

# Prioritising Critical Success Factors for Residential High-Rise Construction Performance: An RII-Based Empirical Study of Construction Professionals in Pune, India

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## Abstract

Residential high-rise construction projects are increasingly exposed to performance risks arising from vertical complexity, constrained urban sites, intensive stakeholder interfaces, safety hazards, digital coordination requirements and pressure for timely delivery. This study identifies and prioritises the critical success factors (CSFs) affecting high-rise building construction performance in the Indian residential context. A structured questionnaire was administered to 50 construction professionals including project managers, site engineers, consultants, contractors, supervisors, and safety/quality personnel associated with high-rise residential projects. The survey instrument contained CSF statements measured on a five-point Likert scale. Data were analysed using descriptive statistics, Cronbach's Alpha, normality testing, Pearson correlation, Kaiser-Meyer-Olkin (KMO) and Bartlett's tests, one-sample t-tests and the Relative Importance Index (RII). The reliability analysis indicated excellent internal consistency for the 47-item questionnaire (Cronbach's Alpha = 0.921). The RII results show that all twelve CSF groups were important, with values ranging from 0.781 to 0.871. Top management support and leadership ranked first (RII = 0.871), followed by site constraints and environment (RII = 0.869), technology infrastructure and interoperability (RII = 0.862), and communication and collaboration (RII = 0.862). The hypothesis testing results confirmed that CSFs are significantly above neutral importance and that milestone-related CSFs are positively associated with overall CSF performance. The study contributes an integrated CSF-based framework linking leadership, site logistics, digital coordination, stakeholder integration, workforce capability, risk control and resource management with construction performance outcomes. The findings provide practical guidance for developers, consultants, contractors and project managers seeking to reduce delays, rework, safety incidents and coordination failures in high-rise residential projects.

**Keywords:** Critical success factors; high-rise construction; residential buildings; Relative Importance Index; construction performance; project management; stakeholder coordination; BIM readiness.

## Highlights

- The study ranks twelve critical success factor groups affecting residential high-rise construction performance using RII.
- Top management support, site constraints, technology infrastructure and communication emerged as the highest-priority factors.
- The manuscript proposes a practical CSF-based framework for improving time, cost, quality, safety and stakeholder satisfaction outcomes.

## 1. Introduction

High-rise building construction has become a major response to rapid urbanisation, limited land availability, increasing housing demand and infrastructure densification in developing cities. In contrast with low-rise building work, high-rise projects require intensive vertical logistics, complex structural and service coordination, multi-agency decision-making, strict safety control and continuous quality monitoring. As the height and scale of a project increase, small planning errors, design changes, resource shortages and communication gaps can multiply into substantial delays, cost escalation, rework and disputes.

Construction project success is no longer evaluated only through the traditional time-cost-quality triangle. Contemporary construction performance studies emphasise safety performance, environmental performance, stakeholder satisfaction, technological capability, risk resilience and value delivery as additional success dimensions [1], [2], [9]. This expanded

view is particularly relevant for high-rise residential projects because they combine long project durations, buyer expectations, regulatory approvals, repetitive floor cycles, constrained sites and high capital investment.

Critical success factors (CSFs) represent the limited number of managerial, technical, organisational and human areas in which satisfactory performance is necessary for project success. In high-rise construction, these factors include realistic planning, top management support, stakeholder coordination, skilled manpower, timely materials, reliable subcontractors, safety culture, quality assurance, risk management, digital documentation, BIM readiness and strong monitoring systems. If these factors are systematically identified and prioritised, project teams can focus on the most influential areas instead of treating all project issues with equal intensity.

The Indian residential high-rise sector faces recurring problems such as delayed approvals, design revisions, labour shortage, inefficient procurement, weak monitoring, unsafe work practices, delayed payments and limited technology adoption. Many project teams are aware of these issues, but they may not have a structured ranking of which CSFs require the highest managerial attention. A ranking-based empirical approach is therefore useful for translating professional judgement into a practical priority framework.

This study addresses that need by prioritising CSFs affecting residential high-rise construction performance using expert questionnaire data, Relative Importance Index (RII) and SPSS-supported validation. The research is based on responses from 50 construction professionals and a case context of residential high-rise construction in Pune, Maharashtra. The novelty of the paper lies in integrating traditional project management factors with digital readiness, site constraints, stakeholder communication and milestone performance into one high-rise-specific framework.

## **2. Literature Review and Research Gap**

### **2.1 Construction project success and CSF studies**

Recent CSF research confirms that construction success is multidimensional and stakeholder dependent. Gunduz and Almuajebh [1] classified sustainable construction project CSFs across stakeholder and management categories and demonstrated the value of systematic categorisation. Sobieraj and Metelski [2] showed that CSFs in investment-construction projects can be quantified and ranked, supporting the use of structured statistical approaches for project success assessment. Sarvari et al. [3] further highlighted management capability, financial strength and skilled human resources as determinants of performance in construction enterprises.

Studies focusing on residential and building projects have similarly identified budgeting, risk management, project management tools, stakeholder involvement and resource control as important factors [4], [5]. These findings support the premise that residential high-rise projects require both managerial commitment and operational control. However, the relative importance of CSFs may vary according to local context, building type, project scale and professional perception.

### **2.2 High-rise construction, stakeholder coordination and technology adoption**

High-rise projects differ from conventional building projects because of repetitive floor cycles, vertical transportation, equipment dependency, structural and MEP interdependencies, façade interfaces and height-related safety exposure. Research on stakeholder management indicates that communication, engagement, relationship management and conflict resolution are central to construction performance [6], [7]. For high-rise projects, weak stakeholder coordination can result in late drawings, approval delays, design clashes, poor sequencing and rework.

Technology adoption is now a major CSF in modern construction. BIM, digital dashboards, mobile inspection tools and cloud-based documentation can improve clash detection, progress monitoring, cost control and site reporting [9], [13]. However, technology adoption depends on management support, staff training, data quality and interoperability. Advanced digital innovations such as blockchain and artificial intelligence also require organisational readiness and stakeholder acceptance [14], [15]. Therefore, technology should not be treated separately from traditional CSFs; it must be integrated with planning, communication and performance control.

### **2.3 Research gap**

The literature shows a rich body of CSF research for general construction, sustainable construction, stakeholder management, technology adoption and project performance. Nevertheless, several gaps remain. First, many studies focus

on general construction projects and do not specifically address the complexity of residential high-rise projects such as vertical logistics, site constraints, safety exposure and MEP coordination. Second, several studies identify CSFs but do not integrate them with practical performance indicators such as time, cost, quality, safety, stakeholder satisfaction and milestone achievement within a single framework.

Third, digital construction factors are often studied separately from conventional CSFs, although actual high-rise projects depend on the interaction between leadership, digital systems, communication, site logistics and workforce capability. Fourth, local construction professionals require a clear priority order to support managerial action. Hence, this study fills the gap by developing and validating a high-rise-specific CSF ranking and performance improvement framework using RII and statistical tests.

### 3. Research Methodology

#### 3.1 Research design

The study adopted a quantitative research design based on a structured questionnaire. The method was appropriate because the objective was to convert the professional judgements of high-rise construction stakeholders into comparable numerical ratings. The questionnaire was developed after reviewing literature on CSFs, high-rise construction performance, stakeholder coordination, risk management, quality, safety and digital construction management.

The target population consisted of construction professionals having direct or indirect experience in residential high-rise projects. Purposive sampling was used because the study required informed responses rather than general public opinion. A mixed survey mode was used: Google Forms were circulated through professional networks and supplementary in-person/site responses were collected wherever clarification was required. Incomplete, repeated and irrelevant responses were removed before final analysis.

#### 3.2 Sample profile and case context

A total of 50 valid responses were used for the final analysis. The respondents represented managerial, technical, execution, design coordination, contractor, supervision, quality and safety functions. The study context was a residential high-rise project environment in Pune, Maharashtra, which reflects common high-rise challenges such as vertical material movement, site constraints, subcontractor coordination, quality control and safety supervision.

*Table 1. Respondent profile used for questionnaire survey*

| Respondent category               | Frequency | Percentage | Relevance to study                                                    |
|-----------------------------------|-----------|------------|-----------------------------------------------------------------------|
| Project / planning managers       | 8         | 16%        | Leadership, scheduling and milestone-control decisions                |
| Site engineers                    | 14        | 28%        | Execution-level views on resources, productivity and site constraints |
| Consultants / design coordinators | 7         | 14%        | Design coordination, approvals and technical communication            |
| Contractors / subcontractors      | 8         | 16%        | Resource planning, work sequencing and subcontractor coordination     |
| Supervisors / foremen             | 6         | 12%        | Daily site supervision and labour coordination                        |
| Quality and safety personnel      | 7         | 14%        | QA/QC, safety compliance and risk-control inputs                      |
| Total                             | 50        | 100%       | Valid responses used for analysis                                     |

*Table 2. Respondent experience profile*

| Experience group | No. of respondents | Percentage |
|------------------|--------------------|------------|
| 0-5 years        | 12                 | 24%        |
| 6-10 years       | 17                 | 34%        |
| 11-15 years      | 11                 | 22%        |
| Above 15 years   | 10                 | 20%        |

|       |    |      |
|-------|----|------|
| Total | 50 | 100% |
|-------|----|------|

### 3.3 Measurement instrument and analysis techniques

The questionnaire used a five-point Likert scale ranging from 1 = very low importance/strongly disagree to 5 = very high importance/strongly agree. The instrument covered 47 items related to leadership, communication, technology infrastructure, training, safety, risk management, vertical logistics, cost control, time control, quality management, site constraints, financial capability and resource availability.

Data were coded and analysed using Microsoft Excel and IBM SPSS Statistics. Descriptive statistics were used to summarise central tendency and dispersion. Cronbach's Alpha was used to test reliability. Normality tests were used to understand distributional patterns. Pearson correlation examined relationships among major CSF groups. KMO and Bartlett's tests checked factor-analysis suitability. One-sample t-tests assessed whether CSF means were significantly above the neutral value of 3.00. The Relative Importance Index was used as the principal ranking method because it is transparent, widely used in construction management research and suitable for Likert-scale prioritisation.

$$RII = \Sigma W / (A \times N)$$

where  $\Sigma W$  is the total weighted score assigned by respondents, A is the highest scale value (5), and N is the number of respondents (50). Thus, the denominator for each RII calculation was 250.

## 4. Results

### 4.1 Reliability and statistical suitability

The reliability analysis confirmed that the questionnaire had excellent internal consistency. The overall Cronbach's Alpha value for the 47-item CSF questionnaire was 0.921, which exceeds the commonly accepted threshold of 0.90 for excellent reliability. The technology-related, leadership/collaboration and organisational/financial subscales also showed acceptable to excellent reliability.

*Table 3. Reliability statistics*

| Scale                             | No. of items | Cronbach's Alpha | Interpretation |
|-----------------------------------|--------------|------------------|----------------|
| Overall CSF questionnaire         | 47           | 0.921            | Excellent      |
| Technology-related CSFs           | 8            | 0.887            | Good           |
| Leadership and collaboration CSFs | 8            | 0.902            | Excellent      |
| Organisational and financial CSFs | 8            | 0.864            | Good           |

The KMO value was 0.704, indicating acceptable sampling adequacy for exploratory interpretation. Bartlett's Test of Sphericity was significant (approx. chi-square = 568.420, df = 276, p = 0.000), showing that the correlation matrix was suitable for grouped CSF interpretation. Because the sample size was 50, these tests were used as supportive validation rather than as the main basis for factor extraction.

*Table 4. KMO and Bartlett's test output*

| Test                                               | Value   |
|----------------------------------------------------|---------|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy    | 0.704   |
| Bartlett's Test of Sphericity - Approx. Chi-Square | 568.420 |
| df                                                 | 276     |
| Sig.                                               | 0.000   |

## 4.2 RII ranking of critical success factors

The final RII ranking shows that all twelve CSF groups were important for residential high-rise construction performance because all values were above 0.78. The highest priority was assigned to leadership, site constraints, technology infrastructure and communication. These results indicate that performance improvement in high-rise construction requires both strategic managerial support and operational site-level control.

*Table 5. RII ranking of critical success factors*

| Rank | Critical success factor                        | N  | Mean  | SD    | RII   |
|------|------------------------------------------------|----|-------|-------|-------|
| 1    | Top Management Support and Leadership          | 50 | 4.355 | 0.455 | 0.871 |
| 2    | Site Constraints and Environment               | 50 | 4.345 | 0.285 | 0.869 |
| 3    | Technology Infrastructure and Interoperability | 50 | 4.310 | 0.464 | 0.862 |
| 4    | Communication and Collaboration                | 50 | 4.310 | 0.486 | 0.862 |
| 5    | Skills, Training and Technology Awareness      | 50 | 4.220 | 0.504 | 0.844 |
| 6    | Structural and Design Complexity               | 50 | 4.170 | 0.387 | 0.834 |
| 7    | Policy, Standards and Regulatory Support       | 50 | 4.095 | 0.517 | 0.819 |
| 8    | Vertical Logistics and Material Handling       | 50 | 4.050 | 0.633 | 0.810 |
| 9    | Organizational Strategy and Readiness          | 50 | 4.030 | 0.470 | 0.806 |
| 10   | Safety and Risk Management                     | 50 | 4.015 | 0.706 | 0.803 |
| 11   | Sustainability and Environmental Integration   | 50 | 3.980 | 0.626 | 0.796 |
| 12   | Financial Capability and Resource Availability | 50 | 3.905 | 0.612 | 0.781 |

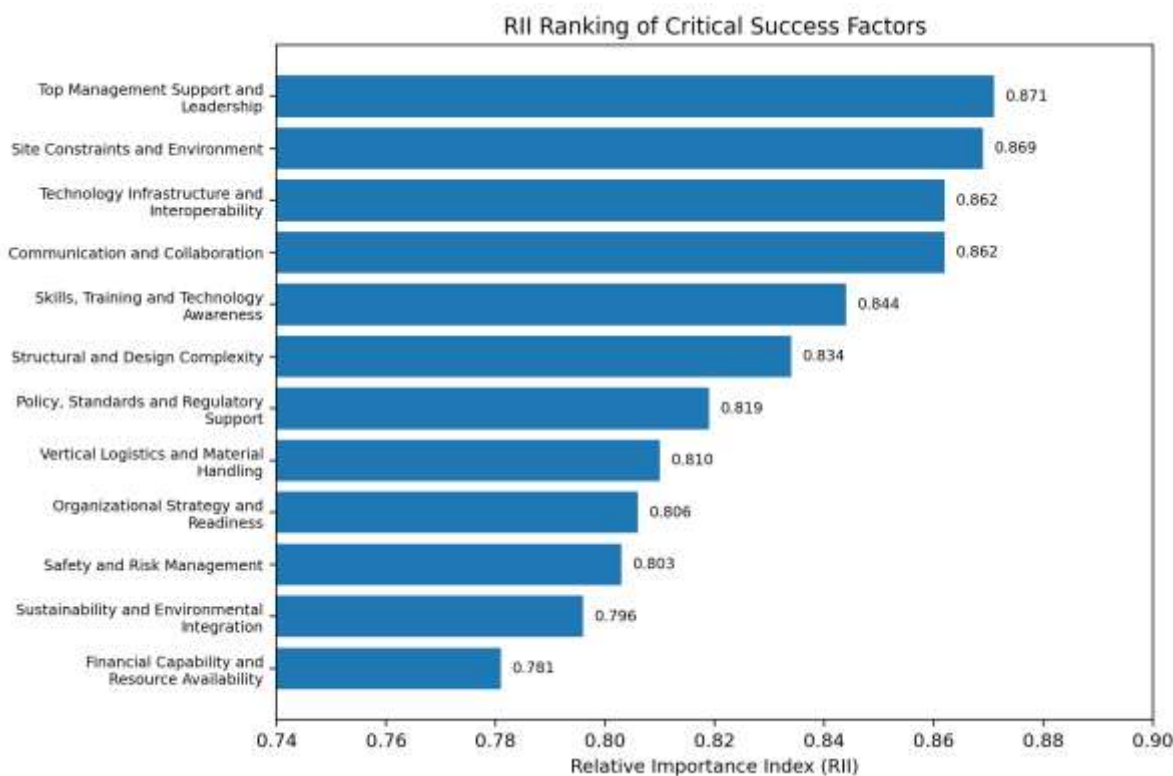


*Figure 1. Relative Importance Index ranking of critical success factors.*

## 4.3 Correlation and hypothesis testing

Pearson correlation analysis showed positive associations between leadership, technology, communication, safety and overall project success. Communication had the strongest association with overall project success ( $r = 0.721$ ), followed by leadership ( $r = 0.701$ ), technology ( $r = 0.693$ ) and safety ( $r = 0.628$ ). These results support the argument that high-rise performance is influenced by the interaction of managerial, technological and safety-related factors rather than by a single isolated factor.

Table 6. Pearson correlation matrix of major CSF groups

| Variables               | Leadership | Technology | Communication | Safety  | Overall project success |
|-------------------------|------------|------------|---------------|---------|-------------------------|
| Leadership              | 1.000      | 0.612**    | 0.684**       | 0.571** | 0.701**                 |
| Technology              | 0.612**    | 1.000      | 0.646**       | 0.538** | 0.693**                 |
| Communication           | 0.684**    | 0.646**    | 1.000         | 0.552** | 0.721**                 |
| Safety                  | 0.571**    | 0.538**    | 0.552**       | 1.000   | 0.628**                 |
| Overall project success | 0.701**    | 0.693**    | 0.721**       | 0.628** | 1.000                   |

The hypothesis testing results confirmed all five hypotheses. The overall CSF mean was significantly above the neutral value of 3.00 (mean = 4.149,  $t = 51.364$ ,  $p = 0.000$ ). Communication and collaboration recorded a mean of 4.310,  $RII = 0.862$  and a significant positive correlation with the overall CSF mean ( $r = 0.288$ ,  $p = 0.042$ ). The milestone-related CSF composite also showed significant results (mean = 4.257,  $t = 45.750$ ,  $p = 0.000$ ), with a strong positive relationship with overall CSF performance ( $r = 0.700$ ,  $p = 0.000$ ).

Table 7. Hypothesis testing summary

| Hypothesis | Statement                                                                                        | Test / evidence                                        | Result                                                 | Decision |
|------------|--------------------------------------------------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------------|----------|
| H1         | Historical CSFs provide a significant foundation for current residential construction practices. | One-sample test of overall CSF mean                    | Mean = 4.149, $t = 51.364$ , $p = .000$                | Accepted |
| H2         | Stakeholder collaboration and communication significantly contribute to project success.         | One-sample test and Pearson correlation                | Mean = 4.310, $RII = 0.862$ , $r = 0.288$ , $p = .042$ | Accepted |
| H3         | Relative importance of CSFs can be assessed through $RII$ /expert survey analysis.               | $RII$ ranking of twelve CSFs                           | $RII$ range = 0.781 to 0.871                           | Accepted |
| H4         | CSFs significantly influence project milestones and timely completion.                           | One-sample test and correlation of milestone composite | Mean = 4.257, $r = 0.700$ , $p = .000$                 | Accepted |
| H5         | CSF-based framework can improve time, cost, quality, safety and stakeholder satisfaction.        | CSF framework composite and $RII$ synthesis            | Mean = 4.308, $t = 48.570$ , $p = .000$                | Accepted |

## 5. Discussion

### 5.1 Interpretation of top-ranked CSFs

Top management support and leadership obtained the highest  $RII$  value (0.871), indicating that respondents viewed senior management commitment, quick decision-making, timely resource support and effective supervision as the strongest drivers of high-rise project performance. This finding aligns with TQM and sustainable construction studies that emphasise leadership as a foundation for quality, safety, resource allocation and organisational performance [1], [10]. In high-rise projects, delayed decisions can affect approvals, procurement, subcontractor sequencing and daily execution. Therefore, leadership must be operationalised through decision trackers, weekly reviews, escalation mechanisms and responsibility matrices.

Site constraints and environment ranked second ( $RII = 0.869$ ). This is a high-rise-specific finding because urban high-rise projects often have restricted access, limited storage, traffic limitations, neighbouring buildings, safety barricades and complex material movement requirements. Site constraints affect productivity, floor-cycle reliability, material handling and safety. The result suggests that site logistics planning should be treated as a strategic CSF, not merely as a site administration issue.

Technology infrastructure and interoperability ranked third ( $RII = 0.862$ ), confirming the growing importance of BIM, digital drawings, document control, dashboards and integrated reporting systems. High-rise projects generate large amounts of information across structural, architectural, MEP, façade and finishing disciplines. If digital tools are not interoperable or if teams use outdated drawings, rework and disputes increase. This result supports studies on BIM and digital construction that emphasise organisational readiness, data standards and technology integration [9], [13].

Communication and collaboration also obtained a high RII value (0.862). The result is consistent with stakeholder management research, which shows that engagement, timely decisions and coordination influence project success [6], [7]. In high-rise residential projects, communication failures can affect drawing approvals, inspection clearances, work-front availability and subcontractor interfaces. Thus, project teams should maintain a formal communication protocol using RFI registers, drawing logs, coordination meetings and approval trackers.

## 5.2 Practical implications for high-rise project management

The findings indicate that project performance can be improved by connecting the highest-ranked CSFs with measurable control actions. Leadership should be translated into decision control and accountability. Site constraints should be translated into access planning, storage planning, crane/hoist scheduling and material movement sequencing. Technology infrastructure should be translated into BIM-enabled design coordination, cloud document control and dashboard-based progress tracking. Communication should be translated into integrated stakeholder meetings, RFI control, variation management and issue closure systems.

The framework developed from the results is especially useful for residential high-rise projects because it links CSF priorities with outcomes such as faster approvals, reliable floor cycles, reduced rework, improved safety, better quality and fewer stakeholder disputes. The framework can be used by developers, project management consultants, contractors and site teams during planning and execution reviews.

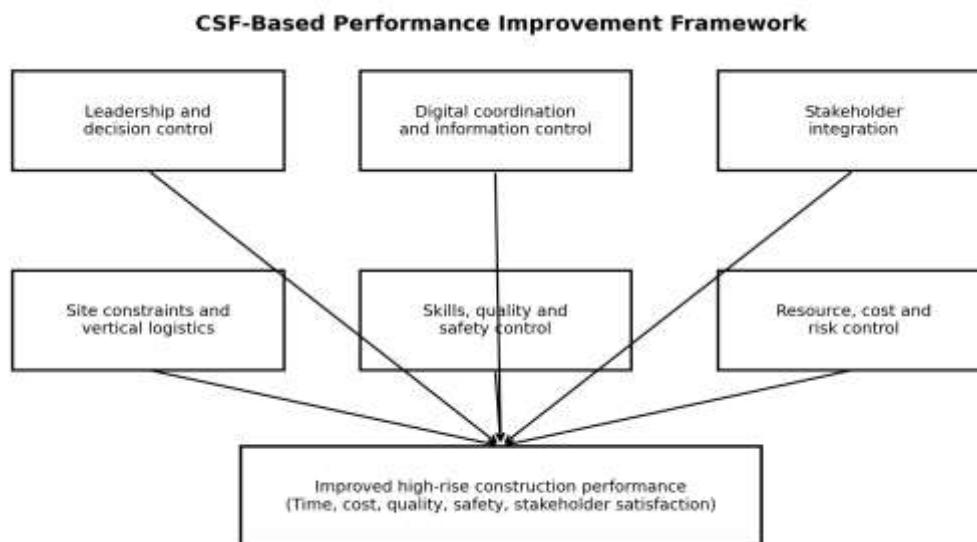


*Figure 2. Proposed CSF-based performance improvement framework.*

*Table 8. Practical CSF-based framework for project performance improvement*

| Framework area                       | Linked CSF / result basis                                    | Control action for project                                                                  | Expected outcome                                           |
|--------------------------------------|--------------------------------------------------------------|---------------------------------------------------------------------------------------------|------------------------------------------------------------|
| Leadership and decision control      | Rank 1: Top management support and leadership                | Weekly decision review, decision tracker, responsibility matrix and escalation system.      | Faster approvals, reduced delay and better accountability. |
| Site condition and logistics control | Rank 2: Site constraints and environment; vertical logistics | Site access plan, storage plan, crane/hoist schedule and floor-wise material movement plan. | Improved productivity, safer                               |

|                                    |                                                |                                                                                                   |                                                          |
|------------------------------------|------------------------------------------------|---------------------------------------------------------------------------------------------------|----------------------------------------------------------|
|                                    |                                                |                                                                                                   | movement and reliable floor cycle.                       |
| Technology and information control | Technology infrastructure and interoperability | BIM/digital drawings, cloud document control, RFI register and dashboard-based progress tracking. | Reduced drawing conflict, rework and communication gap.  |
| Stakeholder coordination control   | Communication and collaboration                | Regular coordination meetings among client, consultants, contractors and subcontractors.          | Timely decisions, fewer disputes and smoother execution. |
| Skill, quality and safety control  | Skills, training, safety and quality CSFs      | Training, toolbox talks, QA/QC checklists, safety audits and permit-to-work system.               | Reduced accidents, better workmanship and lower rework.  |
| Financial and resource control     | Financial capability and resource availability | Cash-flow planning, procurement schedule, supplier tracking and labour/equipment planning.        | Better cost control and uninterrupted work progress.     |

## 6. Conclusion

This study prioritised critical success factors affecting residential high-rise construction performance using questionnaire responses from 50 construction professionals. The research confirms that high-rise performance is a multidimensional outcome influenced by leadership, site conditions, technology infrastructure, communication, workforce capability, design complexity, regulatory support, logistics, safety, sustainability and resource availability.

The RII results revealed that Top Management Support and Leadership was the most important factor (RII = 0.871), followed by Site Constraints and Environment (RII = 0.869), Technology Infrastructure and Interoperability (RII = 0.862), and Communication and Collaboration (RII = 0.862). The reliability, correlation and hypothesis testing results strengthened the validity of the findings. The overall CSF mean was significantly above neutral importance, and milestone-related CSFs showed a strong positive relationship with overall CSF performance.

The study contributes a practical CSF-based framework that integrates strategic decision control, site logistics planning, digital coordination, stakeholder communication, training, safety, quality, risk and resource management. The framework can support evidence-based decision-making in residential high-rise projects and help reduce delay, cost overrun, rework, safety incidents and stakeholder conflict.

## 7. Recommendations

- Develop a formal leadership control system with weekly senior-management reviews, decision logs and escalation mechanisms.
- Prepare a high-rise-specific site logistics plan covering material storage, hoist/crane utilisation, access routes, safety zones and floor-wise movement.
- Use BIM/digital drawing management, RFI tracking and cloud-based document control to reduce clashes and rework.
- Implement structured stakeholder coordination meetings involving client, consultants, contractors, subcontractors and quality/safety teams.
- Conduct regular training, toolbox talks, QA/QC checks and safety audits to improve workforce capability and reduce site incidents.
- Use monthly CSF performance reviews to connect time, cost, quality, safety and stakeholder satisfaction indicators with corrective actions.

## 8. Limitations and Future Research

The study has limitations. First, the sample size was limited to 50 respondents and was based on purposive sampling; therefore, the results should be interpreted as context-specific rather than universally generalisable. Second, the findings are perception-based and do not directly measure actual project performance data such as delay days, cost variance or accident frequency. Third, the study used a cross-sectional survey, so it does not capture changes in CSF importance across different project phases. Fourth, the research focused on residential high-rise projects in a local construction context, which may differ from commercial towers, infrastructure megaprojects or projects in other regions.

Future studies may expand the sample size, include multiple cities or project types, combine RII with structural equation modelling, and validate the CSF framework using actual project performance records. Longitudinal research can also examine how CSF priorities change from planning to execution, finishing and handover stages. Future research may further assess the role of BIM maturity, artificial intelligence, digital twins and predictive analytics in improving high-rise construction performance.

## Declarations

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**Conflict of interest:** The authors declare no known conflict of interest. This statement may be revised by the authors according to the target journal requirements.

**Ethical statement:** The study used professional survey responses for academic purposes. Respondent identity and organisation-specific details were not disclosed.

**Data availability:** Anonymised questionnaire data may be made available by the corresponding author on reasonable request.

**Author contributions:** Conceptualisation, data collection, analysis, writing and review should be completed according to the final author list before journal submission.

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