iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** X **Month of publication:** October 2019

DOI: http://doi.org/10.22214/ijraset.2019.10124

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue X, Oct 2019- Available at www.ijraset.com

Managing the Risks Faced by Indian Road Construction Projects

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Abstract: Road construction projects undergo many risks during construction process, so it is required to manage these risks before starting any road construction.
This research presents a complete framework for managing risks in road construction projects using Failure mode & Effect Analysis (FMEA) system.
In this research risk management is done through undergoing five major steps: 1. Identification of risk factors 2. Assessment of risk factors in terms of its occurrence, consequences and detectability through questionnaire survey. 3. Ranking of risk factors based on Risk Priority Number (RPN, function of occurrence, consequence and detectability of risk 4. Risk Allocation 5.Treating the risks by designing risk response strategies.
Keywords: Highway Construction Projects, Risk Analysis, Failure Mode & Effect Analysis (FMEA), RPN.

I. INTRODUCTION

Road construction projects undergo many risks during construction process, so it is required to analyze these risks before starting any road construction.

Road construction requires large amount investment, but in road construction several risks may come into play as threat which increase the cost, time and decrease the quality of road construction. So, it is required to analyze the risks in road construction to take suitable response against risks before starting of road construction. To complete any project successfully it is necessary manage the risks associated to respective project.

In Failure Mode & Effect Analysis Risks are prioritized on the basis of Risk Priority Number (RPN). Risk has mainly three components, Occurrence (O), Consequence (C) and Detectability (D). RPN is function of O, C & D i.e.

$$RPN = O \times C \times D$$

Risk Occurrence (RO) refers to probability of occurrence of risk event.

Risk Consequence (RC) refers to impact of occurred risk on objectives of project.

Risk Detectability (RD) refers to likelihood of discovering and correcting a risk event prior to harm occurrence.

In past researches risks in highway construction projects are analyzed by using risk score which depends upon only the occurrence and consequence of risk event, but it is also required to consider the current control on risk event and there is no doubt that Failure Mode & Effect Analysis is one of the most useful technique which analyze the risks beyond occurrence and consequence by considering detectability of risk.

II. OBJECTIVE OF RESEARCH

Objectives of this research are given below-

A. To identify the risk factors in highway construction projects.
B. To assess the Occurrence, Consequences and detectability of Risk factors through questionnaire survey to Calculate RPN of each risk factor.
C. To prioritize the risk factors on the basis of their RPN values.
D. Risk Allocation and Risk Response strategy for each risk factor.

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III. PROPOSED METHODOLOGY

1) Step 1: Identification of risk factors

Total 48 risk factors were identified through literature review and discussion with road construction experts. A questionnaire form is prepared in following format-

Table: 1 Questionnaire Form

Risk No.	Risk Factor	RO	RC	RD	Risk Allocation	Risk Response
R1	Lack of experience of consultant, contractors					
R2	Lower Contractor Productivity					
R3	Insufficient availability of time to complete project					
R4	Change in construction scope					
R5	Change of owner of project					
R6	Rework due to errors					
R7	Incomplete or complexity in project team					
R8	Non-reliability in construction work quality					
R9	Design Errors and Omissions					
R10	Uncertainty in horizontal and vertical alignment					
R11	Uncertainty in access requirement					
R12	Issues related to obtaining railway and government permit					
R13	Change in rules, regulations and policies of government					
R14	Expropriations Risk					
R15	Encroachment Risk					
R16	Obsolete technology					
R17	Delay in approval of submittals					
R18	Insufficient availability of lands					
R19	Uncertainty in Land acquisition cost and schedule					
R20	Natural Obstructions i.e. hill, river, trees etc.					
R21	Lack of availability of utilities					
R22	Uncertainty in price of utilities					
R23	Unskilled members in organization					
R24	Labour dispute and strike					
R25	Conflict between project related parties					
R26	Labour productivity issues					
R27	Poor communication and coordination between project team					
R28	Bankruptcy risk					
R29	Lack of resources					
R30	Fluctuation in prices of material and equipments					
R31	Quality issues of materials and equipments					
R32	Unanticipated damage during construction					
R33	Failure, damage, fire or theft of material and equipment					
R34	Safety issues i.e. labour injuries					
R35	Poor soil conditions					
R36	Chance of rise in G.W.T					
R37	Unforeseen climate conditions on site location					
R38	Poor drainage facilities on site location					
R39	Existing traffic					
R40	Force Majeure					
R41	Heritage Issues					
R42	Mineral mining issues					
R43	Insufficient availability of fund/money					
R44	Conflict in contract document					
R45	Delay in payment					
R46	Adverse weather Conditions					

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2) *Step 2:* Crisp Rating

Crisp Rating used in questionnaire: Table: 2

Linguistic term	Crisp Rating
Very High(VH)	5
High(H)	4
Medium(M)	3
Low(L)	2
Very Low(VL)	1

Note: During Questionnaire survey, experts were also asked to whom risk should be allocated and which type of response is required against risk.

3) *Step 3:* Questionnaire Survey

Risk assessment is done through Questionnaire survey. Total 24 questionnaire forms in above format (Table:1) were filled by road construction experts. Respondent profile is given in Table:3

Respondent Profile: Table: 3

Respondent	Average Experience	Average cost of completion of project	Average time of completion of project
8 Contractors	8 years	147 Cr.	15 Months
8 Clients	9 years	133 Cr.	12 Months
8 Consultants	7 years	102 Cr.	18 Months
24 Overall	8 years	127.33 Cr.	15 Months

After performing questionnaire survey, responses from questionnaire were unified using Relative Importance Index Method which is given by,

$$\overline{RII} = \frac{\Sigma w}{A \times N}$$

Where $\sum W$ = Sum of responses i.e. sum of crisp rating of factor given by respondents, A = Maximum value of crisp rating which is 5, N = No. of respondents

As per RII concept ROI, RCI & RDI of each risk factor is calculated using following formulas,

$$\text{Risk Occurrence Index } (\overline{ROI}) = \frac{\sum W}{A \times N}$$

$$\text{Risk Consequence Index } (\overline{RCI}) = \frac{\sum W}{A \times N}$$

$$\text{Risk Detectability Index } (\overline{RDI}) = \frac{\sum W}{A \times N}$$

4) *Step 4:* RPN Calculation

Risk Priority Number (RPN) is calculated by using following formula

$$RPN = ROI \times RCI \times RDI \times 10 \quad \ldots\ldots eq.1$$

5) *Step 5:* Ranking of Risk Factors

After calculating RPN of each risk factor using eq.1, Ranking of Risk Factors was done on the basis of Risk Priority Number (RPN) of Risk Factors. Higher the RPN, Higher the Risk, Thus Ranking of Risk Factors is done as per decreasing order of RPN in such a way that the rank of maximum RPN is one.

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6) Step 6: Risk Response Plan and Risk Response Strategies

During Questionnaire survey Experts were also asked to whom risk should be allocated. From Questionnaire it was concluded that risk should be allocated to either Client or Consultant or Contractor.

There are four risk response strategies which are commonly accepted-

a) Risk Avoidance refers to reducing the probability of occurrence of risk to zero by some changes in actual workplan.

b) Risk Mitigation refers to reducing the consequences or impact of risk on objectives of project.

c) Risk Transfer refers to shifting the responsibility of bearing the risk's consequences to third partye.g. insurance policies.

d) Risk Acceptance refers to dealing with risk's consequences directly through planning the time and cost contingencies to response the risk.

Risk Occurrence Index (ROI), Risk Consequence Index (RCI) and Risk Detectability Index (RDI), Risk Priority Number (RPN), Rank, Risk Allocation Plan and Risk Response Strategy of each risk factor are given in FMEA Table: 4, which can be considered as concluded part of Research.

Table: 4– FMEA Table

Risk No.	Failure Mode	ROI	RCI	RDI	RPN	Rank	Risk Allocation	Risk Response
R18	Insufficient Availability of Lands	.883	.660	.675	4.416	1	Client	Avoid
R38	Unforeseen Climate Condition on Site Location	.641	.760	.900	4.384	2	Contractor	Accept
R19	Uncertainty in Land acquisition cost and schedule	.875	.616	.750	4.042	3	Client	Avoid
R29	Lack of Resources	.750	.675	.741	3.751	4	Contractor	Mitigate
R45	Insufficient availability of Funds/Money	.550	.641	.916	3.229	5	Client	Avoid
R12	Issue related to obtaining railway and government permit	.808	.675	.566	3.086	6	Client	Avoid
R47	Delay in payment	.633	.625	.775	3.066	7	Client	Accept
R36	Poor Soil Conditions	.708	.525	.591	2.196	8	Client	Avoid
R41	Force Majeure	.558	.625	.600	2.092	9	Contractor	Accept
R4	Change in construction scope	.536	.600	.650	2.090	10	Client	Mitigate
R20	Natural Obstructions i.e. hill, river, trees etc.	.458	.588	.741	1.995	11	Client	Avoid
R33	Unanticipated damage during construction	.600	.416	.750	1.872	12	Contractor	Mitigate
R35	Safety issues i.e. labour injuries	.491	.550	.658	1.776	13	Contractor	Mitigate
R6	Rework due to errors	.525	.483	.683	1.731	14	Contractor	Mitigate
R34	Failure, Damage, fire or theft of material and equipment	.550	.608	.466	1.558	15	Contractor	Avoid
R24	Labour Dispute and Strike	.408	.591	.633	1.526	16	Contractor	Mitigate
R11	Uncertainty in access requirement	.466	.575	.566	1.516	17	Client	Avoid
R39	Poor drainage facilities on site location	.500	.408	.741	1.511	18	Contractor	Mitigate
R30	Fluctuation in prices of material and equipment	.333	.608	.741	1.5	19	Contractor	Mitigate
R37	Chance of rise in Ground Water Table	.425	.625	.550	1.460	20	Contractor	Mitigate
R46	Conflict in contract document	.466	.500	.625	1.456	21	Contractor	Mitigate
R2	Lower Contractor productivity	.466	.516	.558	1.341	22	Contractor	Mitigate
R26	Labour productivity issue	.483	.550	.491	1.304	23	Contractor	Mitigate
R48	Adverse Weather Conditions	.483	.391	.600	1.133	24	Contractor	Accept
R32	Quality issue of materials and equipments	.400	.650	.433	1.125	25	Consultant	Avoid
R25	Conflict between project related parties	.450	.400	.616	1.108	26	Contractor	Mitigate
R10	Uncertainty in horizontal and vertical alignment	.516	.425	.500	1.96	27	Client	Avoid
R44	Mineral Mining issues	.300	.491	.741	1.91	28	Contractor	Mitigate
R22	Uncertainty in price of utilities	.408	.430	.591	1.36	29	Contractor	Mitigate
R3	Insufficient availability of time to complete project	.316	.475	.683	1.25	30	Contractor	Mitigate
R9	Design errors and omission	.408	.500	.491	1.001	31	Consultant	Avoid
R28	Bankruptcy risk	.258	.500	.766	.0988	32	Contractor	Avoid
R13	Change in rules, regulations and policies of government	.491	.366	.550	.0988	33	Client	Accept
R27	Poor communication/coordination between project team	.483	.475	.425	.0975	34	Contractor	Mitigate
R1	Lack of experience of consultant, contractors	.350	.616	.250	.0916	35	Client	Avoid
R8	Non-reliability in construction work quality	.575	.316	.500	.0908	36	Consultant	Mitigate

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R15	Encroachment Risk	.300	.480	.591	.0851	37	Client	Avoid
R17	Delay in approval of submittals	.608	.508	.266	.0821	38	Client	Mitigate
R16	Obsolete technology	.291	.375	.725	.0791	39	Contractor	Mitigate

R40	Existing Traffic	.633	.325	.375	.0771	40	Client	Avoid
R23	Unskilled member in organization	.383	.533	.358	.0730	41	Contractor	Mitigate
R21	Lack of availability of utilities	.416	.408	.416	.0706	42	Contractor	Mitigate
R43	Heritage issues	.266	.383	.691	.0703	43	Client	Avoid
R5	Change of owner of project	.225	.447	.675	.0678	44	Contractor	Mitigate
R7	Incomplete or complexity in project team	.391	.458	.308	.0551	45	Contractor	Mitigate
R14	Expropriations Risk	.291	.358	.458	.0477	46	Contractor	Mitigate

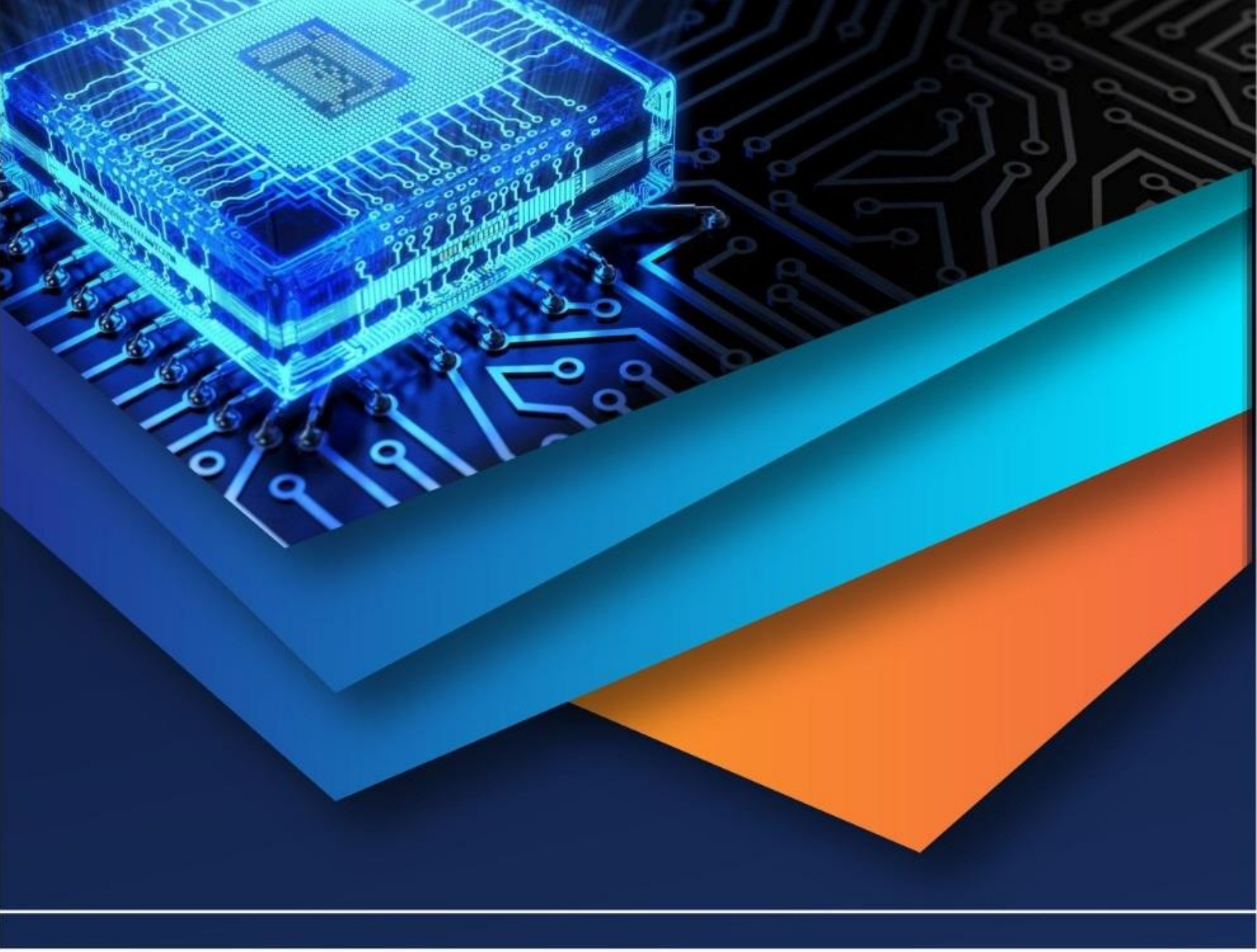
IV. CONCLUSION

Failure Mode & Effect Analysis (FMEA) is one of the most accepted risk analysis technique which analyzes the risks beyond occurrence and consequence of risks because FMEA also consider the current control on risk or detectability of risk event as third parameter. During research it was observed that questionnaire survey through personal interview is the best method to collect information about risk occurrence, risk consequence, risk detectability, risk allocation and risk response. As per conclusion insufficient availability of land was found to be most important risk factor in highway construction. So it is clear that before staring highway construction, it is required to acquire the required land for highway construction. Unforeseen climate conditions is second and uncertainty in land acquisition cost and schedule is third most important risk factors which affect the objectives of highway construction. FMEA table was designed in the last step of research which shows not only the ROI, RCI, RDI, RPN, and Rank of risk factor but also to whom risk should be allocated and which type of response should be given to each risk factor. In this research it was conclude that risk should be allocated to either clients or contractors or consultants related to project. It is clear from FMEA table that about 90% risks are allocated to contractors, so contractors are the most risks affected project related parties. Risk response strategies are last but most important part of risk analysis. Four risk response strategies were found most suitable to response the risks which are: 1. Risk Avoidance 2. Risk Mitigation 3. Risk Transfer 4. Risk Acceptance. Response to each risk is given in FMEA

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