"RISK MANAGEMENT IN HYDRO-ELECTRIC 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

Mr. Santu Kar
(Assistant Professor)

By

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173 234

HIMACHAL PRADESH, INDIA

June, 2016

CERTIFICATE

This is to certify that the work which is being presented in the thesis titled **"RISK MANAGEMENT IN HYDRO-ELECTRIC 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"** and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Sonia Sharma** (Enrollment No. 142606) M. Tech. Construction Management during a period from July 2015 to June 2016 under the supervision of **Mr. Santu Kar** Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

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ACKNOWLEDGEMENT

Foremost, I would like to express my sincere gratitude to my guide and supervisor **Mr. Santu Kar,** Department of Civil Engineering, for the continuous support of my thesis study, for his patience, motivation, enthusiasm, and immense knowledge. His guidance has helped me in all the time of this study and writing of this report. I could not have imagined having a better advisor and mentor for my thesis study. I would also like to thank him for lending me his precious time when I had went to him.

My special thanks are due to **Dr. Ashok Kumar Gupta,** Head of the Civil Engineering Department, for all the facilities provided.

I am also very thankful to all the faculty members of the department, for their constant encouragement during the project.

I also take the opportunity to thank all my friends who have directly or indirectly helped me in my project work.

Last but not the least I would like to thank my parents, who taught me the value of hard work by their own example.

Date:-

Place:- Waknaghat **Sonia Sharma**

ABSTRACT

Construction projects are usually more complicated, unique and risky due to the nature of different activities involved. Hydroelectric projects are not so much successful in Indian scenario due to the different risks involved in different activities in hydroelectric projects. So the main objective of this research is to evaluate most, common and major risks involved in hydroelectric projects. A risk management process is evolved to achieve the project objectives in terms of time, cost, quality, safety and environmental sustainability. In order to achieve the project objectives, a proper risk management is necessary. Risk management is a process of identifying, classifying, analyzing, assessing and controlling of risks in a project. There are several techniques for risk analysis such as calculating Risk Potential, Sensitivity Analysis and Monte Carlo Simulation. In this project questionnaire survey was conducted among twenty respondents from different organizations to collect data. Risk potential values of different factors are calculated to rank the risk factors based on the ratings given by respondents. Also risk assessment matrix has been formed based on the probability index and severity index to prioritize risk factors. After the analysis top ten factors has been found such as land acquisition problems, resettlement and rehabilitation, unpredicted geological structure at tunneling sites, precipitation/ flooding, labor strikes, adverse geological conditions, access conditions, time constraint, natural disasters, paucity of funds which should be given more importance and should be managed properly to achieve the project objectives. Also some risk mitigation techniques are suggested in this report for top ranked factors which may be referred in the hydroelectric projects in future.

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ABBREVIATIONS

APRAM	Advanced Programmatic Risk Analysis and Management Model
CCF	Chinese Construction Firm
CFSI	Counterfeit, Fraudulent, and Suspect Items
CRMS	Construction Risk Management System
ERA	Estimating using Risk Analysis
ERM	Enterprise Risk Management
LDRC	Late Deliverable Risk Catalog
PCA	Principal Component Analysis
PI	Probability Index
RM3	Risk Management Maturity assessment Model
RPC	Regional Power Committee
SI	Severity Index

CHAPTER-1

INTRODUCTION

1.1 General

Construction projects are usually more complicated and risky due to the nature of different activities involved. Risks vary between projects because each construction project is unique and risks can be raises from different sources. No construction project is totally free from risks. Risk plays an important role in the success of any construction project. Risk is defined as any action which will have an effect on the achievement of project objectives. The core element of project success is to meet the time, cost and quality as targeted. In order to achieve these targets, risk may appear in different ways and may result in time overrun, budget overrun, loss of life, environmental damage, financial losses and various other failures. Risk can be managed, minimized, shared, transferred, or accepted. It cannot be ignored. In order to manage a project, risk management is an important step in project success. The purpose of risk management is to attain the project objectives in terms of time, cost, quality, safety and environmental sustainability. Risk management may be described as a corresponding set of actions and methods used to control risks. In order to achieve the project objectives, a proper risk management is necessary. Risk management is a process of identifying, classifying, analyzing, assessing and controlling of risks in a project.

1.2 Need of study

Need of this project is to know the importance of risk management in hydroelectric projects. There are several risk factors involved in the construction of hydroelectric projects which may delay the project and also may increase the cost of the project. Development of hydro power projects becoming riskier due to sudden change in socio-economic environment, political uncertainties etc. Hydro projects have become weaker due to increase in occurrence of natural disasters in recent times. Risk mitigation has therefore become more challenging.

In Indian scenario hydro-electric projects are not so much successful. There are so many projects in India which are being delayed or stopped due to several risks like labor risks or political risks and environmental risk factors (e.g. Rattle Hydroelectric Project in J&K and Subansri Lower Hydroelectric Project in Assam).

Different risk factors involved in the construction of hydro-electric projects. So there is need to study the various risks involved in the construction of hydro-electric projects so that in future it will be beneficial for hydro-electric projects. So risk factors should be managed in a proper way to avoid such type of delay and failure of project in future.

1.3 Objective

India is one of the pioneering countries in establishing hydro-electric power projects. The potential for hydroelectric power in India is one of the greatest in the world. Hydroelectric power plant has complex structures and involves large amount of funds with a long-running construction phase. This situation imposes uncertainty factors with considerably high risks. The construction stage is identified as a critical period in hydro power projects where many unpredicted factors take place. Failure to handle project risks leads to major troubles for the client such as completion time delays and cost overruns.

The objective of this project is to evaluate the most, common and major risks in hydroelectric projects which cause bad effect on the project to achieve its objectives.

The main objectives of this project are:-

1. To identify the risks involved in hydroelectric projects.
2. To classify risks according to their nature and potential consequence.
3. Risk analysis and managing risks in hydroelectric projects.

1.4 Scope of the project

In this project the various risk factors in hydroelectric projects are identified by questionnaires survey and then analysis of those factors are done. A proper risk management is to be developed for successful project execution in Indian scenario.

The scope of this study is to analyze the various risk factors and managing the risks involved in various construction activities in Indian scenario.

1.5 Research methodology

Research starts with literature review in order to provide the theoretical context about the project. Various risks involved in hydroelectric project are identified and analyzed and then various methods of risk management are adopted. Consequently outcome from interviews and questionnaires are presented to show that how industry deals with risks. Discussion is done on the results from the questionnaire and then risks identified are analyzed. Finally the final recommendations are drawn up in the conclusion section.

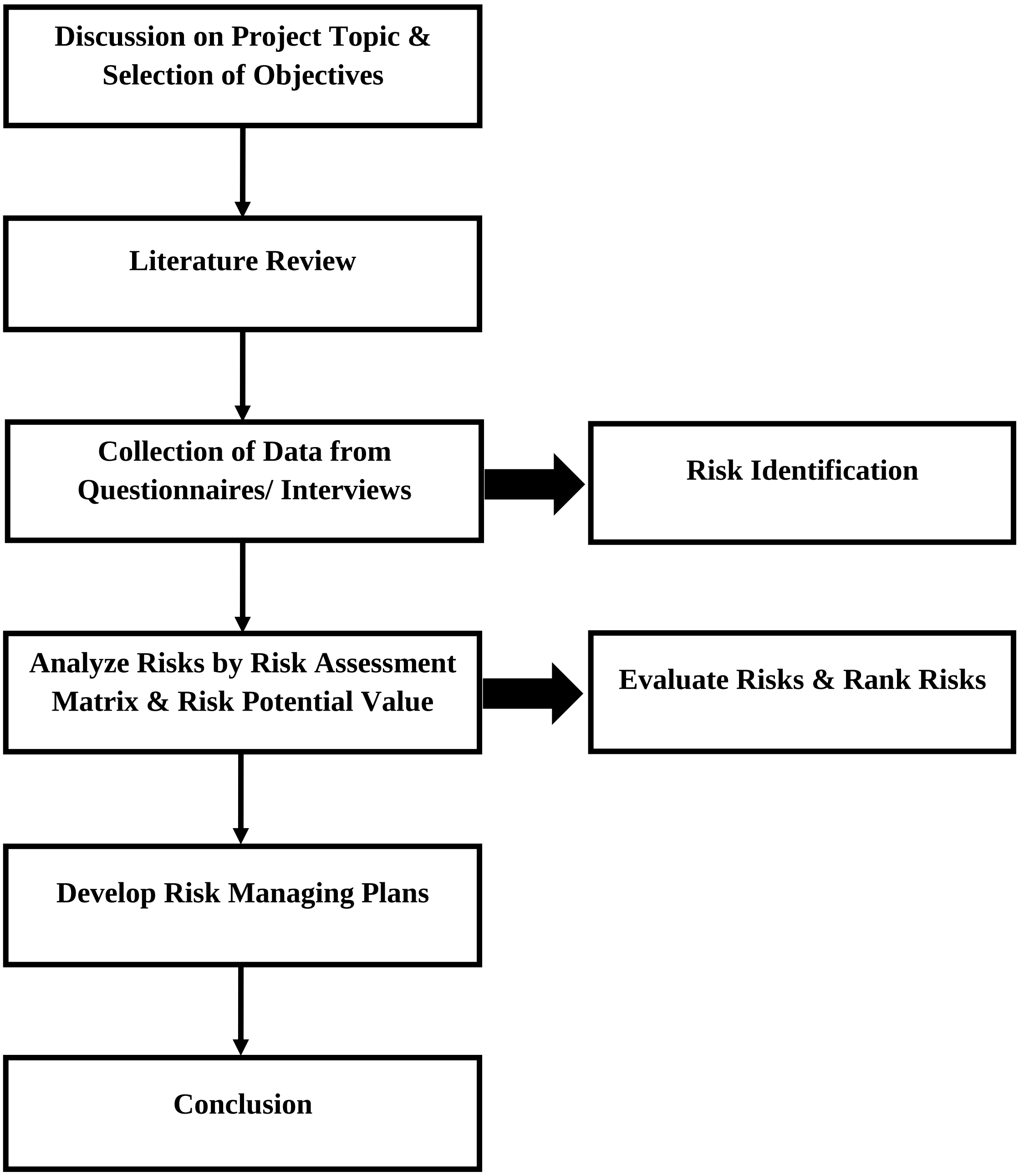

Fig. 1.1 Research methodology

Research methodology:-

1. Discussion on project topic and selection of objectives.
2. Literature review.
3. Collection of data from questionnaire survey, interviews, telephonic conversations, mailing and past experience.
4. Statistical analysis of survey data and results.
5. Identify risks in hydroelectric projects.
6. Classify risks based on risk assessment matrix.
7. Analyze risks by risk assessment matrix and risk potential value method. Determine the likelihood and consequences of risks.
8. Evaluate risks and rank risks.
9. Develop risk managing plans.
10. Conclusion.

CHAPTER-2

LITERATURE REVIEW

2.1 General

Risk management aims to manage the risks in construction projects by adopting risk management process which includes risk identification, risk assessment and risk control. An extensive research in this field has been conducted till now. Some of the previous work done by various authors in the study of risk management of construction projects has been conducted below.

2.2 Summary

[1] Refer to a paper by Al-Bahar and Crandall, on "Systematic risk management approach for construction projects" and is published in the Journal of Construction Engineering and Management, ASCE, 1990 which includes a new risk model named as construction risk management system (CRMS) to help contractors to identify project risks and to analyze and manage them systematically. The influence diagramming technique and Monte Carlo simulation are the tools used to analyze and evaluate project risks. The proposed CRMS consists of the following four processes:

- Risk identification.
- Risk analysis and evaluation.
- Response management.
- System administration.

In this model stress is placed on how to identify and manage risks before, rather than after, they turn up into losses.

[2] Refer to a paper by Kangari, on "Risk management perceptions and trends of U.S. construction" and is published in Journal of Construction Engineering and Management, ASCE, 1995. In this paper current attitude of large U.S. construction firms toward risk is discussed and the ways by which contractors conduct the risk management are shown. The study is carried out on U.S. contractors which show that in recent years contractors have been more willing to assume risks. The survey also establishes that contractors presently suppose the risk associated with real quantities of work.

[3] Refer to a paper by Akintoye and Macleod, on "Risk analysis and management in construction" is published in International Journal of Project Management, 1997 which describes, time, cost and quality of the project is affected by risk associated with construction projects. This paper describes the construction industry's perception of risk associated with its activities and the extent to which the industry uses risk analysis and management techniques. This paper concludes that risk management is necessary in construction to minimize losses and enhancing profitability. Risk analysis and management in construction depend mainly on observation, opinion and knowledge. Proper risk analysis and management techniques are seldom used due to lack of awareness and doubts on the suitability of these techniques for construction industry activities.

[4] Refer to a paper by Hillson, on "Towards a risk maturity model" published in The International Journal of Project & Business Risk Management, 1997 which describes a risk management maturity with four levels of maturity (naive, novice, normalized, natural) and each level linked to four attributes. The level of maturity of an organization can be assessed by using this model and then targets are identified for improvement. Action plans are produced for developing or enhancing their risk capability.

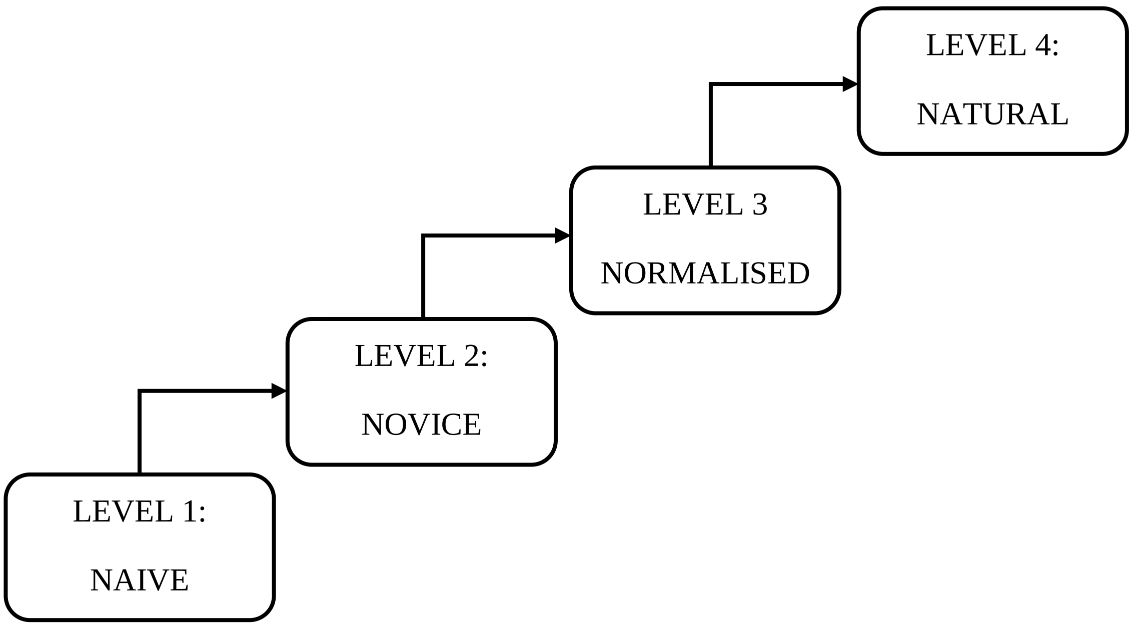

Fig. 2.1 The four levels of risk maturity[4]

Risk management maturity presented in this paper allows organizations to bench mark their risk capability against four standard levels of maturity and then identify what to be needed for improvement and develop their ability to manage risk. Risk management maturity provides a guideline to organizations wising to improve their approach to risk management, allowing them to assess their current level of maturity, identify targets for perfection and build up action plans for increasing their risk capacity.

[5] Refer to a paper by Minato and Ashley, on “Data-driven analysis of “Corporate Risk” using historical cost control data” and is published in Journal of Construction Engineering and Management, ASCE, 1998. In this paper author find that risk management includes three phases of risk identification, risk quantification and risk control. The author concludes that risk management approach may be broken into two ways. One way is analyzing risks by the single characteristics connected with individual projects and the extra approach may be to categorize risks into parallel groups, those that exist at the same time and regularly in company's projects and adopt business strategies across projects. This paper is concerned with the second approach. This study postulates that there exist some co-variable risks, or corporate risk, with a company, and maintains the theory that such risks could be diminished efficiently using strategies made at the higher levels of corporate management rather than strategies at the project level. The main objective of this paper is to provide managers with a theoretical framework of risk analysis methodology that will support analyzing a project's risks from their company's point of view.

[6] Refer to a paper by Mak and Picken, on “Using risk analysis to determine construction project contingencies” and is published in Journal of Construction Engineering and Management, ASCE, 2000. This paper shows that estimating using risk analysis (ERA) is a methodology that can be used to verify the contingency by identifying uncertainties and estimating their financial implications. A study of the result of ERA was carried out to evaluate the changeability and evenness of the contingency estimates between non-ERA and ERA projects. In this paper result of a survey are presented which compares a total of 287 non-ERA and 45 ERA projects. The results show a highly significant difference in variation and consistency between these groups. It indicates victorious use of the ERA method for public works projects to reduce unnecessary allowance for risk.

[7] Refer to a paper by Barber, on “Understanding internally generated risks in projects” and is published in International Journal of Project management, 2005. In this paper author identifies the risks that are poorly managed in projects. Internally generated risks

arise within a project management team or its host organization, their management systems, culture and decisions (e.g. arising from their rules, policies, processes, structures, actions, behaviors etc.). A literature research shows that a little research has been done on internally generated risks. So the research hypothesis is tested in this paper to understanding internally generated risks. The study was conducted on nine projects and the results shows that internally generated risks are frequent, major and poorly managed. Such risks are often complex and sensitive and hence can be difficult to quantify and to classify. This paper concludes that internally generated risks are important and require special attention and to be managed effectively.

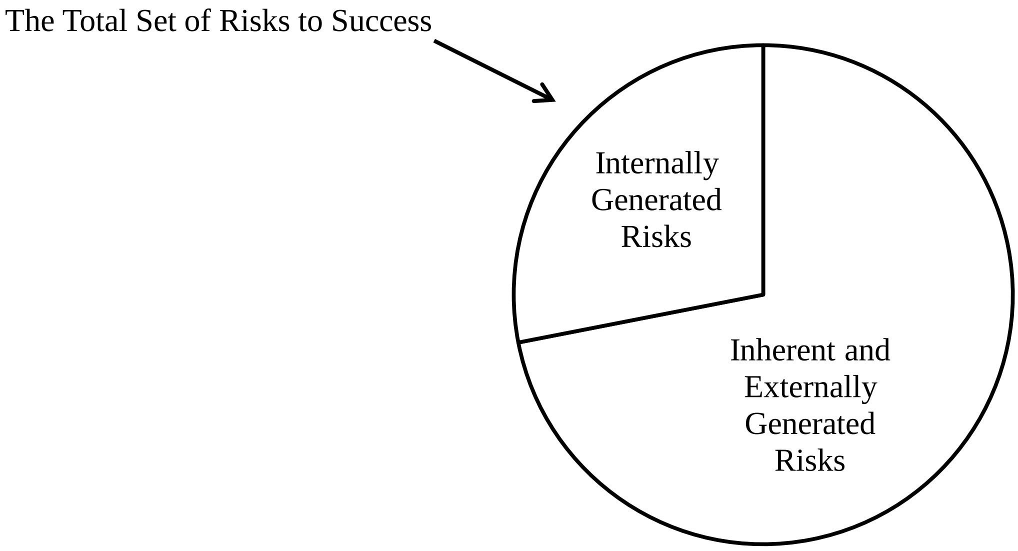

Fig. 2.2 Distinction between internally generated, inherent, and externally generated risks[7]

[8] Refer to a paper by Imbeah and Guikema, on "Managing construction projects using the advanced programmatic risk analysis and management model" and is published in Journal of Construction Engineering and Management, ASCE/August 2009. This paper describes a model entitled Advanced Programmatic Risk Analysis and Management Model (APRAM) for managing calendar, cost, and value risks in the construction industry. This paper focuses on cost, schedule, and quality as main criteria by which construction projects would be judged a success. This paper has shown that APRAM provide a risk analysis technique that can minimize the expected costs of project failure by integrating project risks of time, budget, and quality through the allocation of resources.

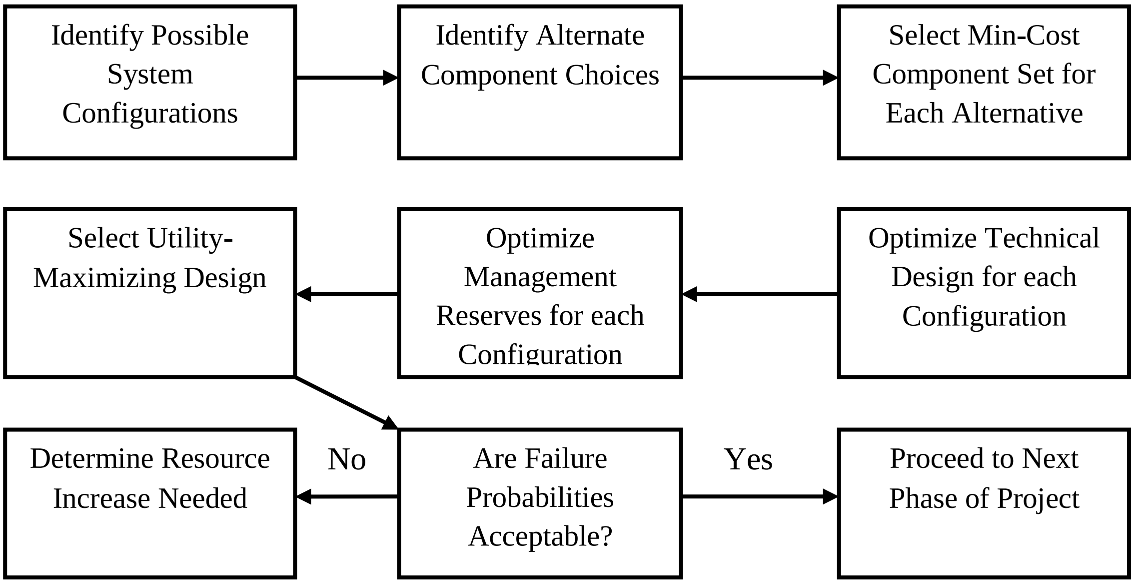

Fig. 2.3 APRAM Process[8]

[9] Refer to a paper by Zou, Chen and Chan, on "Understanding and Improving your risk management capability: Assessment model for construction organizations" and is published in Journal of Construction Engineering and Management, ASCE/ August 2010. In this paper a Web-based risk management maturity assessment model (RM3) is developed for construction organizations. The RM3 contains five attributes and these attributes are measured against a four-level scale.

Five Attributes:

- Management(people and leadership)
- Organizational risk culture
- Ability to identify risks
- Ability to analyze risks
- Development and application of regular risk management process.

Four Maturity Levels:

- Level 1: initial
- Level 2: repeatable
- Level 3: managed
- Level 4: optimized

The maturity levels are spread on a scale between 0 and 1.

In this paper it was found that the risk management maturity may be affected by size and history of a construction industry. Bigger and longer history of a construction industry, more mature they are in risk management.

[10] Refer to a paper by Kucukali, on “Risk assessment of river type hydropower plants by using fuzzy logic approach” and is published in World Renewable Energy Congress-Sweden, 2011. In this paper risk evaluation of river type hydropower plant projects a fuzzy ranking tool has been developed. Instead of probabilistic reasoning expert judgment have been used. External project risks have been considered in this model and a survey was conducted with experts having experience in river type hydro power projects. On the basis of survey site geology and environmental issues were the most vital risks in hydropower projects.

[11] Refer to a paper by Kansal and Sharma, on “Risk assessment methods and application in the construction projects” and is published in International Journal of Modern Engineering Research (IJMER), 2012. This paper assesses the use and method of risk identification techniques in construction industry. Brainstorming, delphi technique, checklist, flowchart etc. are the most commonly used risk identification techniques used in construction. Risk significant index method is used for analyzing the risks in this study. This paper concludes that each risk assessment method has their limitations so this paper effort to devise integrated risk assessment tools. It was observed that presently used risk assessment methods can be integrated into new approach to apply risk assessment efficiently.

[12] Refer to a paper by Mahendra, Pitroda and Bhavsar, “A study of risk management techniques for construction projects in developing countries” and is published in International Journal of Innovative Technology and Exploring Engineering (IJITEE), October 2013. In this paper a risk management technique is used which includes well-documented procedures to control the risks likely to occur during any construction project lifecycle. According to this paper the risk management technique should be applied into any construction project at the initial stage of the project to get maximum benefit of the technique.

Fig. 2.4 Risk Management Process[12]

[13] Refer to a paper by Patel, on "A study on risk assessment and its management in India" is published in American Journal of Civil Engineering, 2013. In this paper author develop a method for risk mitigation which includes a well-documented course of action. From the research author finds that risks arise in most of the construction projects due to lack of systematic procedures. Risks are managed in a very informal manner. In this research author finds that brain-storming sessions are the most preferred method to identify risks in Indian construction industry. The risks related with Indian construction projects included financial risks, construction risks and demand risks. In this study the author concludes that there should be well-documented process to risk mitigation which is a one-stop solution to all the risks that would originate in the future.

[14] Refer to a paper by Tixier, Hallowell, Albert, Boven and Kleiner, on "Psychological antecedents of risk-taking behavior in construction", published in Journal of Construction Engineering and Management, ASCE, 2014 which describes the relationship between emotions and risk- taking behavior of people working in the construction projects. A principal component analysis (PCA) was performed to identify emotions among various groups of participants. Some tests were used to check the differences in risk perception between participants who belong to different emotional groups.

The result of this analysis shows that the mild negative group observed significantly more risk than positive group. According to situational awareness individuals in positive emotional states may be more prone to hold in risk taking behaviors than their equivalents because they detect fewer risks in the equal environment.

[15] Refer to a paper by Patel and Singhal, on "Perception and management of risk in hydropower projects" and is published in International Conference on Hydropower for

Sustainable Development, 2015. This paper describes that risks involved in the development of hydropower projects are mainly time delays and cost overruns due to delay in timely availability of legal approvals, resettlement factors, land acquisition problems and project management and execution decisions. The main objective of this paper is to find out the risks involved in the development of hydropower projects and to manage the risks. The author introduces a new approach for hydropower project risk assessment through the fuzzy set of concepts.

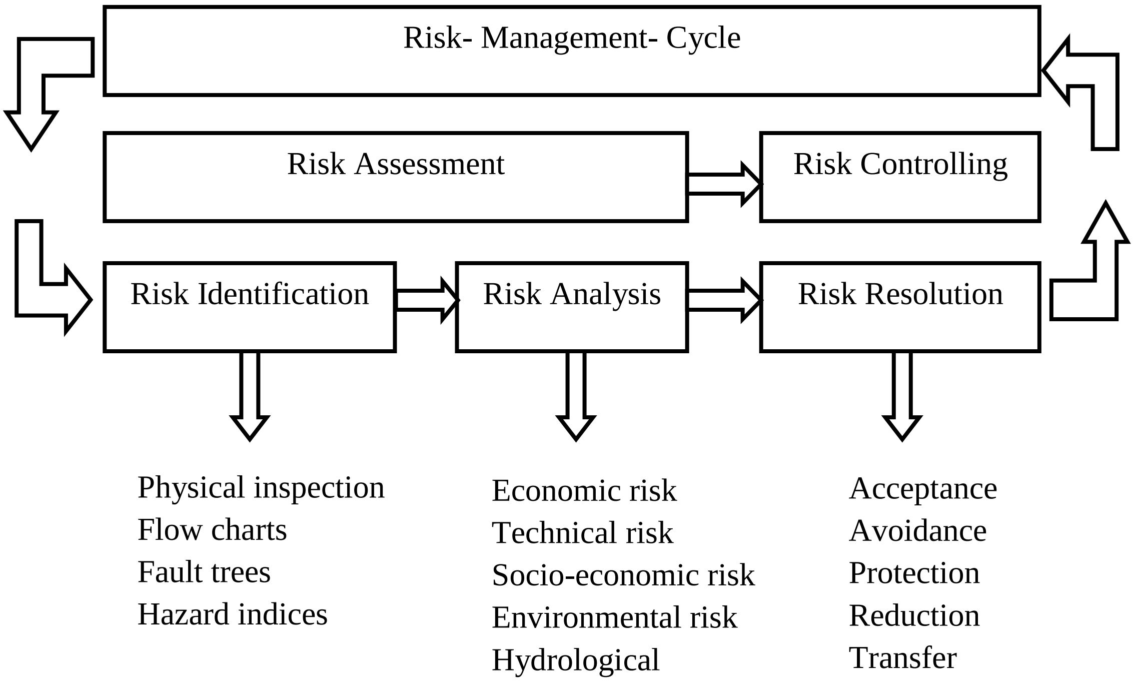

Fig. 2.5 Risk management cycle[15]

[16] Refer to a paper by Dharmapalan, Gambatese, Fradella and Vahed, on “Quantification and assessment of safety risk in the design of multistory buildings” published in Journal of Construction Engineering and Management, ASCE, 2015 which describes the construction safety risk of each of the design elements present in multistory buildings. The research includes identification of typical construction activities and cumulative risks in design elements and construction activities and to develop design risk assessment tool for industry to evaluate the safety risk of designs. The risk factors developed were integrated into an online tool titled as Safety in Design Risk Evaluator (SliDeRule). A database was created which consist of building systems, design features and construction activities.

[17] Refer to a paper by Barry, Leite, and O'Brien, on "Late Deliverable Risk Catalog: Evaluating the impacts and risks of late deliverables to construction sites" and is published in Journal of Construction Engineering and Management, ASCE, 2015. This paper describes the risk associated with late deliverables to construction location. So the research team (RT300) develops a late deliverable risk catalog (LDRC) to examine the impacts of late deliverable on cost, quality, safety, schedule etc. and managing and mitigating their impacts on construction of a project.

The limitation found out with late deliverable risk catalog is that it will help the project team to identify potential issues and not mitigate the problems caused by late deliverables and it does not provide the actual cost increase or time delay associated with late deliverables.

[18] Refer to a paper by Zhao, Hwang, Low and Wu, on "Reducing hindrances to enterprise risk management implementation in construction firms" is published in Journal of Construction Engineering and Management, ASCE, 2015. In this paper significant hindrances to enterprise risk management (ERM) execution in Chinese construction firms (CCFs) are recognized and the interrelationships among these critical hindrances are investigated. In this paper some critical hindrances are find out from the literature review among which "insufficient resources (e.g. time, money and people)" was documented as the top hindrance.

[19] Refer to a paper by Shaikh, on "Risk management in construction projects" is published in International Journal of Current Engineering and Scientific Research (IJCESR), 2015. This paper describes that various risks like technical, sociopolitical and business risks in a construction industry and the record of construction industry to manage with these risks has not extremely good. Proper risk analysis and management techniques are rarely in use by construction industry due to the lack of experience and knowledge in the area. Various risks due to cost overruns and uncertain delays are faced by the people in construction industry so this paper identifies and evaluate the current risks and uncertainties in the construction industry through literature survey and questionnaire survey. The perception of risk by contractors and consultants is mostly based on their intuition and experience. The most utilized risk response measures are risk elimination and risk transfer.

This document describes four processes of risk management:-

- Risk identification
- Risk quantification
- Risk response development
- Risk response control.

[20] Refer to a paper by Choubey, on "Mitigation of hydro project development risk insurance need" and is published in International Conference on Hydropower for Sustainable Development, 2015. This paper attempts to present some insight into probable main risks for project progress, mitigation actions for recognized risks through insurance covers where ever applicable and scope of various commercially available insurance covers. This paper concludes a well elaborated insurance policy with proper add on covers, placed with experienced insurance company, will help in mitigating the losses suffered in case of any unfortunate insurable event occurred during project development.

[21] Refer to a paper by Naderpajouh, Hastak, Gokhale, Bayraktar, Iyer and Arif, on "Counterfeiting risk governance in the capital projects supply chain" and is published in Journal of Construction Engineering and Management, ASCE, 2015. The aim of this research is to study authority of the risks associated with CFSI in the capital projects supply chain. First, the status of the industry concerning CFSI is modernized through a multistage inspection of the industry. An analysis of the survey results underscores the lack of awareness in the construction industry about the risks associated with CFSI and highlights the need for guidelines and collaboration at the industry level. Therefore, improvement strategies and practices are explored, and a structure to govern the risk of CFSI in the capital projects supply chain is projected.

CHAPTER-3

RISK FACTORS IDENTIFICATION & DATA COLLECTION

3.1 General

As we know that construction of hydroelectric projects are usually more complicated and risky due to the nature of different activities involved. This situation imposes uncertainty factors with considerably high risks.

Keeping this mind, a questionnaire survey is conducted to evaluate most, common and major risks in hydroelectric projects. The various risk factors involved in the construction of hydroelectric projects are determined from literature review, telephonic conversations and from the past record of construction of hydroelectric projects and a questionnaire is designed and different risk factors were put into eight categories, with 12 risks related to financial problems, 21 related to construction, 6 related to environment, 11 related to socio-political risks, 11 related to management, 5 related to physical risks, 4 related to legal risks and 6 are technical risks. The questionnaire consisted of three sections. Section I consists information about the company profile and section II contains information about respondent. Section III carried a total of 76 risks associated with construction of hydroelectric projects and asked respondents to review and indicate the probability of these risks using five point scale ranging from 1 to 5 (rarely, sometimes, frequently, very frequently, mostly) and the level of impact on each project objective that would result in as very low, low, medium, high, and very high (1 to 5). To achieve the objectives of this research, questionnaire was deemed to be the most helpful tool for collecting information. The general methodology of this study relies mostly on the survey questionnaires, which were distributed through electronic mailing to 36 respondents (mainly people who work in hydroelectric projects who enjoy a leading role in planning and construction management, e.g., project managers, general managers, civil engineers) from government and construction companies in the defined area of study. Usable questionnaire were completed and returned by 20 respondents consisting of 2 contract officers, 2 senior managers, 3 project managers, 4 construction managers, 9 engineers. Subsequently results from interviews and questionnaires are presented. The result from questionnaire survey was a list of total 87 risk factors identified in hydroelectric projects.

3.2 Questionnaire survey

QUESTIONNAIRE REGARDING RISKS IN HYDRO-ELECTRIC POWER PROJECTS

(Please fill the appropriate boxes with yellow color as shown)

Section I: Company Profile

1. Company Name [ ] **(Please write full Name)**

2. Phone No: [ ]

3. Nature of Company:

Client	[ ]	e.g.	Client	[ ]
Contractor	[ ]		Contractor	[yellow]
Designer	[ ]			
Consultant	[ ]			
Other: (Please Specify)	[ ]			**(Please write full Name)**

4. Age of the Company:

- 1-5 Years [ ]
- 6-10 Years [ ]
- 10-15 Years [ ]
- More Than 15 Years [ ]

Section II: Respondent Profile

1.Name (Optional) [ ] **(Please write full Name)**

2. Position in the Company:

- Engineer [ ]
- Construction Manager [ ]
- Project Manager [ ]
- Contract/Business Development Officer [ ]
- Business/Cluster Head [ ]
- Site Co-coordinator [ ]

Or Any Other (Please specify) [ ] **(Write full designation)**

3. Experience in the Construction Industry

- 1-2 Years [ ]
- 3-4 Years [ ]
- 5-6 Years [ ]
- 7-10 Years [ ]
- 10 Years and above [ ]

Section III: Risks in Hydroelectric Projects

1. Which of the following risks are generally faced in the construction of hydroelectric projects?

(R= Rarely, S= Sometimes, F= Frequently, VF= Very Frequently, M= Mostly, VL= Very Low, L= Low, M= Medium, H= High, VH= Very High)

Table 3.1 Questionnaire regarding risks in hydro-electric projects

S. No.	Type of Risk	Probability (A)					Impact (B)					Total Risk (AB)
		R	**S**	**F**	**VF**	**M**	**VL**	**L**	**M**	**H**	**VH**	
A	**Financial Risks**											
1	Loss due to fluctuation of interest rate	1	2	3	4	5	1	2	3	4	5	
2	Low credibility of shareholder and lender	1	2	3	4	5	1	2	3	4	5	
3	Change in bank formalities and lenders	1	2	3	4	5	1	2	3	4	5	
4	Loss due to rise in fuel prices	1	2	3	4	5	1	2	3	4	5	
5	Increased material cost	1	2	3	4	5	1	2	3	4	5	
6	Insurances risk	1	2	3	4	5	1	2	3	4	5	
7	Improper estimation	1	2	3	4	5	1	2	3	4	5	
8	Payment delays	1	2	3	4	5	1	2	3	4	5	
9	Invoices delay	1	2	3	4	5	1	2	3	4	5	

		R	S	F	VF	M	VL	L	M	H	VH	
10	Owner financial capacity	1	2	3	4	5	1	2	3	4	5	
11	Paucity of funds	1	2	3	4	5	1	2	3	4	5	
12	Tax rate	1	2	3	4	5	1	2	3	4	5	
B	**Construction Risks**											
1	Labor availability	1	2	3	4	5	1	2	3	4	5	
2	Drop in labor productivity	1	2	3	4	5	1	2	3	4	5	
3	Differing site conditions	1	2	3	4	5	1	2	3	4	5	
4	Adverse geological conditions	1	2	3	4	5	1	2	3	4	5	
5	Faulty construction work at site	1	2	3	4	5	1	2	3	4	5	
6	Labor strikes	1	2	3	4	5	1	2	3	4	5	
7	Labor disputes	1	2	3	4	5	1	2	3	4	5	
8	Equipment quality	1	2	3	4	5	1	2	3	4	5	
9	Equipment maintenance	1	2	3	4	5	1	2	3	4	5	
10	Material delivery	1	2	3	4	5	1	2	3	4	5	

		R	S	F	VF	M	VL	L	M	H	VH	
11	Material shortage	1	2	3	4	5	1	2	3	4	5	
12	Material procurement	1	2	3	4	5	1	2	3	4	5	
13	New technology	1	2	3	4	5	1	2	3	4	5	
14	Nominated vendors	1	2	3	4	5	1	2	3	4	5	
15	Delay in permits and licenses	1	2	3	4	5	1	2	3	4	5	
16	Site location (rural/urban)	1	2	3	4	5	1	2	3	4	5	
17	Access conditions	1	2	3	4	5	1	2	3	4	5	
18	Seepage problem from dam	1	2	3	4	5	1	2	3	4	5	
19	Blasting work	1	2	3	4	5	1	2	3	4	5	
20	Unpredicted geological structure at tunneling sites	1	2	3	4	5	1	2	3	4	5	
21	Design changes	1	2	3	4	5	1	2	3	4	5	
C	**Environmental Risks**											
1	Natural disasters	1	2	3	4	5	1	2	3	4	5	
2	Earthquake	1	2	3	4	5	1	2	3	4	5	

		R	S	F	VF	M	VL	L	M	H	VH	
3	Landslides	1	2	3	4	5	1	2	3	4	5	
4	Precipitation/ Flooding	1	2	3	4	5	1	2	3	4	5	
5	Unpredicted weather conditions	1	2	3	4	5	1	2	3	4	5	
6	Adverse environmental conditions	1	2	3	4	5	1	2	3	4	5	
D	**Socio-political Risks**											
1	Changes in laws and regulations	1	2	3	4	5	1	2	3	4	5	
2	Land acquisition problems	1	2	3	4	5	1	2	3	4	5	
3	Resettlement & rehabilitation	1	2	3	4	5	1	2	3	4	5	
4	Litigations	1	2	3	4	5	1	2	3	4	5	
5	Pollution and safety rules	1	2	3	4	5	1	2	3	4	5	
6	Bribery/ Corruption	1	2	3	4	5	1	2	3	4	5	
7	Language/ Cultural barrier	1	2	3	4	5	1	2	3	4	5	
8	Law and order	1	2	3	4	5	1	2	3	4	5	
9	War and civil disorder	1	2	3	4	5	1	2	3	4	5	

		R	S	F	VF	M	VL	L	M	H	VH	
10	Social acceptance	1	2	3	4	5	1	2	3	4	5	
11	Requirements for permits and their approval	1	2	3	4	5	1	2	3	4	5	
E	**Management Risks**											
1	Change in top management	1	2	3	4	5	1	2	3	4	5	
2	No past experience in similar project	1	2	3	4	5	1	2	3	4	5	
3	Short tender time	1	2	3	4	5	1	2	3	4	5	
4	Internal management problem	1	2	3	4	5	1	2	3	4	5	
5	Improper project feasibility study	1	2	3	4	5	1	2	3	4	5	
6	Poor relation and disputes with partner	1	2	3	4	5	1	2	3	4	5	
7	Team work	1	2	3	4	5	1	2	3	4	5	
8	Time constraint	1	2	3	4	5	1	2	3	4	5	
9	Project delay	1	2	3	4	5	1	2	3	4	5	
10	Quality control process	1	2	3	4	5	1	2	3	4	5	

		R	S	F	VF	M	VL	L	M	H	VH	
11	Type of contract	1	2	3	4	5	1	2	3	4	5	
F	**Physical Risks**											
1	Damage to structure	1	2	3	4	5	1	2	3	4	5	
2	Damage to equipment	1	2	3	4	5	1	2	3	4	5	
3	Labor accidents	1	2	3	4	5	1	2	3	4	5	
4	Equipment breakdown	1	2	3	4	5	1	2	3	4	5	
5	Material theft & damage	1	2	3	4	5	1	2	3	4	5	
G	**Legal Risks**											
1	Breach of contract by project partner	1	2	3	4	5	1	2	3	4	5	
2	Lack of enforcement of legal judgment	1	2	3	4	5	1	2	3	4	5	
3	Improper verification of contract document	1	2	3	4	5	1	2	3	4	5	
4	Uncertainty and unfairness of court justice	1	2	3	4	5	1	2	3	4	5	

		R	S	F	VF	M	VL	L	M	H	VH	
H	**Technical Risks**											
1	Incomplete design	1	2	3	4	5	1	2	3	4	5	
2	Inadequate specification	1	2	3	4	5	1	2	3	4	5	
3	Inadequate site investigation	1	2	3	4	5	1	2	3	4	5	
4	Change in scope	1	2	3	4	5	1	2	3	4	5	
5	Construction procedures	1	2	3	4	5	1	2	3	4	5	
6	Insufficient resource availability	1	2	3	4	5	1	2	3	4	5	
I	**Any other risks (Please specify)**											
1		1	2	3	4	5	1	2	3	4	5	
2		1	2	3	4	5	1	2	3	4	5	
3		1	2	3	4	5	1	2	3	4	5	
4		1	2	3	4	5	1	2	3	4	5	
5		1	2	3	4	5	1	2	3	4	5	

CHAPTER-4

RESULTS & ANALYSIS

4.1 General

During construction of hydroelectric project, risks can result from many circumstances. Risk management process consisted of two main phases: (1) risk analysis which includes the identification, prioritization and assessment of risk and (2) risk management which includes planning appropriate responses, monitoring and managing those responses. Based on the data analyzed earlier, a total of 7 sources of risks in hydroelectric projects are identified and analyzed. Once the risk factors in hydroelectric project are determined, risk probability and risk impact can be calculated.

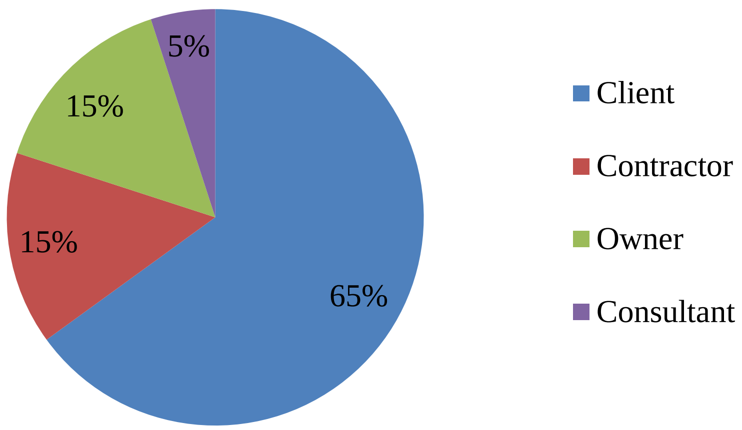

Fig. 4.1 Response rate for different categories for the questionnaire

4.2 Risk analysis and assessment through questionnaire survey

After the risks are identified they must be individually assessed as to their potential likelihood and outcome. Probability index and severity index is calculated as follows:

(A) Probability Index (Risk Probability) $=\frac{\sum an}{N\times A}\times 100$

(Where a= constant expressing the weight assigned to each responses from 1 to 5, n= probability of each response, N= total number of responses, A= highest weight (i.e. 5 in this case)

(B) Severity Index (Risk Impact) $=\frac{\sum an}{N\times A}\times 100$

(Where a= constant expressing the weight assigned to each responses from 1 to 5, n= impact of each response, N= total number of responses, A= highest weight (i.e. 5 in this case)

Risk Potential = Risk Probability (A) x Risk Impact (B)

4.3 Risk assessment

After the risks are identified they must be individually assessed as to their potential probability and consequence. Analysis of data for risk assessment can be done by following methods:

1. Risk assessment matrix
2. Risk potential value

Qualitative risk analysis assesses the importance of the identified risks to determine their probability and potential impact on hydroelectric project objectives and allowing risks to be prioritized for more analysis by developing prioritized list. The primary technique for this is the risk assessment matrix. The product of risk probability and risk impact will give risk potential value.

Table 4.1 Risk Potential Value

Risk I.D	Risk Factors	Probability Index (Risk Probability) A	Severity Index (Risk Impact) B	Risk Potential (A x B)
	Financial Risks			
F1	Loss due to fluctuation of interest rate	0.41	0.38	0.16
F2	Low credibility of shareholder and lender	0.56	0.61	0.34
F3	Change in bank formalities and lenders	0.34	0.41	0.14
F4	Loss due to rise in fuel prices	0.4	0.42	0.17

Risk I.D	Risk Factors	A	B	(A x B)
F5	Increased material cost	0.65	0.78	0.51
F6	Insurances risk	0.55	0.61	0.34
F7	Improper estimation	0.62	0.8	0.50
F8	Payment delays	0.53	0.69	0.37
F9	Invoices delay	0.46	0.54	0.25
F10	Owner financial capacity	0.62	0.81	0.50
F11	Paucity of funds	0.65	0.82	0.53
F12	Tax rate	0.5	0.59	0.30
	Construction Risks			
C1	Labor availability	0.61	0.73	0.45
C2	Drop in labor productivity	0.58	0.72	0.42
C3	Differing site conditions	0.63	0.67	0.42
C4	Adverse geological conditions	0.77	0.81	0.62
C5	Faulty construction work at site	0.61	0.73	0.45
C6	Labor strikes	0.78	0.87	0.68
C7	Labor disputes	0.66	0.72	0.48
C8	Equipment quality	0.62	0.7	0.43
C9	Equipment maintenance	0.56	0.61	0.34
C10	Material delivery	0.66	0.76	0.50
C11	Material shortage	0.64	0.75	0.48
C12	Material procurement	0.54	0.67	0.36
C13	New technology	0.54	0.66	0.36

Risk I.D	Risk Factors	A	B	(A x B)
C14	Nominated vendors	0.53	0.55	0.29
C15	Delay in permits and licenses	0.54	0.64	0.35
C16	Site location (rural/urban)	0.7	0.72	0.50
C17	Access conditions	0.76	0.82	0.62
C18	Seepage problem from dam	0.62	0.69	0.43
C19	Blasting work	0.68	0.71	0.48
C20	Unpredicted geological structure at tunneling sites	0.83	0.88	0.73
C21	Design changes	0.68	0.72	0.49
	Environmental Risks			
E1	Natural disasters	0.66	0.84	0.55
E2	Earthquake	0.55	0.77	0.42
E3	Landslides	0.74	0.7	0.52
E4	Precipitation/Flooding	0.77	0.9	0.69
E5	Unpredicted weather conditions	0.6	0.69	0.41
E6	Adverse environmental conditions	0.58	0.66	0.38
	Socio-political risks			
SP1	Changes in laws and regulations	0.5	0.64	0.32
SP2	Land acquisition problems	0.85	0.95	0.81
SP3	Resettlement & rehabilitation	0.84	0.91	0.76

Risk I.D	Risk Factors	A	B	(A x B)
SP4	Litigations	0.62	0.73	0.45
SP5	Pollution and safety rules	0.5	0.55	0.28
SP6	Bribery/Corruption	0.45	0.52	0.23
SP7	Language/Cultural barrier	0.47	0.48	0.23
SP8	Law and order	0.44	0.59	0.26
SP9	War and civil disorder	0.35	0.6	0.21
SP10	Social acceptance	0.54	0.65	0.35
SP11	Requirements for permits and their approval	0.54	0.69	0.37
	Management Risks			
M1	Change in top management	0.54	0.68	0.37
M2	No past experience in similar project	0.59	0.74	0.44
M3	Short tender time	0.47	0.63	0.30
M4	Internal management problem	0.57	0.69	0.39
M5	Improper project feasibility study	0.53	0.76	0.40
M6	Poor relation and disputes with partner	0.58	0.74	0.43
M7	Team work	0.56	0.73	0.41
M8	Time constraint	0.69	0.81	0.56
M9	Project delay	0.65	0.81	0.53
M10	Quality control process	0.63	0.71	0.45

Risk I.D	Risk Factors	A	B	(A x B)
M11	Type of contract	0.65	0.72	0.47
	Physical Risks			
P1	Damage to structure	0.53	0.73	0.39
P2	Damage to equipment	0.5	0.66	0.33
P3	Labor accidents	0.61	0.66	0.40
P4	Equipment breakdown	0.57	0.71	0.40
P5	Material theft & damage	0.58	0.57	0.33
	Legal Risks			
L1	Breach of contract by project partner	0.43	0.53	0.23
L2	Lack of enforcement of legal judgment	0.46	0.53	0.24
L3	Improper verification of contract document	0.49	0.59	0.29
L4	Uncertainty and unfairness of court justice	0.39	0.51	0.20
	Technical Risks			
T1	Incomplete design	0.52	0.7	0.36
T2	Inadequate specification	0.55	0.69	0.38
T3	Inadequate site investigation	0.6	0.72	0.43
T4	Change in scope	0.59	0.71	0.42
T5	Construction procedures	0.61	0.71	0.43
T6	Insufficient resource availability	0.61	0.77	0.47

Risk I.D	Risk Factors	A	B	(A x B)
	Any other risks (Please specify)			
AO1	Interstate aspects	0.04	0.04	0.00
AO2	Lack of existing infrastructural facilities like road and communication	0.04	0.04	0.00
AO3	Non availability of hydrological data	0.05	0.05	0.00
AO4	Security restrictions in border areas	0.05	0.05	0.00
AO5	Contractual problems	0.05	0.05	0.00
AO6	Skills development of staff	0.04	0.04	0.00
AO7	Consistency of staff	0.04	0.04	0.00
AO8	Clients willingness to pay	0.03	0.05	0.00
AO9	Demand/Criticality of the project	0.04	0.05	0.00
AO10	Complexity of project	0.02	0.04	0.00
AO11	Too many stakeholders	0.03	0.05	0.00

4.4 Scatter diagram

Scatter Diagram is plotted between risk probability and risk impact to find out the factors which lie in the high and critical risk category.

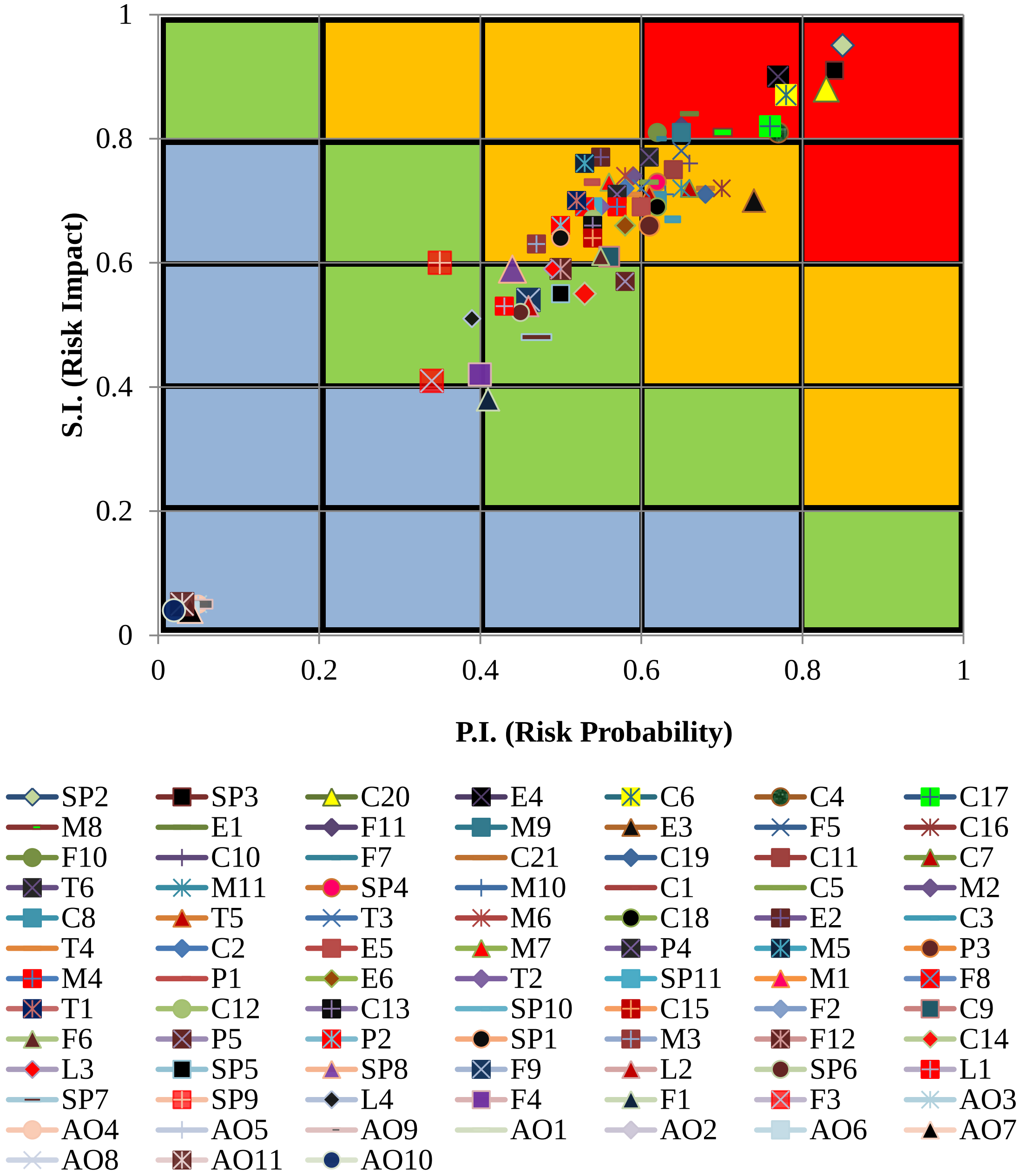

Fig. 4.2 Scatter diagram of risk distribution

4.5 Risk assessment matrix

Probability and impact of individual risks are assessed and sorted into Low, Medium, High and Critical. There are 4 categories defined in the diagram. The rating is based on the position of risk. The results from this examination were prioritized risks level in a table to determine the most important risks and to apply correct resources for the highest ranked risks.

Table 4.2 Risk Categories

Category	Criteria	Color
1	Requires maximum attention	
2	Requires good amount of attention	
3	Comparatively less attention to be paid	
4	Less attention to be paid	

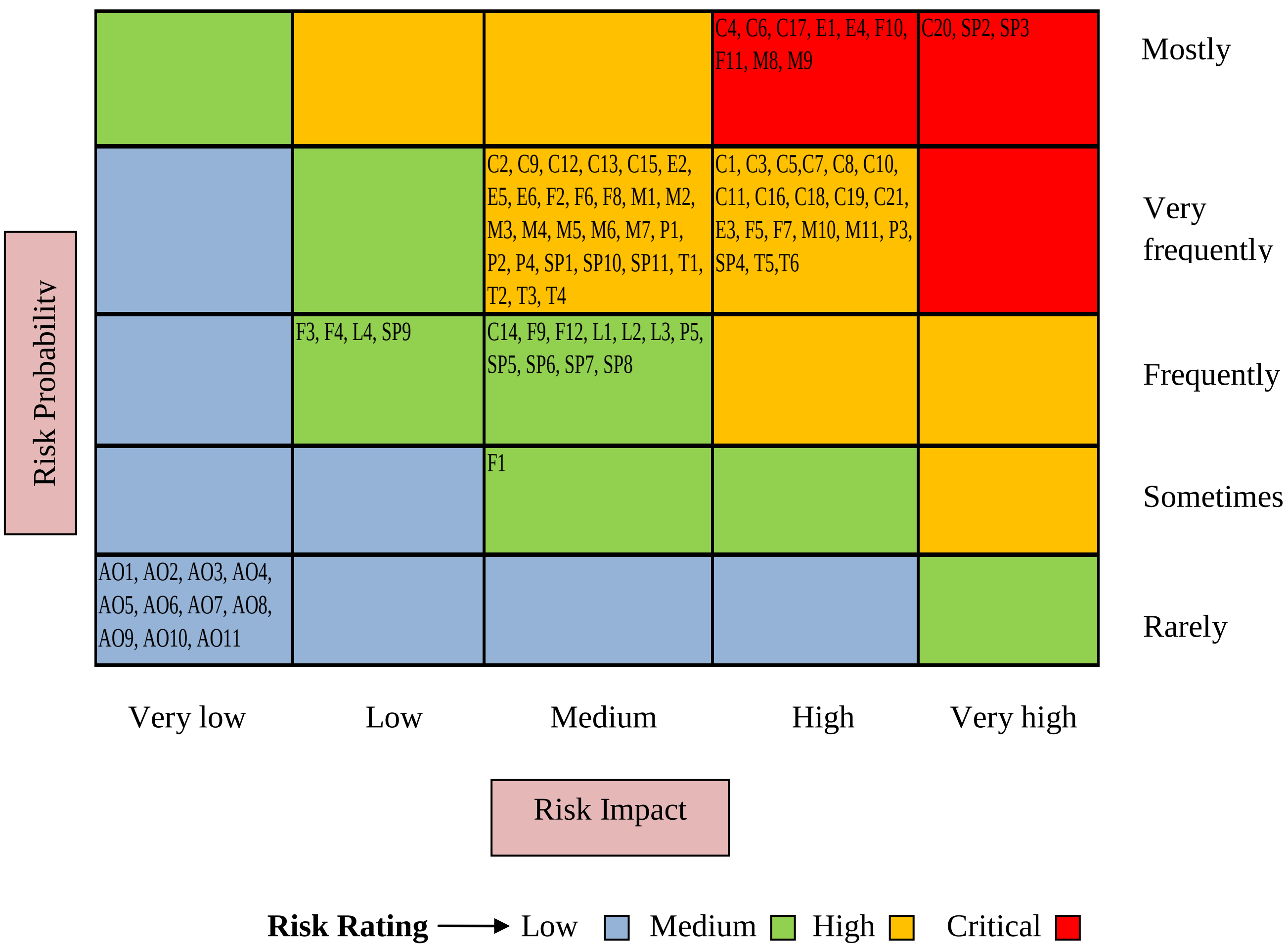

Fig. 4.3 Risk Assessment Matrix

Risks with very high probability and very high impact which lie in the critical region such as C20(Unpredicted geological structure at tunneling sites), SP2(Land acquisition problems), SP3(Resettlement & rehabilitation), C4(Adverse geological conditions), C6(Labor strikes), C17(Access conditions), E1(Natural disasters), E4(Flooding), F10(Owner financial capacity), F11(Paucity of funds), M8(Time constraint), M9(Project delay) are required further analysis.

4.6 Risk potential value

In risk potential value method ranking of different risk factors is to be done according to their probability of occurrence and impact of each risk factor on the project. According to risk potential value method (A x B) major risk factors can be identified among the factors which lie in the critical region in the risk assessment matrix.

Higher risk rating will indicate the more important risk. The results from this analysis were prioritized risk's level in a table to determine the most important risks and to apply appropriate resources for the highest ranked risks.

Risk Probability=A
Risk Impact= B
Risk Potential Value= A x B

Table 4.3 Ranking of risk factors according to risk potential value method

Risk I.D.	Risk Factors	Risk Potential Value (A x B)	Rank
SP2	Land acquisition problems	0.81	1
SP3	Resettlement & rehabilitation	0.76	2
C20	Unpredicted geological structure at tunneling sites	0.73	3
E4	Precipitation/Flooding	0.69	4
C6	Labor strikes	0.68	5
C4	Adverse geological conditions	0.62	6
C17	Access conditions	0.62	7
M8	Time constraint	0.56	8
E1	Natural disasters	0.55	9
F11	Paucity of funds	0.53	10
M9	Project delay	0.53	11

Risk I.D.	Risk Factors	(A x B)	Rank
E3	Landslides	0.52	12
F5	Increased material cost	0.51	13
C16	Site location (rural/urban)	0.50	14
F10	Owner financial capacity	0.50	15
C10	Material delivery	0.50	16
F7	Improper estimation	0.50	17
C21	Design changes	0.49	18
C19	Blasting work	0.48	19
C11	Material shortage	0.48	20
C7	Labor disputes	0.48	21
T6	Insufficient resource availability	0.47	22
M11	Type of contract	0.47	23
SP4	Litigations	0.45	24
M10	Quality control process	0.45	25
C1	Labor availability	0.45	26
C5	Faulty construction work at site	0.45	27
M2	No past experience in similar project	0.44	28
C8	Equipment quality	0.43	29
T5	Construction procedures	0.43	30
T3	Inadequate site investigation	0.43	31
M6	Poor relation and disputes with partner	0.43	32
C18	Seepage problem from dam	0.43	33
E2	Earthquake	0.42	34

Risk I.D.	Risk Factors	(A x B)	Rank
C3	Differing site conditions	0.42	35
T4	Change in scope	0.42	36
C2	Drop in labor productivity	0.42	37
E5	Unpredicted weather conditions	0.41	38
M7	Team work	0.41	39
P4	Equipment breakdown	0.40	40
M5	Improper project feasibility study	0.40	41
P3	Labor accidents	0.40	42
M4	Internal management problem	0.39	43
P1	Damage to structure	0.39	44
E6	Adverse environmental conditions	0.38	45
T2	Inadequate specification	0.38	46
SP11	Requirements for permits and their approval	0.37	47
M1	Change in top management	0.37	48
F8	Payment delays	0.37	49
T1	Incomplete design	0.36	50
C12	Material procurement	0.36	51
C13	New technology	0.36	52
SP10	Social acceptance	0.35	53
C15	Delay in permits and licenses	0.35	54
F2	Low credibility of shareholder and lender	0.34	55
C9	Equipment maintenance	0.34	56
F6	Insurances risk	0.34	57

Risk I.D.	Risk Factors	(A x B)	Rank
P5	Material theft & damage	0.33	58
P2	Damage to equipment	0.33	59
SP1	Changes in laws and regulations	0.32	60
M3	Short tender time	0.30	61
F12	Tax rate	0.30	62
C14	Nominated vendors	0.29	63
L3	Improper verification of contract document	0.29	64
SP5	Pollution and safety rules	0.28	65
SP8	Law and order	0.26	66
F9	Invoices delay	0.25	67
L2	Lack of enforcement of legal judgment	0.24	68
SP6	Bribery/Corruption	0.23	69
L1	Breach of contract by project partner	0.23	70
SP7	Language/Cultural barrier	0.23	71
SP9	War and civil disorder	0.21	72
L4	Uncertainty and unfairness of court justice	0.20	73
F4	Loss due to rise in fuel prices	0.17	74
F1	Loss due to fluctuation of interest rate	0.16	75
F3	Change in bank formalities and lenders	0.14	76
AO3	Non availability of hydrological data	0.00	77
AO4	Security restrictions in border areas	0.00	78
AO5	Contractual problems	0.00	79
AO9	Demand/Criticality of the project	0.00	80

Risk I.D.	Risk Factors	(A x B)	Rank
AO1	Interstate aspects	0.00	81
AO2	Lack of existing infrastructural facilities like road and communication	0.00	82
AO6	Skills development of staff	0.00	83
AO7	Consistency of staff	0.00	84
AO8	Clients willingness to pay	0.00	85
AO11	Too many stakeholders	0.00	86
AO10	Complexity of project	0.00	87

CHAPTER-5

RISK MANAGEMENT

5.1 Risk Management

After evaluating the risks, suitable risk treatment strategies are formulated. The objective of risk management is to eliminate the potential impact as far as possible and to increase the control of risk. Best risk management is to inspect each risk and decide as to how to get ready for the risk of event, if it occurs. Depending upon the Risk Priority (Low, medium, high and critical); strategy of action on crucial measures, considered measures or let risk happen, needs to be decided. Risks falling in the categories of critical or high need special attention and those in the categories of medium or low need careful attention. Response to risks generally falls into one of four categories:

(i) Risk Avoidance, whether to avoid the risk carrying activity

(ii) Risk Transfer, whether to transfer the risk to another participant

(iii) Risk Reduction, whether to reduce the risk

(iv) Risk Retention, whether to accept the risk

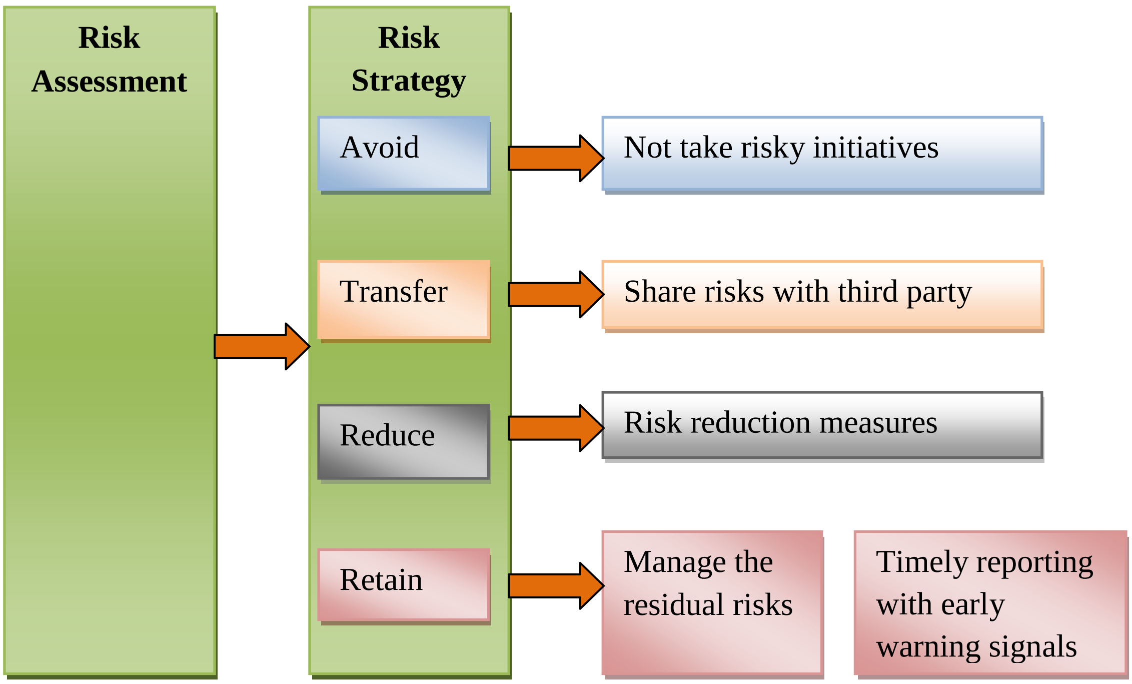

Fig. 5.1 Risk management strategies

(i) Risk Avoidance:

Risk avoidance may appear the answer to all risks but avoiding risks also means losing out on possible gain that accepting the risk may have permitted. For example, not entering into a dealing to stay away from the risk of loss also avoids the opportunity of earning profits.

Risk avoidance is eliminating a specific risk, usually by eliminating the cause. All risks can never be eliminated, but specific risk events can often be eliminated.

(ii) Risk Transfer:

Risk transfer is a mitigation measure by having another party to accept the risk. It is shifting of the risk burden by the construction company to the other project participants such as subcontractor, vendor, or specialist contractors. In risk transfer, the construction company enters into a contractual agreement with subcontractors, vendors, or specialist contractors. The basic principle is that the party who is more competent to maintain control should be able to take risk. Risk transfer is different from insurance as risk is not being transferred to an insurance agency rather it is being transferred to the competent who has adequate historical data and is in a better position to evaluate and accept the risk. For example, the risk can be transferred:

- To a contractor or designer by the client
- To a subcontractor by the contractor
- To insurance companies or banks by the client, contractor or subcontractor.

(iii) Risk Reduction:

Risk reduction is a process of combining loss prevention or loss control to minimize a risk. It is dropping the financial severity of the risk event by dropping the probability of occurrence.

This approach serves to decrease the loss potential and reduce the regularity or severity of the loss. Risk reduction reduces the probability and impact of an unfavorable risk event to a bearable threshold. Taking early action to reduce the likelihood and impact of a risk is often more efficient than attempting to fix the damage after the risk has approved. Risks related to changes in scope of the project can be reduced by:

- Well-defined specifications

- Detailed site survey
- Detailed design
- Minimizing client variation
- Appropriate responsibility matrix
- Implementing safety program

(iv) Risk Retention:

This strategy is used only when it is impossible to avoid, transfer or reduce the risk or, based on an evaluation of the economic loss exposure, it is determined that the little value positioned on the risk can carefully be absorbed. A different thinking in retaining a risk is when the possibility of loss is great or disastrous that they either cannot be insured against or the premium would be infeasible. It is also a viable approach for little risks where the cost of insuring against the risk would be larger over time than the whole losses sustained.

Risk Retention or Acceptance is accepting the consequences. Acceptance can be active e.g., by developing a Contingency Plan / Disaster Management Plan to implement, should the risk event take place or inactive e.g. by accepting a lower profit / time & cost overrun, if some activities overrun.

5.2 Risk mitigation

Table 5.1 Risk mitigation table

S. N.	Risk I.D	Risks	Risk Category	Description	Risk Rating	Suggested Mitigation
1	SP2	Land acquisition problems	Socio-political risk	Land acquisition problem may obstruct the construction activities.	Critical	➢ Liaison and coordination with State Govt. and local authorities / people.
2	SP3	Resettlement & rehabilitation	Socio-political risk	The population getting affected by construction of hydro power projects need to be given special attention to protect their	Critical	➢ Resettlement planning should start early. ➢ Use of external monitors or panels of experts can help companies to

S. N.	Risk I.D	Risks	Risk Category	Description	Risk Rating	Suggested Mitigation
				rights, minimize their losses and to help them to restore a secure means of livelihood.		plan and implement land access and resettlement properly. ➢ The establishment of monitoring committees. ➢ Informal monitoring during daily interactions between resettlement teams and affected households.
3	C20	Unpredicted geological structure at tunneling sites	Construction risk	Unpredicted things like tunnel collapse, high ingress of water, high temperature may make working conditions extremely difficult resulting into unsafe working conditions.	Critical	➢ Comprehensive geological base study, engagement of expert, geologists and robust design mechanism. ➢ Build and use a Knowledge Management System in the form of a repository of all project related information. ➢ Emergency preparedness Plan.
4	E4	Precipitation/ Flooding	Environmental risk	Extreme climate, poor connectivity and scarce facilities may create uncertainties in working leading to project delay.	Critical	➢ Use accurate planning process. ➢ Schedule project network accordingly. ➢ Incorporate such conditions suitably under Force Majeure

S. N.	Risk I.D	Risks	Risk Category	Description	Risk Rating	Suggested Mitigation
						clause of the contract.
5	C6	Labor strikes	Construction risk	Good project management in construction must strongly pursue the efficient utilization of labor. Improvement of labor productivity should be a major and continual concern of those who are responsible for cost control of constructed facilities.	Critical	➢ Proper contract terms and conditions with labor supplying subcontractors. ➢ Incorporating clauses related to local labor employment in the project.
6	C4	Adverse geological conditions	Construction risk	Adverse climate, difficult topography and not enough resources may have impact on working conditions causing initial delay.	Critical	➢ Strong and resourceful project preparation. ➢ Avoid construction in geological unstable area.
7	C17	Access conditions	Construction risk	Access conditions can increase the project cost during construction phase.	Critical	➢ Proper site selection ➢ Identifying access in initial stage of the project and preparing project layout.
8	M8	Time constraint	Management risk	In time constraint activities should be planned properly to	Critical	➢ Resource should be allocated properly. ➢ Regular monitoring of

S. N.	Risk I.D	Risks	Risk Category	Description	Risk Rating	Suggested Mitigation
				avoid any compensation due to delay in completion.		the work and taking corrective action.
9	E1	Natural disasters	Environmental risk	Impact of natural disaster like flood, land slide, earthquake etc. may be harsh enough to adversely affect the project execution.	Critical	➢ Complete hydrological studies to be undertaken. ➢ Obtain regional geological map for identification of seismic source for the contemplated project. ➢ Carry out seismological studies and evaluate seismic parameters. ➢ Take essential design measures to mitigate the earthquake risk. ➢ Evaluate their impact on the project and make required provisions. ➢ Approaching regulator/ Regional Power Committee (RPC) in such events. ➢ Formulate Risk Management Operation plan for Power Plant / Project with allocation of responsibility.

S. N.	Risk I.D	Risks	Risk Category	Description	Risk Rating	Suggested Mitigation
10	F11	Paucity of funds	Financial risk	Most of the hydro electric projects have been constrained by high investment costs. This is fuelled by the limited availability of public and private sector organizations that have suitable investment and financial framework, with associated incentives and fiscal instruments.	Critical	➢ Government should encourage and support private players.
11	M9	Project delay	Management risk	Law & Order and other local problems, poor infrastructure may cause irrecoverable delay.	Critical	➢ Better coordination with Govt. and local agencies. ➢ Develop alternate infrastructure like road, water supply, power back-up etc. ➢ Setting out clear provision regarding delay in the contract agreement.
12	E3	Landslides	Environmental risk	Landslides may make working conditions extremely difficult resulting into time and cost	High	➢ Identify potential land slide in the project area. ➢ Assess their impact on the project and make necessary

S. N.	Risk I.D	Risks	Risk Category	Description	Risk Rating	Suggested Mitigation
				overruns.		provisions.
13	F5	Increased material cost	Financial risk	Significant increase in prices or shortages of construction materials may raise project cost to vary drastically from initial estimates.	High	➢ Enforce contract conditions so as to ensure efficient materials management. ➢ Provide proper price escalation clause in the contract.
14	C16	Site location (rural/urban)	Construction risk	When a location of construction project is far away from available resources, it increases the project cost. Cost of transportation for workmen, equipments, materials, tools etc. increases with distance and adds to the project cost.	High	➢ Proper site selection. ➢ Rate analysis of items should be carried out considering long transportation distance of resources.
15	F10	Owner financial capacity	Financial risk	Owner financing ability and financial capability directly affect the construction of a hydro project due to their poor financial position.	Critical	➢ Developers and jurisdictions require proactive sponsorship at senior management level. ➢ Adequate financial plan at the beginning of the project.
16	C10	Material delivery	Construction risk	Dependency on various contractors for construction & development	High	➢ Adopt proven procedure to filter out inexperienced vendor.

S. N.	Risk I.D	Risks	Risk Category	Description	Risk Rating	Suggested Mitigation
				and for the supply of materials & equipment and any failure on their part may affect construction activities in hydroelectric project.		➢ Strong Project Management System to have control on the network activities. ➢ Proper coordination among various contracting agencies.
17	F7	Improper estimation	Financial risk	Cost estimating is an important aspect of construction of hydro project. The performance and overall project success are often measured by how well the actual cost compares to estimated cost. In other words, the success or failure of a project is dependent on several estimates throughout the course of the project.	High	➢ It is essential that both the client and the contactor make adequate planning in terms of the resources required for the execution of the projects at early stage, prior to the commencement of the work. ➢ There is a need for the estimator to gather a great deal of information prior to estimation, to enable him price the work accurately. ➢ All drawings and other bid documents should be completed and adequate to assist the estimator to have good understanding of the project

S. N.	Risk I.D	Risks	Risk Category	Description	Risk Rating	Suggested Mitigation
						requirements. ➢ Contractors should be pre-qualified at pre-tender stage to ensure that only competent contractors are selected to execute the projects.
18	C21	Design changes	Construction risk	Hydrological data may not be reliable. Changes in design during implementation can have a significant impact on the project cost and schedule.	High	➢ Source data only from authentic agency. Also verify by carrying out independent study.
19	C19	Blasting work	Construction risk	There are many forms of risk associated with blasting work.	High	➢ Explosive storage on-site should be limited as much as possible, but if this is necessary, then all federal, state, and local regulations governing explosive storage must be followed. ➢ Develop specifications that clearly define performance and safety requirements for the work. ➢ Ensure that the

S. N.	Risk I.D	Risks	Risk Category	Description	Risk Rating	Suggested Mitigation
						work is overseen by capable personnel.
20	C11	Material shortage	Construction risk	Material handling, which includes procurement, inventory, shop fabrication and field servicing, requires special attention for cost reduction.	High	➢ Proper material planning and control. ➢ Effective material handling as using the right method, amount, material, place, time, sequence, position, condition, and cost. This involves handling, storing, and controlling of the construction materials. ➢ Stock and waste control.

CHAPTER-6

CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

A proper risk management process is very essential in order to achieve project objectives in terms of time, cost, quality, safety and environmental sustainability. Detail arrangement of risk identification, analysis and the resolution of risks can reduce the chances of time and cost over-run in a hydro-electric project. But there is no systematic approach to deal with the risks in hydroelectric projects and it has been managing in a very informal manner. People have not as much of expertization and awareness on risk management in construction projects.

Questionnaire survey was found to be the most preferred method of risk identification in hydroelectric projects. The results from this research reveal the top ten risk factors such as: land acquisition problems, resettlement & rehabilitation, unpredicted geological structure at tunneling sites, precipitation/ flooding, labor strikes, adverse geological conditions, access conditions, time constraint, natural disasters, paucity of funds which have high risk potential value. These risks commonly delays the completion time of construction of hydroelectric projects. So these types of risks should be managed properly in the hydroelectric project to achieve the project objectives. Also, the suggested risk mitigation techniques for top ranked risk factors may be referred in hydroelectric projects in future.

6.2 Scope for future work

More investigation is required for the risk identification and analysis in hydroelectric projects. Questionnaire survey and qualitative risk analysis has been carried out in this project. Other risk analysis techniques may be adopted to verify the outcome from this research. Risks can be analyzed by Quantitative Risk Analysis, such as Sensitivity Analysis and by using Primavera Risk Analysis software.

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APPENDICES

Appendix-1 Calculation of Probability Index (Risk Probability)

Probability index of different factors are calculated based on the ratings given by the twenty respondents has been shown below.

S. N.	Type of Risk	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13	R 14	R 15	R 16	R 17	R 18	R 19	R 20	P.I. $\frac{\sum an}{N\times A}\times 100$
A	**Financial Risks**																					
1	Loss due to fluctuation of interest rate	1	4	1	3	3	4	1	1	3	1	2	2	1	1	1	3	1	2	2	4	0.41
2	Low credibility of shareholder and lender	4	3	4	2	4	2	1	3	2	4	2	3	3	2	3	3	3	4	2	2	0.56
3	Change in bank formalities and lenders	1	1	2	1	3	2	1	2	1	1	1	3	2	1	3	1	2	3	2	1	0.34
4	Loss due to rise in fuel prices	2	2	1	3	4	2	2	3	2	2	1	1	2	2	2	3	1	1	3	1	0.4
5	Increased material cost	4	2	3	4	4	3	3	3	3	4	3	3	2	3	3	3	3	5	3	4	0.65
6	Insurances risk	3	4	3	3	3	2	1	3	2	3	3	2	3	1	3	4	3	3	3	3	0.55
7	Improper estimation	4	5	2	4	4	3	1	4	3	4	3	3	2	2	1	4	2	3	4	4	0.62
8	Payment delays	2	3	1	4	2	4	2	4	3	2	2	2	1	3	2	2	1	5	4	4	0.53
9	Invoices delay	2	3	1	3	2	3	2	3	3	2	2	2	1	2	2	3	1	4	2	3	0.46
10	Owner financial capacity	3	4	4	4	4	2	1	5	2	3	2	4	4	1	1	2	3	5	4	4	0.62

S. N.	Type of Risk	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13	R 14	R 15	R 16	R 17	R 18	R 19	R 20	P.I. $\frac{\sum an}{N\times A}\times 100$
11	Paucity of funds	4	3	1	4	3	4	1	5	3	3	4	2	3	3	4	3	2	5	4	4	0.65
12	Tax rate	3	4	1	3	4	3	1	3	3	3	3	1	1	1	1	4	2	3	3	3	0.5
B	**Construction Risks**																					
1	Labor availability	2	2	2	3	4	3	2	5	3	3	3	2	2	3	4	3	3	5	4	3	0.61
2	Drop in labor productivity	3	2	2	4	4	3	2	4	3	3	3	2	2	2	2	2	2	5	4	4	0.58
3	Differing site conditions	2	3	1	3	3	3	3	3	4	4	3	3	2	4	5	4	3	4	3	3	0.63
4	Adverse geological conditions	3	4	5	3	3	3	3	3	5	4	3	5	5	4	3	4	5	5	4	3	0.77
5	Faulty construction work at site	2	5	3	4	3	4	2	4	3	2	2	2	3	2	2	4	3	4	3	4	0.61
6	Labor strikes	1	4	5	5	3	4	3	4	4	4	2	5	5	3	4	4	5	4	4	5	0.78
7	Labor disputes	1	3	5	5	3	3	3	2	3	3	3	5	4	3	3	3	5	3	4	2	0.66
8	Equipment quality	3	5	2	5	3	4	1	3	4	3	3	2	2	1	3	5	2	3	3	5	0.62
9	Equipment maintenance	3	5	1	5	3	4	1	3	4	3	3	1	2	1	1	4	1	3	3	5	0.56
10	Material delivery	4	4	3	4	3	3	2	4	3	4	4	3	3	2	2	4	3	5	4	2	0.66
11	Material shortage	4	5	3	4	2	3	2	4	3	4	3	2	3	2	2	3	4	5	4	2	0.64
12	Material procurement	3	4	1	4	2	3	2	3	3	3	3	1	1	2	2	4	1	4	4	4	0.54
13	New technology	4	5	1	3	2	3	2	3	3	3	3	2	1	2	3	5	2	2	2	3	0.54
14	Nominated vendors	3	4	3	3	4	2	2	2	2	3	3	3	2	2	2	4	3	3	2	1	0.53

S. N.	Type of Risk	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13	R 14	R 15	R 16	R 17	R 18	R 19	R 20	P.I. $\frac{\sum an}{N\times A}\times 100$
15	Delay in permits and licenses	2	4	1	3	2	4	3	2	4	2	2	1	2	3	3	3	3	5	3	2	0.54
16	Site location (rural/urban)	4	5	1	3	4	3	2	4	4	4	4	3	2	4	4	5	3	5	3	3	0.7
17	Access conditions	3	5	4	4	3	2	3	4	4	4	3	4	4	3	5	5	4	4	4	4	0.76
18	Seepage problem from dam	2	5	2	4	3	3	4	3	3	2	2	2	2	4	4	4	2	5	3	3	0.62
19	Blasting work	2	4	4	5	4	3	3	3	3	2	2	4	4	2	3	4	4	4	5	3	0.68
20	Unpredicted geological structure at tunneling sites	4	4	5	4	4	3	4	3	5	4	4	4	5	4	4	4	5	4	4	5	0.83
21	Design changes	3	5	4	4	3	4	3	3	4	2	2	4	4	3	2	4	4	5	3	2	0.68
C	**Environment-al Risks**																					
1	Natural disasters	3	5	3	4	4	3	3	4	3	3	3	3	3	3	2	4	3	2	4	4	0.66
2	Earthquake	2	4	2	4	3	3	3	3	3	3	2	2	2	2	3	4	2	1	3	4	0.55
3	Landslides	1	5	4	5	4	2	3	3	4	3	2	4	4	3	5	5	4	3	5	5	0.74
4	Precipitation/ Flooding	2	5	5	5	3	2	3	4	4	2	2	5	5	4	4	5	5	5	4	3	0.77
5	Unpredicted weather conditions	1	3	3	3	3	1	3	3	4	3	3	3	3	4	4	3	3	4	3	3	0.6
6	Adverse environment-al conditions	1	3	2	4	3	2	3	3	3	3	3	3	3	3	4	3	2	3	3	4	0.58
D	**Socio-political Risks**																					

S. N.	Type of Risk	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13	R 14	R 15	R 16	R 17	R 18	R 19	R 20	P.I. $\frac{\sum an}{N\times A}\times 100$
1	Changes in laws and regulations	2	4	1	3	3	3	3	3	3	2	2	1	2	3	4	3	1	2	2	3	0.5
2	Land acquisition problems	3	5	5	4	4	2	3	3	5	4	4	5	5	5	4	5	5	5	4	5	0.85
3	Resettlement & rehabilitation	3	4	5	4	4	3	3	3	5	4	4	5	5	5	5	4	5	5	4	4	0.84
4	Litigations	3	5	3	3	3	3	3	4	3	3	3	2	2	1	2	4	3	5	3	4	0.62
5	Pollution and safety rules	2	4	2	3	4	3	3	2	3	2	2	2	1	1	2	4	2	5	2	1	0.5
6	Bribery/ Corruption	1	3	1	4	2	4	3	2	4	1	1	1	1	2	1	3	1	5	3	2	0.45
7	Language/ Cultural barrier	1	3	3	3	1	3	3	1	3	1	1	2	2	3	2	2	3	4	3	3	0.47
8	Law and order	2	4	1	3	3	3	3	1	3	2	2	1	1	2	2	3	1	2	2	3	0.44
9	War and civil disorder	1	2	1	3	2	2	3	1	2	1	1	1	1	3	1	2	1	1	3	3	0.35
10	Social acceptance	2	4	2	3	1	3	3	1	3	3	3	2	3	3	3	3	2	4	3	3	0.54
11	Requirements for permits and their approval	1	4	3	3	4	2	3	2	2	1	1	3	3	2	3	3	3	5	3	3	0.54
E	**Management Risks**																					
1	Change in top management	3	3	3	3	2	3	1	2	3	3	3	3	2	1	3	3	3	5	2	3	0.54
2	No past experience in similar project	1	5	4	3	4	3	1	2	2	1	2	4	4	2	3	4	4	4	3	3	0.59

S. N.	Type of Risk	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13	R 14	R 15	R 16	R 17	R 18	R 19	R 20	P.I. $\frac{\sum an}{N\times A}\times 100$
3	Short tender time	2	4	2	4	3	2	1	3	2	2	2	2	2	1	3	3	2	2	3	2	0.47
4	Internal management problem	2	5	3	3	2	3	1	2	3	3	2	3	3	3	2	5	3	4	2	3	0.57
5	Improper project feasibility study	3	5	1	3	5	3	1	3	3	3	2	1	1	1	3	4	2	3	3	3	0.53
6	Poor relation and disputes with partner	2	5	3	3	4	3	1	2	3	1	2	3	3	2	3	5	3	4	3	3	0.58
7	Team work	3	5	2	4	3	2	1	3	2	3	3	2	2	3	2	3	2	5	3	3	0.56
8	Time constraint	2	4	5	4	3	2	1	4	4	2	2	4	4	3	3	4	5	5	4	4	0.69
9	Project delay	3	5	3	5	4	2	1	4	2	3	3	3	2	2	3	4	3	5	5	3	0.65
10	Quality control process	3	4	4	3	3	2	1	3	3	4	3	4	3	3	3	4	3	4	3	3	0.63
11	Type of contract	2	5	5	5	1	3	1	4	3	2	2	4	4	3	3	4	4	4	3	3	0.65
F	**Physical Risks**																					
1	Damage to structure	1	3	2	3	4	4	3	2	4	2	1	2	3	3	3	3	2	2	3	3	0.53
2	Damage to equipment	1	3	1	3	3	4	3	3	4	2	1	2	1	3	3	4	1	2	3	3	0.5
3	Labor accidents	2	3	3	4	4	2	4	3	2	2	2	3	2	4	4	3	3	4	4	3	0.61
4	Equipment breakdown	3	4	2	4	3	2	3	3	3	3	2	2	2	3	3	4	2	4	3	2	0.57
5	Material theft & damage	1	4	5	5	3	1	3	2	1	1	1	4	2	3	3	4	5	4	3	3	0.58
G	**Legal Risks**																					

S. N.	Type of Risk	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13	R 14	R 15	R 16	R 17	R 18	R 19	R 20	P.I. $\frac{\sum an}{N \times A} \times 100$
1	Breach of contract by project partner	1	5	1	3	1	2	3	3	2	1	2	1	2	2	2	3	1	1	3	4	0.43
2	Lack of enforcement of legal judgment	1	5	2	3	2	2	3	2	2	2	1	2	2	2	1	4	2	3	2	3	0.46
3	Improper verification of contract document	1	5	1	2	2	3	3	3	3	2	2	1	1	3	3	4	1	4	2	3	0.49
4	Uncertainty and unfairness of court justice	1	5	1	2	1	1	3	1	1	2	1	1	2	3	3	5	1	2	1	2	0.39
H	**Technical Risks**																					
1	Incomplete design	1	5	1	3	4	2	3	3	2	2	1	1	2	2	2	5	1	5	3	4	0.52
2	Inadequate specification	1	5	2	3	4	3	3	2	3	2	1	2	2	3	3	4	2	4	3	3	0.55
3	Inadequate site investigation	1	5	3	3	4	3	3	3	3	2	2	3	3	3	3	4	3	4	3	2	0.6
4	Change in scope	2	5	2	4	4	3	3	4	3	2	2	2	2	2	3	3	2	4	4	3	0.59
5	Construction procedures	2	5	3	3	3	2	3	3	2	3	3	3	3	3	3	4	3	4	3	3	0.61
6	Insufficient resource availability	2	5	1	4	4	3	3	4	4	3	3	1	2	2	3	5	1	5	4	2	0.61
I	**Any other risks (Please specify)**																					
1	Interstate aspects		4																			0.04

S. N.	Type of Risk	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13	R 14	R 15	R 16	R 17	R 18	R 19	R 20	P.I. $\frac{\sum an}{N \times A} \times 100$
2	Lack of existing infrastructural facilities like road and communica-tion		4																			0.04
3	Non availability of hydrological data		5																			0.05
4	Security restrictions in border areas		5																			0.05
5	Contractual problems		5																			0.05
6	Skills development of staff					4																0.04
7	Consistency of staff					4																0.04
8	Clients willingness to pay								3													0.03
9	Demand/ Criticality of the project								4													0.04
10	Complexity of project								2													0.02
11	Too many stakeholders								3													0.03

Appendix-2 Calculation of Severity Index (Risk Impact)

Severity index of different factors are calculated based on the ratings given by the twenty respondents has been shown below.

S. N.	Type of Risk	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13	R 14	R 15	R 16	R 17	R 18	R 19	R 20	S.I. $\frac{\sum an}{N\times A}\times 100$
A	**Financial Risks**																					
1	Loss due to fluctuation of interest rate	2	1	1	2	3	4	1	1	3	2	2	2	1	1	2	2	1	2	3	2	0.38
2	Low credibility of shareholder and lender	4	2	3	3	4	3	3	3	3	3	4	3	2	3	3	2	3	3	3	4	0.61
3	Change in bank formalities and lenders	2	1	2	1	3	2	2	2	2	2	2	2	2	3	2	1	3	2	2	3	0.41
4	Loss due to rise in fuel prices	2	1	3	2	4	3	1	2	3	3	2	2	3	1	3	1	1	1	2	2	0.42
5	Increased material cost	5	2	4	4	5	4	4	4	4	4	5	4	4	4	4	2	4	4	4	3	0.78
6	Insurances risk	3	4	3	2	3	3	3	2	3	3	4	3	3	3	3	4	3	3	3	3	0.61
7	Improper estimation	3	4	4	5	3	4	4	4	4	4	4	4	4	4	5	4	4	3	5	4	0.8
8	Payment delays	4	3	1	4	3	5	3	4	5	4	4	2	1	3	4	4	1	5	5	4	0.69
9	Invoices delay	3	3	1	3	2	4	3	3	3	3	3	1	1	3	3	3	1	5	3	3	0.54
10	Owner financial capacity	4	2	4	4	4	5	4	5	5	4	4	4	4	4	4	2	4	5	4	5	0.81
11	Paucity of funds	5	3	4	4	5	3	4	5	3	5	4	3	4	4	4	3	4	5	5	5	0.82
12	Tax rate	4	4	1	4	4	4	2	3	4	3	4	2	1	3	2	3	2	3	4	2	0.59
B	**Construction Risks**																					
1	Labor availability	3	2	2	4	5	5	3	5	5	4	4	3	2	4	3	3	4	5	4	3	0.73
2	Drop in labor productivity	5	2	2	4	5	4	2	4	4	5	4	3	2	3	2	3	4	5	4	5	0.72
3	Differing site conditions	3	3	1	4	3	2	4	3	2	5	3	3	1	4	4	3	5	4	5	5	0.67
4	Adverse geological conditions	5	4	4	4	4	4	4	3	4	5	5	4	4	4	5	4	4	3	4	3	0.81

S. N.	Type of Risk	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13	R 14	R 15	R 16	R 17	R 18	R 19	R 20	S.I. $\frac{\sum an}{N\times A}\times 100$
5	Faulty construction work at site	2	5	3	4	3	5	4	4	5	4	2	3	3	3	4	5	4	3	4	3	0.73
6	Labor strikes	4	4	5	5	3	4	3	4	4	4	4	5	5	4	5	4	5	5	5	5	0.87
7	Labor disputes	2	3	5	5	3	2	3	2	2	4	3	5	5	3	4	3	5	4	5	4	0.72
8	Equipment quality	4	5	1	5	4	3	4	2	3	4	4	2	1	4	4	5	3	3	4	5	0.7
9	Equipment maintenance	4	5	1	5	2	3	3	2	3	4	4	2	1	3	3	5	1	3	3	4	0.61
10	Material delivery	5	4	4	5	3	2	3	4	2	5	4	4	4	4	3	4	4	5	4	3	0.76
11	Material shortage	5	5	3	5	3	1	3	5	1	5	4	3	3	3	4	5	3	5	5	4	0.75
12	Material procurement	4	4	2	5	3	2	3	4	2	4	4	2	2	3	3	3	2	5	5	5	0.67
13	New technology	5	5	3	3	2	1	3	3	1	5	5	3	3	3	4	5	3	2	4	3	0.66
14	Nominated vendors	3	4	3	3	4	1	3	1	1	2	3	3	3	2	3	4	3	3	3	3	0.55
15	Delay in permits and licenses	3	4	2	3	2	5	3	2	5	3	3	2	2	3	4	3	4	5	4	2	0.64
16	Site location (rural/urban)	4	5	1	3	5	3	3	4	3	4	4	1	1	4	5	5	2	5	5	5	0.72
17	Access conditions	3	5	4	4	4	4	3	5	5	4	4	4	4	3	5	5	4	3	4	5	0.82
18	Seepage problem from dam	2	5	2	4	3	4	3	3	4	3	3	3	2	4	3	4	4	5	4	4	0.69
19	Blasting work	2	4	4	5	4	4	3	2	4	2	2	4	4	3	3	4	4	5	5	3	0.71
20	Unpredicted geological structure at tunneling sites	5	4	5	4	4	2	4	4	5	5	5	5	5	4	5	4	5	5	4	4	0.88
21	Design changes	4	5	2	4	3	3	4	5	3	4	4	2	2	3	4	5	2	5	4	4	0.72
C	**Environmen-tal Risks**																					
1	Natural disasters	4	5	2	5	4	5	4	5	5	4	4	3	2	4	4	5	5	4	5	5	0.84
2	Earthquake	3	4	2	5	3	5	4	5	5	4	3	2	2	4	4	4	4	5	5	4	0.77
3	Landslides	2	5	2	4	4	4	4	4	4	3	3	3	2	3	4	4	4	3	4	4	0.7
4	Precipitation/ Flooding	4	5	5	5	3	4	4	5	4	4	4	5	5	4	5	5	5	5	5	4	0.9
5	Unpredicted weather conditions	1	3	3	3	3	3	4	3	5	4	2	3	3	3	5	4	5	4	4	4	0.69

S. N.	Type of Risk	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13	R 14	R 15	R 16	R 17	R 18	R 19	R 20	S.I. $\frac{\sum an}{N\times A}\times 100$
6	Adverse environmental conditions	1	3	3	4	3	2	4	2	4	4	2	3	4	4	4	3	4	4	4	4	0.66
D	**Socio-political Risks**																					
1	Changes in laws and regulations	5	4	2	3	3	3	4	2	3	5	3	3	2	2	3	4	2	5	3	3	0.64
2	Land acquisition problems	5	5	5	5	5	4	4	4	4	5	5	5	5	5	5	4	5	5	5	5	0.95
3	Resettlement & rehabilitation	4	4	5	5	5	5	4	3	5	4	4	5	5	4	5	4	5	5	5	5	0.91
4	Litigations	4	5	3	4	4	4	4	4	4	4	3	2	2	3	3	5	3	4	4	4	0.73
5	Pollution and safety rules	3	4	2	3	4	2	4	2	2	2	3	2	2	2	2	4	1	5	3	3	0.55
6	Bribery/ Corruption	1	3	2	4	2	3	4	2	3	1	1	2	3	3	2	2	2	5	4	3	0.52
7	Language/ Cultural barrier	3	3	1	3	1	2	4	1	2	3	3	1	1	3	3	3	1	4	3	3	0.48
8	Law and order	4	4	2	4	3	2	4	2	2	3	4	2	2	2	3	3	2	5	3	3	0.59
9	War and civil disorder	4	2	1	5	2	3	4	3	3	3	4	2	1	4	4	2	1	5	4	3	0.6
10	Social acceptance	3	4	2	4	1	4	4	2	4	3	3	2	3	4	4	3	2	5	4	4	0.65
11	Requirements for permits and their approval	3	4	3	3	4	4	4	2	4	3	3	3	3	3	4	3	4	5	3	4	0.69
E	**Management Risks**																					
1	Change in top management	3	3	5	3	2	4	3	2	4	3	3	4	4	2	3	3	5	5	3	4	0.68
2	No past experience in similar project	4	5	4	3	4	4	3	3	4	4	3	3	4	3	4	5	4	2	4	4	0.74
3	Short tender time	4	4	2	4	3	3	3	4	3	4	3	3	2	3	3	4	1	3	4	3	0.63
4	Internal management problem	3	5	4	4	2	4	3	3	4	3	3	3	4	2	4	5	4	4	3	2	0.69
5	Improper project feasibility study	5	5	5	4	5	2	3	5	2	4	4	5	4	3	4	4	3	3	3	3	0.76
6	Poor relation and disputes with partner	5	5	3	3	4	3	3	4	3	5	5	3	3	2	4	5	3	5	3	3	0.74
7	Team work	3	5	4	4	4	3	3	4	3	3	3	4	3	3	3	4	4	5	4	4	0.73

S. N.	Type of Risk	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13	R 14	R 15	R 16	R 17	R 18	R 19	R 20	S.I. $\frac{\sum an}{N\times A}\times 100$
8	Time constraint	3	4	5	4	3	3	3	5	3	3	3	5	5	4	4	4	5	5	5	5	0.81
9	Project delay	4	5	3	5	5	4	3	5	4	4	4	3	3	3	3	5	3	5	5	5	0.81
10	Quality control process	4	4	4	3	3	3	3	3	3	4	3	4	4	4	3	4	4	5	3	3	0.71
11	Type of contract	2	5	5	5	1	2	3	4	2	2	2	5	5	4	3	4	5	5	4	4	0.72
F	**Physical Risks**																					
1	Damage to structure	3	3	2	3	5	5	4	4	5	3	4	2	3	4	4	3	2	5	4	5	0.73
2	Damage to equipment	3	3	1	3	4	5	4	3	5	3	3	1	2	4	4	4	3	4	3	4	0.66
3	Labor accidents	3	3	3	3	4	3	3	5	3	3	3	3	3	3	3	3	3	5	4	3	0.66
4	Equipment breakdown	4	4	2	4	3	3	4	4	3	4	4	3	3	4	4	4	2	4	4	4	0.71
5	Material theft & damage	2	4	2	4	3	2	3	3	2	2	2	2	2	3	3	4	2	4	4	4	0.57
G	**Legal Risks**																					
1	Breach of contract by project partner	2	5	1	3	1	3	4	4	3	2	1	1	1	4	4	5	1	3	2	3	0.53
2	Lack of enforcement of legal judgment	2	5	2	3	2	2	4	3	2	1	1	2	2	3	3	4	2	4	2	4	0.53
3	Improper verification of contract document	2	5	1	4	2	4	4	4	4	2	2	1	1	4	4	4	1	4	3	3	0.59
4	Uncertainty and unfairness of court justice	2	5	1	4	1	1	3	2	1	2	2	2	2	3	3	5	1	4	4	3	0.51
H	**Technical Risks**																					
1	Incomplete design	3	5	1	4	5	4	3	4	4	3	3	2	1	4	4	5	1	5	4	5	0.7
2	Inadequate specification	3	5	2	4	5	4	3	4	3	3	3	3	2	4	3	4	2	4	4	4	0.69
3	Inadequate site investigation	4	5	3	4	5	2	3	4	2	3	4	3	3	3	4	5	3	4	4	4	0.72
4	Change in scope	5	5	2	4	4	2	3	4	3	5	4	2	3	4	3	4	1	5	3	5	0.71
5	Construction procedures	3	5	3	3	3	4	3	5	4	3	3	2	4	3	4	4	3	5	4	3	0.71
6	Insufficient resource availability	5	5	1	5	5	4	3	5	4	5	4	2	3	4	3	5	1	5	4	4	0.77

S. N.	Type of Risk	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	R 13	R 14	R 15	R 16	R 17	R 18	R 19	R 20	S.I. $\frac{\sum an}{N\times A}\times 100$
I	**Any other risks (Please specify)**																					
1	Interstate aspects		4																			0.04
2	Lack of existing infrastructure-al facilities like road and communica-tion		4																			0.04
3	Non availability of hydrological data		5																			0.05
4	Security restrictions in border areas		5																			0.05
5	Contractual problems		5																			0.05
6	Skills development of staff					4																0.04
7	Consistency of staff					4																0.04
8	Clients willingness to pay								5													0.05
9	Demand/ Criticality of the project								5													0.05
10	Complexity of project								4													0.04
11	Too many stakeholders								5													0.05