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Research on factors affecting construction cost overrun based on SEM

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Abstract

To address the issue of construction cost overruns, this study, after reviewing extensive literature, identified four key factors influencing construction cost overruns: Resource Constraint (RC), Change Design (CD), Contractor Management (CM), and Communication Coordination (CC). These factors were examined in detail using a Structural Equation Model (SEM). The research findings here are expected to provide a reference and actionable recommendations for cost control in construction firms.

Keywords: Resource constraint, Change design, Contractor management, Coordination, Construction cost overruns

1.Introduction

The architecture and construction sector, a crucial part of the national economy, is often subject to the risk of cost overruns in projects (Asiedu & Adaku, 2020). The issue of cost overruns has long been a concern in China's construction industry. This issue not only affects the progress of individual construction programs but is likely to trigger a chain of reactions that undermine the operations of construction projects and compromise the financial well-being of project owners, resulting in a range of negative socio-economic impacts. Therefore, it is imperative to identify the key contributing factors to cost overruns in the construction industry and find solutions to this problem (Shoar, Yiu, Payan, & Parchamijalal, 2023).

Most existing studies on the issue of cost overrun in the construction industry in China were qualitative analyses of contributing factors to the building cost; however, few employed questionnaire surveys to collect data about the factors that affect construction cost overruns, or established a structural equation model (SEM) to perform in-depth research on these factors. This indicates a significant gap in Chinese literature, and filling in this gap is of both theoretical and practical significance to lead the nation's construction industry to a path of healthy and sustainable development.

Therefore, in this study, a cost-overrun evaluation system for the construction industry was constructed based on factors including contractor experience, communication and coordination, and inadequate construction planning. With data collected from construction practitioners in 16 cities in Anhui Province, this study empirically validated the relations between the multiple variables in the model. In addition, according to our research findings, actionable solutions and recommendations were proposed to provide more insights into the issue of cost overrun and optimize cost management of the construction industry in China.

2. Research Review

The notion "cost overrun" in the construction industry is defined as the situation where the project goals are not met within the preset budget (Durdyev, Ismail, & Bakar, 2012); it serves as the measure of how much the real expense surpasses the budget, which is calculated by dividing the contract value by the initial contract award value. The result of the calculation is often converted into a percentage (Love, Wang, Sing, & Tiong, 2013).

Researchers in the field of architecture and construction hold varied perspectives on the causes of cost overruns in construction projects. Specifically, there are two main schools of thought—the first is the mental strategist school, and the other is the

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evolutionist school. The former argue that the main causes for cost overruns in construction projects are the political (strategic deception) and psychological (cognitive biases, including optimism bias and planning error) impacts on the project decision-makers (Flyvbjerg, Stewart, & Budzier, 2016); the latter, however, attribute the issue of cost overruns in the construction industry to a combination of key project decision-makers' and designers' cumulative cost changes (technical errors), project modifications (scope changes), and a sequence of events or actions that increase the project's cost from start to finish (Love, Ahiaga-Dagbui, Smith, Sing, & Tokede, 2018).

Though project managers are aware of the critical role of budgeting for the successful progress of construction projects, they are constantly subject to the risk of cost overruns. Flyvbjerg et al. (2003), based on a statistically significant study of cost performance in transport infrastructure projects, found that 258 projects in 20 nations suffered from cost overruns, with the road and rail-related projects accounting for 90% of the overall cases. They concluded that the risk of building cost overruns has not decreased over the last 70 years, notwithstanding differences in literature and practice on the causes and possible solutions. As their study revealed, the average budget overruns for rail and road projects were 45% and 20%, respectively. Ameyaw and Oteng-Seifah (2010), in their investigations of the construction procurement decisions of 62 construction projects in Ghana, found that the average cost overrun was 23%. The work by Asiedu and Alfen (2014) yielded similar results, revealing that cost overruns occurred in 72% of Ghana's 321 public building projects. In summary, though studies on the contributing factors to cost overruns in the construction industry of different countries or regions yielded slightly different results due to cultural gaps, most identified factors are universal.

Doloi (2013), while investigating the roles of key stakeholders in construction projects, identified some additional factors that contributed to cost overruns in construction projects—governmental fiscal policies, the actions of project stakeholders (especially in government-funded projects), and inadequate project management. Other factors have also been reported to account for why the building cost exceeded budgets, such as contract management (Venkateswaran & Murugasan, 2017), design change (Doloi, 2013), stakeholder communication and coordination (Mahamid, 2018), resource constraints (RCs) (Abdelalim, Salem, Salem, Al-Adwani, & Tantawy, 2024), and price fluctuations (Ahiaga-Dagbui, Love, Smith, & Ackermann, 2017). Jamaludin et al. (2014) also unfolded a range of primary causes for cost overruns of construction projects—inadequate design drawings and specifications during the construction phase, fluctuating material prices, financial challenges faced by contractors, fluctuations in client demands, scheduling, and monitoring costs of plant and machinery, rising labor costs, poor planning, and lack of coordination between parties. The report by Samarghandi et al. (2016) reveals that several issues, such as lack of experience, improper design and design delays, irrational contract deadlines and labor relations requirements, late material and equipment delivery, and poor planning and scheduling, are the primary reasons for cost overruns. Kamaruddeen et al. (2020) and Omran et al. (2023) also identifid a series of factors that contribute to failed construction projects, including inadequate planning and scheduling, lack of experience, frequent design changes, inaccurate cost and time estimates, contractors facing slow information flow between the parties, financial difficulties faced by the owner, insufficient number of workers on site, poor site supervision/management, inadequate supply of materials, delayed availability of equipment, and poor management of materials and the scope of the project.

In summary, studies on the cost overrun of construction projects at the global scale have identified factors, such as RCs, communication and coordination of stakeholders, frequent design changes, and project contractor experience, as the main causes for the excessive expenses over the preset budget (Enshassi, Kumaraswamy, & Al-Najjar, 2010; Jam et al., 2025). These research findings have provided insights into the cost management of the construction industry globally. However, the contributing factors to construction cost overruns might differ as the economic backgrounds, market dynamics, and regulatory policies vary from country to country. For instance, the factors identified in the Chinese construction industry may differ from those identified by more developed countries: due to accelerated urbanization and continuous investments into infrastructure construction, China's construction sector is seeing an increased volume and growing complexity. Therefore, studying the contributing factors to the construction cost overruns in China cannot only identify the unique challenges that China's construction industry faces in cost management, but also allow us to find tailored solutions to improve cost control and policy development for China's construction sector.

Few works examined the issue of cost overruns in construction projects, and fewer, if any, have established structural equation models (SEMs) to analyze the drivers of cost overruns or used questionnaire surveys to collect data in this regard. To fill in this research gap is of both theoretical and practical significance for optimized cost control of construction projects and healthy development of the construction industry in China.

3 Research framework

3.1. Conceptual framework

In this study, a conceptual framework for the analysis of construction cost overruns based on the project management theory (Richardson, 2010) was established as our research framework, as shown in Fig. 1.

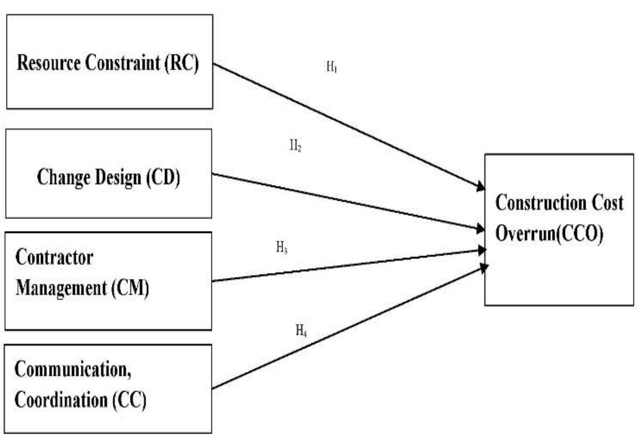

Fig. 1. Conceptual framework of our study

As Fig. 1 shows, the Construction Cost Overrun (CCO) framework examines the causes for CCO from four dimensions: Resource Constraint (RC), Change Design (CD), Contractor Management (CM), and Communication Coordination (CC).

3.2. Hypotheses for research

3.2.1. Impacts of resource constraints on construction cost overruns

It is widely acknowledged that the consideration of resources (such as labour, supplies, and machinery) is crucial for cost management of construction projects, and it is required to make timely adjustments as the project proceeds. For instance, the shortage of workforce, overtime work, or delayed delivery of projects will directly lead to a rise in the labour cost and consequently result in cost overruns in these projects.

Price swings or limited availability of materials are identified as two primary contributing factors to cost overruns in construction projects. Amini et al. (2023), through a questionnaire survey based on 43 universal criteria in previous research, collected information from professionals engaged in the construction industry in Iran, and analysed the collected survey data using the relative importance index (RII) and SPSS. They found that issues in materials, such as changes in the price or shortage of materials, had a domino effect on the cost of construction projects—these issues would cause early price swings, which would escalate into financial troubles, and hence raise the cost of construction projects.

Labour-relevant issues also have significant impacts on the costs of construction projects. Hussien (2025), in a study that examined the correlation between project performance and labour productivity, identified the importance of preventing delays and alleviating cost overruns. In that study, the RII was employed as the metric of the significance of each factor, and regression was performed to measure the correlation between time-cost performance and labour productivity; The skill level (RII = 0.88), a primary element that drives workforce productivity, was found to be one of the key contributing factors, and the labour efficiency exhibited a significant correlation with both the cost overrun ($R^2 = 0.61$) and the time reduction ($R^2 = 0.67$). In sum, Hussien's study revealed that poor labour efficiency would increase the labour cost, hence raising the overall cost of the construction projects and resulting in cost overruns.

Per the review above, the first hypothesis (H1) in this work was proposed as follows:

H1: Construction cost overruns are significantly reduced by resource limitations.

3.2.2. Impacts of Design Change (DC) on construction cost overruns

The Design Change (DC) is another key contributor to cost overruns of construction projects. Johnson and Babu (2018) found that the design change, which was pursued by customers and consultants, accounted for the primary cause of cost overruns in construction projects, as the changes in the design would result in strict timelines and financial strains during the early planning stage of construction programs.

Ramadhan and Waty (2025) examined the impact of some factors in construction projects, such as design changes and planning errors, on the project result using the partial least squares structural equation modeling (SEM) method. Based on data collected from 127 construction professionals engaged in programs overseen by PT XYZ, a top contractor in Indonesia, they found that changes in the design contributed to 40% project delays and 56.5% cost overruns. Their findings highlighted the need to optimize the design management process to alleviate the negative impacts of design changes on the construction cost.

Aslam et al. (2019) also examined the impacts of DC on the expenses of construction projects as well as the causes of these changes. Based on the literature review, they also identified the DC as a key contributor to cost overruns and examined the causes of DC from the perspectives of the contractors, consultants, and the project owners. By integrating the impacts of DC and the causes into a platform, they tried to find solutions to the effective management of the design process.

Based on previous works alike, the second hypothesis (H2) for our study was proposed as follows:

H2: Design modifications significantly reduce construction cost overruns.

3.2.3 Impacts of Contractor Management (CM) on construction cost overruns

Contractor management is considered another potential factor that affects the cost of construction projects. Ahiaga-Dagbui et al. (2017) found that the contractor managers often underestimate the expenses due to cognitive biases, especially over-optimism, during the project planning stage: many construction project managers' cost estimation was 20%–30% lower than the actual expenses due to the lack of risk assessment or emergency planning.

In another study, Doloi (2013) examined the factors that contribute to the cost performance of construction projects in the dimensions of customers, consultants, and contractors, and found that poor planning and scheduling were the most significant contributors. Through confirmatory factor analysis (CFA) on the replies from three sets of respondents, he found that the key drivers for good cost performance include proper planning and efficient site administration, and in this logic, he concluded that cost overruns in construction projects were mainly attributable to the poor project planning and management of the contractor. He also noted that budgeting mistakes in the early stage of a project usually escalate and result in a ripple effect throughout the whole course of the project. Annamalaisami and Kuppuswamy (2021), based on a questionnaire survey on the construction projects in India and an extensive literature review, tried to identify the causes of construction cost overruns. They found that project control deficiency is a sign of inadequate risk management, poor site management, and technical performance often indicate inappropriate construction methods, construction errors are quality problems that are often hard to fix, and poor planning & scheduling contribute negatively to the project's cost performance.

Based on these previous works, the third hypothesis (H3) in our work was proposed, as follows:

H3: Construction cost overruns are significantly impacted negatively by the experience of the contractor.

3.2.4 Impacts of communication & coordination on construction cost overruns

Poor communication is a significant contributing reason to scheduling and overspending in the global construction industry. Gamil et al. (2019) employed two methods to identify the causes and measure the severity of communication in construction projects. Specifically, they reviewed literature to determine contributing factors to poor communication across different construction industries and determine their impact percentages, and found that in higher-income countries with access to information and communication technologies and advanced communication systems, the contribution of poor communication to construction cost overruns is greater than in their lower-income counterparts. In addition, they performed a qualitative study through interviews with construction experts to analyze their comments on their findings through literature review and their perceptions of the severity of poor communication. Overall, they concluded that poor communication contributes significantly to time and cost overruns in construction projects.

Shoar et al. (2023), by creating a structural equation model (SEM), clarified the connection between construction cost overruns and the causes behind inadequate communication in construction programs. Their model describes the extent to which the causes and consequences of inadequate communication in building projects are related. Their modelling data were collected through a questionnaire survey among construction experts in Malaysia. They used a five-point Likert scale to assess the relative significance of the features. The exploratory factor analysis was used to organize the components into related constructs. Each group of causative factors had a direct impact on the group of influencing factors, according to a hypothesised model that was created and then translated to Smart-PLS. To test the hypotheses, t-values and p-values were used. The model's exterior and internal components were assessed and found to meet the necessary thresholds. An SEM was created to clarify the connection between the reasons and consequences of inadequate communication in building projects. The model clarified the extent to which the causes and consequences of inadequate communication in building projects are related.

Based on these works, the fourth hypothesis (H4) of our study was proposed as follows:

H4: Overruns in construction costs are negatively correlated with collaboration and communication.

4. Research Methods

4.1 Research design

To examine the impacts of the contractor expertise, coordination, and communication on the construction cost overruns, this study employed the quantitative research approach, where the phenomena were measured using numerical data to evaluate the theories. A questionnaire survey was performed using currently available scales from various sources to gather data.

The target population of our work is construction workers in 16 cities in Anhui Province. The questionnaire included a range of questions regarding the contributing factors to construction costs. A Likert scale with five points—1 for strongly disagree, 2 for disagree, 3 for neutral, 4 for agree, and 5 for highly agree—was used to gauge respondents' responses (Allen & Seaman, 2007). Accurate analysis and data quantification were therefore guaranteed. In our survey, 360 questionnaires were distributed, and 330 were collected, where 320 were considered valid (a validity rate of 88.89%) after 10 invalid ones were removed for irregular or incomplete replies.

4.2 Research methods

The AMOS 26.0 software was used to perform an SEM analysis, and an in-depth analysis was realized through the SEM, a multivariate analytic technique that concurrently considers correlations between latent and observable variables. The model would provide more insights into the relations between Contractor Management (CM), Communication and Coordination (CC), Resource Constraint (RC), and Design Change (DC), hence providing an ideal tool for our research.

Specifically, the CFA using AMOS 26.0 software was used to determine the factor loadings, Composite Reliability (CR), and convergent validity of each indicator factor, and SEM was used to test the hypotheses of this research model.

5. Results

5.1 CFA

One statistical technique for confirming the connection between latent variables (also known as factors) and observable variables in a hypothesised model is CFA (Thompson, 2004). Unlike exploratory factor analysis (EFA), CFA requires researchers to have clear theoretical assumptions about the model before analysis and to verify the rationality of these assumptions through data. Since the hypotheses were outlined in Section 4 and the survey data were provided, this article is well-suited for CFA analysis.

Using SEM in AMOS to ascertain model fit and assess how well the model developed via exploratory factor analysis suited the observed data, we examined model fit indices using CFA. The CFA statistical technique is used to confirm that a measuring instrument's factor structure properly represents the researcher's intended notions. The normal fit index (NFI), incremental fit index (IFI), and chi-squared/degrees of freedom ratio (CFI) are common model fit tests that evaluate how well the built model fits the real data. This study chose to evaluate the fit indices and criteria listed in Table 1 in accordance with the suggestions made by Kline (2005) and Hoe (2008). The fact that each model fit result met the fit criteria demonstrated an acceptable model fit.

Table 1. Results for statistical

Fit Indicators	Statistical Results	Fit Standard	Results
CMID/DF	1.316	<3	excellent
RMSEA	0.025	<0.08	excellent
NFI	0.963	>0.9	excellent
IFI	0.991	>0.9	excellent
TLI	0.990	>0.9	excellent
CFI	0.991	>0.9	excellent

The CFA's findings (Fig. 2) demonstrated an excellent model fit as every fit index satisfied widely accepted evaluation standards. The CMIN/DF ratio, calculated at 1.316, is comfortably below the 3.0 threshold, showing that the data is well-fitted by the model. The RMSEA value of 0.025 is significantly lower than the acceptable limit of 0.08, reflecting a minimal error in the model and confirming a strong overall fit. Furthermore, the NFI, IFI, TLI, and CFI values were 0.963, 0.991, 0.990, and 0.991, respectively, all of which are well above the 0.9 threshold, signifying excellent model adequacy and a robust fit to the data. The measurement model's excellent applicability and stability are therefore shown by the findings of the CFA.

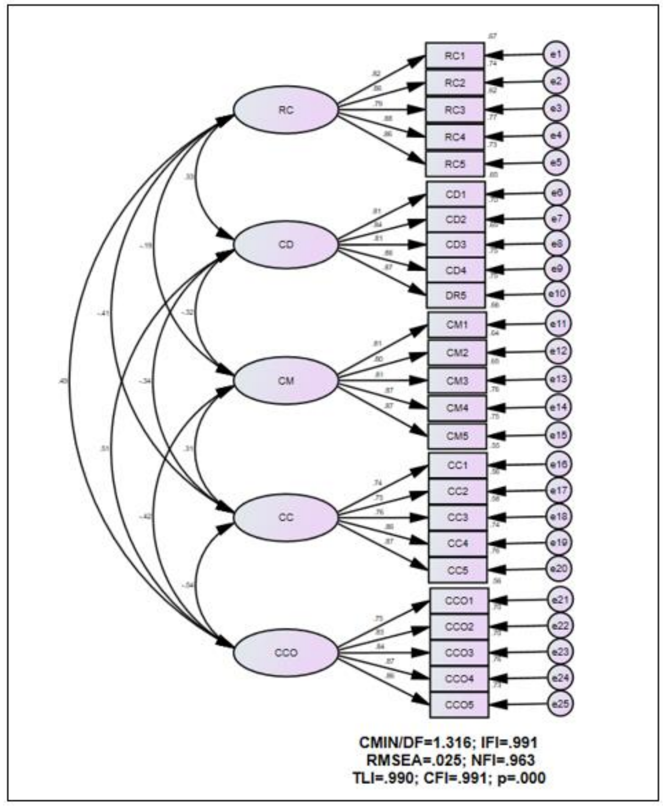

Fig. 2. Measurement model

Testing validity and reliability comes next. The dependability of the measuring instrument is first assessed by computing the Cronbach's alpha coefficient. Its stability and consistency may be ascertained from the indications. The validity and reliability of the scale will next be further investigated via the use of CR, discriminant validity, and convergent validity tests. The scale, which commonly employs the following discriminant criteria, has strong reliability and validity, as seen in Table 2:

Every standardized factor loading exceeds 0.500;
Over 0.500 is the average variance extracted (AVE) (

$AVE = (\sum \lambda^2) / n$, $\lambda =$ Factor loading, $n =$ Number of measurement indicators, $\theta = 1 - \lambda^2$);

3) More than 0.700 for comprehensive reliability (CR) ($CR = (\sum \lambda)^2 / \left[(\sum \lambda)^2 + \sum (\theta) \right]$, $\lambda =$ Factor loading, $n =$ Number of measurement indicators, $\theta = 1 - \lambda^2$).

4) Test of reliability: Cronbach's α. High internal consistency is indicated by a coefficient of more than 0.700.

Table 2. Data results for Reliability and validity

Factor	Item	Loadings	CR	AVE	Cronbach's α
RC	RC1	0.821	0.924	0.708	0.914
	RC2	0.862			
	RC3	0.785			
	RC4	0.88			
	RC5	0.857			
CD	CD1	0.806	0.921	0.701	0.921
	CD2	0.837			
	CD3	0.808			
	CD4	0.864			
	CD5	0.868			
CM	CM1	0.81	0.918	0.692	0.917
	CM2	0.801			
	CM3	0.806			
	CM4	0.872			
	CM5	0.866			
CC	CC1	0.739	0.898	0.638	0.895
	CC2	0.747			
	CC3	0.762			
	CC4	0.862			
	CC5	0.874			
CCO	CCO1	0.748	0.917	0.690	0.916
	CCO2	0.835			
	CCO3	0.839			
	CCO4	0.87			
	CCO5	0.857			

This table displays the findings of the convergent validity study. Strong convergent validity is shown by the fact that each construct's AVE and CR values satisfied the requirements. Every construct's AVE value was higher than 0.5, indicating that each indicator effectively reflects its underlying variables. Specifically, the AVE for RCs was 0.708 and the CR was 0.924; the AVE for design changes was 0.701 and the CR was 0.921; the AVE for CM was 0.692 and the CR was 0.918; the AVE for communication and coordination was 0.638 and the CR was 0.898; and the AVE for construction cost overrun was 0.690 and the CR was 0.917. Overall, every factor loading exceeded 0.500. The AVE and CR values for all constructs met convergent validity requirements, indicating that the questionnaire design effectively measures each underlying variable. Every Cronbach's α coefficient was higher than 0.700, indicating high internal consistency.

In terms of discriminant validity, the correlation coefficient for each latent variable was smaller than the associated AVE's square root, suggesting that the model has good discriminant validity. The square roots of the AVEs for contractor experience, communication and coordination, RCs and design changes, and construction cost overruns were 0.841, 0.837, 0.832, and 0.799, respectively (see Table 3 below). These values are all greater than the correlation coefficients.

Table 3. Data results for discriminant validity

	AVE	RC	CD	CM	CC	CCO
RC	0.708	0.841				
CD	0.701	0.333	0.837			
CM	0.692	−0.191	−0.322	0.832		
CC	0.638	−0.405	−0.344	0.307	0.799	
CCO	0.690	0.492	0.512	−0.418	−0.543	0.831

Note: In the table, the numbers on the off-diagonal indicate the correlation coefficients between the variables, while the diagonal numbers represent the square root of each variable's average variance extracted (AVE)

5.2 Hypothesis testing

We will test our hypotheses based on CFA to investigate the connections among contractor experience, coordination and communication, resource limitations, and design modifications. The theories listed below are examined: A SEM (Fig. 3) was used to evaluate the study hypotheses. The pathways inside the structural model are compiled in Table 4, which also displays the findings that validate the connections and their orientations. We started by putting the direct hypothesis to the test. P-values were used to assess both accepted and rejected hypotheses. P-values below 0.05 indicated that a relationship was considered valid (Wu, 2009).

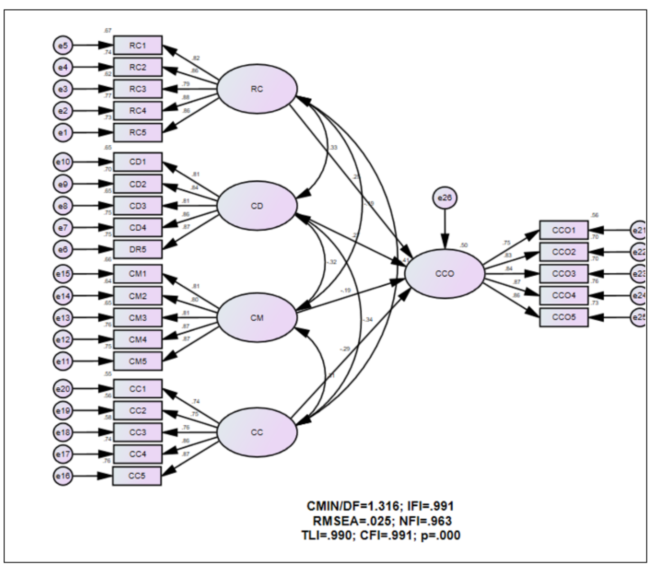

Fig. 3. Model for structural

Table 4 shows that RCs are positively correlated with construction cost overruns (unstandardized estimate = 0.248, CR = 5.835, P < 0.001). Insufficient resources are one of the core drivers of construction project cost overruns. Their impact persists throughout the entire project cycle (design, construction, and completion), often amplifying the magnitude of cost overruns through the dual pathways of "direct cost increases" and "indirect efficiency losses." Therefore, Hypothesis H1: Construction cost overruns are significantly reduced when resource limits are in place.

Design modifications significantly reduce construction cost overruns (unstandardized estimate = 0.267, CR = 6.237, P < 0.001). The greater and more frequent the design changes, the greater the likelihood and magnitude of a construction project's overrun. Therefore, Hypothesis H2: Design modifications significantly reduce construction cost overruns and are encouraged.

Construction cost overruns are significantly impacted negatively by the experience of the contractor (unstandardized estimate = −0.195, CR = −4.818, P < 0.001). Experienced contractors generally perform better in project management, cost control, and risk management, and are better able to anticipate potential cost issues and avoid budget overruns. Contractor experience helps them manage resources and control costs more effectively during project execution, lowering the possibility of cost overruns. Therefore, Hypothesis H3: Experience of the contractor significantly affects the likelihood of building cost overruns. Construction cost overruns were also significantly impacted negatively by cooperation and communication (unstandardized estimate = −0.29, CR = −6.502, P < 0.001). Effective communication can promptly identify and resolve potential project issues, avoid misunderstandings and poor decisions caused by information asymmetry, and thus reduce additional costs. Good communication and coordination can promote alignment among project parties on budgets and resources, lowering the possibility of cost overruns. Therefore, Hypothesis H4: It was shown that cooperation and communication had a major detrimental effect on building cost overruns.

Table 4 shows that all the hypotheses (H1, H2, H3, and H4) were accepted.

Table 4. Data results for hypothesis testing

H	Path	Estimate (UE)	Estimate (SE)	S.E.	C.R.	P	Result
H1	CCO<---RC	0.222	0.248	0.038	5.835	***	Supported
H2	CCO<---CD	0.232	0.267	0.037	6.237	***	Supported
H3	CCO<---CM	−0.17	−0.195	0.035	−4.818	***	Supported
H4	CCO<---CC	−0.262	−0.29	0.04	−6.502	***	Supported

Note: ***p < 0.001.

6 Conclusions and Recommendations

6.1. Conclusion

Using 16 cities in Anhui Province as case studies, this study collected evaluation data from construction practitioners and empirically validated the connections among the variables in the model that was built. The findings are: First, construction cost overruns are significantly reduced by resource limits. CFA using AMOS 26.0 software determined the factor loadings, combined reliability, and convergent validity of each indicator factor. The predicted correlations in this work were further tested using structural modeling, which validates the validity of these results. Second, design changes can positively impact construction cost overruns. Third, the more experienced the contractor, the significantly lower the likelihood and magnitude of project cost overruns. Fourth, communication and coordination skills are significantly negatively correlated with construction cost overruns. Higher communication efficiency is associated with lower overrun risk.

6.2 Recommendations

6.2.1 Implications for academia

The many variables driving construction project cost overruns are the focus of this research, including contractor experience, communication and coordination, RCs, design changes, and inadequate construction planning. This research fills a gap in the current research landscape regarding regional, multi-factor analysis in the construction management area. This study provides a solid foundation for the advancement of construction project management theory by shedding light on the complex interactions between various components of the cost control process via empirical examination and analysis of typical projects in Anhui Province. Furthermore, both quantitative and qualitative methodologies are used in this investigation, providing a reference for future academic research. Future scholars can build on this foundation to further explore the adaptability and variability of these factors across different regions, project types, and institutional environments, thereby promoting the deepening and diversification of construction project management theory.

6.6.2 Implications for policymakers and regulators

For owners and project managers in the construction industry, this study has a number of useful management ramifications. The work indicates that cost overruns are not caused by a single factor, but rather the combined effects of multiple management shortcomings, such as insufficient initial project planning, mismatched contractor capabilities, and frequent design revisions. Therefore, in practice, companies should prioritize scientific and systematic approaches during the project launch phase, improve inter-team communication, optimize contractor selection mechanisms, and establish a management system that can flexibly respond to resource fluctuations and design changes. Furthermore, to improve overall project management skills and accomplish the objectives of cutting costs and boosting efficiency, the study recommends promoting the use of digital management tools, including information integration platforms and BIM.

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Author contributions

Qian Wu contributed to conceptualization, methodology, software, validation, analysis, investigation, and data collection. Ali Khatibi contributed to draft preparation, manuscript editing, visualization, supervision, and project management. Jacquline Tham contributed to software, validation, and analysis. All authors read and approved the manuscript before submission and publication.

Institutional review board statement

Not applicable.

Data availability statement

Due to the nature of this research, participants of this study did not agree for their data to be shared publicly, so supporting data is not available.

Competing interest

The authors have no relevant financial or non-financial interests to disclose.

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