary report with you upon completion of the research.

Appendix 2. Basic Information of Participants

Participants	Age	Position	Education	Household Registration	Firm Size	Project Types	Years of experience
P01	45	Project Manager	Higher Education	Guangdong Province (excluding Shenzhen City)	Large	Commercial Building	12
P02	48	Project Chief Engineer	Higher Education	Shenzhen City	Large	Residential Building	15
P03	39	Project Manager	Higher Education	Shenzhen City	Large	Residential Building	11
P04	35	Project Manager	Higher Education	Shenzhen City	Medium	Public Building	9
P05	52	Project Manager	Higher Education	Shenzhen City	Large	Commercial Building	18
P06	37	Project Manager	Higher Education	Guangdong Province (excluding Shenzhen City)	Medium	Public Building	10
S01	45	Safety Supervisor	Higher Education	Guangdong Province (excluding Shenzhen City)	Large	Residential Building	12
S02	38	Safety Supervisor	Higher Education	Guangdong Province (excluding Shenzhen City)	Medium	Commercial Building	10
S03	36	Safety Supervisor	Higher Education	Shenzhen City	Large	Residential Building	7
S04	32	Safety Supervisor	Higher Education	Guangdong Province (excluding Shenzhen City)	Large	Commercial Building	8
S05	35	Safety Supervisor	Vocational/High School	Shenzhen City	Large	Public Building	12
S06	30	Safety Supervisor	Higher Education	Outside Guangdong Province	Medium	Commercial Building	6

S07	28	Safety Supervisor	Higher Education	Guangdong Province (excluding Shenzhen City)	Large	Residential Building	3
S08	28	Safety Supervisor	Higher Education	Outside Guangdong Province	Medium	Commercial Building	2
T01	48	Team Leader	Junior High School or Below	Guangdong Province (excluding Shenzhen City)	Large	Commercial Building	10
T02	35	Team Leader	Higher Education	Shenzhen City	Medium	Residential Building	8
T03	32	Team Leader	Vocational/High School	Outside Guangdong Province	Large	Public Building	7
T04	30	Team Leader	Vocational/High School	Outside Guangdong Province	Medium	Residential Building	5
T05	45	Team Leader	Vocational/High School	Guangdong Province (excluding Shenzhen City)	Large	Commercial Building	8
T06	30	Team Leader	Higher Education	Guangdong Province (excluding Shenzhen City)	Large	Commercial Building	3
T07	45	Team Leader	Vocational/High School	Shenzhen City	Medium	Public Building	9
T08	30	Team Leader	Vocational/High School	Outside Guangdong Province	Medium	Residential Building	2
W01	23	Concrete Worker	Vocational/High School	Outside Guangdong Province	Large	Commercial Building	3
W02	22	Concrete Worker	Vocational/High School	Outside Guangdong Province	Large	Public Building	2
W03	22	Rebar Worker	Vocational/High School	Outside Guangdong Province	Medium	Commercial Building	3

W04	24	Rebar Worker	Junior High School or Below	Guangdong Province (excluding Shenzhen City)	Medium	Residential Building	5
W05	24	Welder	Junior High School or Below	Outside Guangdong Province	Medium	Residential Building	6
W06	23	Welder	Vocational/High School	Outside Guangdong Province	Medium	Commercial Building	5
W07	28	Scaffolder	Junior High School or Below	Shenzhen City	Medium	Residential Building	8
W08	23	Scaffolder	Vocational/High School	Outside Guangdong Province	Large	Public Building	3
W09	25	Scaffolder	Junior High School or Below	Guangdong Province (excluding Shenzhen City)	Large	Residential Building	5
W10	23	Scaffolder	Junior High School or Below	Outside Guangdong Province	Medium	Residential Building	3

Appendix 3. Coding framework of safety management measures for construction sites

Theme	Code	Definition	Examples
Technical engineering measures	Technical Foundation for Safety	Construction sites generally employ a variety of technical and engineering measures to ensure safety.	For hazardous and major projects such as deep foundation pits, high formwork, and large machinery and equipment, we adhere to the principle of 'technology first.' We must develop specific construction plans, organize expert reviews, and strictly adhere to these plans to ensure the project's success. This forms the technical foundation for ensuring safety. (P01)
	Safety Hazard	The protective measures pose safety hazards.	In theory, all high-altitude work areas should be equipped with guardrails and safety nets, but in practice, they are often temporarily removed due to construction progress and work handovers. Ideally, 'every hole must be covered, every edge must have a guardrail,' but in reality, lack of protection often occurs. (S04) The biggest concerns with temporary power systems are 'one switch for multiple machines' and 'random wiring'. We utilize the TN-S grounding protection system and a three-level distribution

			system with two-level protection; however, teams often run wires privately to save time. Now, we've installed insulating brackets and protective covers in key areas, and the situation has improved. (S06)
Management Control Measures	Insufficient Security Checks	There are issues with the quality of hazard detection.	We conduct daily safety inspections and weekly comprehensive inspections; however, these inspections are sometimes superficial, primarily detecting superficial issues such as 'insufficient fire extinguisher pressure,' and often fail to delve into systemic risks. (S02)
	Formalistic Security Training	Current safety training suffers from a pronounced tendency toward formalism.	The third-level safety training is often simply a 'sign-and-done' exercise, leaving workers with limited real input. This is especially true for subcontractors, as training time is severely compressed, resulting in significantly reduced effectiveness. (T03)
	Inadequate Subcontracting Management	General contractors have limited influence over the safety management of their subcontractors.	Ideally, all subcontractors should be included in a unified safety management system. However, in reality, professional and labour subcontractors each have their own management practices, making complete unification difficult. Especially for small subcontractors, insufficient safety investment is common. (P03)
Personal protective measures	Lack of PPE	Although PPE is widely available on construction sites, its use is suboptimal.	Some workers find safety belts cumbersome and don't wear them when working at height. Some don't wear helmets or fasten their straps in hot weather. (S07)
	Inhumane PPE	The effectiveness of personal protective measures depends not only on the quality of the equipment but also on workers' willingness and ability to use them correctly.	It's not that we don't want to be safe, but sometimes it's inconvenient. For example, wearing a hard hat can be very uncomfortable in the summer, and not wearing goggles when sanding can make it difficult to see. If the equipment were more user-friendly, we would be more willing to use it. (W04)

Appendix 4. Coding framework of factors affecting building safety management

Theme	Code	Definition	Examples
Organization	Safety Investment (SI)	To prevent and control safety accidents, ensure the safety of personnel and property, and meet regulatory standards and project objectives, the project team plans, allocates, implements, and manages resources (funds, human resources, technology, and	Reasonable safety measures account for approximately 2%-3% of the total project cost; however, the actual investment is often insufficient. Some projects maliciously underbid bids, resulting in 'cutting corners' on safety after construction begins." (P04)

		time) throughout the entire project lifecycle.	
	Leaders' Commitment (LC)	Project managers take responsibility for employee safety, actively promote it, and set an example by doing so.	If project managers truly prioritize safety, address it at every regular meeting and conduct on-site safety inspections, the safety landscape of the entire project will be completely different. Conversely, if leaders only focus on progress and not safety, the safety officer's words carry little weight. (S01)
	Construction Schedule (CS)	Short project timelines complicate project safety.	Ownership often demands early delivery, forcing us to rush the construction. And when we rush, safety procedures are streamlined. (P06)
Group	Safety Culture (SC)	The sum of shared safety values, beliefs, attitudes, behavioral norms, and practices of a project team and organization.	In some carpentry groups, veteran workers take the lead in wearing safety belts, and new workers follow suit. In other masonry groups, anyone wearing a hard hat is mocked as 'cowardly.' This group atmosphere has a greater impact than rules and regulations. (S03)
	Invisible Pressure (PI)	The pressure of being different from other team members.	I actually knew that safety belts should be worn when working at heights, but the veteran workers didn't use them. As a newcomer, I would have seemed out of place if I had used one. However, I gradually grew accustomed to it. (W02)
	Safety Leadership (SL)	Project managers' ability to guide and influence others to achieve organizational safety goals.	Morning shift meetings require more than just reading a script for safety briefings; they must be written in language workers can understand and contextualized to the specific tasks of the day. Hidden dangers must be pointed out immediately, but a simple fine shouldn't be enough; the reasons for the danger must be explained. (T05) I require managers to adhere to the 'three ones': a safety check on the first day of the day on site, a safety discussion at the first weekly production meeting, and a safety review at the first monthly scheduling meeting. If you stick to this, workers will naturally take it seriously. (P01)
Individual	Safety Knowledge (SF)	Throughout the project lifecycle, the project team applies specialized knowledge, skills, tools, and methods to identify, assess,	Worker mobility is high these days, and many newly arrived migrant workers lack basic safety knowledge. They don't know where the risks lie, let alone how to prevent them. In this

		control, and mitigate potential hazards (including personal, property, environmental, and informational risks) in project activities, thereby achieving safety objectives.	situation, avoiding accidents is a matter of luck; accidents are often inevitable. (S08)
	Safety Awareness (SA)	Project members' awareness of potential dangers.	At first, I thought safety was just about meeting inspections, but after witnessing a fall accident, I truly understood that safety is for my own benefit. Now, I not only pay attention to safety myself, but I also frequently remind my fellow workers. (W05)
	Work Experience (WE)	Practical knowledge, skills, abilities, and understanding of relevant industries accumulated through actual work.	Scaffolding may seem simple, but it actually presents many hidden dangers. For example, if the distance between the uprights is too large or there are too few sweeping poles, it may not be immediately noticeable, but it could lead to collapse. Experienced workers can spot these problems, but novices won't. (W07) Experienced workers sometimes rely on their experience to 'take shortcuts,' skipping safety steps. New workers, while cautious, often struggle to accurately assess risks. So, it's not true that more experience equals safety. (T07)