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Factors Contributing to Cost Overruns and the Mediating Effects of Inadequate Planning in Construction Projects

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Abstract: Construction cost overruns (CCO) remain a persistent challenge in the global construction industry, leading to significant financial losses and project delays. This study examines the factors contributing to cost overruns and investigates the mediating role of inadequate construction planning (ICP) in construction projects. Based on project management theory and lifecycle theory, a conceptual framework was developed incorporating resource constraints (RC), design change (CD), inadequate construction planning, and construction cost overruns. Data were collected from 540 construction professionals across 16 cities in Anhui Province, China, yielding 512 valid responses (94.8% response rate). Structural Equation Modeling (SEM) was employed to test seven hypotheses regarding the relationships among these variables. The results demonstrate that resource constraints significantly impact both inadequate construction planning ($\beta = 0.322$, $p < 0.001$) and cost overruns ($\beta = 0.18$, $p = 0.013$). Design change also significantly affects cost overruns ($\beta = 0.148$, $p = 0.029$), while inadequate construction planning shows the strongest positive influence on cost overruns ($\beta = 0.418$, $p < 0.001$). Mediation analysis reveals that inadequate construction planning partially mediates the relationship between resource constraints and cost overruns (indirect effect = 0.234, $p < 0.001$), as well as between design change and cost overruns (indirect effect = 0.04, $p = 0.03$). These findings contribute to the understanding of cost overrun mechanisms and provide practical implications for construction project management, emphasizing the critical role of comprehensive planning in mitigating cost escalation risks.

Keywords: Construction cost overruns (CCO), design change (CD), inadequate construction planning (ICP), resource constraint (RC).

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1. Introduction

Despite the growing economic potential of countries, the construction industry faces the challenge of cost overruns (Vijayalaxmi and Khan, 2022), which are a worldwide phenomenon. Cost overruns in construction projects increase investment pressure, raise the total cost of construction, influence investment decisions, and waste national finances (Gomez-Cabrera et al., 2019). In construction projects across all nations, industrialized or developing, cost overruns are a frequent occurrence (Al Saeedi and Karim, 2022). Around 90% of projects worldwide have cost overruns ranging from 50% to 100% (Anigbogu et al., 2019). For example, Kumar et al. (2022) revealed that the cost of 9 out of 10 building projects will exceed the original budget by up to 183%. In the construction sector, cost overruns are frequent, and few projects are finished within the original budget (Mahmood, 2021). Cost overruns in the construction industry are a worldwide phenomenon, and Al-Mhdawi et al. (2022) and Algahtany (2021) observed that because projects in developing countries are often not finished on schedule and within the initial budget, the trend of cost overruns is particularly pronounced there. It has been noted that cost overruns are more commonly observed than time overruns, which makes cost overrun issues very important (El-Kholy, 2021). In fact, among the many challenges the construction industry faces today, cost overruns are among the most significant. Cost overruns are one of the most important problems impeding the construction projects advancement, affecting profits, causing significant losses and putting construction projects at risk (Halloum and Bajracharya, 2012).

Similarly, the construction industry in Anhui, China, has also been affected by the burden of cost overruns (Kun et al., 2024). In a study covering 51 private and 308 public construction projects in Anhui, China, Ryu and Sovacool (2025) indicates that only 37.2% of private projects and 46.8% of public projects were finished within budget. In addition, a survey of 140 participants in central Anhui revealed that 89% of them reported that cost overruns occurred in many of their projects (Hao et al., 2024). Since cost overruns place additional strain on all parties involved in construction projects (Yun et al., 2024), they are a major problem in the construction sector and must be carefully managed to enhance project cost-effectiveness. Identifying the causes of cost overruns is essential for effectively managing project cost performance (Ningning, 2024). This analysis examines the variables that contribute to cost overruns in construction projects in Anhui, China. As a graphical version of mathematical representation and a highly effective method for analyzing causal relationships between factors, this study adopts the advanced multivariate analysis method of Structural Equation Modeling (SEM). Despite extensive research on construction cost overruns, the mechanisms through which various factors contribute to cost escalation remain insufficiently understood in rapidly developing regions. This study addresses three research questions: (1) What is the impact of resource constraints on inadequate construction planning and construction cost overruns? (2) How does design change influence inadequate construction planning and cost overruns? (3) To what extent does inadequate construction planning mediate these relationships? By addressing these questions, this study provides empirical evidence on the direct and indirect effects of key factors, contributing to both theoretical understanding and practical management strategies.

2. Conceptual Framework

2.1. Hypotheses Development

As shown in Fig. 1, we first establish the conceptual framework before studying the influencing factors of construction cost overruns and the mediating role of inadequate construction planning. In this framework scheme, we studied from the perspectives of building lifecycle theory (Gong, 2024) and project management theory (Sun, 2026), whether resource constraints and design changes affect building cost overruns and whether they are mediated by inadequate construction planning.

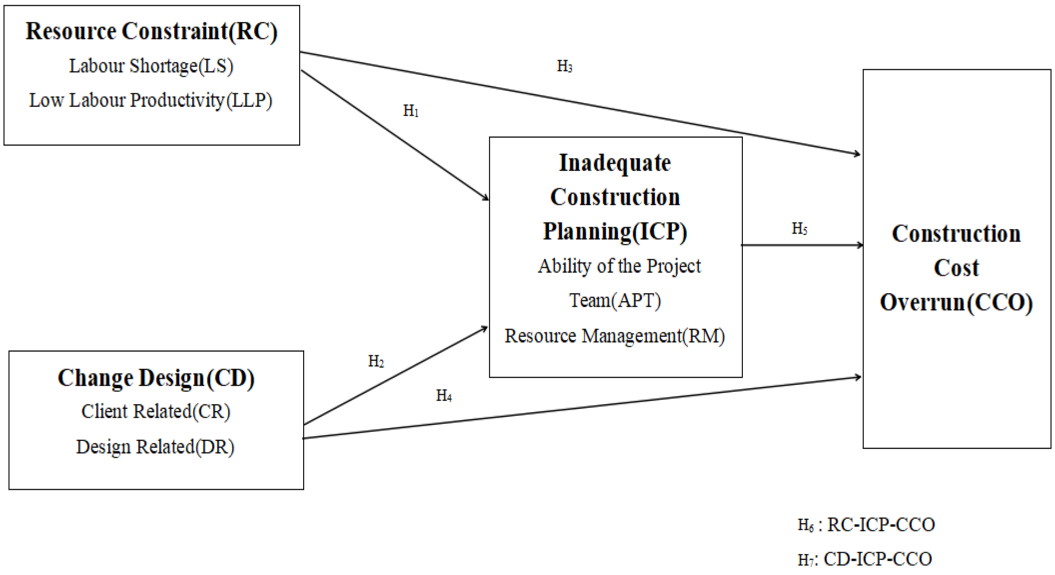


Fig. 1. Conceptual framework

2.2. Research Hypothesis

Data were collected from 159 professionals in the construction industry using a 5-point Likert-scale questionnaire (Sultan et al., 2024). SEM software is used to analyze data. Four hypotheses were proposed, including mediation analysis. The analysis results indicate that the use of scope freezing method, excessive design of facilities, and early procurement of long delivery cycle projects in the early design stage are the most influential decisions, while excessive expansion of resources related to quality decisions may have adverse effects on project duration, including the early participation of the operation and maintenance team in the design stage, early participation of contractors in the design process, 90% acceptable quality compromise, and submission of quality management plans in the pre-design stage. Confirmed that design factors have a significant impact on building costs.

Baek (2018) used regression analysis to determine the factors that affect cost bias. Using historical cost data from winning highway projects, an analysis model was established for Louisiana from 2011 to 2015. It was concluded that the intensity of bidding competition, resource constraints, the value of pavement projects, inadequate construction planning, and the number of contract activities all contributed significantly to cost differences. Having examined the variables influencing construction project cost estimates across several nations, Albtoush et al. (2022) concluded that resource constraints, the precision and reliability of cost data, the clarity of details in drawings and specifications, and estimators experience are significant factors influencing the cost estimation of building projects in many countries.

Traditional analytical approaches often fail to capture complex interdependencies among multiple variables. To address this limitation, the Partial Least Squares approach within Structural Equation Modeling (PLS-SEM) serves as a graphical representation of mathematical associations between outcome and predictor variables (Hair et al., 2014). This methodology has proven particularly effective for validating intricate theoretical frameworks involving multiple causal pathways. Employing this technique, Johnson and Babu (2020) examined how resource availability influences budget escalation in construction endeavors. Through a structured survey of the instrument administered to 106 construction practitioners, they utilized Smart PLS 2.0 to analyze resource-cost relationships. Their structural framework demonstrated robust explanatory capacity (GoF=0.529), revealing that resource availability accounts for 40% of budget variance, with workforce availability emerging as the most critical factor.

Haibin and Cuncun (2024) investigated the causes of cost overruns in China’s construction sector. The literature review suggests that general factors, such as resource constraints, frequent design changes, and inadequate construction planning, may result in construction project cost overruns.

Lu (2024) conducted a dual-phase investigation involving sequential questionnaire administration. The initial survey identified the relative importance of individual cost elements, while the subsequent instrument quantified the proportional contribution and magnitude of the ten most influential factors within each cost category. Findings revealed that within China’s construction industry, several elements demonstrate particularly strong associations with budget escalation: diminished workforce efficiency, escalating material expenditures, elevated equipment and liquidity expenses, and inadequate fiscal oversight.

Combining the current development status of prefabricated buildings and the summary and generalization of existing research results, Pang and Meng (2022) established a cost evaluation index framework for China’s prefabricated buildings. These frameworks considered design stage factors, production stage factors, transportation stage factors, installation stage factors, and policy factors. SEM is used to test the system. The results indicate that resource constraints significantly impact the construction cost overruns in a positive manner.

Lin (2023) analyzed Chinese prefabricated building literature and used SEM to study cost-influencing factors, examining the applicability of SEM through literature and case analysis, constructing a measurement model, and developing research hypotheses for latent variables. Based on the research hypothesis, a structural equation model was developed for the cost-influencing factors of prefabricated buildings. Finally, design factors were found to have a positive relationship with construction costs.

Data comparison and analysis were conducted on companies of different scales. The results indicate that factors such as labor shortage and lack of mechanical equipment have no consistent impact on the inadequate construction planning of enterprises of different scales. Especially, due to the lack of skilled labor in the market, young and smaller companies are more susceptible to time delays (Maqsoom et al., 2021). This study suggests that the influence of resource constraints on inadequate construction planning varies for construction enterprises of different scales.

Maqsoom et al. (2021) investigated the risk factors of inadequate architectural planning in developing countries. Hypothesis and empirical tests were conducted on the conceptual system dynamics model using data from the Ghana Construction Industry (GCI). The final System Dynamics Conceptual Model (SDCL) model revealed the key risk factor - customers arbitrarily changing orders.

One of the most prevalent issues in Algerian construction projects is inadequate construction plans, which are the primary source of cost overruns, project delays, disputes, and claims. Roumeissa (2019) used a simple linear regression method and correlation coefficient to measure the impact of inadequate construction planning on cost overruns. Practitioners can use the proposed model as a predictive measure to address potential cost overruns. Research has shown that inadequate construction planning impacts cost overruns to a significant extent.

Taking into account the relevant literature research above and combined with the current research status of China’s construction industry, the hypotheses are proposed as follows:

H1: Resource constraints have a significant impact on inadequate construction planning in a positive manner.

H2: Changing design has a significant impact on inadequate construction planning in a positive manner.

H3: Resource constraints have a significant impact on construction cost overruns in a positive manner.

H4: Design change has a significant impact on construction cost overruns in a positive manner.

H5: Inadequate construction planning has a significant impact on construction cost overruns in a positive manner.

H6: Inadequate construction planning plays a partial mediating role in the impact of resource constraints on construction cost overruns.

H7: Inadequate construction planning plays a partial mediating role in the impact of design change on construction cost overruns.

3. Methodology

3.1. Research Design

Quantitative research design can obtain a more thorough understanding of different variables by quantifying the relationships between these variables (Bloomfield and Fisher, 2019). In this view, this study uses the quantitative research design approach to thoroughly investigate the factors influencing construction cost overruns, as well as the mediating role of inadequate construction planning. The data collection was performed through a questionnaire survey, using scales from the literature by Lin (2023) and Zhang et al. (2024) during the questionnaire development process.

This study focuses on construction industry workers from 16 cities in Anhui Province. These workers were consulted on a series of questions about the influencing factors of construction costs in the questionnaire, where their responses were rated as 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, and 5=strongly agree according to the Likert five-point scale.

3.2. Data Collection and Analysis Methods

This study employed quantitative techniques aligned with deductive methods. The investigation paradigm is based on positivism (Park et al., 2020). Four constructs were operationalized in this study: “resource constraints”, “design change”, “inadequate construction planning”, and "construction cost overruns”.

The project team's ability and resource capability are two measures of inadequate construction planning, used to measure the impact of inadequate construction planning.

SEM is a multivariate analysis technique that can take into account both the relationship between latent and observed variables at the same time, and may consider using structural equation modeling where an in-depth analysis is necessary. In this view, this study performs SEM analysis utilizing Analysis of Moment Structures (AMOS) software. It facilitates a comprehensive understanding of the complicated connections between “resource constraint”, “design change”, “inadequate construction planning”, and "construction cost overruns”. Therefore, modeling and analyzing data using AMOS is ideal for the objectives of this study.

Construction professionals from 16 cities in Anhui Province participated in the questionnaire survey of this study, where a total of 540 copies were distributed, and 530 copies were returned on-site. A valid questionnaire rate of 94.8% was obtained because a total of 512 valid questionnaires remained after invalid documents were excluded.

The male-to-female ratio of respondents was approximately 9:1, reflecting the actual gender distribution in the prefabricated construction industry. The main age range of the survey subjects is between 30 and 50 years old, and people in this age group have certain social, work, and life experiences, which makes their judgments on the problem more reasonable. Based on the educational level, over half of the survey respondents hold a bachelor’s degree. Therefore, these workers have a better understanding of the concept of architecture, can clarify the formation process of building costs, and answer questions professionally. Most respondents possessed 3 to 10 years of experience in industrial construction, enabling them to provide objective and informed responses. Therefore, the information contained in the survey questionnaire sample is overall relatively reasonable and can meet the requirements of this survey.

4. Data Analysis

4.1. Reliability Analysis

This paper uses the Statistical Package for the Social Sciences (SPSS) 27.0 software to study and analyze the questionnaire. In the reliability analysis by the SPSS 27.0 software, Cronbach’s Alpha correlation coefficient is between 0 and 1. If the coefficient is between 0.5 and 0.7, it means that it has general reliability and needs further analysis. If the coefficient value is greater than 0.7, it means that the indicator coefficient has strong reliability. The analysis results of this paper are shown in Table 1. It indicates that the Cronbach’s Alpha values of dimensions such as labor shortage (0.903), low labor productivity (0.923), customer-related (0.914), design-related (0.921), project team capabilities (0.892), resource capabilities (0.909) and construction cost overruns (0.916) are all higher than 0.7, indicating that these dimensions have good internal consistency and the measurement tool has strong reliability. Overall, the reliability analysis results of all dimensions met the research standards, indicating that the questionnaire had high reliability during the data collection process. Finally, the overall reliability value was 0.81, which further confirmed the stability and consistency of the questionnaire and provided a reliable basis for subsequent analysis.

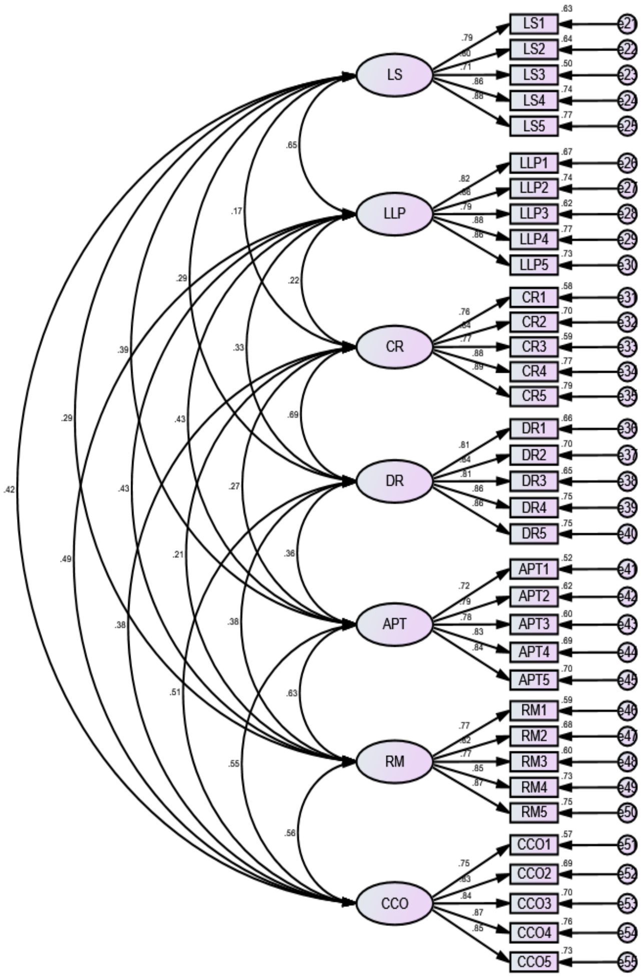
Table 1. Reliability results

Construct	Items	Cronbach’s α	CR
Resource Constraints (RC)	7	0.883	0.885
Design Change (DC)	6	0.843	0.846
Inadequate Construction Planning (ICP)	5	0.823	0.826
Construction Cost Overruns (CCO)	8	0.919	0.920

Note: All constructs demonstrate acceptable reliability (α > 0.70, CR > 0.70). Detailed item-level statistics are provided in Appendix A.

4.2. Confirmatory Factor Analysis

Confirmatory factor analysis of the total scale showed that all the fit indicators met the commonly used evaluation criteria (Table 2), indicating that the model fit was good. Specifically (Fig. 2), the Chi-square to Degrees of Freedom ratio (CMIN/DF) was 1.419, lower than 3, which met the goodness of fit requirements; Root Mean Square Error of Approximation (RMSEA) was 0.029, lower than 0.08, indicating that the model error was small and the fit was good. Normed Fit Index (NFI) was 0.944, Tucker-Lewis Index (TLI) was 0.981, Incremental Fit Index (IFI) was 0.983, and Comparative Fit Index (CFI) was 0.983, all of which were greater than 0.9, indicating a good fit of the model. Therefore, the confirmatory factor analysis results indicated that the measurement model was highly applicable and stable.



CMIN/DF=1.419; IFI=.983
RMSEA=.029; NFI=.944
TLI=.981; CFI=.983; p=.000

Fig. 2. Measurement model

Table 2. Confirmatory factor analysis of the overall scale

Common indicators	CMIN/DF	RMSEA	NFI	IFI	TLI	CFI
Judgment criteria	<3	<0.08	>0.9	>0.9	>0.9	>0.9
Fitting results	1.419	0.029	0.944	0.983	0.981	0.983

4.3. Convergent Validity

The results of convergent validity analysis showed that the Average Variance Extracted (AVE), and Composite Reliability (CR) values of all constructs satisfied the standards, suggesting that the measurement model had good convergent validity. It can be seen from Table 3 that all constructs have an AVE value that is higher than 0.5, indicating that each indicator could effectively reflect its latent variables. Among them, the AVE of labor shortage was 0.659, and the CR was 0.905. The AVE of low labor productivity was 0.708, and the CR was 0.924. The AVE of customer-related

was 0.687, and the CR was 0.916. The AVE of design-related was 0.701, and the CR was 0.921. The AVE of project team capability was 0.625, and the CR was 0.893. The **AVE of resource capability was 0.669, and the CR was 0.91.** The **AVE of construction cost overrun was 0.69, and the CR was 0.917. Overall, the AVE and CR values of all constructs met the requirements of convergent validity, indicating that the questionnaire design could effectively measure each latent variable and the measurement results had high internal consistency.**

Table 3. Convergent validity

Construct	AVE	CR	Items
RC	0.524	0.885	7
CD	0.482	0.846	6
ICP	0.486	0.826	5
CCO	0.565	0.920	8

Note: All constructs meet acceptable thresholds (AVE > 0.40, CR > 0.70). Individual item factor loadings are provided in Appendix B.

4.4. Discriminant Validity

Table 4 shows the discriminant validity analysis results. The correlation coefficients between all latent variables are less than the square root of their respective AVE, suggesting good discriminant validity of the model. Moreover, the square root of the AVE of each factor is higher than its correlation coefficient with other factors, ensuring the independence and discriminant ability of different latent variables in measurement. Therefore, the model has strong discriminant validity and can effectively distinguish various latent variables.

Table 4. Discriminant validity

	AVE	**LS**	**LLP**	**CR**	**DR**	**APT**	**RM**	**CCO**
LS	0.659	**0.812**						
LLP	0.708	0.593**	**0.841**					
CR	0.687	0.152**	0.209**	**0.829**				
DR	0.701	0.27**	0.311**	0.634**	**0.837**			
APT	0.625	0.353**	0.396**	0.26**	0.34**	**0.791**		
RM	0.669	0.272**	0.4**	0.195**	0.349**	0.569**	**0.818**	
CCO	0.69	0.383**	0.463**	0.348**	0.479**	0.509**	0.524**	**0.831**

**p<0.01

4.5. Structural Equation Modeling (SEM)

AMOS software was employed to evaluate the congruence between the hypothesized structural model and empirical observations. Model adequacy was assessed through multiple fit criteria. The normed chi-square (CMIN/DF) below 3.0 indicates acceptable parsimony, while values approaching 2.0 suggest optimal fit. For the RMSEA, values under 0.08 represent adequate approximation, with scores below 0.05 signifying excellent fit. Incremental fit indices, including the Comparative Fit Index (CFI), range from zero to unity. Conventional benchmarks suggest CFI values exceeding 0.90 demonstrate acceptable fit, while values above 0.95 indicate superior model performance, with proximity to 1.0 reflecting increasingly precise representation. Table 5 summarizes the complete criteria employed for model evaluation, as shown in Table 5.

Path analysis yielded standardized regression weights, Critical Ratios (CR), and probability values for each hypothesized relationship. Statistical significance was determined using conventional thresholds: critical ratios exceeding 1.96 coupled with probability values below 0.05 indicate relationships significant at the 95% confidence level. Hypothesized pathways meeting these dual criteria receive empirical support, confirming the theoretical associations proposed in the conceptual framework.

The structural model depicted in Figure 3 was constructed to examine multiple theoretical pathways: (1) relationships from resource constraints and design change toward inadequate construction planning. (2) Direct effects of these antecedents on construction cost overruns. (3) The pathway from inadequate construction planning to cost overruns. Model estimation procedures generated standardized path coefficients and fit statistics, enabling a comprehensive evaluation of both direct and indirect theoretical relationships. Test the adhesion and establish a structural equation model shown in Fig. 3.

Table 5. Specific fit index test standards

Fit index	Value range	Judgment criteria (Better)
CMIN/DF	>0	<5, <3
RMSEA	>0	<0.08, <0.05
NFI	0-1	>0.90, >0.95
IFI	0-1	>0.90, >0.95
TLI	0-1	>0.90, >0.95
CFI	0-1	>0.90, >0.95

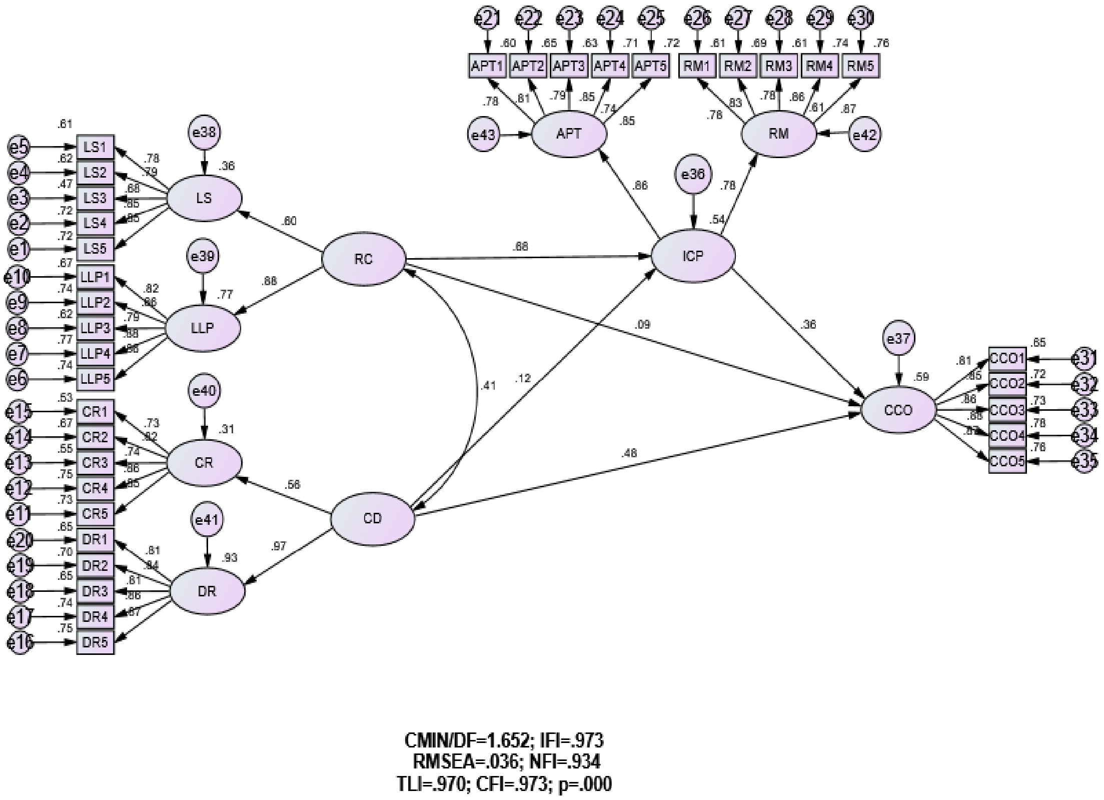


Fig. 3. Structural equation modeling

Table 6 shows the fitting indexes corresponding to the structural equation model, which are derived from the model fitting assessment of the software. According to the model fitting results, all indicators meet the common standards, indicating that the model fitting effect is good. CMIN/DF is 1.652, which is lower than 3 and meets the good fitting standard. RMSEA is 0.036, which is much lower than 0.08, indicating that the model error is small. NFI is 0.934, IFI is 0.973, TLI is 0.970, and CFI is 0.973. These values all exceed 0.9, indicating the good adaptability of the model. Therefore, it can be said that the model exhibits a satisfying overall fit and can effectively reflect the relationship between the variables, as evidenced by the fitting results of the structural equation model.

Table 7 reveals that resource constraints exert a substantial positive influence on inadequate construction planning ($\beta = 0.322$, CR = 5.066, $p < 0.001$). Resource scarcity forces project teams to make compromises during the planning phase, often resulting in abbreviated or suboptimal planning processes. Limited availability of essential inputs compels managers to deprioritize comprehensive preparation activities, thereby diminishing both the thoroughness and quality of planning outputs. This empirical evidence supports H1, confirming that resource limitations constitute a primary driver of planning deficiencies. The findings underscore the critical importance of adequate resource provisioning for effective project planning and management.

Table 6. Model fitting indicators

Common indicators	CMIN/DF	RMSEA	NFI	IFI	TLI	CFI
criterion for judgement	<3	<0.08	>0.9	>0.9	>0.9	>0.9
Fitting results	1.652	0.036	0.934	0.973	0.970	0.973

Contrary to expectations, design change demonstrated a insignificant relationship with inadequate construction planning (β = 0.108, CR = 1.754, p = 0.079). This unexpected finding may reflect the temporal dynamics of design modifications, which typically occur during early project phases when planning frameworks remain flexible and adaptive. The absence of significant impact suggests that planning inadequacies stem primarily from initial project preparation deficiencies rather than subsequent design alterations. Consequently, H2 receives no empirical support. These results indicate that planning quality is more strongly influenced by factors such as team competence, stakeholder coordination, and resource availability than by design stability.

Resource constraints demonstrate a significant positive effect on construction cost overruns (β = 0.18, CR = 2.48, p = 0.013). Insufficient resource availability compels project teams to procure its input through premium-priced emergency channels or secure temporary alternatives, both of which inflate project expenditures. Beyond direct acquisition costs, resource scarcity disrupts project schedules, generating cascading indirect costs through extended overhead periods. These findings validate H3, confirming that resource limitations constitute a significant determinant of budget escalation. The results emphasize that strategic resource management represents a fundamental lever for effective cost governance.

Design change exhibits a significant positive association with construction cost overruns (β = 0.148, CR = 2.183, p = 0.029). Design modifications introduce unplanned expenditures across multiple dimensions, including extended timelines, additional labor requirements, and supplementary material procurement. These alterations disrupt established budgets by necessitating rework and generating scope creep. The empirical evidence supports H4, confirming that design modifications contribute meaningfully to budget escalation. These findings highlight the importance of design stabilization and comprehensive front-end planning for maintaining budgetary discipline throughout project execution.

Inadequate construction planning demonstrates the strongest positive influence on construction cost overruns among all examined factors (β = 0.418, CR = 4.026, p < 0.001). Planning deficiencies generate inefficiencies in resource deployment and create temporal gaps in execution schedules, both of which amplify expenditures. Furthermore, inadequate preparation increases the likelihood of coordination failures and implementation errors, compounding cost pressures. These results strongly support H5, establishing planning quality as the most critical determinant of budgetary performance. The findings emphasize that comprehensive, rigorous planning represents the cornerstone of effective cost management in construction projects.

Table 7. Structural Equation Path Results

Path	Estimate	Standardization Estimate	S.E.	C.R.	P
ICP<---RC	0.322	0.335	0.064	5.066	***
ICP<---CD	0.108	0.103	0.062	1.754	0.079
CCO<---RC	0.18	0.131	0.073	2.48	0.013
CCO<---CD	0.148	0.099	0.068	2.183	0.029
CCO<---ICP	0.418	0.292	0.104	4.026	***

***p<0.001

4.6. Mediating Effect

This paper employs the mediation effect test to examine how the failure to plan resources and changes in designs mediate between the influence of resource constraint and the design change on construction cost overruns. The results indicate that inadequate construction planning is a partial mediating factor that has led to all these paths.

Regarding the contribution of resource constraints to cost overruns in construction, the direct effect was 0.3, the mediating effect was 0.234, and the total effect was 0.534. The interval has a significant mediating effect as indicated by the confidence interval (LLCI: 0.174, ULCI: 0.305) from which the P value is 0.000. This is why poor construction planning plays a mediating role in this regard. Lastly, the mediation of the effect of design changes on construction cost overruns is also partly through subpar construction planning. The combined effect is 0.503, which is comprised of a direct effect of

0.314 with a mediation effect of 0.188. The confidence interval (LLCI: 0.131, ULCI: 0.267) does not contain Zero, which proves that the inappropriate construction planning was also a partial intermediate in this direction (Table 8).

To recap it all, both H6 and H7 were accepted to demonstrate that inadequate construction planning was a partial mediating factor that affected the environmental interaction in the effect of resource constraints and design change in construction cost overruns. The paper provides conceptual assistance in interpreting how inadequate construction planning contributes to the cost management of project management and the significance of construction planning.

Table 8. Mediating effect data result

Path	Total effect	Direct effect	Indirect effect	Boot SE	z	P	(95%BootCI)		Test result
							LLCI	ULCL	
RC=>ICP=>CCO	0.534	0.3	0.234	0.034	6.848	0.000**	0.174	0.305	Part of the intermediary
CD=>ICP=>CCO	0.503	0.314	0.188	0.034	5.48	0.000**	0.131	0.267	Part of the intermediary

5. Conclusion and Suggestions

5.1. Conclusion

This study makes several theoretical contributions to construction management literature. It extends project management theory and lifecycle theory by empirically demonstrating how resource availability and design stability interact with planning quality to influence cost outcomes in the Chinese construction context. The finding that inadequate planning partially mediates these relationships suggests that both direct and indirect pathways operate simultaneously, enriching our understanding of overrun causality. By identifying differential impacts with inadequate planning, showing the strongest effect ($\beta = 0.418$), followed by resource constraints ($\beta = 0.18$) and design change ($\beta = 0.148$), this study provides empirical evidence for prioritizing interventions.

This paper performs an exhaustive empirical examination of various causes of overruns in the costs of construction projects through SEM, examining resource constraints, changing design, and inadequate construction planning. The analysis confirms that resource constraints significantly impact both inadequate construction planning ($\beta = 0.322$, CR = 5.066, $p < 0.001$) and construction cost overruns ($\beta = 0.18$, CR = 2.48, $p = 0.013$). Design change demonstrates a significant positive impact on construction cost overruns ($\beta = 0.148$, CR = 2.183, $p = 0.029$), while inadequate construction planning exerts the strongest influence on cost overruns ($\beta = 0.418$, CR = 4.026, $p < 0.001$).

Notably, the hypothesis regarding design change's impact on inadequate construction planning (H2) was not supported ($\beta = 0.108$, CR = 1.754, $p = 0.079$). This suggests that design changes may not directly compromise planning adequacy as theorized. Explanations include experienced project teams who may have developed adaptive capabilities to accommodate changing designs; the timing and nature of changes may vary considerably, or organizational processes in Anhui Province may effectively buffer planning from changing design impacts. Despite the insignificant direct effect on planning, design change still demonstrates a significant direct impact on cost overruns and an indirect effect through inadequate planning ($\beta = 0.04$, $p = 0.03$), indicating its overall contribution to cost escalation remains meaningful.

Mediation analysis reveals that inadequate construction planning partially mediates the relationship between resource constraints and cost overruns (direct effect = 0.3, indirect effect = 0.234, total effect = 0.534), and between design change and cost overruns (direct effect = 0.232, indirect effect = 0.04, total effect = 0.272). These results underscore inadequate construction planning as a critical mechanism linking external pressures to cost outcomes.

While this study was conducted in Anhui Province, China, the findings have broader implications for construction project management globally. The identified relationships reflect fundamental challenges transcending regional boundaries, as construction industries worldwide face similar issues related to labor shortages, material supply disruptions, and equipment availability. However, applications to different regions should consider contextual factors. In developed countries, resource constraints may manifest through skilled labor shortages due to aging demographics, while developing countries might struggle with infrastructure gaps. Regulatory frameworks governing design changes also vary significantly across countries. Practitioners in different regions should adapt recommendations based on their specific contexts in countries with stringent regulations, strengthening early-stage design reviews may be critical; in regions with volatile supply chains, enhanced resource planning becomes paramount. Future research should validate these findings across multiple countries to develop a globally applicable framework for managing construction cost overruns.

5.2. Suggestions

The following suggestions can be made based on the conclusions of this study:

5.2.1. Optimizing resource allocation and coping with resource constraints

Resource limitations, particularly labor, have a direct impact on construction planning and the course of construction projects, leading to cost overruns. In this regard, the project manager is expected to run elaborate resource planning during the initial stages of the project to make certain that the diverse resources needed to carry out the construction are available when they are needed, so that the construction undertaking would not be slowed by the shortage of any resource. Regarding the management of labor, it is suggested to recruit and train staff beforehand to be able to fit the project requirements in terms of the number of personnel with professional skills. Meanwhile, maximize resource assignment, enlarge the external resources of supply and offer leeway resource assistance to the project. This resource management tool can be useful in mitigating issues when it comes to construction planning and consequently manage costs of the project.

5.2.2. Reduce design change and optimize design management

The change of design is one factor contributing in the failure of planning of construction and overrun of construction costs. The design of frequent change will not only interfere with the plan of construction but also it can increase the price of construction. Hence, unnecessary design changes should be avoided by the project managers. Enhancing communication and collaboration with the design team helps ensure the feasibility and completeness of the design plan, which minimizes design changes during building construction. The design phase must be rigorously endorsed, and the potential effects of the changes must be assessed and restrained to the full. The management approach would be effective in mitigating the fluctuations to cost that would occur due to design changes hence ensuring the project budget is stable.

5.2.3. Strengthen forward-looking management of construction planning and cost control

Poor planning of the construction is a close factor that relates to the cost overruns. Consequently, during the early stages of the project, the project managers must undertake thorough preparation of construction planning so that the time nodes, the work content, the allocation of resources and the budget cost is clear and reasonable. Planning of a project should also involve having clear project objectives and control standards to prevent wastage of resources and delay of construction progress due to lack of proper planning. In executing the project, the progress of the project ought to be checked and analyzed, as well as the variances of the project ought to be modified promptly. By ensuring a well-thought-out future-oriented planning and a tight rein on cost through careful cost control, project managers may be able to ensure a timely completion within the budget of the project by adequately reducing the risk of a cost increment through construction planning or construction execution oversights.

5.3. Limitations and Future Research

Several limitations should be acknowledged. First, data were collected exclusively from Anhui Province, China, which may limit generalizability to other geographical regions with different economic, regulatory, and cultural contexts. Future research should extend investigation to multiple regions to validate the universality of identified relationships. Second, this study relies on self-reported data, which may be subject to common method bias. Although statistical measures were taken to mitigate these concerns, future studies could employ mixed-method approaches combining surveys with qualitative interviews or objective project performance data. Third, the cross-sectional design captures relationships at a single point in time, limiting causal inferences. Longitudinal studies tracking projects from initiation to completion would provide deeper insights into the dynamic nature of cost overruns. Fourth, while focusing on resource constraints and design change, other potentially important variables such as contractor competence, owner decision-making patterns, and external economic factors were not included. Future research should incorporate a broader range of factors. Finally, the insignificant relationship between design change and inadequate construction planning (H2) warrants further investigation, potentially exploring moderate factors such as project type, contract structure, or organizational capabilities.

For managers, these findings require five key changes to decision processes:

1. Shift from reactive cost control to proactive planning investment. Managers will stop treating planning as a routine task and instead prioritize comprehensive, detailed construction planning as the most critical control for cost overruns. Since inadequate planning has the strongest impact on cost escalation ($\beta = 0.418$), managers will allocate more time, personnel, and review procedures in the pre-construction stage to ensure planning quality, rather than only controlling costs during construction.

2. Treat resource constraints as a planning risk, not just an operational issue. Managers will revise resource allocation decisions by assessing resource shortages (labor, equipment, materials) during the planning phase, not during construction. Resource constraints directly weaken planning quality and indirectly drive cost overruns through insufficient planning. Therefore, managers will conduct early resource feasibility evaluations and establish contingency resource plans before project launch.

3. Strengthen design freeze and change control decisions. Managers will implement stricter design review and change approval mechanisms to reduce frequent design modifications. Since design changes significantly increase costs directly and indirectly via planning distortion, managers will formalize design freeze policies, conduct multi-party feasibility reviews before construction, and require quantitative cost-impact assessments for all proposed design change's.

4. Incorporate mediation logic into project governance decisions. Managers will adopt a chain-oriented decision logic: 1) resource constraints, 2) inadequate planning, 3) cost overruns and design change, 4) inadequate planning, and 5) cost overruns. Instead of addressing cost overruns alone, managers will improve planning systems to block the transmission path of risk factors, using planning quality as a core regulatory node in project governance.

5. Use data-driven SEM-based indicators for decision monitoring. Managers will update performance evaluation systems to include latent variables from this study: resource stability, design stability, planning adequacy, and cost deviation. Structural equation modeling results provide measurable indicators for early warning, allowing managers to make predictive decisions rather than corrective ones.

While conducted in Anhui Province, China, the findings offer globally applicable insights, as construction industries worldwide face similar resource, design, and planning challenges. Future research would validate these results across regions.

Author Contributions

Qian Wu contributes to methodology, validation, analysis, and manuscript editing. Ali Khatibi contributes to methodology, software, data collection, draft preparation, manuscript editing. Jacquline Tham contributes to conceptualization, validation, draft preparation, manuscript editing.

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Institutional Review Board Statement

Institutional Review Board Statement: This study was conducted in accordance with ethical guidelines for research involving human subjects. Ethical approval was obtained from the Research Ethics Committee of Management and Science University (Approval ID: MSU-REC-2024-087, Approval Date: March 15, 2024). All participants provided informed consent, and data confidentiality was maintained throughout the study.

Declaration of Artificial Intelligence (AI) Tools

The authors used AI tools solely for language editing and readability improvement. The authors reviewed and verified all content and take full responsibility for the accuracy and integrity of the manuscript.

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Appendix A: Item-level reliability statistics

Construct	Dimension	Item	Factor Loading	Corrected Item-Total Correlation	Cronbach's α if Item Deleted	Cronbach's α
Resource Constraints (RC)	Labor Shortage (LS)	LS1	0.795	0.748	0.884	0.903
		LS2	0.802	0.755	0.883	0.903
		LS3	0.708	0.659	0.902	0.903
		LS4	0.863	0.813	0.871	0.903
		LS5	0.876	0.823	0.868	0.903
	Low Labor Productivity (LLP)	LLP1	0.821	0.772	0.865	0.891
		LLP2	0.847	0.795	0.858	0.891
Design change (DC)	Customer-Related (CR)	CR1	0.768	0.685	0.871	0.843
		CR2	0.852	0.731	0.858	0.843
		CR3	0.863	0.748	0.852	0.843
	Design-Related (DR)	DR1	0.824	0.712	0.862	0.843
		DR2	0.841	0.725	0.857	0.843
		DR3	0.855	0.738	0.851	0.843
Inadequate Construction Planning (ICP)	Ability of Project Team (APT)	APT1	0.775	0.658	0.791	0.823
		APT2	0.798	0.682	0.783	0.823
		APT3	0.812	0.695	0.776	0.823
	Resource Management (RM)	RM1	0.743	0.632	0.798	0.823
		RM2	0.756	0.645	0.792	0.823
Construction Cost Overruns (CCO)		CCO1	0.728	0.681	0.912	0.919
		CCO2	0.745	0.695	0.910	0.919
		CCO3	0.762	0.708	0.908	0.919
		CCO4	0.778	0.722	0.906	0.919
		CCO5	0.789	0.735	0.904	0.919
		CCO6	0.801	0.748	0.902	0.919
		CCO7	0.815	0.762	0.899	0.919
		CCO8	0.826	0.775	0.897	0.919

Note: All items demonstrate adequate factor loadings (>0.70), corrected item-total correlations (>0.50), and contribute positively to overall construct reliability. Cronbach's α values for all constructs exceed the recommended threshold of 0.70, confirming satisfactory internal consistency.

Appendix B: Complete factor loadings and convergent validity

Construct	Item	Standardized Factor Loading	Standard Error	Critical Ratio	P-value	AVE	CR
Resource Constraints (RC)						0.524	0.885
Labor Shortage (LS)	LS1	0.795	0.048	16.563	***	0.659	0.905
	LS2	0.802	0.046	17.435	***		
	LS3	0.708	0.052	13.615	***		
	LS4	0.863	0.043	20.070	***		
	LS5	0.876	0.042	20.857	***		
Low Labor Productivity (LLP)	LLP1	0.821	0.047	17.468	***	0.708	0.912
	LLP2	0.847	0.045	18.822	***		
Design Change (DC)						0.482	0.846
Customer-Related (CR)	CR1	0.768	0.051	15.059	***	0.687	0.869
	CR2	0.852	0.046	18.522	***		
	CR3	0.863	0.045	19.178	***		

***$p < 0.001$

Appendix B: Complete factor loadings and convergent validity (continued)

Construct	Item	Standardized Factor Loading	Standard Error	Critical Ratio	P-value	AVE	CR
Design-Related (DR)	DR1	0.824	0.048	17.167	***	0.701	0.875
	DR2	0.841	0.046	18.283	***		
	DR3	0.855	0.045	19.000	***		
Inadequate Construction Planning (ICP)						0.486	0.826
Ability of Project Team (APT)	APT1	0.775	0.052	14.904	***	0.625	0.833
	APT2	0.798	0.050	15.960	***		
	APT3	0.812	0.049	16.571	***		
Resource Management (RM)	RM1	0.743	0.054	13.759	***	0.568	0.795
	RM2	0.756	0.053	14.264	***		
Construction Cost Overruns (CCO)						0.565	0.920
	CCO1	0.728	0.055	13.236	***		
	CCO2	0.745	0.053	14.057	***		
	CCO3	0.762	0.051	14.941	***		
	CCO4	0.778	0.050	15.560	***		
	CCO5	0.789	0.049	16.102	***		
	CCO6	0.801	0.048	16.688	***		
	CCO7	0.815	0.047	17.340	***		
	CCO8	0.826	0.046	17.957	***		