"RISK MANAGEMENT IN HIGHWAY PROJECTS"

A Thesis

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

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Under the supervision of

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by

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152609

to

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CERTIFICATE

This is to certify that the work is being presented in thesis tittle "**RISK MANAGEMENT IN HIGHWAY PROJECTS"** in partial fulfilment of the requirements for the award of the degree of Master of Technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Ankit Dadhich** during a period from July 2016 to April 2017 under the supervision of **Mr Santu Kar** Assistant professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

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

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Date- Ankit Dadhich

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ABSTRACT

Construction industry is the key of development to any country in present scenario. It involves various uncertainties and risk associated with different aspects and at different level of execution which has to be identified and monitored properly as it can have a huge impact on the project objectives (scope, time , cost etc.). In consideration of the same if any kind of wastage of resources takes place that will result in huge monetary losses. These losses are due to various types of risk associated with such development projects. A crucial role is played by these risks for the completion of project successfully within the time schedule and allotted budget. Thus a risk management strategy is very essential to identify, analyse, plan risk response and monitor and control the project. The objectives of risk management are to increase the probability of positive events and to reduce the consequences of negative events by identifying and analysing the different risk factors occurring in a particular project before hand and take suitable actions to reduce their impact on project objectives. Indian transportation industry contributes largely to its economy and has second largest road network in the world accounting of 4.7 million kilometres and also planning commission of India plans to spend nearly 20 % of total investment of USD 1 trillion during the 12th Five year plan (2012-2017) to develop roads. Thus delay in the Highway projects can effect the economy of the country in huge manners. Thus the aim of this study is to identify the risk factors associated with the highway constructions in India and to find the critical factors by analysing the identified factors based on ratings obtained through a Questionnaire survey circulated among different consultants, contractors, supervisors, involved in highway construction industry and to suggest mitigation techniques to reduce the impact of these risk involved in construction of highways in India to boost the economy to meet the increasing demand of roads and highway of the increasing population. An attempt to present a systematic approach to calculate the impact of risk at activity level and project level has also been done using the @Risk software in which activity time allowance at activity and project has been calculated considering the different percentage of occurrence of risk at activity level and project level.

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CHAPTER-1

INTRODUCTION

1.1 GENERAL

The construction industry in India is estimated to be worth $ 120 billion per year and contributes 5.5 % to GDP. However this industry continues to face challenges around skill shortage, Rise in material and labour cost, socio-economic changes. Finances are the major source of worry as international funding is limited in India. But in recent years construction industry is growing due to booming economy activity, large scale expansion plans, and infrastructure projects including transportation, energy and natural resources. Therefore, managing construction risk in India is critical and need to focused upon. It is necessary to study and identify commonly occurring risks in construction projects pertaining to different factors reoccurring in project scenario. The aim of this research is to identify critical risk factors and assessment of those factors occurring in Indian highway projects.

In India, 12th Five year plan (2012-2017), which targets the economic growth at 8.2 % , infrastructure is considered as one of the major area to achieve the target. The global construction industry is growing and forecast to register consistent growth in terms of construction spending with developing countries like India and china leading the growth chart, due to huge transportation infrastructure investments from government in these nations, the industry could rise at impressive rates. Global industry analyst (GIA) pointed out India, China Indonesia, and Vietnam to be frontrunners in terms of construction spending in coming future. Seeing the potential analyst suggest that infrastructure bottlenecks the GDP by 2% annually for any country. On a project or hierarchy specific level, all members of the project whether stakeholders, parties etc., all should have the same notion to way the risk management process is conducted to make it successful. It is essential to realise that the uncertainties are unavoidable that can occur at any stage of the project and need to be identified, and quantify their impact on the project objectives, either positive or negative. It may not be possible to identify all risk but if identified earlier at a preliminary stage it can help to make a project successful, making revenues for all project participants. Effective governance and risk management is the key to success for any project in current scenario and thus very important to be considered in the project. Various researchers have tried to identify different risk factors that can hinder the completion of a project successfully in different parts of the world. Many variables have been found in the literature earlier and therefore, previously identified factors are also included in the research that are applicable with context to the Indian transportation industry. Every highway project include some degree of risk and most of the managers are not prepared to identify potential risk sources when it comes to on field application and also identifying all risk factors associated with a project is a time consuming and counter productive task thus attempts to identify risk factors on field are doomed to fail in Indian highway industry. In this research, factors were identified that hinders the successful completion of highway construction project in India. The identified risk factors were then analysed through a Questionnaire survey providing ratings for identified factors from professionals, consultants, contractors, and project managements experts.

1.2 NEED OF THE PROJECT

Highway construction includes various uncertainties and unforeseen circumstances on site due to involvement of large no. of activities, different people from different trades and continuously changing conditions if work due to long stretches and varying environment, geographical conditions at different places, removal of existing structures, shifting of utilities, land acquisition etc. , are major problems faced in recent times for completion of such projects. Thus to identify critical risk factors and their impact on project completion is very important. Highway projects if delayed not only effects the firm and contractors involved but also effect the economy of the country like India as it is a major contributor to the GDP of the country.

1.3 OBJECTIVE OF THE PROJECT

1. To find out the different risk factors in highway projects.
2. To analyse those factors to find critical factors and to rank those factors.
3. To suggest mitigation techniques for the identified critical risk factors.
4. To develop a systematic approach to calculate the impact of risk at activity level and project level.

1.4 SCOPE OF THE PROJECT

To identify risk factors affecting completion of highway construction in India by comparative study of major highway projects from different parts of India. Major focus is made on the projects in Western, Northern, Central, Northern Eastern projects.

1.5 METHODOLOGY

The project methodology involves the identification of the risk factors associated with the construction of highway projects in different parts of the country by review of research papers, annual reports of Departmental of Indian road congress and N.HA.I etc.,and to find critical risk factors among them by Questionnaire survey among consultants, supervisors and managers and other industry related personnel's by calculating their probability of occurrence and impact on the project objectives.

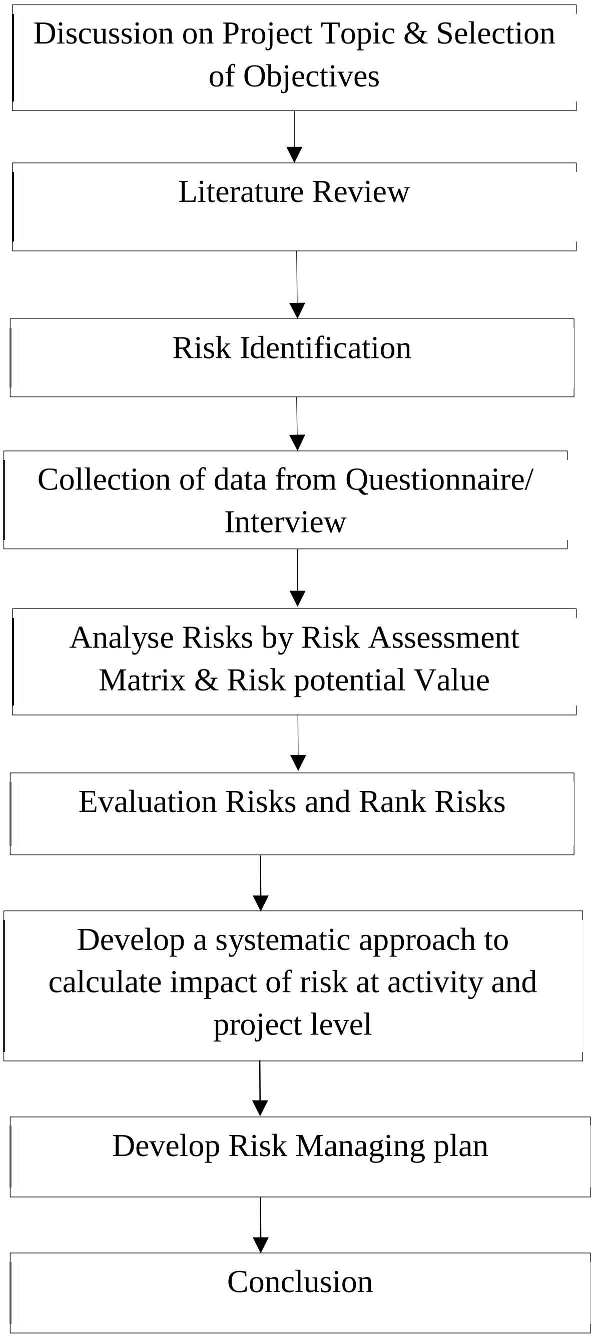

Fig. No. -1.1 Research Methodology

CHAPTER-2

Literature Review

Risk management may be described as "A systematic way of looking at areas of risk and consciously determining how each should be treated. It is a management tool that aims at identifying sources of risk and uncertainty, determining their impact, and developing appropriate management responses" (X.W.ZOU,2013). A systematic process of risk management has been divided into risk classification, risk identification, risk analysis and risk response planning (Patel Kishan,2012). An effective risk management method can help to understand not only at areas of risk but also help to plan the response that how these risk should be managed at different phases of project. The importance of risk management is increasing day by day not only to construction industry but also to other industries. Thus a definite set of tools and techniques are required to complete every project or task successfully. Compared to other projects highway projects are subjected to more risk conditions due to unique features of construction activities, such as long periods, complicated processes, varying environmental conditions, financial intensity, and dynamic organisation structures. The main aim of this investigation is not to identify a list of risk factors but to ascertain the key risks that can significantly influence the delivery of highway projects in India.

2.1 Risk Management process & its Importance-

The various steps involved in risk management frame work as per ISO 31000:2009 are –

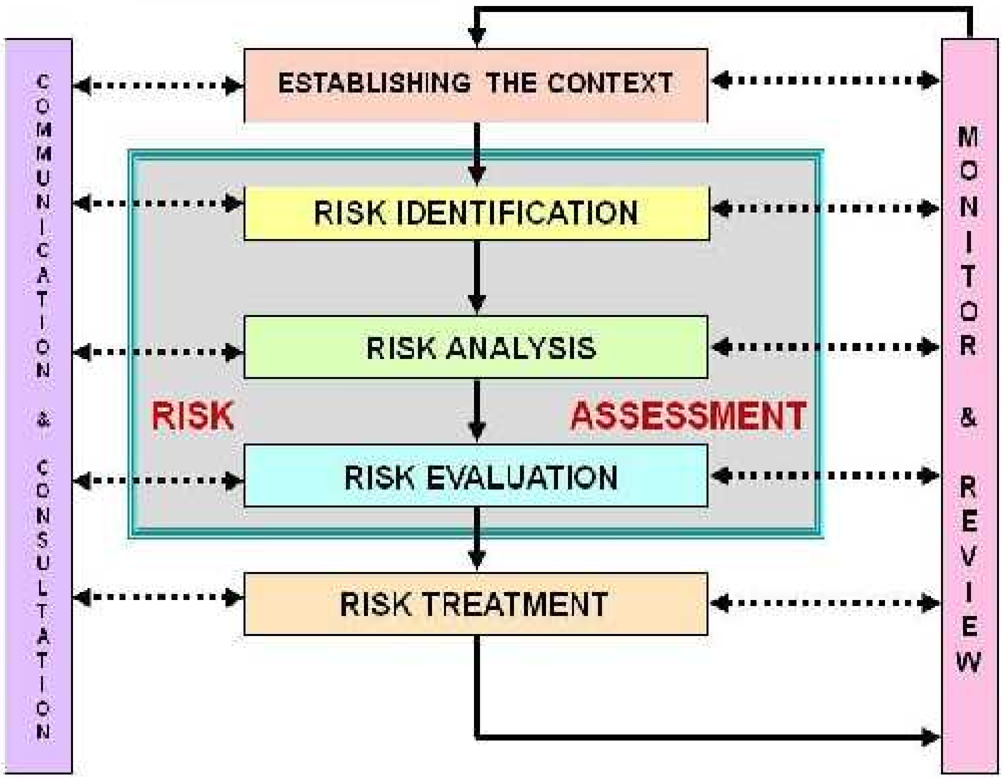

Fig. No. -2.1 ISO 31000:2009 Risk Management Process

4.1.1 Risk Identification - Risk management always starts with risk identification which is considered the most important phase of risk management process. Its purpose is to compile a list of risks important for a particular project. To identify risk it is first important to research the necessary sources of risk, adverse events that include risk, and also the effects of the undesirable scenario. 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 management team, subject matter expert, customers, end user, project managers, stakeholders, and outer experts (Patel Kishan, 2012). The various methods used for risk identification are listed below.

i. **Brainstorming:** This is one of the most popular techniques. Generally, it is used for idea generation, it is also very useful for risk identification. All relevant persons associated with the project gather at one place. There is one facilitator who is briefing about various aspects with the participants and then after that note down the factors identified by all persons. Before closing it the facilitator review all factors eliminate the unnecessary ones.

ii. **Delphi Techniques:** This techniques is similar to brainstorming but the participants are not at the same place and does not know each other. They will identify the factors without consulting to each other. The facilitator like in brainstorming sums up the identified factors and eliminate the undesired ones.

iii. **Interview/ Expert Opinion:** Experts or personnel with sufficient experience in a project can be a great help in avoiding/ solving similar problems over and over again. All the participants or the relevant persons in the project can be interviewed for the identification of risk factors affecting project objectives.

iv. **Questionnaires :** A questionnaire is a research instrument consisting of series of question and it prompts to gather information from respondents. It consist of predetermined checklist of factors of risk identified by documentation reviews, past experience of project members and case studies of pre- executed projects.

2.1.2 Risk Classification- Many researchers classify risk in different categories based on various parameters and assumptions. (A.N Shifana,2016) and (M.El-Sayegh,2015) classification is used, which is given as under.

1. Technical risk.
2. Construction risk.
3. Physical risk.
4. Organisational risk.
5. Financial risk.
6. Socio-Political risk.
7. Environmental risk.

A. Technical risk – Technical risk can be defined as the circumstances which arise in the integration of critical technologies, and sub system dependent on them due to which project will not achieve its objectives successfully. Inadequate designs, lack of risk management, complexity of projects etc. are some of the sources of technical risk in the project.

B. Construction risk – A construction risk can be defined as any exposure to possible loss during the execution of project, as every project is different, each offers a multitude of varying risk. To ensure the success of project, the project team must be able to recognise and assess possible risk factors which can occur during execution of that project. Change in scope, Unidentified obstruction, change in law and regulation, delay in material procurement etc. are the factors which can lead to time overrun of the project.

C. **Physical risk –** These are referred to physical difficulties and constraints to achieve defined objectives. Equipment damages, labour injuries, site conditions are some of the physical risks which can significantly affect the project completion time.

D. **Organisational risks –** These risks factors depend on the organisational experience, experience of workers, engineers and their mental perspective and techniques to identify and handle the risk, collaboration among different trades and efficiency of workers. These factors can affect the durations if different activities and ultimately the completion time of projects.

E. **Financial risk –** The risk factors associated with the capital required to execute the work under given timeline, to complete the project on time the firm should be both technically as well financially sound. Arranging the finances to handle risk is not the key factor but to arrange them at the right time, when it is actually required is the key factor to achieve the deadline. As it is observed that in India finance play a very critical role in project completion because delay can cause a huge losses in terms of liquidity damages and recent scenario clearly demonstrates the situation as there are many companies who have faced significant downfall due to losses in large compensation due to overrun of projects.

F. **Socio-Political –** These category of risk involves the social political aspects related to projects. It has been noticed that there have been many problems related to social and political aspects for the project completion in India. It consists of different departments and political influence in projects which can cause some delay in project completion or may arise some disputes between the parties. These kind of problems are very common in big projects like Hydro and highway projects. Land disputes, local citizen issues are some of risk associated with social and political aspects or projects.

G. **Environmental risk –** The risk associated with the environmental conditions of the project site can also play a significant role in completion of projects. Rainfalls, earthquake, natural calamities, pollution and safety rules etc. are some of the risks factors which can cause delay in construction completion time.

2.1.3 Risk Analysis – Risk analysis, a component of the risk management process, deals with the causes and effects of the events which cause harm to the project objectives. The aim behind such analysis is a precise and objective calculation of risk. It allows decision making process to be certain to large extent. It attempts to capture all feasible options and to analyse the various outcomes of any decision. Risk analysis involves assessing the identified risk. This first requires that risk is first quantified in terms of their impact on the cost and time on project. The use of risk analysis gives an insight to what happens if the project does not proceed according to the plan. when the active people and their prospective are applied to the different problems coming in the project, there will be a clearer vision of the risks and can be handled easily. Risk analysis can be broadly classified in two categories i.e Quantitative and qualitative risk analysis as per ISO 31000:2009.

2.1.3.1 Qualitative risk analysis – Risk analysis whether qualitative or quantitative is focused on finding the probability of occurring of risk and their consequences (Alimohandi Seddigh, 2009). This is used to find the occurrence of risk and their impact on the project. Hence the risks can be prioritized and can be handled on the basis of their priority of affecting the project objectives. We can also access to the roots of the risk which are causing exposure of project to severe conditions that demands our attention to the matter. This process is very important as it prioritizes the risk according to their potential effect on project objectives. Some of the common methods of Qualitative risk analysis are explained below.

A. **Risk probability and Impact Assessment –** risk probability and impact can be described in qualitative terms as –

   Risk Probability is the likelihood that a risks may occur.

   Risk Impact is the effect on project objectives if the risk occur which can have negative impact on the project objectives. Risks identified must be individually assessed as to their potential likelihood and outcome.

   Risk probability = $\frac{\sum a}{N * A}$

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

Risk Impact = $\frac{\sum a}{N * A}$

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

Risk potential value = Risk Probability x Risk Impact.

B. Risk Assessment matrix – following is the assessment matrix showing probability and impact of each risk.

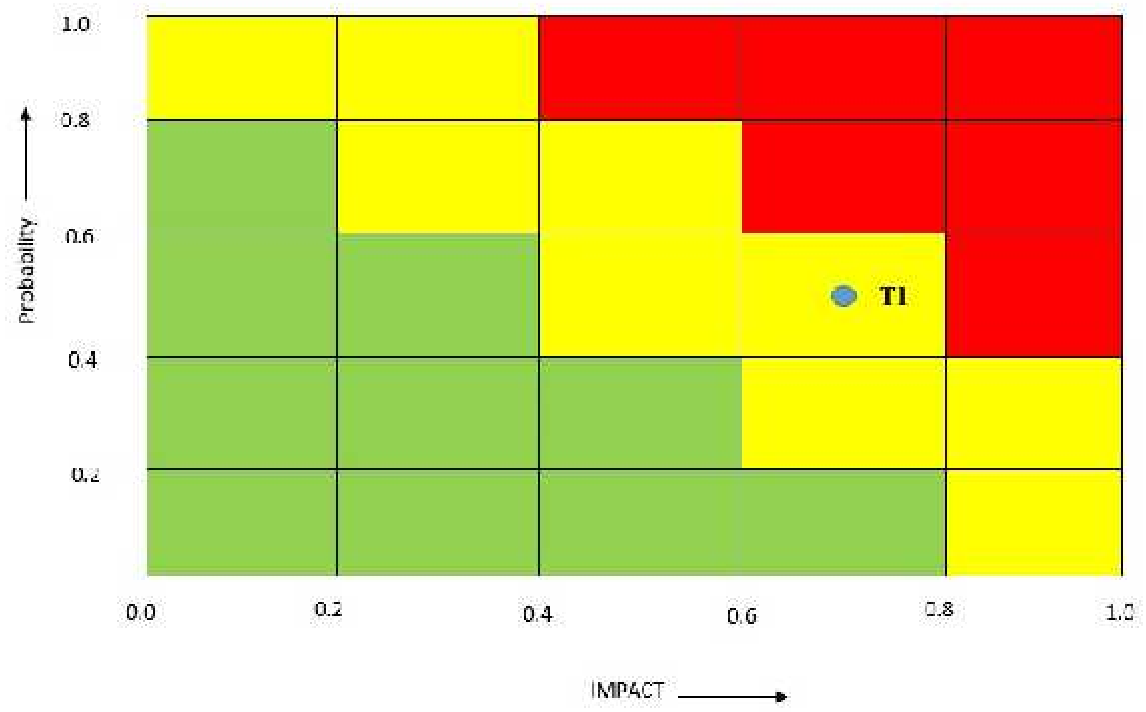

Fig. No. – 2.2 Risk Assessment Matrix

There are following three categories –

(red)	These Signifies the risk having high potential value.
(yellow)	These Signifies the risk having moderate potential value.
(green)	These signifies the risk having low potential value.

C. Relative Importance Index – The relative importance index (RII) was used to rank factors with an index range 0.0-1.0. This method was used by (Ankit

Vishwakarma,2016) ranked various risk based on R.I.I in his research and concluded that higher the R.I.I more significant is the risk factor.

$$\textbf{R.I.I} = \frac{\sum W}{N*A}$$

Where Wi= total sum of each factor (1 = very low, 2 = low, 3 = medium, 4 = high, 5 = very high); A = highest weight (5 in this case), and N = total number of respondents at each variable.

2.1.3.2 Quantitative Risk Analysis – Following are common quantitative analysis techniques.

A. Sensitivity Analysis- This is carried out to identify the uncertain project components which will have maximum impact on the project. Risk is analysed by changing one element at a time and recording their impact on the project objectives being time , cost etc.

B. **Scenario Analysis –** Scenario analysis gives the impact of different scenarios of the project or impact of different risk if that occur simultaneously on the project.

C. Probabilistic Analysis (Monte Carlo Simulation) – A project simulation is done using a model to show the potential impact of different level of uncertainties on project objectives. Monte Carlo simulation is generally used for this analysis. It simulates full system many times, each time randomly choosing a value for each factor from its probability distribution.

D. Decision Tree analysis – This analysis is carried out by decision tree diagrams. Decision trees are very helpful to both formulate the problem and evaluate options. In this analysis there are graphical models used to represent a project and can clearly reflect the effects of each decision at different stages of project.

2.1.4 Risk Evaluation – Based upon the results of the analysis risk are ranked, and the most critical risk are identified and response action to mitigate it is planned based on the ranking obtained from different risks. Critical risks are more preciously dealt and response strategies are made accordingly.

2.1.5 Risk Treatment – After finding out the risk factors and analysing them based on different methods next step in risk management process is to treat the identified risk as described in ISO 31000:2009. Risk treatment involves risk response planning and risk control.

2.1.5.1 Risk Response Planning – It can be done based on following method as described by (A.N.Shifana,2016).

A. **Risk Avoidance –** Risk avoidance is the elimination of some risk by changing some sort of parameters of project. It aims to replan project about the activities or methods in such a way that risk on field disappears or reduced to an acceptable level. The solution may be from any aspect whether being technical, financial, organisational or political whichever have some sort of exposure to the risk. However, care should be taken that avoiding one risk does not lead to taking on unknown risk with even greater consequences.
B. **Risk Transfer –** Transferring risk involves finding some other party who is willing to accept responsibility for its management, and who will bear the liability of the risk should it occur. Transferring a threat does not eliminate it, the threat still exists however it is owned and managed by another party. Transferring risk can be an effective way to deal with financial risk exposure. The aim is to ensure that the risk is owned and managed by the party best able to deal with it effectively. It gives best results when both the sides fully understand its importance and also the rewards obtained through it. The party responsible to handle the risk should have skills, knowledge and capability to properly handle the risk.
C. **Risk Mitigation / Reduction –** Risk mitigation reduces the probability and impact of an adverse risk event to an acceptable limit. Risk mitigation plan should analyse the root cause of the risk and prioritize the risk to be handle in earlier stages of risk management process. Taking early action to reduce the probability or impact of risk is more effective than to repair the damage caused by the risk consequences. It also help to assess and prioritize the mitigation plans and their effectiveness.
D. **Risk Exploit –** This strategy seeks to eliminate the uncertainty associated with a particular upside risk by creating the opportunity. An opportunity is defined as a risk event that if occurs will have a positive effect on achievement of project objectives.
E. **Risk Share –** Allocate risk ownership of an opportunity to another party who is best able to maximise its probability of occurrence and increase the potential benefits if it does happen. Transferring threats and sharing opportunities are similar in that a third party is used, an those to whom the threats are transferred take on the liability and those to whom opportunities are allocate should also be allowed to share in the potential benefits.

F. **Risk Enhance –** This response aims to alter the size of the positive risk and to minimise the size of negative risk. The aim is to enhance the probability of positive risk opportunity, thereby maximising the benefits gained from the project.

G. **Risk acceptance –** Ultimately it is not possible to eliminate all negative events and take advantage of all positive events. This strategy is adopted when it is not possible or practical to respond to the risk by other strategies, or a response is not justified by the risk. When the project manager and the project team decide to accept a risk, they are agreeing to address the risk if and when it happens.

2.1.5.2 Risk control – It is process of assuming a risk but taking steps to reduce, mitigate, or otherwise manage its impact or likelihood. Risk control consists of measure which provide early data gathering or warning systems that provide information to assess more accurately the likelihood, impact or the time of the risk. If warning of a risk can be obtained early enough to take action against it, then information gathering can be preferable to more tangible and possible more expensive actions.

2.2 Summary -

Flanagan and Norman (1993) introduced risk management in construction and provided the basic idea about the risk and importance of risk management in construction industry briefing about the construction industry being prone to various uncertainties and unseen circumstances. It also describes risk management process with identification of risk and analysis of risk by conducting interviews or taking advice from the experience persons, before tiem only one experience was the key to handle the risk.

Ameneh Seddigh (2009) in his research work on lean implementation in risk management process showed that there exist a inherent close interaction between lean methodology and risk management process. This research tries to present more transparency in the system by implementing lean principles and provide a lean risk management process.

Mary Ansell, Mike Holmes (2009) in their research conducted a Questionnaire survey among the Construction management framework, which is contract being develop only among the CMF participants to develop best value in major highway renewals and improvements schemes. The research intended to check the effectiveness of the CMF in achieving the objectives, it also provided with the potential areas of interest of highway projects which help to increase or provide with the best value in the highway projects. It provided with questions which can help to deliver value to highway projects.

Garry D. Creedy (2010) evaluated risk factors leading to cost overrun in delivery of Highway construction projects The analysis has produced important findings concerning the reasons highway projects have overrun and provided evidence of the most important risks on which highway agencies need to focus their efforts.35 risk factors were evaluated and analysed based on statistical modelling.

Debasis Sarkar (2011) discussed about the method of measurement of project risk , based on expected value method (EVM). A case study of underground corridor construction of metro rail in the capital city of an economic nation of south asia has been considered for this research work. The risk analysis for the determination of risk cost, risk time, expected cost and expected time of project has been carried out by EVM, based on analysis expected cost and expected time were found to be 22.5% and 23.4% respectively.

Robert William Muir (2012) presented a thesis on the analysis of lean construction principles to highway projects, the thesis focused on the highway projects in U.S, it concluded that present construction of highway facilities takes lots of time to construct and suggested interventions intended to enhance time performance. The analysis showed that 60% of the projects were overrun by time, and suggested to apply lean construction principles in managing projects to reduce risk in terms of cost and time overrun.

Mohamad.F.Diab, Khaled Nasal (2012) carried out a research to analyse and evaluate the different risk drivers in highway construction projects in U.S. 31 risk drivers were identified and analysed based on the previous projects. This paper presents the study regarding the process of using risk assessment techniques and tools for determining its impact on the project cost and schedule performance ratings on the highway projects. The analysis were carried out using the Chi-square probability test and Fishers Exact test.

Dr. Ptrick.X.W.ZOU (2013) in his research clearly defines the risk management and also identified key risk factors in construction projects from life cycle and stakeholders prospective. 21 major risk factors were identified based on the comparative study and analysis through survey from the various risk factors, which were classifies related to different prospects of the projects such as related to client, related to contractor, related to designer, related sub-contractors, related to stake holders, related to government bodies and superintend.

Usama Hamed Issa (2013) in his studies on implementation of lean construction techniques for minimising risk effects on project completion time proposed that lean construction tools and techniques can be used to minimise the risk associated with the construction projects by eliminating waste reduces risk and also monitoring can be effectively done by using two effective tools percent expected time overrun(PET) and percent plan complete(PPC).

Remon Fyek Aziz (2013) has showed in his studies that construction productivity has been declining from past 40 years worldwide due to lack of effective risk management procedures. In U.K studies indicated that 30% of construction rework, 3-6% of total cost and at least 10% materials are wasted. Australian projects showed cost of rework has been reported as being upto 35% and overrun of 50% of project cost.

Patel Kishan, Rajiv Bhatt (2014) identified critical risk factors related to the building construction projects and provided with the detailed risk management process comprising of risk identification, risk classification, risk assessment and risk response. They also briefed about the principles of risk management and benefits which can be obtained by using risk management techniques in construction projects not only limited to the building projects but can be applicable to all kinds of construction projects.

Rasheed..A.Salawu (2014) in his studies on the Review of risk assessment models for Highway construction projects reviewed various risk assessment techniques and models and content analysis of the literatures was done to find their effectiveness , the research concluded that various improvements on risk modelling is necessary for effective risk management and timely completion of projects.

Rogério Cabral de Azevedo (2014) showed risk management has become has become an increasingly challenging activity only 13% of audit committee members classified the risk management of a company as effective. So their exist limitation of risk management process due to various uncertainties in project environment.

T.H.Nguyen (2014) in his studies on the transportation project in India showed that 23% of infrastructure projects are related to transportation industry from which 22% contributes the highway projects so management of risk in critical to ensure timely completion of projects and also provided various critical risk factors in transportation sector which included Highway, Railways, Oil and gas , shipping and ports and other transportation related projects. It also provided that evidences that Indian construction face challenges regarding rise in cost of material and economic changes and also lack of skills and effective risk management procedures.

M. El-Sayegh and Mahmoud H. Mansour (2015) in their study on risk assessment and allocation in highway construction projects in UAE founded out 31 risk factors associated with highway construction projects and classified and analysed them based on RII.

Awad S. Hanna(2015) provided factors of risk misallocation Highway construction projects The research was designed to identify the top misallocated risks in the highway construction industry and to provide recommendations to more appropriately allocate these risks on highway construction projects. 9 misallocated criteria were evaluated.

Xavier Brioso (2015) in his research integrated ISO 21500 guidance on project management , lean construction and PMBOK provided that traditional management system , flow processes have not been controlled or improved in orderly fashion which led to complex , uncertain, confused flow processes , expansion of non-value activities and reduction of output. It showed how the principles of traditional project management system are not able to control the uncertainties and let to high risk exposure conditions and delay in achievement of project objectives, thus suggest to include new innovative methods of risk management as a continuous process of construction projects.

Yogita Honrao (2015) in his research of study of delay in execution of infrastructure projects present the causes of delay in highway projects and also analysed those causes on the basis of frequency index, severity index and importance index and rank those factors to find the critical factors, 52 delay factors were analysed and causes of delay related to contactors , related to owner , related to consultant , related to external environment were presented based on the results obtained.

Nadereh Moini (2016) model interconnectivities among systems and subsystems of transport and critical infrastructures vulnerable to climatic events that impose the highest impacts on people and regional economies from chronic to episodic events. Various factors causing impact or Road system and rail road system were evaluated. With the objective of vulnerability assessments of critical infrastructures to climatic events, the study presented a holistic approach to analyse risks threatening each system through the likelihood assessments of occurrences of hazards, the spectrum of impacts imposed on the system, and links and interconnectivities between the system and other related systems.

Ankit Vishwakarma, Ashwini salunkhe (2016) in their research on the risk assessment in construction of highway projects identified risk factors related to highway projects and analysed and rank using refractive importance index(RII) based on questionnaire survey, 36 risk factors were identified, analysed by RII ranking of those factors were done to find the 10 most critical risk factors.

A.N.Shifana, Biju Augustine (2016) in their research on conceptual study on risk management process in construction projects provided a case study in which risk management process was applied to a construction process and results were presented in terms of cost matrix , time matrix and quality matrix showing probability and impact curves related to cost, time and quality. They also discussed and classified risk in different categories and also presented the factors affecting risk.

CHAPTER-3

Risk Identification & Data Collection

3.1 General -

Indian transportation industry contributes largely to its economy and has the second largest road network in the world accounting of 4.7 million kilometres and also planning commission of India aims to spend nearly 20 % of the total investment of USD 1 trillion during the 12^{th} are expected to reach Five year plan (2012-2017) to develop roads, as per Union Budget (2014-2015) and MORTH Annual report (2012-2013). National highways are expected to reach 85000 kilometres by the end of 2017. Indian roads bear 85% of the country's passenger traffic and 60% of the freight traffic. So the risk management in highway construction industry in India is very critical and can have huge impact in terms of monetary losses. So, delay in highway construction are affecting the economy of the country and research has showed that many highway construction projects are delayed due to various factors evident from delay of major highway project such as NHDP which has been delayed by more than 2 years.

NHDP was started to upgrade, rehabilitate and widen major highways to a higher standard in 1998 which included upgradation of 49260 km's of road highway work and construction in order to boost economic development in country. Delay in such projects thus affects the economy in major way.

Based on the ratings obtained for each risk factor from experts and highway persons from the industry the ranking for the different factors were obtained. The response rate was 61% out of the questionnaires send and the respondents included persons from contracts, administration, engineering, consultants and contractors. The percentage response rate from different departments are shown below.

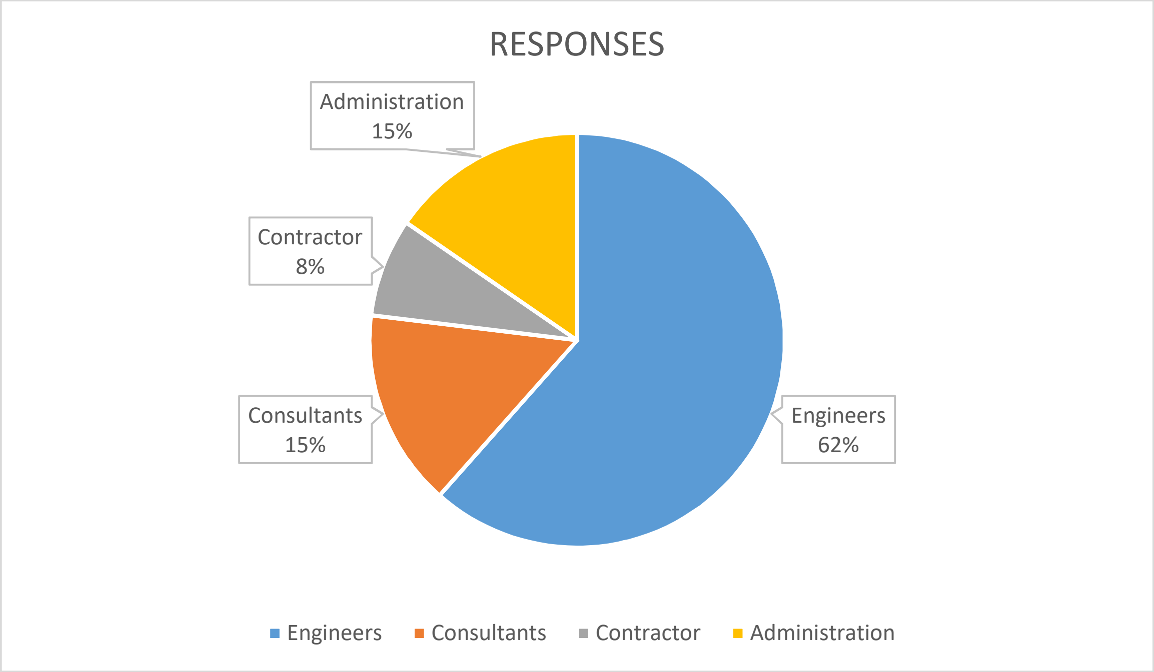

Fig. No. – 3.1 Respondents Percentages

4.2 Explanation of Risk Factors – Based on the study of delay projects and various literatures 71 risk factors were identified which can effect the successful completion of project objectives in Indian highway construction industry. The various factors and their explanation are listed below. The risk were factors were classified in to seven different categories such as Technical risks having 15 risk factors, Organisational risk having 18 risk factors, Construction risk having 14 risk factors, Financial risk having 6 risk factors, Physical risk having 6 risk factors, Socio Political risk having 7 risk factors and Environmental risk having 5 risk factors.

Table No. – 3.1 Explanation of risk factors

RISK IDENTITY	RISK TYPE	EXPLANATION
	TECHNICAL RISK	
T1	Inadequate Design	Design are the means through which the physical, quantitative and visual descriptions of the project are conveyed to the contractor. Inadequate design can lead to misleading design objectives.

T2	Inadequate specification	Specification are the written instruction to carry out a work ,it also contain the information not possible to draw on a piece of drawing , it basically defines the quality of materials and work to be executed .
T3	Inadequate site investigation	Site investigation tells about the geographical condition of site , inadequate site data can lead to false data about soil condition , water table , access road required , improper cost estimation etc. which can effect project objectives.
T4	Lack of risk management	The inability to identify ,mitigate and response to the risk involved in the project .It can effect the schedule performance and also effect cost in terms of liquidity damage by delaying of project.
T5	Failure to integrate with the system	It signifies the failure to understand and execute the design description physically in form of construction. It cause time overrun, error in construction and also rework .
T6	Design error and suitability to the nature	Design made are not suitable to the construction site due to less spaces or high cost of construction and other factors.
T7	Complexity of project	Every project offers different level of complexity for its execution. More complex the project is , more is the chances of risk occurrence.
T8	Improper estimation of time and cost	The improper estimation of time and cost can lead to insufficient resources and budget to execute the work which ultimately lead to missing of the deadlines.
T9	Errors in project documents	Errors in project documents can lead to ambiguous or misleading objectives and also can cause disputes among parties
T10	Lack of requirement specification in tender document	The specification essential for the construction sometimes are not clear in the tender document which cause errors in execution and also disputes .
T11	Lack of proper planning	Lack of proper planning can lead to shortage or over allocation of resources at certain stages .

T12	Misunderstanding of requirements	The perception of manager sometimes also plays a major role , requirements if not understood correctly can lead to unforeseen activities or wastage of resources.
T13	Lack of previous data of execution	Availability of the previous data of different projects can reduce time for risk management and also to eliminate the risk at the source.
T14	Poor safety procedures	Poor safety procedures can lead to lead to labour injuries and equipment damage which effect productivity and also cost in terms of compensation, repair or replacement.
T15	Misinterpretation of traffic data	Misinterpretation of traffic data in highway construction can lead to reduction in profit of the contractors as most of the highway projects are BOT type nowadays in India.
	ORGANISATIONAL RISK	
O1	Intense competition at tender stage	To became lowest bidder and to get a tender, improper and low bid coated by organisation can later cause cost overrun and liquidity damages in huge amounts.
O2	Consultant leaving the project in midway	Consultants appointed leaves the project due to various factors such as lack of funding, delay in payments, excessive pressure by organisation to complete work fast, contractual disputes etc.
O3	Efficiency of managers/supervisors to handle work	The mind set and efficiency of manager, supervisors play a vital role in managing risk .i.e how effectively he can identify the risk or overcome the consequences of the impact of risk if occurred.
O4	Lack of specified arbitrators to settle dispute fast	Disputes are common in a complex project which involve many contractors and stakeholders but if they are not resolved on time the project can be delayed and huge losses can occur to the organisation . As the legal procedures are very time consuming.
O5	Change of supervisors	The change of supervisors can effect the productivity of the labour as the environment of work changes and time is required to make understanding between the supervisors and workers

O6	Poor performance of some contractors	Projects as a whole is dependent on the performance of the various contractors and stakeholders, if performance of any of them is affected it ultimately affects the project objectives.
O7	Improper distribution of roles and responsibilities	Improper distribution of roles and responsibilities have a negative impact on the efficiency of team members and also can lead interpersonal disputes among team members, this can also occur due to varying experiences and skills of large no. of people involved .
O8	Conflicts between executives	Improper communication between the parties to a construction contract agreement cause conflicts between executives which cause misleading results.
O9	Lack of innovative thinking	Lack of innovative thinking binds the person work with the time consuming manual dependent work which can cause delay in completion of activities.
O10	Team member attitudes towards projects	The attitude of persons towards achieving of goals and milestone plays a major role in achieving it , if supervisors do not work in effective execution of plan the project objectives are effected.
O11	Lack of training	Complexity and variability of construction field make training an important factor in completion of project, training helps them to deal with the foreseen or unforeseen circumstances.
O12	Stakeholder disputes over changes	Thee change in scope or undefined specification in the document can further lead to the disputes between the client and stakeholder over the changes.
O13	Delay or long process time by other authorities	There exist a lot of interdependency in construction industry, the delay by one authority or group can effect the working of other groups ,and ultimately the goal of project.
O14	Lack of communication	Collaboration and communication are very important , lack of communication can result in ambiguous situations and minor or major disputes.
O15	Contractual relation among parties	Contractual relation also plays a major role, if parties do not have a friendly relation it can cause legal problems even on

		small issues, and as no of firms are involved more chances of dispute occurrence prevails.
O16	Poor coordination among parties	The poor coordination between parties can cause resource variability in the execution also it can sometime cause wastage of time due to large idle times.
O17	Inadequate and slow decision making mechanism	Decision making process if not effective and slow will effect the schedule and also can degrade the moral of the working team .
O18	Contractor problems and inadequate experience	Various contractors involved have different experiences and different attitude towards work, lack of experience of contactor can cause error and rework and also can cause delay in completion of activities.
	CONSTRUCTION RISKS	
C1	Change in scope	Change in scope due to unclear specification in document or unidentified obstruction or requirement of construction extra utilities can cause stakeholder, supervisors or executive disputes.
C2	Change in construction procedure	Due to various variabilities occurring on construction site and cause change in construction procedure due to soil condition not good , or very hard strata of rocks etc. which can cause acquiring of some unidentified resources and equipment's.
C3	Delay in material procurement	It depends on the foresight of the managers to identify when to procure material such that they are utilised when they are required, otherwise either there will be no material when actually required or it will be degrading in the godowns.
C4	Poor quality of local materials	Quality of material is important from strength and safety prospective. Minimum standards if not followed can cause damage to the structure during construction stage only.
C5	Change in laws and regulations	Changes in tax rates , excise duties custom charges over materials and other service charges can cause revision of rates and effect the schedule.

C6	Requirement for permits and their approvals	In some condition ,some extra permits or approvals can be required such as underground construction, construction in congested areas etc.
C7	Excessive labour and material movement	Excessive movement of labour and material due to long work stretches can cause wastage of lot of time which can be utilised in value adding activities.
C8	Resource performance	Not only proper allocation of resources, but their performance also plays a major role, skills of labour and efficiency of equipment's decides the completion time and quality of work.
C9	Lower work quality due to time constraints	Management pressure to complete the work under given timeframes can degrade the quality of the work required.
C10	Dewatering due to change in water table	Poor ground investigation about water table can create rise of water table, dewatering required can cause problems and delay.
C11	Insufficient resource availability	Unidentified resources or poor allocation of resources can effect the completion time of activity. Resources if over allocated or under allocated both effect the schedule.
C12	Rework due to error in execution	Unnecessary effort of redoing a process or activity that was incorrectly implemented the first time.
C13	Unskilled workers and poor labour productivity	Poor productivity of labour delays the project because execution of work mainly depends on them, unskilled labours cause error in execution and rework .
C14	Diversion of existing traffic	Diversion of existing traffic posses a challenge in front of the project team , increasing traffic have to be managed adequately , sometimes extra road have to be constructed first for traffic diversions more often in hilly regions.
	FINANCIAL RISKS	
F1	Increase in cost of facilities due to remote locations	Extra cost incurred to bring the utilities at such remote locations.
F2	Delay in removal of encroachments stoppage of disbursement of loan by the lender	It signifies the time wastage in loan approvals due to delay in submission of documents required and the long approval process by the lender can delay the start of the project.

F3	High compensation demands	The compensation demand by the people to give away their land posses extra burden on the overall cost.
F4	Unsettled and lack of project funding	Financial disputes if not settled on time can effect the availability of budget for upcoming activities. Unsettled disputes cause further withdrawing of work by contractor or other legal disputes which also effect the reputation of the firm.
F5	Changes in material prices and price escalation	Price escalation can effect the cash flow of the project, more working capital will be required to borrow more material required as per the schedule.
F6	Delay in running bill payments to the contractor	Delay in running bill payments effect the cash flow ,increases financial burden and also decreases the interest of the contractor to pace with the required schedule.
	PHYSICAL RISKS	
P1	Site conditions	Consideration of the physical land concerning location access, topography, infrastructure(existing or new as well as required upgrades) and the diversion or relocation of utility services.
P2	Damage to equipment’s	Damage to equipment’s can cause delay to complete activities and also much time is wasted in its replacement or repairement.
P3	Labour injuries	Labour injuries decreases the productivity and also creates a fear in mind of other workers. This occur due lack of skills to perform work or to apply false techniques to complete the work fastly.
P4	Equipment and material fire and theft	These condition if occur can ultimately cause some extra cost and delay to buy a new equipment’s.
P5	Removal of structures	Removal of existing structures to meet the requirement of project, some religious obstruction if exist can also create local opposition for its demolition.
P6	Shifting of utilities	Shifting of machinery and utilities is also required due to work commissioning at long stretches and different places, create a problem if site have narrow access roads or roads are not adequate to take load of heavy machinery.

	SOCIO-POLITICAL RISKS	
S1	Local citizens issue	Local citizens issue are very common over the acquisition of land , road blockages ,or due to excessive noise etc.
S2	Interference of local politicians	Interference of local politician can arise over the water , electricity supply or due to some other public issues which can effect their trust over residents.
S3	Delay in environmental and forest clearance	Environmental or forest clearances are now made mandatory due to growing environmental concerns, but due to stringent requirements creates problems for approval.
S4	Laws and order problems	Law and order problems such as prolonged time for dispute resolutions or for court approvals to resume work cause delay and effect the project objectives.
S5	Land acquisition	Land acquisition as per the plan posses great difficulty , it creates issues of high compensation demands , or owner not willing to give land and sometime even results in the form of disputes and prolong delaying of projects.
S6	Language and carrier barrier	India is a land with different cultures and languages which sometimes create a problems for the construction managers or supervisors in making understand the local residents which can cause minor issues.
S7	Monopolising of materials due to closure and other unexpected political conditions	Political pressure may sometime force organisation to borrow material from their source which can sometime cause quality issues.
	ENVIRONMENTAL RISKS	
E1	Weather implications	Schedule for certain activities are to prepare by keeping in mind the weather of the construction site ,unexpected rainfall, thunderstorm can create delays .

E2	Natural disasters	Natural disasters like landslides, earthquake, Tsunami, floods can effect the project objectives. Landslides are more often in hilly areas.
E3	Management of large construction waste	Even construction process itself creates a problems for its completion due to amount of waste generated and to manage them effectively is a time consuming process.
E4	Pollution and safety rules	Stringent rules to protect the environment can cause pressure on contractor to use less pollution causing equipment or safety gadgets which are more expensive to use.
E5	Forest clearance	Highways are constructed by clearing forest and its major problem in the forest areas , need for forest clearance cause problems by forest departments and also by local citizens .

Table No. -3.2 Questionnaire Format

QUESTIONNAIRE REGARDING RISKS IN HIGHWAY CONSTRUCTION PROJE;.CTS

(Please fill the appropriate boxes with yellow colour)

Section -I COMPANY PROFILE

1 **Company Name**

2 **Phone No:**

3 **Nature Of Company :**

Client — E.g: Client

Contractor — Contractor [yellow box]

Designer

Consultant

Other

(please specify)

4 **Age Of the Company**

1-5 years

5-10 years

10-15 years

15-20 years

Above 15

Section -II RESPONDENT PROFILE

1 **NAME**

2 **Position in the Company**

Engineer

Construction Manager

Project Manager

Contract/Business

Development Officer

Business/Cluster Head

Site Co-ordinator

Any other

(Please specify)

3 **Experience in the Construction Industry**

1-2 years

3-4 years

4-5 years

5-6 years

7-10 years

10 years and above

S.NO	TYPE OF RISK	Probability of risk					Impact of Risk				
	(Where R= rarely, S= sometimes, F= Frequently, VF= Very Frequently, M= Mostly and VL = Very low , L= low , M= Medium, H =High , VH = Very High)										
		R	S	F	VF	M	VL	L	M	H	VH
	TECHNICAL RISK										
T1	Inadequate Design	1	2	3	4	5	1	2	3	4	5
T2	Inadequate specification	1	2	3	4	5	1	2	3	4	5
T3	Inadequate site investigation	1	2	3	4	5	1	2	3	4	5
T4	Lack of risk management	1	2	3	4	5	1	2	3	4	5
T5	Failure to integrate with the system	1	2	3	4	5	1	2	3	4	5
T6	Design error and suitability to the nature	1	2	3	4	5	1	2	3	4	5
T7	Complexity of project	1	2	3	4	5	1	2	3	4	5
T8	Improper estimation of time and cost	1	2	3	4	5	1	2	3	4	5
T9	Errors in project documents	1	2	3	4	5	1	2	3	4	5
T10	Lack of requirement specification in tender document	1	2	3	4	5	1	2	3	4	5
T11	Lack of proper planning	1	2	3	4	5	1	2	3	4	5
T12	Misunderstanding of requirements	1	2	3	4	5	1	2	3	4	5
T13	Lack of previous data of execution	1	2	3	4	5	1	2	3	4	5
T14	Poor safety procedures	1	2	3	4	5	1	2	3	4	5
T15	Misinterpretation of traffic data	1	2	3	4	5	1	2	3	4	5

	ORGANISATIONAL RISK										
O1	Intense competition at tender stage	1	2	3	4	5	1	2	3	4	5
O2	Consultant leaving the project in midway	1	2	3	4	5	1	2	3	4	5
O3	Efficiency of managers/supervisors to handle work	1	2	3	4	5	1	2	3	4	5
O4	Lack of specified arbitrators to settle dispute fast	1	2	3	4	5	1	2	3	4	5
O5	Change of supervisors	1	2	3	4	5	1	2	3	4	5
O6	Poor performance of some contractors	1	2	3	4	5	1	2	3	4	5
O7	Improper distribution of roles and responsibilities	1	2	3	4	5	1	2	3	4	5
O8	Conflicts between executives	1	2	3	4	5	1	2	3	4	5
O9	Lack of innovative thinking	1	2	3	4	5	1	2	3	4	5
O10	Team member attitudes towards projects	1	2	3	4	5	1	2	3	4	5
O11	Lack of training	1	2	3	4	5	1	2	3	4	5
O12	Stakeholder disputes over changes	1	2	3	4	5	1	2	3	4	5
O13	Delay or long process time by other authorities	1	2	3	4	5	1	2	3	4	5
O14	Lack of communication	1	2	3	4	5	1	2	3	4	5
O15	Contractual relation among parties	1	2	3	4	5	1	2	3	4	5
O16	Poor coordination among parties	1	2	3	4	5	1	2	3	4	5
O17	Inadequate and slow decision making mechanism	1	2	3	4	5	1	2	3	4	5
O18	Contractor problems and inadequate experience	1	2	3	4	5	1	2	3	4	5
	CONSTRUCTION RISKS										
C1	Change in scope	1	2	3	4	5	1	2	3	4	5
C2	Change in construction procedure	1	2	3	4	5	1	2	3	4	5
C3	Delay in material procurement	1	2	3	4	5	1	2	3	4	5
C4	Poor quality of local materials	1	2	3	4	5	1	2	3	4	5

C5	Change in laws and regulations	1	2	3	4	5	1	2	3	4	5
C6	Requirement for permits and their approvals	1	2	3	4	5	1	2	3	4	5
C7	Excessive labour and material movement	1	2	3	4	5	1	2	3	4	5
C8	Resource performance	1	2	3	4	5	1	2	3	4	5
C9	Lower work quality due to time constraints	1	2	3	4	5	1	2	3	4	5
C10	Dewatering due to change in water table	1	2	3	4	5	1	2	3	4	5
C11	Insufficient resource availability	1	2	3	4	5	1	2	3	4	5
C12	Rework due to error in execution	1	2	3	4	5	1	2	3	4	5
C13	Unskilled workers and poor labour productivity	1	2	3	4	5	1	2	3	4	5
C14	Diversion of existing traffic	1	2	3	4	5	1	2	3	4	5
	FINANCIAL RISKS										
F1	Increase in cost of facilities due to remote locations	1	2	3	4	5	1	2	3	4	5
F2	Delay in removal of encroachments stoppage of disbursement of loan by the lender	1	2	3	4	5	1	2	3	4	5
F3	High compensation demands	1	2	3	4	5	1	2	3	4	5
F4	Unsettled and lack of project funding	1	2	3	4	5	1	2	3	4	5
F5	Changes in material prices and price escalation	1	2	3	4	5	1	2	3	4	5
F6	Delay in running bill payments to the contractor	1	2	3	4	5	1	2	3	4	5
	PHYSICAL RISKS										
P1	Site conditions	1	2	3	4	5	1	2	3	4	5
P2	Damage to equipment’s	1	2	3	4	5	1	2	3	4	5
P3	Labour injuries	1	2	3	4	5	1	2	3	4	5
P4	Equipement and material fire and theft	1	2	3	4	5	1	2	3	4	5
P5	Removal of structures	1	2	3	4	5	1	2	3	4	5
P6	Shifting of utilities	1	2	3	4	5	1	2	3	4	5
	SOCIO-POLITICAL RISKS										

S1	Local citizens issue	1	2	3	4	5	1	2	3	4	5
S2	Interference of local politicians	1	2	3	4	5	1	2	3	4	5
S3	Delay in environmental and forest clearance	1	2	3	4	5	1	2	3	4	5
S4	Laws and order problems	1	2	3	4	5	1	2	3	4	5
S5	Land acquisition	1	2	3	4	5	1	2	3	4	5
S6	Language and carrier barrier	1	2	3	4	5	1	2	3	4	5
S7	Monopolising of materials due to closure and other unexpected political conditions	1	2	3	4	5	1	2	3	4	5
	ENVIRONMENTAL RISKS										
E1	Weather implications	1	2	3	4	5	1	2	3	4	5
E2	Natural disasters	1	2	3	4	5	1	2	3	4	5
E3	Management of large construction waste	1	2	3	4	5	1	2	3	4	5
E4	P0llution and safety rules	1	2	3	4	5	1	2	3	4	5
E5	Forest clearance	1	2	3	4	5	1	2	3	4	5

CHAPTER-4

RESULTS & ANALYSIS

4.1 Ranking of Factors – The ranking obtained from the ratings of the respondents for different risk factors are listed below –

Table No. – 4.1 Ranking of Risk Factors

Risk Identity	Risk Factors	Probability index (P.I)	Severity Index (S.I)	Risk Potential Value (R.P.V)	Rank
S5	Land acquisition	0.750	0.850	0.638	**1**
O13	Delay or long process time by other authorities	0.717	0.817	0.585	**2**
O17	Inadequate and slow decision making mechanism	0.667	0.817	0.544	**3**
F4	Unsettled and lack of project funding	0.617	0.817	0.504	**4**
S2	Interference of local politicians	0.700	0.717	0.502	**5**
T4	Lack of risk management	0.667	0.750	0.500	**6**
C11	Insufficient resource availability	0.617	0.800	0.493	**7**
O6	Poor performance of some contractors	0.633	0.767	0.486	**8**
T8	Improper estimation of time and cost	0.600	0.800	0.480	**9**
O1	Intense competition at tender stage	0.700	0.683	0.478	**10**
C3	Delay in material procurement	0.683	0.700	0.478	
E1	Weather implications	0.633	0.750	0.475	**11**
S1	Local citizens issue	0.633	0.717	0.454	**12**
S3	Delay in environmental and forest clearance	0.617	0.733	0.452	**13**
O18	Contractor problems and inadequate experience	0.600	0.750	0.450	**14**
C6	Requirement for permits and their approvals	0.667	0.667	0.444	**15**
O3	Efficiency of managers/supervisors to handle work	0.617	0.700	0.432	**16**
F6	Delay in running bill payments to the contractor	0.600	0.717	0.430	**17**
C1	Change in scope	0.583	0.733	0.428	**18**
F1	Increase in cost of facilities due to remote locations	0.633	0.667	0.422	**19**

C13	Unskilled workers and poor labour productivity	0.683	0.617	0.421	**20**
E5	Forest clearance	0.617	0.683	0.421	
T11	Lack of proper planning	0.600	0.700	0.420	**21**
C8	Resource performance	0.600	0.700	0.420	
O14	Lack of communication	0.583	0.717	0.418	**22**
T1	Inadequate Design	0.533	0.750	0.400	**23**
O16	Poor coordination among parties	0.567	0.700	0.397	**24**
C2	Change in construction procedure	0.533	0.733	0.391	**25**
P2	Damage to equipment’s	0.533	0.733	0.391	
O4	Lack of specified arbitrators to settle dispute fast	0.600	0.650	0.390	**26**
C7	Excessive labour and material movement	0.583	0.667	0.389	**27**
C14	Diversion of existing traffic	0.550	0.700	0.385	**28**
T7	Complexity of project	0.533	0.717	0.382	**29**
S4	Laws and order problems	0.533	0.717	0.382	
O11	Lack of training	0.583	0.650	0.379	**30**
F5	Changes in material prices and price escalation	0.517	0.733	0.379	**31**
C4	Poor quality of local materials	0.550	0.683	0.376	**32**
C12	Rework due to error in execution	0.500	0.733	0.367	**33**
S7	Monopolising of materials due to closure and other unexpected political conditions	0.533	0.683	0.364	**34**
O15	Contractual relation among parties	0.533	0.667	0.356	**35**
E2	Natural disasters	0.383	0.917	0.351	**36**
T15	Misinterpretation of traffic data	0.500	0.700	0.350	**37**
C9	Lower work quality due to time constraints	0.533	0.650	0.347	**38**
T14	Poor safety procedures	0.517	0.667	0.344	**39**
F3	High compensation demands	0.517	0.667	0.344	
P4	Equipment and material fire and theft	0.517	0.667	0.344	
C5	Change in laws and regulations	0.517	0.650	0.336	**40**
E3	Management of large construction waste	0.517	0.650	0.336	**41**
E4	Pollution and safety rules	0.533	0.617	0.329	**42**
F2	Delay in removal of encroachments stoppage of disbursement of loan by the lender	0.517	0.633	0.327	**43**
T3	Inadequate site investigation	0.483	0.667	0.322	**44**
T5	Failure to integrate with the system	0.483	0.667	0.322	
O9	Lack of innovative thinking	0.583	0.550	0.321	**45**

O10	Team member attitudes towards projects	0.550	0.583	0.321	
O7	Improper distribution of roles and responsibilities	0.533	0.600	0.320	**46**
T2	Inadequate specification	0.467	0.667	0.311	**47**
P1	Site conditions	0.533	0.583	0.311	
T13	Lack of previous data of execution	0.500	0.617	0.308	**48**
T10	Lack of requirement specification in tender document	0.450	0.683	0.308	**49**
O12	Stakeholder disputes over changes	0.450	0.683	0.308	
T9	Errors in project documents	0.467	0.650	0.303	**50**
O8	Conflicts between executives	0.567	0.533	0.302	**51**
T6	Design error and suitability to the nature	0.433	0.683	0.296	**52**
C10	Dewatering due to change in water table	0.467	0.633	0.296	**53**
P5	Removal of structures	0.533	0.517	0.276	**54**
P3	Labour injuries	0.483	0.550	0.266	**55**
O2	Consultant leaving the project in midway	0.400	0.633	0.253	**56**
P6	Shifting of utilities	0.500	0.500	0.250	**57**
T12	Misunderstanding of requirements	0.467	0.533	0.249	**58**
S6	Language and carrier barrier	0.450	0.533	0.240	**59**
O5	Change of supervisors	0.417	0.450	0.188	**60**

4.2 Category Wise Rankings-

1. Technical risk

Table No. – 4.2 Technical Risk Rankings

Risk Identity	**Risk Factors**	**Probability index (P.I)**	**Severity Index (S.I)**	**Risk Potential Value (R.P.V)**	**Rank**
T4	Lack of risk management	0.75	0.67	0.50	**1**
T8	Improper estimation of time and cost	0.80	0.60	0.48	**2**
T11	Lack of proper planning	0.70	0.60	0.42	**3**
T1	Inadequate Design	0.75	0.53	0.40	**4**
T7	Complexity of project	0.72	0.53	0.38	**5**

T15	Misinterpretation of traffic data	0.70	0.50	0.35	**6**
T14	Poor safety procedures	0.67	0.52	0.34	**7**
T3	Inadequate site investigation	0.67	0.48	0.32	**8**
T5	Failure to integrate with the system	0.67	0.48	0.32	
T2	Inadequate specification	0.67	0.47	0.31	
T13	Lack of previous data of execution	0.62	0.50	0.31	**9**
T10	Lack of requirement specification in tender document	0.68	0.45	0.31	
T9	Errors in project documents	0.65	0.47	0.30	**11**
T6	Design error and suitability to the nature	0.68	0.43	0.30	
T12	Misunderstanding of requirements	0.53	0.47	0.25	**12**

2. Organisational risk –

Table No. – 4.3 Organisational Risk Rankings

Risk Identity	**Risk Factors**	**Probability index (P.I)**	**Severity Index (S.I)**	**Risk Potential Value (R.P.V)**	**Rank**
O13	Delay or long process time by other authorities	0.72	0.82	0.59	**1**
O17	Inadequate and slow decision making mechanism	0.67	0.82	0.54	**2**
O6	Poor performance of some contractors	0.63	0.77	0.49	**3**
O1	Intense competition at tender stage	0.70	0.68	0.48	**4**

O18	Contractor problems and inadequate experience	0.60	0.75	0.45	**5**
O3	Efficiency of managers/supervisors to handle work	0.62	0.70	0.43	**6**
O14	Lack of communication	0.58	0.72	0.42	**7**
O16	Poor coordination among parties	0.57	0.70	0.40	**8**
O4	Lack of specified arbitrators to settle dispute fast	0.60	0.65	0.39	**9**
O11	Lack of training	0.58	0.65	0.38	**10**
O15	Contractual relation among parties	0.53	0.67	0.36	**11**
O9	Lack of innovative thinking	0.58	0.55	0.32	**12**
O10	Team member attitudes towards projects	0.55	0.58	0.32	
O7	Improper distribution of roles and responsibilities	0.53	0.60	0.32	
O12	Stakeholder disputes over changes	0.45	0.68	0.31	**13**
O8	Conflicts between executives	0.57	0.53	0.30	**14**
O2	Consultant leaving the project in midway	0.40	0.63	0.25	**15**
O5	Change of supervisors	0.42	0.45	0.19	**16**

3 . Construction Risk –

Table No. – 4.4 Construction Risk Rankings

Risk Identity	Risk Factors	Probability index (P.I)	Severity Index (S.I)	Risk Potential Value (R.P.V)	Rank
C11	Insufficient resource availiblity	0.62	0.80	0.49	**1**
C3	Delay in material procurement	0.68	0.70	0.48	**2**
C6	Requirement for permits and their approvals	0.67	0.67	0.44	**3**
C1	Change in scope	0.58	0.73	0.43	**4**
C13	Unskilled workers and poor labour productivity	0.68	0.62	0.42	**5**
C8	Resource performance	0.60	0.70	0.42	
C2	Change in construction procedure	0.53	0.73	0.39	**6**
C7	Excessive labour and material movement	0.58	0.67	0.39	
C14	Diversion of existing traffic	0.55	0.70	0.39	
C4	Poor quality of local materials	0.55	0.68	0.38	**7**
C12	Rework due to error in execution	0.50	0.73	0.37	**8**
C9	Lower work quality due to time constraints	0.53	0.65	0.35	**9**

C5	Change in laws and regulations	0.52	0.65	0.34	**10**
C10	Dewatering due to change in water table	0.47	0.63	0.30	**11**

5. Financial Risk -

Table – 4.5 Financial Risk Rankings

Risk Identity	**Risk Factors**	**Probability index (P.I)**	**Severity Index (S.I)**	**Risk Potential Value (R.P.V)**	**Rank**
F4	Unsettled and lack of project funding	0.62	0.82	0.50	**1**
F6	Delay in running bill payments to the contractor	0.60	0.72	0.43	**2**
F1	Increase in cost of facilities due to remote locations	0.63	0.67	0.42	**3**
F5	Changes in material prices and price escalation	0.52	0.73	0.38	**4**
F3	High compensation demands	0.52	0.67	0.34	**5**
F2	Delay in removal of encroachments stoppage of disbursement of loan by the lender	0.52	0.63	0.33	**6**

6. Physical Risk –

Table – 4.6 Physical Risk Rankings

Risk Identity	**Risk Factors**	**Probability index (P.I)**	**Severity Index (S.I)**	**Risk Potential Value (R.P.V)**	**Rank**
P2	Damage to equipment’s	0.53	0.73	0.39	**1**

P4	Equipment and material fire and theft	0.52	0.67	0.34	**2**
P1	Site conditions	0.53	0.58	0.31	**3**
P5	Removal of structures	0.53	0.52	0.28	**4**
P3	Labour injuries	0.48	0.55	0.27	**5**
P6	Shifting of utilities	0.50	0.50	0.25	**6**

7. Socio Political Risk –

Table No. – 4.7 Socio Political risk rankings

Risk Identity	**Risk Factors**	**Probability index (P.I)**	**Severity Index (S.I)**	**Risk Potential Value (R.P.V)**	**Rank**
S5	Land acquisition	0.75	0.85	0.64	**1**
S2	Interference of local politicians	0.70	0.72	0.50	**2**
S1	Local citizens issue	0.63	0.72	0.45	**3**
S3	Delay in environmental and forest clearance	0.62	0.73	0.45	**4**
S4	Laws and order problems	0.53	0.72	0.38	**5**
S7	Monopolising of materials due to closure and other unexpected political conditions	0.53	0.68	0.36	**6**
S6	Language and carrier barrier	0.45	0.53	0.24	**7**

8. Environmental Risk –

Table no. 4.8 Environmental Risk Rankings

Risk Identity	Risk Factors	Probability index (P.I)	Severity Index (S.I)	Risk Potential Value (R.P.V)	Rank
E1	Weather implications	0.63	0.75	0.48	**1**
E5	Forest clearance	0.62	0.68	0.42	**2**
E2	Natural disasters	0.38	0.92	0.35	**3**
E3	Management of large construction waste	0.52	0.65	0.34	**4**
E4	Pollution and safety rules	0.53	0.62	0.33	**5**

4.3 Risk Assessment Matrix – Risk assessment matrix showing probability and impact

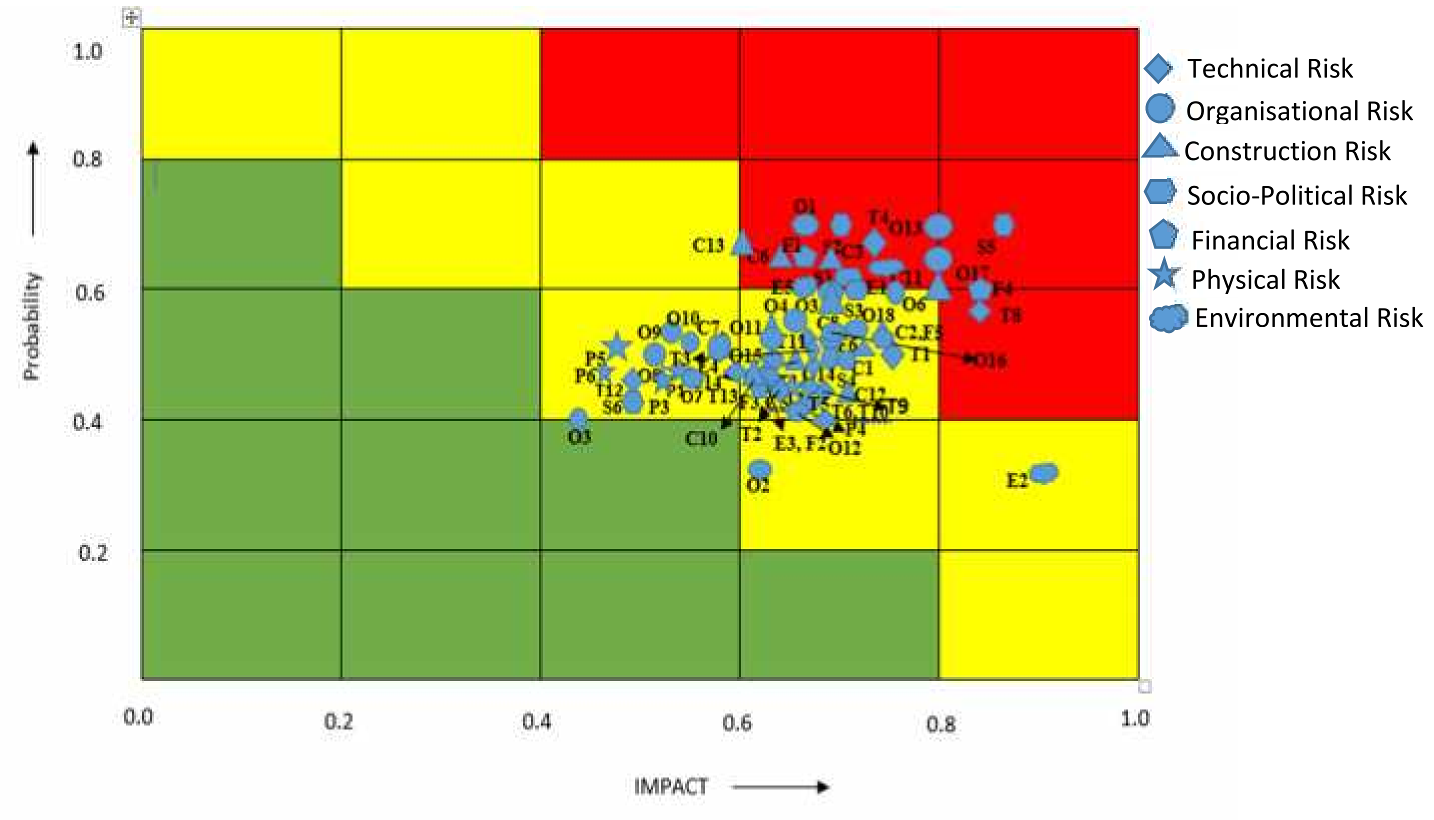

Fig. No. – 4.1 Risk Assessment matrix

4.4 Mitigation Techniques – Based on the rating and rankings obtained for different risk factors 10 most critical activities are identified and some of their mitigation techniques are also listed below.

Table 4.9 – Mitigation Techniques for critical risk factors

RISK IDENTITY	RISK FACTORS	MITIGATION TECHNIQUES
S5	Land acquisition	Various schemes can be used to solve this problem such as compensation to owner, employment to the member of the land owner, lending the land on lease for period of time, sharing profit with the land owner, etc. i.e basically understanding the requirements of land owner this problem can be solved to a large extend .
O13	Delay or long process time by other authorities	Delay or long process time by other authorities can be managed by regular and careful monitoring of schedules. With the help of proper schedules the time at which the other authorities are required can be easily known and they can be contacted before time, when they are actually required and can use time buffer to avoid the delays. This risk can also be avoided by proper use of contracts laws to fix the deadline for each process by other authorities by offering them some sort of incentives if they complete the work before deadline to encourage them to meet the deadline and imposing some sort of penalty if they miss the deadline.
O17	Inadequate and slow decision making mechanism	Inadequate and slow decisions making mechanism can reduced by using Lean construction techniques of conducting regular huddle meetings on daily, weekly and monthly basis to improve decision making mechanism

		identifying different constraints from different activities and planning for them.
F4	Unsettled and lack of project funding	The unsettled project funding is always a big problem for the contractors to perform the work on time. This risk can be reduced or avoided by using appropriate amendments in contracts. By providing special clauses of some percentage of bill amount on the submission of bill itself and remaining amount after verification and to avoid contractor advantage and regulatory clause mentioning if contactor produces some sort of over amount than he is not eligible for this clause next time or you can even impose some sort of penalty.
S2	Interference of local politicians	Involving decision making authorities from government bodies in decision making process projects can avoid the interference of the local Politian's to hinder the project progress. Also transparency in the project process to aware public about the cause and proms of the project outcomes can also help to solve the problem, as it make public aware of the benefits from the project completion.
T4	Lack of risk management	This risk can be reduced my using a proper risk management framework for every project because it is the necessary tool for the successful project completion. Due to lack of risk management projects gets cost and time overruns because there are certain risk associated with them and there are no proper plans to avoid, reduce, transfer or mitigate those risk factors.

C11	Insufficient resource availability	Risk buffering, that is the establishment of some reserve or buffer that can absorb the effects of many risks without effecting the project objectives. It can include allocation of some additional resources to overcome the uncertainties in the future requirement, if the cost of additional resources is less than the impact of the risk.
O6	Poor performance of some contractors	Selection of right contractors is very important because their performance make you win or loose. This risk can be reduced at both planning stage and also at execution level. At initial level Pre qualification type bidding process can be used to select right contractor for the job. During execution level some laws related to maintain certain performance level of completion of milestones or for quality can be included in the contract to reduce the risk of performance imposing some penalty if they fail to meet the required standards.
T8	Improper estimation of time and cost	Despite of advancement in computational facilities, Indian construction industry lack in computing relevant time and cost estimation incorporating different risk factors. This risk can be reduced by using proper statistical and mathematical models which incorporate variable risk parameters and provide more realistic output or estimation of time and cost.
O1	Intense competition at tender stage	Sometimes contractor quotes less amount just to get the contract but it can huge impact on the project objectives. To avoid this various bidding models like Friedman's and Gates bidding model by which you can find out the optimum mark up

		level and more realistic bidding amount. But at the same time care should be taken that the amount to handle risk should be sufficient enough. As contactors usually decrease the contingency amount to reduce bid but later on find it difficult to manage risk due to shortage of funds.

4.5 Sensitivity analysis – Sensitivity analysis is the process which is used to identify the most sensitive factor which can have the maximum impact on the output to be checked. Here, an attempt have been made to find out the most sensitive element which have the maximum impact on its risk potential value. The probability changes have been observed and their impact on their corresponding Risk potential Value are plotted on tornado curve. The Tornado curve defines the sensitivity of the factors on varying probability of different factors on their Risk Potential Values. The risk potential value obtained through experts changes when the probability of occurrence of factors changes.

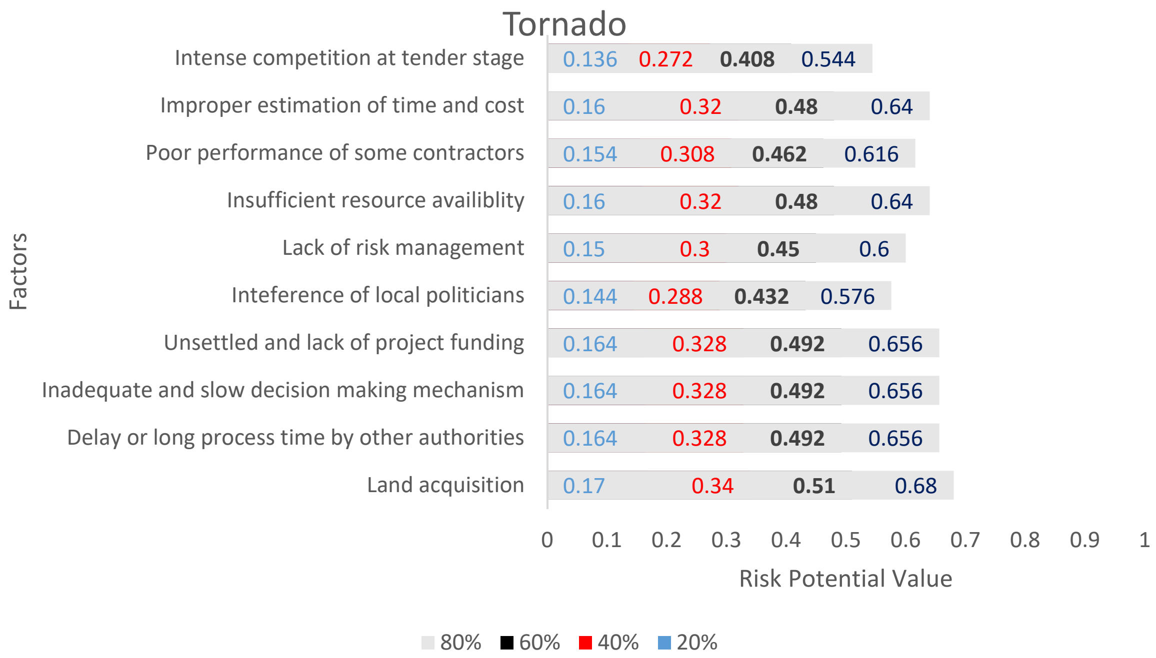

Fig. No. – 4.2 Tornado plot showing sensitivity of different factors

The conclusion could be made from the above plot that when the probability of different factors changes over the range their potential value also changes. Thus the probability of occurrence of risk factor have to be reduce in order to reduce the potential value of risk factors. From the above risk potential values obtained through the experts ratings Land acquisition was the most critical factors and on changing the probability of different risk factors the risk potential values changes as shown above, and I can be seen that at higher probabilities the Land Acquisition factors still remains the most sensitive factor among the identified critical risk factors. Thus, the Land acquisition problem needs to be handles carefully in order to achieve the project objectives and maximum attention is required towards this risk factor.

4.6 Risk Integrating time Variation – Time estimation of different activities is usually done on the productivity basis of labour and machinery for each activity and from that the total project time is calculated, but at the same time a major aspect is missed out by not considering the time variation in project activity incorporating risk factors that can alter the complete of the activities and ultimately the total project duration. The program evaluation and review technique(PERT) is an attempt to closely estimate the project duration by considering three different scenario of time such as the optimistic, most likely and pessimistic duration of different activities and calculating the expected project duration. But the limitation of pert estimation is that we can only control only the total project duration by using different relation, network diagrams and CPM tools.

An attempt has been made to estimate the project duration incorporating the risk of different factors and also variation on the total project duration are also observed using the @Risk software which uses Monte Carlo Simulation techniques and calculate the changes by randomly taking the project duration and variation in total project duration are observed. It provide you the advantage of handling and monitoring of each activity as the Activity time allowance can be predicted using @Risk software and the total summation of these activity durations give us the total project time allowance.

Gabriel A. Barraza in his studies used a techniques Stochastic allocation of project allowances (SAPA) which is used to determine the project time contingency and distribute it to the different activity level so can monitoring of project is more easily done at the activity level. For each activity the planned duration at target duration is considered and the difference between these planned duration and target duration gives us the activity time allowance of each activity and total activity time allowance gives us the project time allowance. Thus, the total time allowance is given as :

T.T.A = P.P.D – P.T.D

Where, PPD is the project planned duration at different risk levels which can be obtained using simulation techniques at different percentage of risk considered different project duration are obtained by defining distribution of variation in each activity. In this case the PERT distribution is used in each activity and simulation is then performed using @Risk for 10,000 trials of iterations was considered. Now to allocate the time allowance to the activity level the planned durations the Dp value is used which defines the duration of activity at a particular risk level such that when these percentile durations are used as planned duration of each activity the acceptable project planned duration is obtained. And the median duration where taken as the target duration of each activity with the 50% risk level. Thus, ATA can be calculated as –

$$\textbf{A.T.A} = \mathbf{Dp}_{i} - \mathbf{Td}_{i}$$

To demonstrate the SAPA method, the schedule of a construction project is used just for the execution of the method using the @Risk software. The schedule of the activities is given below. The schedule was first prepared in MS project to determine the project duration using the expected durations of each activity calculated from the three time estimates using PERT than the variation in project duration are obtained using the @Risk software at different time estimates incorporating different risk percentage. The Msp Schedule for the project is given at the back in appendix.The project duration was coming out to be 325 days while using the scheduling in MS project. The variation in project duration were than observed using simulation in @Risk with PERT distribution assigned in each activity and different project durations and activity durations were identified. The durations were observed with risk level more than 50% as the medians value was coming almost equal for 5- % risk level. So project durations at 60%, 75% and 90% were observed. The simulation results showed the variation of project duration from 177 to 480 days at 10,000 trials with mean of 325 days and standard deviation of 32.51.

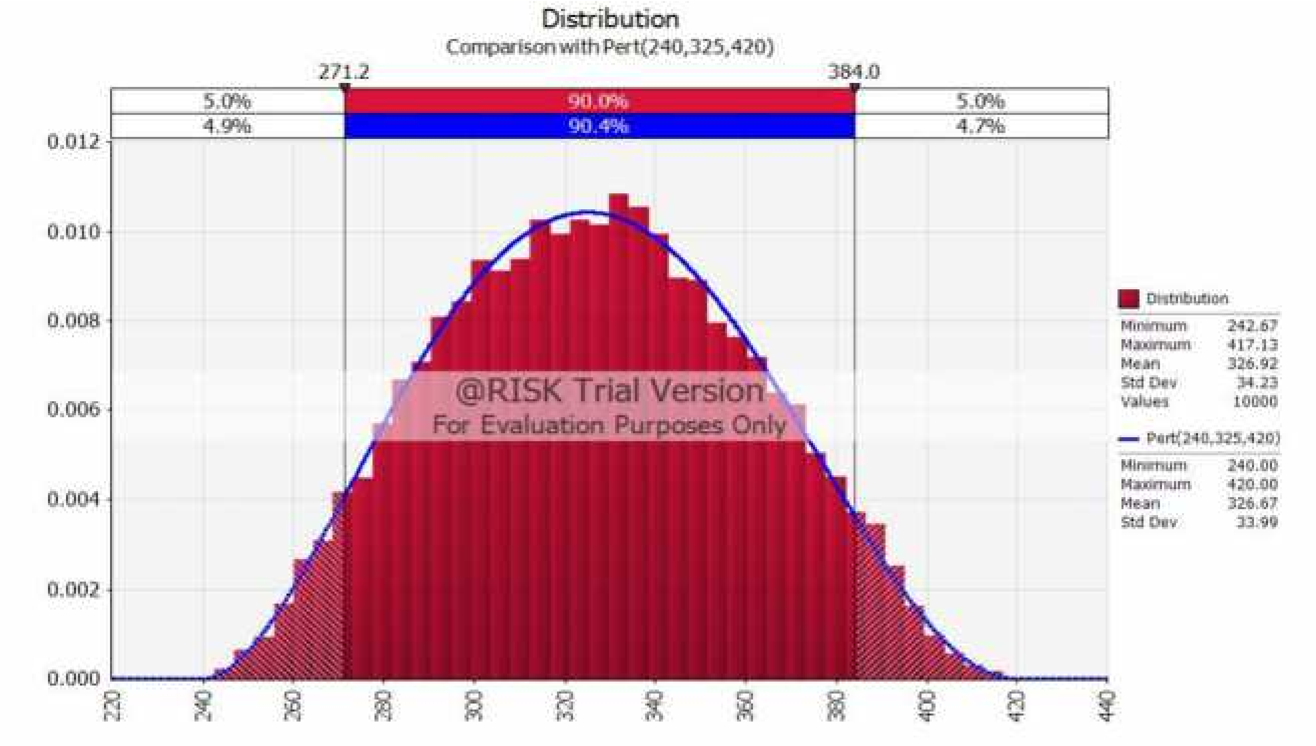

Fig. No. 4.3 – Output graph showing distribution of project durations

Activity time allowance calculations for different percentages are shown below-

Table 4.10 Activity time allowance for different activities at 90% risk

Activity	Dp	Td	A.TA(90%)
Girder casting yard	32	30	2
Mobilisation	27	26	1
Driv piles in abutment A	26	24	2
Install cofferdam in Abutment A	23	21	2
Erect false work in span 1	27	25	2
Drive piles in Pier 1	28	25	3

Erect falsework in Span 2	27	25	2
Rienforced concrete in , Abutment A	22	20	2
Remove and install cofferdam in pier 1	23	21	2
Rienforced concrete , Pier 1 (1/2)	22	20	2
Drive piles in pier 2	28	25	3
Remove and install cofferdam in pier 2	23	21	2
Erect falsework in span 3	27	25	2
Manufacture PC girders , Span 1	78	72	6
Rienforced concrete , Pier 1 (1/2)	22	20	2
Rienforced concrete, pier2 (1/2)	22	20	2
drive piles in Abutment B	29	26	3
Manufacture PC girders , Span 2	78	72	6
Erect PC girders , Span 1	17	15	2
Rienforced concrete ,Per 2 (1/2)	22	20	2
Removeand install cofferdam in Abutment B	23	21	2
Manufacture PC girders span 3	78	72	6

Erect PC girders , Span 2	17	15	2
Rienforced concrete , Abutment B	21	20	1
Insitu concrete deck , Span 1	22	17	5
Remove cofferdam from abutment B	12	10	2
Erect c girders , span 3	17	15	2
Insitu concrete deck, span 2	20	16	4
Approaches , handrails etc	22	20	2
Clean UP and move out	21	17	4
Insitu concrete deck , Span 3	18	15	3
Remove falsework, all spans.	22	20	2

The activity time allowance in critical path was then analysed. The path 2-3-4-6-9-11-12-17-21-24-25-28-29-30 forms the critical path in the project and the sum of time allowances included in this path results in project time contingency, which is equals to **36 days**.

Table 4.11 Activity time allowance for different activities at 75% risk

Activity	Dp	Td	A.T.A(75%)
Girder casting yard	31	30	1
Mobilisation	26	25	1
Drive piles in abutment A	25	24	1

Install cofferdam in Abutment A	21	21	0
Erect false work in span 1	26	25	1
Drive piles in Pier 1	26	25	1
Erect falsework in Span 2	26	25	1
Rienforced concrete in , Abutment A	21	20	1
Remove and install cofferdam in pier 1	22	21	1
Rienforced concrete , Pier 1 (1/2)	21	20	1
Dirve piles in pier 2	26	25	1
Remove and install cofferdam in pier 2	22	21	1
Erect falsework in span 3	26	25	1
Manufacture PC girders , Span 1	75	72	3
Rienforced concrete , Pier 1 (1/2)	21	20	1
Rienforced concrete, pier2 (1/2)	21	20	1
drive piles in Abutment B	28	26	2
Manufacture PC girders , Span 2	75	72	3

Erect PC girders , Span 1	16	15	1
Rienforced concrete ,Per 2 (1/2)	21	20	1
Removeand install cofferdam in Abutment B	22	21	1
Manufacture PC girders span 3	75	72	3
Erect PC girders , Span 2	16	15	1
Rienforced concrete , Abutment B	20	20	0
Insitu concrete deck , Span 1	19	17	2
Remove cofferdam from abutment B	11	10	1
Erect c girders , span 3	16	15	1
Insitu concrete deck, span 2	18	16	2
Approaches , handrails etc	21	20	1
Clean UP and move out	19	17	2
Insitu concrete deck , Span 3	16	16	0
Remove falsework, all spans.	21	21	0

The critical path in the project shows **16 days** as project time contingency at 75 % risk in activity durations which is the sum of activity time allowance in the critical path.

Table 4.12 Activity time allowance for different activities at 60% risk

Activity	**Dp**	**Td**	**A.T.A(60%)**
Girder casting yard	31	30	1
Mobilisation	26	25	1
Driv piles in abutment A	24	24	0
Install cofferdam in Abutment A	21	21	0
Erect false work in span 1	26	25	1
Drive piles in Pier 1	26	25	1
Erect falsework in Span 2	26	25	1
Rienforced concrete in , Abutment A	21	20	1
Remove and install cofferdam in pier 1	21	21	0
Rienforced concrete , Pier 1 (1/2)	21	20	1
Dirve piles in pier 2	26	25	1
Remove and install cofferdam in pier 2	21	21	0

Erect falsework in span 3	26	25	1
Manufacture PC girders , Span 1	73	72	1
Rienforced concrete , Pier 1 (1/2)	21	20	1
Rienforced concrete, pier2 (1/2)	21	20	1
drive piles in Abutment B	27	26	1
Manufacture PC girders , Span 2	73	72	1
Erect PC girders , Span 1	16	15	1
Rienforced concrete ,Per 2 (1/2)	21	20	1
Removeand install cofferdam in Abutment B	21	21	0
Manufacture PC girders span 3	73	72	1
Erect PC girders , Span 2	16	15	1
Rienforced concrete , Abutment B	21	20	1
Insitu concrete deck , Span 1	18	17	1

Remove cofferdam from abutment B	10	10	0
Erect c girders , span 3	16	15	1
Insitu concrete deck, span 2	16	16	0
Approaches , handrails etc	21	20	1
Clean UP and move out	17	17	0
Insitu concrete deck , Span 3	16	16	0

At 60% of risk the total activity time allowance was determined. Further, the activity time allowance in critical path was identified which was equal to **8 days** that gives us the project time contingency at 60 % risk of activities.

Thus, the above analysis shows that by using different distributions project can be handled even at activity level and the variable nature of project activities can be incorporated using simulation techniques. The activity time allowance at different percentages are shown below.

Table 4.13 A.T.A at different percentages

S.No.	Risk Percentages (%)	Project time allowance(A.T.A), (Days)
1	60	8
2	75	16
3	90	36

CHAPTER – 5

CONCLUSION & FUTURE WORK

Conclusions –

1. Risk identification through literature review was done and 71 risk factors were identified. A questionnaire was than conducted which provided response rate of 60 % through which the Risk potential value of each risk factor was calculated.
2. The results from the research reveals the 10 most critical factors for Indian highway construction industry such as: Land Acquisition, Delay or long process time by other authorities, Inadequate and slow decision making, Unsettled and lack of project funding, Interference of local politicians, Lack of risk management, Insufficient resource availability, Poor performance of some contractors, Improper estimation of time and cost, and Intense competition at tender stage.
3. The suggested mitigation techniques can be found helpful for handling critical risk in future.
4. The sensitivity analysis used also clearly gives the variation of risk potential value of different probabilities which showed Land Acquisition as the most sensitive factor at higher probability of occurrence of risk.
5. The research also highlights a systematic approach to identify and monitor the variability of different factors using simulation techniques in @Risk software and project time contingency and activity time allowance can be calculated using the provide SAPA techniques at activity and project level.

Future Scope –

Identification of more risk factors can be done by taking the data of the ongoing of completed projects in future time. Other risk analysis techniques can be using like decision tree analysis. The changes in project time contingency can be observed using different distribution for activities in simulation techniques.

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APPENDIX

APPENDIX 1 – Probability Index of different factors are calculated based on the ratings given by the 12 respondents.

Risk Identity	Risk Factors	R 1	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9	R 10	R 11	R 12	P.I = ∑(a*n)/ N*A
	TECHNICAL RISK													
T1	Inadequate Design	3	2	3	3	2	2	2	2	3	4	2	4	0.53
T2	Inadequate specification	2	1	2	2	3	1	3	3	1	4	2	4	0.47
T3	Inadequate site investigation	2	2	1	3	2	3	2	3	1	3	4	3	0.48
T4	Lack of risk management	4	1	4	3	2	3	3	3	4	5	3	5	0.67
T5	Failure to integrate with the system	1	1	2	3	1	2	1	4	4	4	2	4	0.48
T6	Design error and suitability to the nature	2	1	1	2	2	1	2	2	3	4	2	4	0.43
T7	Complexity of project	3	2	4	2	1	1	2	1	4	4	4	4	0.53
T8	Improper estimation of time and cost	3	3	5	5	2	2	2	2	3	4	1	4	0.60
T9	Errors in project documents	3	3	2	2	1	2	2	1	2	4	2	4	0.47
T10	Lack of requirement specification in tender document	2	1	3	2	1	3	1	2	1	5	1	5	0.45
T11	Lack of proper planning	3	3	5	2	2	2	2	1	4	5	2	5	0.60
T12	Misunderstanding of requirements	2	2	3	2	2	2	2	2	2	3	3	3	0.47
T13	Lack of previous data of execution	2	2	2	2	1	3	3	2	3	3	4	3	0.50
T14	Poor safety procedures	3	3	2	2	2	4	2	2	2	3	3	3	0.52

T15	Misinterpretation of traffic data	2	2	3	2	1	1	1	2	5	4	3	4	0.50
	ORGANISATIONAL RISK													
O1	Intense competition at tender stage	3	2	3	4	5	2	5	3	4	4	3	4	0.70
O2	Consultant leaving the project in midway	2	2	2	1	1	1	1	2	2	4	2	4	0.40
O3	Efficiency of managers/supervisors to handle work	3	4	4	2	3	3	3	3	2	4	2	4	0.62
O4	Lack of specified arbitators to settle dispute fast	4	3	2	1	4	3	4	2	2	4	3	4	0.60
O5	Change of supervisors	2	2	1	2	2	2	2	2	2	3	2	3	0.42
O6	Poor performance of some contractors	3	2	4	3	4	2	4	1	2	5	3	5	0.63
O7	Improper distribution of roles and responsiblities	2	2	2	2	1	2	3	2	3	5	3	5	0.53
O8	Conflicts between executives	3	2	1	2	4	3	4	2	2	4	3	4	0.57
O9	Lack of innovative thinking	3	3	2	3	2	4	2	3	1	4	4	4	0.58
O10	Team member attitutes towards projects	2	2	2	3	4	1	4	4	1	4	2	4	0.55
O11	Lack of training	5	1	3	3	2	3	2	3	1	4	4	4	0.58
O12	Stakeholder disputes over changes	3	2	2	2	1	2	1	2	1	4	3	4	0.45
O13	Delay or long process time by other authorities	3	3	3	2	5	3	5	4	4	4	3	4	0.72
O14	Lack of communication	3	2	3	2	2	4	2	2	4	4	3	4	0.58

O15	Contractual relation among parties	2	3	2	2	2	2	2	2	4	4	3	4	0.53
O16	Poor coordination among parties	3	2	5	2	1	1	3	1	4	4	4	4	0.57
O17	Inadequate and slow decision making mechanism	2	3	4	4	3	3	3	2	5	4	3	4	0.67
O18	Contractor problems and inadequate experience	3	3	3	4	2	2	2	3	3	4	3	4	0.60
	CONSTRUCTION RISKS													
C1	Change in scope	2	3	5	3	2	2	2	2	3	4	3	4	0.58
C2	Change in construction procedure	3	2	4	2	2	3	2	1	3	4	2	4	0.53
C3	Delay in material procurement	4	3	3	3	3	4	3	3	2	5	3	5	0.68
C4	Poor quality of loacal materials	1	3	2	3	3	2	3	3	2	4	3	4	0.55
C5	Change in laws and regulations	3	2	2	3	1	2	1	2	5	4	2	4	0.52
C6	Requirement for permits and their approvals	2	2	3	2	4	3	4	4	5	4	3	4	0.67
C7	Excessive labour and material movement	3	2	3	1	2	3	2	2	5	4	4	4	0.58
C8	Resource performance	4	2	2	3	3	2	3	4	4	3	3	3	0.60
C9	Lower work quality due to time constraints	4	2	2	2	2	3	2	1	4	3	4	3	0.53
C10	Dewatering due to change in water table	2	2	2	2	3	1	3	1	2	4	2	4	0.47
C11	Insufficient resource availiblity	4	3	4	4	2	3	2	3	3	3	3	3	0.62
C12	Rework due to error in execution	3	2	2	3	1	2	1	1	3	5	2	5	0.50

C13	Unskilled workers and poor labour productivity	3	3	3	3	2	4	2	3	5	5	3	5	0.68
C14	Diversion of existing traffic	2	2	2	2	4	3	4	2	1	4	3	4	0.55
	FINANCIAL RISKS													
F1	Increase in cost of facilities due to remote locations	3	3	5	3	3	2	3	4	2	4	2	4	0.63
F2	Delay in removal of encroachments stoppage of disbursement of loan by the lender	2	4	3	2	2	3	2	2	1	4	2	4	0.52
F3	High compensation demands	2	3	2	3	2	2	2	1	5	4	1	4	0.52
F4	Unsettled and lack of project funding	3	3	3	4	3	3	3	4	2	4	1	4	0.62
F5	Changes in material prices and price escalation	2	2	2	4	1	3	2	3	3	3	3	3	0.52
F6	Delay in running bill payments to the contractor	3	3	4	4	2	3	3	2	3	4	1	4	0.60
	PHYSICAL RISKS													
P1	Site conditions	3	3	3	3	2	2	2	3	1	4	2	4	0.53
P2	Damage to equipements	2	2	2	2	3	3	3	2	1	5	2	5	0.53
P3	Labour injuries	3	2	2	3	2	2	2	1	1	4	3	4	0.48
P4	Equipement and material fire and theft	2	2	1	3	3	2	3	1	2	5	2	5	0.52
P5	Removal of structures	4	2	2	3	1	3	1	2	2	5	2	5	0.53
P6	Shifting of utilities	3	3	1	2	2	2	2	3	2	4	2	4	0.50
	SOCIO-POLITICAL RISKS													

S1	Local citizens issue	3	3	3	4	2	4	2	3	4	4	2	4	0.63
S2	Interference of local politicians	3	4	3	4	3	3	3	4	5	4	2	4	0.70
S3	Delay in environmental and forest clearance	3	3	2	5	2	2	2	3	5	4	2	4	0.62
S4	Laws and order problems	2	2	1	4	2	2	2	2	5	4	2	4	0.53
S5	Land acquisition	4	3	3	5	3	4	3	4	5	4	3	4	0.75
S6	Language and carrier barrier	2	2	1	2	2	2	2	3	2	4	1	4	0.45
S7	Monopolising of materials due to closure and other unexpected political conditions	2	3	1	3	2	2	2	3	4	4	2	4	0.53
	ENVIRONMENTAL RISKS													
E1	Weather implications	4	3	3	2	3	4	3	2	2	4	4	4	0.63
E2	Natural disasters	1	2	2	2	1	2	1	1	1	4	2	4	0.38
E3	Management of large construction waste	3	2	1	2	3	3	3	2	2	4	2	4	0.52
E4	Pollution and safety rules	2	2	2	2	3	2	3	3	2	4	3	4	0.53
E5	Forest clearance	4	3	2	4	2	2	2	3	5	4	2	4	0.62

Appendix – 2 Severity Index of different factors are calculated based on the ratings given by the 12 respondents.

Risk Identity	**Risk Factors**	**R 1**	**R 2**	**R 3**	**R 4**	**R 5**	**R 6**	**R 7**	**R 8**	**R 9**	**R 10**	**R 11**	**R 12**	**S.I = ∑(a*n)/ N*A**
	TECHNICAL RISK													
T1	Inadequate Design	4	3	3	5	3	3	4	4	4	4	4	4	0.75
T2	Inadequate specification	4	4	2	4	3	2	3	3	4	4	3	4	0.67
T3	Inadequate site investigation	4	2	1	4	4	3	4	4	4	3	4	3	0.67
T4	Lack of risk management	4	3	4	4	3	3	4	3	4	5	3	5	0.75
T5	Failure to integrate with the system	2	4	2	4	3	2	3	4	4	4	4	4	0.67
T6	Design error and suitability to the nature	3	4	1	4	4	3	4	4	4	4	2	4	0.68
T7	Complexity of project	4	3	5	3	3	2	3	1	5	5	4	5	0.72
T8	Improper estimation of time and cost	4	2	5	5	4	4	4	5	5	4	2	4	0.80
T9	Errors in project documents	3	2	1	3	5	3	5	2	4	4	3	4	0.65
T10	Lack of requirement specification in tender document	4	5	2	3	4	3	4	3	3	4	2	4	0.68
T11	Lack of proper planning	3	2	5	4	3	3	3	2	4	5	3	5	0.70
T12	Misunderstanding of requirements	3	2	3	3	2	2	2	3	2	4	2	4	0.53
T13	Lack of previous data of execution	3	3	2	3	3	3	3	2	3	4	4	4	0.62
T14	Poor safety procedures	4	2	2	3	4	4	4	4	2	4	3	4	0.67
T15	Misinterpretation of traffic data	4	4	3	3	3	2	3	4	5	4	3	4	0.70

	ORGANISATIONAL RISK													
O1	Intense competition at tender stage	4	4	3	4	3	2	3	4	4	4	2	4	0.68
O2	Consultant leaving the project in midway	4	2	2	5	1	4	3	3	2	4	4	4	0.63
O3	Efficiency of managers/supervisors to handle work	3	4	4	4	3	4	3	4	2	4	3	4	0.70
O4	Lack of specified arbitators to settle dispute fast	4	3	3	3	4	3	4	3	2	3	4	3	0.65
O5	Change of supervisors	3	1	1	2	2	2	2	2	2	3	4	3	0.45
O6	Poor performance of some contractors	3	3	4	5	4	4	4	2	4	5	3	5	0.77
O7	Improper distribution of roles and responsibilities	4	3	3	2	1	3	2	3	2	5	3	5	0.60
O8	Conflicts between executives	3	3	2	2	2	2	2	3	4	3	3	3	0.53
O9	Lack of innovative thinking	4	3	1	3	4	2	4	2	1	3	3	3	0.55
O10	Team member attitudes towards projects	3	2	1	3	4	2	4	4	1	4	3	4	0.58
O11	Lack of training	5	2	3	3	3	3	3	4	1	4	4	4	0.65
O12	Stakeholder disputes over changes	3	5	2	3	4	3	4	3	1	5	3	5	0.68
O13	Delay or long process time by other authorities	4	4	4	3	4	4	4	4	5	5	3	5	0.82
O14	Lack of communication	4	3	4	3	3	4	3	4	4	4	3	4	0.72
O15	Contractual relation among parties	3	3	2	3	3	2	3	3	4	5	4	5	0.67

O16	Poor coordination among parties	3	3	5	3	4	3	4	1	5	4	3	4	0.70
O17	Inadequate and slow decision making mechanism	3	4	5	5	4	4	4	2	5	5	3	5	0.82
O18	Contractor problems and inadequate experience	4	4	3	5	3	2	3	4	4	5	3	5	0.75
	CONSTRUCTION RISKS													
C1	Change in scope	4	3	5	3	2	3	3	4	4	4	5	4	0.73
C2	Change in construction procedure	4	4	4	3	4	3	4	2	5	4	3	4	0.73
C3	Delay in material procurement	3	4	3	4	3	4	3	4	4	3	4	3	0.70
C4	Poor quality of local materials	2	3	2	3	5	1	5	3	4	5	3	5	0.68
C5	Change in laws and regulations	3	5	2	3	2	3	2	3	5	4	3	4	0.65
C6	Requirement for permits and their approvals	3	2	4	3	4	3	4	4	2	4	3	4	0.67
C7	Excessive labour and material movement	4	4	3	3	2	3	2	4	2	5	3	5	0.67
C8	Resource performance	5	3	2	3	3	4	3	5	2	4	4	4	0.70
C9	Lower work quality due to time constraints	4	4	2	3	4	3	4	4	1	3	4	3	0.65
C10	Dewatering due to change in water table	3	4	4	2	4	2	4	2	2	4	3	4	0.63
C11	Insufficient resource availability	4	4	5	5	4	4	4	3	3	4	4	4	0.80
C12	Rework due to error in execution	3	3	2	3	3	4	3	5	3	5	5	5	0.73
C13	Unskilled workers and	3	3	5	3	2	3	2	4	1	4	3	4	0.62

	poor labour productivity													
C14	Diversion of existing traffic	4	3	2	3	5	2	5	4	1	5	3	5	0.70
	FINANCIAL RISKS													
F1	Increase in cost of facilities due to remote locations	3	5	5	3	3	3	3	3	3	4	1	4	0.67
F2	Delay in removal of encroachments stoppage of disbursement of loan by the lender	3	4	4	3	4	3	4	2	1	4	2	4	0.63
F3	High compensation demands	2	3	2	4	3	2	3	4	5	5	2	5	0.67
F4	Unsettled and lack of project funding	4	4	5	5	4	3	4	5	5	4	2	4	0.82
F5	Changes in material prices and price escalation	4	4	4	5	2	4	3	4	4	4	2	4	0.73
F6	Delay in running bill payments to the contractor	3	4	5	4	3	4	3	3	5	4	1	4	0.72
	PHYSICAL RISKS													
P1	Site conditions	3	2	4	3	1	3	1	4	4	4	2	4	0.58
P2	Damage to equipment’s	4	3	3	4	3	4	3	4	4	5	2	5	0.73
P3	Labour injuries	3	2	3	3	2	2	2	3	3	4	2	4	0.55
P4	Equipment and material fire and theft	3	3	3	3	4	2	4	4	2	5	2	5	0.67
P5	Removal of structures	4	1	2	3	1	3	1	2	2	5	2	5	0.52
P6	Shifting of utilities	3	2	1	4	2	2	2	3	2	4	1	4	0.50
	SOCIO-POLITICAL RISKS													
S1	Local citizens issue	3	4	5	4	3	3	3	4	5	3	3	3	0.72

S2	Interference of local politicians	4	5	3	4	4	2	4	3	5	3	3	3	0.72
S3	Delay in environmental and forest clearance	3	4	4	5	2	3	2	5	5	4	3	4	0.73
S4	Laws and order problems	3	4	4	4	3	2	3	3	5	4	4	4	0.72
S5	Land acquisition	4	3	5	5	5	5	5	2	5	4	4	4	0.85
S6	Language and carrier barrier	2	3	1	2	3	2	3	4	2	4	2	4	0.53
S7	Monopolising of materials due to closure and other unexpected political conditions	3	4	1	5	3	2	3	4	5	4	3	4	0.68
	ENVIRONMENTAL RISKS													
E1	Weather implications	4	3	4	5	3	4	3	4	3	4	4	4	0.75
E2	Natural disasters	5	4	4	5	4	4	4	5	5	5	5	5	0.92
E3	Management of large construction waste	3	2	1	3	5	3	5	3	2	5	2	5	0.65
E4	Pollution and safety rules	2	1	2	3	4	3	4	3	2	4	4	5	0.62
E5	Forest clearance	4	3	2	5	2	3	2	4	5	4	3	4	0.68

Appendix -3 – MSP schedule of project