Chapter 4: Risk Factor Assessment in Logistics Infrastructure Projects

4.1 Introduction

Risk management in logistics infrastructure projects is very critical to the success of the project. As per the Project risk management guidelines commonly used in performing the risk assessment by identifying the risk factors, then allocating some probabilities to each risk factor and assigning some value to risk factor's impact, after that identifying the critical risks of the project and developing a mitigation plan around it. For this purpose, a Probability Impact Matrix (P-I Method) is used. This is a widely used method for all the projects invariably for projects in the Infrastructure sector, IT Projects and projects of other different nature. This study has been carried out in detail to evaluate the effectiveness of this process in logistics infrastructure Projects.

Airport infrastructure development project has been considered for this research. A comprehensive literature review has been undertaken to identify risk sources, risk attributes, risks factors, risk categories. There is limited research work available for logistics infrastructure projects. However, inferences have been drawn from projects in other areas and have then got substantiated and strengthened by expert opinions, in-depth Interviews, questionnaires and inputs using their rich experience in the field. While seeking expert opinions, experts in the field of logistics infrastructure development projects have been consulted so that the inputs received are relevant to the scope of this research study.

4.2 Literature Review

In project management, risks are taken as significant hindrances for information technology related projects accomplishment. (Dandage, et. al., 2018). Sanchez et. al. (2016) concluded that there are number of studies available on IT/software project risk management but there are very limited number of studies have been carried out for Logistics infrastructure projects. Megaproject development became complex and characterized by several

uncertainties that can influence the project negatively (Dimitriou, 2014; Flyvbjerg, 2014; Brookes, 2015; Mentis, 2015).

Nevertheless, some projects succeed while some fail. Projects fail due to both external reasons which are beyond project managers control and due to internal factors related to proper planning and management. Poor risk management is most vital reason for project collapse and has become a key obstacle in the majority of infrastructure projects developed today (Kalady & Udhas, 2013).

Xu et al. (2018) studied and developed dynamic model that investigate the interdependent effects on project schedule performance. Authors used hybrid method combining system dynamics and discrete event simulation methods and model is also verified using data of bridge construction project. Clarke & Obrien (2016) developed a guiding operational framework as online dashboard to advance decision making techniques for the better management of transport infrastructure. Risk factors in construction projects were identified using survey questionnaire methods and then analyzed using the Analytics Network Process to getting most critical factors (Dada & Jagboro, 2007).

Delays in projects is defined as the deviation from the project duration defined in contract period agreed by all parties. Any deviation in project devilry than excepted is called delay. The delays on projects also causes the cost overruns (Pickavance, 2005). Delays may very negative consequences and this created conflicts among project owners and contractors. According to Abdul Rahman et al. (2013), delays and in turn cost overruns may create financial risks to project owners.

Wu, et. al. (2018) developed a three-dimension framework with three factors probability, business impact and difficulty in detecting such negative events for the public private partnership projects(PPP). Li et al. (2019) developed a risk assessment framework that included risk aggregation, risk rating and then interdependent risk interaction. Risk interaction was achieved using the decision making trial and evaluation laboratory method (DEMATEL). Wang et al. (2016) developed a risk assessment model based on an adapted and flexible analytics hierarchy process and model was applied on cross see route project.

Ahmadabadi & Heravi (2019) developed a structural equation model capturing the risk interactions and project stakeholder's expectations. The SEM model provided risk rating as an output that can be sued to prioritize the risks. Lyu et al. (2019) proposed a model to assess the risk of infrastructures using trapezoidal Fuzzy AHP. Hu & Hsiao (2016) developed a model to address the quality risks for an airline service provider. The developed Kano model provides the satisfaction degree of customers. Rong et al. (2016) provided different models for airport operational safety.

Chang et al. (2015) provided a model for the assessment of international airports specifically safety management system. The developed two stage model used the MCDM model. In the first stage model used ranking system using ANP method and then DEMATEL model was applied in stage 2. MCDM are versatile and provides the robust mechanism for the risk ranking (Hwang & Yoon, 2012).

In complex large infrastructure projects, common risk assessment methods are not suitable (Marle et al., 2013). Risks in any complex project are interdependent and capturing risks will provide better picture of risk interactions. The interaction complexity will further increase as project size increases (Liu et al, 2016). In literature, several authors have used different techniques to study the risk interaction among risk factors like Analytics Network Process (Boateng et al., 2015), Interpretive structural model (Dandage et al., 2018; Iyer & Sagheer, 2010), fuzzy weighted ISM (Tavakolan & Etemadinia, 2017) and SEM (Liu, et al., 2016). In such methods, authors have tried to study the risks and their interdependences and their effect on three project goals viz Cost, Time and Quality. In the literature at what level of risks to be studied is not available. Risks may be studied at macro level or it may be studied at the field level or very detailed manner. Literature also lacks in paths of risk during the project life cycle. Such studies tend to contribute to risk assessment methodology, most of them focused on cost, time and quality. The way infrastructure development projects are managed plays a very important role in the economic growth of the country.

4.3 Research Methodology

The following approach was adopted to carry out this research work:

- Defining the research problem and scope
- Extensive literature reviews to understand the risks and the practices widely used for risk identification and assessment
- Data collection through experts – Experts in logistics infrastructure industry approached (Airports, Road and Rail); Identification of Risk Sources, Risk Attributes, Risk Factors
- Data Analysis using P-I Matrix for Risk Attributes, Risk Factors, Risk Categories
- Drawing Conclusions and going to the next step of the research

The approach followed to carry out this study is elaborated in Fig. 4.1 below.

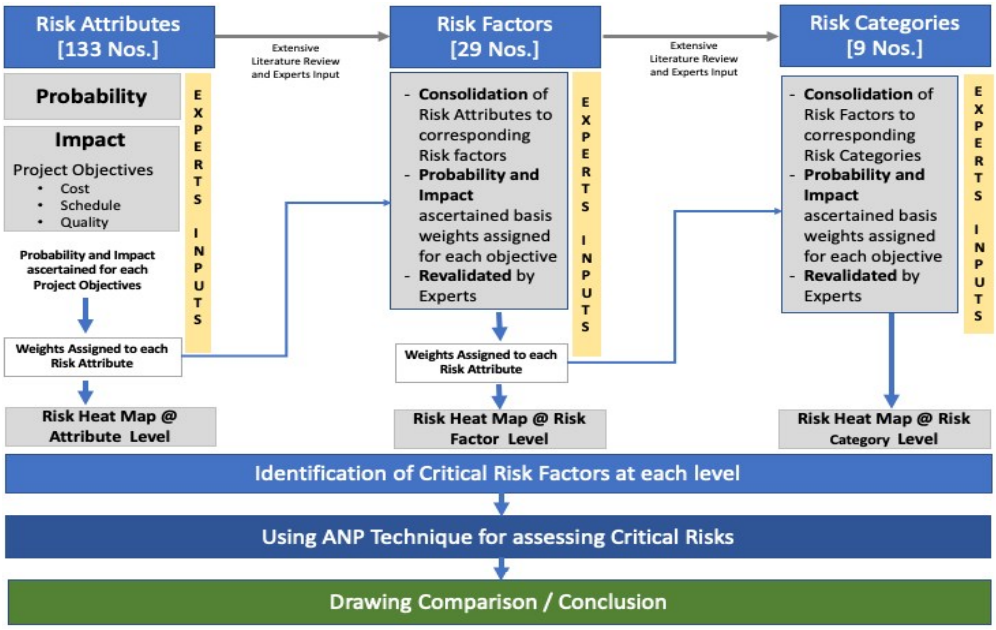

Fig. 4. 1 Identifying critical Risk factors through P-I and ANP Techniques

Table 4. 1 lays down the ratings provided by experts for each risk attribute. The weights assigned to each attribute are based on the inputs provided by the experts and have been revalidated in the final list.

Data Collection involved identifying the Risk Attributes at the micro-level, Risk factors, Risk categories, etc. using literature Review and inputs from experts. At every level of data consolidation, experts have been consulted and

their inputs incorporated to ensure that data is relevant, and data analysis provides the best output as possible. As an outcome of the data collection, 133 Risk attributes have been considered contributing to 29 Risk factors which are then further classified into 9 Risk categories.

For each risk attribute, a probability and Impact factor has been derived, which is based on the input of experts. Based on the inputs received, it has been consolidated using geometric mean to arrive at probability and impact factor for each attribute. risk matrix and risk heat map was then developed for all the 133 risk attributes. Critical risk attributes have been identified with high Probability-Impact factor score (above a score of 1500). The Risk Matrix for attributes is shown in Table 4.1 and Risk Heat Map in Fig. 4.2. Table 4.3 shows the number of risk attributes lying in each of the 4 zones, i.e. Make Do, Monitor, Manage and Mitigate. These 4 Risk zones indicate the severity of the risk on a 5x5 matrix. Risk Heat Map in Fig. 4.3 indicates the mapping of each risk to each zone. 16 out of 133 Risk attributes are lying under the critical zone, i.e. Red Zone.

Risk attributes were assigned weights contributing to risk factors. These weightages were used to derive the probability and Impact factor at Risk factor level.

4.4 Probability and Risk Impact Assessment

4.4.1 Probability-Impact Assessment at Risk Attribute Level

Basis of the detailed literature review and expert inputs Table 4.1 is constructed. Table 4.1 shows enumerated Risk attributes, risk factors, risk categories in logistics infrastructure projects. 133 risk attributes contributing to 29 risk factors and in turn, contributing to 9 risk categories have been shown. Table 4.1 shows the probability of occurrence of the risk attribute and its impact on project objectives Time, cost and quality. Time, Cost and Quality risk factors are calculated multiplying probability and respective time, cost and quality scores. The probability and corresponding time, cost and quality risk factors are mapped on a Heat map shown in Fig. 4.2 to 4.4.

Table 4. 1 Probability and Impact Ratings at Risk Attribute Level

Risk ID	Risk Category [9]	Risk / Risk Factors [29]	Risk Attributes [133]	Attribute Weights	Probability Score	Cost Impact Score	Schedule Impact Score	Quality Impact Score	Cost Risk Factor	Time Risk Factor	Quality Risk Factor	Probability (%)
R1	Design Risk	Pre-bid Assessment Planning	Inadequate Project Feasibility Study	30%	20	40	50	10	800	1000	200	40%
R2			Ineffective Project Conceptualization	40%	20	50	50	10	1000	1000	200	40%
R3			Improper Socio-Economic Assessment	30%	20	20	20	10	400	400	200	40%
R4	Design Risk	Scope Assessment Planning	Inadequate Project Scope Assessment	60%	20	40	50	20	800	1000	400	40%
R5			Improper Resource Planning	40%	40	40	50	40	**1600**	**2000**	**1600**	80%
R6	Design Risk	Regulatory Framework - Planning	Applicable Laws and Policies	30%	20	20	20	10	400	400	200	40%
R7			Political Scenario	30%	20	30	30	20	600	600	400	40%
R8			Regulatory Approvals	40%	30	30	30	20	900	900	600	60%
R9	Design Risk	Timeline Assessment Planning	Improper Project Schedule	100%	30	50	50	30	**1500**	**1500**	900	60%
R10	Design Risk	Cost Assessment Planning	Cost Assessment	100%	40	50	50	30	**2000**	**2000**	1200	80%
R11	Design Risk	Risk Assessment Planning	Inadequate Risks Assessment	100%	40	50	50	30	**2000**	**2000**	1200	80%

Risk ID	Risk Category [9]	Risk / Risk Factors [29]	Risk Attributes [133]	Attribute Weights	Probability Score	Cost Impact Score	Schedule Impact Score	Quality Impact Score	Cost Risk Factor	Time Risk Factor	Quality Risk Factor	Probability (%)
R12	Construction Risk	Site Conditions - Environmental Risk	Unpredicted Weather Conditions	20%	20	10	10	10	200	200	200	40%
R13			Pollution	40%	30	30	30	10	900	900	300	60%
R14			Earthquake/ Natural Calamity	20%	10	10	10	10	100	100	100	20%
R15			Precipitation/ Flood	20%	10	10	10	10	100	100	100	20%
R16	Construction Risk	Site Conditions - Sub-surface	Unexpected Surface conditions	35%	20	10	10	10	200	200	200	40%
R17			Archaeological survey done	25%	10	10	10	10	100	100	100	20%
R18			Inadequate Geotechnical investigation	40%	20	40	40	20	800	800	400	40%
R19	Construction Risk	Site Conditions - Location	Construction area (rural/urban)	20%	10	10	10	10	100	100	100	20%
R20			Access conditions	15%	10	10	10	10	100	100	100	20%
R21			Onsite congestion	15%	10	10	10	10	100	100	100	20%
R22			Delay in permits and licenses	30%	30	50	50	10	**1500**	**1500**	300	60%
R23			Security requirements	10%	20	30	30	10	600	600	200	40%
R24			Safety regulation	10%	20	30	20	10	600	400	200	40%

Risk ID	Risk Category [9]	Risk / Risk Factors [29]	Risk Attributes [133]	Attribute Weights	Probability Score	Cost Impact Score	Schedule Impact Score	Quality Impact Score	Cost Risk Factor	Time Risk Factor	Quality Risk Factor	Probability (%)
R25	Labor Risk	Resources - Labor Risk	Labor Skills Level/ Productivity	20%	40	30	40	40	1200	**1600**	**1600**	80%
R26			Labor Availability	20%	30	30	30	20	900	900	600	60%
R27			Labour disputes	10%	30	30	30	10	900	900	300	60%
R28			Labor Accidents	10%	40	30	30	10	1200	1200	400	80%
R29			Human Resource Planning	20%	30	30	30	10	900	900	300	60%
R30			Working hours restrictions	20%	10	10	30	10	100	300	100	20%
R31	Construction Risk	Resources - Equipment Risk	Availability of new and effective Construction Technology	20%	30	40	40	40	1200	1200	1200	60%
R32			Availability of efficient equipment onsite	30%	30	40	40	40	1200	1200	1200	60%
R33			Availability of Equipment Suppliers	25%	20	20	20	20	400	400	400	40%
R34			Equipment Maintenance	25%	40	40	40	40	**1600**	**1600**	**1600**	80%
R35			Material Delivery	15%	30	20	40	20	600	1200	600	60%
R36			Material Shortage	20%	30	20	40	10	600	1200	300	60%

Risk ID	Risk Category [9]	Risk / Risk Factors [29]	Risk Attributes [133]	Attribute Weights	Probability Score	Cost Impact Score	Schedule Impact Score	Quality Impact Score	Cost Risk Factor	Time Risk Factor	Quality Risk Factor	Probability (%)
R37	Construction Risk	Resources - Material Risk	Material Theft and Damage	5%	30	30	30	10	900	900	300	60%
R38			Non-Conforming material and Rejection	5%	30	20	30	20	600	900	600	60%
R39			Material Monopoly	5%	10	40	20	10	400	200	100	20%
R40			Nominated vendors	10%	10	40	40	40	400	400	400	20%
R41			Availability of Vendors	15%	20	40	40	30	800	800	600	40%
R42			Material Procurement	15%	30	30	40	20	900	1200	600	60%
R43			Material price escalations	10%	30	40	20	20	1200	600	600	60%
R44	Design Risk	Project Parties - Project Owner Engagement	Owner Type (Public/ Private/ PPP)	30%	10	10	10	10	100	100	100	20%
R45			Management Strategy	20%	10	10	10	10	100	100	100	20%
R46			Organization Structure	15%	10	10	10	10	100	100	100	20%
R47			Management Involvement and Control	20%	20	10	10	10	200	200	200	40%
R48			Standing in the Industry	15%	20	10	10	10	200	200	200	40%
R49	Design Risk	Project Parties -	Team Experience	30%	30	30	40	20	900	1200	600	60%

Risk ID	Risk Category [9]	Risk / Risk Factors [29]	Risk Attributes [133]	Attribute Weights	Probability Score	Cost Impact Score	Schedule Impact Score	Quality Impact Score	Cost Risk Factor	Time Risk Factor	Quality Risk Factor	Probability (%)
R50		Engineering and Design Team	Project Goal clarity	15%	10	10	10	10	100	100	100	20%
R51			Complexity of design	20%	20	20	20	20	400	400	400	40%
R52			Ad-hoc Consultants	5%	20	20	20	20	400	400	400	40%
R53			Design Error	10%	20	20	20	20	400	400	400	40%
R54			Experienced Design Agency	20%	20	30	30	30	600	600	600	40%
R55	Construction Risk	Project Parties - Contractor	Contractor pre-qualified	5%	30	40	40	30	1200	1200	900	60%
R56			Use of New Technology	5%	30	30	30	30	900	900	900	60%
R57			Quality of Work	10%	30	30	30	40	900	900	1200	60%
R58			Skilled Resource Availability	20%	30	30	30	30	900	900	900	60%
R59			No. of Subcontractors	5%	30	30	30	10	900	900	300	60%
R60			Contractor Reputation	10%	20	20	10	10	400	200	200	40%
R61			Contractor Speed of Execution	10%	20	20	40	20	400	800	400	40%
R62			No. of Current Projects being handled	5%	20	20	10	10	400	200	200	40%

Risk ID	Risk Category [9]	Risk / Risk Factors [29]	Risk Attributes [133]	Attribute Weights	Probability Score	Cost Impact Score	Schedule Impact Score	Quality Impact Score	Cost Risk Factor	Time Risk Factor	Quality Risk Factor	Probability (%)
R63			Resource Utilization	15%	30	30	40	20	900	1200	600	60%
R64			Non-Compliance to Contractual Commitments (PPP)	10%	30	40	40	30	1200	1200	900	60%
R65	Construction Risk	Project Parties - Project Management (PMC)	Deployed Resource Experience	20%	30	20	40	10	600	1200	300	60%
R66			Quality Assurances	20%	20	20	10	10	400	200	200	40%
R67			Scope Adherence checks	15%	30	30	30	10	900	900	300	60%
R68			Resource Availability for the Project	20%	30	30	30	30	900	900	900	60%
R69			Type of Contract	5%	10	20	10	10	200	100	100	20%
R70			PMC Speed of Execution	20%	10	20	10	10	200	100	100	20%
R71	Construction Risk	Land Acquisition Risk	Social Issues in land acquisition	25%	10	10	10	10	100	100	100	20%
R72			Difficulties in Compensation	25%	10	10	10	10	100	100	100	20%
R73			Land Availability	25%	10	10	10	10	100	100	100	20%
R74			Government Support	25%	20	10	30	10	200	600	200	40%

Risk ID	Risk Category [9]	Risk / Risk Factors [29]	Risk Attributes [133]	Attribute Weights	Probability Score	Cost Impact Score	Schedule Impact Score	Quality Impact Score	Cost Risk Factor	Time Risk Factor	Quality Risk Factor	Probability (%)
R75	Financial Risk	Financial Risk	Fluctuation in Prices	5%	40	20	10	30	800	400	1200	80%
R76			Invoice delay	5%	20	10	10	10	200	200	200	40%
R77			Change in Currency Rate	10%	40	20	10	10	800	400	400	80%
R78			Owner Financial Capacity	10%	30	20	10	10	600	300	300	60%
R79			Timely Progress Payment	2%	20	10	10	10	200	200	200	40%
R80			Rate of Interest Volatility	2%	30	40	40	30	1200	1200	900	60%
R81			Tax Rate Volatility	2%	40	40	10	10	**1600**	400	400	80%
R82			Project Size	10%	20	30	30	20	600	600	400	40%
R83			Equity Risk	10%	20	20	10	10	400	200	200	40%
R84			Liquidity Risk	10%	20	20	10	10	400	200	200	40%
R85			Labour rate sensitivity	2%	40	20	10	10	800	400	400	80%
R86			Poor financial Market Design deficiency	2%	10	10	10	10	100	100	100	20%
R87			Funding Constraints	15%	10	10	10	10	100	100	100	20%

Risk ID	Risk Category [9]	Risk / Risk Factors [29]	Risk Attributes [133]	Attribute Weights	Probability Score	Cost Impact Score	Schedule Impact Score	Quality Impact Score	Cost Risk Factor	Time Risk Factor	Quality Risk Factor	Probability (%)
R88			Ineffective financial management of projects	20%	20	20	10	10	400	200	200	40%
R89	Legal/ Political Risk	Political Risk	Bribery and Construction	5%	30	10	10	10	300	300	300	60%
R90			Wars and Revolutions	5%	10	10	10	10	100	100	100	20%
R91			Changes in Law and Regulations	60%	30	30	10	10	900	300	300	60%
R92			Change in Political Leadership/ Scenario	30%	10	10	10	10	100	100	100	20%
R93	Construction Risk	Socio-Economic Risk	Language/ Cultural barrier	25%	10	10	10	10	100	100	100	20%
R94			public opposition	25%	30	30	30	10	900	900	300	60%
R95			Law and Order	50%	30	30	30	10	900	900	300	60%
R96	Legal / Political Risk	Regulatory Risk	Non-compliance with regulatory, contractual or quality requirements	25%	30	20	20	20	600	600	600	60%
R97			The requirement for permits and their approval	15%	30	30	30	20	900	900	600	60%

Risk ID	Risk Category [9]	Risk / Risk Factors [29]	Risk Attributes [133]	Attribute Weights	Probability Score	Cost Impact Score	Schedule Impact Score	Quality Impact Score	Cost Risk Factor	Time Risk Factor	Quality Risk Factor	Probability (%)
R98			Delay in regulatory approvals	25%	40	40	40	10	**1600**	**1600**	400	80%
R99			Unpredictive Regulatory Policies	35%	10	10	10	10	100	100	100	20%
R100	Legal/ Political Risk	Legal Risk	Litigations during Project Execution	60%	30	40	40	10	1200	1200	300	60%
R101			Litigations Operationalization	40%	20	40	10	10	800	200	200	40%
R102	Commercial Risk	Commercial Risk	Contractual Requirements, Conditions	15%	30	30	30	10	900	900	300	60%
R103			Transparency in Contract Evaluation and Award Process	15%	10	10	10	10	100	100	100	20%
R104			A dispute among the Process Owners and Contractors, Litigations	25%	30	30	30	10	900	900	300	60%
R105			Contract Variations	20%	30	30	30	10	900	900	300	60%
R106			Non-Compliance to Contractual Commitments (PPP)	25%	20	20	20	10	400	400	200	40%

Risk ID	Risk Category [9]	Risk / Risk Factors [29]	Risk Attributes [133]	Attribute Weights	Probability Score	Cost Impact Score	Schedule Impact Score	Quality Impact Score	Cost Risk Factor	Time Risk Factor	Quality Risk Factor	Probability (%)
R107	Construction Risk	Technical Risk	Incomplete Design	10%	20	20	20	10	400	400	200	40%
R108			Inadequate Specification	10%	20	20	20	10	400	400	200	40%
R109			Inadequate Site Investigation	10%	20	20	20	10	400	400	200	40%
R110			Change in Scope	15%	30	30	30	10	900	900	300	60%
R111			Too many Design changes	10%	30	30	30	10	900	900	300	60%
R112			Unproven Engineering and Construction Techniques	10%	10	10	10	10	100	100	100	20%
R113			Inefficient Construction Procedures	10%	20	20	20	20	400	400	400	40%
R114			Insufficient Resource Availability	15%	40	30	40	30	1200	**1600**	1200	80%
R115			Non-Compliance to Quality Requirements	10%	40	30	30	40	1200	1200	**1600**	80%
R116	Design Risk	Project Schedule Risk	Fast Track Schedule	50%	30	40	30	40	1200	900	1200	60%
R117			Project Duration	50%	30	40	30	40	1200	900	1200	60%

Risk ID	Risk Category [9]	Risk / Risk Factors [29]	Risk Attributes [133]	Attribute Weights	Probability Score	Cost Impact Score	Schedule Impact Score	Quality Impact Score	Cost Risk Factor	Time Risk Factor	Quality Risk Factor	Probability (%)
R118	Design Risk	Project Management Risk	Ineffective project planning and project monitoring	20%`	40	40	40	20	**1600**	**1600**	800	80%
R119			Time and cost escalation on account of ineffective resource utilization	10%	30	30	30	20	900	900	600	60%
R120			Management of Schedule Risks	20%	40	30	40	20	1200	**1600**	800	80%
R121			Unavailability of skilled Project Managers and Contractors	25%	40	30	40	20	1200	**1600**	800	80%
R122			Estimate Completeness	5%	30	30	30	20	900	900	600	60%
R123			Productivity of Resources	20%	40	40	40	30	**1600**	**1600**	1200	80%
R124	Force Majeure Risk	Force Majeure Risk	Damage to Structure, Sabatoge	45%	20	30	30	30	600	600	600	40%
R125			Natural Disaster	45%	10	10	10	20	100	100	200	20%
R126			Wars and Revolutions	10%	10	10	10	20	100	100	200	20%
R127	O&M Risk	Operations Management	Operator Incompetence	30%	40	20	10	40	800	400	**1600**	80%

Risk ID	Risk Category [9]	Risk / Risk Factors [29]	Risk Attributes [133]	Attribute Weights	Probability Score	Cost Impact Score	Schedule Impact Score	Quality Impact Score	Cost Risk Factor	Time Risk Factor	Quality Risk Factor	Probability (%)
R128		Risk	High Operating Cost	30%	20	50	10	40	1000	200	800	40%
R129			Operational Quality or Capacity	25%	30	20	30	40	600	900	1200	60%
R130			Economic Viability	15%	40	20	10	20	800	400	800	80%
R131	Customer Risk	Customer Risk	Demand Risk	40%	30	30	20	10	900	600	300	60%
R132			Social Impact Risk	20%	20	10	20	10	200	400	200	40%
R133			Market Environment Risk	40%	10	10	10	10	100	100	100	20%

Probability and Impact Scores for each risk attribute for all the three project objectives (Cost, Schedule and Quality) sought from experts on scale from 10 to 50 (10, 20, 30, 40 and 50). The factors were aggregated by taking Geometric Mean for each risk attribute. P-I scores were calculated by multiplying Probability score with Impact score for Schedule, Cost and Quality. P-I score higher than 1500 considered in Red Zone of Heat Map as per the details shown below.

Scores for Probability and Impact on Project objectives categorized as below:

PROBABILITY

Score	Description	Correspondance to the Risk Matrices	%
10	Rare: very small chance of happening	Low	20%
20	Unlikely: small chance of happening	Medium	40%
30	Likely: Likely to happen	High	60%
40	Expected: very high chance of happening or even certainty – this will happen	Very High	80%
50	Expected: very high chance of happening or even certainty – this will happen	Very High	100%

IMPACT

Score	Description	Correspondence to the Risk Matrices
10	Minor: very small impact. Even if the risk becomes reality, there will be negligible effect on the RF	Very Low
20	Moderate: impact is significant and noticeable. If financial risk, Sterling/Euro amount is significant but fixable with current resources; if strictly operational, it will affect operations but can be worked around.	Low
30	High: serious impact; challenges with working around it.	Moderate
40	Critical: critical impact; business reputation and income effectively being threatened, can prevent RF mission from being realized	High
50	Critical: critical impact; business reputation and income effectively being threatened, can prevent RF mission from being realized	Very High

High score of P-I Matrix is highlighted in Red which indicated critical risk attributes. Risk attributes were assigned a weights (%) basis their importance level contributing to the respective risk factors. These weightages were used to calculate the probability and Impact scores at risk factor level.

Table 4. 2 Risk Attributes count : P-I interval Impact on Cost

Probability						
50	Very High	0	0	0	0	0
40	High	0	5	6	6	2
30	Medium	1	7	27	9	2
20	Low	8	18	6	5	2
10	Very Low	25	2	0	2	0
		10 Very Low	20 Low	30 Moderate	40 High	50 Very High

Impact

Table 4.2 indicates no. of risk attributes lying in each range. that 12 risk attributes lie in Mitigate zone, i.e. critical and to mitigate. 52 risk attributes Manage zone, 34 in Monitor zone and 35 are in the 'Make Do' zone.

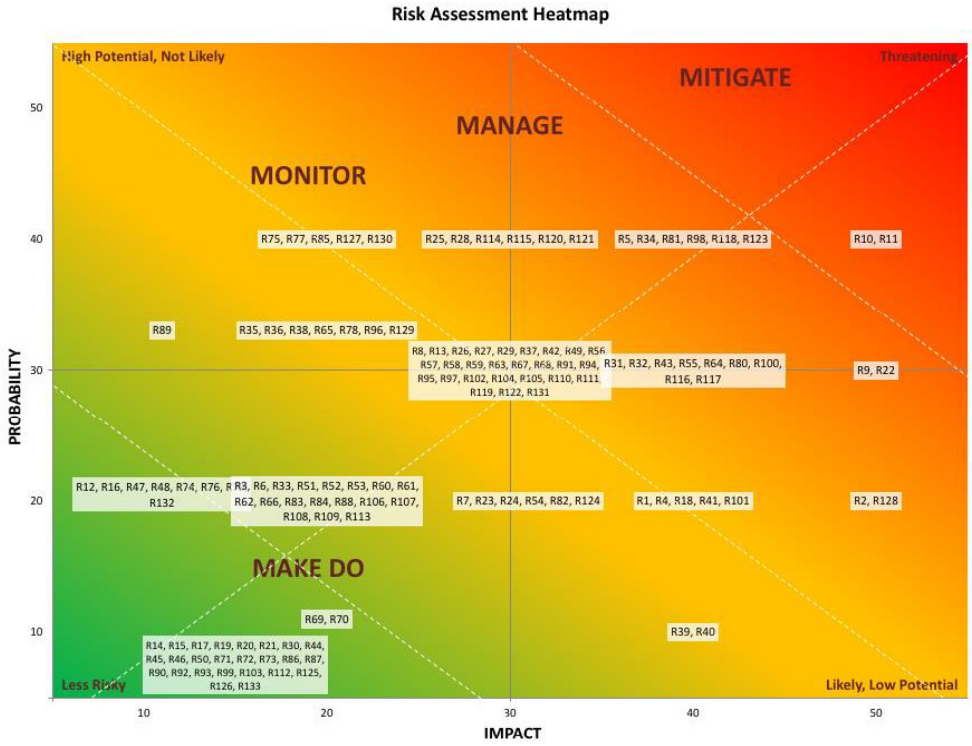

Fig. 4. 2 Risk Heat Map for Impact on Cost at the Risk Attribute level

The heat map in Fig.2 maps all the risk attributes in various risk zones depending on the criticality

Table 4. 3 Risk Attributes count P-I interval impact on Schedule

Probability						
50	Very High	0	0	0	0	0
40	High	6	0	2	8	3
30	Medium	3	3	26	12	2
20	Low	14	13	6	3	3
10	Very Low	26	1	1	1	0
		10 Very Low	20 Low	30 Moderate	40 High	50 Very High

Impact

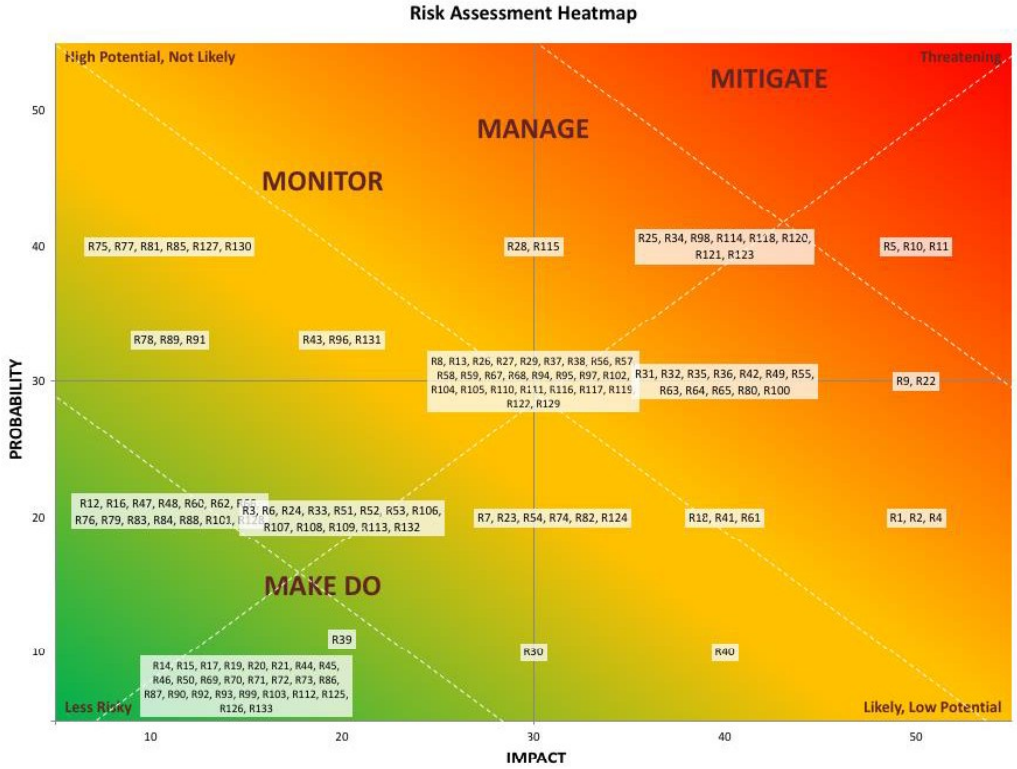

Fig. 4. 3 Risk Heat Map for Impact on Schedule at the Risk Attribute level

Table 4. 4 Risk Attributes count P-I interval Impact on Quality

Probability						
50	Very High	0	0	0	0	0
40	High	5	4	5	5	0
30	Medium	21	12	7	6	0
20	Low	25	10	3	1	0
10	Very Low	26	2	0	1	0
		10 Very Low	20 Low	30 Moderate	40 High	50 Very High

Impact

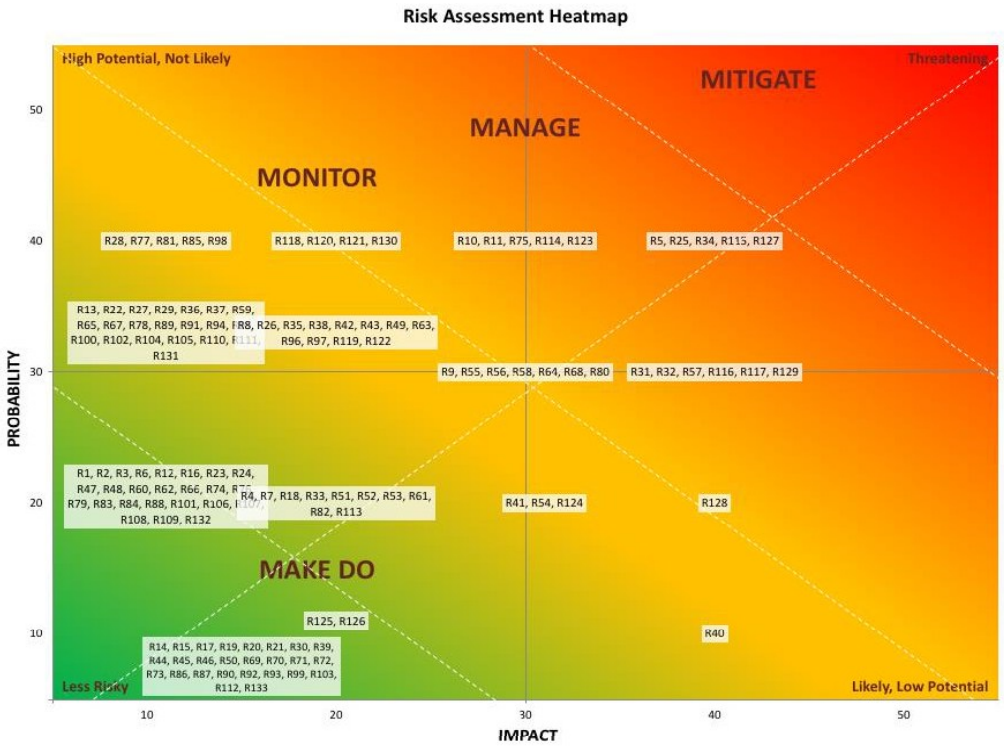

Fig. 4. 4 Risk Heat Map for Impact on Quality at Risk Attribute

Table 4. 5 Critical Risk Attributes as per the P-I Assessment matrix

Risk ID	Risk Category	Risk Factors	Risk Attributes	Probability	Cost	Schedule	Quality
R5	Design Risk	Scope Assessment Planning	Improper Resource Planning	40	40	50	40
R9	Design Risk	Timeline Assessment Planning	Improper Project Schedule	30	50	50	30
R10	Design Risk	Cost Assessment Planning	Cost Assessment	40	50	50	30
R11	Design Risk	Risk Assessment Planning	Inadequate Risks Assessment	40	50	50	30
R22	Construction Risk	Site Conditions - Location	Delay in permits and licenses	30	50	50	10
R25	Labor Risk	Resources - Labor Risk	Labor Skills Level/ Productivity	40	30	40	40
R34	Construction Risk	Resources-Equipment Risk	Equipment Maintenance	40	40	40	40
R81	Legal/ Political Risk	Financial Risk	Tax Rate Volatility	40	40	10	10
R98	Legal/ Political Risk	Regulatory Risk	Delay in regulatory approvals	40	40	40	10
R114	Construction Risk	Technical Risk	Insufficient Resource Availability	40	30	40	30
R115	Construction Risk	Technical Risk	Non-Compliance to Quality Requirements	40	30	30	40
R118	Design Risk	Project Management Risk	Ineffective project planning and project monitoring	40	40	40	20
R120	Design Risk	Project Management Risk	Management of Schedule Risks	40	30	40	20
R121	Design Risk	Project Management Risk	Unavailability of skilled Project Managers	40	30	40	20

Risk ID	Risk Category	Risk Factors	Risk Attributes	Probability	Cost	Schedule	Quality
			and Contractors				
R123	Design Risk	Project Management Risk	Productivity of Resources	40	40	40	30

The above Table 4.5 indicates all critical Risk attributes with high P-I scores and are critical to mitigate. R5 and R34 attributes impact all the three Project objectives whereas R9, R10, R11, R22, R98, R118 and R123 impact both Cost and Schedule objectives.

4.4.2 Probability Impact Assessment at Risk Factor Level

Table 4. 6 Probability and Impact Ratings at Risk Factor Level

S. No.	Risk Category	Risk Factor	Probability	Cost Score	Schedule Score	Quality Score
1	Commercial Risk	Commercial Risk	20	20	20	10
2	Construction Risk	Environmental	20	20	20	10
3	Construction Risk	Site Sub-surface	20	20	20	10
4	Construction Risk	Site Location	20	30	30	10
5	Construction Risk	Equipment	30	40	40	40
6	Construction Risk	Material	30	30	40	20
7	Construction Risk	Contractor	30	30	30	20
8	Construction Risk	Project Management (PMC)	20	20	20	10
9	Construction Risk	Land Acquisition Risk	10	10	20	10
10	Construction Risk	Technical Risk	30	20	30	20

S. No.	Risk Category	Risk Factor	Probability	Cost Score	Schedule Score	Quality Score
11	Construction Risk	Socio-Economic Risk	30	30	30	10
12	Customer Risk	Customer Risk	20	20	20	10
13	Design Risk	Pre-bid Assessment Planning	20	40	40	10
14	Design Risk	Scope Assessment Planning	30	40	50	30
15	Design Risk	Timeline Assessment Planning	30	50	50	30
16	Design Risk	Cost Assessment Planning	40	50	50	30
17	Design Risk	Risk Assessment	40	50	50	30
18	Design Risk	Project Owner Engagement	10	10	10	10
19	Design Risk	Engineering and Design Team	20	20	30	20
20	Design Risk	Project Schedule Risk	30	40	30	40
21	Design Risk	Project Management Risk	40	30	40	20
22	Design Risk	Regulatory Framework Planning	20	30	30	20
23	Financial Risk	Financial Risk	20	20	10	10
24	Force Majeure	Force Majeure Risk	10	20	20	20
25	Labor Risk	Labor	30	30	30	10
26	Legal / Political Risk	Political Risk	20	20	10	10

S. No.	Risk Category	Risk Factor	Probability	Cost Score	Schedule Score	Quality Score
27	Legal and Political Risk	Regulatory Risk	30	20	20	10
28	Legal and Political Risk	Legal Risk	30	40	30	10
29	Operations and Management Risk	Operations & Management Risk	30	30	10	30

Table 4.6 has been arrived by working out Probability and Impact factors for Cost, Schedule and Quality based on the weightage assigned to each attribute as indicated in Table 4.1. Heat Maps for P-I for each objective has been carried out as indicated below.

Probability- Impact Assessment at the Risk Factor level

Table 4. 7 Risk Factors count - P-I interval Impact Cost (RF)

Probability						
50	Very High	0	0	0	0	0
40	High	0	0	1	0	2
30	Medium	0	2	5	4	1
20	Low	0	8	2	1	0
10	Very Low	2	1	0	0	0
		10 Very Low	20 Low	30 Moderate	40 High	50 Very High
				Impact		

Table 4.7 indicates that 3 risk factors lie in Mitigate zone, i.e. critical and to mitigate. 11 risk factors in Manage zone, 12 in Monitor zone and 3 are in the 'Make Do' zone.

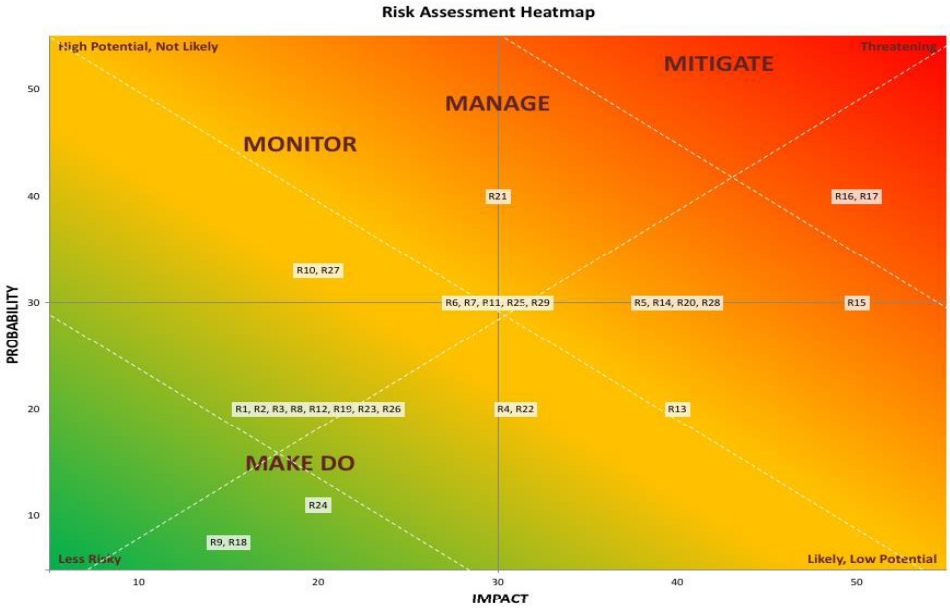

Fig. 4. 5 Risk Heat Map for Impact on Cost at the Risk Factor level

Table 4. 8 Risk Factors count P-I interval impact on Schedule (RF)

Probability						
50	Very High	0	0	0	0	0
40	High	0	0	0	1	2
30	Medium	1	1	6	2	2
20	Low	2	5	3	1	0
10	Very Low	1	2	0	0	0
		10 Very Low	20 Low	30 Moderate	40 High	50 Very High
		Impact				

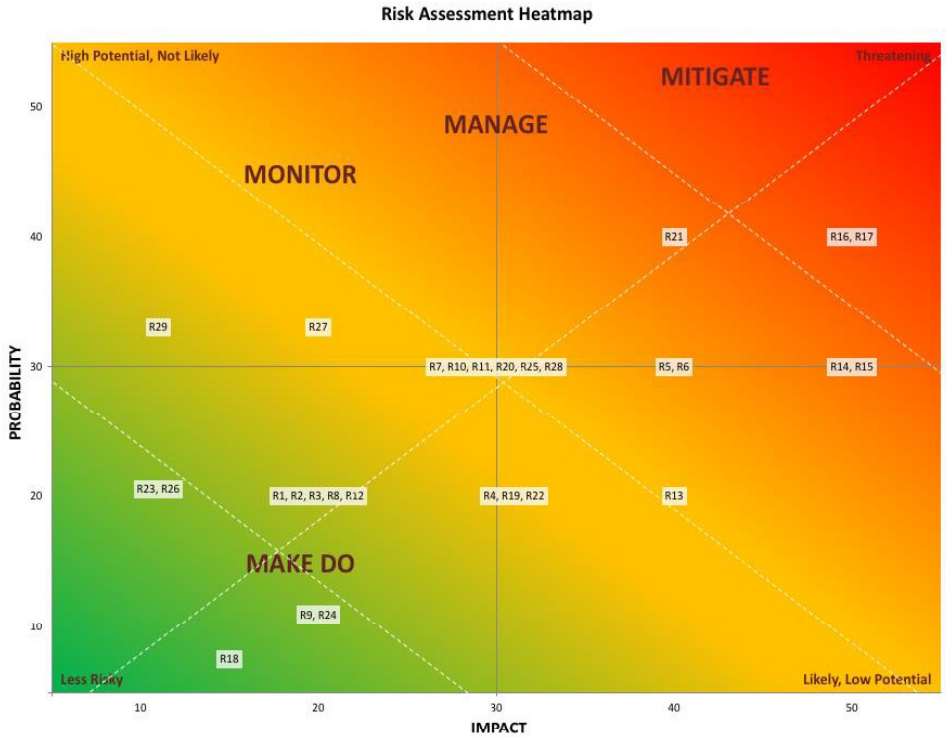

Fig. 4. 6 Risk Heat Map for Impact on Schedule at the Risk Factor level

Table 4. 9 Risk Factors count P-I interval Impact Quality

Probability						
50	Very High	0	0	0	0	0
40	High	0	1	2	0	0
30	Medium	4	3	3	2	0
20	Low	9	2	0	0	0
10	Very Low	2	1	0	0	0
		10 Very Low	20 Low	30 Moderate	40 High	50 Very High
		Impact				

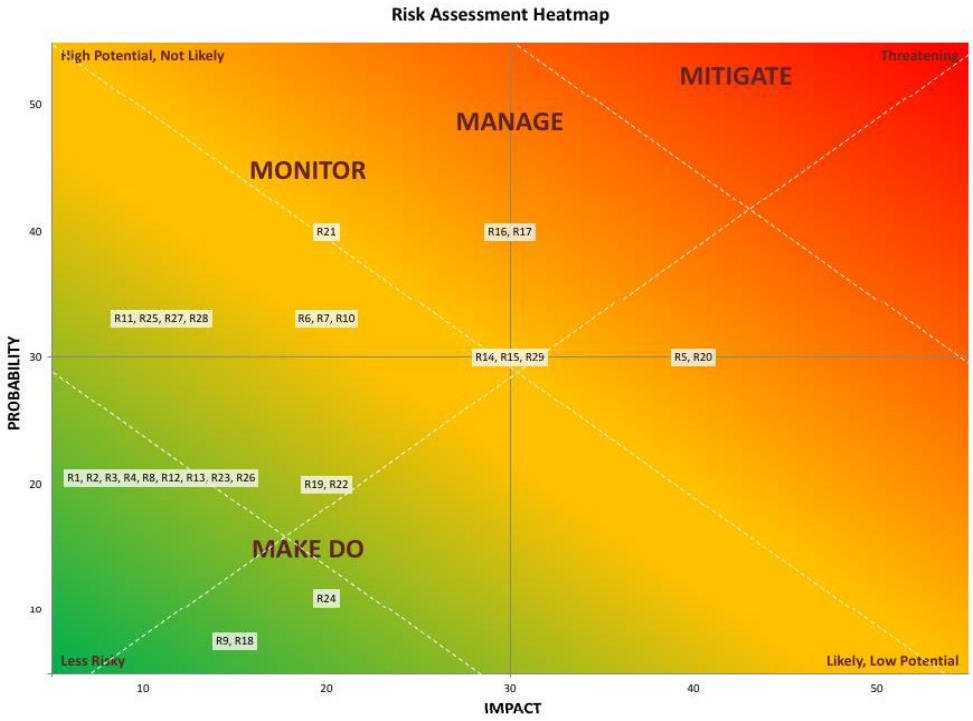

Fig. 4. 7 Risk Heat Map for Impact on Schedule at the Risk Factor level

Table 4.10 below indicate the weighted risk scores for Cost, Time and Quality at risk factor level. It also mentions the weightages for each risk factor contributing to the respective risk category. Impact Score is calculated by multiplying the weightages with respective scores and summing up for respective Risk factor. Same aggregation calculation is carried our for calculating Probability and Impact score at Risk category level.

Table 4. 10 Weightage for Risk Factor contributing to Risk categories

S. No.	Risk Category	Risk/ Risk Factor	Probability Score Risk Category (RC)	Impact Score Cost	Impact Score Schedule	Impact Score Quality	Weightage	Probability Score (Risk Factor)	Impact Score Cost (RF)	Impact Score Schedule (RF)	Impact Score Quality (RF)
1	Commercial Risk	Commercial Risk	20	20	20	10	100%	20	20	20	10
2	Construction Risk	Environmental	30	30	30	20	5%	20	20	20	10
3	Construction Risk	Site Sub-surface					5%	20	20	20	10
4	Construction Risk	Site Location					5%	20	30	30	10
5	Construction Risk	Equipment					15%	30	40	40	40
6	Construction Risk	Material					10%	30	30	40	20
7	Construction Risk	Contractor					15%	30	30	30	20
8	Construction Risk	Project Management (PMC)					10%	20	20	20	10
9	Construction Risk	Land Acquisition Risk					5%	10	10	20	10
10	Construction Risk	Technical Risk					20%	30	20	30	20

S. No.	Risk Category	Risk/ Risk Factor	Probability Score Risk Category (RC)	Impact Score Cost	Impact Score Schedule	Impact Score Quality	Weightage	Probability Score (Risk Factor)	Impact Score Cost (RF)	Impact Score Schedule (RF)	Impact Score Quality (RF)
11	Construction Risk	Socio-Economic Risk					10%	30	30	30	10
12	Customer Risk	Customer Risk	20	20	20	10	100%	20	20	20	10
13	Design Risk	Pre-bid Assessment Planning	20	30	30	20	10%	20	40	40	10
14	Design Risk	Scope Assessment Planning					10%	30	40	50	30
15	Design Risk	Timeline Assessment Planning					10%	30	50	50	30
16	Design Risk	Cost Assessment Planning					10%	40	50	50	30
17	Design Risk	Risk Assessment					10%	40	50	50	30
18	Design Risk	Project Owner Engagement					10%	10	10	10	10
19	Design Risk	Engineering and Design Team					10%	20	20	30	20
20	Design Risk	Project Schedule Risk					10%	30	40	30	40
21	Design Risk	Project Management Risk					10%	40	30	40	20

S. No.	Risk Category	Risk/ Risk Factor	Probability Score Risk Category (RC)	Impact Score Cost	Impact Score Schedule	Impact Score Quality	Weightage	Probability Score (Risk Factor)	Impact Score Cost (RF)	Impact Score Schedule (RF)	Impact Score Quality (RF)
22	Design Risk	Regulatory Framework Planning					10%	20	30	30	20
23	Financial Risk	Financial Risk	20	20	10	10	100%	20	20	10	10
24	Force Majeure	Force Majeure Risk	10	20	20	20	100%	10	20	20	20
25	Labor Risk	Labor	30	30	30	10	100%	30	30	30	10
26	Legal and Political Risk	Political Risk	30	30	20	10	20%	20	20	10	10
27	Legal and Political Risk	Regulatory Risk					40%	30	20	20	10
28	Legal and Political Risk	Legal Risk					40%	30	40	30	10
29	Operations and Management Risk	Operations & Management Risk	30	30	10	30	100%	30	30	10	30

4.4.3 Probability and Impact Assessment at Risk Category Level

Table 4. 11 Probability and Impact Rating scores at-risk category level

S. No.	Risk Category	Probability	Cost Risk	Schedule Risk	Quality Risk
R1	Commercial Risk	20	20	20	10
R2	Construction Risk	30	30	30	20
R3	Customer Risk	20	20	20	10
R4	Design Risk	20	30	30	20
R5	Financial Risk	20	20	10	10
R6	Force Majeure	10	20	20	20
R7	Labor Risk	30	30	30	10
R8	Legal and Political Risk	30	30	20	10
R9	Operations and Management Risk	30	30	10	30

The above factors have been calculated based on the weights assigned to Risk factors basis inputs from experts and have been revalidated for final consideration. The Risk counts and heat maps have been worked, as shown in Table 4.12 - 4.14 and Fig. 4.7 - 4.9 below.

Probability- Impact on Cost at Risk Category Level

Table 4. 12 Probability – Impact on Cost at Risk category level

S. No.	Risk Category	Probability	Cost Risk	Cost Risk Factor	Probability %
R1	Commercial Risk	20	20	400	40%
R2	Construction Risk	30	30	900	60%
R3	Customer Risk	20	20	400	40%
R4	Design Risk	20	30	600	40%
R5	Financial Risk	20	20	400	40%
R6	Force Majeure	10	20	200	20%
R7	Labor Risk	30	30	900	60%
R8	Legal and Political Risk	20	30	600	40%
R9	Operations and Management Risk	30	30	900	60%

P-I score calculated by multiplying risk Probability score with Impact score for Cost related project objective.

Table 4. 13 Risk Factors count for each P-I interval for Impact on Cost

Probability						
50	Very High	0	0	0	0	0
40	High	0	0	0	0	0
30	Medium	0	1	3	0	0
20	Low	0	3	1	0	0
10	Very Low	0	1	0	0	0
		10 Very Low	20 Low	30 Moderate	40 High	50 Very High

Impact

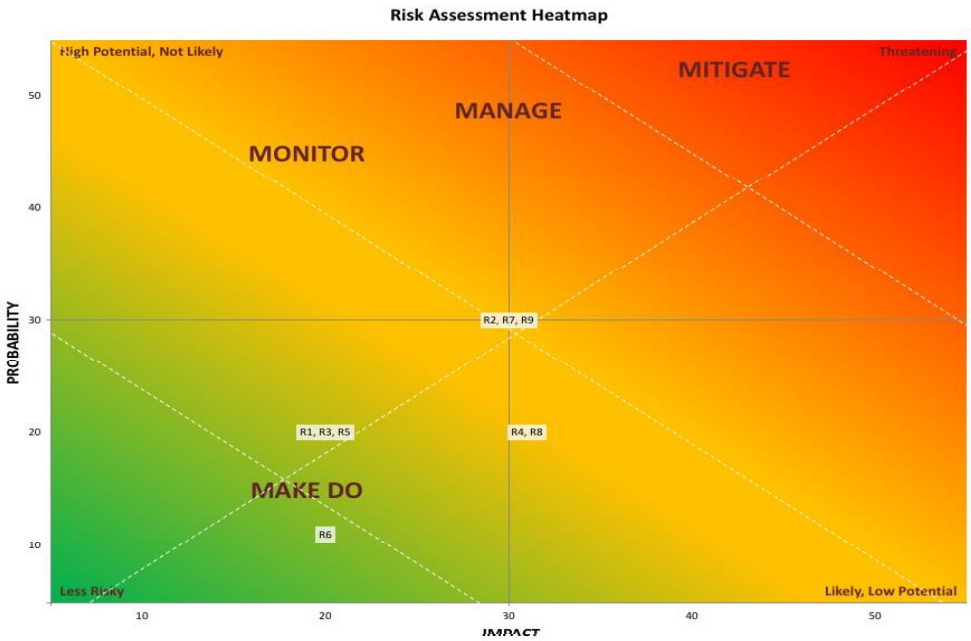

Fig. 4. 8 Risk Heat Map for Impact on Cost at Risk Category level

Table 4. 14 Probability – Impact on Schedule at Risk category level

S. No.	Risk Category	Probability	Schedule Risk	Schedule Risk Factor	Probability %
R1	Commercial Risk	20	20	400	40%
R2	Construction Risk	30	30	900	60%
R3	Customer Risk	20	20	400	40%
R4	Design Risk	20	30	600	40%
R5	Financial Risk	20	10	200	40%
R6	Force Majeure	10	20	200	20%
R7	Labor Risk	30	30	900	60%
R8	Legal and Political Risk	20	20	400	40%
R9	Operations & Management Risk	30	10	300	60%

Table 4. 15 Risk Factors count P-I interval Impact on Schedule

Probability						
50	Very High	0	0	0	0	0
40	High	0	0	0	0	0
30	Medium	1	1	2	0	0
20	Low	1	2	1	0	0
10	Very Low	0	1	0	0	0
		10 Very Low	20 Low	30 Moderate	40 High	50 Very High
				Impact		

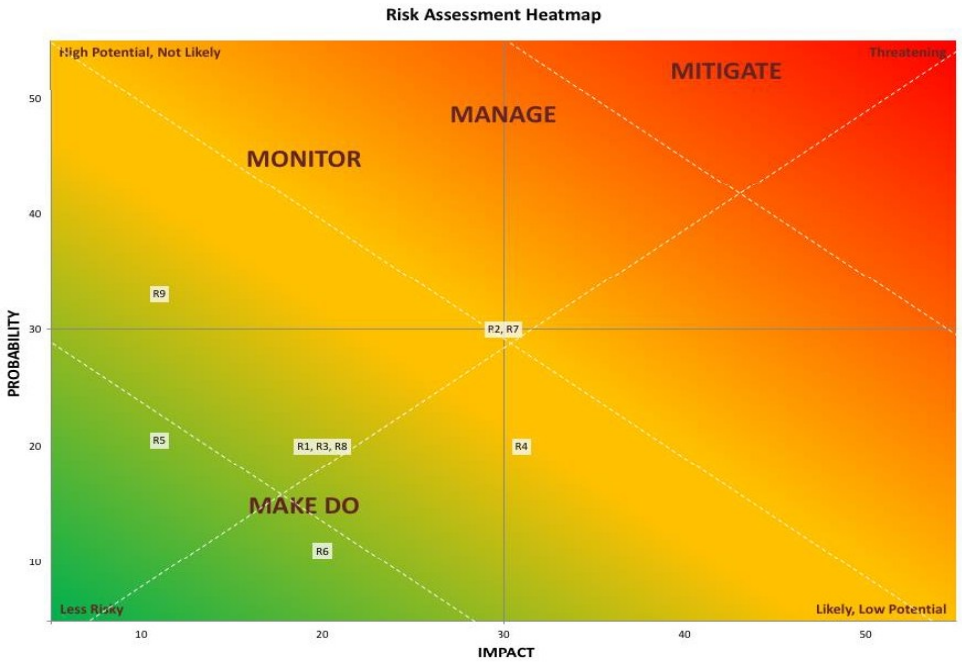

Fig. 4. 9 Risk Heat Map for Impact on Schedule at Risk Category level

Table 4. 16 Probability – Impact on Quality at Risk category level

S.No.	Risk Category	Probability	Quality Risk	Quality Risk Factor	Probability %
R1	Commercial Risk	20	10	200	40%
R2	Construction Risk	30	20	600	60%
R3	Customer Risk	20	10	200	40%
R4	Design Risk	20	20	400	40%
R5	Financial Risk	20	10	200	40%
R6	Force Majeure	10	20	200	20%
R7	Labor Risk	30	10	300	60%
R8	Legal and Political Risk	20	10	200	40%
R9	Operations & Management Risk	30	30	900	60%

Table 4. 17 Risk Factors count - P-I interval Impact on Quality

Probability						
50	Very High	0	0	0	0	0
40	High	0	0	0	0	0
30	Medium	2	1	1	0	0
20	Low	3	1	0	0	0
10	Very Low	0	1	0	0	0
		10 Very Low	20 Low	30 Moderate	40 High	50 Very High

Impact

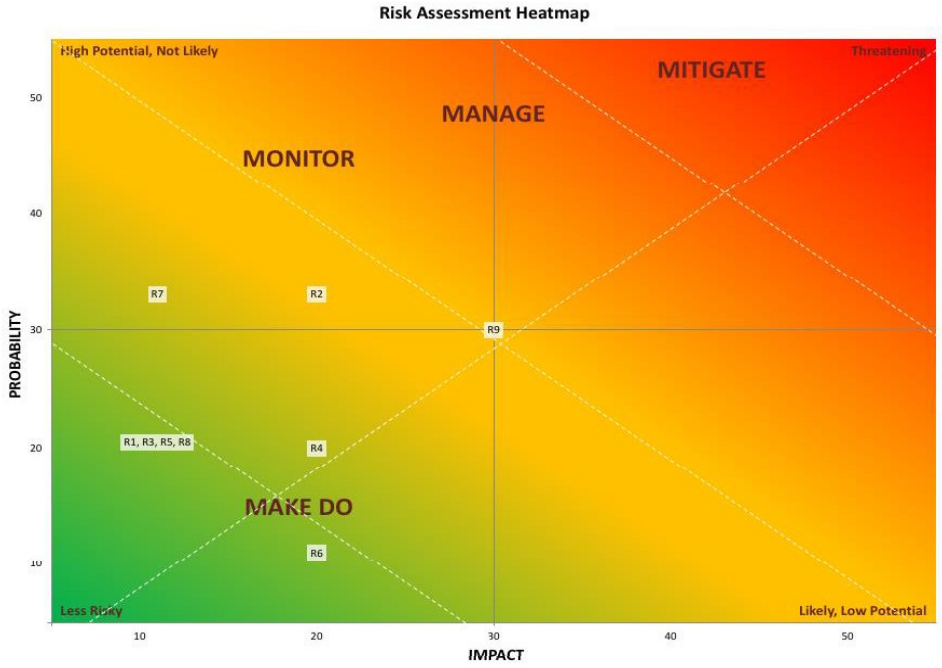

Fig. 4. 10 Risk Heat Map for Impact on Schedule at Risk Category level

4.5 Conclusion

The above results indicate that the results are not consistent while the risk assessment is made at risk attribute, contributing risk factors and at-risk category level. Though risk attributes correspond to the Risk factors, the importance, the probability and the impact is not translated above. This is one of the major risk assessment gaps, which is required to be addressed. A framework has been developed in this research work to cater to such complexities on ground Risk Assessment carried out by project risk managers.

The P-I method has not used any dependencies of risk factors among them. Moreover, this is one of the reasons that risk attributes were not able to translate the same to risk factors. Though there is a good indication, however, priorities are highly difficult to be ascertained.

In mega infrastructure logistics projects, it is very important that the risks are properly identified and addressed. ANP is an important tool to address the problem. The same has been dealt with in details, and both the methods are compared to arrive on the decisive results.

In the next chapter, the nine risk categories have been modelled to study feasible scenarios of their interaction among risk categories. Analytic hierarchy process (ANP) is used to study the interdependencies among the risk categories obtained through risk map/ heat map analysis performed in this chapter 4.