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Multi-analytical Approach for Risk Identification and its Management for Successful Infrastructure Projects

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Abstract

It has been determined that managing risks is a crucial management technique for achieving project goals in terms of time, money, quality, and degree. On the basis of a thorough analysis of agreement states, this article recognizes dangers and categorizes them into eight categories. It is viewed in a personal way. Social body opposition, risk assessment, plan modifications, and work suspension are believed to have the biggest effects on the project's objectives. This research has produced a few suggestions for reducing the hazards associated with development projects or mitigation methods. The contract agreements are employed as a tool to track risk, and the client, contractors, and financial backers who are sponsoring the project must specify how they intend to threaten the executive's plan during the project's lifespan. It is intended that clients, contractors, project workers, and governmental organizations will work together to manage projected hazards as they arise, starting at the attainability stage.

Keywords: Contract document, Frequency Index, Severity Index, Infrastructure projects, Project Risk, Risk distribution, Risk management.

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Introduction

Risk in the construction industry is unavoidable because of the complex dynamic environment in which construction work has to be performed. As construction activities are uncertain in nature, studies affirm that construction is a profoundly hazard-inclined industry. This research focuses on the risk involved, especially in building and infrastructure projects as it constitutes a large part of the construction industry.

What is Risk?

Risk has many definitions, and some are discussed here. According to project management institute, risk is "an uncertain event whose outcomes can have a positive or negative impact on project objectives". Simply it can be defined as chances of something bad happening. Risk is defined as the chances of something happening that may affect the project goals or objectives in a negative way.

Risk Management Model

Many risk management models exist, but the most commonly used one consists of four steps. Risk management is an iterative process mainly consisting of the steps: identification of risk, analysis of risk, response strategies, and monitoring. Risk management recognizes all the risks present in the projects with its exposure magnitudes and helps in taking timely decisions to minimize the risk. Using mitigation measures can result in avoiding many problems. It can also decrease the impact of negative events if they occurs. The risk management model is a circular model that can be improved by adding new learnings with time. Overall risk management process is same, but the approach may differ depending on construction companies and regions. A proper implementation of risk management is necessary before starting a project till its completion for success. Risk identification's purpose is to assess possible risks and their consequences on the project targets. Every construction project contains some degree of risk. The risk management process is shown in Figure 1.

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Risk Identification

First step in managing risk is identifying risk without it we cannot proceed further. So, risk should be identified thoroughly as it is very important to identify each and every

(Source Lidija Rihar, Tena Žužek, Tomaž Berlec and Janez Kušar (2019) Standard Risk Management Model for Infrastructure Projects)

Figure 1: Risk Management Process in Construction Projects

risk involved. Risk identification does not aim to obtain precise and exact predictions for risk events. Its purpose is to recognize all the possible risks with high impact. Thus, it provides insight into what risks are present or can be faced in the future before it actually occurs. Thus, having enough time to prepare for these risks. As risk and uncertainties keeps on changing thus identification of risk is an iterative process with new risk emerging during the lifecycle of a project. Before managing risk factors, it is necessary to identify them.

Various methods of risk identification are shown in Table 1

Probability and Impact Assessment of Risk

Probability of risk is defined as the frequency of that event to occur and the severity of risk is defined as impact of risk once the event has occurred. Overall multiplication of this i.e. probability and severity, give the value of risk impact, which states the risk's criticality.

Frequency index R.I.I $=\sum an\ N*A \times 100$............Equation. (1)

Where,

a = weight assigned by respondent
n = responses probability
N = total number of participants
A = maximum weight

(Source: Choudhry, R.M. and Iqbal, K., (2013) Identification of risk management system in the construction industry in Pakistan)

Severity index S.I $= \sum an\ N*A \times 100$ .... Equation. (2)

Where,

a = weight assigned by respondent
n = responses probability
N = total number of participants
A = maximum weight

(Source: Choudhry, R.M. and Iqbal, K., (2013) Identification of risk management system in construction industry in Pakistan)

Table 1 : Methods used for risk identification

Sr. No.	*Name of method*
1.	Brainstorming
2.	Delphi Technique
3.	Interview/Expert Opinion
4.	Questionnaires
5.	Checklists

(Source: https://www.greycampus.com/opencampus/certified-associate-in-project-management/risk-identification-tools-and-techniques-in-capm)

Literature Review

- **K T Liew, W W Low, K S Wong and S Y Wong (2022):** Structure adventures, for instance, expressways, rail line, air terminals, power stations and ports expect a huge part in the improvement of a country. Past assessments declared, regardless, that most of the system projects experienced cost attacks with an ordinary of more than a quarter higher than the principal cost. Past assessments contemplated that risks occur in the earlier project acquisition, especially the offering stage, will undoubtedly cause a basic effect on the later stage (improvement stage). From the composing overview, it might be that most of the assessments focused on the advancement stage in assessing the bet factors on the establishment cost. The composing review observed that most of the assessment was finished on augmentations, rail course and transportation in a city like China, Hong Kong, and Australia instead of Malaysia. All things considered, risk examination in establishment projects during the pre-improvement stage is huge as it helps with giving a couple of rules to the business specialists to additionally foster their ongoing bet the board plan as well as their route. Along these lines, an ongoing survey is coordinated to perceive the fundamental risks in establishing project costs during the offering stage.
- **Laila M. Khodeir, Mohamed Nabawy (2019):** This paper is concerned with identifying key threats arising from the internal and external environment of stakeholder's organization during the construction of IP. The methodology of the paper includes a literature review of infrastructure challenges, followed by the identification and classification of risk factors using risk breakdown structure. Furthermore, a checklist analysis of key risks was performed. The 'Cairo Festival City" project was analysed as an infrastructure project case study. Purposive sampling was used in order to target 70 specific experts related to infrastructure projects. Finally, the paper generated a full risk register that presents identified challenges gathered from the literature and agreed risks resulting from the Egyptian case study.
- **Lidija Rihar, Tena Zuzek, Tomaz Berlec and Janez Kusar (2019):** This paper outlines a risk management method based on using a standard risk management model and is adapted to the specific nature of infrastructure projects. The standard model can be used to identify and quantify unexpected events in planning and executing a project. The use of a risk map will also be illustrated. A risk map can serve to classify the identified and quantified risk events, depending on the expected loss, to critical risks that call for a more in-depth treatment, and non-critical

risks that are normally not monitored, while no measures are foreseen in advance. A risk map is used to determine the anticipated effects of the measures to mitigate the critical risks and how the anticipated measures enable the transition from a critical risk to a non-critical risk. In this article, the suggested risk management is illustrated using the example of the erection of a reservoir for a hydroelectric power plant. Using the proposed tools for identifying, assessing, prioritizing, and managing risks proved highly successful. With the use of the proposed risk model, the critical risk events were lowered under the acceptable level of the expected losses.

- **Choudhry, R.M. and Iqbal, K., (2013):** used a questionnaire survey technique to gather data for analysis. The study was focused on bridge construction in Pakistan. Thirty-seven risk factors were considered for survey purposes. Seventy-seven filled forms were received, out of which sixty-nine was complete & usable for analyzing data. Further, these 37 risks were categorized into seven categories: financial, design-related, health, contractual, management, construction, and external risks. Relative importance index and Monte Carlo Stimulation was used for analyzing survey data. The financial category was found to topmost category affecting cost and schedule objectives. The top five risks for bridge construction in Pakistan were unavailability of funds, lack of clarity over roles, lack of funds, inadequate site investigation, and inadequate project planning.

Methodology

Flow-chart for Methodology

The Flow chart Methodology is depicted herein below in Figure 2.

Risk Classification

Construction projects consist of internal and external risks, which can be divided into various categories. Classifying into categories is important because these projects contains

Figure 2: Flow Chart for Methodology

various uncertainties and risks. To avoid these risks laws and regulations should be followed. Unfortunately, we can't avoid these risks but we can manage them to decrease their impact. By categorizing risk, we can optimize our risk management process and thus avoid losses.

Management Risk

Management risks and construction risks in building and infrastructure projects is shown in Table 2.

Technical and Construction Risk

Technical risks and construction risks in building and infrastructure projects is shown in Table 3.

Resource and Site-Related Risks

Resource and site-related risk in building and infrastructure projects is shown in Table 4.

Contractual and Legal Risks

Contractual and legal risks in building and infrastructure projects is shown in Table 5.

For this study, a questionnaire survey consisting of 70 risk factors based on literature was designed. These risk factors were categorized into eight major categories: management, technical & construction-related, resource & site-related, socio-political, contractual & legal, economic & financial, environmental, health and safety. This questionnaire was focused on risk factors that affect the project outcomes i.e. (project cost, completion time, specifications, quality, etc.).

Table 2: Management risks and construction risks in building and infrastructure projects

Sr. No.	*Risk factor*
A	Management Risks
1	RF1-Poor coordination or communication among various parties
2	RF2-Poor management skills
3	RF3-Lack of experience of the project team
4	RF4-Personal conflicts between different clients involved
5	RF5-Poor site management and supervision
6	RF6-Shortage of skilful managers and professional's
7	RF7-Improper project planning and budgeting
8	RF8-Change of top management
9	RF9-Inadequate quality planning and quality assurance
10	RF10-Lack of clarity over roles and responsibilities
11	RF11-Restrictions on foreign companies

(Source: Kamalendra Kumar Tripathi1 and Kumar Neeraj Jha (2017) Determining Success Factors for a Construction Organization: A Structural Equation Modeling Approach)

Table 3: Technical risks and construction risks in building and infrastructure projects

Sr. No.	*Risk ID*	*Description of risk factor*
1	RF12	Design errors or design changes
2	RF13	Unclear and incomplete detailing in design drawings and specifications
3	RF14	Using poor construction techniques
4	RF15	Delay in design
5	RF16	Complexity of design
6	RF17	Inadequate experience of contractor in same projects
7	RF18	Construction errors and poor workmanship leading to rework
8	RF19	Approval and permit delays
9	RF20	Pressure to crash project duration (time constraints)
10	RF21	Using complex construction methods/techniques
11	RF22	Changing construction methods/ techniques in between of work

(Source: Kamalendra Kumar Tripathi1 and Kumar Neeraj Jha (2017) Determining Success Factors for a Construction Organization: A Structural Equation Modeling Approach)

Table 4: Resource and site-related risk in building and infrastructure projects

Sr. No.	*Risk ID*	*Description of risk factor*
1	RF23	Low productivity and efficiency of equipment
2	RF24	Breakdown of plant and machinery
3	RF25	Shortage of skillful workers locally
4	RF26	Shortage or delay in delivery of expected materials
5	RF27	Unavailability or shortage of equipment
6	RF28	Low labour productivity
7	RF29	Adverse ground conditions
8	RF30	Unavailability of utilities on-site required for construction
9	RF31	Difficulties in accessing site due to topography of the region
10	RF32	Inadequate preliminary survey and tests of site
11	RF33	Delays in the site possession

(Source: Kamalendra Kumar Tripathi1 and Kumar Neeraj Jha (2017) Determining Success Factors for a Construction Organization: A Structural Equation Modeling Approach)

Table 5: Contractual and legal risks in building and infrastructure projects

Sr. No.	*Risk ID*	*Description of risk factor*
1	RF34	Contradictions in the contract documents
2	RF35	Changes in project scope
3	RF36	Litigations and disputes retarding project progress
4	RF37	Contractual disputes and claims
5	RF38	Huge competition at the tendering stage
6	RF39	Change in codes and regulations
7	RF40	Unreliability of the legal system

(Source: Kamalendra Kumar Tripathi1 and Kumar Neeraj Jha (2017) Determining Success Factors for a Construction Organization: A Structural Equation Modeling Approach)

Questionnaire Structure

The fundamental motivation behind the survey is to accumulate data from respondents. It comprises a foreordained agenda of variables of chance distinguished by documentation surveys, previous experience of undertaking individuals, and contextual analyses of pre-executed projects. The pilot study was finished on poll to look at its clearness and simplicity of figuring out questions. Risk factors viewed as not connected with survey design or those elements found rehashed were eliminated or adjusted.

Result & Discussions

General

The designed survey was filled by 78 respondents who responded to the total of 71 questions. Data obtained from questionnaire survey for severity is shown in Appendix. The probability and severity of each factor is judged to calculate risk potential value. For the ranking of risk factors risk impact value was calculated and further these values were normalized. Statistical analysis like factor analysis, etc. are also performed (Parasaram, 2022).

Analysis of Risk Potential

Once data collection is done from questionnaire survey next step is to analyze risk potential of the factors identified. Risk potential is calculated by multiplication of frequency index and severity index as discussed in research methodology. The frequency of a risk factor is defined as its ability to repeat in a particular period. Severity of a risk factor is defined as how severe a risk factor can be once it has occurred. Risk potential for different categories are calculated in further discussion.

The Risk potential values for the varios risk factors under Management category is summarized herein below in Table 6. Similarly, The risk Potential values for technical & construction category, resource & site-related category and contractual & legal risks are summarized in Table 7, Table 8 and Table 9 respectively.

Table 6: Calculation of FI, SI and RP for management category

Sr. No.	*Risk Factor*	*FI*	*SI*	*RP*
A	Management Risks			
1	RF1-Poor coordination or communication among various parties	2.10	3.18	6.69
2	RF2-Poor management skills	2.01	3.41	6.86
3	RF3-Lack of experience of the project team	1.31	3.91	5.11
4	RF4-Personal conflicts between different clients involved	1.87	3.63	6.79
5	RF5-Poor site management and supervision	2.14	3.45	7.38
6	RF6-Shortage of skilful managers and professional's	2.22	3.82	8.47
7	RF7-Improper project planning and budgeting	2.29	3.33	7.65
8	RF8-Change of top management	2.14	3.03	6.48
9	RF9-Inadequate quality planning and quality assurance	2.00	3.31	6.62
10	RF10-Lack of clarity over roles and responsibilities	2.19	3.00	6.58
11	RF11-Restrictions on foreign companies	1.56	2.60	4.07

Table 7: Calculation of FI, SI and RP for technical & construction category

Sr. No.	*Risk Factor*	*FI*	*SI*	*RP*
	B.Technical and Construction Risks			
	RF12-Design errors or design changes	1.96	3.50	6.87
	RF13-Unclear and incomplete detailing in design drawings and specifications	2.08	3.59	7.46
	RF14-Using poor construction techniques	1.95	3.19	6.22
	RF15-Delay in design	2.23	3.17	7.06
	RF16-Complexity of design	2.00	2.87	5.74
	RF17-Inadequate experience of contractor in same projects	1.91	3.15	6.02
	RF18-Construction errors and poor workmanship leading to rework	2.18	3.14	6.85
	RF19-Approval and permit delays	2.18	2.96	6.45
	RF20-Pressure to crash project duration (time constraints)	2.22	3.10	6.88
	RF21-Using complex construction methods/techniques	1.85	2.94	5.42
	RF22-Changing construction methods/techniques in between of work	1.88	3.01	5.68

Table 8: Calculation of FI, SI and RP for resource and site-related category

Sr. No.	*Risk Factor*	*FI*	*SI*	*RP*
C	Resource & Site Related Risks			
1	RF23-Low productivity and efficiency of equipment	2.06	3.49	7.20
2	RF24-Breakdown of plant and machinery	2.10	3.42	7.20
3	RF25-Shortage of skillful workers locally	2.27	3.44	7.80
4	RF26-Shortage or delay in delivery of expected materials	2.10	3.60	7.57
5	RF27-Unavailability or shortage of equipment	1.85	3.32	6.13
6	RF28-Low labour productivity	2.44	3.19	7.78
7	RF29-Adverse ground conditions	1.97	3.41	6.73
8	RF30-Unavailability of utilities on-site required for construction	1.76	3.00	5.27
9	RF31-Difficulties in accessing site due to topography of the region	1.78	3.08	5.48
10	RF32-Inadequate preliminary survey and tests of site	2.04	3.37	6.87
11	RF33-Delays in the site possession	2.33	3.60	8.41

Table 9: Calculation of FI, SI and RP for contractual and legal risks

Sr. No.	*Risk Factor*	*FI*	*SI*	*RP*
D	D.Contractual & Legal Risks			
1	RF34-Contradictions in the contract documents	1.88	3.40	6.40
2	RF35-Changes in project scope	1.94	3.33	6.45
3	RF36-Litigations and disputes retarding project progress	1.95	3.29	6.42
4	RF37-Contractual disputes and claims	2.18	3.53	7.68
5	RF38-Huge competition at the tendering stage	2.35	3.35	7.85
6	RF39-Change in codes and regulations	1.68	3.17	5.32
7	RF40-Unreliability of the legal system	1.73	2.92	5.06

Table 10: Risk factors ranking and level of criticality

Sr. No.	*Risk Factors*	*RP*	*RI*	*NV*	*Rank*	*Criticality*
1	RF42-Payment delays	8.93	2.99	1.00	1	CR
2	RF6-Shortage of skillful managers and professional's	8.47	2.91	0.92	2	CR
3	RF33-Delays in the site possession	8.41	2.90	0.91	3	CR
4	RF38-Huge competition at the tendering stage	7.85	2.80	0.81	4	CR
5	RF25-Shortage of skillful workers locally	7.80	2.79	0.80	5	CR
6	RF28-Low labour productivity	7.78	2.79	0.79	6	CR
7	RF37-Contractual disputes and claims	7.68	2.77	0.78	7	CR
8	RF7-Improper project planning and budgeting	7.65	2.77	0.77	8	CR
9	RF26-Shortage or delay in delivery of expected materials	7.57	2.75	0.75	9	CR
10	RF43-Failure to meet revenue targets	7.50	2.74	0.74	10	CR
11	RF13-Unclear and incomplete detailing in design drawings and specifications	7.46	2.73	0.73	11	CR
12	RF5-Poor site management and supervision	7.38	2.72	0.72	12	CR
13	RF50-Compensation and land acquisition problems	7.21	2.68	0.69	13	CR
14	RF23-Low productivity and efficiency of equipment	7.20	2.68	0.68	14	CR
15	RF24-Breakdown of plant and machinery	7.20	2.68	0.68	15	CR
16	RF15-Delay in design	7.06	2.66	0.66	16	CR
17	RF20-Pressure to crash project duration (time constraints)	6.88	2.62	0.62	17	CR
18	RF32-Inadequate preliminary survey and tests of site	6.87	2.62	0.62	18	CR
19	RF12-Design errors or design changes	6.87	2.62	0.62	19	CR
20	RF2-Poor management skills	6.86	2.62	0.62	20	CR
21	RF18-Construction errors and poor workmanship leading to rework	6.85	2.62	0.61	21	CR
22	RF4-Personal conflicts between different clients involved	6.79	2.61	0.60	22	CR
23	RF29-Adverse ground conditions	6.73	2.59	0.59	23	CR
24	RF1-Poor coordination or communication among various parties	6.69	2.59	0.58	24	CR
25	RF44-Unpredicted changes in inflation rates	6.68	2.58	0.58	25	CR
26	RF9-Inadequate quality planning and quality assurance	6.62	2.57	0.57	26	CR
27	RF65-Inadequate safety measures	6.58	2.56	0.56	27	CR
28	RF10-Lack of clarity over roles and responsibilities	6.58	2.56	0.56	28	CR
29	RF55-Improper project feasibility study	6.53	2.55	0.55	29	CR

30	RF8-Change of top management	6.48	2.55	0.54	30	CR
31	RF19-Approval and permit delays	6.45	2.54	0.54	31	CR
32	RF35-Changes in project scope	6.45	2.54	0.54	32	CR
33	RF36-Litigations and disputes retarding project progress	6.42	2.53	0.53	33	CR
34	RF71 - Effect of Pandemic	6.42	2.53	0.53	34	CR
35	RF34-Contradictions in the contract documents	6.40	2.53	0.53	35	CR
36	RF56-Outbreak of hostilities (riots, revolutions & terrorism)	6.38	2.53	0.52	36	CR
37	RF14-Using poor construction techniques	6.22	2.49	0.49	37	MR
38	RF64-Accidents occurring during construction	6.21	2.49	0.49	38	MR
39	RF46-Project-funding problems	6.19	2.49	0.48	39	MR
40	RF58-Strict environmental rules and regulations	6.16	2.48	0.48	40	MR

Table 11: Critical risk factors in building and infrastructure projects with risk categorization

Sr. No.	*Risk Factor*	*NV*	*Rank*
A	Management Risks		
1	RF6-Shortage of skillful managers and professional's	0.92	1
2	RF7-Improper project planning and budgeting	0.77	2
3	RF5-Poor site management and supervision	0.72	3
4	RF2-Poor management skills	0.62	4
5	RF4-Personal conflicts between different clients involved	0.60	5
6	RF1-Poor coordination or communication among various parties	0.58	6
7	RF9-Inadequate quality planning and quality assurance	0.57	7
8	RF10-Lack of clarity over roles and responsibilities	0.56	8
9	RF8-Change of top management	0.54	9
10	RF3-Lack of experience of the project team	0.25	10
11	RF11-Restrictions on foreign companies	0.00	11
B	Technical and Construction Risks		
12	RF13-Unclear and incomplete detailing in design drawings and specifications	0.73	1
13	RF15-Delay in design	0.66	2
14	RF20-Pressure to crash project duration (time constraints)	0.62	3
15	RF12-Design errors or design changes	0.62	4
16	RF18-Construction errors and poor workmanship leading to rework	0.61	5
17	RF19-Approval and permit delays	0.54	6
18	RF14-Using poor construction techniques	0.49	7
19	RF17-Inadequate experience of contractor in same projects	0.45	8
20	RF16-Complexity of design	0.39	9
21	RF22-Changing construction methods/techniques in between of work	0.37	10
22	RF21-Using complex construction methods/techniques	0.32	11
C	Resource & Site Related Risks		
23	RF33-Delays in the site possession	0.91	1
24	RF25-Shortage of skillful workers locally	0.80	2

25	RF28-Low labour productivity	0.79	3
26	RF26-Shortage or delay in delivery of expected materials	0.75	4
27	RF23-Low productivity and efficiency of equipment	0.68	5
28	RF24-Breakdown of plant and machinery	0.68	6
29	RF32-Inadequate preliminary survey and tests of site	0.62	7
30	RF29-Adverse ground conditions	0.59	8
31	RF27-Unavailability or shortage of equipment	0.47	9
32	RF31-Difficulties in accessing site due to topography of the region	0.33	10
33	RF30-Unavailability of utilities on-site required for construction	0.28	11
D	Contractual & Legal Risk s		
34	RF38-Huge competition at the tendering stage	0.81	1
35	RF37-Contractual disputes and claims	0.78	2
36	RF35-Changes in project scope	0.54	3
37	RF36-Litigations and disputes retarding project progress	0.53	4
38	RF34-Contradictions in the contract documents	0.53	5
39	RF39-Change in codes and regulations	0.30	6
40	RF40-Unreliability of the legal system	0.24	7

Analysis of Risk Impact and Ranking

After analyzing frequency, severity and risk potential next we have to calculate risk impact values using equation number -1 as described in research methodology. Based on the values of RI normalized values was calculated and factors were ranked. Risk identified in this analysis was classified into three levels namely- critical, moderate and low. These levels were decided based on the normalized values. Critical risk factors are those having a normalization value more than 0.50, moderate risk factors are those having normalization values from 0.25 to 0.50, low risk factors are those having value less than 0.25. Risk factors identified in building and infrastructure projects with ranking and level of criticality are discussed in Table 10.

Categorization of Critical Risk Factors

In Table 11, critical risk factors in building and infrastructure projects with risk categorization is given along with overall ranking and ranking within the category.

Conclusion

Many building and infrastructure projects must face risk and uncertainties during construction, resulting in huge losses in terms of cost, time, quality, productivity, etc. This research aims to create awareness regarding risk management framework in the construction industry. The main objective of this study was to identify risk factors, rank them according to their criticality, and suggest mitigation measures to minimize the effects of risk present in building and infrastructure projects.

Initially, seventy-one risk factors were identified through in-depth study of literature related to risk present in building and infrastructure projects. These seventy-one risk factors were categorized into eight major categories. A questionnaire consisting of these factors was prepared and data was collected through a questionnaire survey. The severity index and frequency index was calculated using RII. The maximum value of SI was found to be 4.08 and the minimum value of SI was found to be 2.60. The top five factors for severity were: Outbreak of hostilities (riots, revolutions & terrorism), Payment delays, Lack of experience of the project team, shortage of skillful managers and professionals and Personal conflicts between different clients involved. The maximum value of FI was found to be 2.44 and the minimum value for FI was found to be 1.31. Top ten critical risk factors found were namely- Payment delays, Delays in the site possession, huge competition at the tendering stage, shortage of skillful workers locally, Low labour productivity, Contractual disputes and claims, Improper project planning and budgeting, shortage or delay in delivery of expected materials and Failure to meet revenue targets. Factor analysis was performed on the critical risk factors identified. Risk mitigation measures was also proposed in this research which are discussed further.

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