# Strategic Risk Integration for Enhanced Cost and Schedule Estimates in Construction Projects

Amit Yadav [1], Dr. Manoj Sharma[2], Dr. Anurag Garg[3]
Research scholar[1], IPSCTM, Gwalior, Affiliated to RGPV, Bhopal (MP)
Professor[2] IPSCTM, Gwalior, Affiliated to RGPV, Bhopal (MP)
Professor[3] IPSCTM, Gwalior, Affiliated to RGPV, Bhopal (MP)

**ABSTRACT**

In the realm of construction project planning, the integration of cost and schedule estimates with risk management is crucial for successful project delivery. This study explores an innovative approach to optimize these estimates by incorporating risk factors into the planning process. We propose a framework that combines quantitative and qualitative risk assessment methodologies, enabling project managers to better forecast potential delays and budget overruns. Utilizing a combination of Monte Carlo simulations and expert judgment, the framework identifies key risk drivers and their impact on project timelines and costs. By employing sensitivity analysis, the model highlights the most significant risks, allowing for targeted mitigation strategies. The results demonstrate a marked improvement in the accuracy of cost and schedule estimates when risks are accounted for, leading to enhanced decision-making and resource allocation. This optimization not only supports better project outcomes but also fosters a culture of proactive risk management within construction teams. Ultimately, the integration of risk into cost and schedule planning represents a paradigm shift in how construction projects are managed, paving the way for more resilient and efficient project execution.

**Keywords:** Construction Management, Cost Estimation, Schedule Planning, Risk Management, Monte Carlo Simulation, Project Optimization.

## 1.INTRODUCTION

The government procurement process relies heavily on the correct selection of contractor. When deciding which bids to accept, decision-makers might follow either the lowest bid (LB)or best value (BV) philosophy. For the concept of lowest tender to apply, it must be determinedwhether or not the supplier's bid is the lowest of those received. In contrast to accepting the lowest bid, the best value tender principle takes into account other factors such as quality, priorperformance, pricing, technology, financial capabilities, etc. In the first part of this chapter, we'll get an overview of the context of best value bidding methods in building projects. After outlining the problem and what inspired us to solve it, we lay out our goals and strategies.

As projects grew more industrialized, a new paradigm for their administration emergedin the early 20th century; this paradigm gave birth to the field of project management as we know it today. The ground-breaking scheduling diagram was established in 1917 by Henry Gantt, commonly called the "father of modern project management," who wanted a visual timeline to display jobs with their individual durations necessary for execution and theinterdependencies between tasks. The Gantt chart is still widely used as a representation of theproject timeline because of the clarity it provides to all parties involved. In today's world, project management is generally accepted and used wherever possible. The evolution of software is responsible for the emergence of complex methods for guaranteeing the success of projects, which in turn necessitated the adoption of new tools and techniques.

## 2.LITERATURE REVIEW

**M. Zhang et al. (2020)** -This paper aims to use bibliometric and content-based analysis methods to review the previous attempts in related fields and present the current research status in this field. The results clarify the major limitations and challenges of the current research from both technical and practical perspectives, in turn suggesting the direction of future research.

**Umair Khalid et.al (2021)** - This paper adopts an empirical research methodology based on literature review and secondary data gathered systematically from peer-reviewed journals. There are around sixty H&S factors and these have been assigned to cluster leadings forming six groups namely: ‘organizational’, ‘managerial’, ‘legislative’, ‘social’, ‘environmental’ and ‘personnel’ factors. In developing the rationale for the safety management system (SMS) framework it has become apparent that the effective safety performance can only be achieved through effective (1) implementation of safety regulations, (2) leadership, (3) safety planning, (4) safety compliance, (5) performance measurement, (6) risk assessment, (7) safety inspection, and (8) Safety Culture.

**H. Wu *et*.al (2022) -**This research, guided by the design science approach, aimed to develop a blockchain-enabled framework for assuring the effectiveness of on-site safety inspection of tower cranes (OSITC). First, a literature review was conducted to identify OSITC challenges and blockchain potential. Then, a blockchain-based conceptual framework was provided, with two major components: smart contracts and the consensus process, being discussed. Finally, using the Hyperledger Fabric architecture, a prototype system was developed to instantiate and test the proposed framework. The findings suggest that the blockchain can protect the OSITC’s effectiveness by allowing safety inspections to be automatically executed via smart contracts and providing relevant stakeholders with trustworthy inspection records via consensus algorithms. This study provides a novel solution for tower crane safety management to construction researchers and practitioners, inspiring more discussions about blockchain technology.

**Salar Ahmadisheykhsarmast et.al (2023)** -This paper presents a novel decentralized blockchain-based system for accident/incident information management of construction projects. The proposed system leverages the benefits and advantages of blockchain, smart contracts, and decentralized IPFS storage to address the security transparency, tampering, and trustworthiness issues of the conventional approaches. The proposed system is simulated by using real-world construction accident data to demonstrate how blockchain technology can provide a novel solution to assure security, transparency, authenticity, availability, and immutability of the accident/incident data for improving safety management.

**Nelson Akindele et.al (2024)-** This analysis reveals a marked increase in research interest and identifies central thematic connections within the body of literature. The systematic review assesses VR technologies, including immersive, desktop-based, BIM-based, 3D game-based, and augmented reality, addressing their roles in hazard identification and safety training. The study also underscores challenges like infrastructure, content modeling, and interoperability and proposes directions for future research. Recommendations include probing into VR's role in cognitive safety risks and the impact of users' prior safety knowledge on learning outcomes. This study suggests that developing tailored VR experiences for specific user groups could significantly advance safety practices in the construction industry.

## 3. METHOD USED IN STUDY

In this study Methods for analyzing the breadth of possible changes in a project and the category of risk analysis have also been covered.

**MODELING-** The project network's information is imported into Microsoft Project, which acts as the project's scheduling engine. Connecting Microsoft Project with Excelenables users to adjust activity parameters and incorporate new project risks and challenges. The deterministic estimates serve as a benchmark for the associated activities and a starting point for analysing cost and schedule variances. To learn how the deterministic estimates shiftas new elements, such as uncertainties, pre-mitigation, mitigation, and post-mitigation, are included, analysts conduct independent Cost Risk Analysis (CRA) and Schedule Risk Analysis(SRA) studies.

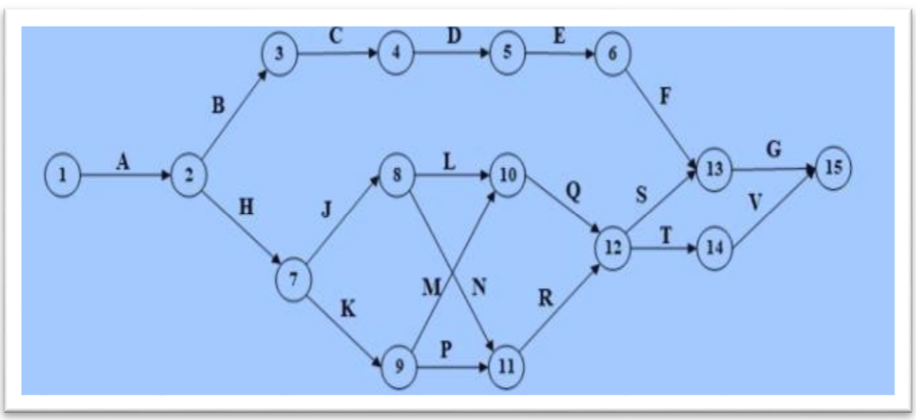
**SIMULATION-** To develop project-specific scenarios, the risk analysis model must be iterated numerous times. Each activity's cost and duration are treated as random variables with a probability density function that is defined at each analysis level. It is possible to sample using either Latin Hypercube sampling or Monte Carlo sampling, and the simulator generates values for each random variable depending on its probability density function.

**Sensitivity Analysis-** When performing a sensitivity analysis, one looks at how each input variable affects the result. The results from the simulations can be used to measure how much one input affects the result. Input values that make up the bottom 10% are mapped to the bottom 10% of the output variable (i.e., 100 lowest values from the 1000 values generated by 1000 iterations in one set of simulation.) the lowest value of the variation caused to mean by the associated input variable is picked from the simulation data and its mean is determined. The contribution of each input variable to the output variation is shown as a percentage of the variance of the output variable. This allows for a comparison of each activity's contribution to the variation, and the identification of the most variance-generating activities for further investigation and control.

## 4.METHODOLOGY

### A HYPOTHETICAL CONSTRUCTION PROJECT NETWORK

A hypothetical project was chosen for performing risk analysis and testing the effectiveness of the proposed framework. The project consists of 19 major activities which are distinguished by milestone events. The project is represented by a hypothetical Activity-On-Arrow (AOA) project network, as shown in figure1.




The network diagram represents the interrelationships and the precedence relations that exist between the activities involved in the project. The network has series and parallel paths along with some cross-links between different paths. Such paths are usually present in projects, and hence, the hypothetical project shows a realistic nature.

**DETERMINISTIC ESTIMATES**

| Activity | Execution Cost (INR) | Duration (Days) | Activity | Execution Cost(INR) | Duration (Days) |
|---|---|---|---|---|---|
| A | 106,400 | 77 | L | 60,800 | 105 |
| B | 60,800 | 112 | M | 110,200 | 119 |
| C | 266,000 | 182 | N | 150,200 | 224 |
| D | 72,500 | 133 | P | 45,600 | 91 |
| E | 95,000 | 133 | Q | 37,300 | 112 |
| F | 38,000 | 84 | R | 55,000 | 98 |
| G | 45,000 | 70 | S | 72,200 | 119 |
| H | 34,200 | 91 | T | 82,800 | 63 |
| J | 218,000 | 126 | V | 190,000 | 84 |
| K | 160,000 | 147 | **Total** | **1,900,000** | **805** |

**Table 1 Deterministic time and cost estimates for activities of the hypothetical project**

According to the deterministic estimate, the hypothetical project has a total project cost of INR 1,900,000 and a project duration of 805 days.

**Uncertainties**

This stage of analysis was done to incorporate the uncertainty involved in the baseline estimate or the deterministic estimate and make the estimate probabilistic. Activities of the hypothetical project under consideration were assigned with PERT cost estimates representing the uncertainty in the baseline estimate, as shown in Table 2.

| Activity | $c_o$ (INR) | $c_m$ (INR) | $c_p$ (INR) |
|---|---|---|---|
| A | 80,000 | 110,000 | 150,000 |
| B | 50,000 | 61,000 | 80,000 |
| C | 240,000 | 270,000 | 310,000 |
| D | 60,000 | 73,000 | 100,000 |
| E | 80,000 | 100,000 | 130,000 |
| F | 30,000 | 40,000 | 60,000 |
| G | 40,000 | 45,000 | 55,000 |
| H | 25,000 | 35,000 | 50,000 |
| J | 200,000 | 220,000 | 250,000 |
| K | 140,000 | 160,000 | 190,000 |

| Activity | $c_o$ (INR) | $c_m$ (INR) | $c_p$ (INR) |
|---|---|---|---|
| L | 55,000 | 61,000 | 70,000 |
| M | 100,000 | 110,000 | 130,000 |
| N | 120,000 | 150,000 | 200,000 |
| P | 40,000 | 46,000 | 60,000 |
| Q | 30,000 | 38,000 | 50,000 |
| R | 50,000 | 55,000 | 70,000 |
| S | 60,000 | 72,000 | 90,000 |
| T | 75,000 | 83,000 | 100,000 |
| V | 180,000 | 190,000 | 210,000 |

The simulation results obtained were used to calculate the required statistical functions and probability density functions to analyze the variations caused to the deterministic estimates. Sensitivity analysis was also carried out by forming tornado graphs from the simulation data to identify activities having the most effect on the variations caused to the total project.

**Pre-mitigation -** The pre-mitigation stage of risk analysis was done to analyze the scenarios in which risks exist in the system and affect the execution of project activities when no mitigation measures are adopted.All activities were considered to have risks associated with its execution, and the risk involved wasquantified in terms of potential deviation that can be caused to the cost from the uncertainties stageof analysis.

| Risk event | co (INR) | $c_m$ (INR) | cp (INR) | Probability of occurrence |
|---|---|---|---|---|
| $PMR_a$ | 80,000 | 110,000 | 150,000 | 40% |
| $PMR_b$ | 50,000 | 61,000 | 80,000 | 20% |
| $PMR_c$ | 240,000 | 270,000 | 310,000 | 25% |
| $PMR_d$ | 60,000 | 73,000 | 100,000 | 30% |
| $PMR_e$ | 80,000 | 100,000 | 130,000 | 50% |
| $PMR_f$ | 30,000 | 40,000 | 60,000 | 40% |
| $PMR_g$ | 40,000 | 45,000 | 55,000 | 50% |
| $PMR_h$ | 25,000 | 35,000 | 50,000 | 25% |
| $PMR_j$ | 200,000 | 220,000 | 250,000 | 10% |
| $PMR_k$ | 140,000 | 160,000 | 190,000 | 35% |
| $PMR_l$ | 55,000 | 61,000 | 70,000 | 25% |
| $PMR_m$ | 100,000 | 110,000 | 130,000 | 45% |
| $PMR_n$ | 120,000 | 150,000 | 200,000 | 30% |
| $PMR_p$ | 40,000 | 46,000 | 60,000 | 10% |

| | | | | |
|---|---|---|---|---|
| $PMR_q$ | 30,000 | 38,000 | 50,000 | 40% |
| $PMR_r$ | 50,000 | 55,000 | 70,000 | 25% |
| $PMR_s$ | 60,000 | 72,000 | 90,000 | 50% |
| $PMR_t$ | 75,000 | 83,000 | 100,000 | 5% |
| $PMR_v$ | 180,000 | 190,000 | 210,000 | 30% |

**Table 3 PERT cost estimates and probability of occurrence for pre-mitigated risk events**

**Mitigation -** The mitigation stage of risk analysis included the mitigation activities without considering any riskapart from the uncertainties involved in the time estimates of activities. This was done to analyze the extent of variations caused by adding the mitigation activities to the system and how it affectsthe total project duration.

| Mitigation activity | to (Days) | tm (Days) | tp (Days) | Probability of occurrence |
|---|---|---|---|---|
| $M_a$ | 1 | 4 | 8 | 100% |
| $M_b$ | 1 | 3 | 5 | 100% |
| $M_c$ | 1 | 2 | 4 | 100% |
| $M_d$ | 1 | 3 | 6 | 100% |
| $M_e$ | 1 | 4 | 8 | 100% |
| $M_f$ | 1 | 5 | 8 | 100% |
| $M_g$ | 1 | 3 | 6 | 100% |
| $M_h$ | 1 | 4 | 9 | 100% |
| $M_j$ | 1 | 4 | 8 | 100% |
| $M_k$ | 1 | 5 | 10 | 100% |
| $M_l$ | 1 | 5 | 9 | 100% |
| $M_m$ | 1 | 3 | 7 | 100% |
| $M_n$ | 1 | 4 | 6 | 100% |
| $M_p$ | 2 | 6 | 8 | 100% |
| $M_q$ | 2 | 8 | 12 | 100% |
| $M_r$ | 2 | 7 | 10 | 100% |
| $M_s$ | 2 | 6 | 13 | 100% |
| $M_t$ | 2 | 8 | 12 | 100% |
| $M_v$ | 1 | 4 | 9 | 100% |

Table 4 PERT time estimates and probability of occurrence for mitigation activities

## 5.RESULTS AND DISCUSSIONS

The results obtained from the simulations run at each stage of the cost risk analysis in the hypothetical project are used to form probability density functions for understanding variations, and tornado graphs for sensitivity analysis. The simulation data is also used to compute the requiredstatistical functions.

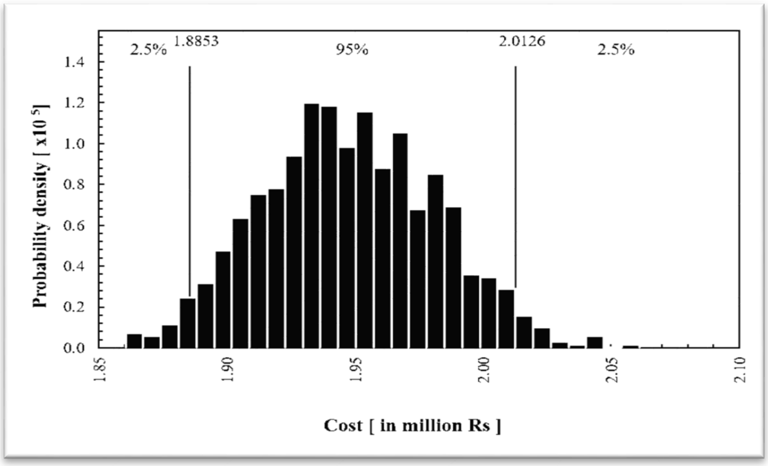



**Figure 1 Probability density function for project cost (Uncertainties)**

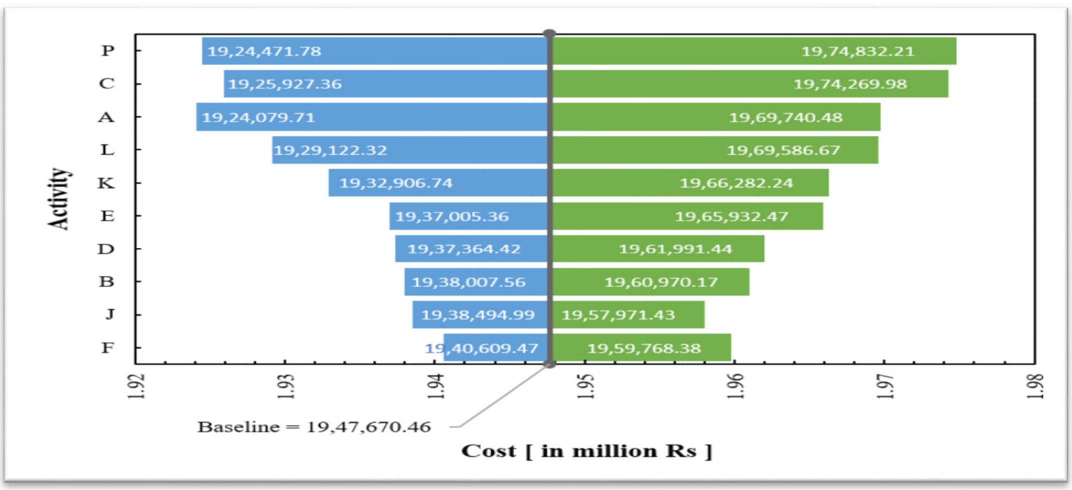



Figure 2 Effect of activities on mean project cost (Uncertainties)

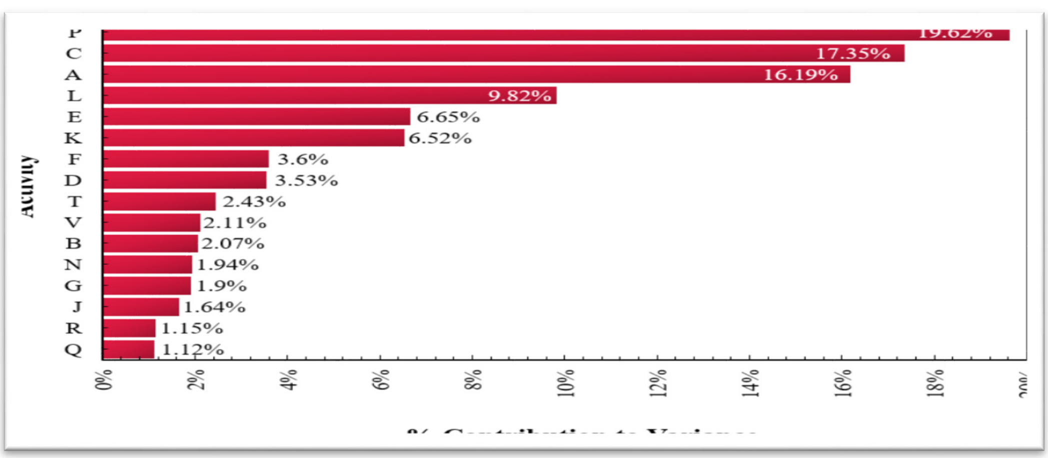


Figure 3 Contribution of activities to variance in project cost (Uncertainties)

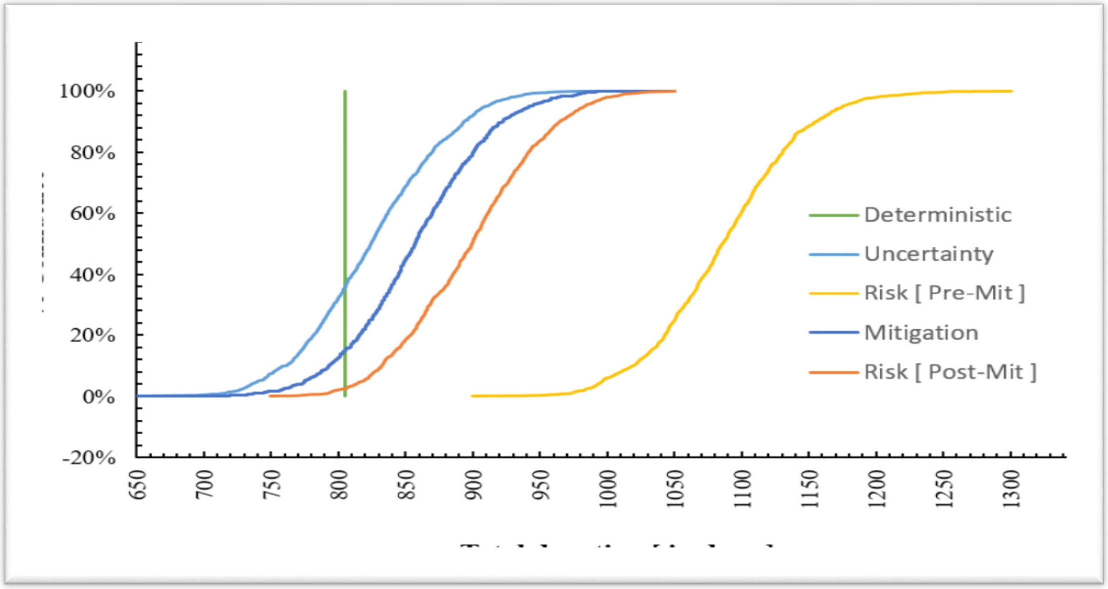



Figure 4 Combined cumulative density functions (SRA)

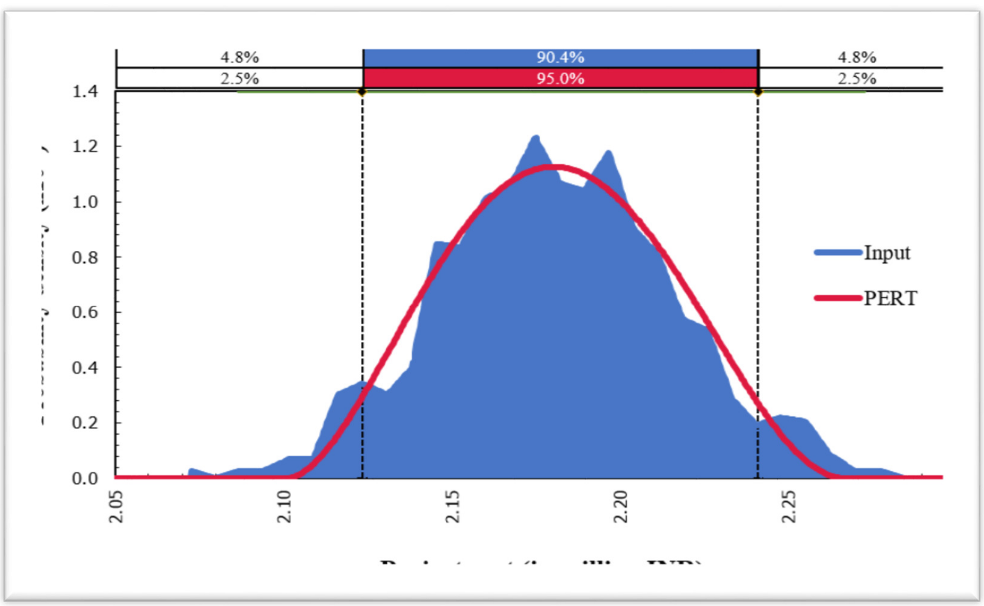



**Figure 5 PERT distribution for the final project cost from CRA**

## 6.CONCLUSION

The main objective of this study was to develop a framework for incorporating risks in planning to control cost and schedule overruns. The proposed model of risk analysis can be effectively usedin project planning to analyze the effects of uncertainties and risks on the project. The analysis carried out on the hypothetical project, and the boundary wall project shows the project schedule and costs change significantly with the incorporation of uncertainties and risks. An increase in project cost and project duration is observed in the final estimates when uncertainties and risks were considered along with a plan for mitigation. But the estimate from the pre-mitigation stage isconsiderably higher as it does not consider any risks or mitigation measures. The higher values ofestimates from the post-mitigation stage are justified by the much higher estimates from the pre- mitigation stage. Hence avoiding risks while planning can cause huge variations in actual project cost and project duration. The proposed model also allows the identification of activities causing major variations.

The mitigation activities increase the project cost and project duration compared to no riskcase, but it is seen that the post-mitigation project cost and project duration is significantly lesser than that from pre mitigation as the residual risks have a lower probability of occurrence and impact. Risk incorporated planning gives a better estimate for project cost and duration, along withan opportunity to plan for the uncertainties and risk events that may occur along with the execution of the project. When considered individually, 50th percentile values of project cost and project duration denotes a 50% chance for the project manager to complete the project within estimated cost and time. However, the combined analysis showed there is only 23.6% probability that the project will be completed within the 50th percentile values from individual cost and schedule riskanalyses and hence, 50th percentile values for project cost and project duration from the combinedcost and schedule risk analysis should be considered to get a 50% probability of success in terms of cost and duration.

## REFERENCES


[1] H.E. Exner, “Physical and Chemical Nature of Cemented Carbides,” International Metals Review, 1979, Vol. No. 24, pp. 149-173.

[2] V. Khodakarami, and A. Abdi, “Project cost risk analysis: A Bayesian networks approach for modeling dependencies between cost items,” International Journal of Project Management, Jan. 2014, Vol. No. 32, pp. 1233-1245.

[3] A.V. Hanagodimath, H.M. Rajashekharswamy, and H.R. Parate, “Project performance in real time construction industry – A case study.” International Journal of Civil Engineering and Technology (IJCIET), 2016, Vol.No.7, Issue 5, pp.93-102.

[4] H. Doloi, “Cost Overruns and Failure in Project Management: Understanding the Roles of Key Stakeholders in Construction Projects,” In Journal of Construction Engineering and Management, Mar. 2013, Vol.No.139, pp.267-279.

[5] M. Schieg, “Risk management in construction project management,” Journal of Business Economics and Management, 2006, Vol. No. 7, Issue. 2, pp.77-83.

[6] A. Chittara, “Time and cost overruns in public sector projects - India,” ELK Asia Pacific Journal of Finance and Risk Management, 2018, Vol.No.9, Issue 2, pp.2349-2325

[7] R.C. de Azevedo, L. Ensslin, and A.E. Jungles, “A Review of Risk Management in Construction: Opportunities for Improvement,” Modern Economy, 2014, Vol.No.5, pp. 367-383.

[8] A.V. Thomas, “Risk perception analysis of BOT road project participants in India,” Construction Management and Economics, 2003, Vol.No.21 Issue 4, pp. 393-407.

[9] P. Xiang, J. Zhou, X. Zhou, and K. Ye, “Construction Project Risk Management Based on the View of Asymmetric Information,” Journal of Construction Engineering and Management, ASCE, Nov. 2012, pp.1303-1311.

[10] A.V. Thomas, S.L. Kalidindi, and L.S. Ganesh, “Modelling and assessment of critical risks in BOT road projects,” Construction Management and Economics, Apr. 2006, Vol.No.24, pp. 407- 424.

[11] L.B. Singh, and S.N. Kalidindi, “Traffic revenue risk management through Annuity Model of PPP road projects in India,” International Journal of Project Management, 2006, pp. 605- 613.

[10] H. Aljassmi, and S. Han, “Analysis of Causes of Construction Defects Using Fault Trees and Risk Importance Measures,” Journal of Construction Engineering and Management, July. 2013, Vol.No.139, Issue 7, pp. 870-880.

[11] C.S. Goh, and H.A. Rahman, “Applying Risk Management Workshop for a Public

Construction Project: Case Study," Journal of Construction Engineering and Management, May. 2013, Vol.No.139, Issue.5, pp. 572-580.

[12] N. Xia, R. Zhong, C. Wu, X. Wang, and S. Wang, "Assessment of Stakeholder-Related Risks in Construction Projects: Integrated Analyses of Risk Attributes and Stakeholder Influences," Journal of Construction Engineering and Management, 2017, Vol.No.143, Issue.8, pp. 04017030- 11.

[13] R.M. Choudhry, M.A. Aslam, J.W. Hinze, and F.M. Arain, "Cost and Schedule Risk Analysis of Bridge Construction in Pakistan: Establishing Risk Guidelines," Journal of Construction Engineering and Management, 2014, Vol.No.140, Issue.7, pp. 04014020-9.

[14] D.A. Nguyen, M.J. Garvin, and E.E. Gonzalez, "Risk Allocation in U.S. Public-Private Partnership Highway Project Contracts," Journal of Construction Engineering and Management, 2018, Vol.No.144, Issue.5, pp. 04018017-5.

[15] A. Shrestha, T.K. Chan, A.A. Aibinu, C. Chen, and I. Martek, "Risk Allocation Inefficiencies in Chinese PPP Water Projects," Journal of Construction Engineering and Management, 2018, Vol.No.144, Issue.4, pp. 04018013-10.

[16] O.A. Jannadi, and S. Almishari, "Risk Assessment in Construction," Journal of Construction Engineering and Management, 2003, Vol.No.129, Issue.5, pp. 492-500.

[17] W. Tang, M. Qiang, C. F. Duffield, D.M. Young, and Y. Lu, "Risk Management in the Chinese Construction Industry," Journal of Construction Engineering and Management, Dec. 2007, Vol.No.133, Issue.12, pp. 944-956.

[18] P. Govan, and I. Damnjanovic "The Resource-Based View on Project Risk Management," Journal of Construction Engineering and Management, 2016, Vol.No.142, Issue.9, pp. 04016034- 16.

[19] D. Nasir, B. McCabe, and L. Hartono, "Evaluating Risk in Construction–Schedule Model ERIC–S: Construction Schedule Risk Model," Journal of Construction Engineering and Management, Oct. 2003, Vol.No.129, Issue 5, pp. 518-527.

[20] S.H. Han, J.E. Diekmann, and J.H. Ock, "Contractor's Risk Attitudes in the Selection of International Construction Projects," Journal of Construction Engineering and Management, Mar. 2005, Vol.No.131, Issue 3, pp. 283-292.