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Modelling Risk for Construction Cost Estimating and Forecasting: A Review

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Abstract: *The study examined the modelling risk for construction cost estimating and forecasting. The reasons why risk management, more specifically, risk analysis, has not been applied more successfully in the construction industry are outlined, and it was determined that the primary obstacles to its widespread use are cultural issues such as ignorance, prejudice, and mistrust of risk analyses. Thus, risk management is the process of identifying, assessing, and prioritizing risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability or impact of unfortunate events or to maximize the realization of opportunities. The study noted that risk management is a critical aspect of business operations, as it involves identifying, assessing, and prioritizing risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability or impact of unfortunate events. Various analysis and modeling techniques are employed to effectively manage risks in different industries. The study concluded that several research studies have shown that, in comparison to other industries, the construction sector applies relatively little risk analysis and management. In order to increase the extent of their integration into the current estimating and forecasting process, the industry must figure out how to smoothly incorporate their activities into the widely used existing methods.*

Keywords: Modelling, Risk Analysis, Risk Management, Cost Estimate, Forecasting

Introduction

There are risks associated with every project and business endeavor. As stated, Abdou, Lewis, and Alzarooni, (2004) assert that compared to other industries, the construction sector is riskier. There are various kinds of risks and uncertainties in construction projects. Political, financial, economic, environmental, and technological are a few of these. Many of these uncertainties will have a range of potential financial outcomes, some of which may turn out to be better or worse than anticipated. Particularly in the construction sector, risk management's potential advantages have not yet been fully appreciated (Mana, 2013). The reasons why risk management, more specifically, risk analysis has not been applied more successfully in the construction industry are outlined by Ward and Chapman (2003), they determined that the primary obstacles to its widespread use are "cultural issues," such as ignorance, prejudice, and mistrust of risk analyses. Ye and Tiong (2000). looked into how risk management was used during Australian projects' conceptual stage. Although the majority of survey participants were aware of risk management, they discovered that there was little use of it during the conceptual stage. They contended that a lack of commitment to professional development and training in the field has resulted in a low knowledge and skill base, which is impeding the widespread adoption of risk management.

Investigating various methods for modeling risk and uncertainty in construction cost forecasting and estimation is the aim of this study. It is split up into three primary sections. An overview and background of the subject are given in the first section. The second section examines the various modeling and analysis methods used in risk management and how they apply to the construction industry. The third and final section examines several earlier research studies and case studies for risk modeling in construction cost forecasting and estimation.

Background

One of the most important tasks in budget development at any stage of a project's life cycle is estimating construction costs. That being said, it is done in an uncertain environment. The amount of information available and the instruments used during various project phases will have a significant impact on the preparation and accuracy of any kind of cost estimate. Due to their inaccuracy, traditional cost estimation techniques and procedures proved to be unsatisfactory decision-making aids, particularly during the feasibility or appraisal stage (Mana, 2013). Regardless of the risks connected with the project and how they may affect the budget and schedule, the majority of projects during that phase are budgeted on a cost per gross floor area basis.

There are several ways to classify cost-estimating techniques and methods, from order of magnitude to the application of artificial intelligence (AI). The estimator obtains cost rates from manuals, databases, or references in the majority of these methods or techniques. They must be modified for the time of use and are typically taken from earlier projects or tenders. A study by the Committee on Budget Estimating Techniques revealed that 35% of the projects in its sample had budget-related issues. The study focused on the causes of budget-related problems in US federal construction projects (Abdou, Lewis, and Alzarooni, 2004). In another scenario Al-Zarooni and Abdou (2000) carried out a survey to look into discrepancies in estimates for public projects in the UAE. Statistics revealed that while there were large variations (positive or negative) between feasibility and contract cost, ranging between -28.5% and +36%, with no discernible pattern for those variations, the differences between the actual and contract costs were at an acceptable level. They claimed that these differences could be explained by the fact that government agencies typically budget for feasibility estimates based on a single unit estimate (cost per square foot), regardless of the risks involved in the projects or the complexity of each building type's construction. In order to find out more about the application of risk management in the conceptual stage of UAE public projects, the same authors' research conducted a survey. They discovered that risk management approaches were hardly ever used in public projects, particularly in the conceptual phase. They contended that the use of risk assessment techniques during the pre-design phase would improve cost estimation and, consequently, decision-making.

Cost and Price

When discussing estimation, two fundamental terms are cost and price. The interpretation of a term like this is contingent upon one's perspective, as stated by (Alkass & Jard 2000). It was clarified that the client bears the cost of the seller's price. Therefore, in a building project, the cost of the subcontractor is the contractor's cost, and the cost of the contractor is the client's cost. Additionally, Gunther, Kurt, and Jan, (2007), stated that price represents the amount we are willing to pay for a commodity, while a cost is directly related to the goods and services used in its production. The authors came to the conclusion that when we talk about cost in estimating, we usually mean price. Therefore, in this paper, cost estimate refers to the total expected expense that the client will need to pay in order to finish a specific building project.

Definition and Framework of Risk Management

Risk management is the process of identifying, assessing, and prioritizing risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability or impact of unfortunate events or to maximize the realization of opportunities. Various studies have provided different definitions of risk management based on their specific focus and context. The International Organization for Standardization (ISO) (2018) defines risk management as the "coordinated activities to direct and control an organization with regard to risk. This definition emphasizes the need for a systematic approach to managing risks within an organization.

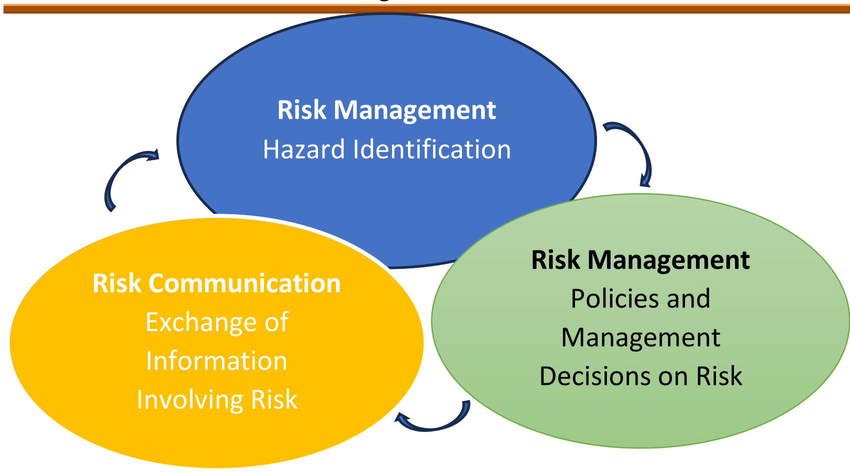
According to the Project Management Institute (PMI) (2020) risk management involves the processes of conducting risk management planning, identification, analysis, response planning, and controlling risk on a project. The Committee of Sponsoring Organizations of the Treadway Commission (COSO) (2004) defines risk management as a process affected by an entity's board of directors, management, and other personnel; applied in strategy setting and across the enterprise; designed to identify potential events that may affect the entity; and manage risk to be within its risk appetite.

Although, diverse meanings of risk can be found in relation to project management. According to Glahn, Peroutka, Wiedenfeld, Wagner, Zylstra, and Jackson, (2009). situations where the actual result for a specific event or activity is likely to differ from the estimate or forecast value are characterized by risk and uncertainty. Risk is further interpreted to be an uncertain event or condition that, if it occurs, has a positive or negative effect on a project objective (Glahn, et. al., 2009).

Going forward, various meanings of risk can be found in relation to project management. According to Mandeep, and David (2022), situations where the actual result for a specific event or activity is likely to differ from the estimate or forecast value are characterized by risk and uncertainty. Risk is defined as an uncertain event or condition that, if it occurs, has a positive or negative effect on a project objective (Project Management Institute 2020) in the Body of Knowledge of the Project Management Institute. They claim that the number of steps, the activities completed at each step, and the jargon used are all inconsistent and therefore confusing. For instance, risk analysis and risk identification are sometimes two distinct processes, and other times they are merged and referred to as risk assessment or risk review. According to Jackson and Flanagan (2002), risk response is also referred to as risk planning, evaluation, treatment, control, or mitigation. The PM Body of Knowledge (Project Management Institute, 2000) provides another current example. According to this definition, risk management is the methodical process of locating, evaluating, and handling project risk. A six-stage framework for risk management is presented in the book and includes risk identification, risk management planning, qualitative and quantitative risk analysis, risk response planning, and risk monitoring and control.

Risk Management Analysis and Modelling Techniques

Risk Analysis



The diagram gives a coordinated risk management analysis that can bear a functional risk management in an organization.

Risk management is a critical aspect of business operations, as it involves identifying, assessing, and prioritizing risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability or impact of unfortunate events. Various analysis and modeling techniques are employed to effectively manage risks in different industries. Quantitative risk analysis techniques involve the use of numerical data to assess the probability and impact of risks. Federico, and Davide (2017) listed some common techniques to include:

1. Monte Carlo Simulation: This technique involves running multiple simulations using different input values to assess the impact of risk on project objectives. It provides a range of possible outcomes and their probabilities, enabling better decision-making.
2. Decision Tree Analysis: Decision trees are used to model decisions and their potential consequences. It helps in evaluating different courses of action based on their expected outcomes and associated risks.
3. Sensitivity Analysis: This technique involves varying one input at a time while keeping others constant to understand the impact on the overall outcome. It helps in identifying which variables have the most significant influence on the results.
4. Expected Monetary Value (EMV): EMV is calculated by multiplying the value of each possible outcome by its probability of occurrence and summing up these values. It provides a single value that represents the average outcome considering both the probability and impact.

According to Federico, and Davide (2017) qualitative risk analysis techniques focus on assessing risks based on subjective judgment rather than numerical data, Federico et. al also discussed some common techniques to include:

1. Risk Probability and Impact Assessment: Risks are assessed based on their probability of occurrence and potential impact on project objectives. This helps in prioritizing risks based on their severity.
2. Risk Mapping: Risk mapping involves visually representing risks based on their likelihood and impact, often using a matrix format. It provides a clear overview of high-priority risks that require immediate attention.
3. SWOT Analysis: SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis is used to identify internal and external factors that may affect the project or organization. By understanding these factors, potential risks can be identified and addressed.

In another manner risk modeling is said involves creating mathematical or computational models to represent various aspects of risk within an organization or project. some common risk modeling techniques was listed by Mcleish, and Metzler, (2014) to include:

1. Probabilistic Risk Assessment (PRA): PRA is a systematic and comprehensive approach to assess risks associated with complex systems. It involves identifying potential hazards, analyzing their likelihood and consequences, and developing risk mitigation strategies.
2. Fault Tree Analysis (FTA): FTA is a deductive failure analysis method used to analyze the causes of system failures. It starts with an undesired event and then identifies all possible causes that could lead to that event.
3. Event Tree Analysis (ETA): ETA is a forward-looking analysis method used to evaluate the possible outcomes following an initiating event. It helps in understanding the sequence of events that may occur after a specific incident.

An effective risk management requires a combination of quantitative and qualitative analysis techniques along with robust risk modeling approaches to identify, assess, and mitigate potential risks (Mcleish, & Metzler, 2014; Federico, & Davide, 2017).

MODELLING UNCERTAINTY IN CONSTRUCTION COST ESTIMATING AND FORECASTING: RELATED CASE STUDIES

Models are available in many different formats and have multiple uses. A model must capture and represent the reality being modeled as closely as is practical; it must include the essential features of reality while being reasonably cheap to construct. and easy to use (Roman, Veda, and Oscar (2022). For a model to be used, most of its variables must be recognized and quantified using some sort of correlation. They further, state that the resulting models can be classified as stochastic or deterministic. Stochastic models incorporate the effects of probability to better reflect reality, whereas deterministic models are typically simpler and don't take probability into account.

Building price and cost models are divided into two groups by Fellows and Liu (2015), constructor-oriented and client-oriented. According to Roman, et. al. (2022), when looking at the use of building price models in the UK, traditional, deterministic approaches like square meters, approximate quantities, elemental, and judgemental estimating are still widely used. Additionally, very little is done with other sophisticated methods that might involve statistical approaches, such as simulation, time series, regression, causal cost models, and time series modeling. In order to provide the client with an estimated project cost during the design phase, client-oriented deterministic cost models are frequently employed. Rather than using the more appropriate market price models of economic theory and project award practice, these models are typically derived from databases that contain cost records from previous projects, adjusted to the time of use. Conversely, in constructor-oriented models, the bids made by subcontractors during the bidding process serve as the initial cost indicators (Abdou, Lewis, & Alzarooni, 2004).

Reflecting the impact of related uncertainty in cost estimation is the primary goal of modeling risks and uncertainty in construction cost estimation and forecasting. procedure to obtain a more accurate approximation. It will give the decision-making process from the perspective of the client and the constructor a clearer picture with more details. The case studies and earlier research on modeling risk and uncertainty in cost estimation and forecasting processes are discussed in the following paragraphs. In 1993, the government of Hong Kong implemented the Estimating using Risk Analysis (ERA) cost-estimating methodology, which is now mandatory for all public works projects in the nation (Mak and Picken 2000). By recognizing uncertainties and calculating their financial effects, it supports the conventional contingency allowances. The primary impetus behind implementing this methodology was to circumvent the inflated contingency allowances that the project team occasionally suggests in an effort to avoid having to look for additional funding in the event of a cost overrun.

The ERA process begins with the base estimate of known scope and risk-free elements, focusing on the primary risks. The fundamental idea behind the method is to pinpoint the project's risk and uncertain areas, describe the risk, and estimate how likely it is to materialize. The risk and uncertainty items are then classified as either variable or fixed. Next, the allowance is added to the base estimate of the expected cost related to the potential risk or uncertainty, along with backup calculations. The process of risk identification and analysis aims to lower the degree of uncertainty as the project progresses through its various phases. The details of ERA are found in United Kingdom Government publications in HM Treasury (1993), (Abdou, Lewis, & Alzarooni, 2004). It is comparable to the Multiple Estimating using Risk Analysis technique (Agnieszka, & Mariusz, 2015).

Agnieszka, and Mariusz, (2015) conducted studies comparing the viability and consistency of contingency estimates between non-ERA and ERA projects in Hong Kong. 45 ERA projects and 287 non-ERA projects in total were examined. The use of the ERA approach has increased the overall estimating accuracy in determining contingency amounts, according to the authors' findings. Also, to investigate the impact of the type and size of the estimate's uncertainty, they recommended expanding the number of projects examined and grouping them based on their sizes and types. Because it maintains the conventional method of presenting a project cost estimate as a base estimate plus a contingency, the ERA approach has the advantage of being adaptable to the Hong Kong construction industry. It also generates a deterministic figure that informs the client of the project's likely cost estimate.

Torp, (2019) looked into stochastic modeling that takes probability and uncertainty into account when estimating and forecasting construction costs. They recommended incorporating Monte Carlo simulation, utility theory, and decision trees into the cost prediction process. The method was used on a contract for home renovation. The study's comparison of the project's actual final cost and its estimated range indicates that the latter was within the former. Merna and Storch (2000) used the CASPAR tool to conduct a risk analysis for an agricultural investment project. After performing a sensitivity and probability analysis on the project base model, the quantitative impact of the project's risk factors was predicted. In particular, the important factors noted in the results were taken into consideration when creating a plan for risk response. According to the authors, the tools can be applied to any kind of investment where income and expenses can be distributed across a network of activities, not just the appraisal of building projects.

Several recent research projects have focused on the application of the fuzzy approach to modeling uncertainty in construction cost estimation and forecasting. Zaden's 1965 introduction of fuzzy set theory offers a method for managing innate uncertainty. Baloi and Price (2003) state that membership functions, linguistic approximation, fuzzy set arithmetic operations, set operations, and fuzzy weighted average are the key ideas of fuzzy set theory as it relates to decision systems.

Using global risk factors that impact construction cost performance, Baloi, (2002). attempted to create a fuzzy decision framework for contractors to manage. They talked about modeling, assessing, and managing global risk factors as a core issue. Comprehensive literature review and initial discussions with contractors led to the identification of major global risk factors. As per the authors' statement, the concept of "global risk" encompasses various risk factors that might cause substantial financial catastrophes but are not explicitly mentioned in cost estimates. These factors, which can be political or economic in nature, are so named because they exert a significant influence even though they are external to the organization. The authors explored various approaches to managing uncertainty and came to the conclusion that decision support systems and fuzzy set theory can be effectively used to model and evaluate the global risk factors influencing construction cost performance. They also mentioned that defining linguistic variables with trustworthy membership functions and identifying global risk factors are necessary before developing the knowledge base portion of the suggested fuzzy decision support system can be constructed.

Carr and Tah (2001) introduced a construction risk management prototype system that integrated a fuzzy approach for risk assessment and analysis. This system aimed to address the complexities and uncertainties inherent in construction projects. The integration of fuzzy logic allowed for the consideration of imprecise and vague information, which is common in the construction industry due to the subjective nature of risk assessment. The prototype system developed by Carr and Tah utilized fuzzy logic to assess and analyze various risks associated with construction projects. Fuzzy logic is a mathematical framework that deals with reasoning that is approximate rather than precise. It allows for the representation of uncertainty and vagueness, making it suitable for modeling the subjective nature of risk assessment. The integration of fuzzy logic in the risk management prototype system enabled the consideration of qualitative and quantitative factors, providing a more comprehensive understanding of risks in construction projects. This approach allowed for the incorporation of expert knowledge and experience into the risk assessment process, enhancing the accuracy and reliability of the results. Furthermore, Carr and Tah's prototype system facilitated the prioritization of risks based on their significance, thereby enabling project managers to allocate resources effectively and implement targeted risk mitigation strategies. By leveraging fuzzy logic, the system provided a flexible and adaptable framework for addressing dynamic risk factors that may evolve throughout the project lifecycle. Carr and Tah's construction risk management prototype system represented an innovative approach to addressing the complexities of risk assessment in construction projects. By integrating fuzzy logic, the system offered a more nuanced understanding of risks, allowing for informed decision-making and proactive risk management strategies.

Chapman and Ward (2000), focused on the development of user-friendly tools and methods for risk analysis and management in the construction industry. Their research highlights the need for simplicity and accessibility in risk management techniques, as this can significantly improve the overall efficiency of the construction process. Another important research project in this area is the work of the Construction Research and Innovation Network (CRIN), which has focused on the development of innovative risk management techniques that can be easily integrated into the construction process. CRIN has developed a range of tools and methodologies, such as the Integrated Project Insurance (IPI) and the Integrated Risk Management System (IRMS), which aim to provide a comprehensive and user-friendly approach to risk management in the construction industry. Their work has led to the development of several tools and methodologies that aim to make risk analysis and management more user-friendly for construction professionals. These tools include the use of risk matrices, which allow for a visual representation of risks and their potential impact on a project, as well as the development of standardized risk assessment methodologies that can be easily understood and applied by construction professionals. The expectation of ease-of-use in techniques for risk analysis and management has shaped many recent research projects in the construction industry. These projects have led to the development of user-friendly tools and methodologies that can significantly improve the efficiency and effectiveness of risk management processes in the construction sector. The work of Chapman and Ward (2000), CRIN, is an example of the research efforts aimed at making risk analysis and management more accessible and efficient for construction professionals.

Jackson and Flanagan (2002) proposed a conceptual model that aimed to integrate risk management into conventional project cost estimating procedures during the appraisal stage of a project. This approach was designed to provide a more comprehensive and accurate assessment of project costs, taking into account potential risks and uncertainties that could impact the project's budget. The Jackson and Flanagan model consists of several key components, which are described in detail below:

1. Identification of Risks and Uncertainties: The model begins with the identification of potential risks and uncertainties that may impact the project's cost. This involves a thorough analysis of the project's scope, schedule, and technical requirements, as well as an examination of external factors such as market conditions and regulatory environments.
2. Quantification of Risk Probabilities and Impact: Once the risks and uncertainties have been identified, the model quantifies their potential probabilities and impacts on the project's cost. This is achieved through a combination of expert judgment, historical data, and statistical analysis.
3. Risk Categorization: The next step involves categorizing the risks based on their probability and impact. This enables the project team to prioritize risks and focus their efforts on those that pose the greatest threat to the project's cost.

4. Development of Risk Management Strategies: With the risks categorized, the model then focuses on developing appropriate risk management strategies to mitigate or control these risks. This may involve the use of contingency plans, insurance, or alternative project delivery methods.
5. Incorporation of Risk Management Strategies into Conventional Cost Estimating Procedures: The final stage of the model involves integrating the risk management strategies into the conventional cost estimating procedures. This ensures that the potential impacts of risks are taken into account when estimating the project's cost, providing a more accurate and comprehensive assessment of the project's financial requirements.

The Jackson and Flanagan (2002) model offers a comprehensive and systematic approach to integrating risk management into conventional project cost estimating procedures during the appraisal stage of a project. By identifying, quantifying, and categorizing risks, and then developing appropriate strategies to mitigate them, the model aims to provide a more accurate and robust assessment of a project's financial requirements, ultimately leading to better decision-making and improved project outcomes.

Conclusion

The study is focused on modelling risk for construction cost estimating and forecasting. It is seen that there is no one model that is used by the different industries. Hence most industries use techniques that meets their industry type in the event of their operations. For the techniques selected for the analysis stage to be successful, it is critical to comprehend the sources of risk and uncertainty as they arise during the identification and classification stages. For construction projects, there isn't a single best analysis or modeling technique. The project parameters and any potential historical data that was available at the time of analysis will determine which option is best. Several research studies have shown that, in comparison to other industries, the construction sector applies relatively little risk analysis and management. In order to increase the extent of their integration into the current estimating and forecasting process, the industry must figure out how to smoothly incorporate their activities into the widely used existing methods.

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