International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 10 Oct. 2022, pp: 403-409 www.ijaem.net ISSN: 2395-5252

Quantitative Risk Analysis by Monte Carlo Simulation Method using @Risk software for an Ongoing Project.

Sowjanya, Proff Aravind Sagar B

Student, Dept. of Infrastructure Construction and Management, Rasta-Centre for Road Technology.

Date of Submission: 01-10-2022 Date of Acceptance: 12-10-2022

ABSTRACT: The construction industry in recent years is mostly driven by private investors. The presence of securitized real estate has increased significantly. It is prone to numerous technical and business risks, many of which are riskier than the traditional ones.Therefore, there is a need of risk assessment. In this study, a case study is done on a construction project, wherein risk factors were identified by study of tender documents, experts' opinion and literature survey.

Risk Index score, Risk heat map, Risk register are been prepared to record all risks and determine severity and mitigation plan. This study gives a prioritized order of the identified risks and their mitigation plans. It can be further used to perform accurate quantitative analysis like Monte Carlo Simulation for thee identified risks.

KEYWORDS:Risk Assessment, Risk index score, Risk heat map, Risk register, quantitative risk analysis, Monte Carlo simulation**.**

I. INTRODUCTION

The construction industry is one of the most difficult, dynamic, and risky industries to work in. It also has a very bad reputation due to the negative consequences of change and the failure to fulfil deadlines, budgets, and quality standards, all of which have a negative impact on project costs. For many construction projects, studying different hazards and how to manage them is a requirement.

By raising the likelihood and implications of positive characteristics while reducing the likelihood and ramifications of bad qualities, risk management is a systematic technique to identifying, assessing, and responding to project risk. According to the Project Management Institute (PMI), risk management is one of the nine knowledge areas of project management. Effective risk management is seen as a crucial component and is required for project success.

The purpose of project risk management, according to the sixth version of the Project Management Body of Knowledge (PMBOK), is to identify and manage risks that are not covered by the other project management processes. These risks have the potential to cause the project to diverge from the plan and fall short of the specified project objectives if they are not managed. As a result, the success of a project is closely correlated with the efficiency of project risk management.

The purpose of project risk management, according to the sixth version of the Project Management Body of Knowledge (PMBOK), is to identify and manage risks that are not covered by the other project management processes.

These risks have the potential to cause the project to diverge from the plan and fall short of the specified project objectives if they are not managed. As a result, the success of a project is closely correlated with the efficiency of project risk management. The project team must understand what amount of risk exposure is acceptable for achieving the project's goals in order to manage risk on a given project efficiently. Measurable risk thresholds that reflect the organization's and the project stakeholders' tolerance for risk serve to define this. The amount of allowable variation around a project aim is expressed by risk thresholds. They are clearly articulated, conveyed to the project team, and included in the descriptions of the project's risk impact levels.

II. LITERATURE REVIEW

Research undertaken on construction risk management and risk management literature includes the following outcomes. [1] Atinkoye A S et.al (1997) – With the use of questionnaires of overall contractors and construction managers, researchers investigated the construction industry's risk perception in connection to its operations, as well as the extent to which the sector applies risk analysis and management strategies.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 10 Oct. 2022, pp: 403-409 www.ijaem.net ISSN: 2395-5252

The majority of risk analysis and management in the construction industry is dependent on perception, judgement, and prior experience. Due to a lack of experience and uncertainty on their applicability for the operations of the sector, formal risk analysis and management methodologies are rarely used in the construction business.

[2] Mulholland et.al (1999) – This model was made systematically for taking into account and quantifying uncertainties in the building plans. This study concentrated on previous project experience and presents a risk assessment methodology with common inputs and predicted outcomes.

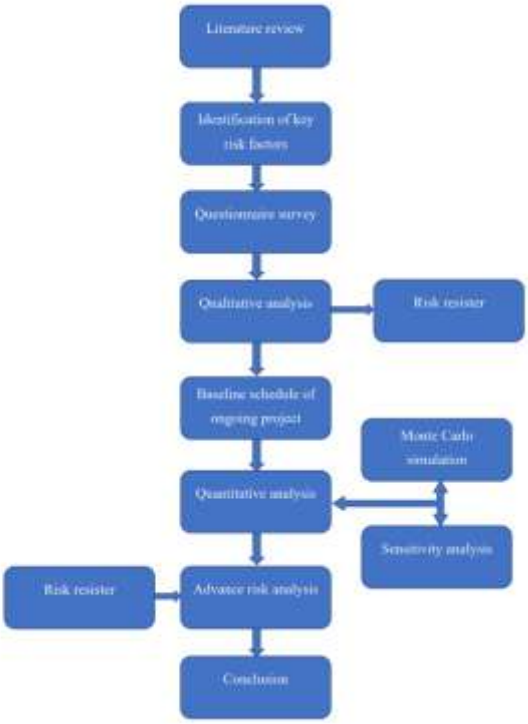
[3] Kong et al. (2015)- This paper presented the significance of Monte Carlo simulation, in contrast to conventional Critical Path Method. Monte Carlo simulation may give a variety of information for risk management, such as the criticality report, criticality allocation, and duration likelihood curves. When contrasted to firm date produced by CPM in the actual situation reported in this research, Monte Carlo simulation offered a range of dates in risk analysis.

[4] Bouyaed (2016)- This paper was illustrated how the Monte Carlo Simulation may help project managers estimate the contingency value that should be assigned to their project in order to reduce the chance of cost overruns. This article also demonstrated the relevance of cost risk analysis in identifying the primary important cost factors that add the most risk to the total project cost, as well as where efforts should be directed in order to avoid costly mistakes.

[5] Avlijas (2018) – Reviewed the Monte Carlo simulation's use in project management, with emphasis on its applicability to time management.

III. METHODOLOGY

Research on construction risk assessment (qualitative and quantitative) and risk management literature. Identifying critical risk allocation and management provisions to include during contract formulation to decrease the possibility of conflicts and minimize risk during and after the job. Risk factors specific to construction Projects were identified using literature survey, expert opinion and study of tender documents.



IV. QUALITATIVE RISK ANALYSIS

RISK BREAKDOWN STRUCTURE

The risks were classified into eight different categories namely, Financial, Management, Market Risk, Political Risk, Environmental Risk, Technical risk / Construction risk, Social Risk and Legal Risk.

The listed risks were given for the Questionnaire survey for 50 people in different field for rating based on the probability of occurrence and level of risks.

Rating	RiskProbability
1	Rare
2	Unlikely
3	Possible
4	Likely
5	MostLikely

Rating	LevelofImpact
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Extreme

The Response was recorded, based on which Risk Index score was calculated using the formula

$$S_j^i = \alpha_j^i \beta_j^i$$

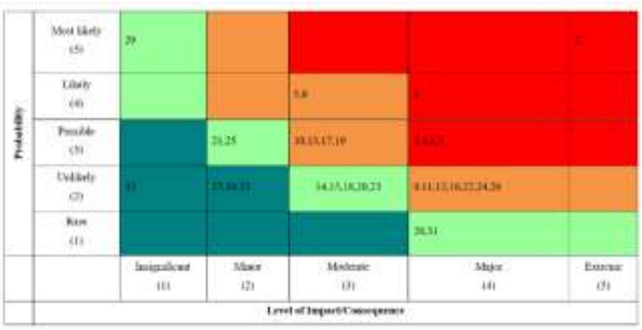
Where, Si= significance score assessed by respondent j for risk i.

α_j^i=probabilityofoccurrenceof risk i, assessed by respondent j; and

β_j^i = degree of impact of risk i, assessedby respondentj.

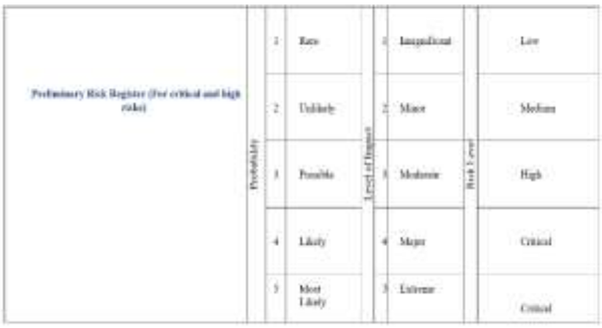
RISK HEAT MAP

Based on the response collected risks were differentiated as Critical, High , Moderate, Minor and unlikely and Risk heat map was prepared accordingly.



RISK REGISTER

Risk Register is prepared with the help of risk breakdown structure. It should be controlled utilizing a suitable information system which records, updates and traces all risk management activities and documentation.



In the above format, preliminary risk register for identified risks was created, which included Probability of occurrence, Level of impact , Risk Level and Mitigation plan for each and every identified risks.

Hence the Qualitative type of risk analysis helps in identifying risks with their probability of occurrence, risk level and helps to understand various mitigation plans to avoid the threats to the project.

V. QUANTITATIVE RISK ANALYSIS

Quantitative Analysis is being done by Monte Carlo Simulation method using @Risk software. This is the type of analysis wherein individual risk's impact on the project/activity is being analyzed. The baseline is imported to @risk software and simulation is run for 500 iterations. The activities which are impacting the schedule delay have been using Tornado diagram. This scheduleis then integrated with 12 primary/ critical risks that have been identified in the qualitative analysis. These risks are linked to activities to which they have impact on. Simulation is

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 10 Oct. 2022, pp: 403-409 www.ijaem.net ISSN: 2395-5252

run again for 500 iterations and the number of days required to be added to the plan is calculated.

SCHEDULE COMPARISION

The baseline schedule for the project is generated using MS Project. The baseline schedule implies that the project was planned to start on 02-06-2020 and complete on 25-06-202.

The actual start date is 02-06-2020 but the actual finish date is 28-07-2022. It can be observed that there is a lag of 399 days in the project which is due to an unknown risk i.e., pandemic. The preconstruction activities like feasibility studies, preparing budgets and approvals have been finished as planned but the construction activities started on 10-08-2021 instead of actual start date of construction activities i.e., 07-07-2020.

SlNO	Description	Planned start	Planned Finish	Planned Duration	Actual Start	Actual Finish	Actual Duration
1	Function hall construction	Tue 02-06-2020	Thu 24-06-2021	333days	Tue 02-06-2020	Thu 28-07-2022	675 days
1.1	Pre construction Activities	Tue 02-06-2020	Mon 06-07-2020	30 days	Tue 02-06-2020	Mon 06-07-2020	30 days
1.2	Construction phase/Execution phase	Tue 07-07-2020	Thu 24-06-2021	303 days	Tue 10-08-2021	Thu 28-07-2022	303 days

Hence the total project duration is 675 days when the unknown risk i.e., pandemic is considered.

MONTE CARLO SIMULATION

Inputs required for the simulation: Schedule with categorization of WBS according to their risk levels (High, Medium, Low).

Duration was estimated using three-point estimation method for all the activities in the WBS.

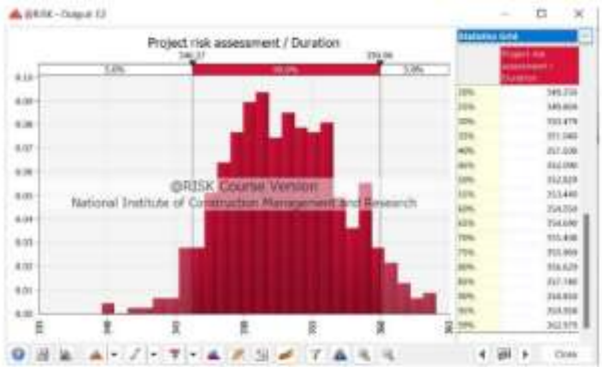
Risk Type	Estimated Duration	
	Optimistic	Pessimistic
Low Risk	-5%	+10%
Medium Risk	-15%	+30%
High Risk	-20%	+60%

The schedule then prepared is imported into @Risk Software to run Monte Carlo Simulation. With the help of above table, activity duration range for all the activities is given in the software. Triangular distribution for activity duration is defined and the simulation is run for 500 number of iterations.

INTERPRETING THE RESULTS

Frequency curve

The simulation program simulates and graphs the findings when the simulation is completed.



The probability of completion of various duration can be occurred using this result. i.e.,

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 10 Oct. 2022, pp: 403-409 www.ijaem.net ISSN: 2395-5252

Probability	Days	Probability	Days
1%	342.869	55%	353.440
5%	345.919	60%	354.050
10%	347.75	65%	354.690
15%	348.919	70%	355.408
20%	349.250	75%	355.969
25%	349.869	80%	356.629
30%	350.479	85%	357.740
35%	351.040	90%	358.850
40%	351.508	95%	359.958
45%	352.090	99%	362.979
50%	352.829		

Result: -The probability of completing the project in 333 days is less than 1.00 percent. As a result, considering the risks stated, the completion date projected in CPM is unlikely to materialize. The average number of days required to complete the project is 353days, maximum being 367 days, and minimum number of days required to complete the project is 338 days by considering the risks other than pandemic.

Criticality Index and Cruciality Index

The criticality Index determines how likely an activity is to be on the critical path. It's a straightforward metric that expresses the likelihood of becoming crucial as a percentage. The CI's fundamental flaw is that it is limited to gauging likelihood, which is not necessary that high CI activities have a large influence on the overall project timeframe.

The cruciality index is the correlation between the duration of the activity and the total project duration.

CRI = correlation (Activity Duration, Project Duration)

This index fulfills the drawbacks of criticality index and indicates the level of impact an activity has on the total project duration. Higher the cruciality index, higher is the impact.

VI. ADVANCE RISK ANALYSIS

Advance Risk analysis is done by integrating schedule with the risk register and performing Monte Carlo simulation.

Risk register lists important project specific risks that can impact a project schedule and thus needs to be cautiously tracked throughout the life cycle of the project.

Typically, each risk event mentioned in risk register might or might not occur, with a given probability of occurrence. If a risk occurs, the size of the impact of the risk is also uncertain. A risk register is built in an Excel worksheet. The row and column format makes it easy to enter a table of risks. @RISK distribution functions can be used to determine the occurrence (or nonoccurrence) of risks and their impacts.

The risks in a register come into "action" during a simulation. On each iteration, @RISK samples whether or not a specific risk occurs and their impacts

Risk	Probability: Occurrence	Probability: Non occurrence	Simulated Occurrence	Occurs?	Schedule impact (days): Min	Most likely	Max	Mean	Simulate # Schedule	Days added to plan
Shortage of skilled workers	82%	18%	1	TRUE	18	20	24	19.71	20	20
Loss due to fluctuation of inflation rate	64%	36%	1	TRUE						0
Poor workmanship of contractors	48%	52%	1	TRUE	8	10	12	9.8646	10	10
Payment Delays/ Project funding issues	70%	30%	1	TRUE						0
Unexpected surface conditions	49%	51%	0	FALSE	8	10	12	9.8646	10	0
Shortage in supply of water	60%	40%	1	TRUE	8	10	12	9.8646	10	10
Unavailability of earth hollars and other construction materials in nearby vicinity	46%	54%	0	FALSE	12	15	18	14.797	15	0
Delay due to untimely submission of reports from PMC	46%	54%	0	FALSE	12	15	18	14.797	15	0
Change of material specification	62%	38%	1	TRUE	9.6	12	14.4	11.838	12	12
Monopoly of suppliers	58%	42%	1	TRUE	8	10	12	9.8646	10	10
Loss due to rise in fuel prices	52%	48%	1	TRUE						0
Delay due to unknown risks	36%	64%	0	FALSE						0
Change in Scope of work	70%	30%	1	TRUE	8	10	12	9.8646	10	10
										[illegible]

Tasks | Risk Register

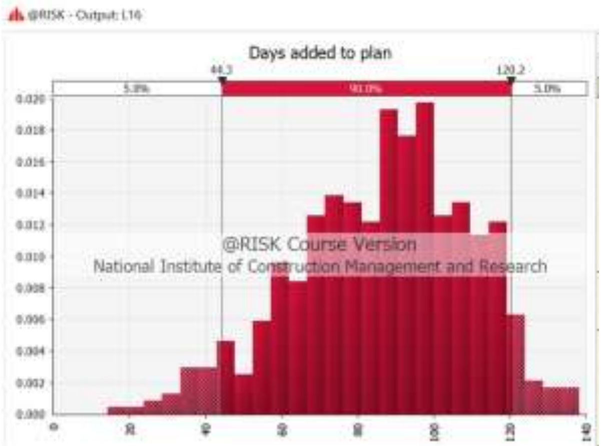
The risk register is prepared in the above format wherein, the probability of these risks to occur was obtained from qualitative analysis performed in phase 1 of the project and discussion withexpert and

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 10 Oct. 2022, pp: 403-409 www.ijaem.net ISSN: 2395-5252

this value is indicated in column B Column D shows simulated occurrence which takes value of either 0 or 1 in each iteration; if this value is 1, then column E flashes "Yes" and if column D says 0, then column E flashes "No". Yes and No means that corresponding risk has occurred or not in that iteration. Simulated schedule impact in column K shows most likely delay if a specific risk occurs and is obtained after extensive discussion with guide and construction professional. This value is added in column L i.e., "Days added to plan" for the risk that occurs in a particular iteration.

Simulation is run for binomial and pert distribution. At the end of 500 iterations, the number of additional days required to complete the project is calculated.

Result



The frequency curve implies that, if the identified risks occur in the iterations, an average of 72 days will be added to plan/schedule. i.e, the project will take 405 days to complete. Hence in total by considering the risk register as well as the delay occurred due to pandemic, 738 days is required.

VII. CONCLUSION

- Qualitative Analysis deals with individual project risks that may or may not occur but are identified and classified as Critical risks, High risks, Moderate risks, Minor and Low risks based on questionnaire survey. Whereas quantitative risk analysis deals with overall project risk affecting the project/activity completion time.
- Thirty-seven risk factors that were identified and presented on a risk heat map gives a broad overview of risk severity within a construction project, and subsequent risk register gives overall risk situation within a project along with mitigation measures and status of risk. It is imperative to update risk register from time to time in order to effectively manage risk.
- Monte Carlo simulation, as an advanced data mining tool in project management, may give a plethora of information for risk management, such as critical path report, criticality distribution and duration probability curves. Monte Carlo simulation may offer decision makers with direct graphical information to help them choose a realistic but acceptable project duration.
- The project has been delayed straight away by one year i.e., 333days due to occurrence of unknown risk/environmental risk.
- In terms of the possibility of finishing the project on time excluding pandemic, the simulation utilizing @RISK software revealed that there are less chances of finishing the project within 333 days (most likely duration). Project is likely to get delayed by 30days when risk register is not considered and by 72days when risk register is considered. This demonstrates that in an unpredictable environment, the due date based on most expected durations, which is commonly employed is not accurate; it is unlikely to be met.
- Therefore, by considering both risk register as well as pandemic risk, the total duration of the project comes to 738 days.
- Hence the advance risk analysis helps in mitigating/minimizing the risks that has huge impact on the schedule so that the project duration can be met. Also, the contingency reserve of 72 days has to be kept at the time of planning.

REFERENCES

[1]. Akintoye, "Risk analysis and management in construction", 31-38, 1997.
[2]. Mulholland, B., "Risk assessment in construction schedules".8-15,1999.

[3]. Project Management Institute, “A Guide to the Project Management Body of Knowledge, 6th edition”, 2017.
[4]. Bouayed,” Using Monte Carlo simulation to mitigate the risk of project cost overruns”. 293-300,2016
[5]. Kong, “Comparison of Project Scheduling techniques: PERT versus Monte Carlo simulation”,2015.
[6]. Palisade Corporation. Palisade.com for @Risk and Top Rank software
[7]. Sharath Babu Khedagi, “Risk Management for a construction project - A case study”, 2018
[8]. Loosemore, “Risk management in projects”, 2005
[9]. Mills A, “A systematic approach to risk management for construction”, 2001