Quantitative Risk Analysis and Risk Response Planning for Construction Projects

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Abstract: It is observed that most of the infrastructure projects fail to meet their cost and time constraints. This paper proposes a risk quantification methodology and demonstrates its application for an industrial construction project. A case study is used to present an application of the proposed risk management methodology to help organisations efficiently choose risk response strategy and allocate limited resources. The research adopts an integrated approach to prioritize risks using Group Technique for Order Preference by Similarity to Ideal Solution (GTOPSIS) and to quantify risks in terms of overall project delays using Judgmental Risk Analysis Process (JRAP), and Monte Carlo Simulation (MCS). A comparison between the results of qualitative risk analysis using GTOPSIS and quantitative risk analysis i.e., JRAP and MCS is presented. It is found that JRAP along with MCS could provide some powerful results which could help the management control project risks. The analysis can help improve the understanding of implications of specific risk factors on project completion time and cost, while it attempts to quantify risks. In turn, this enables the project manager to devise a suitable strategy for risk response and mitigation.
Keywords: GTOPSIS, JRAP, MCS , Risk Analysis

1. INTRODUCTION

Risk Management is formally defined as the process by which an organisation assesses and addresses its future scenarios which should be followed by coordinated and economical application of resources or techniques to minimise monitor and control the probability or impacts. Or in other words understand the situations and maximise the realisation of opportunities. Risk can come from various sources including uncertainty in financial markets, threats from project failures that may be occurred at any phase in design, development, production, procurement or planning life cycles, legal matters, accidents and force majeure events. Here negative events are called as threats and positive events are known as opportunities. The process of risk management cycle is shown below: According to this cycle mainly **six** stages in the process of risk management.

- Identification of risk.
- Analysis of risk
- Evaluation of risk
- Treatment of risk
- Monitoring
- Control risk

Identifying the risk is the process of identifying individual project risks as well as sources of overall project risk, and documenting their characteristics. This is the most important process in risk analysis to recognise the real scenario. The key benefit of this process is the documentation of existing individual project risks and the sources of overall project risk. It also brings together information so the project team can respond appropriately to identify risks. This process is performed throughout the project.

On completion of the Identify Risks process, the content of the risk register may include but is not limited to:
List of identified risks. Each individual project risk is given a unique identifier in the risk register. Identified risks are described in as much detail as required to ensure unambiguous understanding. A structured risk statement may be used to distinguish risks from their cause(s) and their effect(s).

Potential risk owners. Where a potential risk owner has been identified during the Identify Risks process, the risk owner is recorded in the risk register. This will be confirmed during the Perform Qualitative Risk Analysis process.

List of potential risk responses. Where a potential risk response has been identified during the Identify Risks process, it is recorded in the risk register. This will be confirmed during the Plan Risk Responses process. Additional data may be recorded for each identified risk, depending on the risk register format specified in the risk management plan.

Risk report
The risk report presents information on sources of overall project risk, together with summary information on identified individual project risks. The risk report is developed progressively throughout the Project Risk Management process. On completion of the Identify Risks process, information in the risk report may include but is not limited to: Sources of overall project risk, indicating which are the most important drivers of overall project risk exposure; and Summary information on identified individual project risks, such as number of identified threats and opportunities, distribution of risks across risk categories, metrics and trends, etc.

Perform qualitative risk analysis
Perform Qualitative Risk Analysis is the process of prioritizing individual project risks for further analysis or action by assessing their probability of occurrence and impact as well as other characteristics. The key benefit of this process is that it focuses efforts on high-priority risks. This process is performed throughout the project. Perform Qualitative Risk Analysis establishes the relative priorities of individual project risks for Plan Risk Responses. It identifies a risk owner for each risk who will take responsibility for planning an appropriate risk response and ensuring that it is implemented. Perform Qualitative Risk Analysis also lays the foundation for Perform Quantitative Risk Analysis if this process is required. The Perform Qualitative Risk Analysis process is performed

regularly throughout the project life cycle, as defined in the risk management plan. Often, in an agile development environment, the Perform Qualitative Risk Analysis process is conducted before the start of each iteration.

Perform quantitative risk analysis

Perform Quantitative Risk Analysis is the process of numerically analysing the combined effect of identified individual project risks and other sources of uncertainty on overall project objectives. The key benefit of this process is that it quantifies overall project risk exposure, and it can also provide additional quantitative risk information to support risk response planning. This process is not required for every project, but where it is used, it is performed throughout the project. Perform Quantitative Risk Analysis is not required for all projects. Undertaking a robust analysis depends on the availability of high-quality data about individual project risks and other sources of uncertainty, as well as a sound underlying project baseline for scope, schedule, and cost. Quantitative risk analysis usually requires specialized risk software and expertise in the development and interpretation of risk models. It also consumes additional time and cost. The use of quantitative risk analysis for a project will be specified in the project's risk management plan. It is most likely appropriate for large or complex projects, strategically important projects, projects for which it is a contractual requirement, or projects in which key stakeholder requires it. Quantitative risk analysis is the only reliable method to assess overall project risk through evaluating the aggregated effect on project outcomes of all individual project risks and other sources of uncertainty.

SCOPE

- Monte Carlo simulations are used to model the probability of different outcomes in a process that is complicated due to internal and external factors of project.
- It is helpful to understand the schedule and financial risks that may lead to slip from the defined scope of the projects.
- Studies have been conducting worldwide in every type of projects to manage risk effectively and efficiently.
- Different mathematical and simulations standards are applied to get the better prediction result related to project.
- All the projects in the world is focusing on three constraints as time, cost and quality.

OBJECTIVES

The project is focussed on the methods of analysis and managing of construction projects through various simulation methods. Even the uncertainty or risk may be positive or negative

- Minimise the threats and enhance opportunities in the project management.
- Risk and opportunity management is the key to success in existing and future projects of organisation.
- Determine key risk indicators (KRI) and key performance indicators (KPI) to align effort to meet organisational strategic goals.
- Do any type of SWOT analysis to determine overall Strength, Weakness, Opportunities and Threats.
- Risk management contribute overall business continuity of the organisations.

Objectives can be different depending upon the risk management nature and one thing is common and very specific; achieving strategic goals.

METHODOLOGY

Risk management is the process of identifying areas of risk that could negatively impact the success of the project and proactively managing those areas. After high-risk areas are identified, risk control processes are selected and implemented. This chapter deals with the methods that adopted to manage the risk occurred in various construction projects. Certain systematic procedures are following to measure the occurrence of risk in the project.

Definitions of risk probability and impact levels are specific to the project context and reflect the risk appetite and thresholds of the organization and key stakeholders. The project may generate specific definitions of probability and impact levels or it may start with general definitions provided by the organization. The number of levels reflects the degree of detail required for the Project Risk Management process, with more levels used for a more detailed risk approach typically of five levels and minimum of three levels. They are Time, Cost, Scope, Quality and the level of Risk.

Probability and impact matrix.

Prioritization rules may be specified by the organization in advance of the project and be included in organizational process assets, or they may be tailored to the specific project. Opportunities and threats are represented in a common probability and impact matrix usingPositive definitions of impact for opportunities and negative impact definitions for threats. Descriptive terms (such as very high, high, medium, low, and very low) or numeric values can be used for probability and impact. Where numeric values are used, these can be multiplied to give a probability-impact score for each risk, which allows the relative priority of individual risks to be evaluated within each priority level. An example probability and impact matrix is presented below:

Probability	Threats					Opportunities					Probability
Very High 0.90	0.05	0.09	0.18	0.36	0.72	0.72	0.36	0.18	0.09	0.05	Very High 0.90
High 0.70	0.04	0.07	0.14	0.28	0.56	0.56	0.28	0.14	0.07	0.04	High 0.70
Medium 0.50	0.03	0.05	0.10	0.20	0.40	0.40	0.20	0.10	0.05	0.03	Medium 0.50
Low 0.30	0.02	0.03	0.06	0.12	0.24	0.24	0.12	0.06	0.03	0.02	Low 0.30
Very Low 0.10	0.01	0.01	0.02	0.04	0.08	0.08	0.04	0.02	0.01	0.01	Very Low 0.10
	Very Low 0.05	Low 0.10	Moderate 0.20	High 0.40	Very High 0.80	Very High 0.80	High 0.40	Moderate 0.20	Low 0.10	Very Low 0.05	
	Negative Impact					Positive Impact					

Five alternative strategies may be considered for dealing with threats, as follows:

Escalate. Escalation is appropriate when the project team or the project sponsor agrees that a threat is outside the scope of the project or that the proposed response would exceed the project manager's authority. Escalated risks are managed at the program level, portfolio level, or other relevant part of the organization, and not on the project level. The project manager determines who should be notified about the threat and communicates the details to that person or part of the organization. It is important that ownership of escalated threats is accepted by the relevant party in the organization. Threats are usually escalated to the level that matches the objectives that would be affected if the threat occurred. Escalated threats are not monitored further by the project team after escalation, although they may be recorded in the risk register for information.

Avoid. Risk avoidance is when the project team acts to eliminate the threat or protect the project from its impact. It may be appropriate for high-priority threats with a high probability of occurrence and a large negative impact. Avoidance may involve changing some aspect of the project management plan or changing the objective that is in jeopardy in order to eliminate the threat entirely, reducing its probability of occurrence to zero. The risk owner may also take action to isolate the project objectives from the risk's impact if it were to occur. Examples of avoidance actions may include removing the cause of a threat, extending the schedule, changing the project strategy, or reducing scope. Some risks can be avoided by clarifying requirements, obtaining information, improving communication, or acquiring expertise.

Transfer. Transfer involves shifting ownership of a threat to a third party to manage the risk and to bear the impact if the threat occurs. Risk transfer often involves payment of a risk premium to the party taking on the threat. Transfer can be achieved by a range of actions, which include but are not limited to the use of insurance, performance bonds, warranties, guarantees, etc. Agreements may be used to transfer ownership and liability for specified risks to another party.

Mitigate. In risk mitigation, action is taken to reduce the probability of occurrence and/or impact of a threat. Early mitigation action is often more effective than trying to repair the damage after the threat has occurred. Adopting less complex processes, conducting more tests, or choosing a more stable seller are examples of mitigation actions. Mitigation may involve prototype development (see Section 5.2.2.8) to reduce the risk of scaling up from a bench-scale model of a process or product. Where it is not possible to reduce probability, a mitigation response might reduce the impact by targeting factors that drive the severity. For example, designing redundancy into a system may reduce the impact from a failure of the original component.

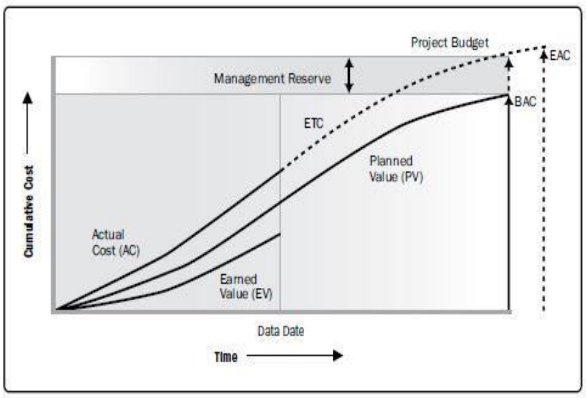
Accept. Risk acceptance acknowledges the existence of a threat, but no proactive action is taken. This strategy may be appropriate for low-priority threats, and it may also be adopted where it is not possible or cost-effective to address a threat in any other way. Acceptance can be either active or passive. The most common active acceptance strategy is to establish a contingency reserve, including amounts of time, money, or resources to handle the threat if it occurs. Passive acceptance involves no proactive action apart from periodic review of the threat to ensure that it does not change significantly.

Quantitative risk analysis uses a model that simulates the combined effects of individual project risks and other sources of uncertainty to evaluate their potential impact on achieving project objectives. Simulations are typically performed using a Monte Carlo analysis.

EARNED VALUE MANAGEMENT (EVM)

Earned value analysis or Earned value management compares the performance measurement baseline to the actual schedule and cost performance. EVM integrates the scope baseline with the cost baseline and schedule baseline to form the performance measurement baseline. EVM develops and monitors three key dimensions for each work package and control account.

Planned value: Planned value (PV) is the authorized budget assigned to scheduled work. It is the authorized.
Earned value: Earned value (EV) is a measure of work performed expressed in terms of the budget authorized.
Actual cost: Actual cost (AC) is the realized cost incurred for the work performed on an activity during specific time period. It is the total cost incurred in accomplishing the work that the EV measured.
Forecasting: As the project progresses, the project team may develop a forecast for the estimate at completion (EAC) that may differ from the budget at completion (BAC) based on the project performance. If it becomes obvious that the BAC is no longer viable, the project manager should consider the forecasted EAC. Forecasting the EAC involves making projections of conditions and events in the project's future based on current performance information and other knowledge available at the time of the forecast. In earned value analysis, three parameters of planned value, earned value, and actual cost can be monitored and reported on both a period-by-period basis (typically weekly or monthly) and on a cumulative basis.



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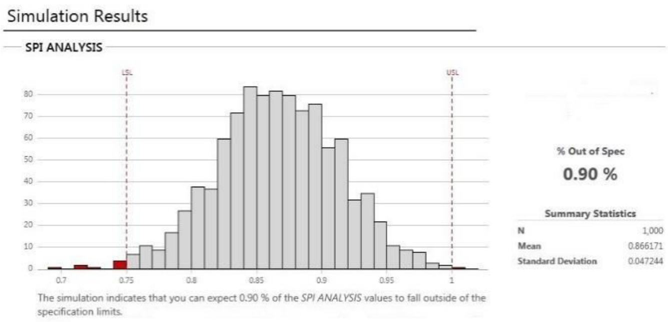
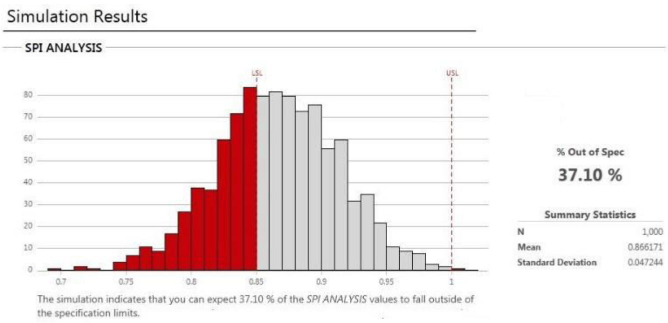
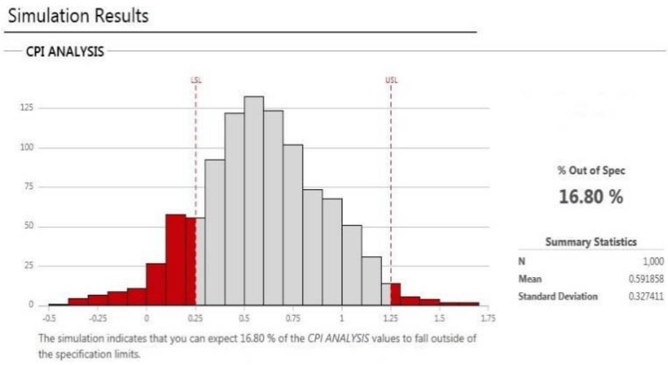
SCHEDULE PERFORMANCE INDEX (SPI) ANALYSIS BY MONTE CARLO SIMULATION





From the above two cases we can understand that the specification limit of 0.75 to 1, which will suitable for our project. So we can set a Schedule Performance Index (SPI) within this limit for better monitoring of the schedule of the project.

COST PERFORMANCE INDEX (CPI) ANALYSIS BY MONTE CARLO SIMULATION



From the analysis we can see the cost performance index may vary from -0.25 to above 1.5. The variations are measured based on the change in schedule and chances of escalation of cost. So by controlling the schedule progress and managing better contracts, we can avoid the chances of variation from CPI that we preferred. By this way we can execute the Monte Carlo Simulation in the case study of construction project that we included. After Monte Carlo Simulation we may go for the "Sensitivity Analysis" based on the complexity of the project which will give more visibility in tracking the progress and forecasting.
Here we calculate the expect level of performance and based on that we have to do the risk over total cost and total time.

Work Breakdown Structure (WBS)	Actual Duration	SPI	Effective Actual Time	Time Over consumes
General Conditions	11.8 d	0.8	8.85d	3d
Long lead Procurement	26.83d	0.9	23.87	2.95d
Mobilise on site	4.61d		4.60d	1.22d
Site grading & Utilities	7.39d	0.8	5.76d	1.63d

Work Breakdown Structure (WBS)	Actual Cost	CPI	Effective Actual cost	Budget Over consumes
General Conditions	11.8 d	0.8	8.85d	3d
Long lead Procurement	26.83d	0.9	23.87	2.95d

Mobilise on site	4.61d		4.60d	1.22d
Site grading & Utilities	7.39d	0.8	5.76d	1.63d

From the above tables we can realize that the project takes an additional time of around 9 days in duration. And also an over budgeting occurred around Rs: 1,73,518.33 /-

From the schedule we can see that we are reaching only about 26 days of duration. If the trend of the schedule cannot be able to complete it will be a great financial risk and the completion time may elapsed.

Monte Carlo Simulation and we can do the speculations or uncertainties in the project. Each organisations have their own criteria of performance index. That should be depends on the enterprise environmental factors and organizational process assets of the project. Normally a construction project may depends its performance factors from internal and any external factors. Identifying such risk key the success of every project managers and stake holders.

CONCLUSIONS

The project risk management process does not have to be complicated or time consuming to be effective. By following a simple, tested, and proven approach that involves seven steps taken at the beginning of each project, the project team can prepare itself for whatever may occur. Of course there will always be changes and there may still be surprises, but the end result is that they are fewer, that the team feels prepared and that the project is not taken off course. Often, the steps in which triggers and preventive actions are identified are overlooked. However, these are vital to the entire risk management process. After a team has completed this exercise once, the members will be better conditioned on what to pay attention to while managing the project so they are more proactive in catching changes or issues early. If these steps in the risk management process are skipped, the team can find themselves in constant reaction mode, simply implementing a contingency plan for each risk after that risk catches them by surprise. They could also ignore a seemingly overwhelming list of project risks, which is why narrowing the list down to the most important risks is critical for making sure the list is used. And the findings are listed below:

- What if analysis can be used for the research and development type project, especially to finding the probability of occurance.Most probably it is suit for operation management.
- By using earned value method we can track the at present and trend based status of the time and cost factors of the ongoing projects.
- Project schedules may not be analysed only by the calculation of physical percentage completions. The hidden uncertainties can be calculated using Monte Carlo simulation techniques.
- Finally, approaches may be different but the aim will be the same; successful completion of the projects.

REFERENCES

1. MasoudNorouziaMartaChàferbcLuisaF.CabezabLaureanoJiménezaDieterBoerd : Circular economy in the building and construction sector: A scientific evolution analysis (2021)
2. AlexisPinsonnaultSkvareninaabMathieuCarriercDanaElena ManolacheaAnneliesBockstaeldeJeanPierreGagnéafgTony Lerouxab : Predictors of noise annoyance from construction of a large metropolitan highway project (2021)
3. NelsonRangelBuitragoa William J.NealbVictorN.deJongec : Risk assessment as tool for coastal erosion management (2020)
4. MatejMasárMáriaHudákováLadislavŠimákDanielBrezina : The current state of project risk management in the transport sector (2019)
5. Saurav Dixit, Satya N. Mandal, Joseph V. Thanikal, Kinshuk Saurabh : Evolution of Studies in construction productivity": A systematic literatureReview(2018)
6. RemonFayek Aziz Eskander : Risk assessment influencing factors for Arabian Construction projects using analytic hierarchy process (2018)
7. XiaohuaJina, GuominZhangb, JunxiaoLiuc, YingbinFenga, JianZuo
: Major Participants in the Construction Industry and Their Approaches to Risks: a Theoretical Framework(2017)