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Review

Towards a Multilevel Framework of Teamwork Processes Affecting Construction Safety Outcomes

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Abstract: The construction industry has one of the highest fatality and injury rates, highlighting the urgent need for research to reduce work-related injuries and fatalities. Given the complex nature of construction teams operating at different project levels, teamwork processes are crucial for ensuring construction safety. However, a comprehensive examination of teamwork processes concerning construction safety is lacking. Contemporary construction literature has a primary focus on a few key team-level factors. This study addresses this research gap by conducting a more holistic literature review, benchmarking knowledge from other industries, and proposing a framework specific to construction safety. The proposed framework integrates insights from team science and construction safety science, taking into consideration the industry's complex team structure and dynamic nature. This study contributes to the improvement of safety outcomes in the construction industry by enhancing the understanding of teamwork processes' impact on construction safety. The findings have practical implications for enhancing safety performance and reducing injuries and fatalities among construction workers.

Keywords: construction management; safety; teamwork; framework

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1. Introduction and Background

The construction industry has one of the highest fatality and injury rates among all industries [1]. In 2021, the industry experienced the highest number of work-related fatalities in the United States, with 986 reported cases [1]. On average, nearly four deaths occurred every working day among U.S. construction workers. Additionally, the industry had 169,200 cases of nonfatal injuries and illnesses [1]. These fatalities and injuries result in significant costs and decreased productivity. These alarming statistics highlight the urgent need for research to investigate effective methods to reduce work-related injuries and fatalities among construction workers.

The successful completion of construction projects requires the collaboration of various teams. Thus, teamwork processes are crucial in ensuring construction safety. While not all construction operations have the same level of complexity in their teamwork processes, Figure 1 provides an illustrative example of the potential dynamics and interdependencies that can exist within construction teams. At the decision-making level, effective teamwork is crucial among the owner's team, the architecture team, the engineering team, the contractor team, and, sometimes, the consulting team. They collaborate closely to make design decisions, control schedules, and establish policies that will significantly impact the entire construction project. The superintendent team plays a vital role at the site management level. They collaborate with the project management team and oversee multiple trade teams on the operation level. On the production level, the interdependence among trade teams is especially significant. Different trade teams often rely on one another to complete construction tasks. Additionally, construction team composition is often dynamic and transient, with trade teams frequently switching projects. As a result, teamwork processes in construction are inherently complicated due to the intricate team structure and the industry's dynamic nature. Understanding and managing these complexities is critical for ensuring effective teamwork processes and enhancing construction safety performance.

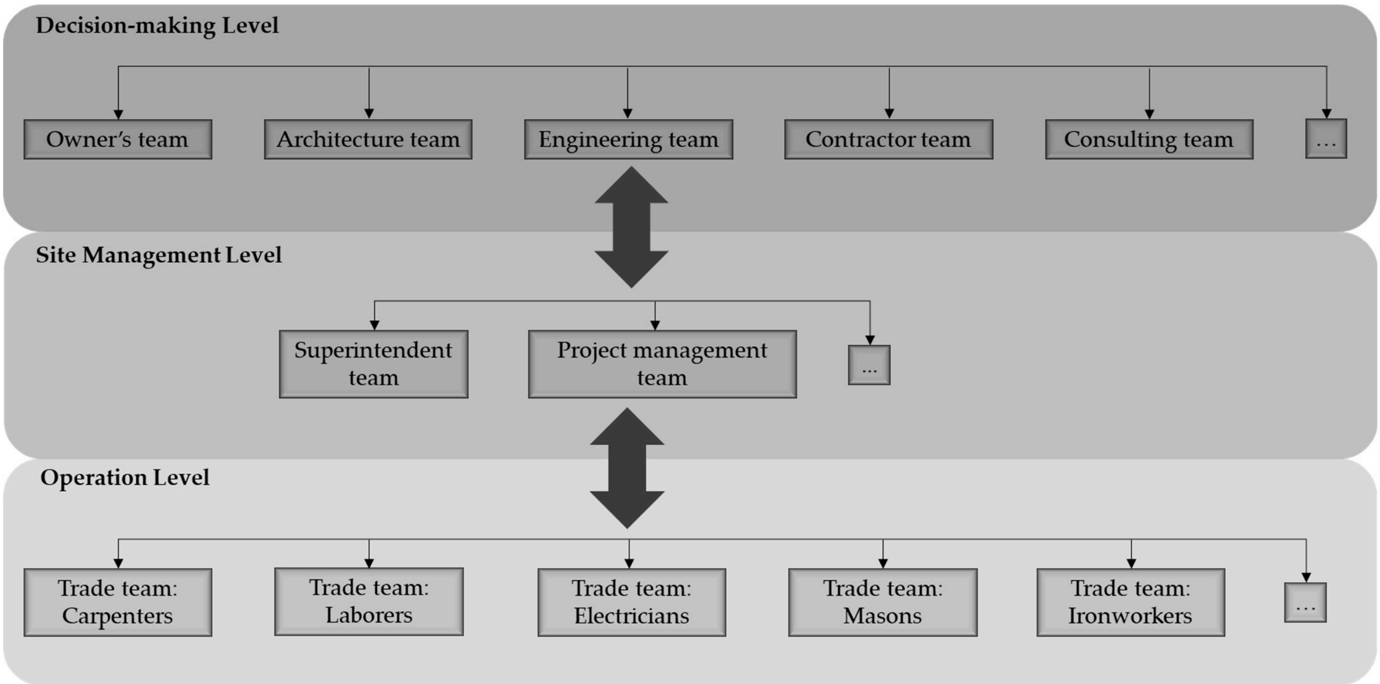

Figure 1. Construction teamwork processes at different levels affecting safety outcomes.

Teamwork is essential in driving safety performance across an organization [2]. Researchers have been studying methods to enhance safety performance in high-reliability organizations where safety failures can have catastrophic consequences [2]. The aviation industry was among the first to recognize the significant impact of teamwork on workplace safety [3]. During the 1970s, the aviation industry faced high rates of preventable accidents, prompting researchers to explore the underlying causes of these accidents. A study conducted by researchers at the National Aeronautics and Space Administration (NASA) found that 70% of aviation accidents resulted from preventable problems associated with teamwork [3]. To address this issue, safety programs such as crew resource management (CRM) were developed, and the Federal Aviation Administration (FAA) has since mandated it across all airlines [2]. Similarly, the healthcare industry has recognized that teamwork plays an essential role in the causation and prevention of safety problems [4,5]. Research efforts in the nuclear power industry [6], the military [7], and the oil drilling industry [8] have yielded comparable results, highlighting the significance of teamwork in ensuring safety. By drawing lessons from these industries and insights from cutting-edge research, the construction industry can benefit from a deeper understanding of how teamwork can enhance safety performance.

In pursuit of the zero injury goal, researchers in construction have investigated various factors that influence safety performance. Recent systematic reviews have revealed that the most researched factors are at the individual level (e.g., individual safety behavior) and the organizational level (e.g., safety culture and regulations) [9]. However, in the context of construction, teamwork processes that impact construction safety have not been comprehensively examined. Moreover, previous research has primarily focused on a few team-level factors, such as safety climate and team leadership. Critical team-level factors, like psychological safety and mutual team trust, remain understudied in construction safety research. Additionally, the teamwork processes framework proposed by Mitropoulos and Memarian in 2012 [3] needs updating, considering the exponential growth in team and construction safety science. Furthermore, even though there have been empirical studies in the construction literature that have explored the relationship between teamwork processes and safety performance, there is a need for a comprehensive and up-to-date framework that integrates various teamwork processes and their impact on safety outcomes in the construction industry. This study was performed to contribute to efforts directed at addressing this need through building a multilevel framework to enhance our understanding of how teamwork processes affect construction safety. The research objectives (ROs) associated with this goal are as follows:

1. To comprehensively review the existing literature on teamwork processes that influence construction safety (RO1).
2. To compare and benchmark the knowledge of teamwork processes in the construction industry against those of other industries (RO2).
3. To propose a framework of teamwork processes that affect construction safety based on recent advancements in team and construction safety science (RO3).
4. To validate and refine the proposed framework through input from industry practitioners, including construction professionals and experts (RO4).

2. Methodology

The research methodology was based on systematically reviewing, evaluating, and synthesizing data from closely related work from other industries on teamwork processes and relevant construction safety-focused research. To achieve the research objectives outlined in the previous section, the literature review process for this paper was divided into three steps, as depicted in Figure 2.

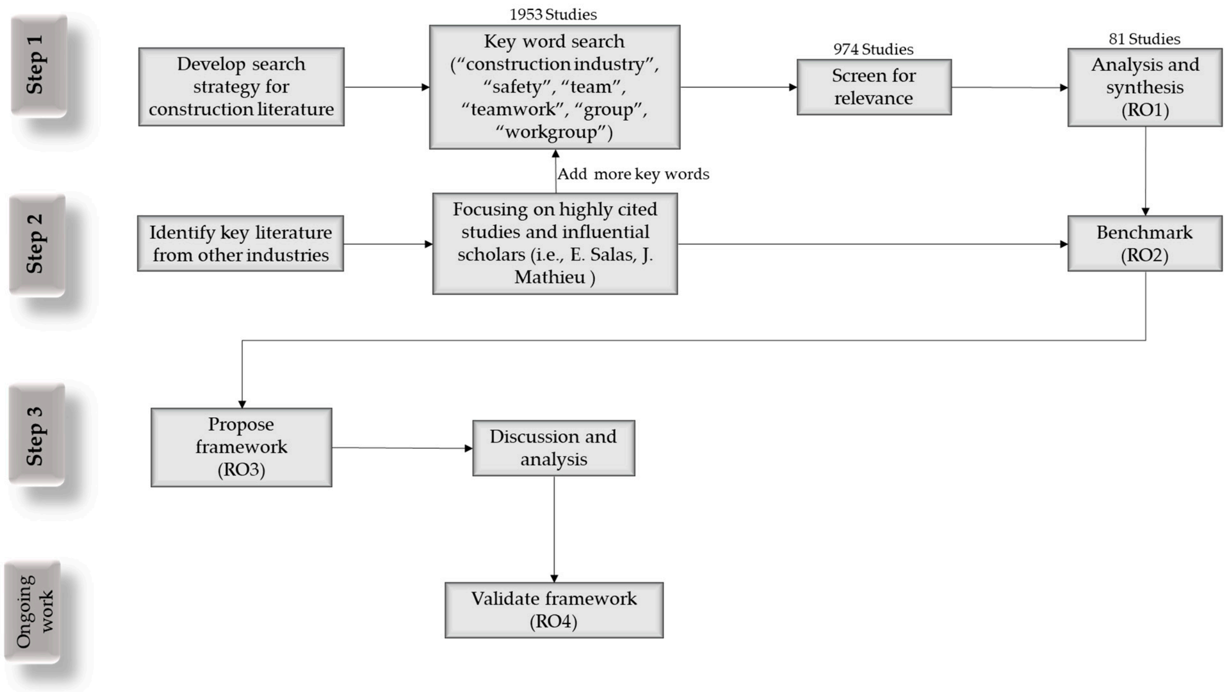

Figure 2. The literature review process.

In Step 1, we conducted a comprehensive literature search to explore the current state of knowledge on the teamwork processes that influence construction safety (RO1). The relevant and reputable databases Scopus and the ASCE Library were utilized to ensure that the search was thorough. The implemented search strategy involved using the keywords "construction safety" and "teamwork" to identify relevant articles. Alternative keywords such as "team", "group", and "workgroup" were also used to enhance the comprehensiveness of the initial search. The search was applied to the title, abstract, and keyword fields, and the initial search yielded 1953 articles. We then applied three eligibility criteria to screen the articles. Firstly, the articles must be in English. Secondly, we limited the publication timeframe to articles published between 2010 and the present. Lastly, we screened the articles for relevance. We examined the abstract and only articles related to construction safety and teamwork processes were selected. A total of 974 articles remained following the screening process. An in-depth evaluation of these articles was conducted. The main body of the articles was examined to ensure only high-quality and relevant articles were included in further analysis. Ultimately, 82 articles were selected. A critical synthesis and evaluation of the findings, methodologies, and limitations of these 82 studies were conducted.

In Step 2, we searched for highly influential articles from other domains, particularly organizational psychology. The literature search was performed using relevant databases: PsycINFO and Google Scholar. We chose PsycINFO as it is a renowned database in the field of psychology and contains a wealth of relevant literature on teamwork processes and safety. We also used Google Scholar to complement the literature search. Keywords used to identify relevant articles included "teamwork", "team processes", "occupational safety", and "team performance". We identified articles that provided valuable insights and theoretical frameworks related to teamwork processes and safety performance. These articles were used to benchmark the knowledge of teamwork processes against those in the construction industry (RO2). In addition, we identified more keywords (such as psychological safety and mutual trust) to supplement the literature search in Step 1.

In Step 3, we proposed a teamwork process framework affecting safety outcomes based on the findings from the previous steps (RO3). The proposed framework was developed by synthesizing relevant concepts, theories, and findings from the selected articles and influential research. It considered the unique characteristics of the construction industry, including the complex team structure, the interdependencies among teams, and the dynamic nature of construction projects. Discussions were then conducted to help advance the understanding of teamwork processes and their role in shaping safety outcomes in the construction industry.

In our next step, the proposed framework will be validated and refined by collecting input from industry practitioners (RO4). This is part of our ongoing work. We have developed a survey to collect feedback and opinions from professionals in the construction industry, including construction workers, project managers, superintendents, and other relevant team members. The survey was based on the constructs identified in the literature review. The quantitative data will be analyzed using the structural equation modeling method, as it is one of the most used methods found in similar research. This will ensure the applicability of the framework in real-world construction projects.

In the following Findings section, we present the results obtained from the first three steps. In the subsequent section, we discuss the implications and significance of the proposed framework and present future work and limitations.

3. Findings

This section focuses on the main findings of our literature review on teamwork and construction safety. A descriptive analysis of the articles identified during our review process has been included along with a summary and critical analysis of the selected articles based on the previously specified research goals and objectives.

3.1. Descriptive Analysis

As shown in Table 1, *Safety Science* has published the most articles (12) on the topic since 2010, followed by the *Journal of Construction Engineering and Management* (11) and *Construction Management and Economics* (10). Overall, 82 publications were included in the analysis, representing recent quality research from various credible scholarly outlets.

Table 1. The publishing sources of identified articles.

Publication Title	No. of Publications
Safety Science	12
Journal of Construction Engineering and Management	11
Construction Management and Economics	10
International Journal of Environmental Research and Public Health	7
Journal of Safety Research	7
Journal of Management in Engineering	6
Accident Analysis and Prevention	4
Engineering, Construction and Architectural Management	4
International Journal of Occupational Safety and Ergonomics	4
American Journal of Industrial Medicine	2
Work	2
Journal of Occupational and Environmental Medicine	1
Reliability Engineering and System Safety	1
Frontiers in Psychology	1
Frontiers in Public Health	1
New Solutions	1
Practice Periodical on Structural Design and Construction	1
Procedia Engineering	1
Annals of Occupational Hygiene	1
Computational Intelligence and Neuroscience	1
Complexity	1
ASCE International Conference on Computing in Civil Engineering	1
Annual Association of Researchers in Construction Management Conference	1
International Conference on Construction and Real Estate Management	1
Total	82

Table 2 shows the distribution of themes among the selected articles. The number of articles spans three time periods to track research trends. Team-level safety climate is the overwhelmingly most studied topic (33 articles), followed by social influence (13), safety leadership (11), and safety communication (11). Notably, a few review articles [9–11] have summarized team-level factors influencing safety. However, it is worth mentioning that the most recent framework outlining the impact of teamwork processes on safety outcomes was developed over a decade ago by Mitropoulos and Memarian [3].

3.2. Current State of Knowledge in Construction

Upon closer examination of the selected literature, the construction field has consistently attempted to apply team science to improve safety. However, when compared to other domains, certain gaps remain.

3.2.1. Team vs. Workgroup

The definition of what constitutes a team has evolved over time, but certain core characteristics have remained consistent. These characteristics include (1) the presence of two or more people, (2) dynamic, interdependent, and adaptive interactions among team members, (3) a shared goal or vision, (4) distributed expertise among team members, and (5) a limited life span [3,12,13].

Within the construction context, we observed some ambiguities surrounding the definitions of "team" and "workgroup". In some cases, these terms were used interchangeably. This ambiguity is not unique to construction but also exists in other domains. For example, in highly cited articles from organizational psychology [14] and the applied psychology domain [15], the authors made no distinction between work teams and workgroups. They claimed that these terms could be used interchangeably. However, other influential articles have advocated for distinguishing between "team" and "workgroup" [13,16]. The key difference between the two terms lies in the fact that workgroups usually lack task interdependency and distributed expertise [13]. Given that construction projects require high levels of interdependence and diverse expertise, we argue that the term "team" is more appropriate in the construction context than "workgroup". Furthermore, using "team" instead of "workgroup" helps avoid confusion with sociodemographic groups such as age, gender, and ethnicity.

Table 2. Publication trends based on themes.

		Publication Period			
Theme	**Description**	**2010–2014**	**2015–2019**	**2020–Present**	**Total**
Team-level safety climate	How do collective safety attitudes and perceptions form at the team level and how do they affect safety outcomes?	7	22	4	33
Social influence	Is social influence shaping workers' safety behaviors?	1	6	6	13
Safety leadership	How does owner and safety manager leadership affect safety performance?	3	5	3	11
Safety communication	What are the different communication styles and how do they affect safety outcomes?	4	4	3	11
Safety perception	Are safety perceptions the same for workers and managers? How will the perception affect safety behaviors?	1	4	3	8
Safety attitude	How does individual safety attitude affect team-level safety climate?	1	0	2	3
Review	Reviewing team-level factors that affect safety outcomes.	1	0	2	3
Social capital	How does social capital influence safety performance?	3	0	0	3
Simulation	Simulating how teamwork processes affect safety outcomes using various methods.	0	1	2	3
Framework	Building a framework of teamwork processes and safety outcomes.	1	0	0	1
Multiteam system (MTS)	Studying the intricate team structure and its influence on safety.	0	0	1	1
Total		22	42	26	90 *

* Some articles have multiple themes and were counted more than once in this table.

It is also worth noting that there are multiple types of teams, including action teams, production teams, management teams, service teams, and multiteam systems (MTSs) [17]. In the previously proposed framework by Mitropoulos and Memarian [3], they focused on action teams and production teams, as members of these teams are the most susceptible to injuries and fatalities. However, we contend that management teams, both at the decision-making and site management levels, play a crucial role in shaping workers' safety perception, team-level safety climate, and organizational safety culture.

3.2.2. Safety Climate vs. Safety Culture

As shown in Table 2, team-level safety climate generated the highest number of articles in our literature search. In fact, extensive research has been conducted on safety climate and safety culture across various domains [9]. However, there is still a lack of consensus on their precise definitions and differences [18–20]. This ambiguity may stem from the shared characteristics and interdependence between culture and climate [2]. Safety climate typically refers to the collective safety attitudes and perceptions at a given point in time [2].

One commonly acknowledged difference between safety culture and safety climate is the transient nature of climate compared to culture, which is more enduring [2,18].

Developing a safety culture within construction teams can be a challenging task. According to data from the United States Census Bureau, the average construction time for commercial buildings is 6.8 months, and for office buildings, it is 7.8 months [21]. During these relatively brief project durations, construction teams may not have sufficient time to establish and fully integrate a comprehensive safety culture. The transient nature of construction teams further complicates the development of a robust safety culture. Many construction teams work together for a limited period on a specific project before disbanding or moving on to other projects. This constant flux of team composition and the short-term nature of team collaboration hinder the establishment of deep-rooted safety values, attitudes, and practices. Hence, we contend that on the team level, safety climate holds a more significant influence on shaping safety outcomes than safety culture, while safety culture remains important at the organizational level.

Initially, safety climate was primarily examined at the organizational level. However, Zohar's work [22] expanded the understanding of safety climate to encompass both the team level and organizational level. Organizational-level safety climate originates from policies and procedures formulated at the decision-making level, while team-level safety climate arises from the implementation of policies and procedures that pertain to supervisory practices and coworker responses [22–24]. Subsequent research revealed that team-level safety climate possesses superior predictive capabilities for safety performance compared to organization-level safety climate [24]. In the construction domain, Lingard et al. [23–25] were among the first to investigate the concept of multilevel safety climate. Their studies highlighted the significance of a supervisor's safety response and coworker social support in influencing safety outcomes. These findings have since been corroborated by other researchers in the construction field [26,27]. Recent efforts have further demonstrated the substantial contributions of safety leadership and coworker social support to team-level safety climate [28,29]. Thus, our proposed framework incorporates team-level safety climate as a mediator for safety outcomes.

3.2.3. Social Identity

In our literature search, the theme that has the second highest number of articles is social influence. Social influence encompasses a broad range of factors, including group norms, social identity, conformity, and more, which have been extensively studied in various fields [30]. Of these factors, social identity has gained the most attention from researchers from the construction industry in recent years. It represents the level of commitment an individual has towards the team, including shared norms, values, and the resulting behaviors [31]. Andersen et al. [31] applied the theory of social identity to investigate its implications for safety. They stated that social identity reflects an individual's commitment to a social group and can influence safety behavior among construction crews [31]. Andersen et al. [32] conducted further research examining the correlation between social identity and safety climate. They found that social identity may serve as an antecedent for safety climate at both team and project levels. Choi et al. [33] investigated the various social identities among construction workers, uncovering that workers associate themselves with distinct social groups they are part of, such as a trade, union, company, or project. They also found that project identity was the weakest among other identities [34].

Social identity at the production team level emerges as a particularly intriguing aspect, as teams on this level (trade teams) are the most dynamic ones. This may explain why both Andersen et al. [32] and Choi et al. [34] observed construction workers have stronger identification with production-level teams. Thus, we incorporated social identity specifically at the production level in our proposed framework.

3.2.4. Safety Leadership

Leadership holds significant importance in construction projects, particularly in relation to safety. Previous research has consistently demonstrated a correlation between safety leadership and safety outcomes [35]. For example, Kines et al. [36] emphasized the long-lasting impact of frontline safety leadership, specifically through safety communication, on safety. Kapp [37] further explored the moderating role of safety climate between safety leadership and safety behaviors, revealing that positive safety climates enhance the influence of frontline supervisors' safety leadership on safety behavior. In a recent study by Lingard et al. [38], a supervisor's safety leadership was found to predict worker's safety behavior, with safety climate acting as a mediator.

While frontline leaders such as forepersons and superintendents play a crucial role in safety leadership, it is important to acknowledge that safety leadership exists at multiple levels. Wu et al. [39] discovered that safety leadership from owners, general contractors, and subcontractors mutually influences each leadership role through the mediating effect of safety culture. However, the strongest evidence in the literature has primarily focused on frontline safety leadership [36–38]. Consequently, in our framework, we incorporated safety leadership as input at the site management level.

3.3. Benchmarking against Key Team Constructs from Other Domains

In addition to the team constructs discussed, we established a need for further investigation of additional team constructs within the construction context. Extensive literature in the field of organizational psychology [2] proposes that five key mediators link team performance inputs to outcomes: psychological safety, mutual trust, collective efficacy, situation awareness, and shared mental models (SMMs). However, the construction domain exhibits limited research on these crucial team constructs.

3.3.1. Psychological Safety

Psychological safety refers to the capacity to freely express oneself without the apprehension of facing detrimental outcomes that may harm one's self-perception, social standing, or professional advancement [40]. At the team level, it signifies a collective belief that the team provides a secure space for engaging in interpersonal risks [41]. Psychological safety is particularly important for high-stakes teams like construction teams, as it facilitates team learning and enhances knowledge, skills, and attitudes related to safety [2]. It also promotes communication, knowledge sharing, and voice behavior and significantly influences individual and team performance [42]. Edmondson [43] even suggests that psychological safety can make the difference between a near miss and a catastrophic accident.

In the construction domain, a few studies have examined psychological safety in the context of lean construction projects [44,45]. Gomez et al. [44] conducted a survey among construction workers from various trades to gather their perceptions of factors that made them feel safe or unsafe on the job site. The survey revealed differences in workers' intragroup and intergroup psychological safety levels—their scope of work did not include an exploration of the impact of psychological safety on team safety performance. Love et al. [46] identified the absence of psychological safety as a contributing factor to construction rework and emphasized its importance for error management. Furthermore, Love et al. [47] analyzed workers' actions before, during, and after a major quality event that led to serious safety incidents and concluded that psychological safety could simultaneously improve both quality and safety outcomes in construction projects. Given the demonstrated significance of psychological safety in enabling safety, it is crucial for further studies to investigate its effect on construction safety.

3.3.2. Mutual Trust

Mutual trust differs from psychological safety as it pertains to the belief that team members can rely on each other [48]. Salas et al. [2] explain that mutual trust has a positive impact on safety as it fosters interpersonal risk-taking behaviors, facilitating collaboration and coordination within the team.

Within the construction industry, mutual trust has been conceptualized as part of social capital dimensions to understand safety performance. Koh and Rowlinson [49] utilized structural equation modeling to explore the relationship between social capital and safety performance. They discovered that shared understanding and mutual team trust were both linked to construction safety performance, measured by achieving good site safety conditions and continuous improvement of safety targets. Building on this, Koh and Rowlinson [50] proposed a multilevel framework that connected social capital to safety performance, highlighting the significance of shared understanding and mutual trust as team-level factors influencing safety performance. They emphasized that team dynamics play a crucial role in construction safety. Li et al. [51] applied a structural equation model to examine the impact of social capital on safety climate and found that mutual trust can enhance safety performance. In a subsequent study, Li et al. [52] introduced safety competency as a mediating factor between social capital and safety performance and reached a similar conclusion, highlighting the positive effect of mutual trust on safety performance. However, when Li et al. [53] invested the effects of social capital between supervisors and workers on individual-level safety performance, the influence of mutual trust between supervisors and workers on workers' safety performance did not appear as significant. These studies demonstrate the potential of mutual trust as a promising topic for further research in the context of construction safety. Further exploration of mutual trust in construction settings can contribute to enhancing safety outcomes.

3.3.3. Collective Efficacy

Collective efficacy pertains to the collective belief within a team regarding their competence to successfully carry out tasks and attain desired results [54]. Meta-analyses conducted by Gully et al. [55] and Stajkovic et al. [56] have consistently shown a positive relationship between collective efficacy and team or group performance. In the field of organizational psychology, researchers [2,57] have recognized collective efficacy as a strong predictor of team performance, particularly in highly interdependent teams where safety is a priority.

Within the construction industry, where teams rely heavily on interdependence and safety is of utmost importance, collective efficacy remains a concept that has received insufficient attention. Salanova et al. [58] incorporated collective efficacy as a psychological factor influencing overall performance in construction, while Okoye et al. [59] emphasized its significance in implementing safety interventions in the construction industry. However, these studies, primarily, are largely theoretical. There is a need for more empirical evidence to demonstrate the impact of collective efficacy on safety performance. Salanova et al. [60] investigated the effect of self-efficacy on safety performance among construction workers and found that workers with higher self-efficacy were more likely to engage in unsafe behaviors. They argued that elevated levels of self-efficacy could lead to overconfidence, resulting in unsafe behaviors. While these insights are valuable, there is a need for research to examine whether a similar effect exists at the team level. The limited literature on collective efficacy in the context of construction suggests a knowledge gap in understanding its effect on construction safety performance, warranting further investigation.

3.3.4. Shared Mental Models (SMMs)

A team mental model entails a mutual comprehension among team members regarding pertinent knowledge, team dynamics, and individual responsibilities within the team [61]. Shared mental models (SMMs) represent the collective cognitive representations of task requirements, procedures, and role responsibilities within a team [2]. SMMs facilitate team coordination and compatible decision making and ultimately improve team effectiveness [2,61]. Burtscher and Manser [62] conducted a systematic review and highlighted the strong positive impact of SMMs on safety performance.

In the construction industry, the significance of SMMs in developing a safety culture has been recognized by Lingard and Blismas [63]. Additionally, as discussed earlier, several studies have investigated the influence of shared understanding, which is similar to SMMs, as a component of social capital on safety performance [49–53]. Mitropoulos and Memarian [3] also incorporated SMMs in their construction teamwork processes model, emphasizing the role of SMMs in enabling coordinated action within dynamic teams. SMMs allow team members to interpret information and environmental cues in a consistent manner, identify errors and threats, and accurately anticipate each other's actions.

Despite the potential benefits of SMMs for enhancing safety performance being known, their use within the construction industry remains limited. Lingard et al.'s study [64] might provide an explanation for the lack of interest in SMMs in construction. When they tested 60 Australian construction professionals on their mental models of occupational health and safety, it emerged that individuals relied on their own frame of reference to understand occupational safety and health, suggesting that SMMs might be "unlikely to exist in construction project teams" [64]. However, it is important to note that their study focused on decision-making-level teams, specifically recruiting architects, engineers, safety professionals, and constructors. SMMs could potentially exist among site management teams and production-level teams. Therefore, there is a need to explore the existence and impact of SMMs among different types of construction teams to gain a comprehensive understanding of their role in enhancing safety performance.

3.3.5. Situation Awareness

Individual-level situation awareness encompasses three levels: the perception of elements, the understanding of their meaning, and the projection of future status [65]. Its purpose is to support human decision making in dynamic environments by considering the limitations of human data processing capacity [66]. At the team level, situation awareness becomes more complex. In addition to individual situation awareness, it includes team coordination and communication processes that require information exchange [67,68]. Team-level situation awareness entails understanding all factors that can impact the team and its performance [2], providing crucial information for decision making. Team-level situation awareness has been proven to promote effective teamwork and safety performance in the healthcare domain [69,70].

Although situation awareness is not a new concept in the construction industry, its application has been limited. Gheisari et al. [71] introduced the situation awareness approach to construction safety management in a project that focused on the impact of safety supervisors' situation awareness on decision making. Lappalainen et al. [66] examined existing situation awareness systems in construction companies and discussed their deficiencies, emphasizing the importance of situation awareness in construction safety management. In more recent literature, there is a trend of using various digital technologies to measure workers' situation awareness. For example, Hasanzadeh et al. [72] used eye-tracking technology to measure workers' situation awareness in real time. Hasanzadeh et al. [73] explored the relationship between workers' visual attention and situation awareness. Choi et al. [74] employed virtual reality (VR) to measure forklift operators' situation awareness. However, as Zhang et al. [75] pointed out, research on the impact of situation awareness on safety performance in the construction industry is limited, and there has been no statistical testing of the relationship between situation awareness and safety behavior. Additionally, it is important to note that most situation awareness research in construction has focused solely on the individual level. There is a need to investigate the effect of team-level situation awareness on construction safety performance.

3.4. Proposed Framework

Based on the literature discussed in the previous sections and the previous frameworks proposed by Mitropoulos and Memarian [3] and Salas et al. [2], we present an updated framework that illustrates how teamwork processes affect construction safety outcomes. This framework is presented in Figure 3.

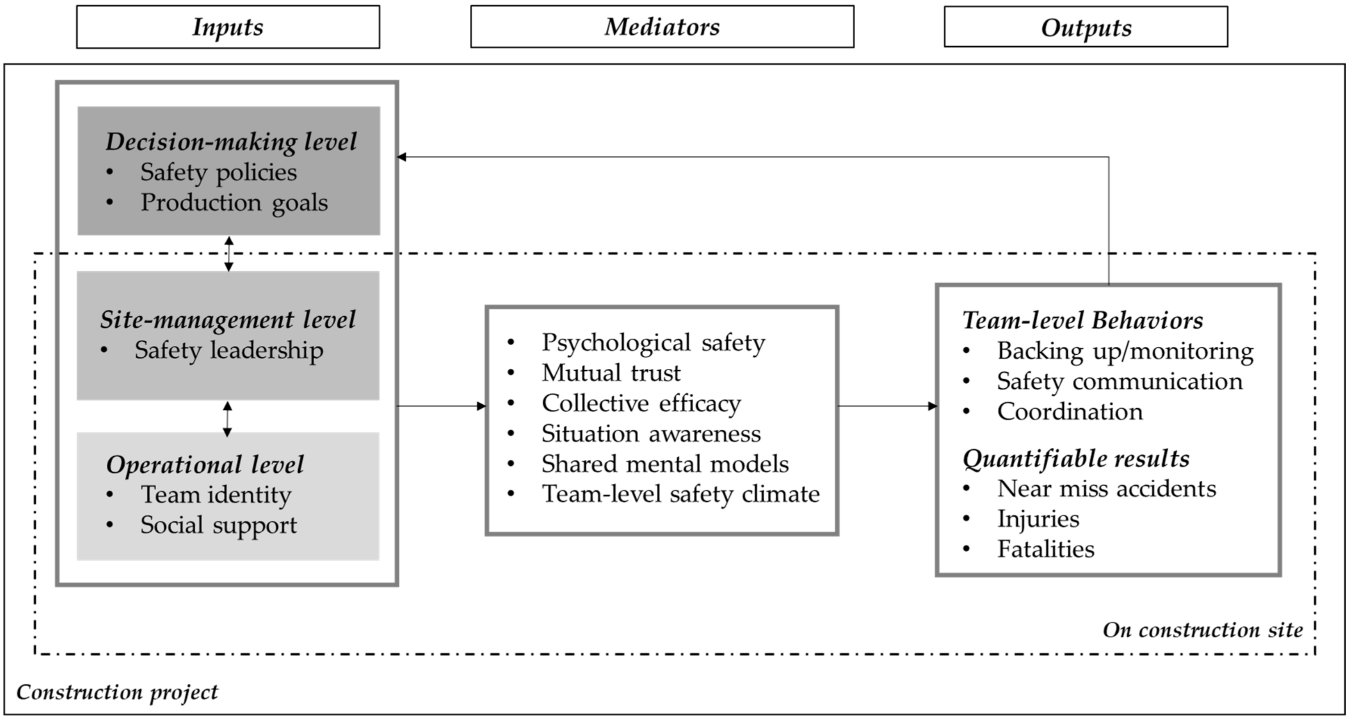

Figure 3. Framework of teamwork processes affecting construction safety outcomes.

This framework follows an input–mediator–output–input (IMOI) model structure [76]. Unlike the input–process–output (IPO) model structure used by Mitropoulos and Memarian [3], the IMOI model incorporates a feedback loop from output to input [76]. This better reflects the iterative nature of teamwork processes in construction teams. It acknowledges that teams undergo multiple cycles of these processes over time rather than a linear progression [76].

The framework highlights three distinct levels of team inputs, with particular emphasis placed on the teams working on construction sites as the primary contributors. These teams engage in close collaboration within the confined work environment where construction activities and accidents are most prevalent. The mediators identified in our framework encompass the five main factors proposed by Salas et al. [2], which have also gained some support in the construction literature, as discussed above. Additionally, we incorporate team-level safety climate as a significant mediator, considering the overwhelming evidence from construction research that emphasizes its influence on safety performance.

Our framework is directed at capturing a comprehensive understanding of safety outcomes through including both quantifiable results, such as near misses, injuries, and fatalities, and team-level behaviors. While quantifiable results serve as valuable indicators of safety performance, they primarily serve as lagging indicators [77]. In contrast, team-level behaviors are regarded as leading indicators of safety performance and encompass crucial aspects such as monitoring and backup behaviors, safety communication, and coordination [2,3,77]. These have been discussed further in the subsequent section.

4. Discussion and Conclusions

In our proposed framework, we attempt to capture the complex and dynamic nature of construction teams. We recognize three distinct levels of teams in construction projects: the decision-making teams, the site management teams, and the operational teams. These levels reflect the hierarchical structure within construction organizations and highlight the different roles and responsibilities each level plays in ensuring safety.

The decision-making teams have the highest level of authority and strategic oversight in construction projects. These teams consist of project owners, executives, and senior management responsible for defining safety policies and setting the overall production goals [3]. Their decisions and actions have a profound impact on shaping the project's organizational safety climate, establishing priorities, and creating an environment that promotes safety throughout the organization.

Moving down the hierarchy, the site management teams operate at the intermediate level. Comprising project managers, construction managers, forepersons, and superintendents, these teams are responsible for the coordination and management of construction activities on-site. They play a crucial role in implementing safety protocols, providing guidance to the operational teams, and addressing safety-related issues that arise during project execution. Safety leadership is particularly important at this level, as it influences the team-level safety climate within the project.

Finally, the operational teams form the foundation of the framework. These teams consist of frontline workers, tradespeople, and laborers actively engaged in the construction tasks. They work closest to potential hazards and face daily safety challenges. Their input into the framework is crucial as they directly experience and navigate the on-site conditions, and their behaviors and decisions directly impact safety outcomes. We contend that their social identity with the project is crucial to safety outcomes because teams on this level are the most dynamic. As the literature has suggested, a higher identification with the project can be an effective means of improving workers' safety behavior in construction projects [34]. Also, coworkers' social support is the most important at this level, which is essential in fostering the team-level safety climate [28,29].

The proposed framework includes the five mediators suggested by Salas et al. [2] to understand construction safety. As presented above, existing construction literature provides some support for these mediators, but further research is necessary to establish their robustness and applicability in the construction industry. Moreover, it is important to validate the framework through empirical evidence. In our next step, we intend to validate the mediators proposed by Salas et al. [2] and specifically examine their impact on construction safety outcomes. As observed in our review, structural equation modeling (SEM) can be a valuable methodological approach to assess the relationships between the mediators and safety outcomes [26,49,52]. By collecting data from different levels of construction teams and analyzing it using SEM, we will try to quantify the influence of each mediator on safety and determine their significance.

This study aimed to advance the understanding of teamwork processes and their influence on construction safety. Through a comprehensive literature review, we identified key teamwork processes that impact safety outcomes in the construction industry. We also compared and benchmarked the knowledge of teamwork processes in construction against other industries, highlighting areas for improvement and adaptation. Based on recent advancements in team science and construction safety science, we proposed a framework that captures the complex and dynamic nature of construction teams. The framework recognizes the hierarchical structure within construction organizations and highlights the distinct roles and responsibilities of decision-making teams, site management teams, and operational teams in ensuring safety.

While the final research objective, which is to validate and refine the proposed framework through industry practitioner input, remains a future step, this study has laid a solid foundation for future research and practical implementation. The proposed framework provides valuable insights for construction organizations seeking to enhance safety practices and create an organizational safety climate. We have also identified a need for longitudinal studies to assess the mediators' effects over time. Construction projects evolve, and teamwork processes, safety culture, and other factors may change throughout the project lifecycle. Longitudinal studies can capture these dynamics and provide a more comprehensive understanding of how the mediators contribute to construction safety at different project stages.

By addressing the research objectives of conducting a comprehensive literature review, comparing industry knowledge, and proposing a framework based on recent advancements, this study contributes to the existing body of knowledge on teamwork processes and construction safety. The framework offers guidance for future research endeavors and practical initiatives aimed at improving safety outcomes in the construction industry.

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