RISK IDENTIFICATION AND MANAGEMENT IN BUILDING AND INFRASTRUCTURE PROJECTS

A

THESIS

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

CIVIL ENGINEERING

With specialization in

CONSTRUCTION MANAGEMENT

Under the supervision

of

Dr. Ashok Kumar Gupta

(Professor and Head)

by

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to

DEPARTMENT OF CIVIL ENGINEERING

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

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HIMACHAL PRADESH, INDIA

May – 2020

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled **"Risk Identification and Management in Building and Infrastructure Projects"** submitted for partial fulfillment of the requirements for the degree of Master of Technology in Civil Engineering with specialization in Construction Management at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Ashok Kumar Gupta, Professor and Head**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

Shubham
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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"Risk Identification and Management in Building and Infrastructure Projects"** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Civil Engineering with specialization in Construction Management submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Shubham Sharma (182603)** during a period from June 2019 to May 2020 under the supervision of **Dr. Ashok Kumar Gupta, Professor and Head,** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat. The above statement made is correct to the best of our knowledge.

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ABSTRACT

Building and infrastructure projects consists of extensive risks. Identification and management of risk plays an important part in projects success or failure. This study assesses the critical risk factors involved in the building and infrastructure projects. A questionnaire was prepared on the basis of a literature review and was filled by various contractors, project managers, site supervisors, and engineers. A total of 70 risk factors were identified and listed under eight categories for this research. The data for severity and frequency of each risk factor was collected through questionnaire survey. Reliability of obtained data was checked using Cronbach's alpha. Severity and frequency of the data was analyzed using relative importance index. Risk factors were ranked according to risk impact value which was calculated using risk priority. Thirty-eight risk factors were found to be critical using normalization of risk impact values. Top ten critical risk factors identified were namely- approval and permit delays, payment delays, unpredicted changes in inflation rates, pressure to crash project duration (time constraints), design errors or design changes, contractual disputes and claims, shortage of skillful managers and professionals, bad weather conditions (continuous rainfall, snow, wind), laws and policies revising, adverse ground conditions. Factor analysis was performed on critical risk factors and it suggested to converge risk factors into three components. Risk mitigation model and guidelines are also suggested such that effect of risk can be minimized resulting in more positive outcomes. This research will help engineers, site supervisors, project managers, risk managers, construction practitioners, etc. to recognize and manage risk present in building and infrastructure projects in such a way that it has minimal negative effects on project objectives.

Keywords: Risk identification, Risk management, Critical risk factors, Frequency index, Severity index, Relative importance index, Risk impact value, Building projects, Infrastructure projects.

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LIST OF ACRONYMS & ABBREVIATIONS

Acronyms	**Caption**
BIP	Building and infrastructure projects
CR	Critical risk
FA	Factor analysis
FI	Frequency index
LR	Low risk
MR	Moderate risk
RII	Relative importance index
RI	Risk impact
RP	Risk potential
SI	Severity index
SPSS	Statistical package for the social sciences

CHAPTER 1

INTRODUCTION

1.1 General

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, therefore, studies affirm that construction is a profoundly hazard inclined industry [**1**]. This research focuses on the risk involved especially in building and infrastructure projects as it constitutes a large part of construction industry. For the successful achievement of project objectives and targets, risk should be managed in an effective manner. Risk management has been known as an important tactic to meet project targets like time, budget, and quality [**2**]. Development ventures are defined by their fluctuating degrees of uniqueness and multifaceted nature, the dynamic association of numerous partners, capital seriousness, dynamic situations, long generation terms, and exposure to the external environment and climate conditions [**3**]. Risks and vulnerabilities are for sure present in all construction projects from commencement to the accomplishment of the project-irrespective of the size of the project, complications involved, and location of the project [**4**].

1.2 Project Management

Project management is combination of techniques, skills, knowledge, and tools. It consists of processes dealing with identification, analysis and response. The main motive of project management is to maximize the results of positive events and minimizing the results of negative events. Managing risk is one of the ten knowledge areas of project management and is known as risk management [**5**]. Project management mainly deals with areas related to integration, cost, resource, scope, procurement, risk, communication, quality, schedule and stakeholder. Major knowledge areas of project management are:

- Management of resources
- Management of procurement
- Management of cost
- Management of integration
- Management of scope
- Management of schedule
- Management of communication
- Management of risk

- Management of quality
- Management of stakeholder

1.3 What is Risk?

Risk has many definitions and some are discussed here. According to project management institute risk is defined as “an uncertain event whose outcomes can have positive or negative impact on project objectives” [**6**]. Simply it can be defined as chances of something bad happening [**7**]. Risk is defined as chances of something happening that may affect the project goals or objectives in a negative way [**8**]. In English language the risk word was introduced in 17th century and it meant “to go against the rock or to run into danger”. Risk is present in every activity and the amount of risk in different activities vary. It depends upon different criteria’s like size, location, people involved, etc. Risk can also be defined as “unpredictability of events in terms of profit or loss” [**9**]. Risk contain possibility of profit and loss, in construction project language project profit or loss depends upon different events present in project. Minimizing the consequences of the risk is an integral part of the management [**10**]. Management of risk provides different ways of assessing risk and uncertainty. The building and infrastructure projects changed a lot over the last few decades. Construction industry is mainly driven by private sector. As involvement of private sector increases the risk and uncertainty involved in it also increases. So, there is need to manage these risks in an effective manner.

1.4 Risk Management Model

A lot of risk management models are there but the most commonly used risk management model consists of four steps. Management of risk is an iterative process mainly consists of the following steps: identification of risk, analysis of risk, response strategies, and monitoring [**11**]. Risk management recognizes all the risks present in 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 occurs [**12**]. 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 of a project till its completion for success of the project. Risk identification's purpose is to assess possible risks and their consequences on the project targets. The risk identification process should consider both positive risks (opportunities) as well as negative risks. It may be from within the project or from external sources [**13**]. Various risk identification techniques are questionnaire surveys, literature review, checklist, documentation review, brainstorming, Delphi technique, case studies of past projects, etc. Common methods used for risk analysis are probability impact matrices, sensitivity analysis, Monte Carlo simulations, decision tree analysis, using fuzzy methods, etc. Risk response is the action taken to mitigate the risk present in a project. Various risk responses are avoidance of risk, transfer of risk, reduction of risk, retaining risk [**14**]. The reason that risk management is not popular among construction industry practitioners is lack of knowledge of risk management framework. There is a need to apply risk management from the commencement of the construction project as knowing the origin of the risk will help practitioners to deal with it in a better way [**15**]. A lot of research has been done so far on the risk associated with construction projects, in spite of that construction projects have to deal with various risks like cost-overrun, time-overrun, quality issues, and contractual issues, etc. Every construction project contains some degree of risk. Risk management process is shown in Figure 1.1.

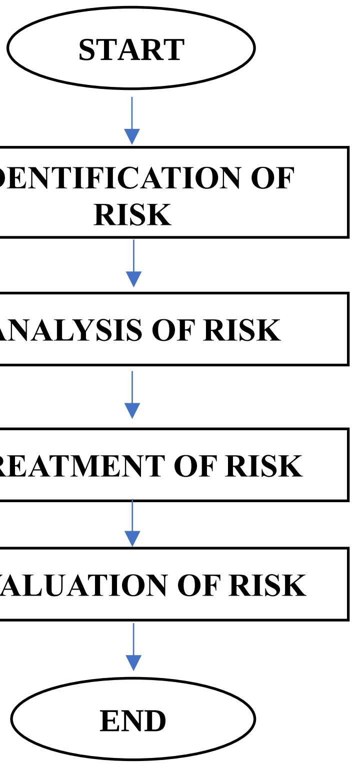

Figure 1.1 Risk management process in construction projects

1.5 Need of Study

1. The purpose of this study is to make awareness regarding the risk management process in construction industry.

2. As construction industry is full of risks and uncertainties with the development of risk management framework risks can be managed in a better way i.e. more positive outcome.
3. project is unique and complex in nature risk management practices will help us in checking which part of project needs more attention as compared to other parts.
4. By using management framework risk can be accessed in real-time.
5. Overall better quality can be achieved with minimum cost and time overruns.
6. Risk management will result in less disputes and legal litigation regarding contracts and claims.
7. Various effects of risks are discussed in Figure 1.2

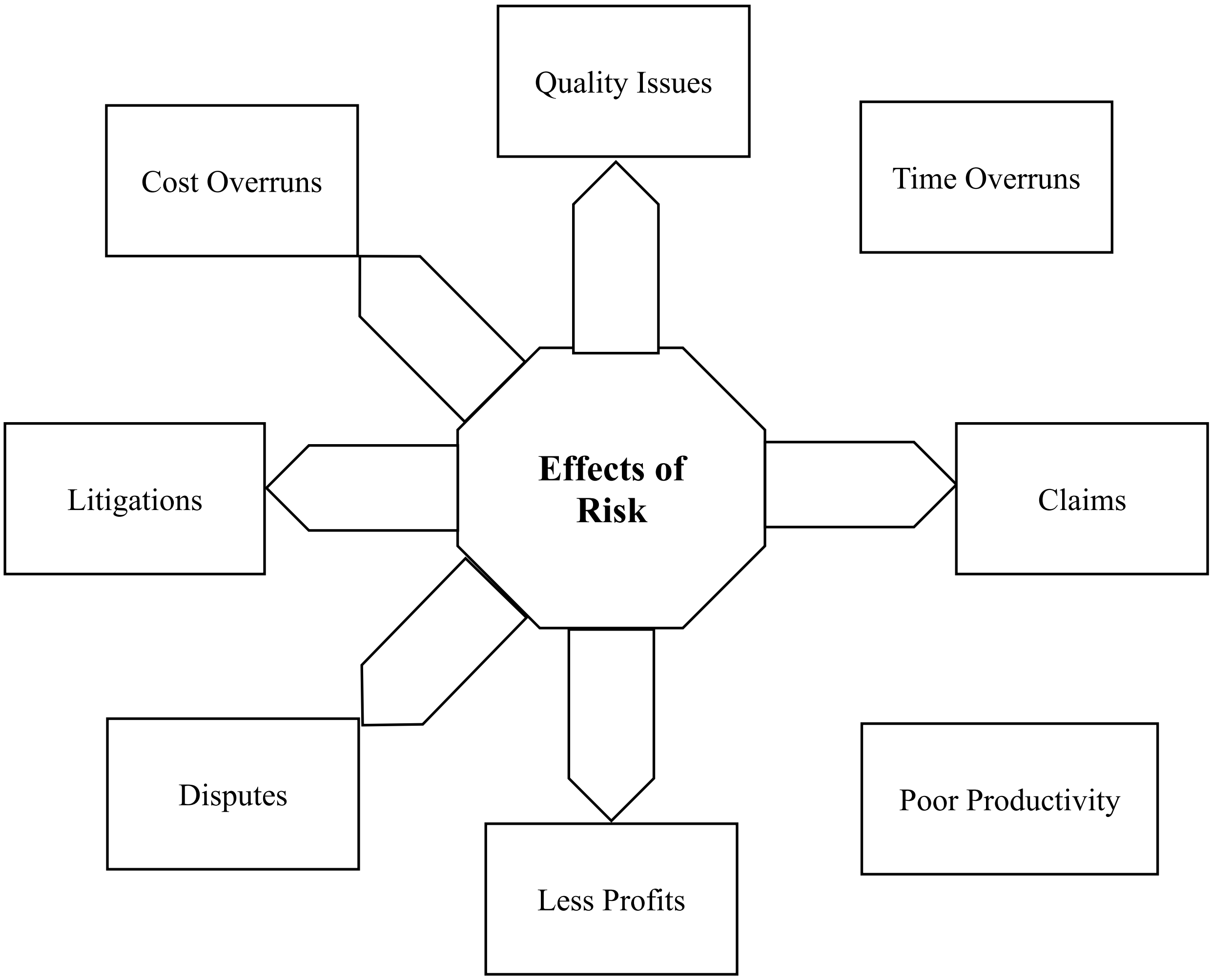

Figure 1.2 Effects of risk on construction projects

To reduce the effects of risk in building and infrastructure projects knowledge of risk management is important. Time overrun make projects delayed and cost overrun sometimes make project companies bankrupt resulting in disputes and litigations. Quality is generally sacrificed to meet cost and time criteria. Poor qualities, cost and time overruns result in claims and disputes. Overall, these risks decrease the profit and increase the losses. So, there is need to manage these risks efficiently.

1.6 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 risk involved [**16,17**]. The purpose of risk identification is not to obtain precise and exact predictions for risk events. Its purpose is to recognize all the possible risks with high impact. Thus, it provides an insight to what risks are present or can be faced in 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 [**18**].

Most of the risk management model suggest that identification of risk should be done as early as possible as it has great impact on project success. This recognition of risk factors will form base for the management strategies and policies. One more important thing is there that we cannot recognize all risks present in construction industry before commencement of the project. Thus, additional emerging risks should be added whenever identified and proper managing strategies should be implemented [**19**]. Management strategies can only be prepared if risk is identified. So identification of risk is very important step as already discussed. In this step, we gather all the possible risks which can be present in a project. All possible scenarios should be studied carefully like source of risk and its effects on project objectives. Participants in the risk identification process should include people from all departments and subject experts because risk can arrive at any stage of the project. Thus, risk identification may include project team, risk managers, matter expert, customers, end-user, project managers, stakeholders, and outer experts. Various methods of risk identification are shown in Table 1.1.

Table 1.1 Methods used for identification of risk

Sr. No.	**Risk identification methods**
1	Brainstorming
2	Delphi Techniques
3	Interview/ Expert Opinion
4	Questionnaires
5	Checklists

The various methods used for risk identification are described below in detail:

1.6.1 Brainstorming

This technique is used for generating idea on a particular topic. In this technique people from different department associated with project gather. A facilitator is there who facilitates the conversation and these people discuss different problems that are faced in past or can be faced in future related to a particular project. So, all the identified factors are noted down and again discussed in last to finalize the risk factors.

1.6.2 Delphi Techniques

The idea of this technique is same as that of brainstorming with only difference that the participants does not gather at same place. The facilitator in this communicate via emails, texts, or other similar platforms. They discuss different risk factors based on suggestions by different participants and come to one common conclusion. In last a list is prepared of identified risk factors.

1.6.3 Interview/ Expert Opinion

In this people with experience in construction projects are interviewed. Expert opinions on risks can help in avoiding risk. By using their experience and opinions a list is prepared of risks affecting project objectives in construction projects.

1.6.4 Questionnaires

A document consisting of number of questions is known as questionnaire. The main purpose of questionnaire is to gather information from respondents. It consists of predetermined checklist of factors of risk identified by documentation reviews, past experience of project members, and case studies of pre- executed projects.

1.6.5 Checklists

Checklists make use of the previous findings documented. Use of checklists is very easy and simple. As this document covers all the possible risks identified in past related to different projects.

1.7 Risk Analysis

Once risk present is identified now the next major step is to assess those risk factors as some factors can be more critical than others. Analysis of risk is the second step of management process [**20,21**]. The purpose of this step is to completely assess the risk factor and to prioritize them as discussed earlier. This step plays an important role as risk mitigation measures are decided based on this step. Analysis of risk can be broadly classified into two categories i.e. quantitative and qualitative risk analysis as per ISO 31000: 2009. Both quantitative and qualitative risk analysis techniques focus on finding the risk factors present in construction projects. Qualitative risk analysis consists of structured and statistical data and quantitative risk analysis consists of data in form of impressions, opinions, checklists, etc. Qualitative technique measures risk in terms of its criticality which gives better idea of risk factor. Generally used method of risk assessment consist of probability and severity of risk factor. In this, the risk factors are analyzed based on the probability and severity of the risk. As the overall impact of risk will depend on the probability i.e. how often it occurs and severity i.e. its impact on project objectives in terms of cost, time, and quality. Analyzing risk like this makes decision making process more precise with real-life conditions faced on site. The purpose of risk management is to assess the outcome of events if project did not proceed according to planned schedule and deadlines. It provides a basic idea that a particular event it did not proceed according to plan can affect this much. Factors identified are prioritized based on their impact on project objectives. Table 1.2 shows different methods commonly used for analysis of risk factors.

Table 1.2 Quantitative and qualitative methods for analyzing risks

Quantitative methods	**Qualitative methods**
Impressions	Probability and impact assessment of risk
Opinions	Risk assessment matrix
Checklists	Relative importance index

Generally used quantitative and qualitative methods of risks analysis are discussed below in detail:

1.7.1 Probability and Impact Assessment of Risk

Probability of risk is defined as frequency of that event to occur and 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 impact of risk which states the criticality of the risk [**22**]. Frequency of risk can be calculated by using equation number 1 and severity of risk using equation number 2.

1. Frequency index

$$\text{R.I.I} = \sum \frac{an}{N*A} \times 100 \qquad (1)$$

Where,

a = weight assigned by respondent

n = responses probability

N = total number of participants

A = maximum weight (5)

2. Severity index

$$S.I = \sum \frac{an}{N*A} \times 100 \qquad (2)$$

Where,

a = weight assigned by respondent

n = responses probability

N = total number of participants

A = maximum weight (5)

1.7.2 Risk Assessment Matrix

The risk matrix is plotted between likelihood and impact of a risk and is divided into three colour codes. This matrix can be divided into more than three colour codes or less than three colour codes depending upon organizations risk assessment plan and risk mitigation strategies. On x-axis impact of risk is plotted and on y-axis likelihood of risk is plotted. Red colour shows high potential value, yellow colour shows moderate potential value and green colour shows low potential value of risk as shown in Figure 1.3. Colour code helps in clear representation of risk factors in terms of their criticality [**23**]. This enables risk managers and project managers to have a clear view of factors regarding which factor needs more attention as compared to others.

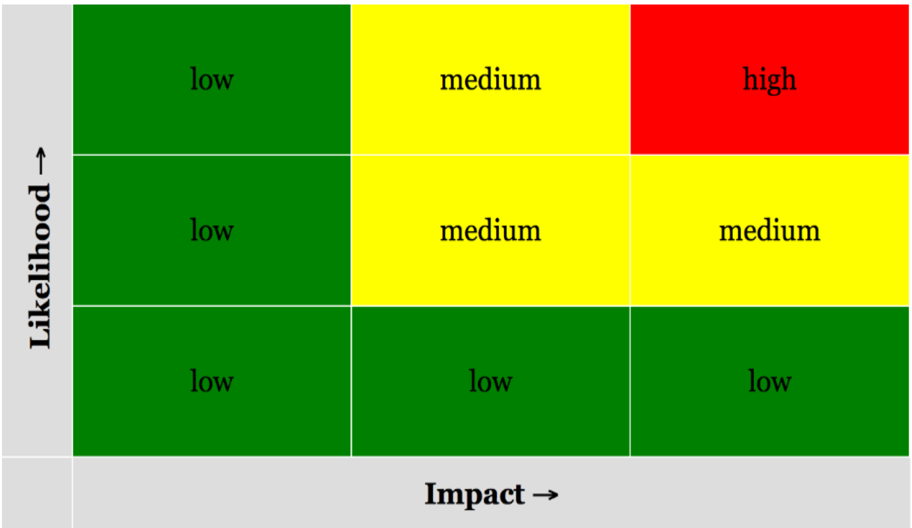

Figure 1.3 Risk Assessment matrix with colour coding

1.7.3 Relative Importance Index

To rank different factors relative importance index can also be used. It has a range between 0.0 to 1.0. This method was used by various researchers in previous research and concluded that higher the RII more significant is the risk factor [**24,25,26**]. It can be find using equation number 3.

$$R.I.I = \sum \frac{Wi}{N*A} \quad (3)$$

Where,

Wi= weighted average

A = maximum weight (5)

N = total number of participants

1.7.4 Sensitivity Analysis

Sensitivity analysis plays an important role in determining uncertain events which can have negative impact on project objectives. Risk is analyzed by changing one element at a time and recording their impact in terms of time, cost, etc.

1.7.5 Probabilistic Analysis

Monte Carlo simulation is used in probabilistic analysis. To identify impact of different risks and uncertainties model is used in project simulation. It is an process in which system chooses random values for different risk factors from its probability distribution. It generally uses 3-point estimates for calculation and analysis i.e. most likely, worst case, best-case scenarios.

1.7.6 Decision Tree and Scenario Analysis

In this analysis, we take help of diagrams known as decision tree diagrams. These tree diagrams are used for formulating the problems faced and evaluating the available options. In scenario analysis, graphical representation is used and it clearly reflects the effects on decisions. It shows the effect of different scenarios that can happen in construction projects individually as well as simultaneously. Decisions tree diagrams are considered as one of the easiest ways of analyzing data. So, we can have an idea that if something goes in particular direction how it will affect our project.

1.8 Risk Register

The data set for risk identified and analyzed should be recorded in a register and that register is known as risk register [**27**]. The register for risk should be prepared by different organizations on their own as they know their process and management strategies better than others. Most of the companies do not use this register because of lack of knowledge and data. The risk event that has passed should also be written for future reference. It should be integral part of risk management system. It is helpful in knowing risk better when similar projects are done. Example of risk register for risk recording is shown in Table 1.3. It can be filled according to the company’s response plans.

Table 1.3 Risk register example for risk recording

Sr. No.	Risk Factor	Risk Response	Remarks

1.9 Risk Treatment

The next step is treating risk with suitable strategies such that its negative effect is minimized. PMBOK defines risk treatment as options available for an organization to minimize the negative effects and maximize the positive effects of a risk. The increment or decrement of risk depends upon this stage. If treatment is done correctly outcome of positive events increases and effect of negative events decreases. The Various risk treatment plans are listed in Table 1.4.

Table 1.4 Various risk treatment plans for mitigating risks

Sr. No.	**Treatment plan**
1	Avoiding Risk
2	Mitigating Risk
3	Transferring Risk
4	Accepting Risk

These four treatments that can be used by construction practitioners while dealing with risk are described in detail below:

1.9.1 Avoiding Risk

Avoiding risk in construction industry means walking away from projects that contain higher risk. This is the best solution when the management team thinks that they cannot manage risk in new projects because of inadequate knowledge and resources. As construction companies has to plan properly before entering into any new project. Examples: avoiding unfamiliar material supplier, etc**.** [**28**].

1.9.2 Mitigating Risk

Mitigating risk means trying to minimize the negative effects and keeping risks low. Different things can be done by project team to mitigate risk in construction industry. Often it is seen that construction projects are more successful when mitigating measures are used. In this generally effect of risk is decreased by changing the scope of the project [**29**]. Example:

implementation of risk management strategies, adopting simple construction techniques, better planning and scheduling, etc.

1.9.3 Transferring Risk

In this treatment risk is transferred to a party that is ready to accept responsibility. Transferring risk is costly as well as safe in nature. In this generally, insurance is done, but it safeguards from any unforeseen situation. Amount of money lose in insuring is very much less than money required for compensation if something goes wrong. This cost can be added in budget so that there are no hidden expenses. This treatment is considered as best with respect to financial stability in case of risk is emerged.

1.9.4 Accepting Risk

This is used when organizations are not able to use other risk treatments. Sometimes construction companies decide to accept the risk when they analyze that the consequences of risk are of low potential or having minor effect on project outcomes. In this, all other options are also considered but sometimes management decides to accept the risk. Risk accepted could have more potential impact than analyzed but this is the only way when company doesn't want to invest resources on mitigating measures.

1.10 Risk Evaluation

To check the above-prepared risk management plan whether going right or not monitoring and control should be implemented. In this new emerged risk are also added in risk management plan. It is the last stage of the process and has an equal importance in this whole process. So, proper control and monitoring should be implemented on the whole process.

1.11 Risk Classification

Construction projects consists of internal and external risks which can be further divided into various categories [**30**]. Classifying into categories is important because these projects contains 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 categorization of risk, we can optimize our risk management process and thus avoiding losses [**31**]. Many researchers classify risk in different categories based on various parameters and assumptions. Risk categorization also depends upon organizations as they classify risk according to their suitability. In this research risk categorization is done by in-depth study of risk categories and combining various categories where necessary. A try is done to cover all the possible risks under these categories. Various risk categories were joined like technical and construction risk categories were joined to form one category. Similarly, contractual and legal was joined to form one category. Resource and site-related category were joined to form one category. Economic category and finance category were joined to form one category. Safety and health category were joined to form one category. A total of eight risk category were recognized. Various different categories that are combined is shown in Table 1.5.

Table 1.5 Various risk categories present in BIP

Category	**Category**	**Category**	**Category**	**Category**
Economic	Political	Finance	Social	Construction
Site-related	Safety	Design	Health	legal
Labour	Management	Market	Equipment	Environment
Finance	Resources	Finance	Natural	Technical

1.11.1 Management Risks

These are those risks which arise due to mismanagement of events/resources by the management team. In this skills, experience of management team plays an important role. They have to take fast and accurate decisions for better results. Any delays or pauses in decision making can result in huge losses. Some of the major management risks present in building and infrastructure projects are listed Table 1.6.

Table 1.6 Management risk in building and infrastructure projects

Risk ID	**Description of risk factor**
R1	Poor coordination or communication among various parties
R2	Poor management skills
R3	Lack of experience of the project team
R4	Personal conflicts between different clients involved
R5	Poor site management and supervision
R6	Shortage of skillful managers and professional's
R7	Improper project planning and budgeting
R8	Change of top management
R9	Inadequate quality planning and quality assurance
R10	Lack of clarity over roles and responsibilities
R11	Government restrictions on foreign companies

Risk categorization is shown in Figure 1.2 for getting idea of various risk categories considered.

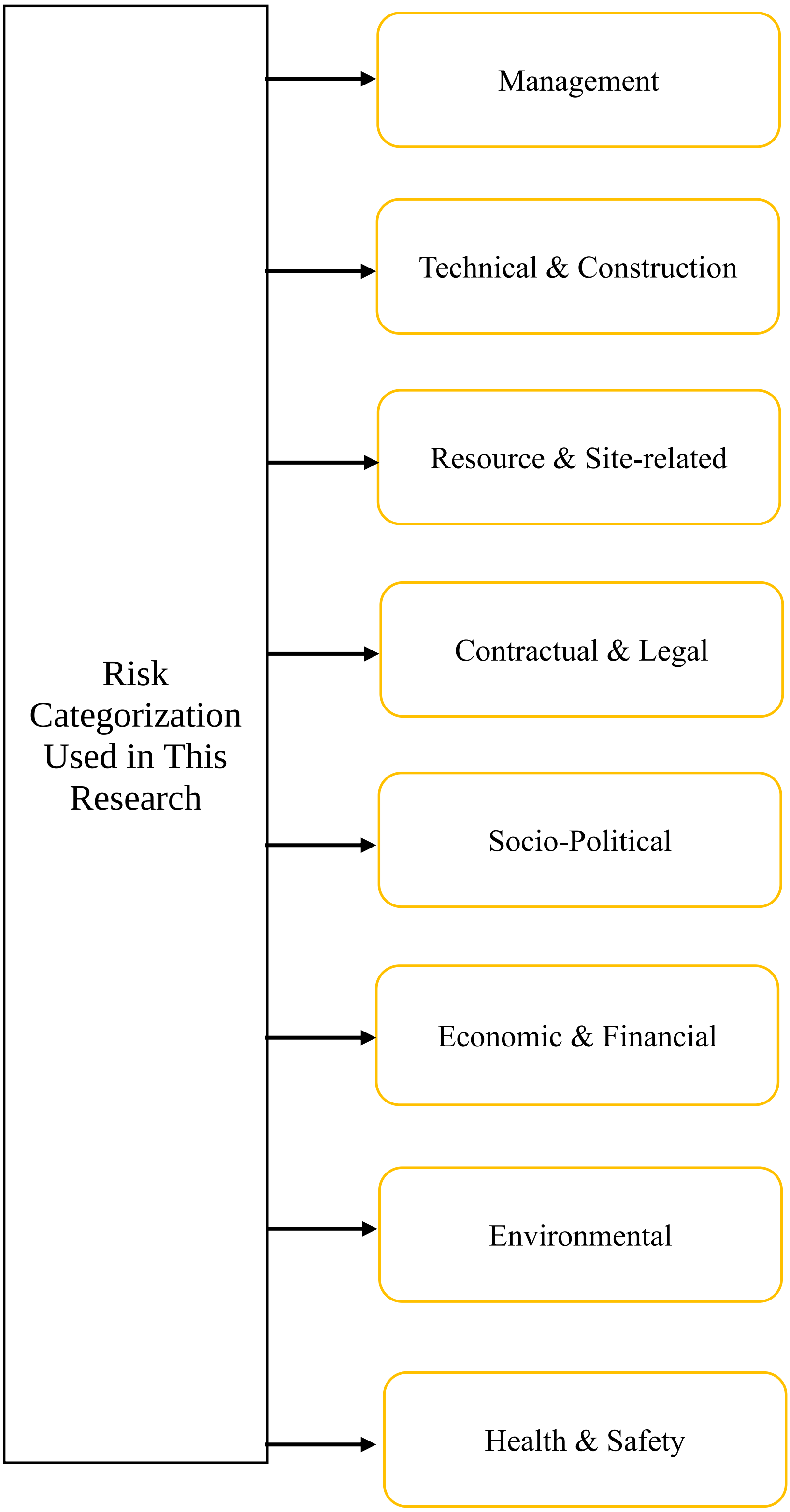

Figure 1.4 Risk categorization used in research

1.11.2 Technical and Construction Risk

Technical risks and construction risk are also very important in project success. In technical risk aspects like specifications, technology, design, and engineering are there. In construction risks aspects like cost/time overruns, quality, construction methods are there. For successful completion of project, these aspects should be managed timely. Some of the major Technical risks and construction risk present in building and infrastructure projects are listed Table 1.7.

Table 1.7 Technical risks and construction risk in building and infrastructure projects

Risk ID	Description of risk factor
R12	Design errors or design changes
R13	Unclear and incomplete detailing in design drawings and specifications
R14	Using poor construction techniques
R15	Delay in design
R16	Complexity of design
R17	Inadequate experience of contractor in same projects
R18	Construction errors and poor workmanship leading to rework
R19	Approval and permit delays
R20	Pressure to crash project duration (time constraints)
R21	Using complex construction methods/techniques
R22	Changing construction methods/techniques in between of work

1.11.3 Resource and Site-Related Risks

Risks like availability of material, labour, and equipment are resource risk. On the other hand, site-related risks are those which are related to site like unforeseen underground conditions, availability of necessary items on-site like electricity, accessibility of site, etc. Some of the major resource and site-related risk present in building and infrastructure projects are listed Table 1.8. Resource related risks plays an important role as sometimes due to shortage of material, lobour and materials projects are delayed for a long time. Due to unavailability of resources productivity also decreases. Overall, this results in increasing cost and time required for completion of the project.

Table 1.8 Resource and site-related risk in building and infrastructure projects

Risk ID	Description of risk factor
R23	Low productivity and efficiency of equipment
R24	Breakdown of plant and machinery
R25	Shortage of skillful workers locally
R26	Shortage or delay in delivery of expected materials
R27	Unavailability or shortage of equipment
R28	Low labour productivity
R29	Adverse ground conditions
R30	Unavailability of utilities on-site required for construction
R31	Difficulties in accessing site due to topography of the region
R32	Inadequate preliminary survey and tests of site
R33	Delays in the site possession

1.11.4 Contractual and Legal Risks

Contractual and legal risks are those which are related to disputes in contract documents, claims, and other problems related to legal system. It can arise at any stage during construction process. This can result in major delays and cost increase as sometimes decisions from court are delayed for long time. Some of the major contractual and legal risks present in building and infrastructure projects are listed Table 1.9.

Table 1.9 Contractual and legal risks in building and infrastructure projects

Risk ID	Description of risk factor
R34	Contradictions in the contract documents
R35	Changes in project scope
R36	Litigations and disputes retarding project progress
R37	Contractual disputes and claims
R38	Huge competition at the tendering stage
R39	Change in codes and regulations
R40	Unreliability of the legal system

1.11.5 Economic and Financial Risk

This risk category is related to risk arising due to increase in taxes, inflation, changing foreign exchange, introducing new economic policies, etc. these risks directly affects the financial capacity of the project as these things are not considered while planning of budget. So, these risks need to be planned at the starting of the project. Sometimes project has to suffer a lot in terms of completion time due to funding problems. So economic and financial risks should be studied carefully and precisely. Some of the major economic and financial risk present in building and infrastructure projects are listed Table 1.10.

Table 1.10 Economic and financial risk in building and infrastructure projects

Risk ID	Description of risk factor
R41	Unpredicted changes in interest rates
R42	Payment delays
R43	Failure to meet revenue targets
R44	Unpredicted changes in inflation rates
R45	Inaccurate assessment of market demand
R46	Project-funding problems
R47	Fluctuation in exchange rate of currency

1.11.6 Socio-Political Risk

Socio-political risks arise due to social and political nature of the area in which project is to be taken. Social risks are those which are related to religious differences, different cultures, etc. political risks are those which arises due to change of government, policies, laws, and regulations. Sometimes new codes or guidelines are imposed in during ongoing project. Some of the major socio-political risks present in building and infrastructure projects are listed Table 1.11.

Table 1.11 Socio-political risks in building and infrastructure projects

Risk ID	Description of risk factor
R48	Unfavourable social environment
R49	Political instability of the government
R50	Compensation and land acquisition problems
R51	Public opposition to the project
R52	Different religious and cultural beliefs

R53	Laws and policies revising in between of project
R54	Labour disputes and strikes
R55	Improper project feasibility study
R56	Govt. officers asking for bribes
R57	Outbreak of hostilities (riots, revolutions & terrorism)

1.11.7 Environmental Risk

Environmental risks are those which arises due to change in nature like landslides, earthquakes, continuous rainfall, etc. These risks generally remain unnoticed till it occurs because of unknown local conditions like weather. Environmental risks can cost huge loss of money and time if not planned properly. Some of the major environmental risks present in building and infrastructure projects are listed Table 1.12.

Table 1.12 Environmental risks in building and infrastructure projects

Risk ID	Description of risk factor
R58	Pollution related to construction activities (dust, harmful gases, etc.)
R59	Strict environmental rules and regulations
R60	Changes in environmental standards
R61	Legal proceedings due to wrong disposal of waste
R62	Bad weather (snow, excess rain)
R63	Natural disasters (floods, landslides, etc.)
R64	Improper assessment of project impacts on environment

1.11.8 Health and Safety Risk

Health and safety risks are those risks which are related to health and safety of people involved in project. These include various safety regulations, preparing for accidents and injuries occurring on-site, etc. Smaller sites and small construction companies most of the times ignore health and safety of the people involved in construction activities. So, government has to make some strict policies regarding health and safety risks along with surprise checks. Anyone found not following health and safety rules and regulations should be fined so that everyone in future follows these regulations. Some of the major health and safety risks present in building and infrastructure projects are listed Table 1.13.

Table 1.13 Health and safety risks in building and infrastructure projects

Risk ID	Description of risk factor
R65	Accidents occurring during construction
R66	Inadequate safety measures
R67	Changed labour safety laws or regulations
R68	Epidemic illness
R69	Damage to property due to unsafe operations
R70	Lack of protection from enclosing area

So, to have an effective risk management plan categorization of risk factors is important. Categorization helps in managing risk more efficiently as it tells which project department should take care of a particular risk. Risk categorization can be different according to company's risk management plan and its execution.

1.12 Outline of the Thesis

The organization of thesis is done into five chapters. Along with chapters, Appendix has also been included for showing additional information and calculation part. These chapters have been discussed in detail in upcoming chapters. Following is the short description of chapters and Appendix included.

1. **Introduction:** In this chapter risk in building and infrastructure projects, need of study, risk categorization, and risk management framework were discussed.
2. **Literature Review:** In this chapter a detailed study of literature related to risk present in building and infrastructure project is done and objectives were decided based on literature.
3. **Research Methodology:** In this chapter methodology of research is written with detailing of tools and techniques used for designing of questionnaire, respondents' profile, and analysis.
4. **Results and Discussions**: In this chapter results of analysis performed were discussed in detail.
5. **Conclusions and Guidelines**: In this chapter conclusions of the research work with risk mitigation model and guidelines are given.

References: References used details

are given

List of publication: Details of papers published

Appendix-A: Questionnaire survey form

Appendix-B: Severity data collected by survey

Appendix-C: Frequency data collected by survey

Appendix-D: Reliability analysis data for data collected

Appendix-E: Factor analysis data for critical risk factors

CHAPTER 2
LITERATURE REVIEW

2.1 General

Risk and uncertainties are defined as events if occur can have positive or negative effect on project objective [**32**]. Generally, accepting risk is a personal choice as different mitigating measures are there which can be incorporated. Some of the previous work done by various authors in the study of risk management in building and infrastructure projects has been conducted below.

2.2 Literature Review

Zhi [33] studied management of risk for overseas construction projects. Zhi classified project risks as external risks and internal risks. Risk management process consists of four main stages- (a) classification of the risk, (b) identification of the risk, (c) assessment of the risk, and (d) response to the risk. For studying the criticality of risks every risk was judged on two criteria. First was the frequency of occurrence of that risk and second was the severity of the occurrence of that risk on objectives. Ranking of risk was done by multiplication of frequency and severity, i.e. R= P*I. The top five risks identified by Zhi in overseas construction projects were inflation, bureaucracy, corruption, low social security & lack of education. The response technique used in overseas projects should be according to the type of project, it can also be different for similar projects depending on location and other significant conditions.

Kangari [34] discussed the risk management by large U.S construction firms and their attitude towards risk. In this study, questionnaire survey technique was used. A total of hundred respondents were considered consisting of top contractors. The results of this study concluded that the contractors understand the contractual and legal risks more seriously. Risk related with quantities were also considered as top risks by the contraction so estimation should be done more accurately. Some other top risks considered were: contract delays, third party delays, changing order negotiations, inflation and financial problems. In risky projects contractors share responsibilities with the owner.

Akintola and MacLeod [35] focused on analysis of risk & its management in the construction industry. A questionnaire survey was prepared which was filled by contractors in the UK and project managers. The survey forms were distributed to hundred top firms in the UK out of which seventy were contractors and thirty were project managers. The response rate of survey forms was found to be 43% with 30 contractors and 13 project management personals completing the form and returning it. A five-point Likert scale was used for rating every risk factor. The organization risk premium index was used for analyzing survey data. The top five risks found in the UK construction industry were contractual arrangements, financial stability, construction-related, market/industry, project (design information).

Shen [36] identified the major delay risks in a project and discussed their possible mitigating measures. Questionnaire survey was prepared and information was collected. Quantitative technique was used for analysis. In this technique opinions, reviews, judgements of experts are considered and discussed thoroughly. The major findings of this study were that there is lack of awareness regarding risk management in construction industry of Hongkong. Making people aware regarding risk management should be done by construction companies as it can save them from huge losses.

Bing and Tiong [37] studies financial crises of Asian construction industry and their efforts to promote risk management in construction projects. It was found that companies involved in international construction business mitigate their financial risks by making deal with local company. This study suggested eight mitigating measures namely- partner selection, control, good relationship, agreement, subcontracting, employment, negotiation, and engineering contract. A mitigation measure consisting of these factors was proposed. This model was applied on three joint ventures and was seen that decision making for international joint ventures was improved.

Uher and Toakley [38] studied risk management in Australian construction industry in the conceptual phase of the project. Questionnaire technique was used for survey. The results of survey showed that participants were aware with risk framework but its use was very low. The main reason for not using risk management in conceptual phase was organization’s lack of interest in training employees to use this framework. Consultants was found to be less interested in this framework as compared to contractors. As very less information is available regarding managing risk.

Gosh and Jintanapakanont [39] identified critical risk factors involved in underground rail projects in Thailand. A questionnaire survey was designed consisting of 59 risk factors based on literature. These factors were focused on risk factors that was affecting the overall project costing, completion time & specifications. Factor-analysis approach was used analyzing survey data. A five-point Likert scale was used for rating every risk factor. The questionnaire was distributed to 150 respondents out of which 122 completed forms were received back. Respondents included project managers, site supervisors, engineers, architects, project operation officers. The top five identified risk factors in Thailand underground rail work were delay in completion risk, finance problems and economic risk, risk related to subcontracting, contract and legal system-related risks, design-related risk.

Wang et al. [40] focused on the risk management framework in developing countries for construction projects. A questionnaire survey was developed consisting of 28 critical risk factors. These risk factors were divided into 3 levels- country level, market level & project level. The main purpose of this research is to make a risk management framework that can be used in construction work in developing countries for positive outcomes. A risk model was proposed named Alien Eyes, which shows different levels and breakdown of risks. 22 risks were found to be critical out of 28 risk factors based on a 7-degree rating system. Mitigation measures were suggested and checked for each and every risk factor. The top five risks in developing countries were found to be: approval and permission by government, law changes in between of the project, unreliability and delay in justice, local partner's creditworthiness, and instability of the political parties.

Bing et al. [41] studied allocation of the risk in UK in PPP/PFI construction projects using a question-survey technique. The findings of this research will help construction practitioners to create better allocation of risk frameworks in the initial stages. After analysis of the survey data, it was clear that either risk was from public sector or it was shared with the private sector. Risks were classified into three levels: macro, meso, micro. Post was used to send 500 questionnaires, out of which 61 were returned and only 53 were useful for analysis relating to risk allocation. The findings of the research show that site-related risk, as well as risk related to political issues, should be checked by public sector. Legislation and relationships risks should be retained by both the parties. Private sector should be responsible for the meso-risks.

Zou et al. [42] identified key risks present in the construction industry of China. Risks were ranked based on their effect on the project objectives (cost-overrun, time-delays, environment, quality issues, safety, etc.) and life cycle of a project. Questionnaire survey method was used for collecting data. A total of 177 survey forms was distributed out of which 86 (46% response rate) was received back and 83 was found valid for data analysis, top 25 risk factors were determined. The survey feedback consists of two parts- the frequency of occurrence and severity of consequences. The conclusion of this research was that everyone should be clear about their responsibilities from the starting stage of the project. This finding was compared with another similar study done in Australia. The unique and top 5 risks in the Chinese construction industry were- problem of funds, lack of experience of contractor in proper management of the project, reimbursement difficulty, no insurance policies taken, and no attention towards construction safety and pollutions.

Schieg [43] identified that projects in which risk management is used results in better understanding of tasks and duties. It gives an idea of quantitative data depending upon different criteria's like size of project, location, etc. it is important that sufficient information is available all the time for taking effective decisions. So, all the ongoing and upcoming process should be properly noted and taken into consideration. In this framework a big event is broken down into smaller events. Thus, mitigation plans are prepared according to that leading to positive outcomes. In last management decides that which risk need more attention.

El-Sayegh [44] examined the risk in the UAE construction industry. A questionnaire survey was designed for this study, consisting of 42 risk factors prepared based on earlier studies in Kuwait, Indonesia, Hong Kong, USA, and China. 200 questionnaire surveys were distributed out of which 70 was received back and 65 completed survey forms were used for analysis. The relative importance index model was used for prioritizing risks depending upon the frequency of the risk and the impact of risk on objectives of the project. Risk factors were classified as internal risk and external risk. Further internal risks were divided into 5 categories- owners related, designers related, contractors related, sub-contractors related, suppliers related and external risks were also classified into 5 categories- political risk, social & cultural risk, economic risk, natural risk, others. The top five important risks in construction industry of the UAE were- inflation in prices, tight schedule to complete project, subcontractors' improper management, and less productivity, delay and shortage of material, design changes by owners. Least significant risks in UAE construction industry were political, cultural, and social risks.

Zavadskas et al. [45] studied assessment of risk in the construction projects. The assessment was done on multi-attribute decision-making methods. In this paper, the risk was divided into three groups- external, project, internal. Only those risk attributes were selected that affect the construction and real estate industry. TOPIS grey and COPRAS-G methods were used for ranking and determining the optimality of different attributes. The proposed model can be used for avoiding negative impacts and increasing the chances of positive outcomes. Decision making has an significant role in construction management. The results of the research show different levels of construction projects and if a risk assessment is done properly, loses can be minimized.

Subramanyan et al. [46] examined construction risk in construction industry of the India. 93 risk factors were recognized by reviewing literature and these risk factors were listed under various subgroups. All these risk factors were included in the questionnaire and were filled by 15 respondents having experience of more than 20 years in the Indian construction industry. For analysis purposes, fuzzy analytical hierarchy process (AHP) was used. The risk was divided into two groups: the first group includes contractor, project manager, owner, resource-specific risk and other group include risk related to environment, consultant, contract-clause, etc. The mitigation measures suggested in this paper are useful if applied in a proper manner, it can increase the chances of positive outcomes.

Enshass et al. [47] used a questionnaire survey technique to collect data for analysis. The study was focused on bridge construction in Pakistan. Thirty-seven risk factors were considered for survey purpose. Seventy-seven filled forms were received and out of which sixty-nine was complete & usable for analyzing data. Further, these thirty-seven risks were categorized into seven categories- financial risks, design risks, health and safety risks, contractual risks, management risks, construction risks, 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, poor site management & supervision, the financial failure of a contractor, inadequate site investigation, and inadequate project planning.

Choudhry and Iqbal [48] 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 purpose. Seventy-seven filled forms were received and out of which sixty-nine was complete & usable for analyzing data. Further, these thirty-seven risks were categorized into seven categories- financial risks, design-related risks, health risks, contractual risks, management risks, construction risks, 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.

Serpella et al. [49] identified that for proper and productive risk management a good methodology, information & experience in that field is required. This research is based on the Chile construction industry which shows both, owners, as well as contractors, never use risk management practices properly which results in a negative outcome and losses. In this paper knowledge-based approach is used and a three-fold methodology is proposed consisting of, risk management model, its assessment, and the use of a best practices model. Initial conclusion was that risk management is still very unsuccessful due to lack of knowledge of risk involved in the construction practices. The use of the proposed approach will help contractors and clients to deal with risk in a better way and avoid losses. Further, this risk management model can be improved by taking more things into account depending on a particular project or specific location.

Ameyaw and Chan [50] evaluated and ranked various risk factors in PPP water supply projects using fuzzy approach in developing countries. A 40-factor risk list was prepared as a questionnaire survey forms. These risks were based on previous literature and case studies in developing countries. All these 40 factors were divided into 3 main factors- financial and economic, legal and social and political, and technical. A seven-point rating system was used in this survey. Probability and severity mean scores were computed separately and then the effect of the risk factor is calculated by taking the square root of multiplication of frequency and severity. The top five risks found were unpredicted exchange rate, corruption, and bribes, water stealing, delay in payment, political issues.

Iqbal et al. [51] studied risk management in construction projects. The study was based on the Pakistan construction industry. For this study, a questionnaire survey was prepared to consist of 37 risk factors. Research was based on finding the significance of different risk factors, ultimately responsible for them. The age score was calculated for each of the risk factors having the same formula as the relative importance index. The risk was classified based on the responsibility of that risk that is contractor, client and on shared bases. Two risk management techniques were used: preventive technique and remedial technique. The top 5 risks involved in the Pakistan construction industry were: payment delays, defective design, lack of funds, accidents in between construction, low performance.

Dandage et al. [52] evaluated risk categories ranking in international projects. TOPSIS technique was used for ranking of the risk categories. The main purpose of this study was to identify major risk categories which affect the project success. Literature review was used for preparing questionnaire survey. Then the survey data was analyzed using TOPSIS for ranking of risk category according to their importance. Eight risk categories were identified and top three categories were namely- political, technical and related to design. This study will help risk managers to manage risk in an improved manner.

Yu et al. [53] identified critical risk factors of transnational PPP projects. A literature review technique was used and 37 articles on TPPP were studied for this research. Selected articles were from 1991 to 2015. The most commonly used methods for the study of TPPP were found to be case studies, surveys, discussions, hybrid methods, etc. The top 5 identified risks were legal risk, tariff risk, cooperation risk between public and private sector, financing risk, and political risk. A checklist is also developed of TPPP critical risk factors that can be used for further research studies and analysis. Checklists are also helpful in understanding risk before it occurs and managing it for better results. Further scope of this research is more papers can be included related to TPPP. Software tools can also be used for analyzing data.

Siraj and Fayek [54] identified common risks in the construction industry. The risk was categorized into following categories (management, environmental, construction and resource-related, technical, contractual & legal related, economic & financial related, social, political, site conditions, health-safety) consisting of 10 risks in each category, that means a total of 110 risk factors was considered. Based on the number of articles considering these risks all the risks were ranked in their individual category as well as overall top 10 risks. for this analysis, a total of 130 articles was selected. Most of the selected articles were considering infrastructure projects in regions of Asia and Europe. The top risks identified from this research were design errors, change in the inflation rate, bad engineering practices, change in government laws in between of the project affecting outcomes.

Willumsen et al. [55] focused on management of risk to add value to the project. In this paper review of literature and empirical study was done to add value to project. Interviews of experts and qualitative analysis was done for empirical study. It was found that stakeholders perception plays an important role in giving importance to a particular item. The results indicate that there is a need of better understanding of different risks according to stakeholder's perception as it adds more value to risk management process. Risk management creates value to the project in terms of project outcomes as well as it tells how threatened was the value of risk. Sometimes to win a tender risk manager ignore the risks involved in a project. Still, there is lack of knowledge of managing risk in construction industry which results in lot of losses in terms of cost, time, quality, etc.

Ugwu et al. [56] examined risk management practice in construction industry of Nigeria. Construction plays an important role in enhancing economic growth. Every construction project some sort of risks. These risks cannot be removed and can only be managed. For this study quantitative approach was used as it is based on experience, knowledge, opinion, beliefs of an expert in the field. A total of two-hundred questionnaire was sent and only one-fifty was valid for the analysis. SPSS was used for the analysis of data using factor analysis approach. The results show that risk can be managed by proper identification of risk, its management, and control. Risk mitigation measures also play an important role in successful completion of project.

Viswanathan et al. [57] studied the effect of risk mitigation measures on success of the international construction projects in Indian scenario. Literature review technique was used to identify nine mitigation measures for risk and three success criteria for the projects namely- performance of cost, schedule, and firm. Factor analysis and structural equation modeling was used for modeling and analysis of data obtained from questionnaire survey of 105 respondents. Three correlated risk mitigation measures were identified namely- pre-planning of project, participation of local people and selection of contract. This paper focuses on developing a risk mitigation model which can be used to deal with different risks involved. The finding of this research will help construction practitioners to improve success rate of projects in India and similar countries.

Monzer et al. [58] focused on the identification of heterogeneous group of experts for assessment of risk present in construction industry. In this paper it was recognized that the risk assessment is based on group of decision-makers. In this analysis decision-makers provide their reviews for probability and impacts of risk factors. Consensus reaching process is used for agreement on same decision but is having some limitations like it consumes a lot of time. Objective of this paper is to measure the criteria for being expert in a field. Expertise level can be calculated by checking years of experience, reputation, knowledge, professional performance, etc. thus weights can be assigned according to the level of expertise.

2.3 Summary of Literature Review

1. The initial findings state that the risk management is still not widely used in construction projects because of lack of proper knowledge regarding its process.
2. It was also found that in most of the articles for research work two or more identification tools were used. Literature review, surveys, interviews was most commonly used identification tools and techniques.
3. Risk was classified on different criteria’s and most commonly used criteria was based on source of risk.
4. The literature suggests that there is need of identification and management of risk in construction industry especially in building and infrastructure projects as very less research is done in that area.
5. There is also need of focusing on risk mitigation measures and their implementation in construction industry. Timely management of risk will result in more positive outcomes in terms of time, cost, etc.

6. However, every construction project contains some risk. We can manage risk but cannot ignore it.

2.4 Objectives

1. To evaluate the probability and severity of the risk factors using relative importance index and overall impact of risk factors using risk impact value.
2. To analyze the statistical association between various risk factors using SPSS and rank all significant project performance risks and opportunities (“risks”).
3. To minimizes the consequences of risk by suggesting risk mitigation model and making recommendations against the critical risk factors identified.

2.5 Scope of the Study

This study will help construction practitioners to understand the risk present in building and infrastructure projects on the basis of risk frequency and severity. Frequency helps in taking decisions such as how frequently a risk can occur during project construction lifetime and severity is knowing how severe a risk can be once it has occurred. This study also recognizes critical risk factors that has maximum negative effect on project objectives. A risk mitigation model is also proposed in this study along with guidelines to manage risk more effectively and efficiently. This research will fill the knowledge gap regarding risk management framework in building and infrastructure projects.

CHAPTER 3
METHODOLOGY

3.1 General

This section explains the structure and technique which was used for achieving objectives of this research. In this study data collection was done using quantitative research method i.e. questionnaire survey. The questionnaire was filled by project manager, site supervisor, engineer, contractor, consultant. The project methodology involves the identification, analysis, and management of the risk factors associated with the building and infrastructure projects. The main purpose of this research is to develop a risk management framework that can be used in construction work for minimizing the consequences of negative events.

3.2 Research Methodology

First step in project methodology is identification of the risk factors associated with the building and infrastructure projects. For this study a questionnaire survey was designed consisting of 70 risk factors based on literature. These risk factors were categorized into eight major categories namely- 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.). Next step of research methodology was analysis of the data obtained. Each risk factor was judged on the basis of severity of risk and frequency of risk. These survey forms were distributed to contractors, consultants, site supervisors, engineers, etc. and was asked to fill these questionnaires based on their understanding and experience of risk involved in building and infrastructure projects. Each of the risk factor is also checked for reliability and if found not reliable either it is improved or removed. Then this data was analyzed for probability of risk and severity of risk using relative importance index. Further risk potential value and risk impact value was calculated and these values were normalized. With the help of normalized values critical risk factors were identified. SPSS was used to analyze the statistical association between various risk factors. Then based on the analyses ranking of risk factors is done. Last step in research methodology was management of risk. In this critical risk factors are taken into account for minimizing the consequences. For this purpose, risk mitigation model was prepared consisting of various important aspects useful in maximizing positive outcomes. Recommendations against the critical risk factors was also proposed. The project methodology is shown in Figure 3.1 using a flow chart:

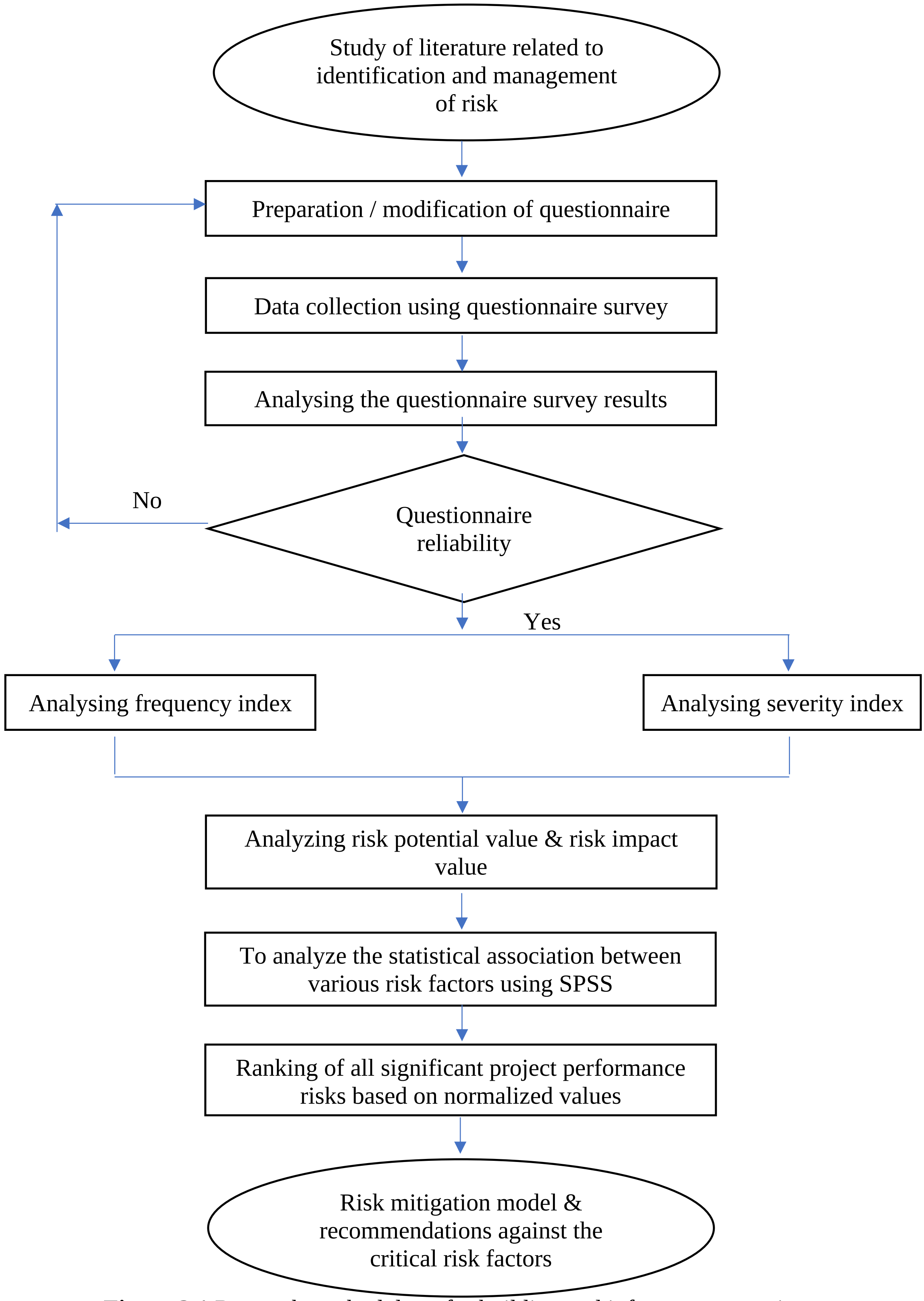

Figure 3.1 Research methodology for building and infrastructure projects

3.3 Building and Infrastructure Projects

In this research we have focused on identification and management of risk in building and infrastructure projects. Building projects consist of residential projects, hospital projects, office buildings, commercial buildings, and mixed development. Infrastructure projects consists of highways, tunnels, bridges, drainage systems, sewage treatment plants, etc [**59**]. Questionnaire survey was prepared based on risk related to building and infrastructure projects as discussed in further topic.

3.4 Questionnaire Structure

The main purpose of questionnaire is to gather information from respondents. It consists of predetermined checklist of factors of risk identified by documentation reviews, past experience of project members, and case studies of pre-executed projects [**60,61,62,63**]. Pilot study was done on questionnaire to check its clarity and ease of understanding questions. Risk factors those were found to be not related to questionnaire structure or those factors which were found repeated was removed or modified. Few risk factors were modified and five risk factors were removed. The questionnaire consisted of three parts: first part consisted of general information of respondent as shown in Figure 3.2. Whole questionnaire is shown in Appendix-A.

1. Name (Optional):	
2. Contact No. (Optional):	
3. Position in the company:	☐ Project Manager ☐ Site Supervisor ☐ Engineer ☐ Contractor ☐ Consultant ☐ Any Other (Specify) ______________
4. Company name:	
5. Years of experience:	☐ < 5Years ☐ 5-10Years ☐ 10-15Years ☐ 15-20Years ☐ >20Years
6. Nature of company:	☐ Owner ☐ Consultant ☐ Contractor ☐ Any Other
Do you implement risk management in your projects?	☐ Yes ☐ No
Do you think it is necessary to implement risk management?	☐ Yes ☐ No

Fig. 3.2 General information of the respondent

3.5 Respondents Profile

The designed survey was filled by one-forty-seven respondents in which they have responded to the total of 70 risk factors. The respondents include project manager, site supervisor, engineer, contractor, consultant. Respondents filling questionnaire was from the state of Punjab and Himachal Pradesh. These respondents were having experience of working in different parts of India thus dealing with a number of situations which need risk management.

Thus, the results of this study can be generalized and can be used by construction practitioners to manage risk efficiently. The numbers of participant and their roles in construction industry are shown below in form of pie chart as Figure 3.3.

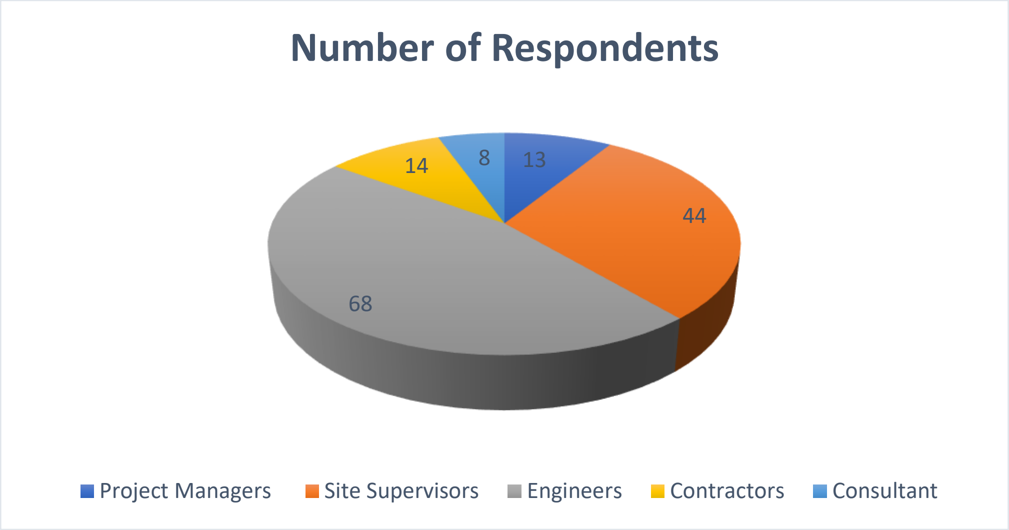

Figure 3.3 Total number of participants in survey

Respondents was having experience of working in different parts of country. Number of years of experience along with number of respondents are shown in Figure 3.4 in the form of bar chart. Probability and severity of each factor was judged. Probability was judged on three-point Likert scale and severity was judged on five-point Likert scale.

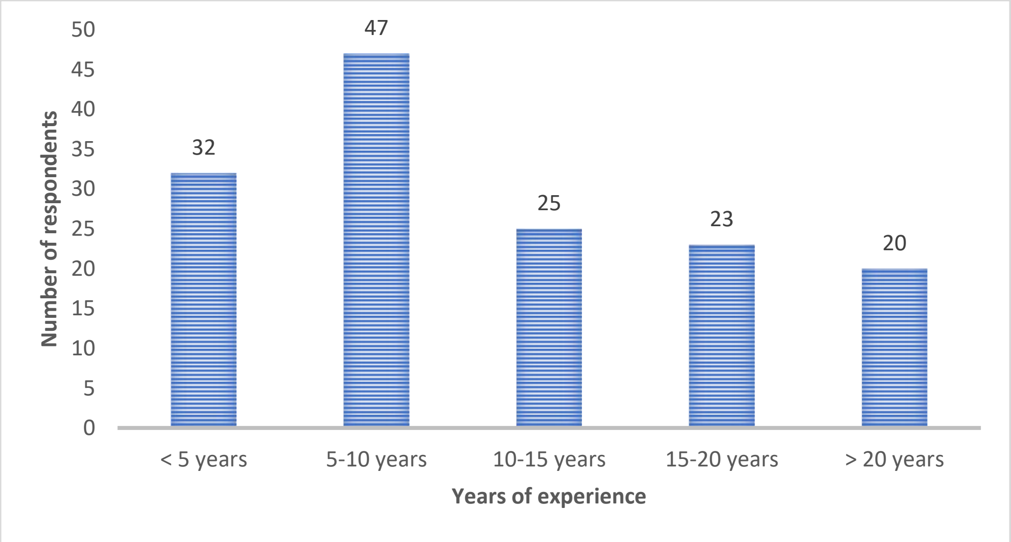

Figure 3.4 Details of participants with number of years of experience

3.6 Risk Models

Analyzing risk is a major part of risk management process, as it provides information about how critical a risk can be if it occurs. Decision made on the basis of this analysis is often precise in nature as this analysis try to cover all the possible options and outcomes. The conducted survey was filled by site supervisors, engineers, contractors, consultants, and project managers. These surveys were filled by people with experience in building and infrastructure projects. Each factor was judged on the basis of probability and severity. Three-point Likert scale was used for frequency and five-point Likert scale was used for severity. Questionnaire survey was filled by respondents according to scale of frequency and severity as shown in Table 3.1.

Table 3.1. Scale for measuring frequency and severity

Likert scale rating	**Probability scale**	**Likert scale rating**	**Severity scale**
1	Low	1	Very low
2	Moderate	2	Low
3	High	3	Moderate
		4	High
		5	Very High

- **Relative importance index**

For measuring frequency index and severity index relative importance index was used as shown in equation number (4). It has a range between 0.0 to 1.0. This method was used in literature for risk based on Likert scale. Higher the R.I.I more significant is the risk factor.

$$\text{R.I.I} = \sum \frac{Wi}{N} \qquad (4)$$

Where,

Wi= weighted average

A = maximum weight (5)

N = total number of participants here

- **Risk Impact Value**

For calculating risk impact value first, we need to find risk potential value (RPV). Risk potential value was calculated using equation number (5) which is multiplication of frequency index and severity index.

$$\text{R.P.V = Frequency index x Severity index} \qquad (5)$$

Further we take square root of RPV to calculate risk impact value, which is shown in equation number (6).

$$\text{R.I.V} = (\text{R.P.V})^{0.5} \qquad (6)$$

3.7 Statistical Analysis and Ranking

The results of risk models are further analyzed statistically to check the association between various identified risk factors using SPSS and rank all significant project performance risks. These analyses are important to ensure reliability and validity of the data obtained from questionnaire survey.

3.7.1 Reliability Analysis

Reliability analysis is a way of checking internal consistency and validity of questionnaire [**64,65,66,67**]. It is important to check internal consistency and validity as it tells us that whether our purpose of performing survey is fulfilled or not. Reliability varies between 0 to 1. The more it is closer to 1 more reliable our data. More reliable means we are able to prepare a questionnaire which is going in same direction i.e. finding critical risk factors. Reliability can be improved by removing some factors which have low reliability. It can also be improved by modification of risk factors in such a way that it asks same thing. Reliability can be found by using different models like- Cronbach alpha analysis, parallel analysis, Guttman analysis, strict parallel analysis, and split-half analysis. In this research we have used Cronbach alpha analysis for checking reliability of our questionnaire. A question should pass from four stages to check that it is valid and reliable.

Table 3.2 Stages for a question to be valid and reliable

Stages	**Process involved**
1	Design of question should meet the criteria of data requirement
2	Survey participant decrypts the question as researcher aims
3	Participant answers the question
4	Researcher decrypts the answer as participant intends

3.7.2 Factor Analysis

After finding critical risk factors, factor analysis was performed to reduce the number of variables. Factor analysis is considered as best data reduction method [**68,69,70**]. Factor analysis uses quantitative data. Factor analysis technique make use of maximum common variance present in different variables and places them into a common score. Before performing factor analysis KMO and Bartlett’s test for adequacy of data is performed to check whether factor analysis can be performed or not. Assumptions considered in factor analysis are- linear relationship between factors, variables having correlation, no multicollinearity and variables are relevant according to analysis. There are number of methods for performing factor analysis like principal component analysis, maximum likelihood method, image factoring, common factor analysis, etc. we will be using principal component analysis in our research work.

3.8 Risk Mitigation Model and Recommendations

To minimizes the consequences, risk mitigation model was suggested in this study along with recommendations against the critical risk factors identified in building and infrastructure projects. Mitigation model plays an important role in ensuring smooth and efficient completion of the project [**71**]. It makes parties responsible for management of certain tasks. Risk in construction projects cannot be ignored, it can only be managed by implementing mitigation measures. Implementing mitigation measures help in minimizing the effects of negative events and maximizing the outcomes of positive events [**72**]. The main purpose of this research is to develop a risk management framework that can be used in construction work for positive outcomes. Further, this risk management framework should be continuously improved for new emerging risk factors encountered during the construction process. Components of risk mitigation model are shown in Figure 3.5 in the form of flow chart.

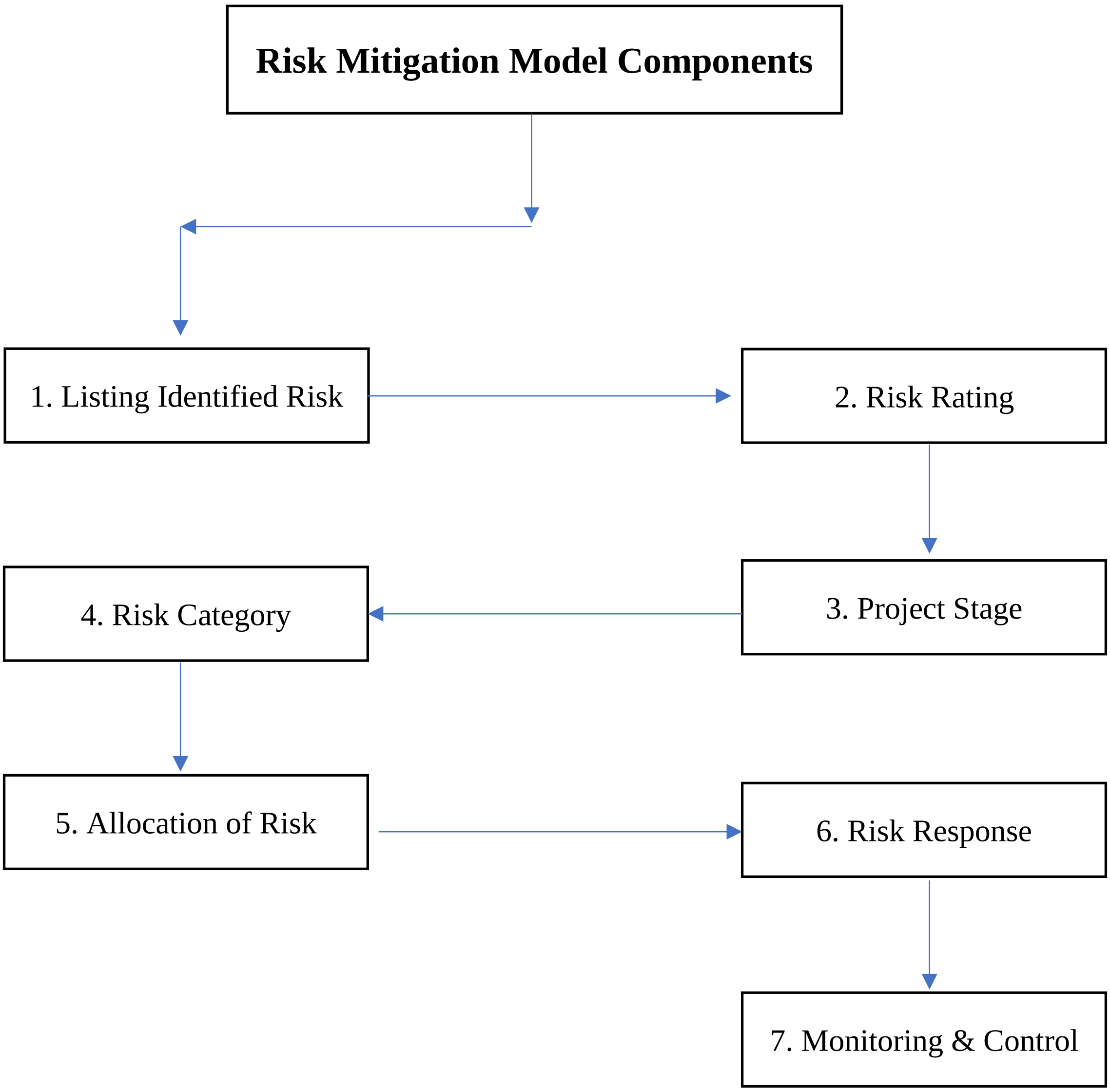

Figure 3.5 Components of risk mitigation model

Risk management is an iterative process. So, continuous control and monitoring will be required on the whole risk management process. Guidelines and recommendations are also suggested for managing risk factors present in building and infrastructure projects.

CHAPTER 4
RESULTS & DISCUSSIONS

4.1 General

The designed survey was filled by 147 respondents in which they have responded to the total of 70 question. Data obtained from questionnaire survey for severity is shown in Appendix-B and data obtained for frequency is shown in Appendix-C. 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 reliability analysis, factor analysis, etc. are also performed.

4.2 Reliability Analysis

Reliability analysis was performed on probability and severity data. For checking reliability Cronbach alpha technique was used. Statistical software SPSS was used for analyzing reliability of the data as shown in Appendix-D. Reliability was checked for individual categories as well as overall reliability was also checked. If value of Cronbach alpha is found to be greater than 0.70 than database is said to be reliable. The overall Alpha coefficient value for severity was found to be 0.941 and individual category alpha value for severity is shown in Figure 4.1. Minimum individual category value of alpha coefficient for severity was found to be 0.706 and maximum individual category value of alpha was found to be 0.879.

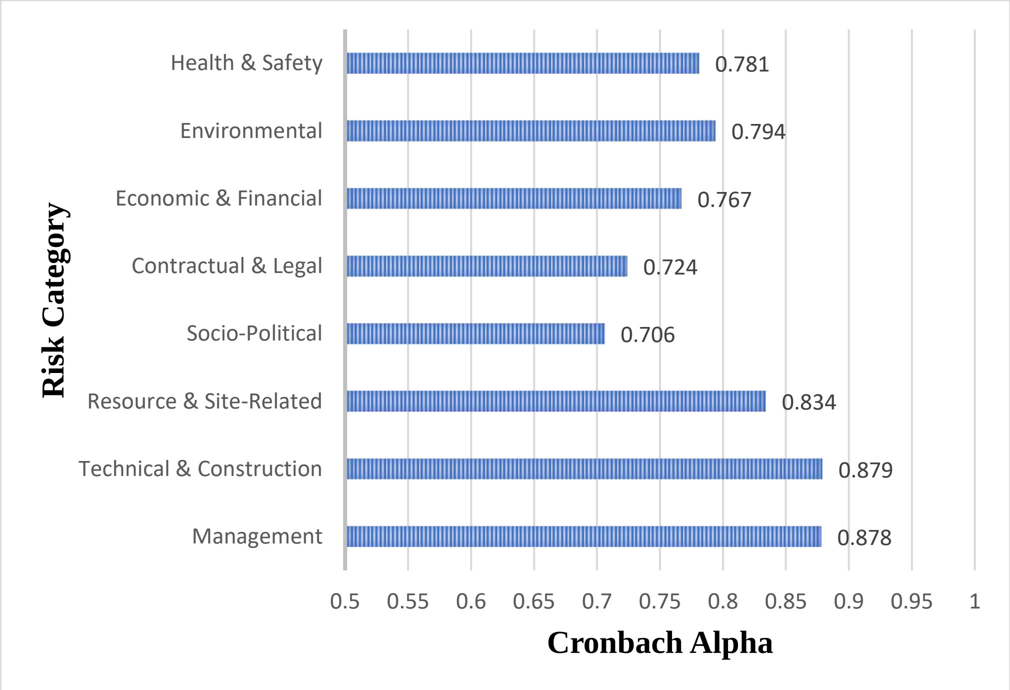

Figure 4.1 Severity Cronbach alpha for different categories

The overall alpha coefficient value for probability was found to be 0.908 and individual category alpha value for probability is shown in Figure 4.2. Minimum individual category value of alpha coefficient for probability was found to be 0.76 and maximum individual category value of alpha was found to be 0.872.

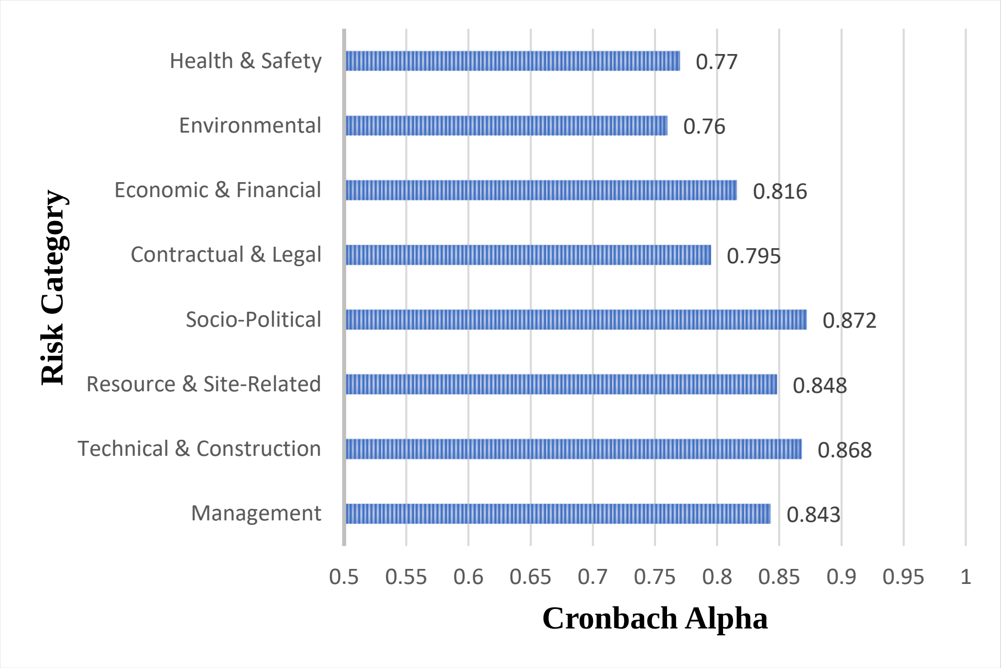

Figure 4.2 Probability Cronbach alpha for different categories

4.3 Frequency Analysis and Ranking

Once data collection is done from questionnaire survey next step is to analyze it Probability of risk is defined as its ability to repeat in a particular period of time. In questionnaire, survey probability was assessed on three-point Likert scale. One signifies low probability, two signifies moderate probability and three signifies high probability. The collected data is analyzed for probability of risk using relative importance index and is known as frequency index as shown in Table 4.1. The calculation consist of four columns- first column indicates the serial number of risk code, second column describes the risk factor, third column consist of three sub-columns which indicate the frequency on scale of three and last column indicate the frequency calculation using relative importance index with rank for frequency. In this the ranking of risk factors is done based on frequency index as shown in Table 4.1.

Table 4.1 Ranking of risk factors in relation with frequency

Risk ID	Risk factor	1	2	3	FI	Rank
R19	Approval and permit delays	22	56	69	2.32	1
R42	Payment delays	21	65	61	2.27	2

R20	Pressure to crash project duration (time constraints)	20	70	57	2.25	3
R38	Huge competition at the tendering stage	22	66	59	2.25	4
R29	Adverse ground conditions	31	57	59	2.19	5
R6	Shortage of skillful managers and professional’s	37	49	61	2.16	6
R12	Design errors or design changes	29	65	53	2.16	7
R50	Compensation and land acquisition problems	27	71	49	2.15	8
R13	Unclear and incomplete detailing in design drawings and specifications	31	65	51	2.14	9
R26	Shortage or delay in delivery of expected materials	33	61	53	2.14	10
R37	Contractual disputes and claims	33	61	53	2.14	11
R23	Low productivity and efficiency of equipment	30	68	49	2.13	12
R24	Breakdown of plant and machinery	35	59	53	2.12	13
R44	Unpredicted changes in inflation rates	40	49	58	2.12	14
R10	Lack of clarity over roles and responsibilities	27	76	44	2.12	15
R17	Inadequate experience of contractor in same projects	42	46	59	2.12	16
R51	Public opposition to the project	30	70	47	2.12	17
R32	Inadequate preliminary survey and tests of site	36	60	51	2.10	18
R9	Inadequate quality planning and quality assurance	34	65	48	2.10	19
R27	Unavailability or shortage of equipment	37	59	51	2.10	20
R55	Improper project feasibility study	38	58	51	2.09	21
R59	Strict environmental rules and regulations	38	58	51	2.09	22
R45	Inaccurate assessment of market demand	36	63	48	2.08	23

R5	Poor site management and supervision	34	69	44	2.07	24
R48	Unfavorable social environment	41	55	51	2.07	25
R25	Shortage of skillful workers locally	40	58	49	2.06	26
R31	Difficulties in accessing site due to topography of the region	38	62	47	2.06	27
R49	Political instability of the government	36	67	44	2.05	28
R53	Laws and policies revising in between of project	41	57	49	2.05	29
R70	Lack of protection from enclosing area	37	66	44	2.05	30
R33	Delays in the site possession	42	57	48	2.04	31
R66	Inadequate safety measures	42	58	47	2.03	32
R54	Labour disputes and strikes	40	66	41	2.01	33
R58	Pollution related to construction activities (dust, harmful gases, etc.)	41	65	41	2.00	34
R4	Personal conflicts between different clients involved	37	74	36	1.99	35
R28	Low labour productivity	47	54	46	1.99	36
R34	Contradictions in the contract documents	47	54	46	1.99	37
R2	Poor management skills	47	55	45	1.99	38
R7	Improper project planning and budgeting	46	57	44	1.99	39
R11	Government restrictions on foreign companies	49	51	47	1.99	40
R36	Litigations and disputes retarding project progress	47	56	44	1.98	41
R16	Complexity of design	47	57	43	1.97	42
R52	Different religious and cultural beliefs	43	65	39	1.97	43
R65	Accidents occurring during construction	42	68	37	1.97	44
R62	Bad weather (snow, excess rain)	47	59	41	1.96	45
R1	Poor coordination or communication among various parties	44	66	37	1.95	46
R15	Delay in design	53	49	45	1.95	47

R56	Govt. officers asking for bribes	51	54	42	1.94	48
R61	Legal proceedings due to wrong disposal of waste	48	61	38	1.93	49
R46	Project-funding problems	57	48	42	1.90	50
R43	Failure to meet revenue targets	53	59	35	1.88	51
R22	Changing construction methods/techniques in between of work	57	52	38	1.87	52
R3	Lack of experience of the project team	51	65	31	1.86	53
R30	Unavailability of utilities on-site required for construction	56	55	36	1.86	54
R47	Fluctuation in exchange rate of currency	51	65	31	1.86	55
R40	Unreliability of the legal system	47	75	25	1.85	56
R60	Changes in environmental standards	58	54	35	1.84	57
R67	Changed labour safety laws or regulations	59	54	34	1.83	58
R63	Natural disasters (floods, landslides, etc.)	56	61	30	1.82	59
R14	Using poor construction techniques	67	43	37	1.80	60
R64	Improper assessment of project impacts on environment	53	72	22	1.79	61
R21	Using complex construction methods/techniques	65	50	32	1.78	62
R41	Unpredicted changes in interest rates	65	57	25	1.73	63
R35	Changes in project scope	66	58	23	1.71	64
R18	Construction errors and poor workmanship leading to rework	71	49	27	1.70	65
R8	Change of top management	75	43	29	1.69	66
R39	Change in codes and regulations	69	57	21	1.67	67
R68	Epidemic illness	74	50	23	1.65	68
R69	Damage to property due to unsafe operations	76	52	19	1.61	69
R57	Outbreak of hostilities (riots, revolutions & terrorism)	76	55	16	1.59	70

Frequency of the risk factors ranged between 2.32 to 1.59. Top fifteen frequency risks identified are namely- approval and permit delays with (FI = 2.32), payment delays (FI = 2.27), pressure to crash project duration (time constraints) (FI = 2.25), huge competition at the tendering stage (FI = 2.25), adverse ground conditions (FI = 2.19), shortage of skillful managers and professionals (FI = 2.16), design errors or design changes (FI = 2.16), compensation and land acquisition problems (FI = 2.15), unclear and incomplete detailing in design drawings and specifications (FI = 2.14), shortage or delay in delivery of expected materials (FI = 2.14), contractual disputes and claims (FI = 2.14), low productivity and efficiency of equipment (FI = 2.13), breakdown of plant and machinery (FI = 2.12), unpredicted changes in inflation rates (FI = 2.12), lack of clarity over roles and responsibilities (FI = 2.12). In above discussion, we have calculated frequency of different risk factors based on the data obtained from questionnaire survey. But frequency analysis is not enough to mark a risk as critical or non-critical. So in next topic severity of risk is calculated to meet the criteria of risk potential calculation.

4.4 Severity Analysis and Ranking

Once frequency index is calculated next step is to calculate severity using relative importance index. Severity calculated using relative importance index is known as severity index (S.I). Severity is the measure of risk factor in terms of how severe a risk can be once it has occurred. In questionnaire, severity was judged on five-point Likert scale. One indicates very low severity, two indicate low severity, three indicate moderate severity, four indicate high severity and five indicate very high severity. Calculations for severity of risk is shown in Table 4.2.

Table 4.2 Ranking of risk factors in relation with severity

Sr. No.	**Description of risk**	**Severity of risk**					**S.I**	**Rank**
		1	**2**	**3**	**4**	**5**		
R63	Natural disasters (floods, landslides, etc.)	5	5	33	43	61	4.02	1
R62	Bad weather (snow, excess rain)	5	16	23	46	57	3.91	2
R44	Unpredicted changes in inflation rates	2	10	39	51	45	3.86	3
R7	Improper project planning and budgeting	8	14	38	41	46	3.70	4

R53	Laws and policies revising in between of project	9	14	32	49	43	3.70	5
R36	Litigations and disputes retarding project progress	7	15	37	47	41	3.68	6
R42	Payment delays	6	19	33	48	41	3.67	7
R37	Contractual disputes and claims	6	21	34	41	45	3.67	8
R12	Design errors or design changes	7	14	41	46	39	3.65	9
R19	Approval and permit delays	9	15	37	47	39	3.63	10
R6	Shortage of skilful managers and professional's	8	14	47	43	35	3.56	11
R20	Pressure to crash project duration (time constraints)	8	17	41	46	35	3.56	12
R3	Lack of experience of the project team	5	17	51	39	35	3.56	13
R46	Project-funding problems	10	21	32	45	39	3.56	14
R9	Inadequate quality planning and quality assurance	9	16	39	51	32	3.55	15
R34	Contradictions in the contract documents	8	25	34	39	41	3.54	16
R13	Unclear and incomplete detailing in design drawings and specifications	5	19	49	43	31	3.52	17
R43	Failure to meet revenue targets	8	19	44	41	35	3.52	18
R25	Shortage of skilful workers locally	11	21	36	42	37	3.50	19
R2	Poor management skills	8	14	53	43	29	3.48	20
R68	Epidemic illness	11	24	31	45	36	3.48	21
R50	Compensation and land acquisition problems	10	19	44	39	35	3.48	22
R54	Labour disputes and strikes	11	21	35	47	33	3.48	23
R29	Adverse ground conditions	13	25	33	36	40	3.44	24
R32	Inadequate preliminary survey and tests of site	6	31	37	38	35	3.44	25
R41	Unpredicted changes in interest rates	14	21	31	48	33	3.44	26

R45	Inaccurate assessment of market demand	13	21	36	42	35	3.44	27
R30	Unavailability of utilities on-site required for construction	12	25	37	35	38	3.42	28
R14	Using poor construction techniques	12	15	49	44	27	3.40	29
R40	Unreliability of the legal system	9	21	49	38	30	3.40	30
R17	Inadequate experience of contractor in same projects	10	28	39	38	32	3.37	31
R35	Changes in project scope	11	25	43	37	31	3.35	32
R33	Delays in the site possession	17	21	37	38	34	3.35	33
R48	Unfavourable social environment	14	27	34	41	31	3.33	34
R28	Low labour productivity	12	26	44	35	30	3.31	35
R51	Public opposition to the project	15	24	38	41	29	3.31	36
R10	Lack of clarity over roles and responsibilities	12	18	55	38	24	3.30	37
R15	Delay in design	15	22	44	36	30	3.30	38
R26	Shortage or delay in delivery of expected materials	9	25	51	38	24	3.29	39
R5	Poor site management and supervision	17	19	44	39	28	3.29	40
R4	Personal conflicts between different clients involved	15	21	49	34	28	3.27	41
R60	Changes in environmental standards	9	27	51	39	21	3.24	42
R24	Breakdown of plant and machinery	17	25	43	31	31	3.23	43
R55	Improper project feasibility study	19	24	35	44	25	3.22	44
R23	Low productivity and efficiency of equipment	12	28	49	33	25	3.21	45
R11	Government restrictions on foreign companies	15	26	44	38	24	3.20	46
R18	Construction errors and poor workmanship leading to rework	11	31	48	34	23	3.18	47
R22	Changing construction methods in between of work	14	29	45	35	24	3.18	48

R38	Huge competition at the tendering stage	21	26	37	32	31	3.18	49
R47	Fluctuation in exchange rate of currency	17	28	41	34	27	3.18	50
R16	Complexity of design	17	24	46	37	23	3.17	51
R27	Unavailability or shortage of equipment	13	28	49	35	22	3.17	52
R31	Difficulties in accessing site due to topography of the region	20	25	41	32	29	3.17	53
R21	Using complex construction methods/techniques	16	31	40	33	27	3.16	54
R49	Political instability of the government	18	24	47	34	24	3.15	55
R69	Damage to property due to unsafe operations	19	26	43	35	24	3.13	56
R8	Change of top management	21	28	35	41	22	3.10	57
R57	Outbreak of hostilities (riots, revolutions & terrorism)	21	28	36	44	18	3.07	58
R59	Strict environmental rules and regulations	21	28	41	34	23	3.07	59
R1	Poor coordination or communication among various parties	18	33	45	29	22	3.03	60
R61	Legal proceedings due to wrong disposal of waste	15	31	55	28	18	3.02	61
R52	Different religious and cultural beliefs	20	33	45	27	22	2.99	62
R64	Improper assessment of project impacts on environment	20	35	44	27	21	2.96	63
R39	Change in codes and regulations	24	33	37	32	21	2.95	64
R56	Govt. officers asking for bribes	25	27	44	32	19	2.95	65
R65	Accidents occurring during construction	27	30	39	29	22	2.93	66
R66	Inadequate safety measures	24	34	41	30	18	2.89	67

R58	Pollution related to construction activities (dust, harmful gases, etc.)	28	31	39	28	21	2.88	68
R70	Lack of protection from enclosing area	21	33	49	34	10	2.86	69
R67	Changed labour safety laws or regulations	31	38	36	25	17	2.72	70

The value of SI ranged between 4.02 to 2.72. Top fifteen risk factors identified in severity are namely- natural disasters (floods, landslides, etc.) with (SI = 4.02), bad weather conditions (continuous rainfall, snow, wind) (SI = 3.91), unpredicted changes in inflation rates (SI = 3.86), improper project planning and budgeting (SI = 3.70), changes in government laws and policies (SI = 3.70), delays in resolving disputes and litigations (SI = 3.68), payment delays (SI = 3.67), contractual disputes and claims (SI = 3.67), design errors or design changes (SI = 3.65), approval and permit delays (SI = 3.63), shortage of skillful managers and professionals (SI = 3.56), pressure to crash project duration (time constraints) (SI = 3.56), lack of experience of the project team with (SI = 3.56), project-funding problems (SI = 3.56), inadequate quality planning and quality assurance (SI = 3.55). In above discussion we have calculated the severity of risk factors but alone severity is not enough to judge the potential od risk factors. So in further topic we will be calculating risk potential of different factors involved by multiplying frequency and severity.

4.5 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. Frequency of a risk factor is defined as its ability to repeat in a particular period of time. 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. Classifying risk factors as critical, moderate, low and ranking of risk factors will be done on the basis of risk impact and normalization of risk impact value. For calculation of risk impact, it is important first to calculate risk potential.

As knowing frequency, severity and risk potential of a risk plays an important role in management of the risk factor present in project. Top three risk factors in each category is discussed in discussion of different categories and for other risk factors present in a category, the calculations can be find in corresponding tables. In management category a total of 11 factors were there and top three risk factors in this category are discussed further. ‘Shortage of skillful managers and professional's' was found to have maximum value of risk potential with (FI = 2.16, SI = 3.56 and RP = 7.71). It is seen that lack of required skills can be observed in locally available managers and professionals. Sometimes for quality and complicated work skilled professionals are necessary. To meet these criteria sometimes management, have to recruit people from other areas who are skilled in the work. This is time-consuming as well as costly process. For other management risk factors calculations of FI, SI and RP are shown in Table 4.3 and comparison of RP of management risk is shown in Figure 4.3.

Table 4.3 Calculation of FI, SI and RP for management category

Management Risk	Frequency			FI	Severity					SI	RP
	1	2	3		1	2	3	4	5		
Poor coordination or communication among various parties	44	66	37	1.95	18	33	45	29	22	3.03	5.91
Poor management skills	47	55	45	1.99	8	14	53	43	29	3.48	6.92
Lack of experience of the project team	51	65	31	1.86	5	17	51	39	35	3.56	6.63
Personal conflicts between clients involved	37	74	36	1.99	15	21	49	34	28	3.27	6.51
Poor site management and supervision	34	69	44	2.07	17	19	44	39	28	3.29	6.79
Shortage of skilful managers and professional's	37	49	61	2.16	8	14	47	43	35	3.56	7.71
Improper project planning and budgeting	46	57	44	1.99	8	14	38	41	46	3.70	7.35
Change of top management	75	43	29	1.69	21	28	35	41	22	3.10	5.23
Inadequate quality planning and quality assurance	34	65	48	2.10	9	16	39	51	32	3.55	7.44
Lack of clarity over roles and responsibilities	27	76	44	2.12	12	18	55	38	24	3.30	6.98
Foreign company restriction	49	51	47	1.99	15	26	44	38	24	3.20	6.36

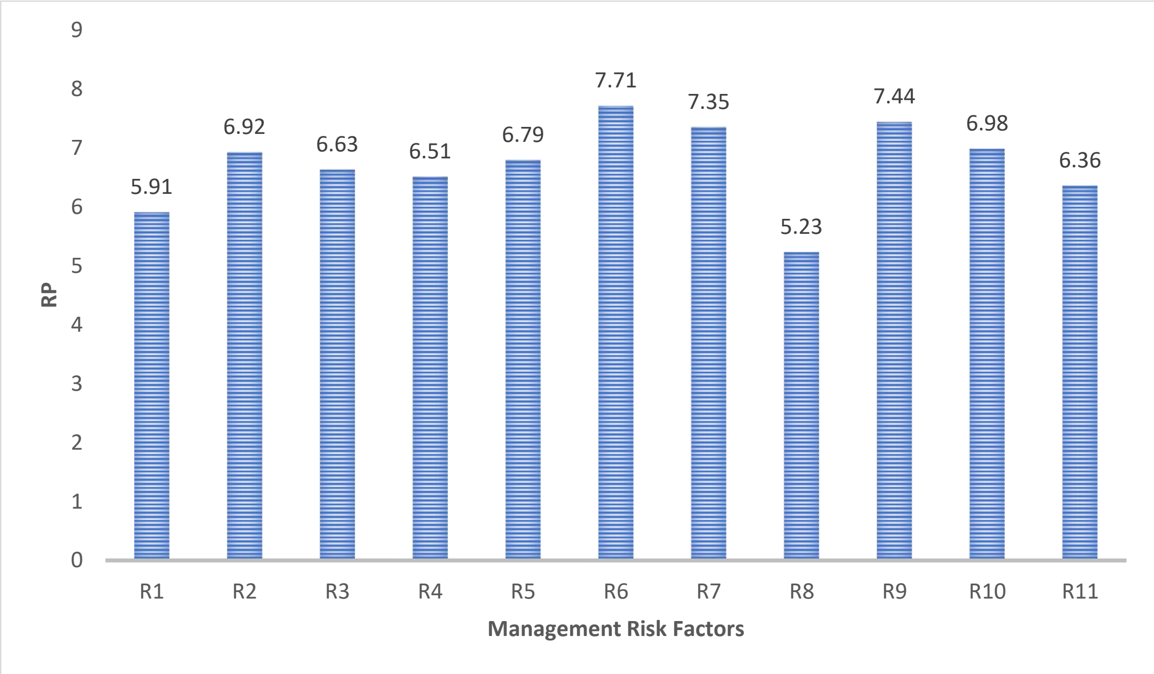

Figure 4.3 Comparison of RP of Management category

It is often seen in market that projects delivered most of the time have quality issues. Second highest value of RP observed in management category was 'inadequate quality planning and quality assurance' with (FI = 2.10, SI = 3.55 and RP = 7.44). Third most important risk factor in management category was 'Improper project planning and budgeting' with (FI = 1.99, SI = 3.70 and RP = 7.35) due to which some projects even fails.

Next risk category is technical & construction related with 11 risk factors present in it and top three risk factors in this category are discussed further. All factors in this category are shown in Table 4.4 with frequency index, severity index and risk potential. In this category the most significant risk factor was 'approval and permit delays' with (FI = 2.32, SI = 3.63 and RP = 8.41). It is often seen that projects are delayed due to late approvals by various departments. Comparison of RP of technical & construction category is shown in Figure 4.4.

Table 4.4 Calculation of FI, SI and RP for technical & construction category

Technical & Construction Risk	**Frequency**			**FI**	**Severity**					**SI**	**RP**
	1	**2**	**3**		**1**	**2**	**3**	**4**	**5**		
Design errors or design changes	29	65	53	2.16	7	14	41	46	39	3.65	7.90
Unclear and incomplete detailing in design drawings	31	65	51	2.14	5	19	49	43	31	3.52	7.51

Using poor construction techniques	67	43	37	1.80	12	15	49	44	27	3.40	6.11
Delay in design	53	49	45	1.95	15	22	44	36	30	3.30	6.42
Complexity of design	47	57	43	1.97	17	24	46	37	23	3.17	6.25
Inadequate experience of contractor in same projects	42	46	59	2.12	10	28	39	38	32	3.37	7.12
Construction errors and poor workmanship leading to rework	71	49	27	1.70	11	31	48	34	23	3.18	5.41
Approval and permit delays	22	56	69	2.32	9	15	37	47	39	3.63	8.41
Pressure to crash project duration (time constraints)	20	70	57	2.25	8	17	41	46	35	3.56	8.03
Using complex construction methods	65	50	32	1.78	16	31	40	33	27	3.16	5.62
Changing construction methods in between	57	52	38	1.87	14	29	45	35	24	3.18	5.94

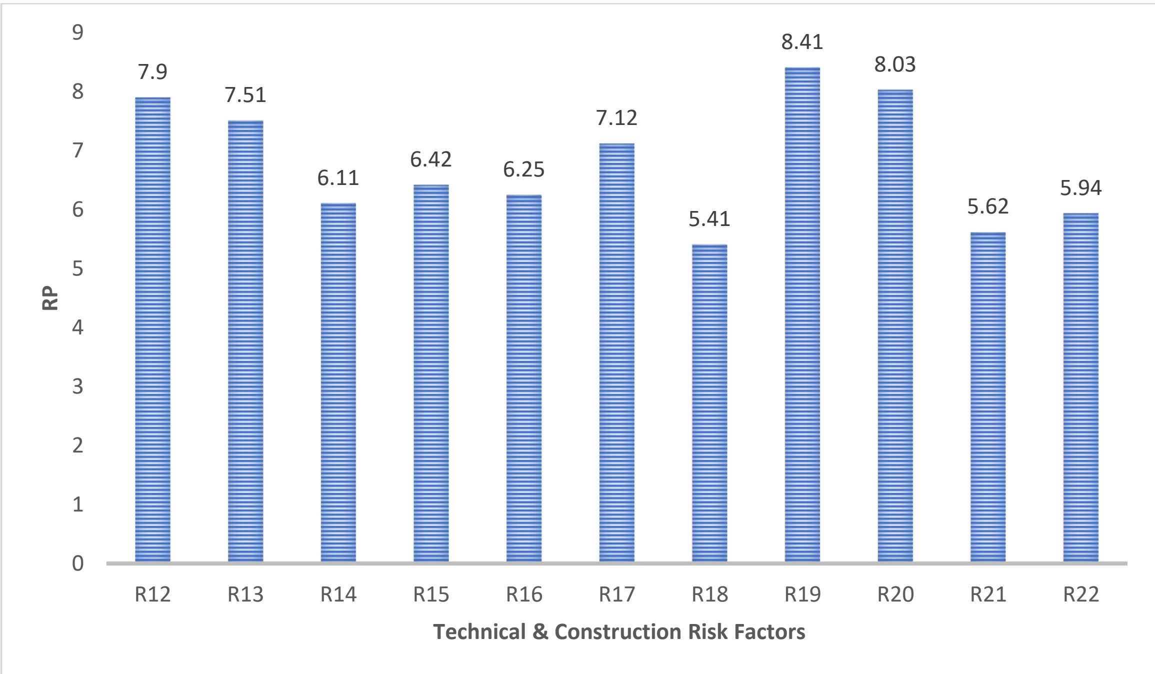

Figure 4.4 Comparison of RP of technical & construction category

Sometimes approvals are delayed for no reason. It's because of lack of seriousness of the employee towards approving the document. Next major factor is 'pressure to crash project duration (time constraints)' with (FI = 2.25, SI = 3.56 and RP = 8.03). This risk factor explains the need to schedule projects with precise planning and resources. The best option for dealing with risk is to have some extra time in between of events. It can be added while planning and scheduling of the project is done. Third most significant factor in this category was found to be 'design errors or design changes' with (FI = 2.16, SI = 3.65 and RP = 7.90). This factor is also a major factor as wrong design can lead to delays and cost overruns.

Third risk category considered in this research is resource & site-related category. Top three risk factors with highest RP in this category are discussed here. This category involved factors related to site and resources. 'Adverse ground conditions' was found to be a major factor with (FI = 2.19, SI = 3.44 and RP = 7.54). Ground conditions is the factor which if not taken care at early stage can result in huge cost and time overruns. Second most significant factor was found to be 'inadequate preliminary survey and tests of site' with (FI = 2.10, SI = 3.44 and RP = 7.24). Inadequate surveys can result in emerging of unknown factors on-site which needs more time and resources to deal. Third most significant factor in this category was found to be 'shortage of skillful workers locally' with (FI = 2.06, SI = 3.50 and RP = 7.21). Skillful laborers are sometimes difficult to find which result in less productive environment. Overall resources and site-related risks need great attention to minimize its negative effects. All other factors in this category are shown in Table 4.5 along with calculations for FI, SI and RP. Calculation for RP is shown in Figure 4.5

Table 4.5 Calculation of FI, SI and RP for resource and site-related category

Resource & Site-Related Risk	**Frequency**			**FI**	**Severity**					**SI**	**RP**
	1	**2**	**3**		**1**	**2**	**3**	**4**	**5**		
Low productivity and efficiency of equipment	30	68	49	2.13	12	28	49	33	25	3.21	6.84
Breakdown of plant and machinery	35	59	53	2.12	17	25	43	31	31	3.23	6.86
Shortage of skilful workers locally	40	58	49	2.06	11	21	36	42	37	3.50	7.21
Shortage or delay in delivery of expected materials	33	61	53	2.14	9	25	51	38	24	3.29	7.03
Unavailability or shortage of equipment	37	59	51	2.10	13	28	49	35	22	3.17	6.64

Low labour productivity	47	54	46	1.99	12	26	44	35	30	3.31	6.59
Adverse ground conditions	31	57	59	2.19	13	25	33	36	40	3.44	7.54
Unavailability of utilities on site required	56	55	36	1.86	12	25	37	35	38	3.42	6.38
Difficulties in accessing site due to topography of the region	38	62	47	2.06	20	25	41	32	29	3.17	6.53
Inadequate preliminary survey and tests of site	36	60	51	2.10	6	31	37	38	35	3.44	7.24
Delays in the site possession	42	57	48	2.04	17	21	37	38	34	3.35	6.83

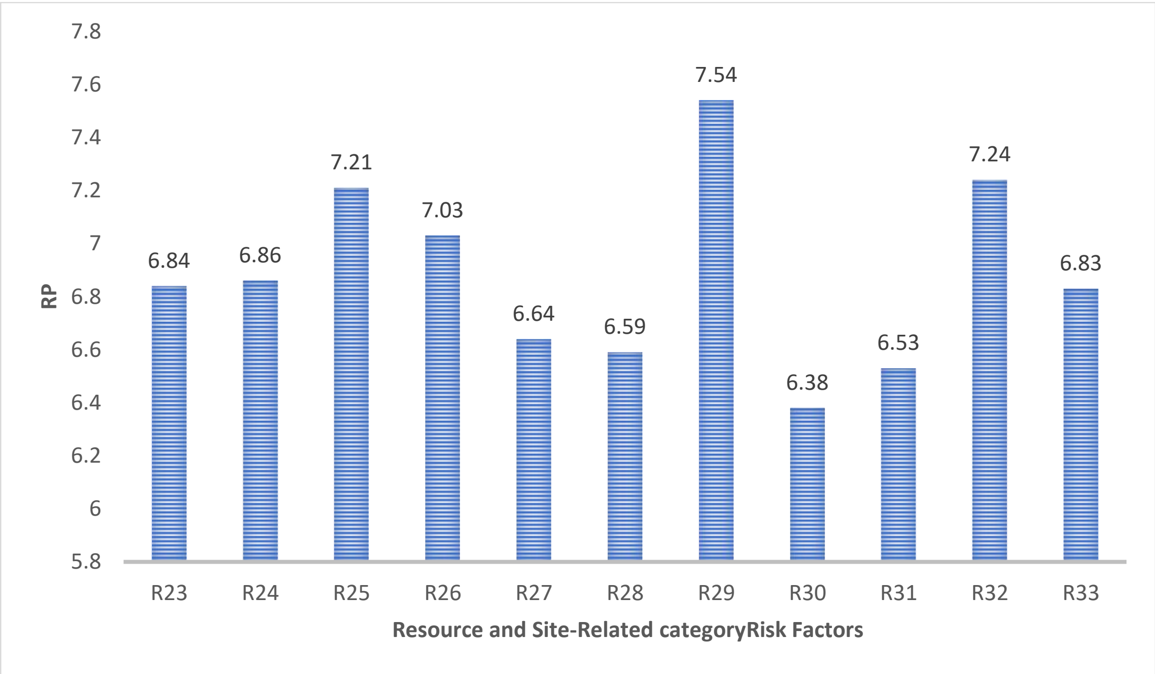

Figure 4.5 Comparison of RP of resource and site-related category

Fourth category used in this research is contractual and legal risks. This category deals with factors related to contracts and legal problems. This category consists of seven risk factors. Top three risk factors in this category are discussed further. Major factor identified in this category was 'contractual disputes and claims' with (FI = 2.14, SI = 3.67 and RP = 7.83). It is generally seen that contract disputes and claims take years to make its final decision resulting huge loss to project. Second most significant factor identified in this category was 'delays in resolving disputes and litigations' with (FI = 1.98, SI = 3.68 and RP = 7.29). Disputes and litigations are not resolved for years resulting in delayed projects. Third major factor in this category was ‘huge competition at the tendering stage’ with (FI = 2.25, SI = 3.18 and RP = 7.15). Calculation of FI, SI and RP for contractual and legal risks s shown in Table 4.6 and comparison of RI for contractual and legal risks is shown in Figure number 4.6.

Table 4.6 Calculation of FI, SI and RP for contractual and legal risks

Contractual & Legal Risk	Frequency 1	2	3	FI	Severity 1	2	3	4	5	SI	RP
Contradictions in the contract documents	47	54	46	1.99	8	25	34	39	41	3.54	7.06
Changes in project scope	66	58	23	1.71	11	25	43	37	31	3.35	5.73
Litigations and disputes retarding project progres	47	56	44	1.98	7	15	37	47	41	3.68	7.29
Contractual disputes and claims	33	61	53	2.14	6	21	34	41	45	3.67	7.83
Huge competition at the tendering stage	22	66	59	2.25	21	26	37	32	31	3.18	7.15
Change in codes and regulations	69	57	21	1.67	24	33	37	32	21	2.95	4.94
Unreliability of the legal system	47	75	25	1.85	9	21	49	38	30	3.40	6.29

Figure 4.6 Comparison of RP of contractual and legal risk category

Initially contractors to get a tender puts a low bid, which on later stage they find it difficult to complete the project within estimated tender cost and it results in delays to project completion. For tenders, contractor should be selected on the bases of previous work undertaken and its completion. Bid value along with previous work is also equally important. Both criteria should be checked carefully while selecting a contractor as sometimes for big projects inexperienced contractor may fail badly and find it difficult to finish project within specified time and cost.

Fifth category considered in this research is economic and financial risk. In this category a total of seven risk factors are there and it deals with factors related to economics and finance. This factor is also important in deciding projects success or failure in building and infrastructure projects. Top three risk factors for this category are namely- 'payment delays' is the most significant risk factor identified in this category with (FI = 2.27, SI = 3.67 and RP = 8.35). Most of the times payments are delayed for the required work resulting in delays and cost overruns. Second most significant factor identified in this category was 'unpredicted changes in inflation rates' with (FI = 2.12, SI = 3.86 and RP = 8.20). As inflation rate keep on changing during a project construction lifetime, therefore, it has great impact on decided budget. All factors in this category are discussed in Table 4.7 along with FI, SI and RP. Comparison of RP of economic and financial risk category is shown in Figure 4.7.

Table 4.7 Calculation of FI, SI and RP for economic and financial risk

Economic & Financial Risk	**Frequency**			**FI**	**Severity**					**SI**	**RP**
	1	**2**	**3**		**1**	**2**	**3**	**4**	**5**		
Unpredicted changes in interest rates	65	57	25	1.73	14	21	31	48	33	3.44	5.95
Payment delays	21	65	61	2.27	6	19	33	48	41	3.67	8.35
Failure to meet revenue targets	53	59	35	1.88	8	19	44	41	35	3.52	6.60
Unpredicted changes in inflation rates	40	49	58	2.12	2	10	39	51	45	3.86	8.20
Inaccurate assessment of market demand	36	63	48	2.08	13	21	36	42	35	3.44	7.17
Project-funding problems	57	48	42	1.90	10	21	32	45	39	3.56	6.75
Fluctuation in exchange rate of currency	51	65	31	1.86	17	28	41	34	27	3.18	5.92

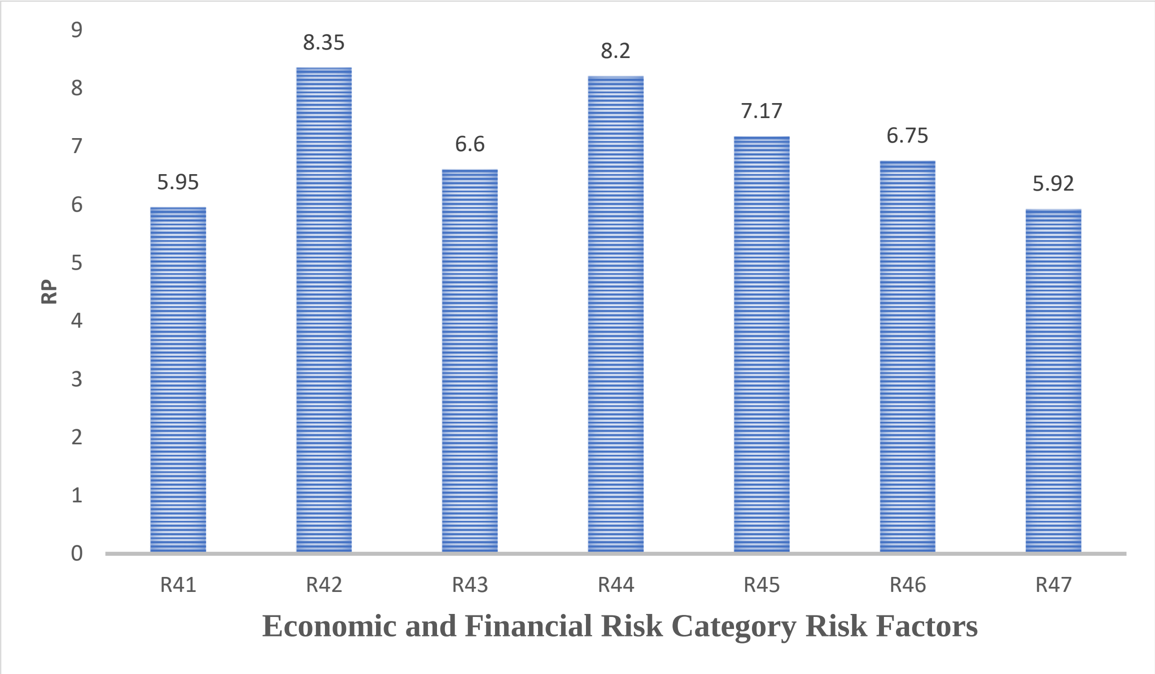

Figure 4.7 Comparison of RP of economic and financial risk category

Third major risk identified was 'inaccurate assessment of market demand' with (FI = 2.08, SI = 3.44 and RP = 7.17). It results in huge losses as market demand changes and product prepared don't get attention from buyers.

Sixth Category used in this research is socio-political risk. A Total of ten risk factors are there in this category. This category deals with the social and political risks present in building and infrastructure projects. Topmost factor identified in this category was 'laws and policies revising' with (FI = 2.05, SI = 3.70 and RP = 7.60). Most of the times contractors are not prepared for new policies and regulations. Laws and policies sometimes also change with change in government. In worst case even some projects have to shut down because of not able to follow new regulations. Other factors of this category with FI, SI and RP are discussed in Table 4.8 and comparison of RP of socio-political risk category is shown in Figure 4.8.

Table 4.8 Calculation of FI, SI and RP for socio-political risk

Socio-Political Risk	**Frequency**			**FI**	**Severity**					**SI**	**RP**
	1	**2**	**3**		**1**	**2**	**3**	**4**	**5**		
Unfavourable social environment	41	55	51	2.07	14	27	34	41	31	3.33	6.88
Political instability of the government	36	67	44	2.05	18	24	47	34	24	3.15	6.47

Compensation and land acquisition problems	27	71	49	2.15	10	19	44	39	35	3.48	7.47
Public opposition to the project	30	70	47	2.12	15	24	38	41	29	3.31	6.99
Different religions and cultural beliefs	43	65	39	1.97	20	33	45	27	22	2.99	5.89
Laws and policies revising	41	57	49	2.05	9	14	32	49	43	3.70	7.60
Labour disputes and strikes	40	66	41	2.01	11	21	35	47	33	3.48	6.98
Improper project feasibility study	38	58	51	2.09	19	24	35	44	25	3.22	6.72
Government officers asking for bribes	51	54	42	1.94	25	27	44	32	19	2.95	5.72
Outbreak of hostilities (riots, revolutions & terrorism)	76	55	16	1.59	21	28	36	44	18	3.07	4.88

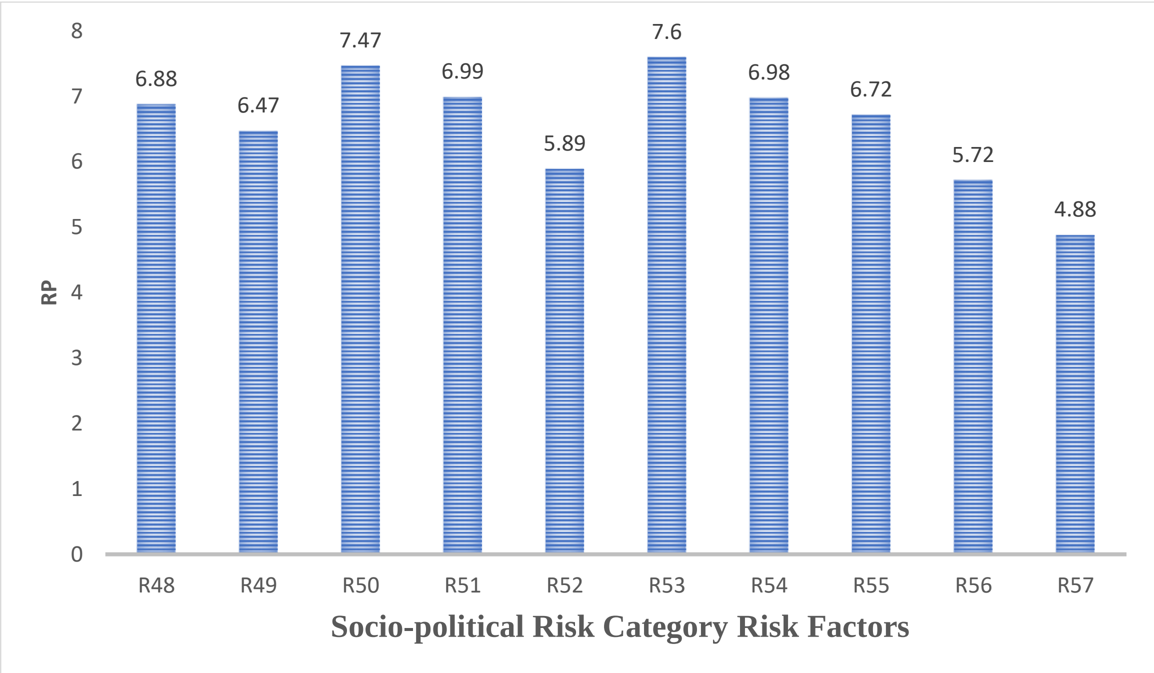

Figure 4.8 Comparison of RP of socio-political risk category

Second major factor identified in this category was ‘compensation and land acquisition problems’ with (FI = 2.15, SI = 3.48 and RP = 7.47). This problem is generally faced where land acquisition is required as a lot of money goes in compensating the land acquired. This type of problem is very common in road expanding or new road making process. As people built their houses along the road, while expanding the road acquisition and compensation comes into account. The third most significant factor in this category was ‘labour disputes and strikes’ with (FI = 2.01, SI = 3.48 and RP = 6.98). This factor results in stoppage of work and delayed completions. Disputes can be due to less wages or any other problems between the parties involved.

Environmental risk is the seventh category used in this study. This category consisted of seven risk factors. This category mainly deals with problems related with environment and effects of project on environment. Most significant risk recognized in this category was ‘bad weather conditions’ with (FI = 1.96, SI = 3.91 and RP = 7.66). This factor can result in huge losses if not recognized at right time as mostly it depends on local conditions of the area. Sometimes continuous bad weather can result in huge cost and time overruns. Second most significant risk factor identified in this category was ‘natural disasters’ with (FI = 1.82, SI = 4.02 and RP = 7.33). Natural disasters result in huge losses in terms of cost as well as time and it can be managed by mitigation measures like insurance, etc. We cannot plan for natural disasters but having knowledge regarding it will surely help in minimizing losses. Third major risk factor recognized was ‘strict environmental rules and regulations’ with (FI = 2.09, SI = 3.07 and RP = 6.41). Due to strict rules some companies might face problems because of their attitude of not following any regulations. Other factors in this category are discussed in Table 4.9 along with FI, SI and RP.Comparison of RP of environmental risk category is shown in Figure 4.9.

Table 4.9 Calculation of FI, SI and RP for environmental risk

Environmental Risk	**Frequency**			**FI**	**Severity**					**SI**	**RP**
	1	**2**	**3**		**1**	**2**	**3**	**4**	**5**		
Pollution related to construction activities (dust, harmful gases, etc.)	41	65	41	2.00	28	31	39	28	21	2.88	5.77
Strict environmental rules and regulations	38	58	51	2.09	21	28	41	34	23	3.07	6.41
Changes in environmental standards	58	54	35	1.84	9	27	51	39	21	3.24	5.98
Legal proceeding due to wrong disposal of waste	48	61	38	1.93	15	31	55	28	18	3.02	5.84

Bad weather	47	59	41	1.96	5	16	23	46	57	3.91	7.66
Natural disasters (floods, landslides, etc.)	56	61	30	1.82	5	5	33	43	61	4.02	7.33
Improper early assessment of project impacts on environment	53	72	22	1.79	20	35	44	27	21	2.96	5.29

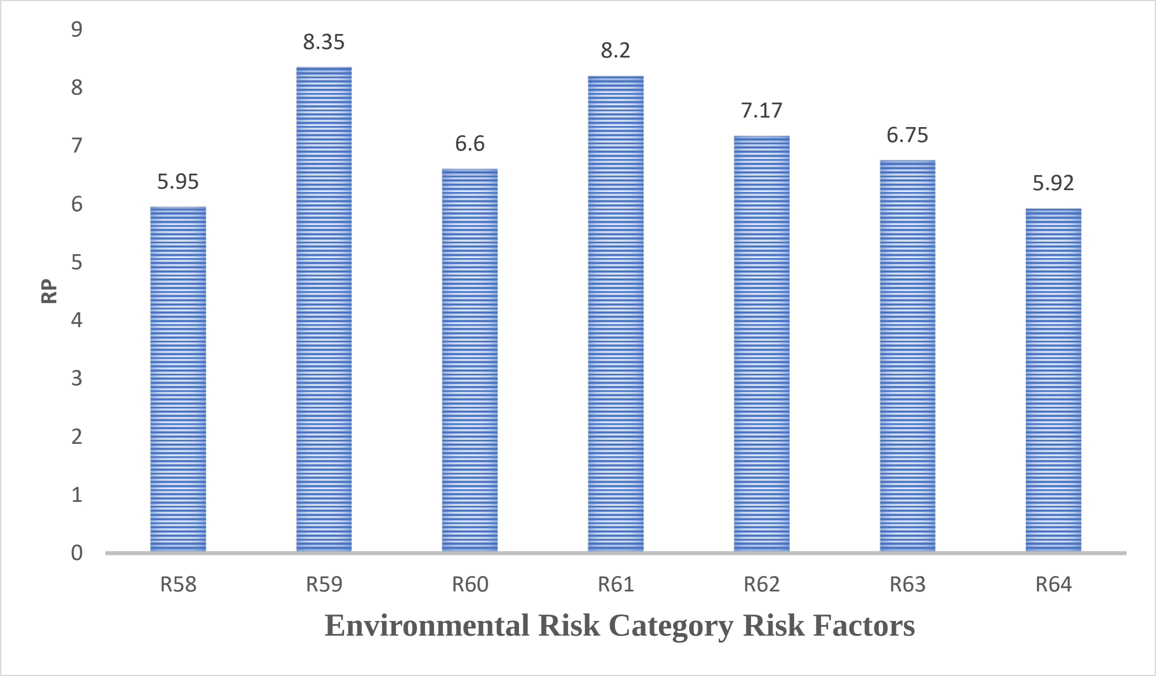

Figure 4.9 Comparison of RP of environmental risk category

Last category used for this study is related to health and safety. In this category a total of six risk factors were there. Very less attention is given towards health and safety of employees working in most of the projects especially projects on small scales. For factors of this category FI, SI and RP is shown in Table 4.10. Comparison of RP of health and safety risk category is done in Figure 4.10.

Table 4.10 Calculation of FI, SI and RP for health and safety risk

Health & Safety Risk	**Frequency**			**FI**	**Severity**					**SI**	**RP**
	1	**2**	**3**		**1**	**2**	**3**	**4**	**5**		
Accidents occurring during construction	42	68	37	1.97	27	30	39	29	22	2.93	5.75
Inadequate safety measures	42	58	47	2.03	24	34	41	30	18	2.89	5.88

Changed labour safety laws or regulations	59	54	34	1.83	31	38	36	25	17	2.72	4.98
Epidemic illness	74	50	23	1.65	11	24	31	45	36	3.48	5.76
Damage to property due to unsafe operations	76	52	19	1.61	19	26	43	35	24	3.13	5.05
Lack of protection from enclosing area	37	66	44	2.05	21	33	49	34	10	2.86	5.85

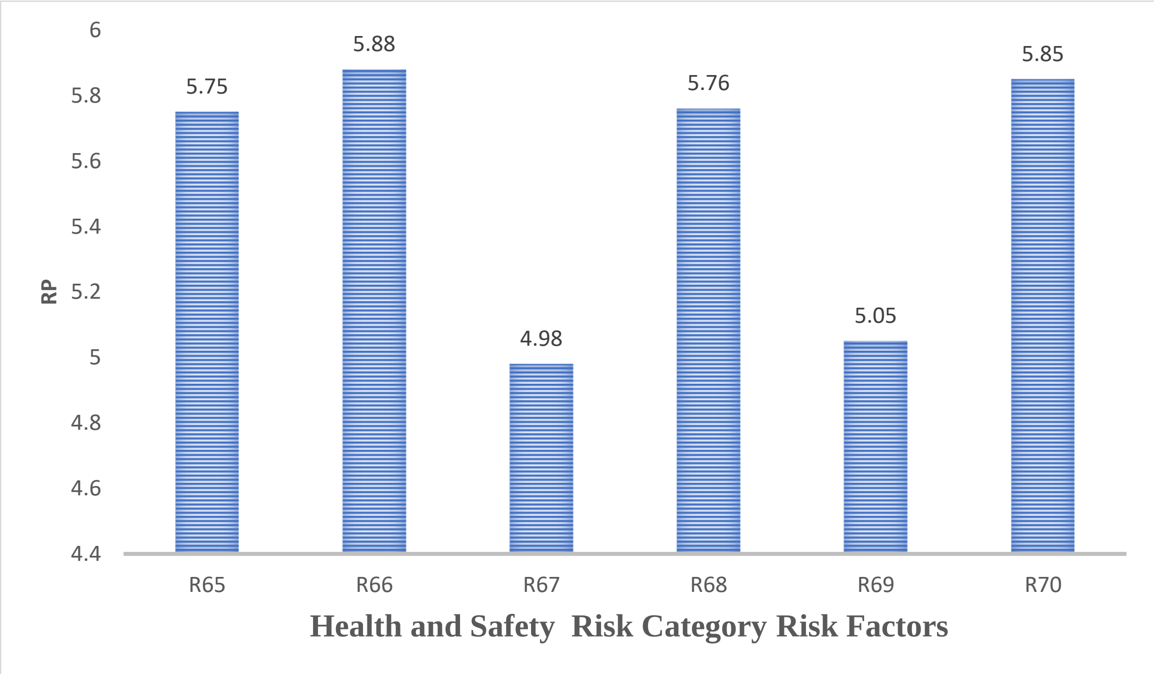

Figure 4.10 Comparison of RP of health and safety risk category

Most the time contractors try to save money allotted for personal protective equipment. Top risk factor identified in this category was ‘inadequate safety measures’ with (FI = 2.03, SI = 2.89 and RP = 5.88). Inadequate safety results in increased injuries and accidents will may pause the ongoing work. Second major factor identified was ‘Lack of protection from enclosing area’ with (FI = 2.05, SI = 2.86 and RP = 5.85). Most of the times there is no protection from the surrounding which results in injuries and accidents. Protection from surrounding can be from adjacent building, equipment, cliff, etc. Third major factor identified in this category was ‘epidemic illness’ like eye flue, etc. with (FI = 1.65, SI = 3.48 and RP = 5.76) which may result in stoppage of work on-site and results in project delays and cost overruns.

4.6 Analysis of Risk Impact and Ranking

After analyzing frequency, severity and risk potential next we have to calculate risk impact values using equation number 6 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 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 4.11.

Table 4.11 Risk factors ranking and level of criticality

Sr. No.	Description of risk	RP	RI	NV	Rank	Level
R19	Approval and permit delays	8.41	2.90	1.00	1	CR
R42	Payment delays	8.35	2.89	0.98	2	CR
R44	Unpredicted changes in inflation rates	8.20	2.86	0.95	3	CR
R20	Pressure to crash project duration (time constraints)	8.03	2.83	0.90	4	CR
R12	Design errors or design changes	7.90	2.81	0.87	5	CR
R37	Contractual disputes and claims	7.83	2.80	0.85	6	CR
R6	Shortage of skillful managers and professional’s	7.71	2.78	0.82	7	CR
R62	Bad weather (snow, excess rain)	7.66	2.77	0.81	8	CR
R53	Laws and policies revising in between of project	7.60	2.76	0.79	9	CR
R29	Adverse ground conditions	7.54	2.75	0.78	10	CR
R13	Unclear and incomplete detailing in design drawings	7.51	2.74	0.77	11	CR
R50	Compensation and land acquisition problems	7.47	2.73	0.76	12	CR
R9	Inadequate quality planning and quality assurance	7.44	2.73	0.75	13	CR
R7	Improper project planning and budgeting	7.35	2.71	0.73	14	CR
R63	Natural disasters (floods, landslides, etc.)	7.33	2.71	0.72	15	CR
R36	Litigations and disputes retarding project progress	7.29	2.70	0.71	16	CR
R32	Inadequate preliminary survey and tests of site	7.24	2.69	0.70	17	CR
R25	Shortage of skillful workers locally	7.21	2.68	0.69	18	CR

R45	Inaccurate assessment of market demand	7.17	2.68	0.68	19	CR
R38	Huge competition at the tendering stage	7.15	2.67	0.67	20	CR
R17	Inadequate experience of contractor in same projects	7.12	2.67	0.67	21	CR
R34	Contradictions in the contract documents	7.06	2.66	0.65	22	CR
R26	Shortage of expected materials	7.03	2.65	0.64	23	CR
R51	Public opposition to the project	6.99	2.64	0.63	24	CR
R10	Lack of clarity over roles and responsibilities	6.98	2.64	0.63	25	CR
R54	Labour disputes and strikes	6.98	2.64	0.62	26	CR
R2	Poor management skills	6.92	2.63	0.61	27	CR
R48	Unfavourable social environment	6.88	2.62	0.60	28	CR
R24	Breakdown of plant and machinery	6.86	2.62	0.59	29	CR
R23	Low productivity and efficiency of equipment	6.84	2.61	0.59	30	CR
R33	Delays in the site possession	6.83	2.61	0.58	31	CR
R5	Poor site management and supervision	6.79	2.61	0.57	32	CR
R46	Project-funding problems	6.75	2.60	0.56	33	CR
R55	Improper project feasibility study	6.72	2.59	0.55	34	CR
R27	Unavailability or shortage of equipment	6.64	2.58	0.53	35	CR
R3	Lack of experience of the project team	6.63	2.58	0.53	36	CR
R43	Failure to meet revenue targets	6.60	2.57	0.52	37	CR
R28	Low labour productivity	6.59	2.57	0.52	38	CR
R31	Difficulties in accessing site due to topography of the region	6.53	2.56	0.50	39	MR
R4	Personal conflicts between different clients involved	6.51	2.55	0.49	40	MR
R49	Political instability of the government	6.47	2.54	0.48	41	MR
R15	Delay in design	6.42	2.53	0.47	42	MR
R59	Strict environmental rules and regulations	6.41	2.53	0.47	43	MR
R30	Unavailability of utilities on-site required for construction	6.38	2.53	0.46	44	MR
R11	Government restrictions on foreign companies	6.36	2.52	0.45	45	MR
R40	Unreliability of the legal system	6.29	2.51	0.43	46	MR
R16	Complexity of design	6.25	2.50	0.42	47	MR

R14	Using poor construction techniques	6.11	2.47	0.38	48	MR
R60	Changes in environmental standards	5.98	2.45	0.34	49	MR
R41	Unpredicted changes in interest rates	5.95	2.44	0.33	50	MR
R22	Changing construction methods/techniques in between of work	5.94	2.44	0.33	51	MR
R47	Fluctuation in exchange rate of currency	5.92	2.43	0.32	52	MR
R1	Poor coordination or communication among various parties	5.91	2.43	0.32	53	MR
R52	Different religious and cultural beliefs	5.89	2.43	0.31	54	MR
R66	Inadequate safety measures	5.88	2.43	0.31	55	MR
R70	Lack of protection from enclosing area	5.85	2.42	0.30	56	MR
R61	Legal proceedings due to wrong disposal of waste	5.84	2.42	0.30	57	MR
R58	Pollution related to construction activities	5.77	2.40	0.28	58	MR
R68	Epidemic illness	5.76	2.40	0.27	59	MR
R65	Accidents occurring during construction	5.75	2.40	0.27	60	MR
R35	Changes in project scope	5.73	2.39	0.27	61	MR
R56	Govt. officers asking for bribes	5.72	2.39	0.26	62	MR
R21	Using complex construction methods/techniques	5.62	2.37	0.23	63	LR
R18	Construction errors and poor workmanship leading to rework	5.41	2.33	0.17	64	LR
R64	Improper assessment of project impacts on environment	5.29	2.30	0.13	65	LR
R8	Change of top management	5.23	2.29	0.11	66	LR
R69	Damage to property due to unsafe operations	5.05	2.25	0.05	67	LR
R67	Changed labour safety laws or regulations	4.98	2.23	0.03	68	LR
R39	Change in codes and regulations	4.94	2.22	0.02	69	LR
R57	Outbreak of hostilities (riots, revolutions & terrorism)	4.88	2.21	0.00	70	LR

Thirty-eight critical risk factors were identified in building and infrastructure projects. Top ten critical risk factors identified were namely- approval and permit delays with (RI = 2.90), payment delays with (RI = 2.89), unpredicted changes in inflation rates with (RI = 2.86), pressure to crash project duration (time constraints) with (RI = 2.83), design errors or design changes with (RI = 2.81), contractual disputes and claims with (RI = 2.80), shortage of skillful managers and professionals with (RI = 2.78), bad weather conditions with (RI = 2.77), changes in government laws, regulations, and policies with (RI = 2.76), adverse ground conditions with (RI = 2.75). Twenty-four moderate risk factors were identified in building and infrastructure projects and eight low risk factors have also been recognized. Highest value of (RI = 2.90) was observed and minimum value of (RI = 2.21) was observed. For critical risk factors RI ranged from (2.90 to 2.57), for moderate risk factors RI ranged from (2.56 to 2.39) and for low risk factors RI ranged from (2.37 to 2.21). Comparison of number of factors in critical, moderate and low risk level are shown in Table 4.12.

Table 4.12 Number of factors in each level

Sr. No	Risk rating	Number of factors
1	Critical	38
2	Moderate	24
3	Low	8

4.7 Categorization of Critical Risk Factors

Thirty-eight risk factors were found to be critical based on normalized values. Factors having normalized value greater than 0.50 are considered to be critical factors. Nine risk factors were found critical from resource and site-related category, six risk factors were from socio-political category, seven risk factor belongs to management category, five risk factors were associated with technical and construction category, five risk factors were related to contractual and legal category, two risk factors were related to environment category. So, top three critical risk categories identified were resource and site-related category, followed by management category, followed by socio-political category. Least critical category was found to be health and safety with no factor in critical risk factors. In Table 4.13 critical risk factors in building and infrastructure projects with risk categorization is given along with overall ranking and ranking within category.

Table 4.13 Critical risk factors in building and infrastructure projects with risk categorization

Critical risk factor categorization	Risk impact Value	Overall ranking	Ranking within category
Resource / Site related			
Adverse ground conditions	2.75	10	1
Inadequate preliminary survey and tests of site	2.69	17	2

Shortage of skillful workers locally	2.68	18	3
Shortage of expected materials	2.65	23	4
Breakdown of plant and machinery	2.62	29	5
Low productivity and efficiency of equipment	2.61	30	6
Delays in the site possession	2.61	31	7
Unavailability or shortage of equipment	2.58	35	8
Low labour productivity	2.57	38	9
Management			
Shortage of skillful managers and professional's	2.78	7	1
Inadequate quality planning and quality assurance	2.73	13	2
Improper project planning and budgeting	2.71	14	3
Roles and responsibilities not clear	2.64	25	4
Poor management skills	2.63	27	5
Poor site management and supervision	2.61	32	6
Lack of experience of the project team	2.58	36	7
Socio-Political			
Approvals and permit delays	2.90	1	1
Laws and policies revising	2.76	9	2
Compensation and land acquisition problems	2.73	12	3
Public opposition to the project	2.64	24	4
Labour disputes and strikes	2.64	26	5
Unfavourable social environment	2.62	28	6
Technical / Construction			
Pressure to crash project duration (time constraints)	2.83	4	1
Design errors or design changes	2.81	5	2
Incomplete detailing in design drawings and specifications	2.74	11	3
Contractor's lack of experience in similar projects	2.67	21	4
Improper project feasibility study	2.59	34	5
Economic / Finance			
Payment delays	2.89	2	1
Unpredicted changes in inflation rates	2.86	3	2
Inaccurate assessment of market demand	2.68	19	3
Project-funding problems	2.59	33	4

Failure to meet revenue targets	2.57	37	5
Contractual / Legal			
Contractual disputes and claims	2.80	6	1
Delays in resolving disputes and litigations	2.70	16	2
Huge competition at the tendering stage	2.67	20	3
Contradictions in the contract documents	2.66	22	4
Environmental			
Bad weather conditions (continuous rainfall, snow, wind)	2.77	8	1
Natural disasters (floods, landslides, etc.)	2.71	15	2

4.8 Factor Analysis of Critical Risk Factors

Thirty-eight critical risk factors were found in this research. Factor analysis was performed on these risk factors to categorize them into few variables. Before performing factor analysis, we have to perform Kaiser-Meyer- Olkin (KMO) test, which measures the adequacy of sample. KMO measures partial correlation among variables by measuring the proportion of variance among them. Valid values according to Kaiser-Meyer-Olkin is shown in Table 4.14.

Table 4.14 KMO value considerations for FA

KMO Value	Consideration for FA
0.0 to 0.49	unacceptable
0.50 to 0.59	miserable
0.60 to 0.69	mediocre
0.70 to 0.79	middling
0.80 to 0.89	meritorious
0.90 to 1.00	marvelous

Generally, $0 < KMO < 1$. If, $KMO > 0.5$, sample is considered adequate. In our research KMO value was found to be 0.793 which indicates adequate sample therefore factor analysis can be performed. For Bartlett’s test of sphericity, assuming significance level 95%, $\alpha = 0.05$. In this test p-value was found to be less than 0.05, indicating validity of factor analysis. Initially those components were selected whose eigenvalues was found to be greater than or equal to 1.0. Then to check this parallel analysis were performed using Monte-Carlo PCA parallel analysis. Parallel analysis was performed taking 38 number of variables, 147 respondents, and 100 replications. Five components were found to have eigenvalues greater than or equal to 1.0. Results of factor analysis on critical risk factors are shown in Table 4.15.

Table 4.15 Results of factor analysis on critical risk factors

	Critical risk factors			
Group 1	R5	R17	R28	R46
	R6	R19	R29	R50
	R7	R20	R32	R51
	R10	R24	R33	
	R12	R26	R36	
	R13	R27	R38	
Group 2	R3	R42	R45	R62
	R25	R43	R48	
	R34	R44	R53	
Group 3	R2	R23	R46	R63
	R9	R37	R55	

On Comparing data of parallel analysis with values of total variance it was found that only three components were valid according to parallel analysis. So, finally three components were considered. The values obtained from parallel analysis and total variance table is shown in Appendix-E. Twenty-one factors was found to be in component one, ten factors were in component two and seven factors was in component three.

CHAPTER 5
CONCLUSIONS AND GUIDELINES

5.1 General

A lot of building and infrastructure projects has to face risk and uncertainties during construction period resulting in huge losses in terms of cost, time, quality, productivity, etc. This research aims to create awareness regarding risk management framework in 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.

5.2 Conclusions

Initially, seventy risk factors were identified through in-depth study of literature related to risk present in building and infrastructure projects. These seventy risk factors were categorized into eight major categories. A questionnaire was prepared consisting of these factors and data was collected through questionnaire survey. Reliability analysis was performed on collected data to ensure reliability of the data. Overall reliability for severity was found to be 0.941 and for probability it was 0.908 which ensures high reliability of data collected. Severity index and frequency index was calculated using RII. Maximum value of SI was found to be 4.02 and minimum value of SI was found to be 2.72. Top five factors for severity were namely- natural disasters (floods, landslides, etc.), bad weather (snow, excess rainfall), unpredicted changes in inflation rates, improper project planning and budgeting, changes in government laws, regulations, and policies. Maximum value of FI was found to be 2.32 and minimum value for FI was found to be 1.59. Top five factors for probability was namely- approval and permit delays, payment delays, pressure to crash project duration (time constraints), huge competition at the tendering stage, adverse ground conditions. After that RP and RI was calculated for all the factors. Risk potential value ranged between 8.41 to 4.88. Risk impact value ranged between 2.90 to 2.21. Normalized values for different risk factors was found on the basis of RI. Factors having normalized value greater than 0.50 are considered as critical risk factors. Thirty-eight risk factors were found to be critical in building and infrastructure projects. Top ten critical risk factors found were namely- approval and permit delays, payment delays, unpredicted changes in inflation rates, pressure to crash project duration (time constraints), design errors or design changes, contractual disputes and claims, shortage of skillful managers and professionals, bad weather (snow, excess rain), changes in government laws, regulations, and policies, adverse ground conditions. Factor analysis was performed on the critical risk factors identified. KMO value for measuring sample adequacy was found to be 0.793. on performing factor analysis, it suggests that the critical risk factors can be divided into three groups. (27.21 %) of total respondents implement risk management in their projects and (85.03 %) of respondents think risk management should be implemented in projects. Risk mitigation measures was also proposed in this research which are discussed further.

5.3 Mitigation Measures and Guidelines

In this, part mitigation measures for risk present in building and infrastructure projects are recommended. Mitigation measures are divided into two parts: first part consist of risk mitigation model and second part consist of guidelines. Following these mitigation measures will help construction practitioners to manage risk in an efficient manner with more positive outcomes and minimizing negative effects of risk.

5.3.1 Risk Mitigation Model

For dealing with risk in an effective manner this study suggests a risk mitigation model. This model consists of seven major parameters. This model will surely help project managers, risk managers, engineers, management team who has to deal with risk and uncertainties on-site during construction stages of the project.

- First parameter is identification of risk factors present in building and infrastructure project. It plays an important role in managing risk as without knowing which risk and uncertainties are present, we can't manage it. So, identification of risk should be done thoroughly keeping all aspects in mind. Past studies, researches, experienced employees can help in risk identification.
- Second important parameter is rating of identified risk. This means while dealing with risk it should be clear that how critical risk can be in terms of cost, time, quality, productivity, etc. As some risks need immediate attention as compared to other. In other terms some risks are more critical as compared to others. So, risk can be rated according to their ability to affect project objectives. Risk can be rated as low, moderate, and high.
- Third parameter in risk mitigation model is categorization of risk. Risk categorization also plays an important role to determine which team involved in project should manage a particular risk. This categorization of risk clarifies which section needs to manage a particular risk example: management team, technical team, finance team, etc.

- Fourth parameter is defining stage of risk at which it will occur. A particular risk can occur in single stage as well as in multiple stages. So, to manage it properly there is need to know its ability in different stages. Risk can emerge at any stage so a continuous check should be there. Various stages of a project can be classified as feasibility, procurement, construction, operation, and transfer.
- Fifth parameter in risk mitigation model is risk allocation. Most of the times while dealing with risks, parties don't take responsibility for risk present and often state responsible others for management of that risk. To deal with this risk allocation should be there as it will define parties responsible for management of risk present in projects. For a particular risk responsibility may lie with owner, contractor, consultant or it can be shared by different parties. Allocation should be done properly as it will help in effective management of risk.
- Sixth parameter of mitigation model is risk response. Responding to risk means how we plan to deal with it such that its negative effects can be minimized. Responding to risk can be decided by concerned authorities of companies. Response to risk can be updated at any time in between of project depending on need to modify it.
- Seventh parameter is monitoring and remarks. In this, a continuous monitoring and control is there on the risk factors as well as on the mitigation strategies. It's important to check whether our mitigation strategies working on minimizing the effects of the risk or we need to modify it. Finally, remarks are written if any required.

5.3.2 Guidelines

- Risk management framework should be implemented before starting of the project.
- Each and every party involved in project should be clear regarding their responsibilities and duties.
- Quick and precise decisions should be taken for any arising problems or difficulty.
- Active involvement of all the parties involved in a project is necessary.
- Things required approvals should be approved as soon as possible if found correct.
- Discussing project progress reports weekly, monthly, etc. with related parties.
- While selecting contractors in tendering process previous work done by them should be checked properly.
- Proper preliminary assessment of the project should be done.
- Surprise site inspection should be done by higher authorities.
- Contract documents should be prepared with great clarity and complete description of work to be performed such that no conflict arises at later stages.

- Local climate conditions of area in which project is to be taken should be considered before accepting any project.
- Availability of resources should be ensured before starting of the project.
- Continuous check should be there for new risk emerging time to time in between of project.
- Local codes and guidelines of the country in which project is ongoing should be followed.

5.4 Future Scope of Study

The future scope of this study is similar analysis can be done project-specific like for bridge projects, tunnel projects, hospital projects, power generation projects, nuclear projects, water projects, etc. Moreover, geographical location can also be considered as risk may slightly vary for different regions across the world. Adding these parameters in future research will help in obtaining more useful results.

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LIST OF PUBLICATIONS

1. Sharma, S. and Gupta, A.K., (2019) "Risk identification and management in construction projects: literature review". Proceedings of IRAJ International Conference on Advances in Mechanical, Civil, And Construction Engineering, pp. 22-26. (Published)
2. Sharma, S. and Gupta, A.K., (2020) "Risk identification and management in construction projects". International Journal of Humanities, Arts and Social Sciences, 5(6), pp. 224-231. (Published)
3. Sharma, S. and Gupta, A.K., (2020) "Identification and management of risks in building and infrastructure projects". Journal of Construction Engineering, Technology & Management. (Submitted)
4. Sharma, S. and Gupta, A.K., (2020). "Analysis of factors affecting cost and time overruns in construction projects". Trends and Recent Advances in Civil Engineering. (Submitted)

APPENDIX-A
QUESTIONNAIRE SURVEY REGARDING RISK INVOLVED IN BUILDINGS & INFRASTRUCTURE PROJECTS
Section I: General Information

1. Name (Optional):	
2. Contact No. (Optional):	
3. Position in the company:	☐ Project Manager ☐ Site Supervisor ☐ Engineer ☐ Contractor ☐ Consultant ☐ Any Other (Specify) ________________________
4. Company name:	
5. Years of experience:	☐ < 5Years ☐ 5-10Years ☐ 10-15Years ☐ 15-20Years ☐ >20Years
6. Nature of company:	☐ Owner ☐ Consultant ☐ Contractor ☐ Any Other
Do you implement risk management in your projects?	Yes ☐ No ☐
Do you think it is necessary to implement risk management?	Yes ☐ No ☐

Section II: Likert Scale

Scale for measuring frequency:

Sr.no.	**Scale**	**Level of importance (Score)**
1	Low	1
2	Moderate	2
3	High	3

Scale for measuring severity:

Sr.no.	**Scale**	**Level of importance (Score)**
1	Very Low	1
2	Low	2
3	Moderate	3
4	High	4
5	Very High	5

Section III: Risk Factors Assessment

In this section assessment of risk will be done based on frequency and severity. The frequency refers to risk occurrence possibility level. The severity refers to the impact of risk on project objectives in terms of cost, time, quality, etc. once the risk event occurs.

	Sr. No.	**Description of risk factors**	**Frequency**				**Severity**				
			1	**2**	**3**		**1**	**2**	**3**	**4**	**5**
Management Risks	**1**	Poor coordination or communication among various parties									
	2	Poor management skills									
	3	Lack of experience of the project team									
	4	Personal conflicts between different clients involved									
	5	Poor site management and supervision									
	6	Shortage of skillful managers and professional’s									
	7	Improper project planning and budgeting									
	8	Change of top management									

	Sr. No.	Description of risk	Frequency				Severity				
			1	2	3		1	2	3	4	5
	9	Inadequate quality planning and quality assurance									
	10	Lack of clarity over roles and responsibilities									
	11	Restrictions on foreign companies									
Technical & Construction Risks	**12**	Design errors or design changes									
	13	Unclear and incomplete detailing in design drawings and specifications									
	14	Using poor construction techniques									
	15	Delay in design									
	16	Complexity of design									
	17	Inadequate experience of contractor in same projects									
	18	Construction errors and poor workmanship leading to rework									
	19	Approval and permit delays									
	20	Pressure to crash project duration (time constraints)									
	21	Using complex construction methods/techniques									
	22	Changing construction methods/techniques in between of work									
Resource & Site Related Risks	**23**	Low productivity and efficiency of equipment									
	24	Breakdown of plant and machinery									
	25	Shortage of skillful workers locally									
	26	Shortage or delay in delivery of expected materials									
	27	Unavailability or shortage of equipment									
	28	Low labour productivity									
	29	Adverse ground conditions									
	30	Unavailability of utilities on-site required for construction									
	31	Difficulties in accessing site due to topography of the region									
	32	Inadequate preliminary survey and tests of site									
	33	Delays in the site possession									
Contractual & Legal Risks	**34**	Contradictions in the contract documents									
	35	Changes in project scope									
	36	Litigations and disputes retarding project progress									
	37	Contractual disputes and claims									
	38	Huge competition at the tendering stage									
	39	Change in codes and regulations									
	40	Unreliability of the legal system									
Economic & Financial Risks	**41**	Unpredicted changes in interest rates									
	42	Payment delays									
	43	Failure to meet revenue targets									
	44	Unpredicted changes in inflation rates									
	45	Inaccurate assessment of market demand									
	46	Project-funding problems									
	47	Fluctuation in exchange rate of currency									

	Sr. No.	Description of risk	Frequency				Severity				
			1	2	3		1	2	3	4	5
Socio-Political Risks	**48**	Unfavourable social environment									
	49	Political instability of the government									
	50	Compensation and land acquisition problems									
	51	Public opposition to the project									
	52	Different religious and cultural beliefs									
	53	Laws and policies revising in between of project									
	54	Labour disputes and strikes									
	55	Improper project feasibility study									
	56	Govt. officers asking for bribes									
	57	Outbreak of hostilities (riots, revolutions & terrorism)									
Environmental Risks	**58**	Pollution related to construction activities (dust, harmful gases, etc.)									
	59	Strict environmental rules and regulations									
	60	Changes in environmental standards									
	61	Legal proceedings due to wrong disposal of waste									
	62	Bad weather (snow, excess rain)									
	63	Natural disasters (floods, landslides, etc.)									
	64	Improper assessment of project impacts on environment									
Health & Safety Risks	**65**	Accidents occurring during construction									
	66	Inadequate safety measures									
	67	Changed labour safety laws or regulations									
	68	Epidemic illness									
	69	Damage to property due to unsafe operations									
	70	Lack of protection from enclosing area									

Any suggestions or comments:

………

………………………………………………………………………………………………………

Thank you for contributing your valuable time and your thoughtful suggestions to complete this survey.

APPENDIX-B

P.I.D	Risk ID														
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
P1	4	3	3	5	1	3	3	4	3	5	1	2	3	4	2
P2	4	4	3	4	3	3	5	4	2	4	3	5	3	4	2
P3	5	4	3	5	4	4	4	3	4	3	3	4	4	4	5
P4	3	5	5	1	5	3	5	2	4	3	4	4	4	3	3
P5	5	3	5	3	3	3	4	2	1	4	2	4	4	2	1
P6	4	1	3	3	4	3	5	2	4	4	1	5	3	3	3
P7	5	4	5	4	5	5	5	5	4	4	3	4	3	4	4
P8	3	3	5	3	4	4	5	4	4	2	1	4	4	3	2
P9	2	2	2	2	5	1	5	1	3	3	4	3	4	3	3
P10	2	5	4	3	5	5	5	2	4	4	3	2	4	3	4
P11	3	4	3	4	4	1	5	1	4	4	4	5	5	4	5
P12	2	5	4	2	3	4	4	2	5	4	3	3	3	3	5
P13	5	4	5	3	4	5	4	4	4	5	5	3	3	5	4
P14	5	3	3	2	1	3	5	1	4	4	5	5	2	4	3
P15	5	5	1	2	3	3	5	5	4	4	4	4	4	4	3
P16	1	4	3	4	5	3	5	3	4	2	2	5	3	5	2
P17	3	3	3	4	3	5	4	4	5	1	4	2	4	5	1
P18	3	4	3	5	4	5	5	2	4	3	3	5	3	4	3
P19	4	4	3	3	5	4	4	2	3	4	3	4	5	4	3
P20	4	4	2	3	3	4	4	5	5	3	4	5	3	3	1
P21	2	3	3	4	3	5	5	2	4	3	3	4	3	5	3
P22	1	3	3	1	1	2	1	1	2	1	2	2	2	3	2
P23	3	5	1	2	5	1	4	3	5	4	2	1	5	5	5
P24	1	2	4	5	4	5	5	1	4	3	5	1	5	2	2
P25	5	5	5	3	5	3	3	4	4	3	4	5	5	3	4
P26	3	4	5	4	4	5	5	5	4	5	3	5	5	3	5
P27	4	4	3	3	4	3	4	3	4	3	3	5	5	5	3
P28	2	2	3	2	3	3	3	2	2	3	2	5	5	3	3
P29	3	4	4	3	3	1	3	4	4	5	3	3	3	3	3
P30	2	3	5	5	3	5	5	5	4	3	2	4	5	3	3
P31	4	4	4	3	3	5	5	4	5	3	4	4	4	4	5
P32	3	4	3	4	3	3	4	1	5	3	2	4	4	3	1
P33	4	2	5	4	4	5	3	2	2	2	5	5	5	3	1
P34	3	4	4	4	4	4	3	4	5	4	5	4	4	3	5
P35	4	5	5	3	3	4	4	4	4	4	5	4	4	4	4
P36	2	3	3	1	1	1	1	1	1	2	2	3	2	1	1
P37	3	3	3	5	4	5	5	3	4	5	3	4	3	4	2
P38	5	3	4	3	3	2	1	2	3	3	3	4	2	3	4
P39	3	5	5	2	3	4	3	2	3	4	2	5	5	1	2
P40	3	5	3	2	5	3	2	5	5	4	3	5	3	4	5
P41	2	3	3	2	1	3	3	2	3	2	2	3	3	3	2
P42	2	1	2	2	2	2	1	1	1	2	1	2	2	1	2
P43	3	3	4	4	4	2	5	3	3	3	3	1	5	4	2
P44	1	4	5	5	5	5	3	2	4	2	4	4	4	4	1
P45	3	3	2	3	2	3	3	3	3	3	3	5	3	3	2
P46	2	2	2	1	3	2	5	2	1	5	5	5	3	3	2
P47	5	5	4	3	5	3	4	4	4	3	4	4	4	4	4
P48	3	5	3	2	3	3	4	4	3	3	3	4	4	3	4
P49	3	4	5	4	3	4	4	4	3	3	3	5	4	3	4
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P.I.D	Risk ID													
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P.I.D	**Risk ID**													
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APPENDIX-C

P.I.D	Risk ID														
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P.I.D	**Risk ID**													
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P.I.D	**Risk ID**													
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P.I.D	**Risk ID**												
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P71	2	2	1	3	2	3	1	1	1	3	1	2	2
P72	2	2	1	2	3	2	1	1	3	2	1	1	3
P73	1	3	2	2	2	2	3	1	2	2	2	3	3
P74	2	1	1	3	1	1	3	2	3	2	1	2	2
P75	1	3	2	1	2	2	2	2	1	1	1	1	2
P76	1	2	2	2	2	2	2	2	2	3	2	1	1
P77	1	2	2	3	2	1	2	3	3	2	2	1	2
P78	2	2	2	1	2	2	1	3	2	3	1	2	2
P79	1	3	3	3	2	2	1	2	2	2	1	2	3
P80	1	3	1	2	1	2	1	1	2	2	1	3	2
P81	2	2	1	3	3	2	2	1	2	1	1	2	3
P82	2	3	2	1	1	1	2	3	2	1	1	2	3
P83	3	2	2	2	3	2	2	1	1	2	1	1	2
P84	1	3	2	2	1	2	2	2	3	1	1	1	1
P85	3	1	1	1	1	3	2	2	1	3	2	2	3
P86	1	2	1	1	1	2	1	1	1	1	2	1	1
P87	2	3	3	2	1	3	1	2	2	2	2	1	2
P88	2	3	3	3	1	1	1	1	3	2	1	2	2
P89	2	2	2	1	2	3	2	2	3	2	1	1	2
P90	2	2	2	2	1	2	2	1	2	2	2	1	2
P91	2	3	3	3	2	2	2	2	1	2	1	1	2
P92	2	2	2	2	2	1	1	3	2	1	2	2	3
P93	3	3	3	2	3	3	3	3	3	3	2	3	3
P94	3	1	2	2	1	1	1	1	1	1	2	2	2
P95	1	3	1	3	3	1	2	1	2	3	1	1	2
P96	3	3	1	1	2	1	3	2	1	1	3	2	2
P97	2	2	1	2	2	1	1	2	2	1	1	1	2
P98	1	1	1	2	1	1	1	2	1	1	2	1	1
P99	2	2	2	3	3	2	2	2	3	1	1	2	1
P100	3	2	1	2	2	2	2	1	3	2	1	1	1
P101	2	1	2	3	2	3	2	1	1	2	1	2	3
P102	3	1	1	2	3	1	2	2	2	2	2	1	2
P103	3	1	2	2	2	3	2	1	3	2	2	1	2
P104	2	1	1	3	1	1	3	2	3	1	3	1	3
P105	1	2	2	3	2	2	2	2	2	2	1	1	2
P106	3	1	1	3	1	3	2	2	1	3	3	3	1
P107	2	1	1	1	3	1	2	3	2	1	2	2	2
P108	1	2	2	3	1	3	1	1	2	2	3	1	2
P109	2	3	1	2	1	2	3	2	2	1	1	2	3
P110	3	1	3	3	3	1	2	3	3	3	2	2	2
P111	2	1	1	1	2	1	1	1	1	2	1	1	1
P112	1	3	1	2	3	1	1	2	1	1	1	2	3
P113	2	3	3	2	2	2	1	1	3	3	3	1	3
P114	3	3	3	2	3	2	2	3	3	3	2	2	3
P115	2	1	2	3	3	1	3	1	3	1	2	2	2
P116	2	1	3	2	2	2	2	2	3	2	1	1	2
P117	1	2	1	1	3	2	1	3	2	1	2	1	1
P118	3	2	3	3	3	3	3	3	3	3	3	2	3
P119	3	2	3	3	3	3	3	3	3	3	2	3	3
P120	3	3	3	2	2	3	3	3	3	3	2	3	2

P121	3	3	3	2	3	3	3	3	3	3	3	3	3
P122	3	3	3	1	3	1	3	2	3	2	1	1	3
P123	1	2	2	1	3	2	1	2	2	2	1	1	3
P124	2	3	1	2	1	1	3	2	3	2	3	1	3
P125	3	1	2	3	2	1	3	2	2	2	1	1	1
P126	2	1	1	1	2	3	3	1	1	1	3	2	3
P127	2	2	1	2	2	1	1	2	2	3	1	1	1
P128	2	2	2	1	2	1	1	2	1	3	1	1	3
P129	2	2	2	2	2	3	2	2	2	2	3	1	1
P130	3	3	2	2	3	2	1	2	3	3	1	2	2
P131	2	3	3	1	1	2	1	3	1	2	1	1	2
P132	2	2	2	2	1	2	2	1	2	1	3	2	2
P133	1	2	1	2	2	1	2	2	2	1	2	1	2
P134	3	3	2	3	2	3	1	1	3	2	1	1	3
P135	2	3	2	1	3	3	2	3	2	1	1	2	1
P136	1	2	1	1	1	1	1	1	1	1	1	1	2
P137	2	1	2	1	2	2	1	3	2	1	3	1	2
P138	2	2	1	2	2	1	2	2	2	1	1	1	2
P139	2	2	3	3	2	2	2	2	1	2	1	3	1
P140	2	1	3	1	2	2	3	2	3	1	1	1	3
P141	2	1	2	2	1	2	2	2	2	2	3	1	3
P142	3	2	1	1	2	1	1	2	3	3	1	3	2
P143	3	2	3	2	3	1	3	2	3	3	1	2	3
P144	2	2	3	3	2	2	2	2	1	1	3	1	1
P145	1	2	3	2	2	1	1	2	3	2	1	2	2
P146	2	2	2	1	1	2	2	1	3	1	2	2	1
P147	2	2	1	3	1	2	1	2	1	2	1	1	2

APPENDIX-D

RELIABILITY ANALYSIS OF DATA COLLECTED

Table 1. Case processing summary of severity and frequency

		N	%
Cases	Valid	147	100.00
	Excluded[a]	0	.0
	Total	147	100.00

[a] Listwise deletion based on all variables in the procedure

Table 2. Item total statistics for severity data

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if item Delated
Poor coordination or communication among various parties	229.8776	1365.464	.494	.940
Poor management skills	229.4218	1378.533	.402	.941
Lack of experience of the project team	229.3469	1372.954	.473	.941
Personal conflicts between different clients involved	229.6395	1365.712	.497	.940
Poor site management and supervision	229.6190	1365.114	.493	.940
Shortage of skilful managers and professional's	229.3401	1373.048	.455	.941
Improper project planning and budgeting	229.2041	1371.177	.456	.941
Change of top management	229.8027	1362.406	.507	.940
Inadequate quality planning and quality assurance	229.3537	1366.696	.527	.940
Lack of clarity over roles and responsibilities	229.6054	1371.665	.466	.941
Government restrictions on foreign companies	229.7007	1363.732	.523	.940
Design errors or design changes	229.2517	1374.121	.443	.941
Unclear and incomplete detailing in design drawings and specifications	229.3878	1378.581	.406	.941
Using poor construction techniques	229.5034	1364.074	.551	.940

Delay in design	229.6054	1362.898	.519	.940
Complexity of design	229.7347	1365.059	.504	.940
Inadequate experience of contractor in same projects	229.5374	1366.867	.487	.940
Construction errors and poor workmanship leading to rework	229.7211	1374.107	.425	.941
Approval and permit delays	229.2789	1366.723	.512	.940
Pressure to crash project duration (time constraints)	229.3401	1368.979	.496	.940
Using complex construction methods/techniques	229.7415	1367.714	.457	.941
Changing construction methods/techniques in between of work	229.7279	1362.802	.537	.940
Low productivity and efficiency of equipment	229.6939	1377.762	.375	.941
Breakdown of plant and machinery	229.6735	1362.865	.501	.940
Shortage of skilful workers locally	229.4082	1375.202	.388	.941
Shortage or delay in delivery of expected materials	229.6122	1375.266	.428	.941
Unavailability or shortage of equipment	229.7347	1379.703	.356	.941
Low labour productivity	229.5986	1369.708	.454	.941
Adverse ground conditions	229.4626	1368.716	.434	.941
Unavailability of utilities on-site required for construction	229.4830	1368.882	.443	.941
Difficulties in accessing site due to topography of the region	229.7347	1377.114	.342	.941
Inadequate preliminary survey and tests of site	229.4626	1369.538	.469	.941
Delays in the site possession	229.5578	1362.276	.502	.940
Contradictions in the contract documents	229.3605	1377.547	.364	.941
Changes in project scope	229.5510	1365.674	.504	.940
Litigations and disputes retarding project progress	229.2245	1375.559	.420	.941
Contractual disputes and claims	229.2381	1372.840	.435	.941
Huge competition at the tendering stage	229.7415	1366.303	.448	.941
Change in codes and regulations	229.9524	1371.457	.405	.941
Unreliability of the legal system	229.5034	1373.622	.436	.941

Unpredicted changes in interest rates	229.4626	1372.894	.405	.941
Payment delays	229.2313	1378.672	.379	.941
Failure to meet revenue targets	229.3878	1385.308	.296	.941
Unpredicted changes in inflation rates	229.0408	1387.163	.328	.941
Inaccurate assessment of market demand	229.4626	1371.771	.419	.941
Project-funding problems	229.3469	1370.940	.439	.941
Fluctuation in exchange rate of currency	229.7279	1375.830	.368	.941
Unfavourable social environment	229.5782	1372.067	.410	.941
Political instability of the government	229.7551	1374.926	.388	.941
Compensation and land acquisition problems	229.4286	1367.562	.491	.940
Public opposition to the project	229.5986	1373.215	.402	.941
Different religious and cultural beliefs	229.9184	1374.980	.382	.941
Laws and policies revising in between of project	229.2041	1393.506	.196	.942
Labour disputes and strikes	229.4286	1384.068	.296	.941
Improper project feasibility study	229.6871	1369.737	.431	.941
Govt. officers asking for bribes	229.9524	1382.785	.292	.941
Outbreak of hostilities (riots, revolutions & terrorism)	229.8367	1373.083	.404	.941
Pollution related to construction activities (dust, harmful gases, etc.)	230.0204	1367.609	.438	.941
Strict environmental rules and regulations	229.8367	1375.672	.367	.941
Changes in environmental standards	229.6599	1380.884	.365	.941
Legal proceedings due to wrong disposal of waste	229.8844	1377.021	.396	.941
Bad weather (snow, excess rain)	228.9932	1385.048	.304	.941
Natural disasters (floods, landslides, etc.)	228.8844	1386.569	.313	.941
Improper assessment of project impacts on environment	229.9456	1375.449	.379	.941
Accidents occurring during construction	229.9796	1382.308	.285	.941
Inadequate safety measures	230.0136	1375.972	.369	.941
Changed labour safety laws or regulations	230.1837	1374.781	.371	.941
Epidemic illness	229.4218	1389.396	.229	.942
Damage to property due to unsafe operations	229.7755	1369.244	.442	.941
Lack of protection from enclosing area	230.0476	1368.114	.507	.940

Table 3. Reliability statistics for severity

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.942	.942	70

Table 4. Item total statistics for frequency data

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if item Delated
Poor coordination or communication among various parties	136.8844	378.062	.251	.908
Poor management skills	136.8503	375.553	.315	.908
Lack of experience of the project team	136.9728	379.657	.197	.909
Personal conflicts between different clients involved	136.8435	377.051	.303	.908
Poor site management and supervision	136.7687	376.686	.306	.908
Shortage of skilful managers and professional's	136.6735	376.098	.293	.908
Improper project planning and budgeting	136.8503	375.553	.319	.908
Change of top management	137.1497	371.936	.441	.907
Inadequate quality planning and quality assurance	136.7415	376.590	.302	.908
Lack of clarity over roles and responsibilities	136.7211	378.066	.274	.908
Government restrictions on foreign companies	136.8503	374.731	.334	.908
Design errors or design changes	136.6735	376.673	.305	.908
Unclear and incomplete detailing in design drawings and specifications	136.7007	376.197	.319	.908
Using poor construction techniques	137.0408	372.752	.394	.907
Delay in design	136.8912	374.536	.337	.908
Complexity of design	136.8639	377.584	.251	.908

Inadequate experience of contractor in same projects	136.7211	373.997	.351	.907
Construction errors and poor workmanship leading to rework	137.1361	377.790	.253	.908
Approval and permit delays	136.5170	374.402	.392	.907
Pressure to crash project duration (time constraints)	136.5850	374.902	.398	.907
Using complex construction methods/techniques	137.0612	373.085	.402	.907
Changing construction methods/techniques in between of work	136.9660	375.855	.304	.908
Low productivity and efficiency of equipment	136.7075	376.428	.317	.908
Breakdown of plant and machinery	136.7143	374.890	.350	.907
Shortage of skilful workers locally	136.7755	377.230	.266	.908
Shortage or delay in delivery of expected materials	136.7007	377.855	.253	.908
Unavailability or shortage of equipment	136.7415	375.878	.314	.908
Low labour productivity	136.8435	372.640	.409	.907
Adverse ground conditions	136.6463	376.271	.305	.908
Unavailability of utilities on-site required for construction	136.9728	375.616	.318	.908
Difficulties in accessing site due to topography of the region	136.7755	376.600	.294	.908
Inadequate preliminary survey and tests of site	136.7347	374.552	.362	.907
Delays in the site possession	136.7959	377.657	.249	.908
Contradictions in the contract documents	136.8435	374.201	.357	.907
Changes in project scope	137.1293	374.867	.374	.907
Litigations and disputes retarding project progress	136.8571	373.205	.395	.907
Contractual disputes and claims	136.7007	376.197	.310	.908
Huge competition at the tendering stage	136.5850	376.738	.317	.908
Change in codes and regulations	137.1224	374.766	.358	.907
Unreliability of the legal system	136.9864	376.616	.330	.908
Unpredicted changes in interest rates	137.1088	373.865	.402	.907
Payment delays	136.5646	377.056	.307	.908

Failure to meet revenue targets	136.9592	372.820	.421	.907
Unpredicted changes in inflation rates	136.7143	374.301	.348	.907
Inaccurate assessment of market demand	136.7551	373.912	.390	.907
Project-funding problems	136.9388	372.003	.419	.907
Fluctuation in exchange rate of currency	136.9728	375.287	.351	.907
Unfavourable social environment	136.7687	377.384	.256	.908
Political instability of the government	136.7823	373.637	.409	.907
Compensation and land acquisition problems	136.6871	375.573	.358	.907
Public opposition to the project	136.7211	376.655	.312	.908
Different religious and cultural beliefs	136.8639	374.913	.358	.907
Laws and policies revising in between of project	136.7823	374.966	.339	.908
Labour disputes and strikes	136.8299	377.183	.281	.908
Improper project feasibility study	136.7483	377.505	.257	.908
Govt. officers asking for bribes	136.8980	374.668	.343	.908
Outbreak of hostilities (riots, revolutions & terrorism)	137.2449	376.049	.355	.907
Pollution related to construction activities (dust, harmful gases, etc.)	136.8367	374.042	.388	.907
Strict environmental rules and regulations	136.7483	376.477	.292	.908
Changes in environmental standards	136.9932	371.993	.439	.907
Legal proceedings due to wrong disposal of waste	136.9048	379.142	.206	.909
Bad weather (snow, excess rain)	136.8776	373.697	.386	.907
Natural disasters (floods, landslides, etc.)	137.0136	374.329	.380	.907
Improper assessment of project impacts on environment	137.0476	375.470	.374	.907
Accidents occurring during construction	136.8707	372.949	.436	.907
Inadequate safety measures	136.8027	374.502	.356	.907
Changed labour safety laws or regulations	137.0068	371.130	.470	.906
Epidemic illness	137.1837	378.398	.241	.908
Damage to property due to unsafe operations	137.2245	374.408	.401	.907
Lack of protection from enclosing area	136.7891	374.661	.370	.907

Table 5. Reliability statistics for frequency

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.909	.909	70

APPENDIX-E

FACTOR ANALYSIS OF CRITICAL RISK FACTORS

Table 1. KMO & Bartlett's test of adequacy

KMO and Bartlett's Test		
Kaiswe-Meyer-Olkin Measure of Sampling Adequacy		.793
Barlett's Test for Sphericity	Approx. Chi- Square	1511.90
	df	703
	Sig.	.000

Table 2. Values of total variance explained

Total Variance Explained						
Component	Initial Eigen Values			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	18.812	49.505	49.505	18.812	49.505	49.505
2	5.911	15.555	65.061	5.911	15.555	65.061
3	3.375	8.882	73.942	3.375	8.882	73.942
4	1.323	3.482	77.424	1.323	3.482	77.424
5	1.144	3.011	80.434	1.144	3.011	80.434
6	0.980	2.579	83.013			
7	0.931	2.450	85.463			
8	0.842	2.216	87.679			
9	0.798	2.100	89.779			
10	0.649	1.708	91.487			
11	0.461	1.213	92.700			
12	0.345	0.908	93.608			
13	0.288	0.758	94.366			
14	0.239	0.629	94.995			
15	0.213	0.561	95.555			
16	0.201	0.529	96.084			
17	0.193	0.508	96.592			
18	0.147	0.387	96.979			
19	0.138	0.363	97.342			
20	0.132	0.347	97.689			
21	0.118	0.311	98.000			

22	0.101	0.266	98.266			
23	0.074	0.195	98.461			
24	0.073	0.192	98.653			
25	0.061	0.161	98.813			
26	0.056	0.147	98.961			
27	0.052	0.137	99.097			
28	0.049	0.129	99.226			
29	0.047	0.124	99.350			
30	0.039	0.103	99.453			
31	0.035	0.092	99.545			
32	0.032	0.084	99.629			
33	0.031	0.082	99.711			
34	0.027	0.071	99.782			
35	0.024	0.063	99.845			
36	0.022	0.058	99.903			
37	0.019	0.050	99.953			
38	0.018	0.047	100.000			
Extraction Method: Principal Component Analysis						

Table 3. Monte Carlo PCA for parallel analysis

Component	Random eigen value	Standard deviation
1	2.1258	.0747
2	1.9837	.0547
3	1.8837	.0529
4	1.7826	.0433
5	1.7014	.0396
6	1.6227	.0407
7	1.5547	.0354
8	1.4907	.0345
9	1.4284	.0312
10	1.3711	.0300

Table 4. Comparison of initial eigen values with parallel analysis

Initial Eigen Values				Parallel Analysis		Comment
Component	Total	% of Variance	Cumulative %	Component	Random eigen value	
1	18.812	49.505	49.505	1	2.1258	Retained
2	5.911	15.555	65.061	2	1.9837	Retained
3	3.375	8.882	73.942	3	1.8837	Retained
4	1.323	3.482	77.424	4	1.7826	Not retained
5	1.144	3.011	80.434	5	1.7014	Not retained

Table 5. Component correlation matrix

Component	1	2	3
1	1.000	.562	.612
2	.562	1.000	.484
3	.612	.484	1.000
Extraction Method: Principal Component Analysis Rotation Method: Oblimin with Kaiser Normalization			

Correlated because it is greater than 0.5

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