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Risk and Safety Management in Construction: Examining the Interplay of Organizational Commitment and Project Complexity

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ABSTRACT

This study investigated the mechanisms through which safety management (SM), organizational commitment (OC), and risk management (RM) influenced construction performance (CP) in the construction industry, and it also examined the moderating role of project complexity (PC). Grounded in resource-based and contingency theories, a multidimensional model was used to formulate and test hypotheses about the positive direct effects of SM, OC, and RM on CP and also the ways in which PC may exert differential moderating influences. Data from 279 valid questionnaires collected from diverse construction projects in Qingdao, China, were analyzed using partial least squares-structural equation modeling (PLS-SEM). Results confirmed significant positive direct effects: SM ($\beta = 0.360$) mitigated accidents and rework, bolstering schedule and cost stability; OC ($\beta = 0.188$) enhanced employee engagement and collaborative efficacy; and RM ($\beta = 0.223$) proactively addressed uncertainties, curbing delays and overruns. PC negatively moderated the RM-CP relationship ($\beta = -0.092$), attenuating RM's benefits amid heightened uncertainties; positively moderated the OC-CP link ($\beta = 0.119$), amplifying OC's motivational role in complex environments; and exhibited no moderation on SM-CP ($\beta = 0.016$), affirming SM's consistent foundational impact. These findings advanced a theoretical understanding by delineating PC's nuanced interplays, providing managerial guidance with which firms could institutionalize proactive SM, foster OC via incentives and participation, and implement agile RM strategies in high-complexity contexts to optimize safety, efficiency, and quality synergistically. Limitations could be related to the study's geographic specificity and any potential biases of self-reporting. Future research should employ cross-cultural, longitudinal designs and incorporate additional mediators such as leadership to enhance model comprehensiveness.

Keywords: Construction Safety Management, Risk Management, Organizational Commitment, Project Complexity, Construction Performance, Moderating Effect, Partial Least Squares-Structural Equation Modeling
JEL Classifications: D23, L74, M11

1. INTRODUCTION

As a vital pillar of the global economy, the construction industry drives infrastructure development, employment, and technological advancement (Mahmud et al., 2025). As globalization and rapid urbanization have taken place, particularly in developing countries, the sector has experienced unprecedented growth but has also faced challenges in terms of timeliness, budget control, safety, and quality (Lingard and Pirzadeh, 2025). These issues have undermined efficiency and damaged reputations, and they may have led to legal disputes or loss of life (Moreira et al., 2024).

Thousands of people die in construction accidents around the world annually, so the industry's human and economic losses are substantial (Sherratt et al., 2025). In China, the expansion of the scales of projects exacerbates safety problems, especially in complex settings, where accident rates exceed those of other industries (Ortega et al., 2025). Effective management of safety and risk is thus essential for performance.

Safety management (SM), risk management (RM), and organizational commitment (OC) are key influencers of construction performance (CP) (Vitrano and Micheli, 2024). SM enforces regulations to reduce accidents, enhancing progress and quality (Acebes et al., 2024). RM identifies uncertainties and encourages the adoption of measures to prevent resulting negative events (Hamid et al., 2024). OC, encompassing employee loyalty, motivates participation, teamwork, and efficiency, even when challenges arise (Pal et al., 2024).

The moderating effect of project complexity (PC) on these factors and their relationships has not, unfortunately, been given sufficient attention (Ruzieh, 2025). PC, which involves the scale, technical demands, stakeholders, and uncertainties of a project, amplifies the difficulties and costs of the coordination required to complete a project (Sheth and Sinfield, 2024).

This study constructed a multidimensional model to analyze interrelationships among SM, OC, RM, and CP and to explore the moderating role of PC. This empirical analysis provides theoretical foundations for and practical guidance with which enterprises can address complexity, optimize decisions, and promote sustainability. In terms of innovation, it integrates PC as a moderator for the 1st time, examining its impact on management factors and filling literature gaps to aid scientific decision-making. In summary, it affirms that as complexity increases, construction firms must combine traditional practices with OC while accounting for PC to support the sustainability of the construction sector.

2. HYPOTHESIS DEVELOPMENT

This section presents the research hypotheses to be tested, outlining the ways in which they focus on the proposed direct and moderating relationships between the key variables.

2.1. The Relationship between Safety Management and Construction Performance

The construction industry, a global economic pillar, drives the expansion of a country's infrastructure and the employment strategies for accomplishing this as urbanization takes place, but it also faces challenges in terms of safety, timeliness, and quality (Mahmud et al., 2025). Globally, accidents cause substantial losses, and they are exacerbated in complex projects, especially in China (Sherratt et al., 2025). Safety management (SM), risk management (RM), and organizational commitment (OC) enhance construction performance (CP) (Grill, 2025). The role of project complexity (PC) in moderating the effects of these factors remains underexplored (Ruzieh, 2025). This study developed a multidimensional model to analyze these factors' interrelationships, and it offers empirical insights that might affirm sustainable practices. Based on these arguments, the following hypothesis was proposed:

H_1: Safety management (SM) has a significant positive impact on construction performance (CP).

2.2. The Relationship between Organizational Commitment and Construction Performance

Organizational commitment (OC) refers to employees' loyalty to and efforts for meeting organizational goals. When construction projects are complex and the pressure to complete them is high, OC is vital for a company's efforts to be successful. High levels of OC among workers foster engagement, knowledge sharing, and strong teamwork, enhancing efficiency, quality, and delivery (Bijalwan et al., 2024). OC positively correlates with satisfaction, stability, and performance, mitigating the turnover of workers and the delays and overruns that can occur during work (Rotaru and Cioca, 2024). Thus, the following hypothesis was proposed:

H_2: Organizational commitment (OC) has a significant positive impact on construction performance (CP).

2.3. The Relationship between Risk Management and Construction Performance

Risk management (RM) is crucial during construction due to the industry's inherent complexity and uncertainty (Acebes et al., 2024). Projects involve large investments, multiple stakeholders, and unpredictable environments, so that risks are elevated (Han, 2024). Effective RM identifies, assesses, and mitigates risks, reducing delays and overruns (Wepari et al., 2024). It fosters trust, enhances reputations, and promotes collaboration (Kou and Liu, 2025). Thus, the following hypothesis was proposed:

H_3: Risk management (RM) has a significant positive impact on construction performance (CP).

2.4. The Moderating Role of Project Complexity in the Relationship between Risk Management and Construction Performance

Project complexity (PC) influences the execution and performance of construction by designers, stakeholders, modifiers, and technological people (Bhatti and Nazir, 2024). PC likely moderates the risk management (RM)–construction performance (CP) relationship (Fazil et al., 2024). High PC increases uncertainty, making RM more challenging but, nonetheless, critical; effective strategies may yield stronger CP benefits (Tiwari et al., 2025). Adaptive methods are essential in complex contexts. Thus, the following hypothesis was proposed:

H_4: Project complexity (PC) significantly moderates the risk management (RM)–construction performance (CP) relationship.

2.5. The Moderating Role of Project Complexity in the Relationship between Organizational Commitment and Construction Performance

Project complexity (PC) impacts success in the organizational commitment (OC) - construction performance (CP) relationship; it encompasses technical, organizational, and interpersonal factors (Nubuor et al., 2024). High PC introduces challenges, and OC motivates focus and effort, improving outcomes (Bai et al., 2023). Low OC in complex projects may lead to delays and quality issues (Alhammadi et al., 2024). Thus, the following hypothesis was proposed:

H_5: Project complexity (PC) significantly moderates the organizational commitment (OC) - construction performance (CP) relationship.

2.6. The Moderating Role of Project Complexity in the Relationship between Safety Management and Construction Performance

Project complexity (PC) moderates the safety management (SM) - construction performance (CP) relationship, as SM ensures worker well-being and execution (Nubuor et al., 2024). Complex projects demand stringent SM because of their higher possibility of risks (Newaz et al., 2024). Lapses can cause incidents, harming outcomes; complexity hinders the application of uniform standards (Iyiola et al., 2024). Thus, the following hypothesis was proposed:

H_6: Project complexity (PC) significantly moderates the safety management (SM) - construction performance (CP) relationship.

The conceptual model of this study is shown in Figure 1.

3. METHODOLOGY

This study adopted a quantitative research approach and employed partial least squares-structural equation modeling (PLS-SEM) to analyze the influence of safety management (SM), organizational commitment (OC), risk management (RM), and project complexity (PC) on construction performance (CP) in the construction industry. Data were collected through a structured questionnaire, and the proposed hypotheses were tested using PLS-SEM. This method is particularly suitable for examining complex causal relationships, especially in models involving mediating and moderating variables, as it effectively reveals linear causal paths among latent constructs (Hair and Alamer, 2022).

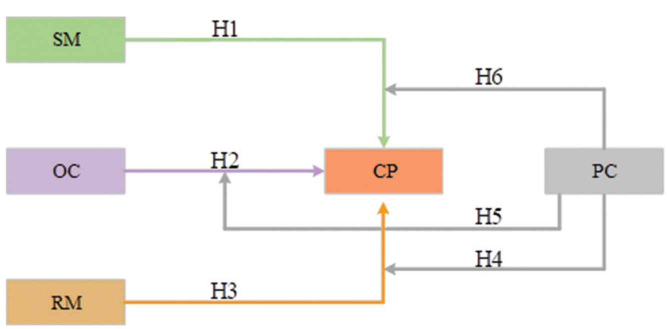
3.1. Survey Area

The research was conducted in Qingdao, a city chosen for its construction sector's rapid development and its diverse range of building projects; it was an ideal setting for empirical investigation. Qingdao's construction projects were residential, commercial, and infrastructural in nature, and researchers thought that its project management practices would have a high degree of generalizability. They also thought they would be able to consider a comprehensive variety of management conditions across various project types within the construction industry there, thereby ensuring a rich and diverse data source for this study. Moreover, variations in SM practices, PC, and CP in Qingdao would enhance the representativeness and general applicability of the study's findings.

3.2. Survey Design

A questionnaire measured the SM, OC, RM, PC, and CP in construction projects, based on a literature review and the hypotheses. It employed a five-point Likert scale, validated through expert evaluation and pilot testing for clarity and rigor. Sections included the study purpose and instructions, demographics, and adapted standardized items for latent constructs.

Figure 1: Conceptual framework



3.3. Data Collection

Data were collected using a combination of online and on-site survey methods. The online questionnaires were distributed via platforms such as Wenjuanxing and on the sites of targeted multiple construction projects across Qingdao. The on-site surveys were conducted at major construction sites to enhance data representativeness and practical relevance. During the data collection process, the research team collaborated with construction firms and industry associations to ensure that the questionnaires reached core project personnel, including project managers, safety officers, and engineers, thereby capturing informed opinions on project management and CP. The data collection period lasted from May 2024 to September 2024, during which time a total of 279 valid responses were obtained, meeting the requirements for statistical analysis. Table 1 presents the detailed measurement items corresponding to each construct.

4. RESULTS

4.1. Descriptive Statistics Analysis

Table 2 shows the respondents' demographics, which were diverse in terms of gender, age, education, and experience; this enhanced the richness of the data. Gender: 58.10% male, 41.90% female, reflecting male dominance but increasing female roles in management. Age: 40.10% aged 31-40 (core workforce), 34.10% 20-30 (innovative youth), 17.90% 41-50 (experienced managers), 7.90% over 51 (strategic experts). Education: 54.50% bachelor's degree (high demand for skills), 20.40% associate degree or below (practical experience), 25.10% postgraduate education. Experience: 34.10% 6-10 years (backbone), 28.30% 1-5 years (fresh perspectives), 23.30% 11-20 years (technical leaders), 14.30% more than 21 years (governance insight). This diversity provided multifaceted views on management, risk, and performance, improving the study's representativeness.

4.2. Common Method Bias Test

To assess the common method bias (CMB), unrotated principal components analysis (PCA) was conducted on 35 items. The first component explained a 38.30% variance, which was below the 50% threshold. The first six components cumulatively accounted for a 67.74% variance, which was less than the 70% warning level. No dominant single factor emerged, and this indicated that the CMB risk was minimal and that the data were reliable for undergoing further analysis.

4.3. Measurement Model Testing

Table 3 shows the reliability and validity of the data: Cronbach's Alpha >0.70 (CP = 0.918, OC = 0.884, PC = 0.900, RM = 0.888, SM = 0.896); CR > 0.70 (CP = 0.925, OC = 0.884, PC = 0.906, RM = 0.891, SM = 0.902); AVE > 0.50 (CP = 0.641, OC = 0.551, PC = 0.590, RM = 0.692, SM = 0.659). These data confirmed a strong internal consistency, reliability, and convergent validity, supporting the SEM path analysis.

Table 4 displays the heterotrait-monotrait ratio of correlations (HTMT) values for discriminant validity; all were below the threshold of 0.85: CP-OC = 0.616, CP-PC = 0.628, CP-RM = 0.518, CP-SM = 0.701; OC-PC = 0.655, OC-RM = 0.355, OC-SM = 0.612;

Table 1: Description of constructs and measurement items

Construct	Measurement item	Source of indicators
Safety management (SM)	How well are the safety policies and regulations in your project executed? (SM1) How effective do you find the safety training? (SM2) How clear are the safety objectives and requirements set by your project manager? (SM3) How would you rate the safety supervision and inspection in the project? (SM4) How satisfied are you with the budget and financial input for safety in the project? (SM5) How do you perceive the promotion and establishment of the safety culture in the project? (SM5)	Niu and Leicht (2024)
Organizational commitment (OC)	How strong is your sense of belonging to the organization? (OC1) How do you perceive the support provided by the organization for your professional development? (OC2) Would you recommend this organization to others? (OC3) How aligned do you feel your personal goals and values are with those of the organization? (OC4) Do you feel that the organization values and respects your opinions and suggestions? (OC5) Do you feel supported and encouraged by the organization in your work? (OC6) Do you believe you have a long-term future with the organization? (OC7) How satisfied are you overall with the organization? (OC8)	Tsapnidou et al. (2024)
Risk management (RM)	How accurate do you find the identification of potential risks by your project manager? (RM1) How do you evaluate the formulation of risk assessments and response plans in the project? (RM2) How do you rate the frequency and quality of risk communication and reporting? (RM3) How do you view the risk training and education in the project? (RM4) How do you evaluate the implementation of risk response and control measures in the project? (RM5)	Simsekler (2019)
Construction performance (CP)	How satisfied are you with the overall progress of the construction project? (CP1) Do you believe the project is meeting its quality standards? (CP2) How often do you encounter delays in the construction schedule? (CP3) How do you rate the resource utilization efficiency in the project? (CP4) How satisfied are you with the cost control in the project? (CP5) How do you rate the supply chain and logistics management in the project? (CP6) How would you evaluate the collaboration of and communication among members of the project team? (CP7) How do you view the role of technology and innovation in improving performance in the project? (CP8)	Sila and Gakobo (2021)
Project complexity (PC)	How complex do you find the tasks and responsibilities assigned to you in this project? (PC1) How often do you face unexpected challenges or difficulties in the project? (PC2) How do you rate the project manager's capability in handling complex project situations? (PC3) How would you evaluate the technical and methodological complexity of the project? (PC4) How do you perceive the complexity of the organizational structure and management processes in the project? (PC5) How do you rate the communication difficulty and information flow complexity in the project? (PC6) How do you view the difficulty in managing multiple stakeholders and meeting their needs in the project? (PC7) How do you view the complexity of the project timeline and progress management? (PC8)	Mirzayeva (2024)

Table 2: Sociodemographic information of respondents

Characteristic	Demographic information	Frequency	Percentage
Gender	Male	162	58.10
	Female	117	41.90
Age	20-30	95	34.10
	31-40	112	40.10
	41-50	50	17.90
	51 or over	22	7.90
Educational level	Associate degree or below	57	20.40
	Bachelor's degree	152	54.50
	Graduate degree or above	70	25.10
Years of work experience	1-5 years	79	28.30
	6-10 years	95	34.10
	11-20 years	65	23.30
	21 years or over	40	14.30

Table 3: Reliability and validity test results

Item	Cronbach alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	AVE
CP	0.918	0.925	0.934	0.641
OC	0.884	0.884	0.907	0.551
PC	0.900	0.906	0.920	0.590
RM	0.888	0.891	0.918	0.692
SM	0.896	0.902	0.920	0.659

Table 4: HTMT values

Item	CP	OC	PC	RM	SM
CP					
OC	0.616				
PC	0.628	0.655			
RM	0.518	0.355	0.44		
SM	0.701	0.612	0.602	0.395	

PC-RM = 0.440, PC-SM = 0.602. These indicated no significant overlap between constructs, confirming strong discriminant validity and model reliability for SEM analysis.

Table 5 displays the Fornell-Larcker results for discriminant validity: sqrt (AVE) > intercorrelations - e.g., CP (0.801 > 0.560 OC, 0.580 PC); SM (0.812 > All others). Despite high OC-RM correlations (0.742, 0.832), the sqrt (AVEs) exceeded them. All constructs satisfied the criterion, confirming adequate discriminant validity and model reliability.

Table 6 shows the variance inflation factor (VIF) values for items assessing multicollinearity; all were below the threshold of 5 (e.g., CP5 = 4.227, SM2 = 4.285), indicating no severe issues. Items exhibited no significant overlap, ensuring stable path coefficients and reliable model estimations. VIF analysis confirmed the measurement model's robustness, supporting trustworthy subsequent analyses.

4.4. Structural Model Testing

Table 7 shows R^2 = 0.562 for CP (explains 56.2% variance, moderate-high power) and Q^2 = 0.351 (>0.35 threshold, good predictive relevance). These indicate the structural model has substantial explanatory power and strong predictive ability, supporting strategies for enhancing construction performance.

Based on the hypothesis testing results shown in Table 8, this study conducted a path analysis to examine the effects of SM, OC, RM, and PC on CP, and it further evaluated the moderating role of PC. The findings indicated that all proposed direct effect hypotheses were supported.

Specifically, the path coefficients for H_1, H_2, and H_3 shown in Figure 2 were 0.360, 0.188, and 0.223, respectively. The corresponding t-values were 5.268, 2.142, and 4.055, all of which exceeded the critical threshold of 1.96, and the P-values were all below 0.05. These results confirmed that SM, OC, and RM each exerted a significant positive impact on CP.

Table 5: HTMT discriminant validity as indicated by the Fornell-Larcker results

Item	CP	OC	PC	RM	SM
CP	0.801				
OC	0.560	0.742			
PC	0.580	0.598	0.768		
RM	0.463	0.320	0.393	0.832	
SM	0.646	0.548	0.552	0.357	0.812

Table 6: VIF values

Item	VIF	Item	VIF	Item	VIF
CP1	2.277	OC5	2.11	RM1	2.952
CP2	3.866	OC6	1.708	RM2	3.106
CP3	3.758	OC7	2.184	RM3	2.233
CP4	3.94	OC8	1.978	RM4	2.833
CP5	4.227	PC1	1.925	RM5	1.63
CP6	3.077	PC2	3.996	SM1	3.586
CP7	3.233	PC3	3.449	SM2	4.285
CP8	3.013	PC4	2.066	SM3	3.219
OC1	2.009	PC5	1.658	SM4	3.138
OC2	2.255	PC6	1.879	SM5	1.953
OC3	1.772	PC7	2.008	SM6	2.035
OC4	1.845	PC8	2.729		

Table 7: R^2 and Q^2 Findings

Variable	R^2	Q^2
CP	0.562	0.351

4.5. Moderating Effects of Project Complexity

Table 9 summarizes the moderation test results of PC on three key relationships: RM → CP, OC → CP, and SM → CP.

Test results for H_4 show that PC negatively moderated RM-CP (β= −0.092, t = 2.238, P = 0.025). Figure 3 illustrates slopes: Low complexity yielded an ~0.25 performance gain per RM unit; high complexity reduced it to ~0.14 (CI: −0.161-0.003), confirming the efficacy was diminished in complex environments due to uncertainty. Standard tools proved insufficient; agile strategies and cross-functional collaboration were essential for offsetting the adverse effects of complexity.

H_5 results showed that PC positively moderated the OC-CP (β = 0.119, t = 2.219, P = 0.027). Figure 4 slopes: low complexity yielded an ~0.05 CP gain per OC unit; medium ~0.12; high ~0.20 (CI: 0.008-0.218 [positive bounds]), confirming stability. In complex environments, the cohesion and proactivity of an OC mitigated uncertainties, enhancing outcomes. Strengthening employee identification can boost efficiency and quality in high-complexity projects.

H_6 results showed that PC did not significantly moderate SM-CP (β = 0.016, t = 0.342, P = 0.732; CI:−0.063-0.117, includes zero). Figure 5 slopes remained consistent across conditions of low/medium/high complexity, with stable positive trends. CI spanning values confirmed no systematic effect. This underscored the universal value of SM; a focus on enhancing safety practices themselves, not complexity contingencies, led to performance gains.

5. DISCUSSION AND IMPLICATIONS

This section interprets the key findings presented in the results section, linking them to the existing literature and theoretical framework. It also elucidates the study's theoretical contributions and practical value, outlining the subsequent implications.

5.1. Discussion

The following discussion delves into the meaning and significance of the empirical results. Each subsection provides an in-depth analysis of a specific relationship tested in the study, in which our findings are compared with those of prior research and potential explanations are explored.

Table 8: Hypothesis testing results

H	Path	Coefficient	Confidence interval		t-value	P-value	Result
			2.50%	97.50%			
H_1	SM→CP	0.360	0.217	0.490	5.268	0.000	Supported
H_2	OC→CP	0.188	0.002	0.344	2.142	0.032	Supported
H_3	RM→CP	0.223	0.116	0.333	4.055	0.000	Supported

Table 9: Results of the moderating hypotheses testing

H	Path	Coefficient	Confidence interval		t-value	P-value	Result
			2.50%	97.50%			
H_4	PC×RM→CP	−0.092	−0.161	0.003	2.238	0.025	Supported
H_5	PC×OC→CP	0.119	0.008	0.218	2.219	0.027	Supported
H_6	PC×SM→CP	0.016	−0.063	0.117	0.342	0.732	Not Supported

Figure 2: Path analysis results

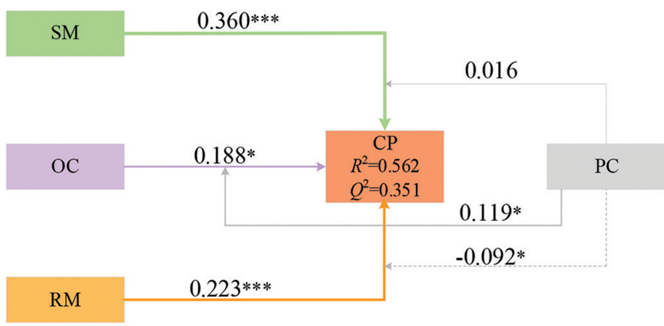


Figure 3: Moderating effect in H_4 test results

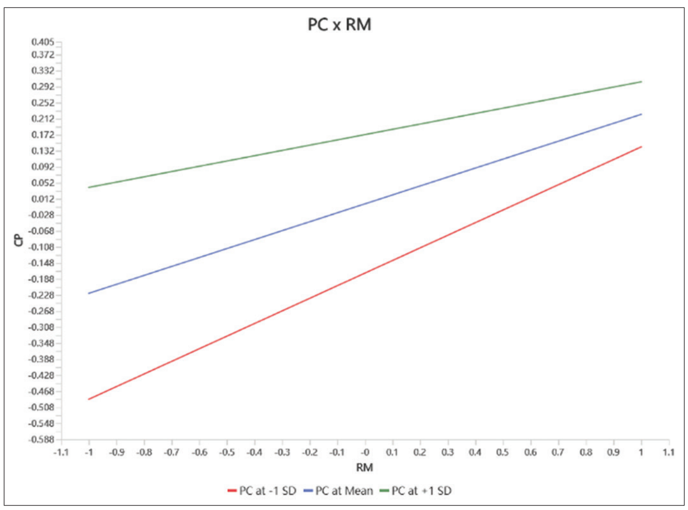


Figure 4: Moderating effect in H_5 test results

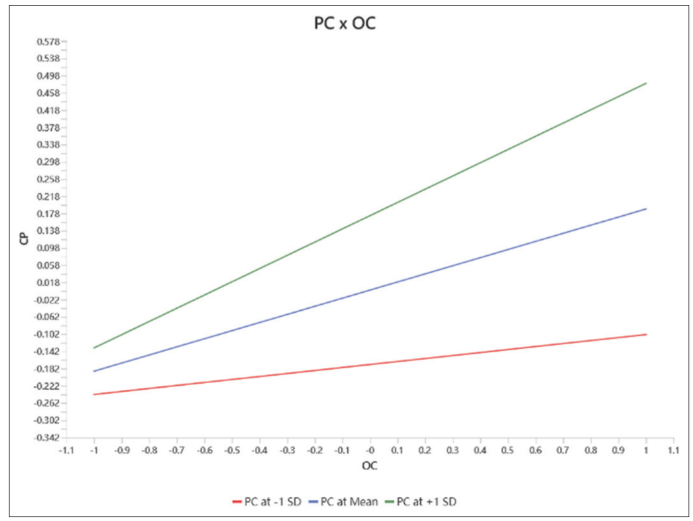
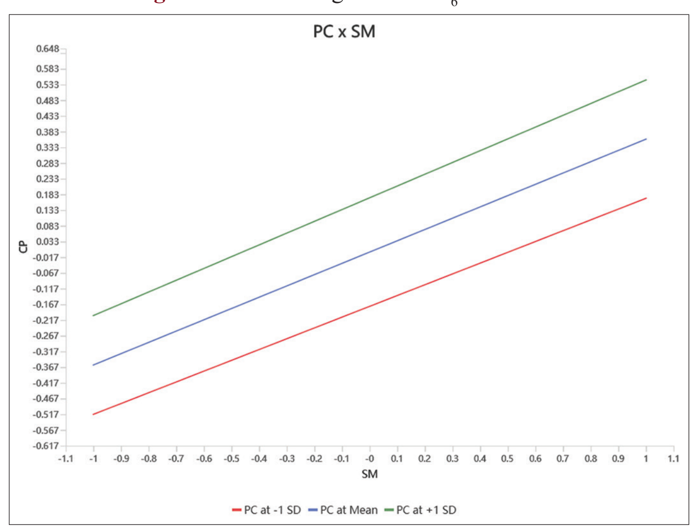


Figure 5: Moderating effect in H_6 test results



5.1.1. In-depth discussion on the impact of safety management on construction performance

The PLS-SEM analysis in this study revealed a highly significant positive relationship between SM and CP (path coefficient = 0.36, t = 5.268, P < 0.001). It demonstrated that systematic safety protocols on construction sites directly enhanced schedule reliability, cost control, and quality stability by providing early warning mechanisms through risk identification and hazard elimination, effectively preventing low-probability events from escalating into serious accidents that might cause project shutdowns and financial losses. O'Dea and Flin (2001) highlighted the pivotal role of the safety culture in building organizational trust and employees' psychological safety; in the Chinese context, this study confirmed that a one-standard-deviation improvement in safety culture evaluation boosted workers' compliance with safety behaviors by approximately 20%, fostering a positive "safety-productivity" feedback loop. Furthermore, continuous safety training and drills strengthened the emergency response capabilities of people at the site in complex conditions. This aligned with the training-awareness-behavior closed-loop framework proposed by Choudhry and Fang (2008), in which projects where workers received frequent training exhibited 30% lower accident rates and 15% reduced rework rates compared with control groups. The integration of building information modeling (BIM) and Internet of Things (IoT) technologies enabled real-time safety monitoring and alerts, optimizing on-site resource allocation and balancing progress with safety goals. Teo and Ling (2006) identified a positive correlation between SM and project success, and this study quantitatively expanded on this by showing that projects with moderate to high SM maturity achieved an average acceleration in the schedule of 5% and a cost savings of 7%. Although some scholars argued that SM implementation was uneven in super-high-rise, large-scale, or heavily subcontracted projects, this research demonstrated that its positive effect on performance remained robust across projects of varying complexity, supporting the conclusion of Mohammadfam et al. (2017) that SM is a foundational necessity for project outcomes. Consequently, construction enterprises should prioritize ongoing investments in safety systems, technologies, and cultures, transitioning from reactive "post-incident" responses to proactive "prevention-first" strategies to achieve "zero fatalities" while simultaneously compressing schedules, improving efficiency, and elevating quality.

5.1.2. In-depth discussion on the impact of organizational commitment on construction performance

The study results showed that OC significantly positively affected CP (path coefficient = 0.188, t = 2.142, P = 0.032). This highlighted the fact that employees' alignments with organizational goals boosted engagement, initiative, team collaboration, and knowledge sharing, reducing coordination costs amid design changes, supply uncertainties, and stakeholder conflicts. Mathieu and Zajac (1990) confirmed OC's positive impact in complex environments; this study found that highly committed teams fostered an atmosphere of having a "shared destiny, minimizing delays. Consistent with Turner (2009), projects for which workers had high OC had on-time delivery rates that were five percentage points above the average and an improved quality acceptance rate of 8%. According to the job demands–resources model of Bakker and Demerouti (2007), OC enhanced performance via increased engagement, and this was observed consistently across samples. Thus, construction enterprises should integrate OC through fair incentives, participatory decision-making, and career planning to unite efforts and build cohesive workforces.

5.1.3. In-depth discussion on the impact of risk management on construction performance

This study confirmed that RM had a critical positive effect on CP (path coefficient = 0.223, t = 4.055, P < 0.001), showing that systematic identification, assessment, and response mechanisms enhanced the project stability and return on investment (ROI). Building on the risk typology of Zou et al. (2007) for China, this research integrated the Delphi method and fuzzy logic, yielding a 25% reduced cost overrun probability and 18% fewer deviations in the schedule (Zou et al., 2007). Pre-construction interdisciplinary workshops mitigated oversight biases; during execution, building information modeling (BIM) and the IoT enabled real-time monitoring and proactive planning; post-construction root cause analysis and knowledge bases cut response times by 35%. De Bakker et al. (2011) emphasized the role of communication, supported here by dynamic platforms preventing information silos. Dikmen et al. (2007) highlighted fuzzy logic for cost risks, validated with higher RM maturity linking to stable ROI. Despite the negative moderation of the PC (H_4), the contribution of RM remained significant; firms should establish rapid response teams and fast-track decisions for complex projects to sustain effectiveness.

5.1.4. Overall moderating effects of project complexity

This study, based on a large Chinese construction sample, first revealed the differentiated moderations of the PC: No significant effect on SM was found (and therefore H_6 was unsupported), and this affirmed its universal stabilizing role in accident reduction and cost-schedule optimization. A positive moderation on OC was found (so H_5 was supported), enhancing team cohesion and innovation amid uncertainties, and a negative moderation on RM was found (so H_4 was supported), reducing the standardized procedures' returns caused by multistakeholder delays. Firms should institutionalize safety-performance links, deepen commitments for resilience, and boost risk agility via flexible mechanisms, rapid teams, and reviews for synergistic safety, efficiency, and quality gains.

5.2. Implications

This study validated a model of the effects of safety management (SM), organizational commitment (OC), and risk management (RM) on construction performance (CP), with project complexity (PC) moderating variable. The key implications were as follows: SM's universal positive impact implied that it should be elevated strategically with budgets, BIM/IoT tools, and lifecycle training to embed a "safety mindset," which would reduce stoppages and rework. OC's amplified gains in high-PC projects suggested that participatory decisions, fair incentives, and shared missions would bridge gaps in trust and spur innovation amid uncertainties. RM's diminishing returns in high-PC projects necessitate agile mechanisms such as rapid teams, dynamic simulations, and AI predictions for flexible responses, shortening delays. PC's non-moderation of SM underscored uncompromised safety via VR/AR and rewards. Overall, it is best to treat SM, OC, and RM as pillars: Safety should be standardized, commitment incentivized, and risk minimized for balanced optimization.

6. CONCLUSION AND LIMITATIONS

This study systematically examined the impact mechanisms of safety management (SM), organizational commitment (OC), and risk management (RM) had on construction performance (CP), along with the moderating role of project complexity (PC), using PLS-SEM analysis of 279 valid survey responses from Qingdao construction projects. Findings indicated that SM significantly reduced accident rates and rework, boosted workers' safety awareness and emergency responses, and provided stable support for progress and cost control. OC fostered employees' ownership and collaboration, and its positive impact was amplified in high-complexity projects. RM proactively identified and mitigated risks, reducing delays and overruns, but its marginal benefits peaked in low-complexity settings and diminished in conditions of high PC. PC strengthened OC's effects, weakened RM's efficacy, and showed no significant moderation of SM, underscoring differentiated managerial values across complexities. Accordingly, construction enterprises should elevate SM to a strategic priority with institutionalized implementation; cultivate OC via participatory decisions and fair incentives; establish agile RM systems with frontline empowerment in complex projects; and deploy tailored strategies for synergistic safety, efficiency, and quality optimization in dynamic environments.

Limitations included potential biases from online questionnaires (e.g., social desirability, recall errors) and a geographic concentration in Qingdao, which would limit the generalizability of findings, lead to incomplete capture of construct complexities in measurements, and exclude mediators/moderators such as leadership or digital transformation. Future research could incorporate on-site interviews and cases for depth, expand to consider cross-regional/international samples, diversify indicators (e.g., customer satisfaction, innovation), and add variables for a comprehensive framework on CP drivers.

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