

# Risk Assessment in Construction Estimating: Identifying and Mitigating Uncertainties in Project Budgets

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## **Abstract**

The construction industry has uncertainties from fluctuating material price, labor shortage, environmental factors and the changing regulations. These risks undermine the accurate cost estimation necessary to financial plan any project, and budget overruns and project delays follow. This paper covers a comprehensive study on the major risk which affect the construction estimating work, which cover financial, technical, environmental and operational risks. It explores how advanced tools and methods, including Building Information Modeling, (BIM), Monte Carlo simulation, artificial intelligence (AI) and blockchain can mitigate these risks. Using in depth case studies of projects with severe cost overruns and successful projects where proactive risk management took place, this paper provides practical insights for future projects. It also outlines the direction that construction risk management is heading and suggests the way risk assessment and estimation processes can be enhanced.

**Keywords:** Risk Assessment, Construction Estimating, Cost Overrun, Risk Mitigation, Monte Carlo Simulation, BIM, AI, Blockchain, Project Uncertainty, Construction Risk Management.

## **Introduction**

Basically inevitably the construction industry is risky, and cost overruns happen constantly because of all kinds of uncertainty. The Project Management Institute recently found that an astounding 86 percent of construction projects exceed their initial budget [1], with some projects budgeted run over as much as 50 percent. These deviations are most frequently the product of risks that were not taken into account in the first place, or that were not considered in the first place, but perhaps undervalued.

Construction project management is one of the most difficult and important one among them is accurate cost estimation. It is about predicting, or estimating, the total cost of a project, and in doing so, one has to factor in labor, materials, equipment, overhead and contingency for the risks. While we have best efforts in place, estimates are often disrupted by unforeseen factors like sudden material price spikes, labor shortages, environmental changes and operational inefficiencies.

The paper digs deeper into the core construction estimating risks – financial, technical, environmental and operational – as well as embraces how construction risk management paradigm is changing with the advance of such technologies as Building Information Modeling (BIM), Monte Carlo simulations, artificial intelligence (AI) and blockchain. This research based on a review of current trends and case studies generates a roadmap for improvement construction estimating practices.

## Key Risks in Construction Estimating

### Financial Risks

Accurate construction cost estimation has always been a challenge with respect to financial risk. Among the main contributing factors to these risks are the volatility of material prices, the instantaneous saturation of material prices, which leads to indirect financial strain for construction projects. For example, as the COVID-19 pandemic and ongoing geopolitical tensions (such as the war in Ukraine) cause material shortages and skyrocketing costs in a myriad of global supply chains. In 2021 alone steel prices has increased more than 50%, which has screwed project budgets globally [2].



**Figure 1: A graphical representation of the key categories of risks in financial aspect of construction estimation.**

Construction projects, in particular long term projects that extend beyond initial financial planning periods, are further further complicated by inflation and interest rates. Among the risks to international projects are currency fluctuations, which can change enormously over the time from estimation to execution.

Labor shortages are also pushing up the cost of labor across the construction industry, as well. The problem is compounded by demographic trends: many skilled workers reach retirement age, and the industry has fewer younger recruits.

### Technical Risks

Project design, engineering, and new technology integration uncertainties are referred to as technical risks. Yet, poor scopes of projects, incomplete documentation and design defects can also cause large cost increases

during construction. The International Journal of Project Management has reported that technical risks in particular, risk changes, and unforeseen engineering challenges account for about 25% of project cost overruns [4].

The Berlin Brandenburg Airport is a notorious example of technical risk mismanagement: a project that endured a ten year delay and burned through billions of euros in extra costs. Technical design flaws in the project included fire safety systems that didn't work, structural miscalculations [5], which shows that this type of project needs robust technical risk assessment during planning phase.

There are risks connected to the introduction of the latest cutting edge construction technologies without proper oversight. The more projects that begin to adopt digital tools such as BIM, the greater the potential for technical disruptions if stakeholders are not provided sufficient training on the use of these systems. However, BIM also provides the opportunity to mitigate technical risks where it is used to its full potential. BIM produces detailed 3D models of projects and enables their early identification of design conflicts within the planning phase to reduce costly rework later in the project.

### **Environmental Risks**

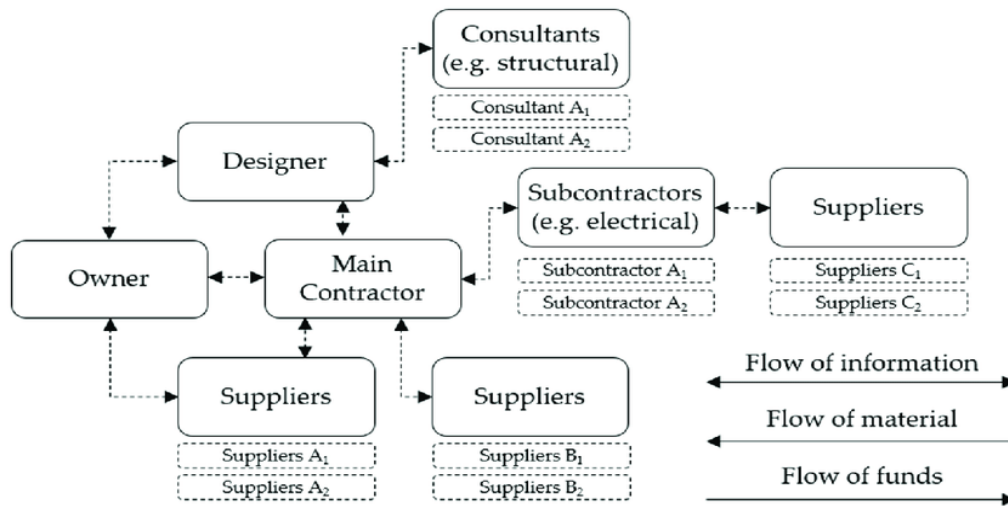
Perhaps the most unpredictable, yet impactful risks in construction are environmental risks. Included are natural disasters, extreme weather events, unforeseen site conditions that result in schedule delays and cost overruns. About 15 per cent of infrastructure projects globally run into delays because of environmental risk [6], according to the United Nations Office for Disaster Risk Reduction (UNDRR).

Environmental risks, though, are getting worse: storms, floods, and wildfires are becoming more common and more intense, capturing the focus of construction projects like never before. Given that the location of projects sits within areas subjected to natural disasters, delays, cause of site damage, and even reconstruction efforts should be allowed for in the completion and estimates of the projects.

One such example is the building of the Gotthard Base Tunnel in Switzerland, which confronted serious environmental difficulties, including high water stress and agitated rock arrangements. In the end, something unforeseen caused delays and dramatic cost increases. It allows projects to conduct environmental assessments that are thorough and to develop contingency plans so that when a risk like this occurs, projects are prepared for it.

### **Operational Risks**

Operational risks include events for which there is an uncertainty in project execution such as labor availability, supply chain disruptions, equipment malfunctions and subcontractor performance. During the COVID 19 pandemic operational risk was severe – supply chain breakdowns and labor shortages delayed projects adding to costs. The Construction Management Association of America (CMAA) found in a study of 2020 that 60% of construction projects experienced delays due to operational risks including the material and equipment procurement disruptions.



**Figure 2: Supply Chain Of A Construction Company.**

Supply chain issues are only part of the risk; we have labor shortages as well. For instance, the Canadian construction industry is forecast to lose approximately 156,000 workers to retirements between 2023 and 2027, which will make an all already critical labor shortage even more acute [9]. Not only does this shortage in skilled labor delay projects, but construction companies must pay more for constructing those projects as they compete for a shrinking pool of workers.

## Emerging Technologies and Their Role in Mitigating Risks

### Artificial Intelligence (AI) and Machine Learning

Artificial intelligence and machine learning are reinventing construction risk management: with better forecasting and smarter decision making. Project managers can use AI algorithms that can process immense historical data to find out about the patterns and to predict potential risks. A 2022 study suggests that AI based models, like Bayesian networks can predict the cost overruns with 78.86% accuracy that's superior to the traditional risk assessment process [10].

To that end, machine learning models can be integrated into project scheduling software to be continuously learning from real time data in the construction site and predicting possible delays before they happen. It helps make project management more dynamic, since AI tools can suggest tweaks to resource allocation and time lines to keep a project moving in the face of changing conditions.

### Blockchain Technology

The construction industry is adopting blockchain technology for contract and procurement management. Blockchain gives a secure and decentralized platform to record transactions and minimise the chance of fraud and disputes. One key innovation enabled by blockchain are smart contracts — self executing contracts with terms written into code. These contracts help pay contractors based on the completion of certain project milestones, and fast and swiftly reward the contractors for completed work, all while reducing the chances of disputes with the contractors [11].

It also helps bring down the complexity of the procurement process by utilizing blockchain technology to build an immutable record of transactions. Thus, Materials are purchased from approved suppliers under pre negotiated prices thus minimizing the risks of procurement delay or overrun of cost due to price changes.

### Building Information Modeling (BIM)

The most widely adopted technology to improve the construction risk management is Building Information Modeling (BIM). The 3D modeling in BIM is integrated with real time data for better project stakeholder collaboration and better forecasting. BIM helps planners spot potential design conflicts by visualizing every aspect of a project in detail, reducing the risk of expensive rework that occurs on the construction side.

A study published in Construction Management and Economics found that BIM projects achieved this reduction of up to 25% in cost overrun largely as a result of increased project coordination through earlier identification of risks [12]. With BIM, projects are better communicated between all parties involved — the contractors, the subcontractors, and even the client — as it gives everyone a unified platform to store and see all project related information.

### **Monte Carlo Simulation**

A quantitative risk assessment tool that models certain in construction project as simulating hundreds of scenarios of how the project may proceed through Monte Carlo simulation. So now project managers have a way to compare alternative cost scenarios and adjust their estimates as a result. Large scale projects, where multiple risk factors interact and affect project budget, have been found to be useful for Monte Carlo analysis. In fact, Osei-Kyei et al. (2022) found that Monte Carlo simulation methods for project cost reduction are 20% less variable than traditional methods of projects base [13]. The benefits of this tool are especially apparent with complex projects, which utilize a comprehensive view of how risks (material price fluctuations, labor shortages, environmental disruptions) contribute to project costs.

### **Case Studies**

#### **Sydney Opera House**

One of the worst cases of bad risk management in the construction industry was, and continues to be, the Sydney Opera House. Once a result of frequent design changes, technical errors as well as failings in contingency planning, the project first was expected to cost only AUD7 million but ended up cost \$102 million. Significant delays and cost overruns were the result of not doing sufficiently thorough risk assessments early in the project. Sydney Opera House teaches the lessons that robust risk management frameworks should be incorporated at the early phase of the project lifecycle when dealing with complex designs and unpredicted technical challenges [14].

#### **Heathrow Terminal 5**

As an example, construction of Heathrow Terminal 5 is viewed as the construction of a model of effective management of risks. To control budget and mitigate risks, as is common in many large infrastructure projects, the project team used BIM that were used in conjunction with Monte Carlo simulations and risk sharing contracts. While the project was complicated, and very large, it was delivered within its £4.3bn budget, demonstrating the value of proactive risk assessment, backed up by sophisticated technological tools in managing the delivery of large construction projects. Regular risk reviews, dynamic budgeting practices, and the integration of advanced digital tools like BIM, enabled real time communication and decision making by all project stakeholders, formed the key to the project's success [15].

### **Conclusion**

Construction estimating involves risk assessment and its direct impact on the financial success of any project. Mitigation of risks can reduce the risk of cost overruns and delay substantially, and construction managers can identify and mitigate these risks early on during the project's lifecycle. AI, BIM, blockchain, to name a few, such technologies are proving extremely valuable by adding depth to risk management capabilities and accuracy in construction estimates.

Sydney Opera House and Heathrow Terminal 5 are used as case studies to demonstrate how risk management can result in very high cost overruns or project success. The advances in modern construction project complexity require advanced technological solutions to be integrated into risk management frameworks. Moreover, current labor shortfalls, environmental problems and financial uncertainties in the industry only affirm the need for a far greater adoption of comprehensive risk mitigation strategies.

With the changing construction industry, constant improvement in implementing technologies and best practices to manage risks is what would be required to ensure achieving on time and on budget future projects.



In utilizing AI, BIM, blockchain, and quantitative risk analysis tools the industry can reduce project uncertainty and enhance overall project outcome.

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