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ANALYSING AND MANAGING POTENTIAL RISKS IN CONSTRUCTION PROJECTS

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ABSTRACT
Construction projects operate within complex socio-technical systems where uncertainty is inherent. Risks arising from design, finance, procurement, human resources, regulatory processes, and environmental conditions can jeopardize project objectives of cost, time, quality and safety. This paper presents a comprehensive framework for identifying, assessing, allocating and mitigating risks in apartment construction projects. Drawing on a mixed-methods approach, primary data were collected through structured questionnaires, site observations and semi-structured interviews with industry practitioners. Quantitative prioritization was performed using the Relative Importance Index (RII) and mean ranking; these results were validated using the Analytic Network Process (ANP) implemented in Super Decisions to account for interdependencies among factors. Results identify technical risks (inadequate design, poor site investigation), financial risks (payment delays, cost escalation), and managerial risks (inadequate scheduling, poor coordination) as predominant across the project life cycle. Stage-wise analysis highlights variations in risk dominance between pre-construction, construction and completion phases. The paper further proposes stakeholder-specific risk allocation and a set of practical mitigation measures such as enhanced upfront planning, robust procurement strategies, financial contingencies and systematic monitoring. The integration of RII and ANP provides both ranking clarity and a networked validation of risk interrelationships. The framework is intended to assist project managers, contractors and clients in prioritizing interventions, reducing uncertainties and improving the likelihood of project success. This study offers actionable guidance for practitioners to strengthen risk management. This study offers actionable guidance for practitioners to strengthen risk management. This study offers actionable guidance for practitioners to strengthen risk management.

Keywords: Relative Importance Index (RII), Analytic Network Process (ANP), Risk Assessment, Risk Mitigation, Construction Projects, Project Management.

I. INTRODUCTION
The construction industry is central to economic development but is characterized by complexity, fragmented delivery chains and high exposure to uncertainty. In many countries, including India, large numbers of projects experience cost overruns and schedule delays, often due to a combination of technical, financial, regulatory and human factors. Construction projects, especially apartment developments in urban settings, involve multiple parties — clients, consultants, contractors, subcontractors, suppliers and regulators — whose interactions create numerous points of vulnerability. Risk management in construction aims to reduce exposure to unwanted outcomes by identifying potential events, assessing their likelihood and impact, allocating responsibility and deploying mitigation measures. Effective risk management increases the probability of meeting project objectives and reduces the incidence of claims, disputes and rework. Despite a wide array of tools available — from Monte Carlo simulation to fuzzy logic and multi-criteria decision-making methods — practitioners often underuse structured approaches due to data limitations, lack of expertise or

perceived complexity. This research focuses on apartment construction projects, where problems such as inadequate site investigation, design errors, procurement delays and labour productivity shortfalls are commonly reported. A major contribution of this work is the combined use of the Relative Importance Index (RII) for transparent ranking and the Analytic Network Process (ANP) for validating interdependencies, thereby blending simple statistical prioritization with a networked decision model. The methodology is applied to field data obtained through questionnaires and expert interviews, enabling stage-wise analysis across pre-construction, construction and completion phases. By providing both ranking and network validation, the study helps practitioners identify high-leverage risks and tailor mitigation strategies according to project stage and stakeholder capabilities. The paper also outlines pragmatic mitigation measures aimed at planners, contractors and clients, including tighter design controls, contingency budgeting, phased procurement and enhanced communication protocols. The research emphasizes actionable steps such as improved governance, contractual clarity and increased training for site personnel. The research emphasizes actionable steps such as improved governance, contractual clarity and increased training for site personnel. The research emphasizes actionable steps such as improved governance, contractual clarity and increased training for site personnel. The research emphasizes actionable steps such as improved governance, contractual clarity and increased training for site personnel. The research emphasizes actionable steps such as improved governance, contractual clarity and increased training for site personnel. The research emphasizes actionable steps such as improved governance, contractual clarity and increased training for site personnel. The research emphasizes actionable steps such as improved governance, contractual clarity and increased training for site personnel. The research emphasizes actionable steps such as improved governance, contractual clarity and increased training for site personnel. The research emphasizes actionable steps such as improved governance, contractual clarity and increased training for site personnel. The research emphasizes actionable steps such as improved governance, contractual clarity and increased training for site personnel. The research emphasizes actionable steps such as improved governance, contractual clarity and increased training for site personnel.

II. LITERATURE REVIEW

Risk and its management in construction have been explored widely. The Project Management Institute (PMI) defines risk as an uncertain event that, if it occurs, affects at least one project objective [1]. Early works by Al-Bahar and Crandall developed frameworks for systematic risk management suitable for construction projects [2]. Subsequent literature has focused on categorization of risks, measurement techniques and allocation strategies. Studies have used both qualitative and quantitative approaches ranging from simple checklists and expert panels to probabilistic modeling and multi-criteria decision-making [3]–[6].
Analytical Hierarchy Process (AHP) and its extension ANP have been applied to prioritize risks while accounting for dependencies among criteria [7], [8]. Fuzzy logic has been useful where linguistic judgments predominate and crisp data are scarce [9]. Recent advances include hybrid methods (e.g., AHP with fuzzy logic or AHP/ANP combined with Monte Carlo) to leverage strengths of different techniques [10], [11]. In Indian construction contexts, researchers have reported a high prevalence of risks associated with approvals, finance and labour practices, suggesting the need for locally tuned frameworks [12], [13]. While many studies provide valuable taxonomies of risks, fewer works combine stage-wise analysis with networked validation, an aspect this study addresses by integrating RII and ANP to produce both ranked and interdependent views of risk profiles.

III. RESEARCH OBJECTIVES

The study objectives are:

- Identify potential risk factors in apartment construction projects.

- Assess severity and likelihood of risks through quantitative and qualitative methods.
- Rank risks using RII and validate using ANP.
- Allocate risks to stakeholders and recommend mitigation.
- Develop practical recommendations for project managers and policymakers.

IV. RESEARCH METHODOLOGY

A. Data Collection

Primary data were collected from practitioners involved in apartment construction projects in urban regions. The survey instrument included 48 risk items grouped under six categories: technical, financial, construction, organizational, socio-political and EHS (Environmental, Health & Safety). Respondents rated each item on a five-point Likert scale for both probability and impact. The sample included 100 completed questionnaires from project managers, site engineers, safety officers and procurement specialists. Semi-structured interviews (n=12) provided contextual insights and validated survey findings.

B. Quantitative Analysis

Relative Importance Index (RII) was calculated for each risk item to obtain an initial ranking. RII is defined as RII = $(\Sigma w)/(A*N)$, where w is the weight given by respondents, A is the highest weight (5) and N is the total responses [14]. Mean rankings complemented RII and allowed cross-validation. Stage-wise RII was computed to capture stage-specific dominance.

C. ANP Validation

To validate the prioritized list and examine interdependencies, the Analytic Network Process (ANP) was implemented using Super Decisions software. ANP allows clustered elements to influence each other and captures feedback loops, providing priority vectors that reflect both direct importance and indirect influence [7]. Pairwise comparisons were conducted among risk clusters and top-ranked items, and consistency ratios were checked to ensure decision reliability.

D. Risk Allocation and Mitigation

Based on the combined results, risk allocation matrices were developed assigning responsibility to clients, contractors or consultants. Mitigation measures were designed following standard strategies: avoidance, mitigation, transfer and acceptance. A validation workshop with five industry experts refined these measures for feasibility.

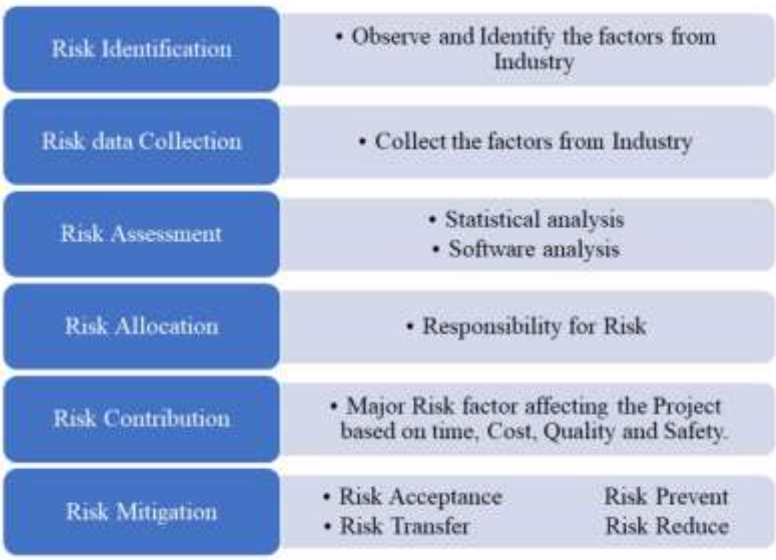

Figure 1: Methodology Chart

Table 1: Apartment construction- Pre-Construction Stage- Technical Risk

S .No	Risk factor	Impact	Inadequat	Inadequate	Inadequate Site Investigation	Change	Constructio n	Insufficient	Human	Improper
1	Delay in approval from government	Will delay the initiation of work	✔	✔	✔	✔	✔			✔
2	Confirmation on Maximum flood level detail	Will affect the design & takes further time for releasing the tender drawings.	✔	✔	✔		✔	✔		
3	Master schedule to be approved	The project will not be in control & affect the tracking part if not approved on time.	✔	✔	✔	✔	✔			✔
4	Usage of inappropriate planning tools and	will affect the schedule and takes further time for	✔	✔	✔		✔			✔
	Techniques	completion								
5	Delay in approval of sewer connection	Will cause delay in closeout and completion	✔	✔	✔	✔	✔			✔
6	Approval of vendors has been delayed	Will affect legally if it is not done on time	✔	✔	✔	✔	✔	✔		
7	Approval of architectural drawings has been delayed	Delay the start of the works in the site	✔	✔		✔				
8	Improper selection of contractors and sub-contractors	Will affect the quality of work and takes further time for completion	✔							
9	Lack of proper data and survey before designing	Will delay the designing work and also have error in design	✔	✔	✔					
10	Schedule finalization	Schedule needs to be finalized and signed off or it will delay the site works	✔	✔	✔	✔	✔	✔	✔	✔
11	Delay in demolition of existing structures	Will delay the initiation and execution	✔		✔					

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12	Delay in submission of layouts required for statutory approval	Will Impact the start of works	✔	✔	✔	✔	✔			✔
13	Machine layout finalization	This may lead to change in the scope of work	✔				✔	✔		
14	Selection of inappropriate equipment	Will increase the cost and delay the work	✔				✔		✔	✔
16	Schedule of finishes	Will lead to conflict regarding material selection, impact on cost & time	✔				✔			
17	Change in the scope of the project	This would impact the time and cost of the project	✔			✔				
19	Lift drawing approval after deadline	This would in turn affect the time and budget of the project	✔	✔			✔			
20	Electrical drawing approval after deadline	Delay the start of works in the site	✔	✔			✔			
21	Procurement process agreement	Will be delayed in Procurement & Commencement of works at site	✔			✔	✔	✔		
22	Procurement time cycle	Delay in Procurement & Commencement of works at site	✔				✔			
23	Budget finalization	Will Affect the overall fund allocation to the project	✔							
24	Monsoon impact	Will affect the execution of work	✔		✔					
25	Utilities equipment make finalization	Will impact on the cost and time of the project	✔				✔			
26	Delay in making decision	Will delay the work	✔							
27	Improper site facilities	Will Impact the time, and delay the site works	✔							
28	Resizing of project	Will affect the entire design process on the entire package & increasing the timeline of the project.	✔	✔	✔	✔	✔	✔	✔	✔
29	Structural design incomplete or in error	Will impact the time, cost and delay the works	✔	✔	✔					
30	Staff training	If not done, it will affect the project							✔	
31	Staff availability	If not available, proper monitoring cannot be done	✔						✔	
32	Site Logistic	Will Impact the time, and delay the site works	✔	✔	✔					
33	Labour Accommodatio n	Will Impact the time, and cost and cause delay in project	✔						✔	

34	Safety control/Implem entation Plan	Will Impact the Safety record	✔							
35	Quality control Manual/Imple mentation plan	Will impact the monitoring of quality control for the works to be carried out at site	✔							

V. RESULTS AND DISCUSSION

A. Overall Rankings

RII results indicate that inadequate design documentation (RII=0.86), payment delays (RII=0.83), and poor contractor selection (RII=0.81) ranked highest across the sample. Stage-wise analysis showed that technical factors dominated pre-construction, while labor productivity and site logistics were most significant during construction. Completion-stage issues centered on statutory approvals and final inspections.

B. ANP Findings

ANP results corroborated RII rankings but also revealed strong feedback between financial and technical clusters: financial delays exacerbate contractor performance issues, which in turn lead to rework and design changes. The network analysis assigned higher composite priorities to a small set of interdependent risks, suggesting that focusing on these leverage points can yield significant improvements.

C. Risk Allocation

The allocation matrix assigned financial management primarily to clients and lenders, whereas technical controls and QA/QC were assigned to contractors with oversight by consultants. EHS responsibilities were distributed across contractors and the client's safety officer.

D. Practical Implications

Findings point to several practical measures: enact stricter front-end engineering controls, adopt staged procurement, establish escrow or milestone-based payment mechanisms, train supervisors in productivity-enhancing methods, and deploy a centralized risk register with regular review cycles. These steps can be integrated into project governance documents and contractual clauses.

E. Comparison with Literature

The dominance of technical and financial risks aligns with prior studies [2], [12], while the observed interdependency between clusters supports the adoption of ANP as noted by Saaty [7]. The study extends existing knowledge by offering a pragmatic pathway for allocating responsibility and providing a validated list of prioritized risks for apartment projects in urban India.

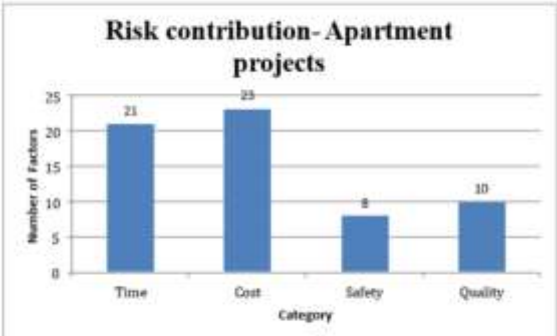

Figure 2: Risk contribution for apartment projects

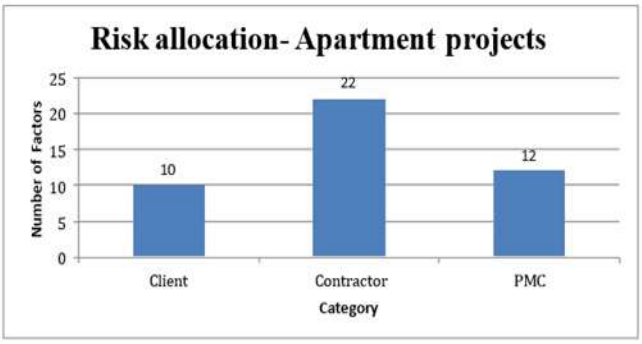

Figure 3: Risk allocation for apartment construction

VI. CONCLUSIONS

This paper presents a hybrid framework integrating RII and ANP to identify, prioritize and validate risks in apartment construction projects. The combined approach offers transparent rankings complemented by networked validation, which together yield actionable priorities and allocation schemes. Technical deficiencies, payment-related disruptions and contractor selection emerged as principal concerns. Interventions focusing on front-end design rigor, financial controls and procurement protocols are likely to deliver the most value. The framework is adaptable and can be applied to other project types or regions after contextual calibration. Future research might incorporate dynamic risk monitoring using digital tools and explore machine-learning models for predictive risk analytics.

Conflict of Interest

The authors declare no conflicts of interest, including financial or other relationships that may bias the work. All authors have made substantial contributions to this research and have approved the final manuscript. This work has not been previously published or submitted for publication elsewhere.

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