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Risk Assessment and Management of Underground Metro Construction (Bengaluru Scenario)

Shaik Umar Faruq, Yalamanjula Venkata Archan, Maddikera Lokanath Reddy

Abstract*: Construction projects are characterized as very complex projects, where uncertainties are part of it. Risk is an uncertain event or condition that, if it occurs, has a positive or a negative impact on one or more project objectives, such as time, cost, scope or quality. Risk management includes the process concerned with the conducting the risk identification, analysis, responses and management planning and control on a project The study aims at carrying out the risk assessment and management process in the construction of Bangalore Underground Metro project. At first, the risks associated with the project and also with the similar projects in past are identified and listed based on the historic reviews, interviews and literature review. A questionnaire survey is prepared for the risks that are listed and probability and impact of these risks on the projects are found out, and risks are prioritized based on the risk index score which forms the probability-impact matrix and risk register is formed. A schedule is prepared in Primavera P6, and then integrated with Primavera Risk Analysis (PERT Master) software which analyze the schedule for the risk events assigned to the activities and for the defined probability distributions and then schedule of the project is simulated using the Monte Carlo simulation for the both pre mitigated and the post mitigated analysis, and then results are compared. Response strategies are suggested for the moderate to higher priorities risks.

Keywords: Risk, Project objectives, Questionnaire survey, Risk index score, Probability-Impact Matrix, Primavera Risk Analysis, Monte Carlo simulation, Pre mitigated, Post mitigated analysis, Response strategies.

I. INTRODUCTION

Construction project are complex in nature and have more uncertainties from different sources of project and it is a crucial sector for nation economy and also due to labor intensiveness, mobility, diversity and, which makes industry risky. it involves many stakeholders which makes difficult to review the networks in construction. Risk management is an integral part of the project management.

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For an infrastructure project, it is often distributed effectively by identifying & investigating the sources of risks related to each activity of the project. These risks consists of likelihood and impact. The key activities in underground corridor construction accommodates design, traffic diversion, utility diversion, survey works, soil excavation, steel struts, installations, backfilling and restoration. The questionnaire survey and interviews carried for identification and assessment of various risks atdifferent phases of project.

A. Aim

Aim of the study is to identification of risks factors in the construction of Bangalore Underground Metro project and suggesting the mitigation measures of those risks.

B. Objective of the Study

- To make out various risks factors in construction of Bangalore underground metro project.
- To analyze the identified risks qualitative by questionnaires surveys, experts' interviews and preparing the probability impact matrix.
- To analyze the risks quantitatively using the primavera risk analysis and assess the impact on estimated schedule of the project.
- To plan the mitigation measures for the analyzed risks.

II. METHODOLOGY

In The methodology for the project is given below

- Literature study related to risk analysis and risk management and simulation methods related to metro construction and tunneling projects.
- Identifications of sources and types of risk events in underground metro project.

Preparation of questionnaire survey based on the literature review, brain storming and expert interviews related to project.

- Collection of responses for identified risks i.e., impact of risk on the project objectives.
- Analyzing the data collected by qualitative process and preparing the probability- impact matrix.
- Quantitative analysis for schedule using simulation technique by using Primavera Risk analysis.
- Suggestion of mitigation measures for medium to high risk.
- Conclusion, recommendations and suggestion for future study.

A. Risk Identification

The literature review in risk management with special reference to metro rail construction provides a list of possible risks that may occur during the project and the risks are broadly categorized as:

1. Geological risks
2. Design risks
3. Construction risks
4. Legal risks

5. Financial risks
6. Management risks
7. Policy and Political risks
8. Environmental risks
9. Social risks
10. Safety risks

The identified risks are then converted into a form of questionnaire with a probability of occurrence and possible impacts on schedules and cost ranking from 0-5 as given in table I

Table- I: Ranking of Probability and Impact

Categor y	Very Low	Lo w	Mod erat e	Hig h	Very High
Probab ility	1	2	3	4	5
Impact	1	2	3	4	5

B. Data Collection

This thesis is based on the Bangalore Underground metro project package 2. The project involves Design & Construction of Underground structures (Tunnel & Stations) of total length 2.76 Km in package 2 and the stations are Vellara, MG Road, Shivaji Nagar station with estimated cost of 1329.14 crores for package 2 and Cantonment, Pottery Town in package 3 with 1299.23 crores for package 3 and the period of construction is 1259 days. The questionnaire survey is floated among the project managers and engineers involved in the project for collecting responses for identified of risks.

C. Method of Surveying

The study relies mainly on the survey questionnaire and the data received from the project manager, engineers, personnel related to project by mail and personnel meeting.

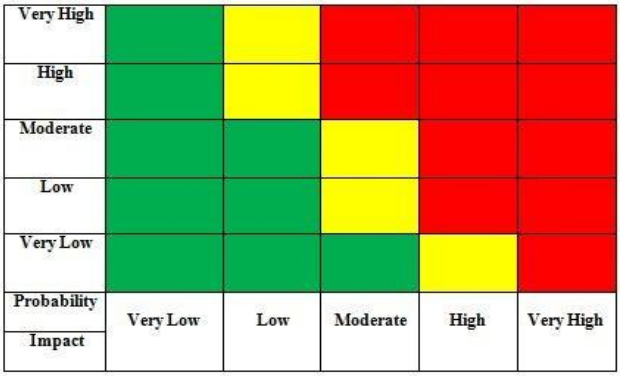
D. Questionnaire Structure

Risk factors and their categorization for this study are classified as follows:

1. Geological risks
2. Design risks
3. Construction risks
4. Legal risks
5. Financial risks
6. Management risks
7. Policy and political risks
8. Environmental risks
9. Social risks
10. Safety risks.

Risk are prioritized for the quantitative analysis based on the risk index score from analyzing the survey result and rating are given for the risks based on the likelihood and impact and further risks are categories and prioritized using the probability and impact matrix and each risks is added to probability and impact matrix to know the categorization as high risk ,moderate risk and low risk its degree of severity on the project objectives. Table shows the 5x5 probability-impact matrix used for the project.

Table- II: Ranking of Probability and Impact



The matrix gives the information regarding the probability and impact of various risk level base on the risk rating and then categorized into the low(green), moderate(yellow) and high risk(red), often the Moderate to high risk are focused more and addressed in detail. The definition of various risk levels is given below and their acceptance criteria.

Table- III: Definition of Risk

Risk Level	Action and Time scale	Category
LOW	No immediate measure required and are kept in the watch list, periodic monitoring made to ensure that the controls are effectively implemented.	Acceptable
MODERATE	Actions are required to control, like engineering/administrative/operation/safety/training /behavior monitoring	Not Acceptable
HIGH	Immediate action is required, work should not start until the impact/risk is reduced completely	Not Acceptable

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Table- IV: Defined conditions for Probability of occurrence of risks

Probab ility	Very Low	Lo w	Mo der ate	Hig h	Ver y Hig h
values	<10%	10-30%	30-60%	60-80%	>80%
Probab ility	Very Low	Lo w	Mo der ate	Hig h	Ver y Hig h

The range of percentages for impact on schedule and cost are defined below and are adopted for the analysis are risks in the project.

Table- V: Defined conditions for Impact of risk on schedule and cost

Impa ct	Ver y Low	Lo w	Mod er at e	Hig h	Ver y Hig h
Schedule	<2%	2-4%	5-8%	9-12%	>12%
Cost	<1%	1-2%	2-4%	5-8%	>8%

E. Quantitative risk analysis using Primavera Risk

The quantitative risk analysis is done by the Monte Carlo simulation technique using the primavera risk analysis software developed by oracle.

III. QUNATITATIVE RISK ANALYSIS USING PRIMAVERA RISK

The quantitative risk analysis is done by the Monte Carlo simulation technique using the primavera risk analysis software developed by oracle.

A. Primavera Risk Analysis Software (PERT Master)

Primavera Risk Analysis adopts the Monte Carlo simulation techniques which gives the extensive possibilities for the project by replacing deterministic values of the project with the probability distributions for task durations and quantifying uncertainty to assess contingencies, and also risks factors are described for the events that effect the project schedule and developing a risk factors on the project model by simulating the many hundreds or thousands of times, choosing most likely minimum and maximum duration values for the defined activities.

In general, the technique in primavera risk analysis encompass five steps:

- Schedule validation- the schedule of the project is validated for the identifying the basic defects in the schedule and are corrected before proceeding to pre analysis check.
- Developing the risk model- defining the problem or uncertainties for the deterministic duration by developing the pessimistic, most likely and optimistic duration to schedule by using the duration quick risk.
- Identification of uncertainties- assign the risk factors that are specified by probability of occurrence and impact on the project objectives with probability distribution for duration
- Analysis the model - the model is analyzed using the Monte Carlo simulation for determining the ranges and probability outcomes for events and contingencies for the project.
- Decision making – based on the results obtained and decision is taken for the project.

Importing the schedule and schedule validation

B. Importing the schedule and schedule validation

Fig 1 shows the part of schedule is imported and schedule validation is performed for identifying the basic defects in schedule and correction are made for the major defects before proceeding to schedule preanalysis check. Fig 2 gives part of the report for the schedule validation.

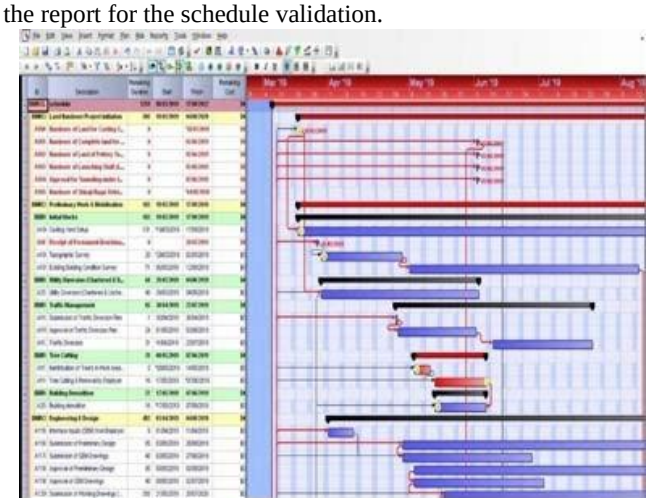

Fig. 1. Part of schedule of the project imported to primavera risk analysis.

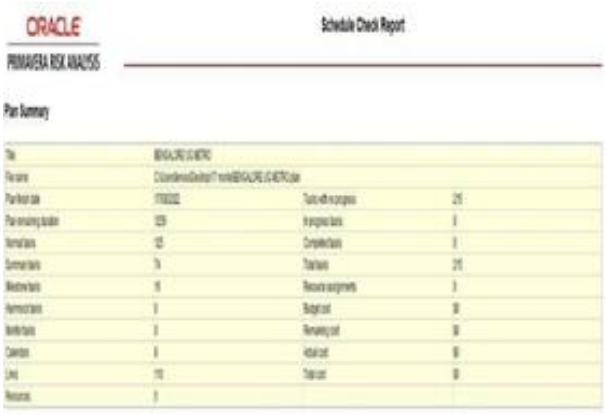

Fig. 2. Plan summary of the schedule validation report.

C. Performing pre-risk analysis

Assigning the Duration quick Risk values for the task and templated risks values used for the selected activities.

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And the values are based on the according to the uncertainties associated with the project and risk analysis is performed prior to the risks that are assigned to task for the determine values of uncertainties that is duration quick values for the activities to know the probability of completion of the project

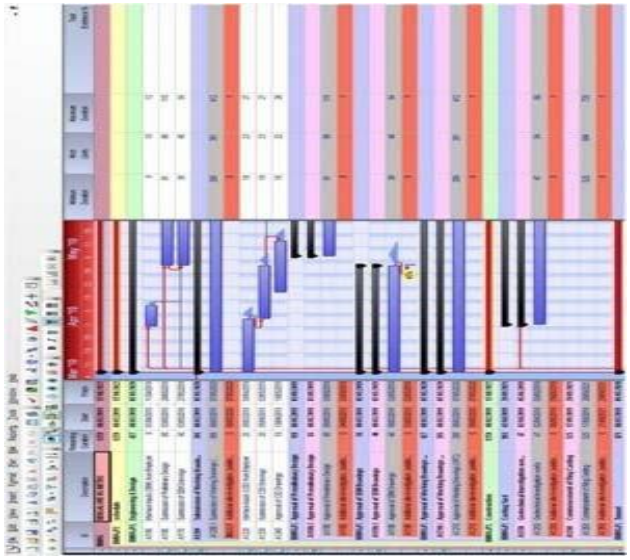

Fig. 3. Quick risk values loaded for pre risk analysis.

D. Develop and import the risk model

The risk model is developed or imported for prepared risk register and mapping of the risk events to the schedule tasks and the assigned schedule risk task are analyzed using the triangular and uniform distribution.

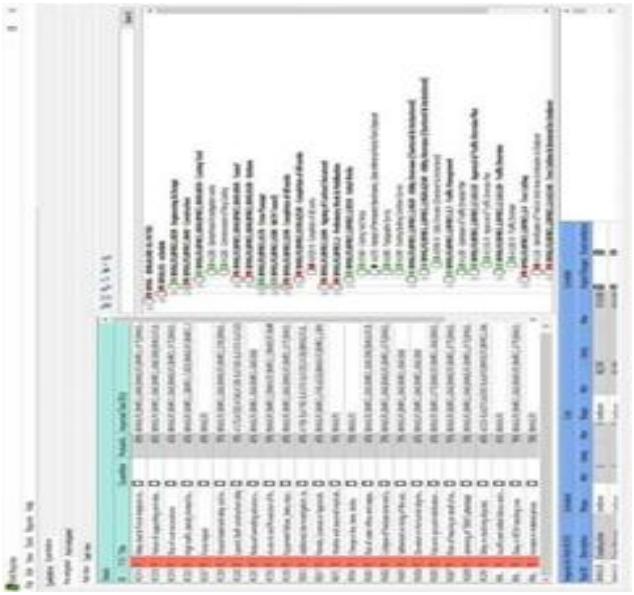

Fig. 4. Mapping of risk event to schedule tasks.

E. Carrying out Monte Carlo analysis

The probability distribution for the simulation is selected and the developed model is run for the monte Carlo simulation. The number iteration is kept as 1000 and also 5000 iteration is performed to check variation in the output obtained. The model is simulated for the triangular. Fig simulation of schedule of the project using primavera risk analysis.

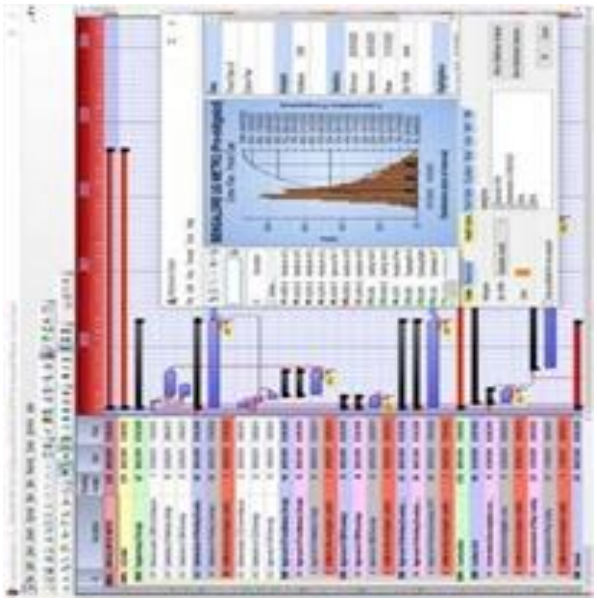

Fig. 5. Simulation of schedule and distribution graph for the project in primavera risk analysis.

IV. RESULT & DISCUSSION

The questionnaire survey, expert interviews and other document analysis has identified the total of 87 out of these 75 are potential risks to the project and out of these 43 risks are major threats that varying from medium to high risks to the project..

A. Qualitative Analysis

The results of qualitative analysis are compiled into an excel sheet. The summary of the analysis of and the risk categories are presented below in given table

Very High					
High				GEOTECHNICAL	
Moderate		MARKET	FINANCIAL SAFETY	CONSTRUCTION DESIGN ENVIRONMENTAL	
Low		SOCIAL	LEGAL MANAGEMENT POLITICAL AND POILCY		
Very Low					
Probability / Impact	Very Low	Low	Moderate	High	Very High

Fig. 6. Probability – Impact Matrix for Schedule of the project.

The results are summarized based on average risk index score and out of those Construction, Design, Environmental, Geotechnical are high risk and Financial, legal, Management, Political & policy and Safety are medium risk and market social are lower risk to schedule of the project.

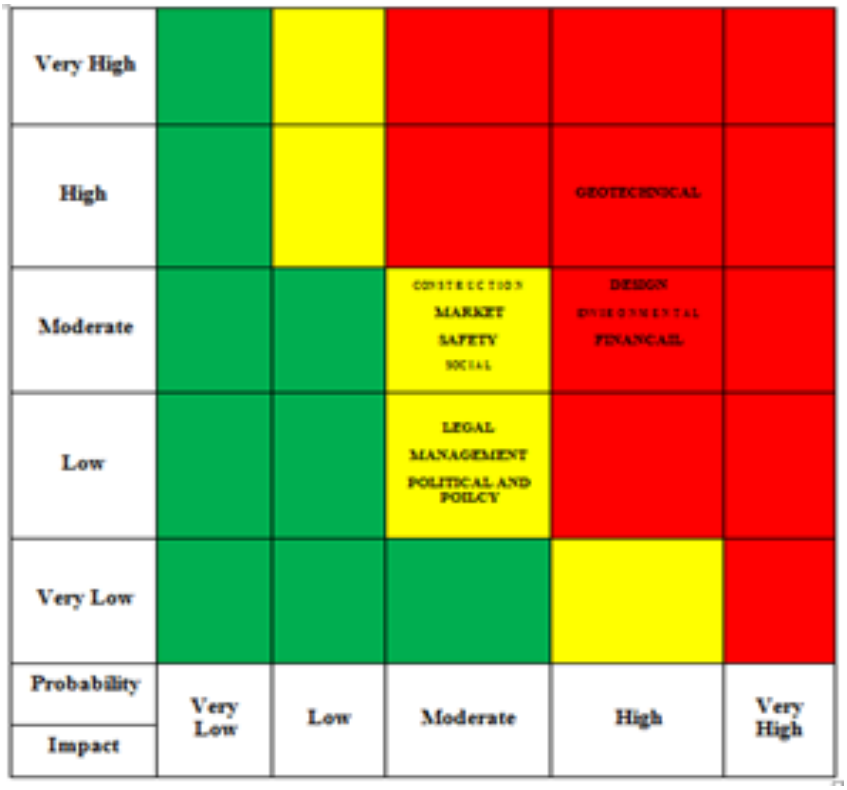

Fig. 7.Probability – Impact Matrix for Cost of the project.

B. Pre-Mitigation Schedule Risk Analysis

Table- VI: Pre-mitigated Schedule risk analysis results for Iteration 1000

Summary Statistics of Pre mitigated analysis for the Total Duration (Iteration 1000)			
Percentile	Date of Completion	Percentile	Duration
0%	26/09/2022	0%	1299 days
5%	20/10/2022	5%	1323 days
10%	27/10/2022	10%	1330 days
15%	2/11/2022	15%	1336 days
20%	7/11/2022	20%	1341 days
25%	10/11/2022	25%	1344 days
30%	14/11/2022	30%	1348 days
35%	17/11/2022	35%	1351 days
40%	23/11/2022	40%	1357 days
45%	29/11/2022	45%	1363 days
50%	2/12/2022	50%	1366 days
55%	8/12/2022	55%	1372 days
60%	14/12/2022	60%	1378 days
65%	21/12/2022	65%	1385 days
70%	29/12/2022	70%	1393 days
75%	9/1/2023	75%	1404 days
80%	20/01/2023	80%	1415 days
85%	2/2/2023	85%	1428 days
90%	17/02/2023	90%	1443 days
95%	13/03/2023	95%	1467 days
100%	4/5/2023	100%	1519 days

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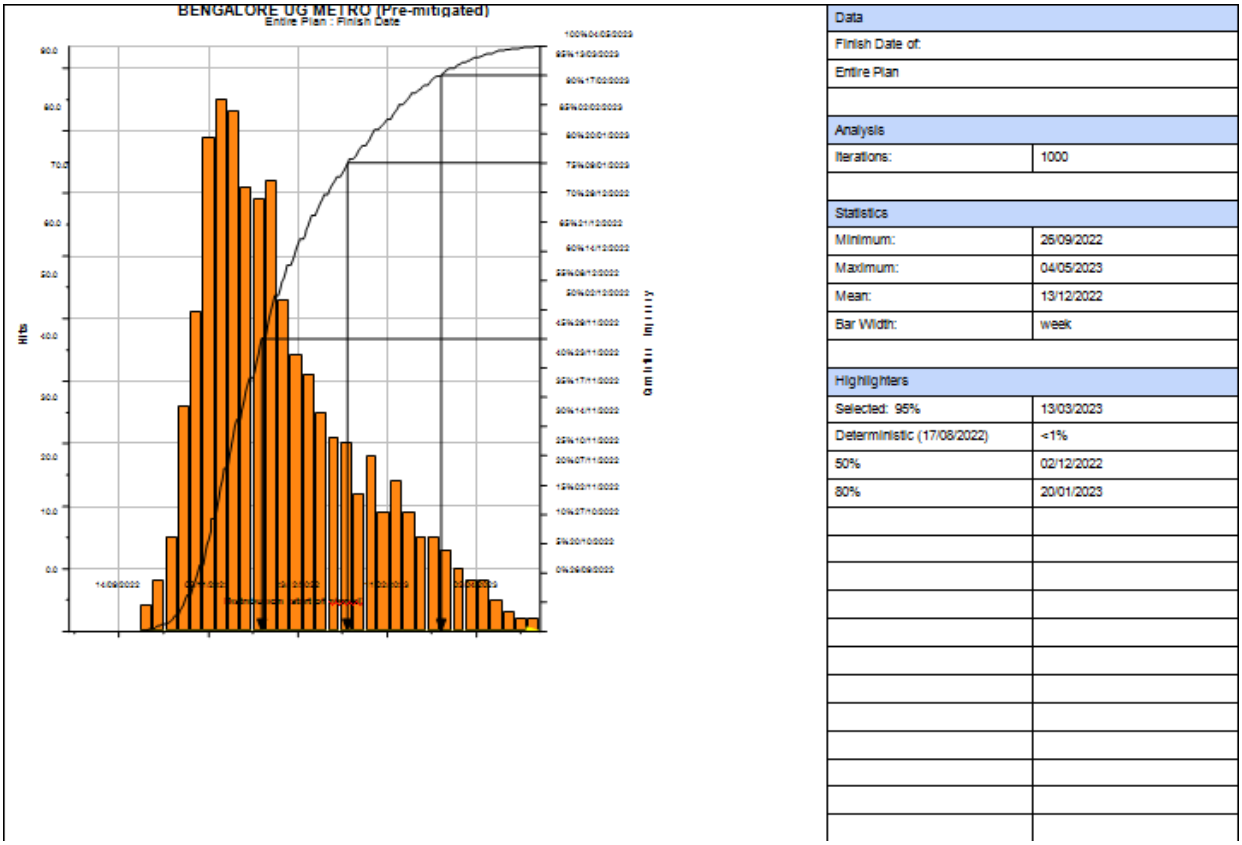
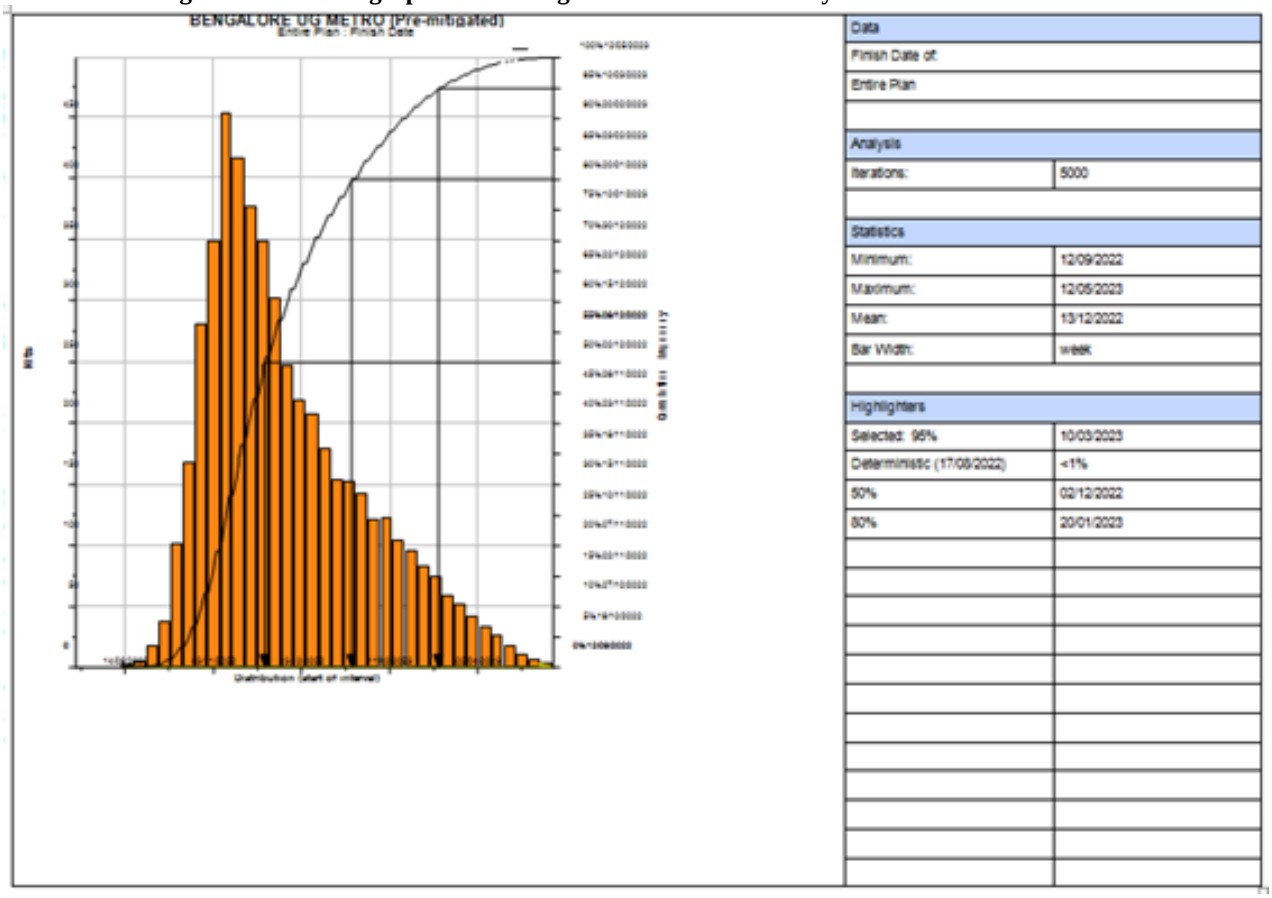


Data	
Finish Date of:	
Entire Plan	
Analysis	
Iterations:	1000
Statistics	
Minimum:	26/09/2022
Maximum:	04/05/2023
Mean:	13/12/2022
Bar Width:	week
Highlighters	
Selected: 95%	13/03/2023
Deterministic (17/08/2022)	<1%
50%	02/12/2022
80%	20/01/2023

Fig. 8. Distribution graph of Pre-mitigated Schedule risk analysis for Iteration 1000.



Data	
Finish Date of:	
Entire Plan	
Analysis	
Iterations:	5000
Statistics	
Minimum:	12/09/2022
Maximum:	12/05/2023
Mean:	13/12/2022
Bar Width:	week
Highlighters	
Selected: 95%	10/03/2023
Deterministic (17/08/2022)	<1%
50%	02/12/2022
80%	20/01/2023

Fig. 9. Iteration Distribution graph of Pre-mitigated Schedule risk analysis for Iteration 5000.

Table- VII: Pre-mitigated Schedule risk analysis results for Iteration 5000

Summary Statistics of Pre mitigated analysis for the Total Duration (Iteration 5000)			
Percent Ile	**Date of Completion**	**Percenti le**	**Duration**
0%	12/9/2022	0%	1285 days
5%	19/10/2022	5%	1322 days
10%	27/10/2022	10%	1330 days
15%	2/11/2022	15%	1336 days
20%	7/11/2022	20%	1341 days
25%	10/11/2022	25%	1344 days
30%	15/11/2022	30%	1349 days
35%	18/11/2022	35%	1352 days
40%	23/11/2022	40%	1357 days
45%	28/11/2022	45%	1362 days
50%	2/12/2022	50%	1366 days
55%	8/12/2022	55%	1372 days
60%	15/12/2022	60%	1379 days
65%	22/12/2022	65%	1386 days
70%	30/12/2022	70%	1394 days
75%	10/1/2023	75%	1405 days
80%	20/01/2023	80%	1415 days
85%	3/2/2023	85%	1429 days
90%	20/02/2023	90%	1446 days
95%	10/3/2023	95%	1464 days
100%	12/5/2023	100%	1527 days

C. Post-Mitigation Schedule Risk Analysis

Table- VI: Post-mitigated Schedule risk analysis results for Iteration 1000

Summary Statistics of Post mitigated analysis for the Total Duration (Iteration 1000)			
Percent ile	**Date of Completion**	**Percenti le**	**Duration**
0%	29/08/2022	0%	1271 days
5%	6/9/2022	5%	1279 days
10%	8/9/2022	10%	1281 days
15%	14/09/2022	15%	1287 days
20%	16/09/2022	20%	1289 days
25%	20/09/2022	25%	1293 days
30%	22/09/2022	30%	1295 days
35%	23/09/2022	35%	1296 days
40%	27/09/2022	40%	1300 days
45%	29/09/2022	45%	1302 days
50%	3/10/2022	50%	1306 days
55%	5/10/2022	55%	1308 days
60%	7/10/2022	60%	1310 days
65%	12/10/2022	65%	1315 days
70%	14/10/2022	70%	1317 days
75%	19/10/2022	75%	1322 days
80%	25/10/2022	80%	1328 days
85%	1/11/2022	85%	1335 days
90%	11/11/2022	90%	1345 days
95%	30/11/2022	95%	1364 days
100%	23/01/2023	100%	1418 days

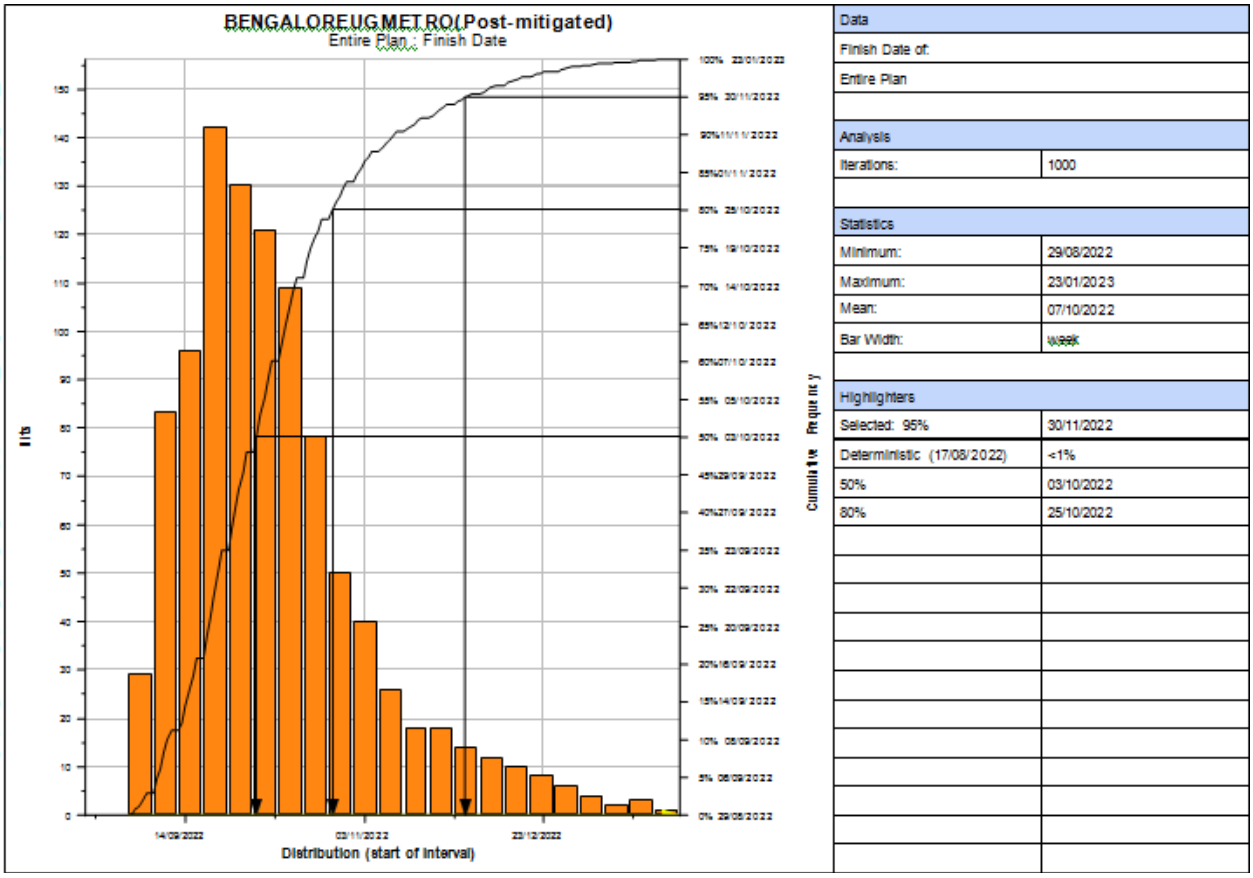


Fig. 10. Distribution graph of Post-mitigated Schedule risk analysis for Iteration 1000.

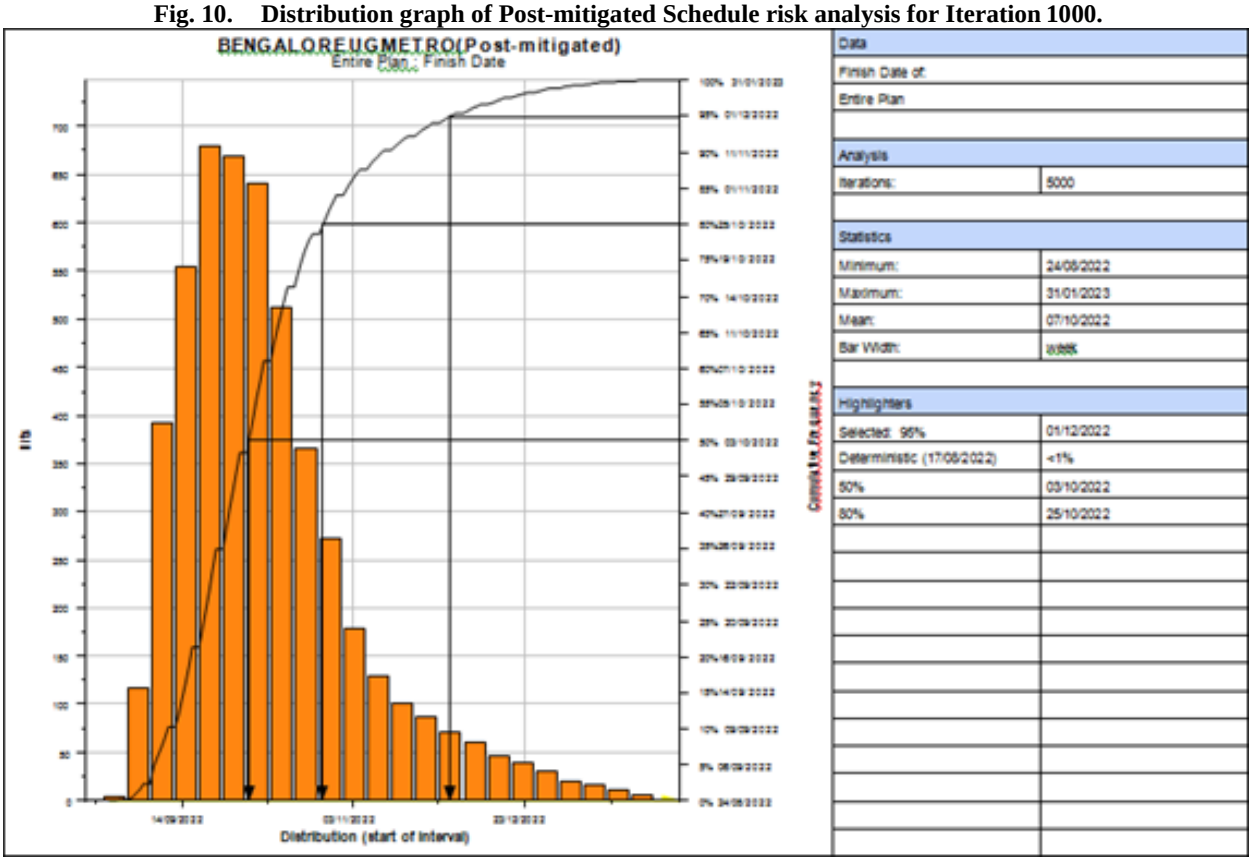


Fig. 11. Iteration Distribution graph of Post-mitigated Schedule risk analysis for Iteration 5000.

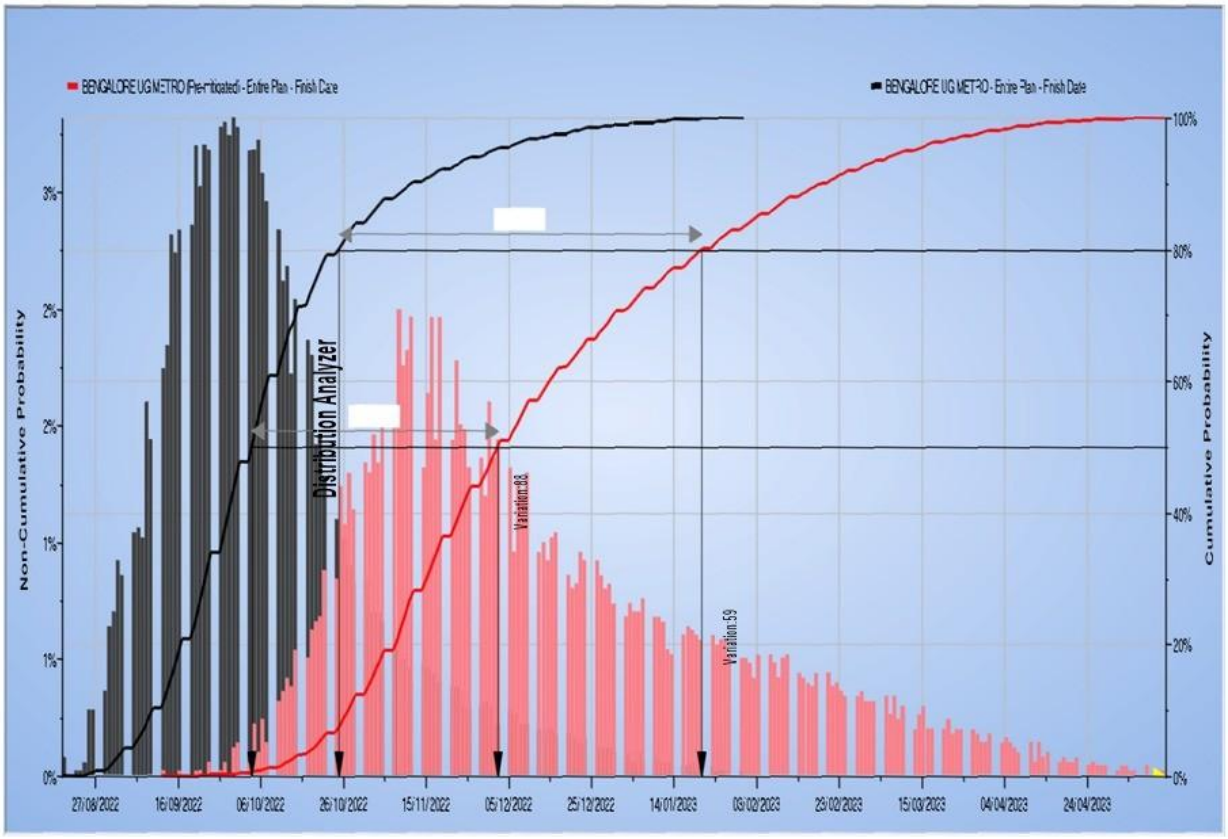


Fig. 12. Distribution Analyzer between the Pre mitigated and Post mitigated schedule risk analysis for iteration 1000.

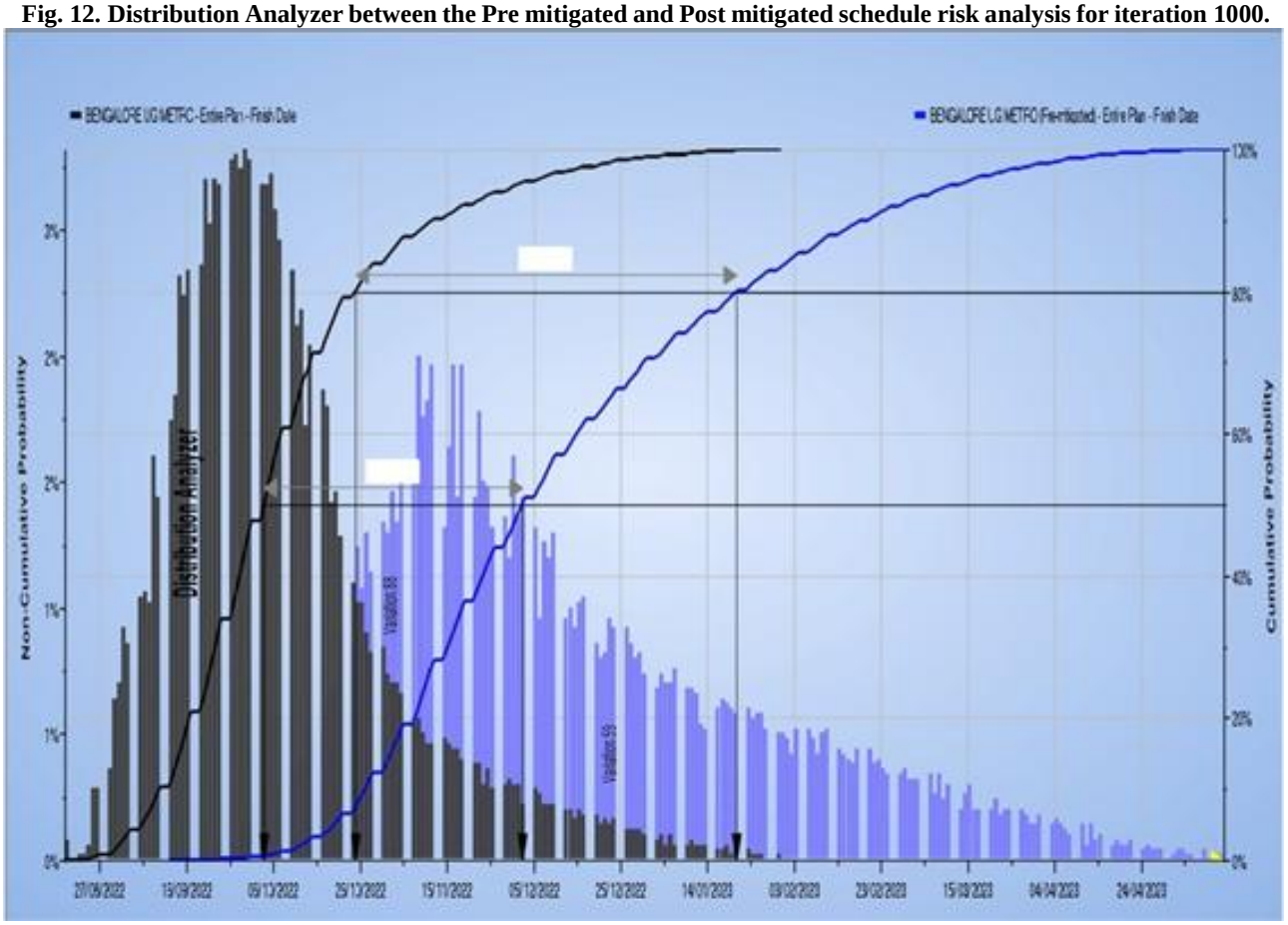


Fig. 13. Distribution Analyzer between the Pre mitigated and Post mitigated schedule risk analysis for iteration 5000.

V. DISCUSSIONS

From the qualitative analysis based on average risk index score the construction, design, environmental, geotechnical are high priority risks and financial, legal, management, political & policy and safety are medium priority risks and market, social are low priority risks for the schedule of the project. Similarly, from the qualitative analysis design, environmental, geotechnical, financial are high priority risks and construction, legal, management, market, political & policy, social and safety are under medium priority risks that have impact on cost of the project. For duration simulation the values obtained from the pre mitigated schedule risk analysis for the 1000 and 5000 iteration using the triangular distribution has a mean duration of 1378 days for the both iteration and the maximum completion of 1519 and 1517 days and for the 95% probability of completion being 1467 and 1464 days respectively. The minimum value exceeds the estimated duration for both iterations indicating the 0% possibility for the achievement of the project within the estimated time. The results of post mitigation risk analysis for schedule calculated by assigning the planned risk responses strategies for the risk events and simulating for the iteration of 1000 and 5000 using triangular distribution has mean duration of 1311 for both iteration and maximum completion of 1418 and 1426 days and for the 95% probability of completion of the project being 1364 and 1365 days respectively with less variation for the both iteration the deterministic value for the completion of the project after post mitigation analysis is < 1% and the calculated variation between the pre-mitigation and the post mitigation for the 50 % percentile is 59 days and for 80% percentile is 88 days and calculated mean variation is being 67 days, that indicates the schedule of the project being saved from the delay by adopting the suitable mitigation strategies for the risk events of the project.

VI. CONCLUSION

Risks are considered as integral part of any construction project. So, it becomes predictable to consider the impact of these risks on cost and time. By identifying the risks before initializing the project and adopting necessary risk management techniques like the quantitative analysis and response planning leads to better project plans. Risk management deals with the risk events and the allocation of risks to the different parties through suitable contractual clauses and other risk allocation measures. From the results obtained through study it can be concluded that out of 87 risks listed for the underground metro projects, only 75 risks are mainly applicable for the project considered and that are analyzed by qualitative analysis and out of 75 risks, only 17 risk belong to the major and high risks categories and the contributes to 34.5% of total project risk and out of total risk categories the construction risks turnout to be major risks for the project followed by the geotechnical risks. The results obtained from the simulation on duration indicates the schedule estimates of the project are more realistic in nature when compared to the conventional
methods of scheduling that adopts deterministic estimates which neglect the risk events for the project.

SCOPE OF WORK

Risk is considered to be a negative term, even it has two dimensions threat and opportunity Hence while analysis opportunities with positive impacts in risk management along with risks with negative impacts are considered and simulated them. Proposing the risk model by comparing and incorporating the data from the similar projects and deriving the main factors and obtaining the results for the specific project by giving appropriate risk inputs to model
So open-ended distributions like lognormal distribution can be used instead of a closed-ended distribution like triangular distribution.
The work is extended by addition of costs of the project thus improving the model by expanding the scope of input which gives a more realistic results for the project specific.

REFERENCES

1. Bengaluru Metro Rail: Silk Board – KR Puram Corridor, Detailed Project report (Oct 2016), Bangalore Metro Rail Corporation.
2. Debalina Banerjee, (2017) “Risk analysis and decision support in transportation megaprojects” International Journal of Civil Engineering and Technology, Vol.8 (7),836–845.
3. Environmental Risk Assessment Report (Risk Register),(2016), Melbourne Metro Rail Authority, MMR-AJM-PWAA-RP-NN-000813, Reference CMS332569.
4. Environmental Impact Assessment, (2017), Bangalore Metro Rail Project – Line R6, Bangalore Metro Rail Corporation Limited.
5. ITA WG Mechanized Tunneling, (2000), “Recommendations and Guidelines for Tunnel Boring Machines (TBMs)”, International Tunneling Association (ITA), Mechanized tunneling,1-118, France.
6. Lee Yong Siang, (2017) “General Risks for Tunneling Projects: An Overview” Research gate.
7. Lyons, Terry and Skitmore, (2004) “Project risk management in the Queensland engineering construction industry: a survey”. International Journal of Project Management Vol. 22(1), 51-61. [CrossRef]
8. Nigel J. Smith and Tony Merna, (2006), “Managing Risk in construction Projects” Blackwell Publisher Inc, Malden, USA.
9. Risk Integration Management, (2016), “Schedule Risk Analysis Process”, https://www.riskinteg.com/KB/2_Schedule_Risk_Analysis/2_2_process.aspx#
10. S.P. Huang, M.L. Guo, (2015), “Analysis and Strategies of the Common Tunnel Problems” International Conference on Artificial Intelligence and Industrial Engineering, AIIE, China. [CrossRef]

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