

Assessment and Management of Construction Project Risks

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Abstract- Construction projects are inherently complex and involve considerable uncertainty. Risks in construction typically refer to potential events that can adversely affect key project objectives, such as cost, time, quality, and safety. Given these challenges, effective risk management is essential to minimize disruptions and ensure smooth project execution. As a critical competency for project success, risk management entails a structured approach to identifying, assessing, and mitigating risks throughout the project lifecycle. This study examines the severity and likelihood of risk factors across different construction sectors, including industrial, commercial, highway, and apartment projects. The primary focus is on identifying key risk drivers in highway and apartment construction, analyzing both their direct and indirect impacts through quantitative and qualitative methods. A ranking system is used to evaluate critical risks during the planning, execution, and completion phases. Data is collected using a structured questionnaire developed from expert consultations, interviews, and literature reviews. The Relative Importance Index (RII) and mean values are applied to prioritize risks, which are then visualized on a risk matrix. Additionally, the Analytic Network Process (ANP) is employed using Super Decisions software to improve decision-making by evaluating interdependencies among risk factors. This integrated approach helps pinpoint the most significant risk categories, enabling project teams to implement targeted mitigation strategies. Risks are assessed based on their influence on time, cost, quality, and safety. Once identified, they are allocated to relevant stakeholders—clients, contractors, or project management consultancies—based on their ability to manage them effectively. Finally, mitigation strategies are formulated, which may include risk prevention, reduction, transfer, or acceptance, ensuring better project control and successful delivery.

Keywords: Construction Projects, Risk Management, Risk Identification, Risk Assessment, Risk Mitigation, Cost Overruns, Schedule Delays, Quality Control, Safety Risks, Highway Construction, Apartment Projects, Quantitative Analysis, Qualitative Analysis, Risk Matrix, Relative Importance Index (RII), Analytic Network Process (ANP), Decision-Making Tools, Stakeholder Allocation, Project Lifecycle.

1. INTRODUCTION

The construction sector serves as a fundamental pillar of economic development, contributing substantially to national GDP. In the Indian context, this industry generated approximately ₹11 lakh crores during the 2018-19 fiscal year. Characterized by a diverse ecosystem encompassing large corporations, specialized medium-scale enterprises, and numerous subcontracting SMEs, the sector operates within a highly volatile environment that exposes it to multiple risk factors. Construction projects encounter potential hazards across all phases, from initial financing and design through to final execution and project handover. These vulnerabilities originate from various unpredictable elements including workforce availability, material price fluctuations, environmental conditions, and evolving regulatory frameworks. Without proper management, these factors can result in schedule delays, budgetary excesses, compromised work quality, and workplace safety concerns. In construction terminology, risk denotes the probability of events - whether advantageous or detrimental - that may influence project goals. Consequently, risk management emerges as a strategic necessity rather than merely a responsive protocol. The process incorporates five critical components: Risk Identification: Systematic detection of potential

threats, Risk Evaluation: Analysis of probability and consequences, Risk Distribution: Assignment of responsibilities according to stakeholder capabilities, Risk Control: Formulation of management approaches, Risk Surveillance: Continuous oversight throughout project duration.

This research concentrates on the detection, examination, and regulation of principal risk elements in industrial, commercial, highway, and residential construction projects. The methodology integrates both numerical and descriptive techniques, incorporating on-site inspections, specialist consultations, and methodical surveys. Analytical instruments including the Relative Importance Index (RII) and Analytic Network Process (ANP) implemented through Super Decisions software facilitate the examination of risk importance and interrelationships. Effective risk management enables the recognition of elements that might adversely affect project cost, timeline, safety standards, or quality parameters. Implementing a forward-looking strategy is essential for assessing risk frequency and intensity, followed by development of suitable control measures. In emerging economies like India, insufficient technical knowledge frequently obstructs proper execution. Nevertheless, targeted training programs and awareness initiatives can substantially enhance risk management outcomes when implemented by skilled engineering professionals. Risk Management (RM) represents an organized, anticipatory methodology employed across multiple industries. As highlighted by the Project Management Institute (PMI, 2004), effective risk management constitutes a crucial element for project achievement. The construction sector, with its distinctive project characteristics and elevated uncertainty levels, necessitates customized risk management solutions. Although recognition of its importance has grown, numerous organizations continue to inadequately utilize available RM methodologies and instruments. Threat Recognition: Methodical identification of potential hazards through ongoing, structured examination. Risk Analysis: Assessment using either quantitative or qualitative methods Responsibility Assignment: Appropriate distribution of risks among involved parties (Flanagan & Norman, 1993) Risk Reduction: Implementation of tactics including prevention, assumption, transference, or insurance coverage (Al-Bahar & Crandall, 1990).

Continuous Oversight: Persistent management via consistent communication and record-keeping. Properly executed RM improves project adaptability and facilitates informed decision-making throughout all project stages, particularly when risk parameters undergo transformation over time.

2. LITERATURE SURVEY

Traditionally, risk was perceived solely as a potential loss, but contemporary perspectives acknowledge that uncertainties can also create opportunities, influencing project objectives both positively and negatively. Given the intricate and unique nature of construction projects, risk management remains a demanding yet crucial process, structured around five key phases: identification, assessment, contribution analysis, allocation, and mitigation. Risk identification draws from historical data, expert insights, and existing research, encompassing both internal (controllable) and external (uncontrollable) factors—such as market fluctuations, technical challenges, and political instability. Risk analysis, integrating identification and assessment, helps predict potential outcomes and supports informed decision-making. Various methodologies are used for risk assessment. Traditional quantitative techniques include Monte Carlo Simulation, Sensitivity Analysis, and the Critical Path Method (CPM). Meanwhile, advanced models like the Analytical Hierarchy Process (AHP), Risk Assessor Model, and Fuzzy Neural Networks provide greater adaptability, particularly for qualitative risk evaluation. AHP classifies risks into categories such as technical, financial, construction-related, organizational, socio-political, and environmental health & safety. The Fuzzy Analytical Network Process (FANP) further refines this by modeling interdependencies among risks during construction. In highway projects, major risks include land acquisition delays, inefficiencies in investment systems, economic volatility, and design deficiencies. A comprehensive literature review underscores these concerns and shapes the framework of this study: Dziadosz et al. (2015) advocated for structured risk analysis using hybrid (qualitative-quantitative) methods, emphasizing tools like risk matrices and PROMETHEE for decision-making. Serpell et al. highlighted the necessity for maturity models and standardized digital tools to improve risk management

adoption. Gładysz et al. identified gaps in time-risk management, particularly in developing nations where fragmented practices and poor documentation hinder efficiency. Renault & Agumba examined construction-specific risk management, recommending tailored, dynamic models to address industry complexities.

3. METHODOLOGY

This study adopts a structured approach to identify and assess risk factors in construction projects by combining field observations, literature review, structured/semi-structured interviews, and questionnaire surveys. The risks were evaluated in relation to their impact on time, cost, quality, and safety, and categorized into six key domains:

- 1. Technical
- 2. Financial

- 3. Construction
- 4. Organizational
- 5. Socio-political
- 6. Environmental Health & Safety (EHS)

These risk categories were analyzed across the three major phases of project execution—pre-construction, construction, and completion. Both direct and indirect influences of risk were examined using quantitative and qualitative techniques. The study spans various project types including industrial, commercial, highway, and apartment constructions.

To prioritize and validate the risks, statistical tools were applied, including the Relative Importance Index (RII). For advanced modeling, the Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) were utilized via Super Decisions software, enabling a detailed analysis of risk interdependencies and mitigation priorities shown in Figure 1.

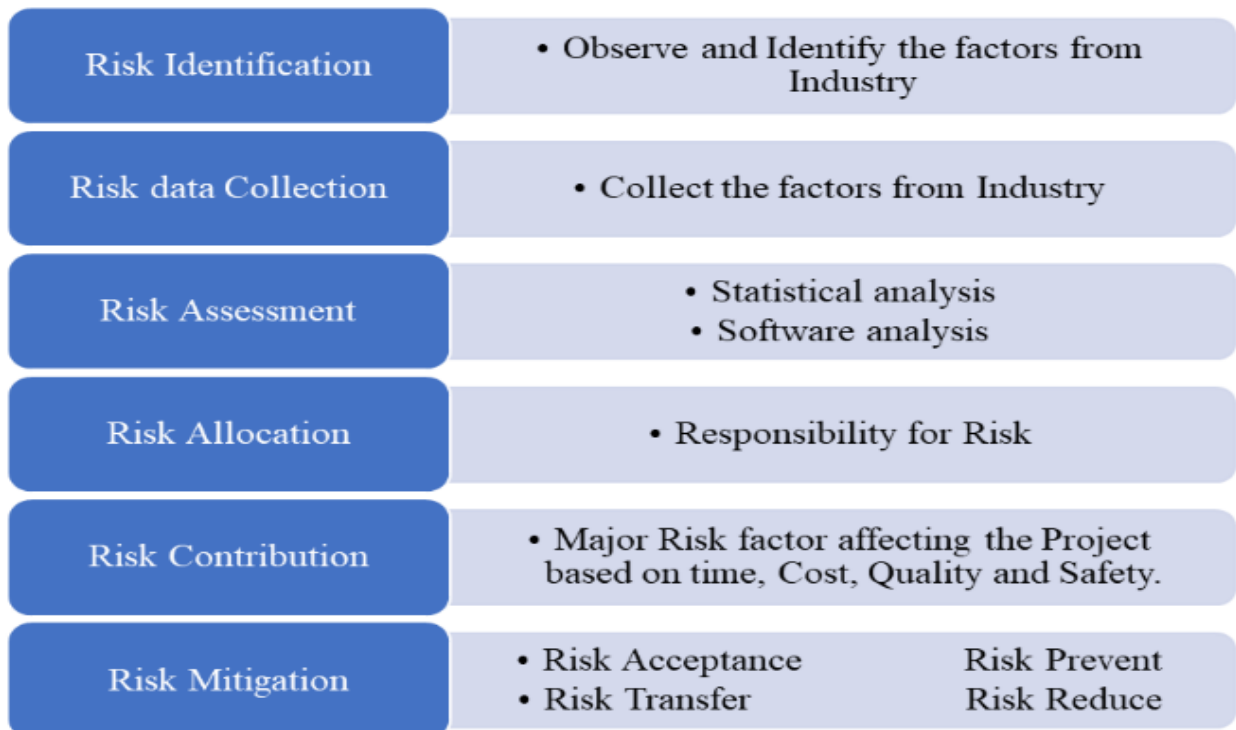


Figure 1 Methodology Chart

3.1 Data Collection Methods

Risk data was collected using the following four methods:

- Site Observations
- Questionnaire Surveys (via email)
- Structured/Semi-Structured Interviews with Experts

Comprehensive Literature Review

3.2 Quantitative Analysis

Quantitative techniques were used to statistically assess the frequency and severity of identified risks. These methods allow for objective evaluation and

support informed decision-making in complex construction environments. Key benefits include:

- Analysing multifactor project objectives
- Supporting data-driven decisions in project and risk management
- Enhancing predictive accuracy of risk behaviour

3.3 Qualitative Analysis

Qualitative methods focus on subjective, contextual insights drawn from expert judgment and observational data. These include tools like precedence diagramming and risk prioritization matrices. Such techniques help explain the underlying causes of risks and their human or procedural influences, especially in cases where numerical data may be insufficient or unavailable.

3.4. RISK IDENTIFICATION

Risk identification is a proactive and systematic process vital to minimizing uncertainties in construction projects. Risks are assessed across the project lifecycle—pre-construction, construction, and completion—and categorized through expert interviews, field observations, surveys, and literature reviews.

3.4.1 Risk Categories

Six key risk categories were identified:

- **Technical Risks:** Arise from design flaws, scope changes, or inadequate site investigations. These issues often lead to rework, safety hazards, and construction delays.
- **Financial Risks:** Involve cost escalations, delayed payments, funding shortfalls, and market volatility. These risks threaten project sustainability and profitability.
- **Construction Risks:** Emerge from low labor productivity, poor supervision, equipment issues, or delays in material procurement, directly affecting execution timelines and quality.
- **Organizational Risks:** Include ineffective communication, inexperience among team members, and poor leadership. These reduce coordination and increase project delays.
- **Socio-Political Risks:** Stem from regulatory changes, permitting delays, political unrest, and local protests. They can result in project halts or costly redesigns.

- **Environmental Health and Safety (EHS) Risks:** Include natural disasters, inadequate safety measures, and regulatory non-compliance. These threaten both workforce safety and project credibility.

3.4.2 Phase-wise Risk Breakdown

- **Pre-Construction Stage:**
 - Key risks involve delayed approvals, design uncertainties, and undefined project scope.
 - Technical risks dominate due to incomplete site studies and scope changes.
 - Financial and organizational risks arise from delayed vendor selection and poor communication.
 - Socio-political and EHS risks involve compliance gaps and insufficient hazard preparedness.
- **Construction Stage:**
 - Active risks escalate with technical errors in drawings, delayed procurement, and cost inflation.
 - Construction risks such as labor shortages and equipment failures are common.
 - Organizational risks continue due to inconsistent coordination and documentation.
 - EHS risks become severe with inadequate safety practices and exposure to hazardous conditions.
- **Completion Stage:**
 - Risks include unresolved technical issues, final bill disputes, and quality lapses during commissioning.
 - Financial risks involve contractor claims, penalties, and legal disputes.
 - Organizational inefficiencies, such as poor documentation and staff turnover, hinder close-out.
 - Final-stage EHS risks include incomplete safety checks and unverified fire/life safety systems.

3.4.3 Commercial Project-Specific Risks

In high-performance commercial buildings (e.g., labs, offices), risks are heightened during pre-construction:

- Delayed vendor onboarding (e.g., HVAC, MEP)
- Late-stage design changes
- Scope ambiguity

- Low-quality output from inexperienced contractors

These projects demand early clarity and qualified execution teams due to tighter schedules and quality expectations.

3.5. RISK ASSESSMENT

Risk assessment in construction involves evaluating potential threats based on their likelihood of occurrence and impact on time, cost, quality, and safety. This study systematically assessed risks across industrial, commercial, highway, and apartment projects during pre-construction, construction, and completion stages.

3.5.1 Assessment Approach

A multi-source methodology was used, including:

- Literature review
- Structured questionnaires
- Expert interviews
- Field observations
- Risks were grouped into six domains:
- Technical (e.g., design flaws)
- Financial (e.g., budget overruns, delayed payments)
- Construction (e.g., labor and site issues)
- Organizational (e.g., poor communication)
- Socio-Political (e.g., regulatory delays)
- Environmental Health & Safety (EHS) (e.g., unsafe conditions)

Risks were analyzed using frequency and severity, enabling a ranking framework for each project type and lifecycle stage.

3.5.2 Key Findings by Project Type

Industrial Projects:

Pre-construction: EHS risks (e.g., poor environmental planning) dominate.

Construction & Completion: Financial delays are most significant.

Commercial Projects:

Pre-construction: Organizational issues (e.g., poor planning) lead.

Execution: Site-related construction risks are critical.

Completion: Safety and EHS issues surface most.

Highway Projects:

Pre-construction: Organizational scheduling risks prevail.

Execution & Completion: Financial risks dominate due to cost escalations and delayed payments.

Apartment Projects:

Pre-construction: Technical risks (e.g., design inadequacies) are critical.

Construction: Organizational risks like coordination gaps are major.

Completion: Financial risks, especially payment delays, are frequent.

3.5.3 Software-Based Validation

To validate the risk prioritization, the Analytic Network Process (ANP) was implemented using Super Decisions software. This tool enabled:

Modeling interdependencies among risk types

Creating weight-based risk hierarchies through pairwise comparisons

Visualizing priority risks across project categories

The ANP analysis confirmed field data rankings, providing actionable insights for targeted mitigation and improved decision-making.

3.6. Risk Contribution Analysis

Key Risk Insights by Project Type

A. Industrial Projects

Pre-construction: Key risks include delayed client briefs, communication gaps, incomplete surveys, and late vendor finalization—impacting primarily Time and Quality.

Construction: Monsoon delays, material delivery issues, and administrative inefficiencies dominate. Time, Cost, and Safety are highly impacted.

Completion: Defect rectification delays, vendor legal claims, and poor closeout planning contribute to cost overruns and delayed handovers.

B. Commercial Projects

Frequent risks include design errors, poor coordination, late vendor decisions, and site mobilization delays.

Cost and Time are consistently at risk due to defective workmanship, resource shortages (3M), and administrative delays.

Leadership issues like project manager exits and subcontractor inefficiencies prolong timelines.

C. Highway Projects

Planning Stage: Risks arise from poor feasibility studies, alignment errors, and land acquisition issues.

Execution Stage: Monsoon effects, traffic disruptions, material delays, and contractor inefficiencies dominate.

Completion Stage: Final risks include design errors, poor night shift safety, and cost escalations due to natural obstructions and delays.

D. Apartment Projects

Key contributors include permit delays, financial instability, unsafe conditions, inexperienced contractors, and resource shortages.

Design and foundation changes, communication gaps, and last-minute modifications often cause Time, Cost, and Safety issues.

Material shortages (e.g., sand, water) and high-rise safety risks are notable contributors in the execution phase.

Common Risk Themes Across All Projects

Time and Cost are the most frequently impacted.

Delays in approvals, vendor decisions, and material procurement are recurring issues.

Defective workmanship and lack of coordination increase rework and affect Quality.

EHS risks intensify in the Construction phase, particularly in industrial and apartment projects.

3.7. Risk Allocation Analysis

Risk allocation is the process of assigning responsibility for managing project risks to the party best suited—Client, Contractor, or Project Management Consultant (PMC). Effective allocation enhances control and minimizes impact. Risk profiles

vary across industrial, commercial, highway, and apartment projects, requiring project-specific strategies.

Project-Specific Risk Allocation:

► Industrial Projects

- *Pre-Construction:* Delays in briefs and due diligence often lie with PMC and Client.
- *Construction:* Monsoon and material delays fall on Contractors.
- *Completion:* Snag list resolution is mainly a Contractor responsibility.
Key Insight: PMC handles 42%, Contractor 38.7%, Client 21.1% of risks.

► Commercial Projects

- Risks such as contractor performance, weather delays, and statutory clearances are evenly split.
Key Insight: Client (8 risks), Contractor (9), PMC (9).

► Highway Projects

- *Land acquisition* falls under Client responsibility, while most site-related risks like geotechnical surprises and traffic safety lie with the Contractor.
Key Insight: Contractor bears the highest share—22 of 43 risk items.

► Apartment Projects

- Major risks (e.g., labor shortages, safety, material delays) fall on the Contractor, while Client and PMC share responsibility for design changes and government approvals.
Key Insight: Contractor accountable for 22 of 44 risks.

Table1: Summary & Recommendations

Project Type	Client	Contractor	PMC
Industrial	15	26	33
Commercial	8	9	9
Highway	9	22	12
Apartment	10	22	12

- Contractors carry the largest share of risk (60–70%), especially in execution and safety.
- PMCs play a critical role in early-stage planning and coordination.
- Clients should ensure timely decision-making and approval processes.

Recommendations:

- Contractors: Strengthen procurement systems, enforce safety protocols.
- PMCs: Improve planning, enhance coordination with clients and vendors.

- Clients: Accelerate approvals and scope finalization.

3.8. Risk Mitigation Analysis

Risk mitigation in construction involves four key strategies: Prevent, Reduce, Transfer, and Accept, aimed at minimizing negative impacts on Time, Cost, Quality, and Safety across different project types.

Project-Wise Mitigation Overview

► Industrial Projects

- Preventive Actions: Early client brief and contractor agreement finalization.
- Reduction Measures: Streamlined communication and monsoon planning.
- Acceptance: Weather-related delays.
- Summary: 61.3% risks reduced, 19.2% prevented, 17.3% accepted.

► Commercial Projects

- Prevent: Enforce contractor clauses, monitor statutory clearances.
- Reduce: Improve procurement planning.
- Accept: Uncontrollable weather disruptions.
- Summary: 93% risks preventable; only 1 risk accepted.

► Highway Projects

- Prevent: Conduct detailed feasibility and land planning.

- Reduce: Address geotechnical issues and contractor inefficiencies.
- Accept: Natural obstacles and cost escalations.
- Summary: 80% preventable; 20% accepted.

► Apartment Projects

- Prevent: Fast-track approvals, prequalify contractors.
- Reduce: Manage labor shortages and scope changes.
- Transfer: Lease equipment to minimize ownership risks.
- Accept: Material price inflation.
- Summary: 56% preventable, 32% reduced, 8% accepted, 4% transferred.

Overall Insights & Recommendations

Dominant Strategy:

- Prevention is the most effective, accounting for 60–80% of risk control across all project types.

Role-Based Recommendations:

- Clients: Speed up approvals and define scope early.
- Contractors: Improve procurement and safety standards.
- PMCs: Focus on early-stage planning and oversight.

Table2: Mitigation Strategy Distribution:

Project Type	Prevent	Reduce	Transfer	Accept
Industrial	19.2%	61.3%	1.9%	17.3%
Commercial	93%	7%	0%	7%
Highway	80%	13%	0%	20%
Apartment	56%	32%	4%	8%

4. CONCLUSION

Construction projects are influenced by various risk factors that can disrupt time, cost, quality, and safety

objectives. This study highlights the critical risks across project stages and emphasizes the importance of systematic risk assessment and management.

Table3: The analysis identified and ranked key risk groups by project phase:

Stage	Rank 1	Rank 2	Rank 3
Pre-construction	Organizational Risk	Socio-political Risk	EHS Risk
Construction	Socio-political Risk	Financial Risk	Construction Risk
Completion	Socio-political Risk	Financial Risk	Organizational Risk

Key Findings:

- Socio-political risks emerged as the most critical across all stages.
- Most high-impact risks affect time and cost, burdening clients, contractors, and PMCs.
- Organizational and financial risks also play a significant role during early and final project stages.

Recommendations:

- Focus on early identification and mitigation of socio-political and organizational risks.
- Ensure proper contractor selection and planning to reduce execution delays.
- Treat risk elimination—not just reduction—as a priority for successful project delivery.

Overall, this research underscores the need for proactive risk management at every project phase. By prioritizing and addressing key risks, project managers can enhance control, reduce uncertainty, and achieve better outcomes.

SCOPE FOR FUTURE WORK

This study is only for the industrial construction project, highway construction project, commercial building construction project and apartment construction project. This work can also be extended for some other kind of projects like infrastructural projects and reduce the risk impacts over the projects. In this study, the limited factors are used for analysis. The focus on the sub factors can improvise the results. Further the study can be extended to infrastructure projects and special projects and schemes.

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