JOURNAL OF NORTHEASTERN UNIVERSITY

Volume 25 Issue 04, 2022 ISSN: 1005-3026 https://dbdxxb.cn/ Original Research Paper

QUANTITATIVE RISK ANALYSIS OF 3000KL HIGH SPEED DIESEL (HSD) STORAGE TANK SITE FABRICATION AND ERECTION PROJECT USING PRIMAVERA RISK ANALYSIS SOFTWARE

Khawaja Mubeenur Rahman
Associate Professor, Sinhgad Institute of Management Pune India
rahman.2806@gmail.com

Aniket Sadanand Kamat
MBA Second Year Student, Sinhgad Institute of Management Pune India
kamataniket3@gmail.com

Abstract:
In this paper, sixty-nine risks associated with 3000 KL High Speed Diesel (HSD) storage tank site fabrication and erection project, Pune, Maharashtra, India has been identified and classified in eight categories. After identifying and prioritizing risks associated with project, quantitative risk analysis has been carried out with the help of Monte Carlo's simulation by using Primavera Risk Analysis software. Research has been done by considering three cases i.e. original plan, pre-mitigated condition and post-mitigated condition. In original plan, schedule and cost uncertainties are associated with project schedule and cost. In pre-mitigated condition, all risks identified in project are associated with project schedule and cost without considering risk responses and mitigations. In post-mitigated condition after mitigation results are found. After comparing 80% probabilistic results obtained from all three conditions it has been found that, contingency reserves required for schedule of the project is reduced by 50% and for cost reserves are reduced by 76.95%.
Keywords: Quantitative Risk Analysis, Risk Management, High Speed Diesel (HSD), Project Management Life Cycle, Risk Register, Risk Scoring, Probability- Impact Technique, Monte Carlo Simulation, Primavera Risk Analysis

1. Introduction:

Quantitative risk analysis is numerical method to identify probability and impact risks on overall project with the help of various modelling and simulation techniques. In this project, quantitative risk analysis can be performed with the help of Monte Carlo simulation technique using Primavera Risk Analysis Software. Monte Carlo simulation is iteration based technique generally used computational analysis to identify probability of uncertain events in given project.

According to PMBOK edition 6, risk management plan includes following steps,

- Risk Identification
- Qualitative Risk Analysis
- Quantitative Risk Analysis
- Plan Risk Response

Submitted: 17/10/2022 **Accepted**: 10/11/2022

- Analyze Results after Mitigation
- Apply Contingency Reserves

Third stage is Quantitative risk analysis in which risk are classified based on schedule and cost impact with the help of numeric figures. After classification with the help of Monte Carlo analysis method, mitigation steps and result after mitigation can be identified. After analysing risks proper action plan for reducing impact on schedule, cost and performance can be identified. Risks can be completely avoid or transfer or reduce. So, with reference to each associated risk proper risk response is identified and after mitigation and getting results, suitable contingency reserves needs to be applied on schedule as well as cost to avoid future loss in project work.

2. Review of Literature:

Mohamed A. Aderbag et al. (2018) worked on '**Risk Analysis Related to Costing and Scheduling of Construction Projects'.** In study they have considered cost and schedule risks associated to design and implementation of twenty housing units for low income people in Tripoli, Libiya project. The quantitative risk analysis is performed based on Monte Carlo simulation and results generated on Primavera Risk Analysis software. They have considered three scenarios in this study i.e. original plan, pre-mitigated risks and post-mitigated risks. Original plan covers uncertainty in planned schedule and budget. Pre-mitigated risks covers original plan associated with risks before mitigation and post-mitigated risks covers original plan after mitigation of risks. After gathering suitable data, they have identified forty-four risk associated with the project and categorized them as Design Risks, Financial Risks, Legal & Contractual Risks, Site Construction Risks, Logistics Risks, Environmental Risks, Resource Related Risks, Political and War Risks, and Management risks. The result shows that, in pre-mitigation stage out of total risks 20% were categorized as high, 25% as medium and 55% as low risk. In post- mitigation stage it has been observed that there were 22% medium and 78% low risks still associated with the project. After performing quantitative risk analysis, it has been observed that, schedule contingency reserve for pre-mitigated risk is 3 times to original schedule which has reduced to 1.4 times after mitigation. Similarly, cost contingency reserve for pre-mitigated stage was 44 times more than original cost which is reduced to 10.3 times after mitigation of risk.

Mohamed Nabawy et al. (2020) worked on '**A systematic review of quantitative risk analysis in construction of mega projects'.** In their research the main aim was to study use and benefit of quantitative risk analysis in execution of Mega Projects. Mega projects generally include construction projects which are high budget and long schedule projects. As these projects are long duration many tasks and activities are involve in this projects which increase complexity of project. Due to its complex nature many risks can be associated with it. Hence identifying risks in advance proactively will reduce chances of delay in schedule and rise in budget of project. For proactive analysis methods such as qualitative and quantitative risk analysis are used. Along with qualitative risk analysis, quantitative risk analysis is also important in decision making process. In this paper they have conducted critical analysis of

quantitative techniques which includes Monte Carlo Analysis, Sensitivity Analysis and Earned Value Analysis. Based on this study it has been concluded that most suitable and efficient method of doing quantitative analysis of schedule and budget risks is Monte Carlo Analysis. Sensitivity can be used in case of mega projects when priority is to identify tasks or risks which can cause failure in construction delivery. This paper is also concluded that quantitative risk analysis can help management in decision making regarding mega projects.

3. Research Methodology:

The main purpose of this research is to perform quantitative risk analysis of 3000KL High Speed Diesel (HSD) storage tank site fabrication and erection project. The research has been carried out three cases i.e. original plan, pre-mitigated condition and post-mitigated condition. After identifying risks and prioritizing them, using Monte Carlo's simulation, quantitative analysis has been performed and results are obtained.

Project Title	Design, engineering, manufacturing and site operations management of 3000 KL fixed roof, flat bottom HSD Storage tank (2 Nos.).
Research Objective	To identify risks associated with site fabrication & erection work of 3000 KL HSD storage tank.
Project Location	Chakan Village, Pune, Maharashtra, India
Project Battery Limit	From Inlet Nozzle to Outlet Nozzle of Tank
Project Schedule	From 3rd January, 2022 to 26th May, 2022
Project Cost	Rs. 2,44,10,122.00

Table 1: Project Description

The research has been carried out by considering contractor's point of view in which activities like detail design, drawing preparation, fabrication drawing preparation, supply of raw materials, tools & tackles, manpower, consumables required for fabrication and erection work of project are considered in contractor's scope.

3.1. Quantitative Risk Analysis:

After importing project schedule from Microsoft Project to Primavera Risk Analysis Software, and completing schedule check for the project process of quantitative analysis process will start. For quantitative analysis, project schedule and project cost will be two inputs. Analysis will be carried out by considering three conditions i.e. Original Plan, Pre-mitigated Condition and Post mitigated Condition.

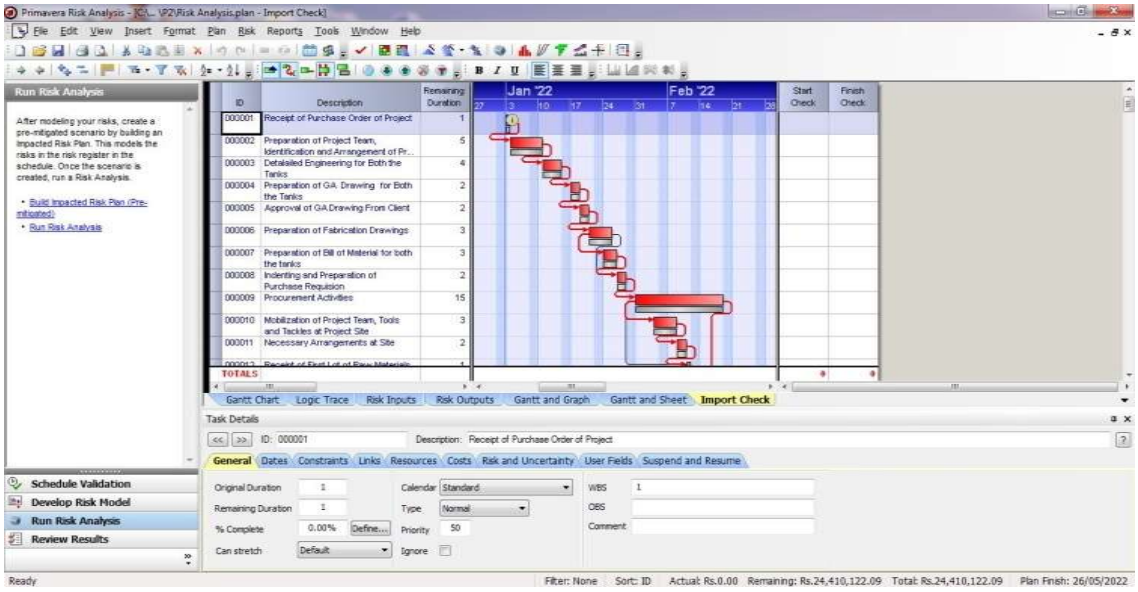

Figure 1: Import Check

In Original plan only uncertainties in schedule and cost are considered for simulation. In which uncertainties are classified as optimistic uncertainties, most likely and pessimistic uncertainties. For that triangular method has been used.

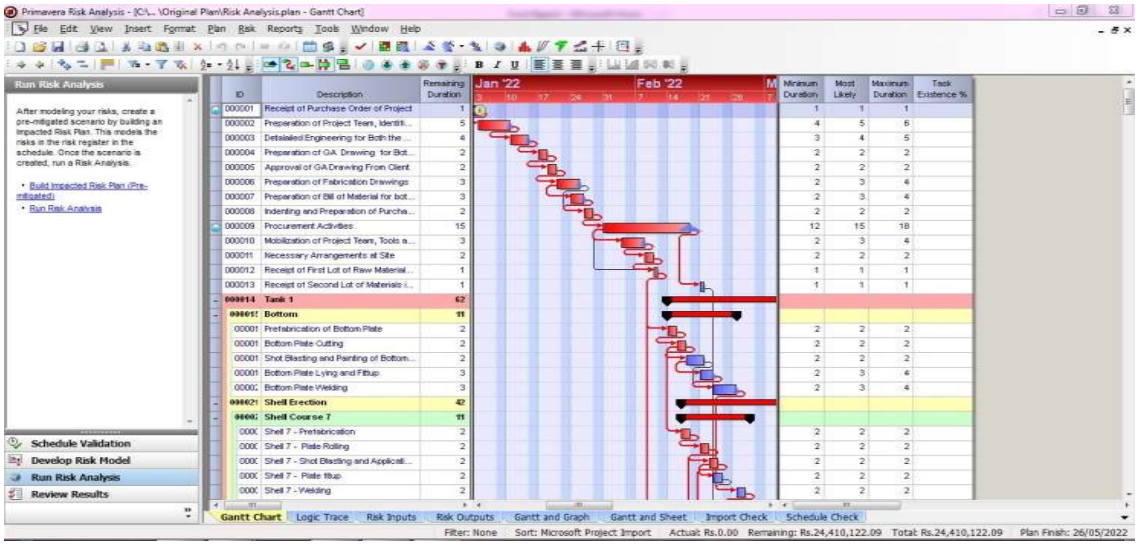

Figure 2: Original Plan with Schedule Uncertainties

After getting results of original plan, risks associated with the project are introduced in Risk Register and its probability of happening and impact on schedule and cost identified and enlisted in Risk Register. Total sixty-nine risks are identified for this project. Quantitative risk analysis has been performed in pre-mitigated condition and results are noted.

Risk			Pre-Mitigation (Data Date = 09/11/20...			
ID	T/O	Title	Probability	Schedule	C...	Score
RISK1	T	Change in Ruling Government	N	VH	VH	0
RISK2	T	Change in Government Policies	VL	H	H	4
RISK3	T	Change in Government Rules a...	L	M	M	6
RISK4	T	Obstruction in Project Work du...	L	L	H	12
RISK5	T	Lack of Political Willngness	VL	L	M	2
RISK6	T	Delay in Statutory Approvals fr...	L	L	M	6
RISK7	T	Changes in Global Politics	VL	VL	VL	1
RISK8	T	Delay in Receipt of Purchase O...	L	L	L	3
RISK9	T	Disagreements in Contract wit...	L	L	VL	3
RISK10	T	Ambiguities in Contract with C...	L	L	VL	3
RISK11	T	Amendment in Labour Laws	VL	L	L	1
RISK12	T	Delay in Third Party Approval (...	L	L	VL	3
RISK13	T	Disagreements in Contract wit...	L	L	VL	3
RISK14	T	Legal Disputes during Executio...	L	M	H	12
RISK15	T	Lack of understanding of Proj...	L	M	VH	24
RISK16	T	Error in Identification of requir...	L	M	M	6
RISK17	T	Error in Project Team Selection	L	L	M	6
RISK18	T	Incapability of Responsible Aut...	L	L	M	6
RISK19	T	Lack of Coordination within Or...	L	VL	M	6
RISK20	T	Miscommunication within Proj...	L	VL	L	3
RISK21	T	Lack of Realistic Planning	L	L	H	12
RISK22	T	Lack of Support from Top Man...	L	VL	L	3
RISK23	T	Error in Project Scheduling	L	H	H	12
RISK24	T	Internal Disputes in Organization	L	L	M	6
RISK25	T	Improper Supply Chain Manag...	L	L	H	12
RISK26	T	Delay in Detail Engineering	L	VL	VL	2

Figure 3: Risk Register

After getting results of pre-mitigated condition, risk mitigation plan has been developed and mitigation steps are introduced in the program. After mitigation of risks, necessary changes in probability risk event and impact on project schedule and cost has been done and quantitative risk analysis has been performed. Results are noted for comparison.

Risk			Pre-Mitigation (Data Date = 09/11/20...				Mitigation			Post-mitigation			
ID	T/O	Title	Probability	Schedule	C...	Score	Response	Title	Total Cost	Probability	Schedule	C...	Score
RISK1	T	Change in Ruling Government	N	VH	VH	0	Accept		Rs.0.00	N	VH	VH	0
RISK2	T	Change in Government Policies	VL	H	H	4	Accept		Rs.0.00	VL	H	H	4
RISK3	T	Change in Government Rules a...	L	M	M	6	Accept		Rs.0.00	L	M	M	6
RISK4	T	Obstruction in Project Work du...	L	L	H	12	Reduce	Conducting D...	Rs.400,000.00	N	VL	M	0
RISK5	T	Lack of Political Willngness	VL	L	M	2	Accept		Rs.0.00	VL	L	M	2
RISK6	T	Delay in Statutory Approvals fr...	L	L	M	6	Reduce	Taking Follow...	Rs.5,000.00	VL	VL	L	1
RISK7	T	Changes in Global Politics	VL	VL	VL	1	Accept		Rs.0.00	VL	VL	VL	1
RISK8	T	Delay in Receipt of Purchase O...	L	L	L	3	Reduce	Taking Follow...	Rs.5,000.00	N	N	L	0
RISK9	T	Disagreements in Contract wit...	L	L	VL	3	Reduce	Conducting d...	Rs.5,000.00	N	N	VL	0
RISK10	T	Ambiguities in Contract with C...	L	L	VL	3	Reduce	Conducting d...	Rs.5,000.00	N	N	VL	0
RISK11	T	Amendment in Labour Laws	VL	L	L	1	Accept		Rs.0.00	VL	L	L	1
RISK12	T	Delay in Third Party Approval (...	L	L	VL	3	Reduce	Taking Follow...	Rs.10,000.00	N	VL	VL	0
RISK13	T	Disagreements in Contract wit...	L	L	VL	3	Reduce	Conducting d...	Rs.0.00	N	N	VL	0
RISK14	T	Legal Disputes during Executio...	L	M	H	12	Reduce	Scope and ot...	Rs.10,000.00	N	VL	M	0
RISK15	T	Lack of understanding of Proj...	L	M	VH	24	Reduce	Discussion wi...	Rs.10,000.00	N	VL	H	0
RISK16	T	Error in Identification of requir...	L	M	M	6	Reduce	Discussion wi...	Rs.10,000.00	N	VL	M	0
RISK17	T	Error in Project Team Selection	L	L	M	6	Reduce	Conduct inter...	Rs.20,000.00	N	VL	M	0
RISK18	T	Incapability of Responsible Aut...	L	L	M	6	Reduce	Conduct inter...	Rs.20,000.00	VL	VL	M	2
RISK19	T	Lack of Coordination within Or...	L	VL	M	6	Reduce	Conduct tea...	Rs.10,000.00	VL	VL	M	2
RISK20	T	Miscommunication within Proj...	L	VL	L	3	Reduce	Conduct tea...	Rs.5,000.00	VL	VL	L	1
RISK21	T	Lack of Realistic Planning	L	L	H	12	Reduce	Understand s...	Rs.2,500.00	VL	VL	M	2
RISK22	T	Lack of Support from Top Man...	L	VL	L	3	Reduce	Convince abo...	Rs.0.00	VL	VL	L	1
RISK23	T	Error in Project Scheduling	L	H	H	12	Reduce	Understand s...	Rs.2,500.00	VL	VL	M	2
RISK24	T	Internal Disputes in Organization	L	L	M	6	Reduce	Conduct tea...	Rs.5,000.00	N	VL	M	0
RISK25	T	Improper Supply Chain Manag...	L	L	H	12	Reduce	Improve inter...	Rs.0.00	VL	VL	H	4
RISK26	T	Delay in Detail Engineering	L	VL	VL	2	Reduce	Try to fasten ...	Rs.15,000.00	N	N	VL	0

Figure 4: Pre-mitigated and Post mitigated Risk Register

4. Results:

Quantitative risk analysis has been performed by using Monte Carlo Analysis with the help of Primavera Risk Analysis Software. Three conditions have been considered for performing quantitative risk analysis i.e. Original Plan, Pre-mitigated Condition and Post- mitigated Conditions.

4.1. Original Plan:

Original plan indicates planned schedule and planned budget of project. Uncertainties in schedule and cost have been introduced as an input and after simulation up to 1000 iterations; results are obtained in the form of distribution diagrams. As deterministic finish date of project is 26th May, 2022 but due uncertainties in duration of activities and tasks, it has been found that 58 % of total project will get finished by 26th May, 2022. At probability of 50% project will get finish by 26th May, 2022 and at probability 0f 80% project will get finish by 30th May, 2022. It means there are 80% chances of completion of project by 30th May, 2022.

Similarly, deterministic project cost is Rs. 24410122.00. By simulation results it has been found that 50% of project can be completed in given budget due to uncertainties in cost. At probability of 80% project will require budget of Rs. 24448651.00 i.e. there is 80% chances of project will get finish at Rs. 24448651.00.

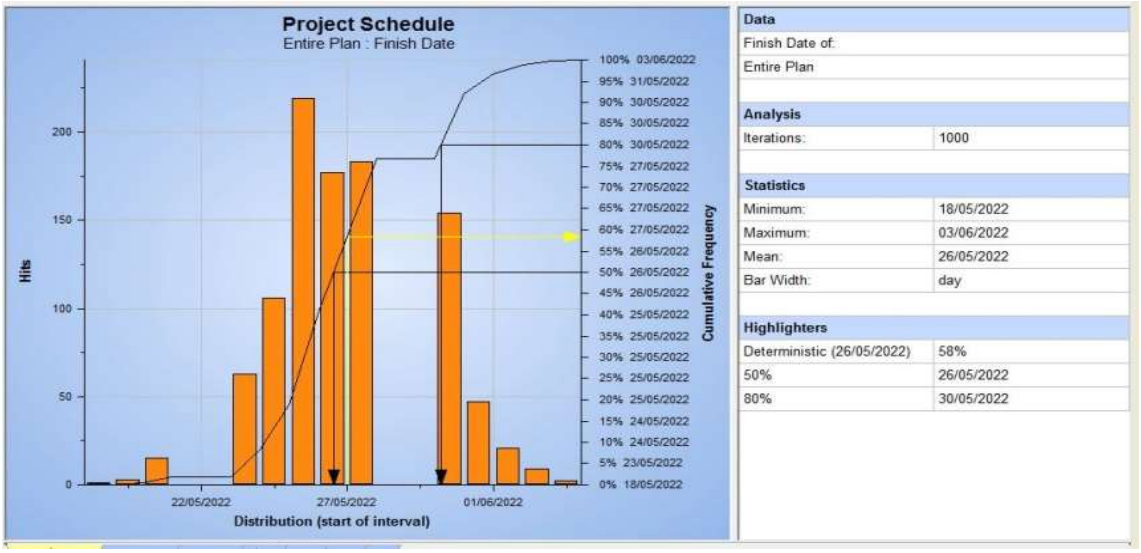

Figure 5: Results- Quantitative Risk Analysis- Schedule (Original Plan Condition)

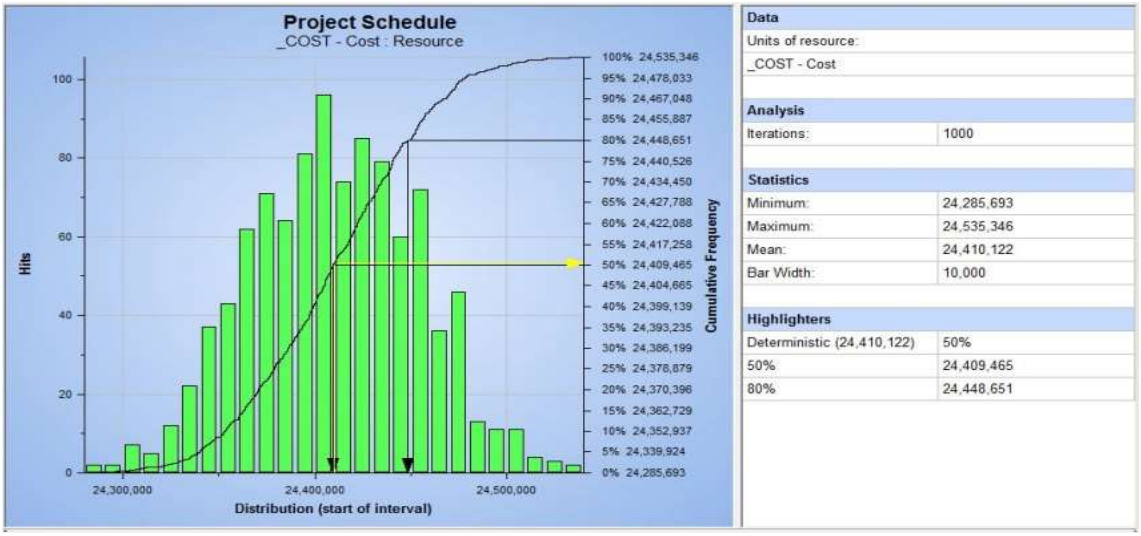

Figure 6: Results- Quantitative Risk Analysis- Cost (Original Plan Condition)

4.2. Pre-Mitigated Condition:

As deterministic finish date of project is 26th May, 2022 but due risk associated with activities and tasks, it has been found that less than 1% of total project will get finished by 26th May, 2022. At probability of 50% project will get finish by 21st June, 2022 and at probability of 80% project will get finish by 05th July, 2022. It means there are 80% chances of completion of project by 05th July, 2022.

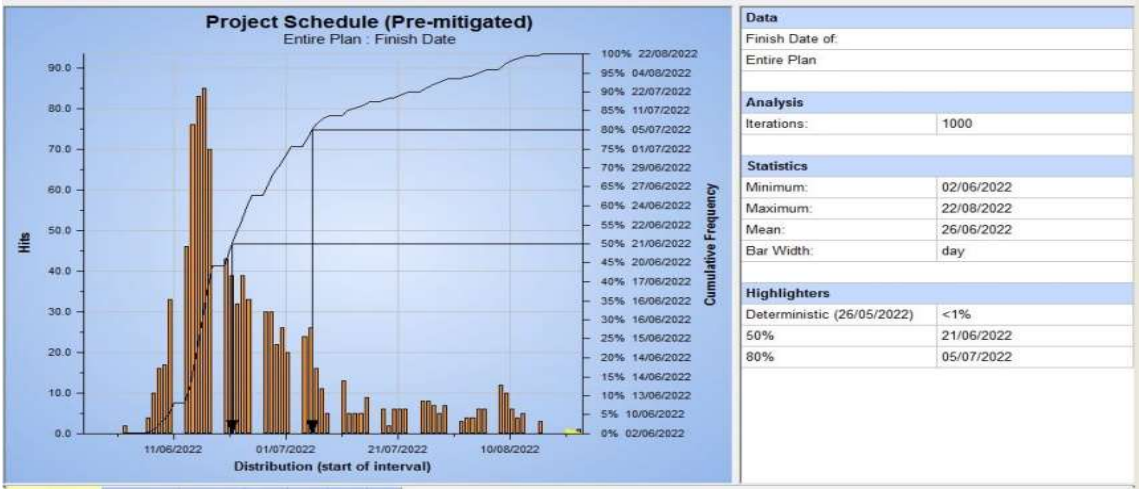

Figure 7: Results- Quantitative Risk Analysis- Schedule (Pre-Mitigated Condition)

Similarly, deterministic project cost is Rs. 24410122.00. By simulation results it has been found that less than 1% of project can be completed in given budget due to risks impacting on cost of the project. At probability of 80% project will require budget of Rs. 26317442.00 i.e. there is 80% chances of project will get finish at Rs. 26317442.00

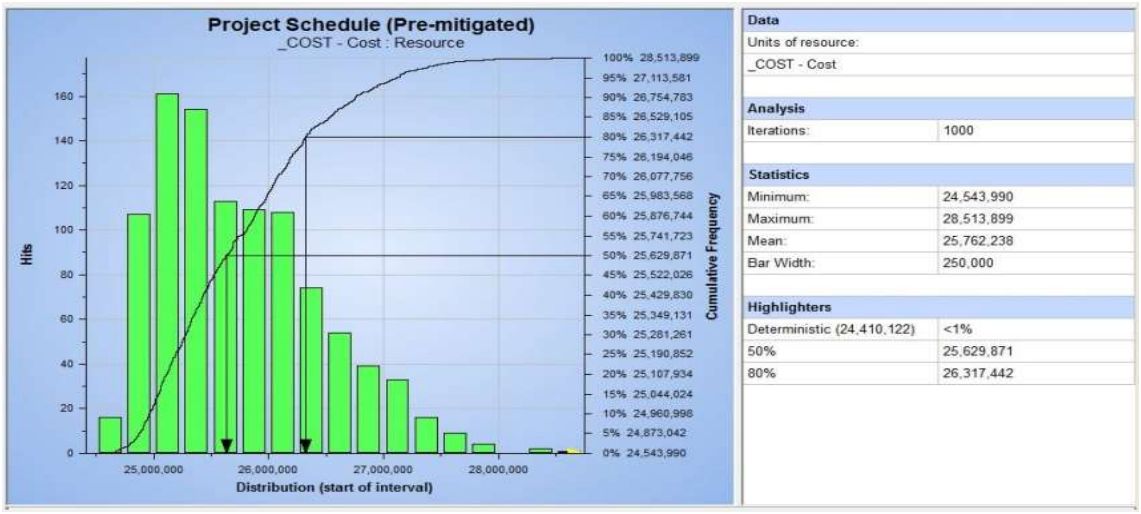

Figure 8: Results- Quantitative Risk Analysis- Cost (Pre-Mitigated Condition)

4.3. Post-Mitigated Condition:

As deterministic finish date of project is 26th May, 2022 but due risk associated with activities and tasks, it has been found that less than 1% of total project will get finished by 26th May, 2022. After mitigation, it has been found that there is 24% chance of completion of entire project by 26th May, 2022. At probability of 50% project will get finish by 06th June, 2022 and at probability of 80% project will get finish by 15th June, 2022. It means there are 80% chances of completion of project by 15th June, 2022.

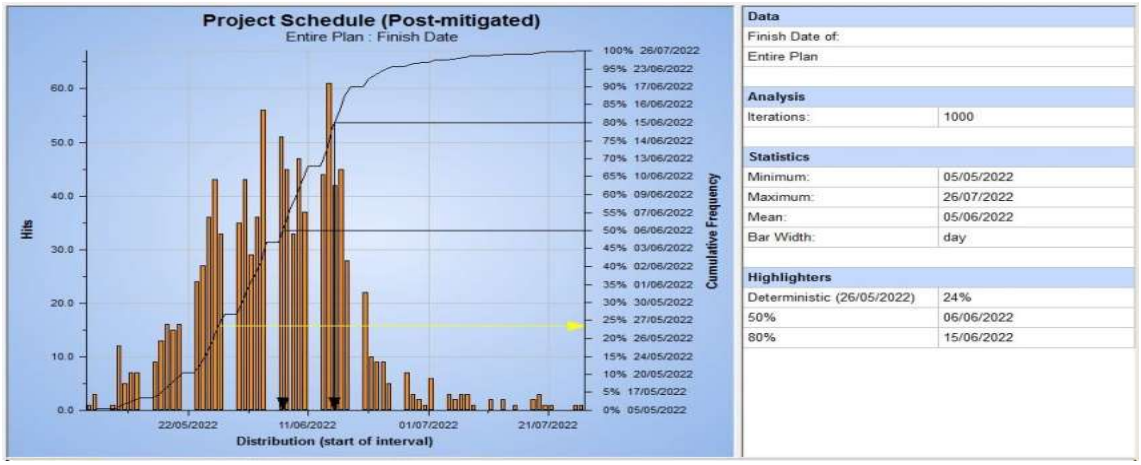

Figure 9: Results- Quantitative Risk Analysis- Schedule (Post-Mitigated Condition)

Similarly, for post- mitigation stage deterministic project cost will be Rs. 25290122.00 (Rs. 24410122 + Rs. 880000.00) which will be addition of deterministic cost before mitigation and mitigation cost. By simulation results it has been found that less than 1% of project can be completed in given budget due to risks impacting on cost of the project but after mitigation it has been found that 12% of project can be completed with new deterministic budget i.e. Rs

25290122.00 At probability of 80% project will require budget of Rs. 25745980.00 i.e. there is 80% chances of project will get finish at Rs. 25745980.00

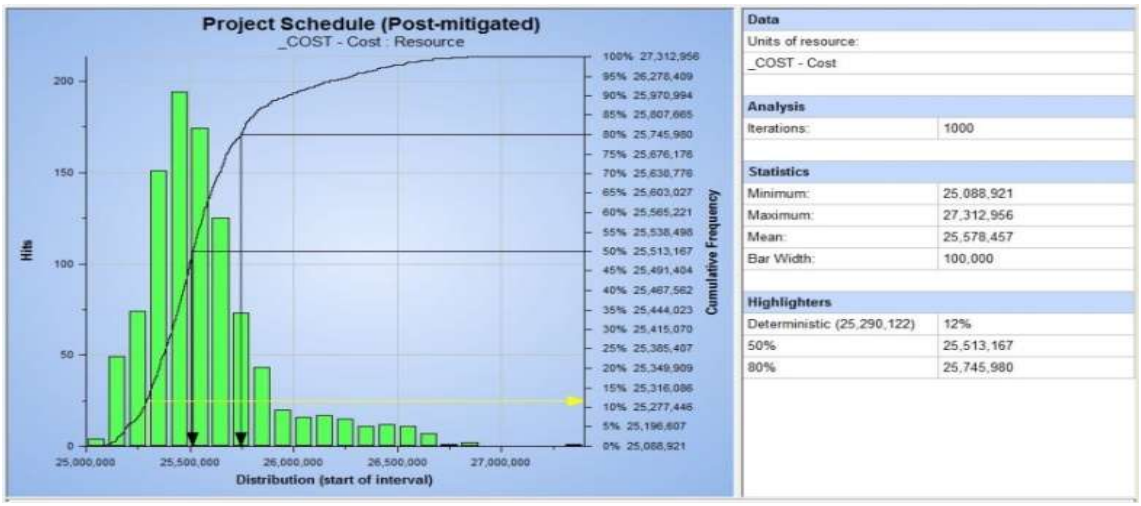

Figure 10: Results- Quantitative Risk Analysis- Cost (Post-Mitigated Condition)

Conclusion:

A comparison of three conditions i.e. original plan, pre-mitigated condition and post-mitigation condition regarding P80% Schedule Contingency and P80% Cost Contingency are shown in the following graphs.

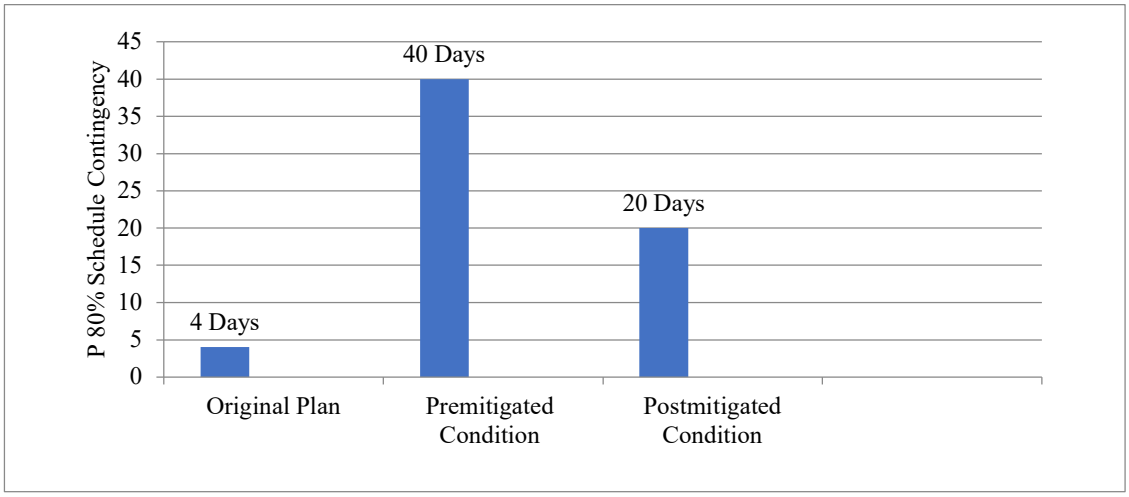

Figure 11: Comparison of P80% Schedule Contingency

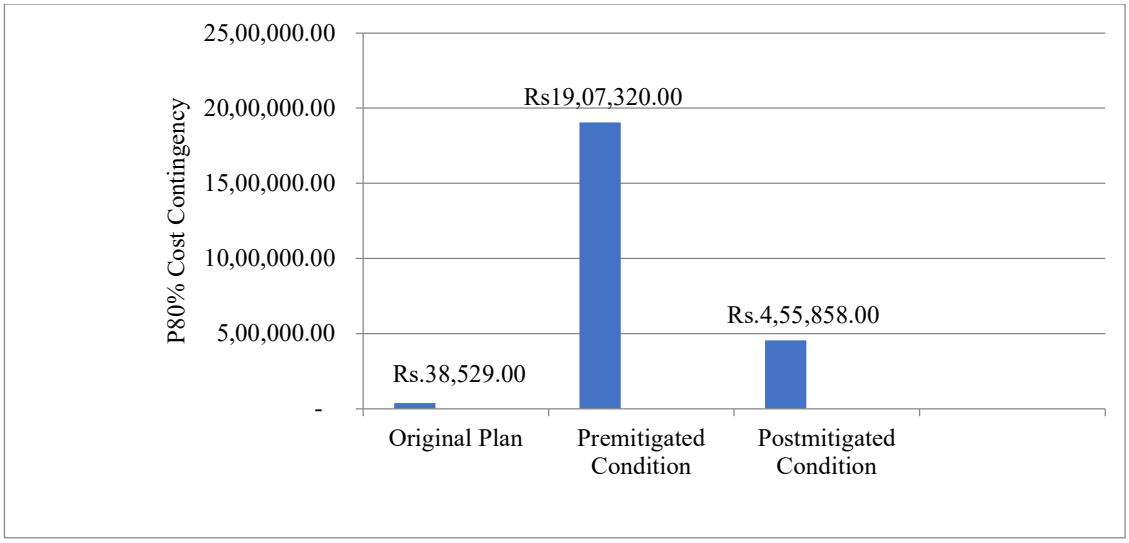

Figure 12: Comparison of P80% Cost Contingency

After performing quantitative analysis using Monte Carlo simulation method and comparing results 80% probability results of three conditions i.e. original plan, pre-mitigated condition and post-mitigation condition it has been concluded that, before mitigation contingency reserves required for schedule and cost with respect to deterministic schedule and cost was 27.97% and 7.81% respectively. But after mitigation contingency reserves contingency reserves required for schedule and cost with respect to deterministic schedule and cost was reduced to 13.98% and 1.80% respectively.

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