Risk Modelling for Infrastructure Projects

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Abstract— Assessing risk in infrastructure projects is an especial element for successful completion of the project. Risk modelling uses the information that is collected during the risk analysis phase for making the decisions on how to improve the scope of the project. The main objective of this research was to determine the relative ranking/percentage of each risk factor involved in the Pune metro rail project. Analytic Hierarchy Process (AHP) approach is used to rank various types of risks involved. AHP is a multi-criteria basic approach that utilizes both qualitative/subjective and quantitative criteria simultaneous and gives more realistic picture or risk involved in the projects. Such analysis helps project managers in understanding which type of risks are highly critical for the project. The establishment of such methodology creates a new approach for the risk quantification and assessment to improve the project risk management effects.

Keywords: Risk Modelling, Infrastructure Projects

I. INTRODUCTION

This report provides an introduction to the processes involved in Risk Modelling of Infrastructure Projects by both quantitative and qualitative approach. The approach involved Questionnaire Survey, AHP, and Risk Assessment Matrix

Risk is a situation in the construction industry involving an exposure to danger which requires certain measures that are needed to prevent risk factors such as planning, monitoring and controlling (Jurie Steyn, 2018). There are many types of risk involved in any Infrastructure Projects, for example Time and Cost overrun, Quality of Project, Environmental Risk and Political Risk etc. Risk modelling uses the information that is collected during the risk analysis phase for making the decisions on how to improve the scope of the project in achieving its cost, time and performance objectives.

- Risk mitigation can be split into four strategies:
- Avoid the risk entirely by eliminating the root cause of the potential problem.
- Transfer the risk to another party through contractual clauses and insurance.
- Reduce the risk by planning effective action in the cases where the problem.
- Accept the risk should only be used as a last resort

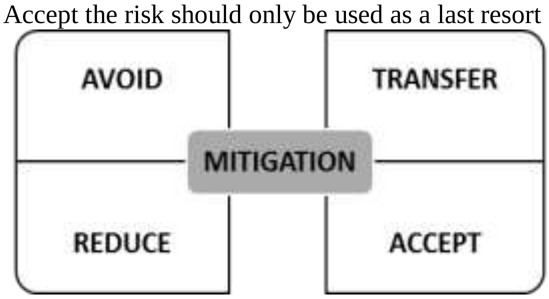

Fig. 1: Risk Mitigation Measures

II. RISK MODELING THROUGH ANALYTICAL HIERARCHY PROCESS

A. *AHP and its Features*

Analytic Hierarchy Process was founded by Saaty et al[80]. It is a method for multi-criteria decision making and uses both qualitative and quantitative criteria in evaluation. It can be used for Real world decision problems and also uses multiple, diverse criteria, qualitative as well as quantitative information. Widely used in:

- Corporate planning
- Portfolio selection
- Benefit/Cost analysis for resource allocation purposes
- Resource allocation
- Source selection, program selection
- The first level indicates the goal for the specific decision
- In the second level, the goal is decomposed of several criteria.
- The lower levels can follow this principal to divide into other sub-criteria.

Information is decomposed into a hierarchy of alternatives and criteria and then synthesized to determine relative ranking of alternatives.

B. *Importance of AHP*

Various types of projects involve multi-criteria decision making, so to balance the qualitative and quantitative risk factors, we have chosen AHP approach that helps in providing for a compromise solution and competitive decision making.

VERBAL JUDGEMENT OF PREFERENCE	NUMERICAL RATING
Extremely preferred	9
Very strongly to extremely preferred	8
Very strongly preferred	7
Strongly to very strongly preferred	6
Strongly preferred	5
Moderately to strongly preferred	4
Moderately preferred	3
Equally to moderately preferred	2
Equally preferred	1

Table 2.1: Ratio scale used in AHP

C. *Consistency Index*

Two indices are used to ensure the consistency of the subjective perception and the accuracy of the comparative weights:

- Consistency index (CI)
- Consistency Ratio (CR)

The CI is expressed as:

$$CI = \lambda_{max} - n / (n - 1)$$

Where, λ_{max} is the largest eigenvalue, and n denotes the numbers of the attributes.

D. Consistency Ratio

Saaty (1980) suggested that the value of the C.I. should not exceed 0.1 for a confident result. On the other hand, the C.R. can be calculated as:

CR= CI/RI

Where, R.I. refers to a random consistency index, which is derived from a large sample of randomly generated reciprocal matrices using the scale 1/9, 1/8,…,1,…,8, 9.

Consistency plays a vital role in AHP. It accepts some small inconsistency in decision i.e. 10%. Pair-wise comparison matrix obtained by decision maker must satisfy Consistency ratio condition as mentioned above. If not decision maker has to revised his decisions and improve the consistency ratio to acceptable range (i.e.<10%).

E. Random Index

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 2.2: Random index

F. Step wise procedure to generate a model through AHP

1) Identifying all major risks involved in Infrastructure Projects.
2) Classification of risks along with factors affecting the risks.
3) Preparing AHP risk matrix by collection of Primary data from industry professionals.
4) Analysis different type of risks as per AHP.
5) Generating weightage of different type of risk through Consistency ratios and index
6) Calculation of Composite risks weightage.
7) Generation of weightage preference for determination of most likely risks.

III. APPLYING AHP APPROACH FOR THE CALCULATION OF RELATIVE RANKING OF ALTERNATIVE RISKS

	Infra	Finance	Environment	Political	Managerial
Infra	1.00	7.00	7.00	2.00	3.00
Finance	0.14	1.00	6.00	3.00	6.00
Environment	0.14	0.17	1.00	3.00	5.00
Political	0.50	0.33	0.33	1.00	5.00
Managerial	0.33	0.17	0.20	0.20	1.00
Column Total	2.12	8.67	14.53	9.2	20

Table 3.1: Type of risks in infra Projects

	Infra	Finance	Environment	Political	Managerial	Weightage
Infra	0.47	0.81	0.48	0.22	0.15	0.43
Finance	0.07	0.12	0.41	0.33	0.30	0.24
Environment	0.07	0.02	0.07	0.33	0.25	0.15
Political	0.2	0.04	0.02	0.11	0.25	0.13
	4					
Managerial	0.16	0.02	0.01	0.02	0.05	0.05

Table 3.2: Risks in infra Projects with Weightage

	Infra	Finance	Environment	Political	Managerial	Row Total	λ
Infra	0.43	1.71	1.02	0.26	0.16	3.58	8.41
Finance	0.06	0.24	0.88	0.39	0.31	1.89	7.74
Environment	0.06	0.04	0.15	0.39	0.26	0.9	6.18
Political	0.21	0.08	0.05	0.13	0.26	0.74	5.61
Managerial	0.14	0.04	0.03	0.03	0.05	0.29	5.54

Table 3.3: Risks Analysis with λmax

λmax	6.7	
Consistency Index (CI)	(λmax - n)/(n - 1)	0.42
Consistency Ratio (CR)	CI/RI	0.29

Table 3.4: Risks Analysis with Consistency Index & Consistency Ratio

	Technical	Hazards	Operations	Resources
Technical	1.00	5.00	4.00	2.00
Hazards	0.20	1.00	2.00	2.00
Operations	0.25	0.50	1.00	5.00
Resources	0.50	0.50	0.20	1.00
Column Total	1.95	7.00	7.20	10.00

Table 3.5: Type of risks in infra Projects

	Technical	Hazards	Operations	Resources	Weightage
Technical	0.51	0.71	0.56	0.20	0.50
Hazards	0.10	0.14	0.28	0.20	0.18
Operations	0.13	0.07	0.14	0.50	0.21
Resources	0.26	0.07	0.03	0.10	0.11

Table 3.6: Risks in infra Projects with weightage

	Technical	Hazards	Operations	Resources	Row Total	λ
Technical	0.50	0.90	0.84	0.23	2.47	4.98
Hazards	0.10	0.18	0.42	0.23	0.93	5.13
Operations	0.12	0.09	0.21	0.57	0.99	4.74
Resources	0.25	0.09	0.04	0.11	0.49	4.32

Table 3.7: Risks Analysis with λmax

λmax	4.79	
Consistency Index (CI)	(λmax- n)/(n-1)	0.26
Consistency Ratio (CR)	CI/RI	0.24

Table 3.8: Risks Analysis with Consistency Index & Consistency Ratio

	Market	Breach	Quality control	Inflation
Market	1.00	5.00	5.00	2.00
Breach	0.20	1.00	3.00	2.00
Quality control	0.20	0.33	1.00	7.00
Inflation	0.50	0.50	0.14	1.00
Column Total	1.90	6.83	9.14	12.00

Table 3.9: Type of risks in Finance

	Market	Breach	Quality control	Inflation	Weightage
Market	0.53	0.73	0.55	0.17	0.49
Breach	0.11	0.15	0.33	0.17	0.19
Quality control	0.11	0.05	0.11	0.58	0.21
Inflation	0.26	0.07	0.02	0.08	0.11

Table 3.10: Finance Risks with weightage

	Market	Breach	Quality control	Inflation	Row Total	λ
Market	0.49	0.93	1.06	0.22	2.70	5.48
Breach	0.10	0.19	0.64	0.22	1.14	6.10
Quality control	0.10	0.06	0.21	0.76	1.13	5.36
Inflation	0.25	0.09	0.03	0.11	0.48	4.40

Table 3.11: Risks Analysis with λmax

λmax	5.33	
Consistency Index (CI)	(λmax- n)/(n-1)	0.44
Consistency Ratio (CR)	CI/RI	0.4

Table 3.12: Risks Analysis with Consistency Index & Consistency Ratio

	Sanitation	Accidents	Pollution	Agriculture	Hazards
Sanitation	1.00	3.00	6.00	7.00	5.00
Accidents	0.33	1.00	5.00	3.00	5.00
Pollution	0.17	0.20	1.00	3.00	5.00
Agriculture	0.14	0.33	0.33	1.00	6.00
Hazards	0.20	0.33	0.20	0.17	1.00
Column Total	1.84	4.87	12.53	14.17	22.00

Table 3.13: Type of Environmental Risks

	Sanitation	Accidents	Pollution	Agriculture	Hazards	Weightage
Sanitation	0.54	0.62	0.48	0.49	0.23	0.47
Accidents	0.18	0.21	0.4	0.21	0.23	0.24
Pollution	0.09	0.04	0.08	0.21	0.23	0.13
Agriculture	0.08	0.07	0.03	0.07	0.27	0.1
Hazards	0.11	0.07	0.02	0.01	0.05	0.05

Table 3.14: Environmental Risks with weightage

	Sanitation	Accidents	Pollution	Agriculture	Hazards	Row Total	λ
Sanitation	0.47	0.73	0.78	0.72	0.25	2.96	6.27
Accidents	0.16	0.24	0.65	0.31	0.25	1.61	6.58
Pollution	0.08	0.05	0.13	0.31	0.25	0.82	6.28
Agriculture	0.07	0.08	0.04	0.10	0.30	0.60	5.77
Hazards	0.09	0.08	0.03	0.02	0.05	0.27	5.38

Table 3.15: Risks Analysis with λmax

λmax	6.06	
Consistency Index (CI)	(λmax- n)/(n-1)	0.26
Consistency Ratio (CR)	CI/RI	0.21

Table 3.16: Risks Analysis with Consistency Index & Consistency Ratio

	Laws	Market	Land
Laws	1.00	7.00	3.00
Market	0.14	1.00	4.00
Land	0.33	0.25	1.00
Column Total	1.48	8.25	8.00

Table 3.17: Type of Political Risks

	Laws	Market	Land	Weightage
Laws	0.68	0.85	0.38	0.63
Market	0.10	0.12	0.50	0.24
Land	0.23	0.03	0.13	0.13

Table 3.18: Political Risks with weightage

	Laws	Market	Land	Row Total	λ
Laws	0.63	1.68	0.38	2.69	4.25
Market	0.09	0.24	0.51	0.84	3.50
Land	0.21	0.06	0.13	0.40	3.13

Table 3.19: Risks Analysis with λmax

λmax	3.63	
Consistency Index (CI)	(λmax- n)/(n-1)	0.31
Consistency Ratio (CR)	CI/RI	0.00

Table 3.20: Risks Analysis with Consistency Index & Consistency Ratio

	Resources	Management
Resources	1.00	7.00
Management	0.14	1.00
Column Total	1.14	8.00

Table 3.21: Type of Marginal Risks

	Resources	Management	Weightage
Resources	0.88	0.88	0.88
Management	0.13	0.13	0.13

Table 3.22: Marginal Risks with weightage

	Resources	Management	Row Total	λ
Resources	0.88	0.88	1.75	2.00
Management	0.13	0.13	0.25	2.00

Table 3.24: Risks Analysis with λmax

Λmax	2	
Consistency Index (CI)	(λmax- n)/(n-1)	0.00
Consistency Ratio (CR)	CI/RI	0.00

Table 3.25: Risks Analysis with Consistency Index & Consistency Ratio

IV. Implications to Managers

Risks	Infrastructure	Financial	Environmental	Political	Managerial
Weightages	0.43	0.24	0.15	0.13	0.05

A. *Weightage Preference:*

Infrastructure Risk (0.43) > Financial Risk (0.24) > Environmental Risk (0.15) > Political Risk (0.13) > Managerial Risks (0.05) = 0.82 or 82% (approx. = 80%)
Political & managerial risks=0.13+0.05
= 0.18 or 18% (approx. =20%)

We can say that if managers focus more on infrastructure, financial and environmental risks majority of the risk can be covered which can lead to the risk minimization in projects.

V. Conclusion

The objective of this paper was to study the risk modelling and to determine the ranking of different types of risks involved in a project. This paper has helped in identification and better understanding of risks with the help of various research papers and articles. We have developed mechanism which has helped in classifying different factors affecting risks and also helped in choosing the particular area of infrastructure i.e.; Pune-Metro rail project. Under this project area, Risk Breakdown Structure was prepared for which the AHP approach has been used for determining the relative ranking of risk factors. The rankings used in AHP calculation were provided by some construction industry professionals of by which, we were able to identify the critical risks involved in the project as infrastructure risk with the highest weightage of 0.43.

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