Asian And Pacific Economic Review
ISSN: 1000-6052

RISK ANALYSIS IN INFRASTRUCTURE

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https://doie.org/10.65985/APER.2025885623

ABSTRACT

This research delves into a risk impact analysis related to infrastructure development through the Engineering, Procurement, and Construction (EPC) contract model, specifically within highway projects. The EPC framework aims to enhance project delivery by consolidating design, procurement, and construction responsibilities under one entity. However, practical applications reveal persistent challenges, including project delays, mismanagement of resources, and inadequate stakeholder collaboration, indicating significant shortcomings in current risk mitigation strategies.

The study employs the Telangana highway expansion project as a case study to explore these issues. It commences with an extensive literature review to pinpoint essential variables tied to EPC-related delays and risks. From this review, theoretical hypotheses regarding potential risk factors were developed. The research methodology included the creation of a structured questionnaire, which underwent pilot testing for clarity and feasibility, aiming to gather primary data from key stakeholders, such as project managers, contractors, and engineers. Following data collection, the analysis aimed to evaluate the hypotheses and measure the impact and significance of different risk factors affecting the project's success.

The study confirms the reliability of its data and identifies the construction phase as the most vulnerable to risk impacts. Critical issues requiring immediate attention include labour shortages, delays in design approvals, and broader external pressures such as government policy shifts and economic instability. These findings indicate that although internal operational efficiency is essential, external macroeconomic and political factors exert a significant influence on project outcomes. The insights from this study offer stakeholders clear, actionable guidance. To improve project performance and ensure timely delivery in EPC-driven infrastructure development, stronger risk assessment and mitigation strategies are required—particularly for high-impact, high-probability risks linked to the construction phase and external environmental factors. Adopting robust risk management frameworks that prioritize proactive risk identification, thorough planning, real-time monitoring, and effective stakeholder coordination will be essential for strengthening outcomes in future large-scale infrastructure projects.

Keywords: EPC Contract, Risk Impact, Highways, Project Delays, Risk Management, Mitigation Strategies, Infrastructure Development.

Introduction: The road network is widely considered the backbone of a modern economy and society, serving as the most vital and pervasive form of transportation infrastructure. Its importance stems from its ability to offer door-to-door connectivity and access to even the most remote areas, linking every segment of a country. A strong road network is a powerful catalyst for economic growth, directly influencing the cost of business and the efficiency of markets (Trade and Commerce, Market Access, Industrial Development, Employment

Generation, Feeder System). Roads are fundamental to improving the quality of life and achieving inclusive development by connecting people to essential services (Accessibility to Services, Poverty Alleviation, Emergency Response, Social Cohesion) and Strategic and Administrative Importance (National Security, Administrative Reach, Flexibility and Door-to-Door Service). In 2014 (around the time of state formation), the density of national highways in Telangana was 2.25 km per 100 sq km. By 2023, this density rose to 4.45 km per 100 sq km. The surfaced-road length in Telangana (all categories) was 60,694 km in 2014, rising to 104,463 km by 2019. In 2014, the length of four-lane (and above) national highways across India was 18,278 km; by 2024 it had grown to 45,947 km. Though this is national data, it indicates the broader push of highway expansion which would impact Telangana too. The state R&B department maintains 32,445 km of roads (of which 4,983 km are national highways) as reported around 2023.

The types of Contracts practiced in Highway Projects: Highway infrastructure projects typically employ different models of contracts, each with specific scopes and responsibilities: EPC (Engineering, procurement and construction), BOT (Build- Operate- Transfer), DBFOT (Design – Built -Finance- Operate – Transfer), HAM (Hybrid Annuity Model). The common of form contract practiced in India & Telangana is International Federation of Consulting Engineers (FIDIC). In infrastructure projects, the Engineering, Procurement, and Construction (EPC) contract model is typically favored, as it designates the contractor as the sole entity responsible for design, engineering, procurement, and construction. This arrangement minimizes risks for the project authority and centralizes accountability. However, the current project presents notable challenges despite the anticipated efficiencies of the EPC model, including significant delays in achieving key milestones. These delays stem from multiple compounding issues, such as slower-than-expected site clearance creating major bottlenecks, mismanagement of resources leading to wasted time, and suboptimal coordination among stakeholders. This situation exemplifies how theoretical advantages may fail to materialize in practical contexts, resulting in unforeseen complications. Risk is a situation where the probabilities of different outcomes are known and can be measured, while uncertainty is when those probabilities are unknown.

OBJECTIVES OF THE STUDY

The objective of the study is

a) To identify the root causes of project delays and underperformance by closely examining various aspects such as site clearance delays, resource misallocation, and other operational inefficiencies.
b) To find the influencing risk factors on the project.
c) To evaluate the practical effectiveness of the EPC contract model in mitigating construction risks within the specific context of the highway project.

Scope of The Study: This study focuses on optimizing the Telangana highway expansion project by analysing its physical and financial progress, delays, and stakeholder coordination. It aims to provide a comprehensive overview of the project's trajectory through key data points like milestones, budget allocations, and timelines, helping to identify areas of failure. The research emphasizes the importance of effective communication and collaboration between stakeholders such as project managers, contractors, and engineers, and will assess current interaction mechanisms to identify mismanagement gaps. Data collection will involve questionnaires targeting project participants to uncover recurring challenges and systemic issues. The findings will inform the development of improved risk management frameworks and actionable recommendations for enhancing the EPC contract model. The overall objective is to diagnose problems within the project and suggest adaptable strategies for better management of large-scale infrastructure initiatives.

Literature Review:

A study by Nurdiana and Susanti highlights that risk is inherent in infrastructure projects, including EPC contracts. The unpredictable nature of the construction industry contributes to these risks. Each contract type has distinct structures and responsibilities, leading to variations in risk nature and distribution. The research focused on the project life cycle under the EPC model, gathering primary data through interviews and questionnaires to identify key risks from the project owner's perspective. Analysis using the Risk Breakdown Structure (RBS) method revealed that the majority of risks were perceived as low (46%), followed by moderate (27%) and high (27%).

Nikila G and Prabakaran P A highlight that while most studies focus on construction phase performance, the engineering and procurement phases are less examined. They emphasize that procurement phase performance is significantly impacted by resource shortages and price fluctuations, identifying procurement risk as crucial in project risk profiles. Researchers recognize procurement as a key area for constraints and opportunities that can enhance overall project performance, making its management critical for timely availability of resources, vital for project success.

Risk management is crucial for smooth road construction project completion, as identified by R. Prasanna Kumar, Afshan Sheikh, and S.S. Asadi. The study assesses 44 risk factors through a questionnaire, analyzing responses with SPSS to highlight significant risks. Key contributors include inefficient planning, unforeseen soil conditions, resources, force majeure, and government issues, while political risks and site conditions have negligible impacts. It is suggested that risks can be mitigated through proper planning updates, traffic management, prefabricated construction to address site and climate conditions, and collaborative efforts with government bodies to minimize criminal and political risks.

Rashid highlights the increasing demands of society driven by advancements in knowledge and technology, resulting in larger and more complex multidisciplinary projects, notably in the infrastructure and oil and gas sectors. The construction process, characterized by uncertainties, benefits from contractors' established risk management strategies. The article focuses on the Risk Management Process (RMP) methodology, which offers a structured approach to risk management. Implementing RMP can lead to clearer project cost estimations and maximization of profits. The article proposes a risk management model utilizing RMP to enhance cost evaluation and control for construction budgeting in infrastructure projects.

Managing risks in infrastructure construction projects is crucial for achieving goals related to time, cost, quality, and scope. The study by Chaitali S. Pawar and colleagues identifies and analyzes risks, categorizing them into eight types through a review of contract conditions. It notes that factors such as social opposition, design changes, and work suspensions significantly affect outcomes. Recommendations include using contract documents for risk management and establishing a comprehensive risk management policy throughout the project lifecycle. The study emphasizes the importance of collaboration among clients, designers, contractors, and government authorities to proactively manage risks from the feasibility stage onward.

An efficient project delivery method is crucial for any construction venture, particularly in rapidly growing contexts. Sayiba and Nayar highlight that EPC (Engineering, Procurement, Construction) contracts outshine other contracting methods in terms of risk allocation, fixed costs, and schedules, making them a favored choice for governments aiming to minimize risks. Their literature review identifies extensive use of EPC contracts in highway constructions, notably in prestigious projects like the Kollam and Alappuzha bypasses in Kerala. The authors conducted interviews and surveys with project personnel to study risk identification, assessment, and treatment strategies for these bypass projects. The findings indicate that risks significantly affect project objectives including cost, schedule, quality, and scope. Specifically, for the Kollam bypass, material availability emerged as the most significant risk, while the Alappuzha bypass faced challenges primarily due to delays in permits, approvals, and changes in scope. Although the projects implemented risk mitigation strategies with some effectiveness, there remains potential for improving response strategies.

MaShenglin highlights the increasing competition in international EPC (Engineering, Procurement, and Construction) projects, emphasizing the necessity for accurate identification and objective classification of risk factors to ensure project success. To enhance China's EPC project risk management, a comprehensive review of existing literature and expert interviews has been conducted. This includes a detailed introduction to the EPC risk management system and processes, an explanation of the main research scope in risk management, along with a summary and commentary on the identification, classification, analysis, evaluation methods, and coping strategies for risks. The conclusion provides recommendations for improving project risk management based on the existing research findings.
B Ravinder, K Srinivas has expressed in their article, the risk management is one of the essential and key elements to be considered for project execution.

Methodology: The methodology of study has been depicted in Fig.3.1.

Research Design: The research follows a mixed-method approach combining qualitative and quantitative methods to analyse the causes, impacts, and mitigation strategies for delays in Risk Impact analysis of projects in India. The study is exploratory and descriptive, focusing on data collection from existing projects, case studies, and expert insights.
Secondary Data: It is gathered through literature review, involves analyzing existing studies, reports, and documents to provide context, validate findings, and identify trends or gaps in research.
Structured Questionnaire Surveys: Closed ended questions with a likert scale are prepared to collect the opinion of the various stakeholders. Project Managers are held responsible for project execution and often involved in planning and Mitigating the Risk assessments. Site Engineers have ground-level insights into day-to-day project delays and the causes of interruptions. National Highways Authority of India (NHAI) Officials oversee project implementation and manage approvals.
Focus Areas: The study focus is a) major factors contributing to project delays, b) common challenges in the risk identification, c) Impact of Risk management on project timelines, d) best practices in managing and mitigating delays. Surveys can provide quantitative data to identify patterns in delay claims across multiple EPC projects.

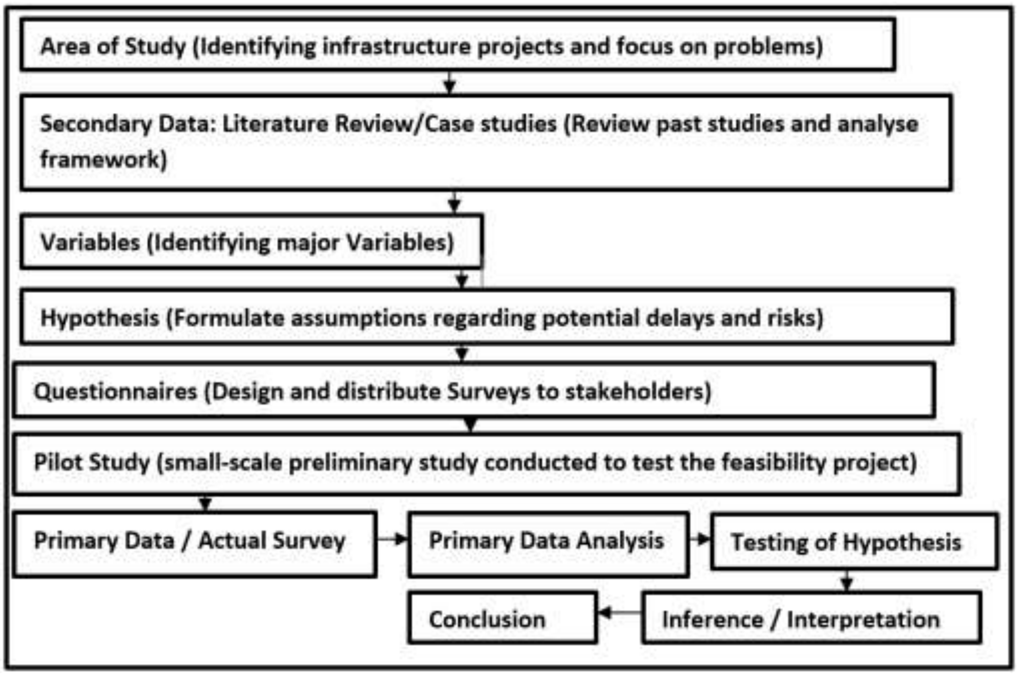


Fig. 3.1: Study Framework

Variables in the Study: Variable identification and classification in risk analysis for infrastructure projects is crucial for understanding how different factors influence project performance, utilizing both independent and dependent variables in the research process. Both the independent and dependent variables are employed by the research to delimit the risk impact assessment. Independent variables are the possible risk factors or conditions that can impact the success of a project. Independent variables are not influenced by other variables within the study but are assumed to have a direct or indirect influence on the success or failure of infrastructure projects. The most prominent independent variables found in this research are: Environmental Conditions; Political situation (govt changes, policy changes) ; Scope changes (Volume of work, Variation, Deviation); Technical risks (Skilled Manpower, Experience) ; Payments (Monthly Bills) . The dependent factor is impact over success of a project etc.,

Hypothesis formulation: A hypothesis is a statement that makes predictions regarding the association between two or more variables. For this study, the hypotheses are designed to evaluate the degree to which various risk factors (independent variables) affect project outcomes (dependent variables) in infrastructure projects implemented under the Engineering, Procurement, and Construction (EPC) model by engaging the statistical package for social sciences (SPSS) Software.

The hypotheses are formulated and they are:

Null Hypothesis (H_{1o}): The pre-construction phase has no risk impact on different phases of a project.
Alternative Hypothesis (H_{1a}): The pre-construction phase has a risk impact on different phases of a project.

Null Hypothesis (H_{2o}): The construction phase has no risk impact on different phases of a project.

Alternative Hypothesis (H_{2a}): The construction phase has a risk impact on different phases of a project.

Null Hypothesis (H_{3o}): The post-construction phase has no risk impact on different phases of a project.
Alternative Hypothesis (H_{3a}): The post-construction phase has a risk impact on different phases of a project.

Null Hypothesis (H_{4o}): The delayed payment/s from clients or government agencies have no impact on contractors' finance.
Alternative Hypothesis (H_{4a}): The delayed payment/s from clients or government agencies have impact on contractors' finance.

Null Hypothesis (H_{5o}): The changes in market conditions will not affect the cost and availability of key resources of a project.
Alternative Hypothesis (H_{5a}): The changes in market conditions will affect the cost and availability of key resources of a project.
Null Hypothesis (H_{6o}): The labour disputes or strikes have will not impact the project timelines and budgets.
Alternative Hypothesis (H_{6a}): The labour disputes or strikes have will impact the project timelines and budgets.

Null Hypothesis (H_{7o}): The delay/s in design approvals will not effect on overall project performance.
Alternative Hypothesis (H_{7a}): The delay/s in design approvals will affect on overall project performance.

Null Hypothesis (H_{8o}): The unforeseen site condition/s will not affect the overall project performance.
Alternative Hypothesis (H_{8a}): The unforeseen site condition/s will affect the overall project performance.

Null Hypothesis (H_{9o}): The quality control issues will not affect the overall project performance.
Alternative Hypothesis (H_{9a}): The quality control issues will affect the overall project performance.

Null Hypothesis (H_{10o}): The skilled labour shortage will not affect the overall project performance.
Alternative Hypothesis (H_{10a}): The skilled labour shortage will affect the overall project performance.

Null Hypothesis (H_{11o}): The changes in government policies will not impact the project.
Alternative Hypothesis (H_{11a}): The changes in government policies will impact the project.

Null Hypothesis (H_{12o}): The economic instability will not impact the project.
Alternative Hypothesis (H_{12a}): The economic instability will impact the project.

Null Hypothesis (H_{13o}): The legal and regulatory delays will not impact project.
Alternative Hypothesis (H_{13a}): The legal and regulatory delays will impact project.

Null Hypothesis (H_{14o}): The social or community protest will not impact project.
Alternative Hypothesis (H_{14a}): The social or community protest will impact project.

SPSS Software: Statistical Package for the Social Sciences (SPSS) is a widely trusted statistical software that simplifies data analysis for researchers across various fields like social sciences, psychology, education, healthcare, and business. Originally developed by IBM, SPSS is designed with an intuitive interface that makes complex statistical analysis accessible, even to those without programming expertise.

One of its greatest strengths is its ability to process large datasets efficiently while producing insightful outputs, including charts, tables, and statistical significance tests. Researchers can seamlessly import data from Excel, CSV, or SQL databases, then clean, transform, and visualize it with ease. SPSS supports a broad spectrum of statistical techniques, from basic descriptive statistics to advanced analyses like regression, ANOVA, factor analysis, and non-parametric tests.

B Ravinder, AB Saraswathi have mentioned their paper, SPSS also offers specialized tools such as reliability analysis (e.g., Cronbach's alpha), chi-square tests, and predictive analytics, making it a powerful choice for academic and professional research. Its well-documented functionalities, user-friendly design, and robust statistical capabilities ensure accuracy, reproducibility, and clarity—essential qualities for producing high-quality, impactful research.

RII (Relative Importance Index)

Relative Importance Index (RII) is a numerical technique of variable ranking and sequencing based on perceived importance as rated by the respondents in a structured survey or evaluation. It is extensively used in research fields like construction project management, risk analysis, human resources, and academic studies to determine important factors impacting decisions or outcomes.

Relative Importance Index (RII) is intended to provide a quantitative and formal means of ranking factors by their felt importance as indicated by respondents. It is particularly utilized in research areas such as risk management, project evaluation, and stakeholder analysis, where there is more than one variable to consider in determining results. RII gives the strength of converting qualitative views (commonly gathered by Likert-scale questionnaires) into a consistent numerical score between 0 and 1, allowing researchers to establish and rank the most significant concerns. This provides effective decision-making, efficient resource utilization, and better-informed stakeholder perception, ultimately facilitating sound planning and problem resolution in complex environments. To carry out this work, the procedure adopted B Ravinder and K Srinivas their paper has been followed.

Probability and Impact Matrix

The Probability Impact Matrix (PIM) is a widely used method of risk assessment to identify, analyse, and rank risks on two important dimensions: the probability of occurrence and the potential impact upon occurrence. It is typically represented as a grid on which the risk's probability of occurrence is placed along one axis and the impact severity along the other. Each risk is evaluated and plotted in a cell within the matrix, which is marked as low, medium, high, or extreme risk. The transparent and ordered procedure enables researchers, project managers, and decision-makers to immediately identify which risks need to be addressed as a matter of urgency and which can be monitored or accepted. The matrix is particularly used in environments where qualitative risk analysis is necessary due to the lack of data. By ranking risks in this ordered procedure, organizations can efficiently allocate resources, plan mitigation measures, and enhance overall organizational or project resilience. The PIM also enables better communication among stakeholders by producing a visible, explicit picture of risk exposure. Its simplicity, flexibility, and effectiveness make it a valuable tool in academic research, project management, and strategic planning in a wide range of studies.

Data Analysis: The study gathered data through a carefully designed questionnaire survey, targeting respondents who were directly relevant to the research topic. To measure their perceptions and opinions, the questionnaire used a Likert scale, typically ranging from 1 to 5. Once responses were collected, they were thoroughly checked to ensure accuracy and completeness, preserving the integrity of the data.

After completing the survey, the cleaned data was entered into SPSS (Statistical Package for the Social Sciences) for further analysis. Descriptive statistics—such as frequencies, means, and standard deviations—were used to summarize the demographic characteristics of the respondents and identify general trends in their answers.

To determine which factors were considered most important, the Relative Importance Index (RII) was calculated for each item. The formula used was $RII = \sum w / (A \times N)$, where "w" is the weight given to each response, "A" is the highest possible score, and "N" is the total number of participants. This approach allowed for a clear ranking of factors based on how significant they were perceived by the respondents.

To strengthen the analysis, the Probability Impact Matrix was used to assess the significance of various factors by evaluating both their likelihood of occurring and the severity of their impact. Each factor was assigned a probability score based on its likelihood and an impact score indicating its potential effect on research outcomes. Factors with high probability and high impact were identified as critical concerns requiring immediate focus, while those with low probability and low impact posed minimal risk. This classification helped prioritize issues effectively.

4.1 Demographic of Respondents

Respondents Categories: The survey was conducted among Employers, Concessionaires, and Consultants, with a total of 40 respondents falling into the following three key professional categories:

Consultants are responsible for feasibility reports, design validation, and monitoring (35%). Contractors or concessionaires handle execution, labor, and material mobilization (57.5%). Employers represent project owners, such as NHAI, and are responsible for funding, compliance, and approvals (7.5%).

The pie chart in Fig. 4.1 illustrates respondent distribution among groups involved in the project: Contractors or Concessionaires account for 57.5%, indicating a predominant role, while Employers represent 35%, showcasing significant funding and oversight responsibilities. Consultants contribute 7.5%, reflecting their limited, specialized advisory capacity.

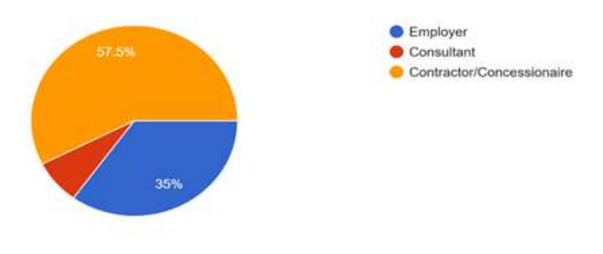


Fig. 4.1. Stakeholder Distribution

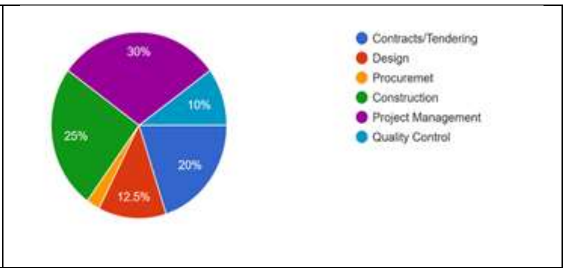


Fig. 4.2. Responses against the role in the project

The pie chart in Fig. 4.2 illustrates the distribution of key project activities: Project Management leads at 30%, followed by Construction at 25%. Contracts and Tendering hold 20%, Design accounts for 12.5%, and Quality Control is at 10%. Procurement, at 2.5%, has the smallest share, indicating a high level of outsourcing.

The pie chart in Fig. 4.3 illustrates the distribution of employee experience within the company. It shows that 35% of employees are newcomers with 0–5 years of experience, contributing fresh energy and perspectives. Following closely, 32.5% are seasoned professionals with over 15 years of experience, providing considerable expertise. Additionally, 20% have 5–10 years, and 12.5% possess 10–15 years of experience. This mix of new talent and experienced veterans fosters a dynamic and well-rounded workforce.

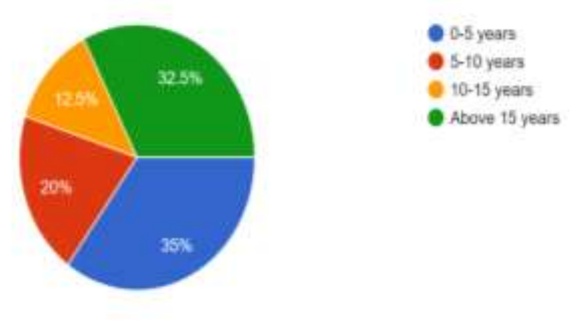


Fig. 4.3. Responses against the Years of Experience

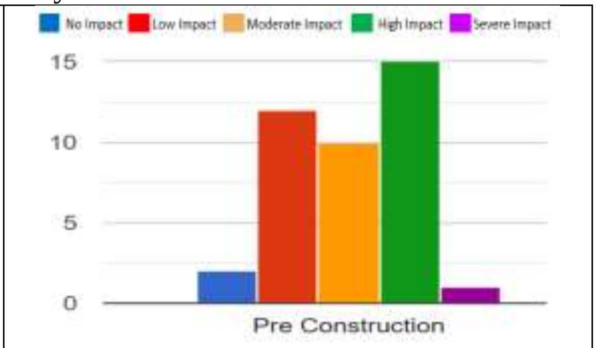


Fig. 4.4. Responses against the Risk Impact

The Fig. 4.4 illustrates that risks perceived during the pre-construction phase are predominantly considered to have a high impact, with fewer categorized as low or moderate. A small number of risks are deemed severe or negligible, indicating that while risks exist, they are mainly manageable at this stage.

The Fig. 4.5 illustrates that risks escalate during the construction phase, with high and severe impact risks being the most frequently reported, while moderate risks persist. Low and no-impact risks are infrequent, indicating the heightened challenges of active project execution.

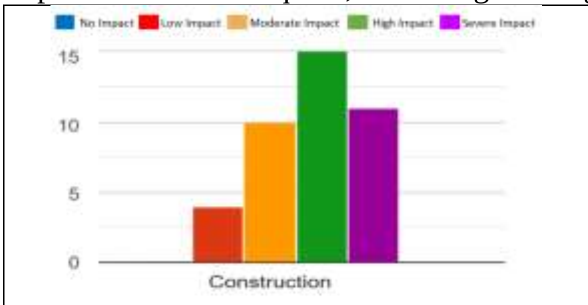


Fig. 4.5. Responses against the Risk Impact

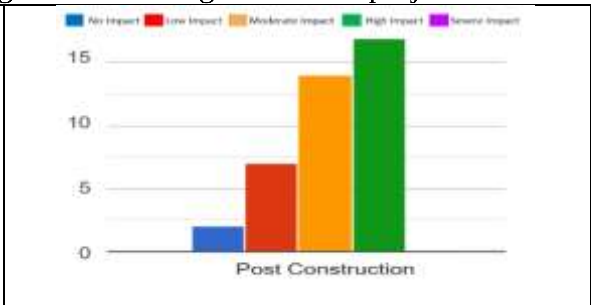


Fig. 4.6. Responses against the Risk Impact

The Fig. 4.6 illustrates the ongoing high-impact risks in the post-construction phase, with moderate and severe risks also increasing, indicating that quality, maintenance, and operational challenges arise after project completion and require careful management.

The Fig. 4.7 illustrates that payment delays from clients or government agencies significantly affect contractors, with 52.5% of respondents reporting a high impact. Additionally, 35% perceive the effect as moderate, while only 10% see it as low. This indicates that delayed payments are a major concern for most contractors in the industry.

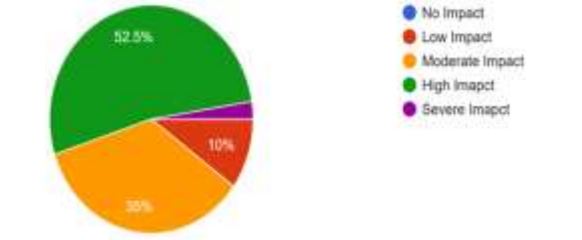


Fig. 4.7. Responses against the payment delays

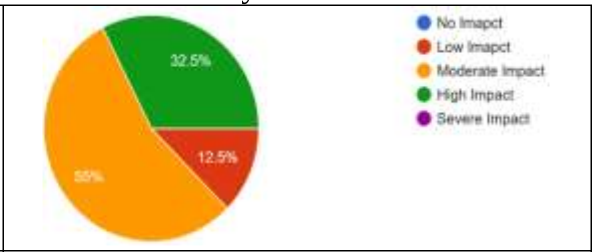


Fig. 4.8. Responses against the Market Dynamics

The Fig. 4.8 illustrates the influence of market conditions on project resource costs and availability. Most respondents (55%) note a moderate impact, 32.5% indicate a high impact, and 12.5% perceive it as low, with no respondents considering the effect severe or negligible. This indicates that market fluctuations pose a typical challenge but are generally manageable.

The Fig. 4.9 shows that 52.5% of respondents perceive the issue as having a moderate impact, while 32.5% consider its impact high. Only 10% see it as low, and a few regards it as severe. Importantly, no respondents felt the issue had no impact, highlighting its overall significance.

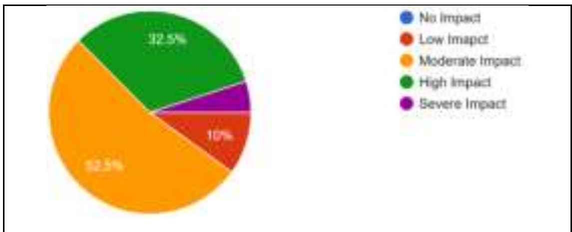


Fig. 4.9. Responses against the Dispute Oblique Strikes

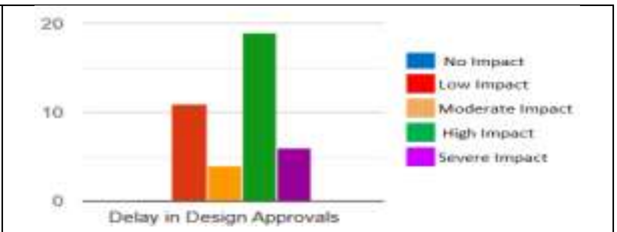


Fig. 4.10. Responses against the technical risks

The Fig. 4.10 illustrates that delays in obtaining design approvals significantly affect project timelines, with most respondents indicating a high impact on progress. While a minority view the impact as low, moderate, or severe, very few believe it to be negligible, highlighting the importance of addressing this issue in project planning.

The Fig. 4.11 illustrates how unexpected construction site issues, like poor soil and unforeseen underground utilities, significantly affect projects. Most respondents view these problems as moderately to highly impactful, with a minority perceiving them as minor, underscoring the need for proactive planning.

Figure 4.12 illustrates the impact of quality issues on project outcomes, showing that most respondents perceive a significant or moderate effect. Very few regard these issues as minor, emphasizing the crucial role of quality standards in ensuring project success.

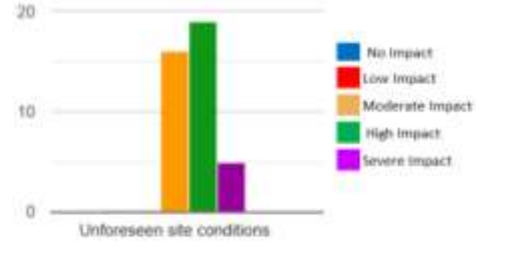


Fig. 4.11. Responses against the technical risks – unforeseen site condition

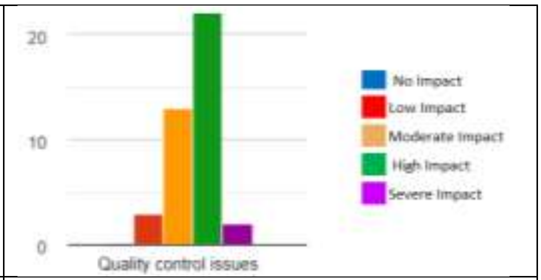


Fig. 4.12. Responses against the technical risks - quality issues

The Fig. 4.13. illustrates differing views on labor shortages, with some seeing it as a severe issue, others as moderate or high-level, and a few considering it minor. This indicates that the impact of labor shortages varies by project and region.

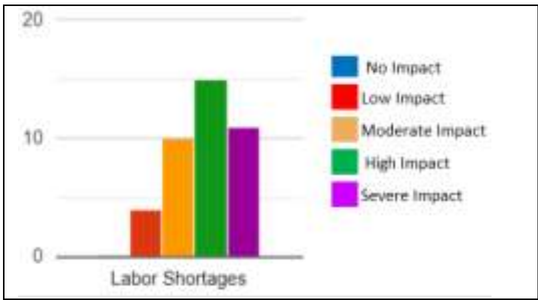


Fig. 4.13. Responses against the technical risks - labor shortages

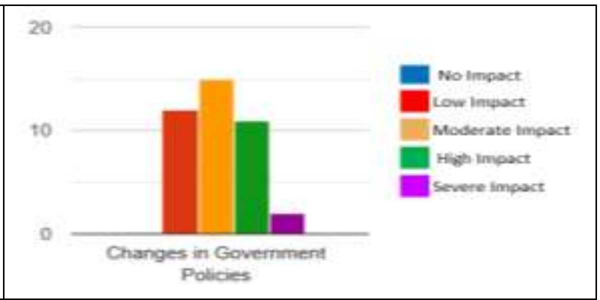


Fig.4.14. Responses against the external factors - government rules or policies

The Fig. 4.14 illustrates that changes in government rules or policies generally cause moderate or low disruption to projects, with teams monitoring these shifts closely. Nonetheless, a significant number of respondents acknowledge that such changes can occasionally have a high impact, serving as a reminder of their potential for unexpected consequences.

The Fig. 4.15 illustrates that economic instability significantly affects projects, with most respondents indicating a moderate impact. A notable number perceive it as having a strong impact, while very few consider it insignificant. Economic unpredictability disrupts all aspects of project operations.

The Fig. 4.16 illustrates the impact of legal or regulatory red tape on projects, highlighting that a majority of respondents experience a significant effect, indicating widespread frustration. Additionally, many categorize the issue as moderate, while a small number regard it as minor. The analysis shows that managing rules and permits can notably hinder project progress.

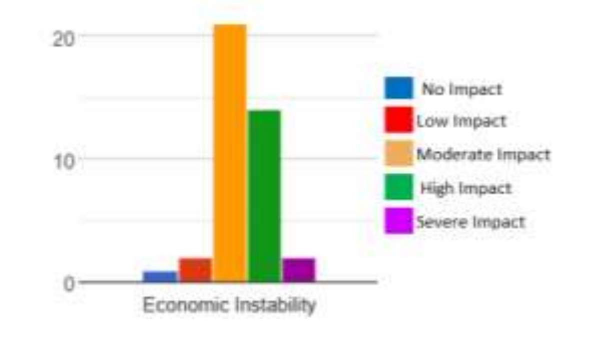
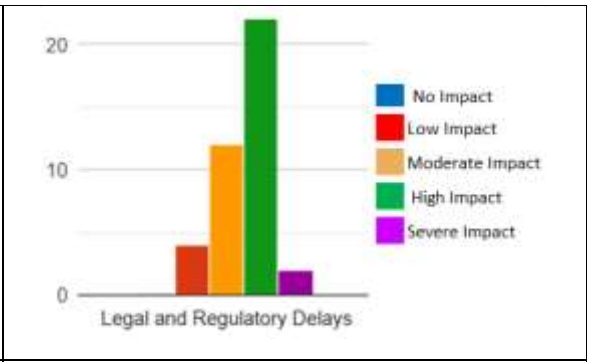
	

Fig.4.15. Responses against the external factors - economic instability	Fig.4.16. Responses against the external factors - legal or regulatory

The Fig. 4.17 illustrates that local community pushback significantly affects projects, with most respondents indicating a moderate to high impact, and some categorizing it as severe. While a few perceive it as a minor issue, the extent of the impact varies by context, with potential for protests to escalate into major obstacles.

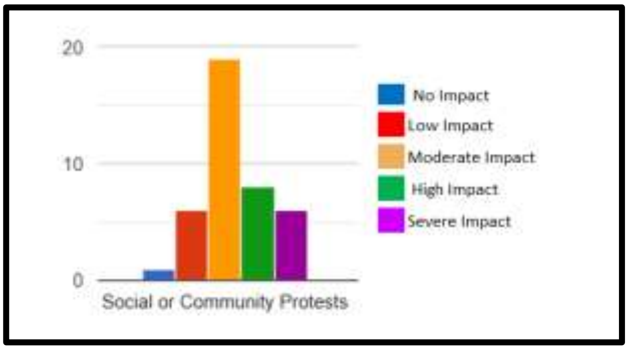


Fig.4.17. Responses against the external factors

Internal Consistency: Prior to data analysis of any survey-based research, it is essential to validate the consistency of the dataset. High internal consistency suggests that the respondents understood and evaluated the survey items similarly. For this study, the internal reliability of 19 variables was assessed using Cronbach's Alpha Reliability. Cronbach's Alpha Score found as 0.842. This outstanding score indicates that the 19 items measuring the impact of various risks causes are highly correlated. Specifically:

a) The survey instrument is reliable and consistent.
b) The data is suitable for advanced inferential statistics such as ANOVA.
c) Respondents have understood and rated the impact levels of delays in a dependable manner.

ANOVA test Summary:

The ANOVA test is a way to check if there are meaningful differences between the average values of multiple groups. In this case, a one-way ANOVA is used when there are more than two groups to compare. The test is done in SPSS by selecting the necessary data: the dependent variable which are mentioned in the table 4.1 and the independent variable is considered the Experience of the experts and professionals who participated in the survey. The results include:

1. **p-value** – if this value is less than 0.05, it suggests there is a meaningful difference between groups, prompting further checks (post-hoc analysis) to find exactly where those differences lie.

Table 4.1. Analysis of Variables by Using SPSS

Questions		Item	Sig. (p)
Q1	Risk Impact	Preconstruction	0.282
Q1		Construction	0.000
Q1		Postconstruction	0.003
Q2	Payment delays	Payment Delays	0.028
Q3	Changes in Market condition	Changes in Market Condition	0.089
Q4	Labour disputes	Labour disputes	0.005
Q5	Technical Risks	Delay in Design Approvals	0.002
Q5		unforeseen Site Conditions	0.003
Q5		Quality Control Issues	0.149
Q5		Labor Shortages	0.022
Q6	External factors	Changes in Government Policies	0.000
Q6		Economic Instability	0.001
Q6		Legal and Regulatory Delays	0.188
Q6		Social or Community Protests	0.000

Table 4.2. Relative Importance Index

Sl.No.	Factor	Sum of Scores	Total Respondents	Relative Index
1	Risk Impact in Preconstruction	121	40	0.60
2	Risk Impact in During construction	153	40	0.76
3	Risk Impact in Post construction	126	40	0.63
4	Payment Delays	139	40	0.69
5	Changes in Market Condition	128	40	0.64
6	Labour disputes	133	40	0.66
7	Delays in design approvals	140	40	0.70
8	Unforeseen site conditions	149	40	0.74
9	Quality control issues	143	40	0.71
10	Skilled/Unskilled labour shortages	153	40	0.76
11	Changes in Government Policies	123	40	0.61
12	Economic Instability	134	40	0.67
13	Legal and Regulatory delays	142	40	0.71
14	Social and community protests	132	40	0.66

If the ANOVA result is below the threshold of 0.05, the alternate hypothesis is accepted. Conversely, if the ANOVA result exceeds 0.05, the alternate hypothesis is rejected.

This allows us to confidently move forward with hypothesis testing, correlation mapping, and insight development.

RII Summary: The RII test helps to rank different factors based on how important people think they are. It's often used in surveys, especially in areas like construction, business, and social sciences, to see which aspects matter most to respondents. A survey is conducted where participants rate various factors on a scale (for example, from 1 to 5, where 1 means "not important" and 5 means "very important"). The RII for each item was calculated using the following formula:

$$\mathrm{RII} = \sum(\mathrm{W})/\mathrm{A} \times \mathrm{N} \text{ - } \quad \text{equation - 4.1}$$

Where:

$\sum$W= the sum of the weights given to each item by the respondents

A = the highest possible weight (e.g., 5 on a 5-point scale)

N = the total number of respondents

Interpretation of RII values:

RII close to **1** → High importance or High criticality

RII close to **0** → Low importance or Low criticality

4.5 Probability Impact Matrix:

The Probability-Impact Matrix helps to identify and rank risks based on two factors: how likely they are to happen (probability) and how serious their effects would be (impact). Each risk gets a score from 1 (very low) to 5 (very high) for both factors. These scores are multiplied to find the overall risk level. As shown in Table 4.2 and the formula as follows:

Probability & Impact Score = Probability X Impact

Table 4.3. Rating Scale

RII Range	Interpretation
0.8 – 1.0	Very High Importance
0.6 – 0.8	High Importance
0.4 – 0.6	Moderate Importance
0.2 – 0.4	Low Importance
0.0 – 0.2	Very Low Importance

Table 4.4. Probability & Impact score

ID	Factor	Impact	Probability	Score
1	Risk Impact in Preconstruction	2	4	8
2	Risk Impact in During construction	5	5	25
3	Risk Impact in Post construction	3	3	9
4	Payment Delays	4	1	4
5	Changes in Market Condition	3	4	12
6	Labour disputes	3	5	15
7	Delays in design approvals	5	4	20
8	Unforeseen site conditions	5	1	5
9	Quality control issues	4	2	8
10	Skilled/Unskilled labour shortages	5	2	10
11	Changes in Government Policies	3	4	12
12	Economic Instability	3	4	12
13	Legal and Regulatory delays	4	3	12
14	Social and community protests	2	2	4

Table 4.5. Rating Matrix

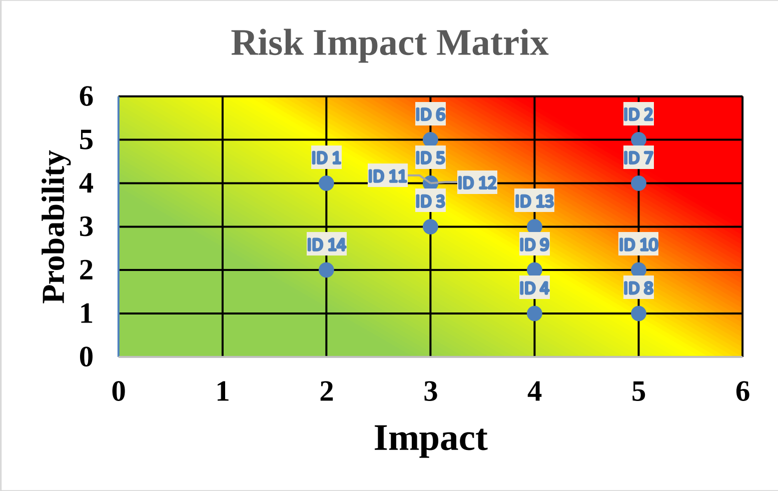
Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Impact				

Legend	
High Risk	>12
Moderate Risk	5 to 12
Low Risk	<5

The results are then placed on a 5x5 grid, where higher-risk items appear in the top-right corner, showing which ones need the most attention. This method makes it easy to see and manage risks effectively.

Each risk was rated on a scale, and the two numbers were multiplied to calculate a risk score. This score was then plotted on a 5x5 grid, showing which risks needed urgent attention. The higher-risk items were marked as a high priority, making it easier to decide what needed action.

Various analytical techniques in this research were utilized to meet various research requirements. Cronbach's Alpha was utilized to measure the internal consistency among survey instruments to guarantee the reliability of constructs prior to further analysis. ANOVA was utilized to identify statistically significant differences between groups to support inferential conclusions regarding relationships among variables. The Relative Importance Index (RII), by contrast, was utilized to prioritize factors by what respondents said, providing a transparent determination of qualitative input. The Probability-Impact Matrix also gave a strategic and visual determination of potential threats, supplementing the statistics with a risk-oriented analysis. Together, the tools provided a rich, multidimensional analysis of the data, integrating reliability testing, inferential statistics, prioritization, and risk assessment.



Graph 4.1. Risk Impact Matrix

Interpretation

This chapter explains the main findings of the study on risk factors affecting Engineering, Procurement, and Construction (EPC) projects. It looks at how reliable the data is, which risks are most significant in different project stages, what causes these risks, and how they are ranked based on importance and impact.

The results from the previous chapter are examined here to answer the research questions and test the initial ideas of the study. The research aimed to risk analysis in infrastructure projects, and the analysis revealed some clear patterns. The interpretation focuses on the reliability of data, significance of risk across project phases, key risk drivers, and the prioritization of risks based on both perceived importance and severity.

These findings are discussed in relation to existing studies, theories, and the overall research topic. This chapter also highlights what the results mean for the industry, where there might be gaps or limitations, and suggests possible directions for future research.

5.1 INTERNAL CONSISTENCY:

Reliability of the Survey: The survey had a Cronbach's Alpha score of 0.842, showing that the questions were consistent and reliable. This means that respondents answered in a way that remained stable across different areas, ensuring the survey results were trustworthy. Because of this high reliability, the identified risk factors can be confidently used for further analysis. In simple terms, the survey produced dependable data, making it useful for understanding risk in infrastructure projects. This strong consistency helps support accurate conclusions in the study.

5.2 HYPOTHESIS TESTING VIA ANOVA

The ANOVA test results highlighted several critical areas where risks have a statistically significant impact based on the experience of the professionals surveyed. Notably, the "During Construction" phase shows a very strong correlation with risk impact (p-value of 0.000). This isn't surprising, as this phase involves a lot of moving parts—labor, materials, site conditions—all of which are prone to disruption. "Post Construction" also shows a significant impact, though less pronounced than during construction (p-value of 0.003). Interestingly, the "Preconstruction" phase didn't show a statistically significant risk impact according to the ANOVA test (p-value of 0.282), suggesting that while risks exist, their impact might be less varied across different experience levels of respondents compared to the other phases.

- **Key Risk Drivers Identified:**
  - **External Factors:** Changes in government policies (p-value 0.000) and economic instability (p-value 0.001) were strongly identified as having a significant impact. This underscores the vulnerability of large infrastructure projects to broader economic and political shifts.
  - **Operational Challenges:** Labor disputes (p-value 0.005) and delays in design approvals (p-value 0.002) were also highlighted as statistically significant contributors to project performance issues. These are areas where internal project management and stakeholder coordination need to be exceptionally strong.
  - **Labor Shortages:** Skilled/Unskilled labor shortages also emerged as a significant technical risk (p-value 0.022). This points to potential challenges in workforce availability and talent management within the construction sector.

5.3 Prioritization of Risks via RII:

The Relative Importance Index (RII) provides a clear ranking of how important various risk factors are perceived to be by the respondents.

- "Risk Impact in During Construction" and "Skilled/Unskilled Labour Shortages" both have a very high RII of 76.50%. This strongly suggests these are the most critical issues from the perspective of those on the ground.
- Other factors with "High Importance" (RII between 60% and 80%) include unforeseen site conditions (74.50%), quality control issues (71.50%), legal and regulatory delays (71.00%), delays in design approvals (70.00%), payment delays (69.50%), economic instability (67.00%), labor disputes (66.50%), social and community protests (66.00%), changes in market conditions (64.00%), and risk impact in post-construction (63.00%).

5.4 Risk Prioritization via Probability-Impact Matrix:

The Probability-Impact Matrix offers a strategic visual representation of risks, classifying them based on likelihood and severity.

- "Risk Impact in During Construction" stands out as a "High Risk" with a score of 25 (highest possible). This reinforces the RII finding and confirms it as a critical area for immediate attention.
- "Delays in design approvals" and "Labour disputes" are also classified as "High Risk" with scores of 20 and 15 respectively.
- Several factors, including "Changes in Market Condition," "Changes in Government Policies," "Economic Instability," and "Legal and Regulatory Delays," are in the "Moderate Risk" category (scores between 5 and 12). While not as immediately critical as high-risk items, they still warrant careful management.

"Payment Delays," "Unforeseen site conditions," and "Social and community protests" are categorized as "Low Risk" based on the probability-impact matrix. While the RII indicated some importance for these, the matrix suggests their combined probability and impact might be lower than other factors, or perhaps the impact, while present, isn't consistently severe across all respondents.

CONCLUSION: This research paints a clear picture of the inherent risks in EPC-led infrastructure projects, particularly in the context of infrastructure projects. While the EPC model aims to streamline project delivery by consolidating responsibilities, it is not foolproof and faces significant challenges in real-world application, as evidenced by persistent delays and resource mismanagement in the Telangana highway expansion project.

The study confirms the reliability of its data and identifies the construction phase as the most vulnerable to risk impacts. Critical issues requiring immediate attention include labour shortages, delays in design approvals, and broader external pressures such as government policy shifts and economic instability. These findings indicate that although internal operational efficiency is essential, external macroeconomic and political factors exert a significant influence on project outcomes.

The insights from this study provide actionable information for stakeholders. To enhance project performance and ensure timely delivery in EPC-led infrastructure projects, there's a clear need for improved risk assessment and mitigation strategies that specifically address the identified high-impact and high-probability risks, especially those related to the construction phase and external factors. Implementing robust risk management frameworks that emphasize proactive identification, comprehensive planning, real-time monitoring, and seamless stakeholder engagement will be vital for future success in similar large-scale infrastructure endeavours.

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