

Risk Assessment Frame work for Cost Estimation in Case of Building
Construction Projects



Soliyana Solomon Tefera

A Thesis Submitted to

The Department of Construction Engineering and Management

School of Civil Engineering and Architectural

Presented in Partial Fulfilment of the Requirement for the Degree of Master's
in Civil Engineering (Construction Engineering Management)

Office of Graduate Studies

Adama Science and Technology University

July 2022

Adama, Ethiopia

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Advisor: Fikreyesus Demeke (PHD)

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APPROVAL PAGE

I, the advisor of the thesis entitled “Framework to Select Risk Assessment Method Used in Cost Estimation in Case of Building Construction Projects” and developed by (Soliyana Solomon Tefera), hereby certify that the recommendation and suggestion made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members, of board of examiners of the thesis by soliyana Solomon have read and evaluated the thesis entitles “Framework to Select Risk Assessment Method Used in Cost Estimation in Case of Building Construction Projects” and examine the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfilment of the requirement of the degree of Masters of Science in Construction Engineering and Management.

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DECLARATION

I hereby declare that this master thesis entitled “Risk Assessment Frame work for Cost Estimation in Case of Building Construction Projects” is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have closely advised/supervised the student while developing this thesis and read the draft thesis entitled “Framework to Select Risk Assessment Method Used in Cost Estimation in Case of Building Construction Projects” Prepared under my guidance by (Soliyana Solomon). Therefore I recommend submitting the thesis to the department for further review and evaluation.

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Signature

Date

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LIST OF ABBREVIATION AND ACRONYMS

2D	Two dimension
AI	Artificial Intelligence
ANN	Artificial Neural Network
BBN	Bayesian belief networks
BIM	Building information modeling
BOQ	Bill of quantity
CBR	Case-based reasoning
CCRAM	Correlated Cost Risk Analysis Model
EDA	Engineering Design Actors
ERA	Estimating using Risk Analysis
FCD	Fuzzy Contingency Determinator
MCS	Monti Carlo simulation
PDF	Portable Document Format
QTO	Quantity take-off
RBE	Risk-based estimate
SPSS	Statically package for the social science
TCM	Total Cost Management
UAC	Unit area cost
UPA	Unit price analysis
WBS	Work break down

ABSTRACT

Cost estimates would not provide information regarding the effect of uncertainty on costs unless cost estimation-related risk analysis is conducted concurrently. Different risk assessment approaches are utilized in cost estimation. However, there is a lack of comprehensive study on the selection of appropriate risk assessment methods for cost estimation depending on project conditions in an organized manner. No such studies are found that have a framework that assists in the selection risk assessment method used in cost estimation. Existing researches are either only on specific model of risk assessment used in cost estimation or address risk assessment independently from the cost estimation. As a result, a risk assessment framework is required to aid in the selection of the risk assessment method used in cost estimation based on project conditions. Therefore, this study will fill this research gap. Through the following objectives identify risk assessment methods used for cost estimation. Assess risk assessment methods and their application in the context of developing countries, the case of Ethiopia. Identify criteria that are used for the selection of the cost estimation risk assessment method. Develop a conceptual framework that helps cost estimators select a suitable method of risk assessment in cost estimation based on their project conditions. To achieve the research objectives both secondary and primary data was utilized. The primary data was analyzed quantitatively by using descriptive statistics with the help of SPSS version 22 software. The validity of the questionnaire used in this study was tested by using the Pearson correlation coefficient. The reliability of the questionnaire was tested by using Cronbach alpha in SPSS. The result from the study showed that 97% of the cost estimators in Addis Ababa use the traditional percentage or contingency estimate method to assess risk in cost estimation. Despite its inability to handle risk in any logical way. It is overly simplistic and heavily dependent on estimators' faith and experience. Training and workshops about the advantages of probabilistic risk assessment methods in cost estimation should be provided to cost estimators.

Keywords: *cost estimation, risk assessment method, conceptual framework, Building projects*

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

A construction cost estimate is regarded as one of the most important responsibilities in the budgeting process. It is, however, carried out under conditions of uncertainty (Eliufoo, 2018). In most situations, the actual cost of building projects surpasses the budgeted amount. This is due to the multiple risks and high levels of unpredictability that exist in this industry (Peleskei et al., 2015). Failure to deal with potential risks can decrease the chance of achieving project objectives and leads to budget overruns.

Construction projects are experiencing cost overruns because of risk and uncertainty (Sharma & Goyal, 2014). Project cost overruns are a common problem in the construction sector across the world (Mukuka et al., 2015). The real cost is, on average, 28% higher than the predicted cost (Rauzana, 2018). However, the problem is very severe in developing countries (Ahady et al., 2017). The cost overruns sometimes exceed 100% of the anticipated cost (Aziz, 2013). There is a higher incidence and magnitude of project cost overruns in Sub-Saharan Africa (Gbahabo, 2017). Like other sub-Saharan African countries, Ethiopia is also facing a serious problem of cost overruns in the construction industry (Zewdu & Aregaw, 2015). The actual cost of most of the construction projects in Ethiopia runs up to 10 % over the budgeted cost (Taye, 2019). 80% of the projects in Ethiopia experience cost overruns (Ahady et al., 2017). The average and maximum cost overruns of building projects in Ethiopia are found to be 26% and 248% respectively (Melaku Belay et al., 2021). In this regard, inaccurate cost estimating causes several issues, including change orders and construction delays (Elfaki, 2014). Project teams should employ some technique of risk identification and analysis to account for a reasonable degree of uncertainty in cost estimation (Kermanshachi et al., 2016). Reliable and efficient risk assessments are essential to deal effectively with potential risks (Guan et al., 2020). Building projects are becoming much more complex and require carefully integrated risk management tools and techniques (Ayalew et al., 2018).

Estimating the cost using risk-based estimate (RBE) mechanisms has excellent predictive power as, 90% of projects had an actual cost within the range of the risk-based estimate (Allahaim et al., 2017).

In this regard, different methods of risk assessment can be used in cost estimation, which include -: Simulation-based Correlated cost risk analysis model (Ökmen & Öztaş, 2015); Monte Carlo, Artificial neural network (ANN) (Afzal et al., 2019); Bayesian belief networks (BBNs) (Guan et al., 2020); Traditional percentage (Islam et al., 2019); and Fuzzy Arithmetic Risk Analysis (Fateminia, Siraj, et al., 2020). However, the actual trend of using cost risk assessment mechanisms exposes the dominance of the deterministic approach over the probabilistic ones. In this regard, at least 95% of Engineering Design Actors (EDA) primarily use the traditional deterministic method of cost risk assessment. The ease of application, as well as the lack of any tested and approved frameworks, were the main reasons for these actors to prefer the deterministic method (Buerthey et al., 2013). On the other hand, each estimation method has its advantages, disadvantages, and specific areas they are applied. Therefore, there is a lack of study on selecting a suitable risk assessment method for cost estimation.

Criteria that are used to choose a method of risk assessment in cost estimation are cost degree of accuracy in estimation, speed, and ease of use (Kim & Kim, 2010). On the other hand, there is a lack of comprehensive study on the method and criteria that are used for selecting suitable risk assessment methods for cost estimation based on the project prevailing condition. Even though each of the risk assessment methods has its advantages, disadvantages, and application. This study will fill this research gap by assessing risk assessment methods in cost estimation. Comparing their benefit, drawback, applications and proposing a framework that assists in the selection of a suitable deterministic risk assessment method in cost estimation based on project conditions.

1.2 Statement of the Problem

Risks and uncertainties involved in construction projects are not being addressed and managed efficiently (Sharma & Goyal, 2014). There are problems regarding inaccurate budgeting for building construction projects (Yang & Chen, 2015). The biggest factor that contributes to overruns of the budget is an inaccurate estimation of the original or initial cost of a project (Afzal et al., 2019). Cost overruns are caused by uncertainties arising from risk events and inaccurate budget estimates (Kwon & Kang, 2019). Finding the exact cost of a project is nearly impossible due to the uncertainties associated with construction projects, ranging from calculation errors to project-related catastrophes (Bakhshi & Touran, 2014). If risks are not properly managed, the project cost will increase (Fergany et al., 2020).

The consequences of risk in construction industries have more severe effects in developing countries, especially in the Sub-Saharan region (Adabre et al., 2021). Lack of risk management in construction projects is one of the major setbacks for construction project performance in Ethiopia. Construction projects have no routine practices employed to manage risks (Hailu, 2018). There is a lack of proper risk management practices in Ethiopian construction projects. The awareness of risk management is still at a relatively low level in the current Ethiopian construction industry (Yadeta, 2019). Most of the parties involved in the Ethiopian building construction projects have heard of the concept of risk management but lack adequate knowledge about the principles of risk management. The common excuse given for not incorporating risk management techniques into projects was a lack of awareness about their significance (Mesfin, 2014). Ethiopian consultants did not provide a formal risk management plan for their projects (Mitikie et al., 2017). Failure to adequately deal with risks has been shown to cause higher costs. There is about a 15.33% cost increment beyond the initially estimated cost of construction projects in Ethiopia (Taylan et al., 2014).

The actual trend of using cost risk assessment mechanisms exposes the dominance of the deterministic approach over the probabilistic ones. In this regard, at least 95% of Engineering Design Actors (EDA) primarily use the traditional deterministic method of cost risk assessment. The ease of application, as well as the lack of any tested and approved frameworks, were the main reasons for these actors to prefer the deterministic method (Buerthey et al., 2013). The traditional percentage method is a deterministic method. It is commonly used for estimating the risk in cost. In which the most likely cost of the project is estimated and a percentage of the likely project cost is added. based on experts' best judgment as a contingency to cater to risk and uncertainties (Eldosouky et al., 2014). This approach is unscientific and inadequate in handling risk in a logical way (Islam et al., 2019). The traditional percentage method is widely used due to its ease of use. But the results of the research by (Otalí & Odesola, 2014) reveal that several of the projects that had implied this method in their projects had cost overruns, indicating that the traditional contingency method is inadequate for risk assessment (Khamooshi & Cioffi, 2013). This method has several weaknesses. It is overly simplistic and heavily dependent on estimators' faith and experiences, the percentage is broadly estimated; and there is a tendency to double count risks (Lhee et al., 2014).

Estimating the cost using risk-based estimate (RBE) mechanisms has excellent predictive power as, 90% of projects had an actual cost within the range of the risk-based estimate (Allahaim et al., 2017). In this regard, different methods of risk assessment can be used in cost estimation, which include -: Simulation-based Correlated cost risk analysis model (Ökmen & Öztaş, 2015); Monte Carlo, Artificial neural network (ANN) (Afzal et al., 2019); Bayesian belief networks (BBNs) (Guan et al., 2020); Traditional percentage (Islam et al., 2019); and Fuzzy Arithmetic Risk Analysis (Fateminia, Siraj, et al., 2020).

Academics have given minimal attention to selecting a good risk assessment model (KarimiAzari et al., 2011). To solve this problem, a fuzzy TOPSIS strategy model of risk assessment was presented in a study by (Zavadskas et al., 2010). But the study did not include cost estimation; it aimed to develop a risk assessment model. A study conducted by (Abdou et al., 2004) investigated several methods of modeling risk and uncertainty in building cost estimation and forecasting. However, it did not describe the methods in depth, their benefits, and their drawbacks. Research by (Ökmen & Öztaş, 2015) conducted a detailed evaluation of the Correlated Cost Risk Analysis Model through scenario and sensitivity analyses. Even though the research assessed in great depth the correlated cost risk analysis method, it did not include any other method of cost risk assessment in the study. Research by (Clark, 2019) presents a framework to conduct a quantity take-off (QTO) and cost estimate within the Building Information Modeling (BIM) environment. The research has proposed a model-based cost estimating tool. However, cost-related risks are not cooperated within the model. (Hung, 2018) Proposed a risk assessment framework using the Artificial Neural Network (ANN). The framework is used to assess project risks and their impact on project costs. But it does incorporate other risk assessment methods used in cost estimation. Research by (Jaskowski & Biruk, 2011) presented a risk analysis and assessment framework by using Monti Carlo simulation. Even though the research assessed in great depth the Monti Carlo simulation method, it did not include any other method of cost risk assessment in the study. (Monzer et al., 2019) has proposed an aggregation-based framework for Construction Risk Assessment with Heterogeneous Groups of experts. The proposed framework provides a systematic, multistep methodology that assesses expertise level in construction risk assessment, and assigns weights to experts' opinions according to their level of expertise.

There are different methods of risk assessment used in cost estimation. Each of the methods has its advantages and disadvantages. Artificial Neural Network (ANN) is a method of risk assessment that requires adequate cost-related information. It produces precise results and it is easy to use (Afzal et al., 2019). Bayesian belief networks (BBNs) are a method of risk assessment that can be used when there is incomplete data. It has a faster processing speed. But it can only deal with discrete functions (Guan et al., 2020). Monte Carlo simulation (MCS) is a method of risk assessment used for cost contingency estimation, but it is subjective (Afzal et al., 2019). (Ökmen & Öztaş, 2015) Correlated cost risk analysis is a method of risk assessment capable of capturing the correlation between cost and risk factors. It has a slower processing speed (Allahi et al., 2017). A fuzzy arithmetic risk analysis is a method of risk assessment that can be used when there is a lack of historical data. It is complex. It relies on expert knowledge (Elbarkouky et al., 2016).

From the reviewed literature, there are different methods of risk assessment used in cost estimation. Each of the estimation methods has its advantages and disadvantages, and specific areas they can be applied to. However, there is a lack of comprehensive study on the selection of appropriate risk assessment methods for cost estimation depending on project conditions in an organized manner. No such studies are found that have a framework that assists in the selection risk assessment method used in cost estimation. Existing studies are either on only one specific model of risk assessment used in cost estimation (Valipour et al., 2018) or address risk assessment independently from the cost estimation (Fang & Marle, 2013). As a result, a risk assessment framework is required to aid in the selection of the risk assessment method used in cost estimation based on project conditions. Therefore, this study will fill this research gap by assessing risk assessment methods in cost estimation. Comparing their benefit, drawback, applications and proposing a framework that assists in the selection of a suitable deterministic risk assessment method in cost estimation based on a list of selection criteria.

1.3 Objectives of the study

1.3.1 General objective

The general objective of the study is to develop a conceptual framework to select a risk assessment method for estimating the cost of a building construction project.

1.3.2 Specific objective

1. Identify risk assessment methods used for cost estimation.
2. Assess their application in the context of developing countries, the case of Ethiopia.
3. Identify criteria that are used for the selection of the cost estimation risk assessment method.
4. Develop a conceptual framework to select a suitable cost estimation risk assessment method according to project-specific conditions.

1.4 Research questions

The current study intends to answer the following questions through the research objectives.

1. What are the risk assessment methods used for cost estimation around the world?
2. What are the current risk assessment methods used for cost estimation by consultants in Ethiopia, in the case of Addis Ababa?
3. What are the criteria that are used for the selection of a risk assessment method for cost estimation?
4. How to prepare a conceptual framework to choose a method of risk assessment in cost estimation?

1.5 Significance of the study

This research helps construction stakeholders to understand the advantages and disadvantages of the risk assessment methods that are used in cost estimation. These methods differ in several ways, and each has its own set of benefits and drawbacks. As a result, there is no perfect risk assessment method that would fit all projects; each has its unique features. The project management team must pick the most appropriate method based on their individual needs. The purpose of this study is to develop a conceptual framework that assists in the selection of risk assessment methods. Hence, stakeholders in the construction sector will be able to use this framework in their projects and benefit from the use of risk assessment in their cost estimation. The risk assessment method will help them to assess the impact of the uncertainties and risks including their potential impact and the likelihood of occurrence. Accurately incorporating these risk methods into their project cost estimate will help to reduce cost overruns.

There is a lack of study on selecting appropriate risk assessment methods for cost estimation depending on project conditions using comprehensive criteria that are utilized to choose the risk assessment methods. This research will fill this gap.

1.6 Scope of the study

The construction industry is vast and includes the construction of physical facilities like road networks, rail systems, waterworks (irrigation energy, water supply, drainage systems, and sewage), and buildings. However, this research focuses only on the building construction sector. Risk assessment is applied at different stages in the construction industry, but this research only assesses risk assessment in the cost estimation stage.

1.7 Limitations of the study

There was a limitation on finding properly organized and compiled data in the Addis Ababa city administration building permit and control office. Which made it difficult and time-consuming to find the population for the study.

1.8 Organization of the Thesis

The research is organized into five chapters as described below.

Chapter one: Introduction is an introductory part containing discussions on background, research problems, the objective of the research, significance of the research, scope, and limitation of the research, and organization or layout of the research.

Chapter Two: Literature review presents relevant related literature on the concept and overview of risk assessment, cost estimation, cost contingency estimation, cost estimation risk, and methods of risk assessment used in cost estimation.

Chapter Three: Methodology this chapter covers how the research is carried out and covers the research method, target population, instrument of data collection, data collection techniques, procedures, and the data analysis method.

Chapter Four: Results and discussion this chapter presents the analysis of the data that was collected from the questionnaires and its result.

Chapter Five: Conclusions and recommendations based on what has been discussed in the previous chapters.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

This chapter presents the findings from different literature reviews on the subjects most relevant to risk assessment methods used for cost estimation in two subsections. The first section gives a general introduction to risk assessment and cost estimation. The second section explains in detail risk-based cost estimation, cost estimation risk, cost contingency estimation, methods of risk assessment used in cost estimation, and the criteria that are used to choose a method of risk assessment in cost estimation.

2.2 Risk assessment

(Gunduz & Laitinen, 2018), defined risk assessment as the analysis of possible hazards, their sources, and protection measures. (Gurcanli et al., 2015), also defined risk assessment as a critical task used for determining uncertainties and appropriate risk-response strategies. According to (Dikmen et al., 2012) The goal of project risk assessment is to identify risks and assess their effect on project outcomes. (Purohit et al., 2018) risk assessments will help in prioritizing risks and provide information on the likelihood of its impact and severity of harm. Risk assessment is divided into three processes and they are: what can go wrong? What is the likelihood? And what are the consequences? (Patel et al., 2016) .(Gul et al., 2018) Scoring (what is the likelihood of the risk ?) is the most important phase in the risk assessment process after determining the scope of the risks (Gul et al., 2018). (Mesfin, 2014) stated that there are two essential factors in risk assessment. And they are the chance of a risk occurrence and the extent of the risk's impact if it occurs.

Since quantitative risk assessment methodologies are insufficient for risk prioritization (Biswas & Zaman, 2019). Assessing the likelihood of the occurrence of risk events requires probabilistic (possibility) analysis using statistical data and subjective reasoning (Fateminia, Siraj, et al., 2020).

(Renuka et al., 2014) identified two of the most difficult aspects of project risk assessment; they are the knowledge requirements for identifying the amount of uncertainty and the construction of complicated models to forecast project outcomes. A study by (Aminbakhsh et al., 2013) stated the challenge of risk assessment that arises due to the necessity of data on too many input factors.

However, if data from previous projects are available, it can simplify the analysis and facilitate practical implementation. A study conducted by (KarimiAzari et al., 2011) concluded that academics have given minimal attention to selecting a good risk assessment model. To solve this choice problem, a group-based fuzzy TOPSIS strategy with an effective algorithm is presented in the study. (Zavadskas et al., 2010) showed how to analyze the risk of construction projects based on multi-attribute decision-making techniques. (Monzer et al., 2019) introduced a systematic framework using fuzzy logic that incorporates evaluations from a diverse set of experts through aggregation to improve building risk assessment procedures.

A study by (Mesfin, 2014) The majority of parties involved in Ethiopian building construction projects believe that using risk management approaches may considerably reduce the impact of risk on project objectives. But do not have adequate knowledge of risk management principles. In building construction projects in Addis Ababa, all contractors consider the risk factor to be relatively significant. However, because of the high level of competition in bidding, most contracting organizations consider estimating risk in a balanced manner (Andom, 2020).

2.3 Cost estimation

Different researchers defined cost estimation differently. (Xu et al., 2016) defined cost estimation as the establishment of the most probable cost of a project. (Juszczyk, 2017) defined cost estimate as a quantitative assessment of the likely cost for resources required to complete a project, based on the available information, at a given point in time. The objective of estimating the cost of a project is to predict the market value of a construction contract (Bakr, 2019). So, cost estimation is one of the most important steps in project management, especially during the bid and award phase. Reliable cost estimates are important for organizational budgeting purposes, for loan applications, and to estimate the commercial feasibility or viability of the project (Gurcanli et al., 2015). It requires collecting, analyzing, and extracting all available information on a project (Taghaddos et al., 2016).

The main problem in construction projects is inaccurate cost estimation, which leads to project failure in terms of time and cost (Sayed et al., 2020). Estimating accuracy is defined as the degree to which the project's final price differs from the single-point value used in the estimate (Whang & Park, 2016).

Cost estimation methods' efficiency, flexibility, and accuracy have a significant impact on every project, product development, and corporate success (Aram et al., 2014). According to (Koshe & Jha, 2016) the basic reason for cost overruns is inaccurate cost estimates. Unfortunately, the price changes so quickly that the initial budget becomes completely unrealistic.

Cost estimation is a factor that defines the project's success or failure (Chimdi et al., 2020). However, unless cost risk analysis is performed concurrently, cost estimation will not provide information about the effect of uncertainty on costs. Not only estimation of costs but also the analysis of risks is required to make the right decisions (Ökmen & Öztaş, 2015). There is a fluctuation between estimated and actual costs caused by cost estimation risks, this variation has a significant negative impact on the total scope of the construction project, particularly on the cost (Ghallab & Hosain, 2020). In this regard, nine out of 10 construction projects go over budget with an 86 percent chance (Abusafiya & Suliman, 2017). The likelihood of exceeding their specified cost targets has not improved, over the previous 70 years. 90% of construction projects underestimated the cost, resulting in cost overruns of 50% to 100% (Kwon & Kang, 2019). In almost 90% of cases, project costs were underestimated, and real costs were on average 28% higher than predicted costs (Rauzana, 2018). Even in the most undeveloped countries, the actual anticipated cost of a project grows by up to 30% by the time it is ready to be completed (Shah, 2016). The trend is more severe in developing countries, where the overrun can sometimes exceed-up to 100% (Aziz, 2013). Cost overrun is one of the most common issues in Ethiopian construction projects (Taye, 2019). According to (Sinesilassie et al., 2018) The cost performance of Ethiopian construction projects is influenced by ignorance and lack of knowledge. The actual cost of most construction projects exceeds the budgeted cost of work performed by up to 10% (Ahady et al., 2017). The average cost overrun of building projects in Ethiopia is found to be 26% (Melaku Belay et al., 2021).

The biggest factor that contributes to overruns of the budget is an inaccurate estimation of the original or initial cost of a project (Ali & Kamaruzzaman, 2010). Inaccurate cost estimating causes several issues, including change orders and construction delays (Elfaki, 2014). The problem of cost overruns in construction projects is due to the uncertainty of risk information and the complexity of risk networks (Afzal et al., 2019). They are caused by uncertainties arising from risk events and inaccurate budget estimates (Kwon & Kang, 2019).

Risks and uncertainties involved in construction projects are not being addressed and managed efficiently (Sharma & Goyal, 2014). There are problems regarding inaccurate budgeting for building construction projects (Yang & Chen, 2015).

(Ghallab & Hosain, 2020) Construction projects have a high degree of risk in cost estimates compared to other types of projects. (Eldosouky et al., 2014) Stated that there are several types of uncertainty. The most important one is uncertainty about the estimated cost of project activities. (Dikmen et al., 2012) Described risk assessment aims to determine the level of uncertainty about estimates. (Zhong & Li, 2015) Using risk assessment methods at the pre-design stage will result in more accurate cost estimates.

2.3.1 Cost estimation method

In construction, several cost estimating methods are utilized. The usefulness of each approach is typically determined by the purpose for which it is used, as well as the amount of information available at the time of estimation and the party using it (Bayram & Al-Jibouri, 2016). On the other hand, the usefulness of a specific cost estimating method is determined by the potentiality of a cost estimating method to offer its users a satisfactory degree of accuracy, speed, ease of use, and ease of updating (Kim & Kim, 2010). There are two types of cost estimation they are conceptual estimates and detailed estimates. As the project definition level increases, the estimating type will progress from conceptual methods to detailed methods (Sayed et al., 2020). Conceptual estimation is the first predesign effort made to determine a project's cost. Conceptual estimates are usually produced at the start of the project during the feasibility analysis (Mohutsiwa & Musingwini, 2015). On the other hand, detailed estimates are prepared from clear and fully developed design and construction documents. detailed estimates are frequently used for bidding, change orders, permits, and approvals (Dandan et al., 2019).

Cost estimation methods are either statistical or based on artificial intelligence. Artificial intelligence employs several techniques such as neural networks (NN), fuzzy logic (FL), and genetic algorithms (GA) (Bayram & Al-Jibouri, 2016). Some of the artificial cost estimation methods are:- Superficial Method; Artificial Neural Networks; Fuzzy Logic, Genetic Algorithms, and Regression Analysis; Neural networks; fuzzy logic; inference systems) (Gurcanli et al., 2015). The traditional cost estimation (statistical) method is defined as the use of Two Dimensional (2D) paper or Portable Document Format (PDF) drawings to prepare the Quantity Takeoff (QTO) by using Microsoft Excel. estimate (Clark, 2019).

The two main traditional cost estimation methods are unit area cost (UAC) and unit price analysis (UPA). UAC is used in the predesign stage, while UPA is used in the post-design stage (Bayram & Al-Jibouri, 2016).

Model-based cost estimation is categorized under the artificial intelligent method .it has been defined as the process of associating properties of elements from the developed three-dimensional model with cost information obtained from the database of the estimator (Bademosi et al., 2019). Two of the most frequently used model-based cost estimation methods for early design stages are Artificial Neural Network (ANN) and case-based reasoning (CBR) (Fazeli et al., 2020). Major advantages of CBR models are transparency of the process, which turns it into a suitable decision support tool; the ability to handle missing attribute information from previous cases; and the feasibility of long-term use due to the ease of updating models through the addition of new cases (Bademosi et al., 2019). Cost estimation methods are categorized as analogy-based, parametric, and engineering models. The analogy-based method is presented in the form of a detailed estimate method .it has been applied uniformly to several cost data sets. The main aspect of the method is the utilization of historical information from completed projects (Pratama & Rasywir, 2016).

Parametric cost estimating methods evaluate the cost through characterization parameters like mass, volume, and cost (Tayefeh Hashemi et al., 2020). Parametric cost estimation employs statistical techniques (commonly regression analysis) to relate the historical construction costs with a few relevant characteristics of the project or project attributes. Historic (bid) based estimating uses data from recently awarded contracts as a baseline for estimating unit prices (Elmousalami, 2020).

Case-based estimation structures the construction process into a detailed list of activities (works), based on which a bill of quantities is prepared. The cost estimate is produced using the historical unit price database (Tiago Filho et al., 2017). According to (Makovšek, 2014) Case-based reasoning can be an effective approach to achieving a high level of accuracy for construction cost estimation in the early design stages. uses the knowledge gained from past projects to resolve new problems (Ahn et al., 2020).

Computers have been employed as tools to assist estimators during the cost estimating process, as they can reduce estimation errors and speed up the time needed to complete the process. For data-driven works, machine learning has some advantages over human-crafted rules: it is accurate, automated, fast, customizable, and scalable (Shin, 2015).

According to (Sinesilassie et al., 2018). Only 1/3 of contractors in Ethiopia use computer-based tools to predict costs, while the others calculate unit costs manually using the traditional estimating approach. The cost performance of Ethiopian construction projects is influenced by ignorance and lack of knowledge (Zewdu & Aregaw, 2015). Reported that Ethiopian contractors' cost management process maturity is 22 % incomplete, 22 %, perform formally, 22 % perform informally, and 28 % managed well.

2.4 Risk-based cost estimation

Risk-based estimation is defined as the probabilistic estimation that captures risk variability associated with assumptions made and characterized through a range of estimated costs. Rather than using a single number to represent project cost, probabilistic approaches that involve simple or complex modeling based on the relationships among cost, schedule, and events related to the project are used to assess uncertainties and related risks and translate the risks into costs (Shane et al., 2015). RBE breaks project costs into smaller components and models these components as the sum of the base estimate and a probabilistically distributed risk contingency that reflects the uncertainties of the corresponding base estimate (Sousa et al., 2015). The RBE process usually follows a risk management process when risks are initially identified and evaluated. Its primary purpose is to quantify the effect of the risk on the project cost (Kłosowski & Gola, 2016). Risk-based estimation (RBE) is an effective way of quantifying uncertainties in project costs. The risk-based estimation approach provides a probabilistic estimation of the project cost by considering the project's potential risk factors (Lee & Cha, 2016). Risk-based estimation serves as an excellent estimating technique that generates reliable estimates (Riantini et al., 2017).

Building projects are fraught with risks and uncertainty that can cause cost escalation (Lee & Cha, 2016). A comparison of building projects using RBE with a sample of construction projects using the conventional estimating approach shows that the projects estimated using RBE have better estimation accuracy than those estimated using more conventional approaches (Liu & Napier, 2010). The most common, conventional approach to account for risks in cost estimation is to include a fixed contingency in the project cost estimate (Merisalu et al., 2021).

2.5 Cost estimation Risk

The main objective of modeling risks and uncertainty is estimating and forecasting construction costs. Is to analyze the effect associated with uncertainty in the cost estimating process and arrive at a more realistic estimate (Sharma & Goyal, 2014). Risk assessment in cost estimation is a systematic approach to discovering, assessing, and responding to risk occurrences throughout the life of a project to achieve an acceptable level of risk reduction or control (Fidan et al., 2011). According to (Ökmen & Öztaş, 2015) cost estimation and cost risk analysis are two of the most important tasks that must be completed for construction projects to be successful. (Kwon & Kang, 2019) described project risk as a critical factor in estimating project budgets. The cost estimate is a basic input to the risk analysis (Eldosouky et al., 2014). Project cost risk assessment is a critical part of making construction project decisions (Sharma & Goyal, 2014). The difference between the expected and actual project outcomes is usually attributed to risk events (Fidan et al., 2011). Every type of risk can be assigned a monetary value, which can be included in the project cash flow (Ghallab & Hosain, 2020). Since any building cost estimation will involve the client in some degree of risk exposure, project managers want a budget estimating process that allows them to respond to risks as accurately and precisely as possible (Kwon & Kang, 2019).

Risk-based estimation (RBE) involves breaking down project costs into small components. Which are then modeled as the sum of the base estimate plus a probabilistically distributed risk contingency that represents the base estimate's uncertainties (Liu & Napier, 2010). Risk-based estimating (RBE) has the potential to overcome the two main cost overrun factors: optimistic bias and strategic misrepresentation. Optimism bias relates to the tendency for people to be over-optimistic by overestimating benefits and underestimating costs, while strategic misrepresentation refers to the deliberate misrepresentation of project costs and risks for political, economic, and other gains (Liu & Napier, 2010).

The risks of cost overrun must be identified and managed effectively to minimize cost overrun. The most common approach for mitigating such consequences is to estimate and set aside a cost contingency (Allahaim et al., 2017). Estimating cost contingencies is an important part of risk management. The risk occurrence probability and related percentages were commonly used in the traditional method to estimate the contingency fund (Afzal et al., 2019).

(Lam & Siwingwa, 2017) considered risk as one of the main causes leading to cost overruns in construction projects. Unfortunately, risks are often ignored or simply dealt with in an arbitrary manner using rules of thumb or percentages. Risks are poorly managed in most cases and the risk retained results in cost overruns during project delivery.

Risk models that are used to predict project outcomes under different scenarios depend on identified risk factors, their interrelationships, and their impact on future projects (Fidan et al., 2011). The Monte Carlo simulation (MCS) is facilitated computationally by using commercially available risk analysis software packages such as Primavera Risk Analysis, Acumen Risk, @Risk for Project, Crystal Ball, Model Risk, and others. Packages such as Crystal Ball, Model Risk, or @Risk for projects are an add-in to Microsoft Excel for cost risk analysis purposes (Eldosouky et al., 2014).

2.5.1 List of risk factors in cost estimation

Risk identification is one of the important steps in recognizing risks that can affect the project budget (Allahi et al., 2017). In estimating project cost, we need to identify the main problem first, and take anticipation action to eliminate negative risk so that the cost estimation will improve (Supriadi et al., 2017). Failure to evaluate risk factors during cost estimation of construction projects jeopardizes a contractor's capability to finish a job (Eliufoo 2018).

According to the research conducted by (Eldosouky et al., 2014), risk factors in cost estimation have been categorized into construction risk factors, physical risk factors, estimator's risk factors, and financial risk factors. For construction, risk factors in cost estimation are: unexpected adverse site conditions, the productivity of laborers, suitability of plants/equipment, materials availability, familiarity with tasks, Breakdown of equipment, and Labor skill/experience Physical risk factors in cost estimation are incomplete design and specifications, design changes, site security, Design errors or specifications, fire accidents, loss, bad weather, operational accidents For an estimator's risk factors in cost estimation are incomplete scope definition, tendering period, cost data quality, access to the site, estimating skill, and current workload. Financial risk factors in cost estimation are funding uncertainty, inflation, and market stability.

Risk factors in cost estimation have been categorized into four groups by (Eliufoo, 2018) into construction risk factors, physical risk factors, estimator's risk factors, and financial risk factors.

The study focused on building contractors in Tanzania. Despite its methodological lapses, it headlined procedural risks relating to construction cost estimation. For construction, risk factors in cost estimation are: unexpected adverse site conditions, the productivity of laborers, suitability of plants/equipment, materials availability, familiarity with tasks, Breakdown of equipment, and Labor skill/experience Physical risk factors in cost estimation are incomplete design and specifications, design changes, site security, Design errors or specifications, fire accidents, loss, bad weather, operational accidents For an estimator's risk factors in cost estimation are incomplete scope definition, tendering period, cost data quality, access to the site, estimating skill, and current workload. Financial risk factors in cost estimation are funding uncertainty, inflation, and market stability.

(Supriadi et al., 2017) identified thirty-six risks that affect cost performance and they are categorized into six groups, which are work packages, alternative methods or designs, activities, material resources, equipment resources, and human resources (labor). Six high risks were identified: excessive material usage, poor volume calculation, excessive overtime, low labor productivity, material price change, and labor shortage. These dangers are divided into three categories: work package, material resources, and labor. The research made Substantial changes to the decisional process which was made by using Failure Mode Effect Analysis and Monte Carlo Simulation. The proposed solution provides the project manager with a clear view of the residual risk of cost overruns. According to (Ekung et al., 2021) The top five critical risks in cost estimation are low construction knowledge, unstable market conditions, change in government regulations, inadequate expertise, and low competition. The knowledge gap related to critical cost estimating risks was addressed by this research. (Ökmen & Öztaş, 2015) identified seven factors of risk: design changes, material cost fluctuations, labor productivity fluctuations, equipment efficiency and breakdown, scope changes, delays and disputes, inflation, and other economic agents.

The developed model can evaluate the uncertainty effect on construction costs in the case of correlated cost risk factors. By using various scenarios in sensitivity analyses. (Hatamleh et al., 2018) Identified critical factors that affect the accuracy of cost estimation and the degree of their importance from contractors' and consultants' viewpoints: experience in pricing construction projects, Clear and detailed drawings, Availability of a database of bids on similar projects, Accuracy, and reliability of cost information, The Projects team's construction experience, Completeness of cost information,

The estimating method used the level of involvement of the project manager, quality of information and flow requirements, The quality of the assumptions used in preparing the estimated time allotted for cost estimation, estimation importance perception, The padding estimates contractor's bidding strategy, and Risk sharing between the parties. A List of risk factors in cost estimation is provided in table 2.1 below.

List of risk factors in cost estimation

Table 2.1 List of risk factors in cost estimation

Reference	(Supriadi, Latief et al. 2017)	(Ekung et al., 2021)	(Eliufoo 2018)	(Ökmen & Öztaş, 2010)	(Hatamleh et al., 2018)
Project team experience in construction type					✓
Availability of data on a similar project					✓
Clear and detailed drawings					✓
Experience in pricing construction project					✓
Inflation			✓		
Funding uncertainty			✓		
Limited tender period			✓		
Incomplete scope			✓		
Delay and disputes				✓	
Scope change				✓	
Equipment efficiency and breakdown				✓	
Fluctuation in labor productivity				✓	
Fluctuation in material cost				✓	
Design change				✓	

Project related factors		✓			
Geographical factors		✓			
Estimating resources		✓			
Expertise of the estimator		✓			
Economic information		✓			
Design information		✓			
Construction knowledge		✓			
Cost data		✓	✓		✓
Inadequate subcontractors' productivity	✓				
Stolen material	✓				
Delay in material delivery	✓				
Lack of specialized labor	✓				
Change in material price	✓				
Low labor productivity	✓				
Too much overtime	✓				
Poor in calculating the volume of work	✓				

2.6 Cost contingency estimation

(Fateminia, Siraj, et al., 2020) categorized risks into two groups: the first one is unknown unknowns that are handled with management reserve and the second one is known unknowns that are addressed proactively. All risks that are dealt with using proactive strategies or active acceptance strategies are handled with contingency reserve. (Baccarini & Love, 2014) defined Contingency as the amount of budget set aside to cover project threats (post-mitigation). Which are incorporated into project cost estimates. A thoroughly integrated risk approach is essential in the process of estimating cost contingencies (Khamooshi & Cioffi, 2013).

Risk assessment is critical during the planning stage of a construction project because it allows for the consideration of various cost and duration scenarios before deciding on contingencies (Dikmen et al., 2012). Too much contingency may result in a project being aborted or uneconomical, and too little may lead to cost escalation and overruns if the risk occurs (Lam & Siwingwa, 2017). Due to the sensitivity of project success to contingency margins, the risk tool employed during the quantitative risk analysis for the determination of contingency is very critical (Buerthey et al., 2012). In construction projects, using appropriate risk analysis tools and contingency determination procedures increases project efficiency and effectiveness (Elbarkouky et al., 2016).

The construction industry lacks standardized methods of estimating cost contingency, making the estimation process deterministic. Those methods are easy to apply despite their ineffectiveness in managing risk. The absence of policy causes estimators to be more drawn toward deterministic methods. There are two methods of contingency determination; they are deterministic and probabilistic methods. The deterministic approach is based on deterministic and point-estimate values, whereas the probabilistic approach is based on stochastic values. The former cannot mathematically incorporate uncertainty, whereas the latter can (Hoseini et al., 2020). The traditional percentage method is deterministic (Eldosouky et al., 2014) in which a percentage of the likely project cost is added as a contingency to cater for risk and uncertainties (Islam et al., 2019). This approach is unscientific and inadequate in logically handling risk. This method has several weaknesses (Para-González et al., 2018). It is overly simplistic and heavily dependent on estimators' faiths in their own past experiences, the percentage is broadly estimated and not appropriate for a specific project: and there is a tendency to double count risks (Lhee et al., 2014).

At least 95% of the Engineering Design Actors (EDA) primarily used traditional methods. The ease of application, the lack of any tested and approved framework, and the fact that most of these actors lacked the necessary skills to use complicated risk analysis methods were the main reasons for their utilization of the deterministic technique (Buerthey et al., 2013). Many contractors believe that including contingency reserves in a project's tender price will make it more competitive. So they would rather cover any risks that arise during the course of the project's execution. (Fateminia, Sumati, et al., 2020).

Using a triangular Monte Carlo distribution model, a Contingency Reserve that offers adequate security to execute the project within the limitations of the economic risk established by the organization can be calculated (Para-González et al., 2018). Traditional techniques of calculating contingency reserves have the following limitations. They rely heavily on historical data and fail to account for some types of uncertainties, such as ambiguity, subjectivity, and vagueness. To overcome this limitation, an interval type-2 fuzzy risk analysis model was prepared. It determines the contingency reserve and addresses the constraints of deterministic contingency estimation methods (Fateminia, Sumati, et al., 2020).

2.7 Method of risk assessment used for cost estimation

The simplest and most commonly used method of risk assessment is the deterministic method (traditional percentage). It is utilized when cost estimators do not want to use a proper risk assessment process due to a lack of time and a limited budget. Deterministic methods are unable to adequately address project-specific risks (Bakhshi & Touran, 2014). The key difference between probabilistic and deterministic methods is that probabilistic methods explicitly model uncertainty with proper statistical distributions. The advantages of using probabilistic risk assessment methods. Are the ability to manage project budgets more effectively; increased trust in project decision-making; the ability to communicate risks clearly; the ability to manage risks more effectively; and internal collaboration and discussion (Senesi et al., 2015). The challenges that firms face when attempting to use probabilistic techniques are a lack of organizational support, procedures, and technical expertise to execute and interpret outputs. These barriers can be overcome by training employees and implementing risk management systems and procedures (Choudhry et al., 2018).

Probabilistic risk assessment should include the identification of risk and vulnerability factors and the prediction of system outcomes under different scenarios considering various sources of uncertainty (Dikmen et al., 2012). The success of risk models depends on identified risk factors, their interrelations, and risk-propagation patterns (Qazi et al., 2020). Monte Carlo Simulation (MCS), Fuzzy Arithmetic risk Analysis, Bayesian belief networks, and, Artificial neural networks (ANN) have been used for risk assessment in cost estimation (Mohamed et al., 2022). Each of the methods is discussed briefly below.

2.7.1 Traditional Percentage

The traditional percentage method is a deterministic method. It is commonly used for estimating cost contingency. In which the most likely cost of the project is estimated and a percentage of the likely project cost is added, based on experts' best judgment as a contingency to cater to risk and uncertainties (Eldosouky et al., 2014). This approach is unscientific and inadequate in handling risk in a logical way (Islam et al., 2019). The traditional percentage method is widely used due to its ease of use. But the results of the research by (Otalí & Odesola, 2014) reveal that several of the projects that had implied this method in their projects had cost overruns, indicating that the traditional contingency method is inadequate for risk assessment (Khamooshi & Cioffi, 2013). This method has several weaknesses. It is overly simplistic and heavily dependent on estimators' faith and experiences, the percentage is broadly estimated and not appropriate for a specific project; and there is a tendency to double count risks (Lhee et al., 2014). At least 95% of the Engineering Design Actors (EDA) primarily used traditional methods. The reasons why these actors predominantly used this method are the ease of application; the unavailability of any tested and approved framework; and the lack of the requisite knowledge for applying complex risk analysis processes (Buerter et al., 2012).

2.7.2 Correlated cost-risk analysis

Correlation is a statistical technique that is used to measure the direction and strength of a relationship between two variables (Zheng et al., 2019). Correlation is an important consideration in cost risk analysis (Khodakarami & Abdi, 2014). The correlated cost risk analysis model (CCRAM) is a risk factor-based simulation model that can analyze construction costs under uncertainty when the costs and risk factors are correlated (Borgonovo & Plischke, 2016). (Ökmen & Öztaş, 2015) developed a correlated cost risk analysis model (CCRAM) using MS Excel and @Risk (an Excel add-in). The study includes a brief description of the model and a detailed evaluation of its indirect, two-sided, and qualitative correlation capturing capability through various scenario and sensitivity analyses. The details of the proposed model's algorithm can be found in (Ökmen & Öztaş, 2010). A study by (Tran & Bypaneni, 2014) used a subjective approach to estimate correlation coefficients of cost risk factors.

2.7.3 Monte Carlo simulation

Monte Carlo simulation (MCS) is a simulation-based method in which any risk-prone parameter is modeled by a probability distribution (Tokdemir et al., 2019). Simulation is a decision-making tool based on the probabilistic theory of an event from historical data (Fateminia, Siraj, et al., 2020). MCS is one of the most common probabilistic methods, which is applied for cost contingency estimation and risk analysis in construction projects (Allahi et al., 2017). This technique is useful in making better decisions to solve problems in which uncertainty and variability in information have traditionally distorted forecasts (Afzal et al., 2019).

A study was developed by (Dikmen et al., 2012) on a web-based application that is used to determine risk-adjusted duration and cost while taking individual risks into account. Using Monte Carlo simulation to generate a scenario. The web-based application can help decision makers to evaluate the cost and duration implications of various risk occurrence scenarios, identify contingencies, and build risk-management plans during the preplanning stage of construction projects. A study by (Chang & Ko, 2017) developed a new method of MCS by improving the relationship between parameter estimation and individual risk source assessment, which was challenging when probability distributions are unbounded. The proposed method is simple and practical for consistently estimating the variable's standard deviation when modeling construction cost as a lognormal cost variable in MCS. A study by (Allahi et al., 2017) Proposed a probabilistic MCS model for project cost contingency estimation, to determine the probability distribution of the contingency cost and the risk coverage level associated with it. The proposed strategy was tested on a real-world building project using the @Risk for Excel software. Research by (Qazi & Simsekler, 2021) used Monte Carlo Simulation to prioritize project risks that integrate the decision-maker's risk attitude, uncertainty about risks both in terms of the associated probability and impact ratings, and correlations across risk assessments.

2.7.4 Artificial neural network (ANN)

Artificial Neural Network (ANN) is a non-parametric model that depends on AI (Artificial Intelligence). Which has been applied for risk analysis in various kinds of projects. Artificial Neural Network ANN is extensively used in project risk management processes to better estimate the cost under high complexity and uncertainty (Zhang, 2018).

Artificial Neural Network (ANN) can learn from the historical record and produce future outcomes and is capable of demonstrating the non-linear relationships that exist between the risk factors. It produces results that are more precise as compared to other traditional techniques. It is perfect in a condition where data are absent within a complex system (Afzal et al., 2019).

Selection of consistence and unbiased inputs as the training data is really important because the existence of bias in the training data is the major factor that limits the performance of Artificial Neural networks (ANN) (Hamid & Kehinde, 2017). A study by (Bakhshi & Touran, 2014) used Artificial Neural Network (ANN) for cost contingency estimation. (Waziri et al., 2017) Conducted a literature review on the application of Artificial Neural Network (ANN) in risk assessment in cost estimation and concluded that Artificial Neural Network (ANN) can handle cost risk data and provide highly accurate and reliable cost estimates.

(Odeyinka et al., 2013) developed a predictive ANN model for evaluating the effects of the identified major risk variables on construction cost flow baseline forecast. Previous attempts have been made to model cash flow forecast using net cash flow, value flow and cost flow approaches. Despite these efforts, significant variations between the actual and modeled forecasts were still observable. To overcome this limitation by using the cost flow approach, a model is developed According to (Otalı & Odesola, 2014) artificial neural networks are the least used approach among other risk assessment methods used in cost estimation.

2.7.5 Bayesian belief networks

Bayesian belief network (BBN) or a causal network is a probabilistic model that can visualize cause-and-effect correlations among a collection of random variables in the form of a directed acyclic graph (Guan et al., 2020). According to (Zhao et al., 2017), BBN explicitly evaluates project cost vulnerability and provides a suitable technique for modeling complex risk interrelationships in any project. BBN has the advantage of modeling flexibility in involving various kinds of cause-effect interdependencies using probabilistic gates instead of merely deterministic ones (Balta et al., 2021). BBN has the ability of back-propagation that helps in measuring the probability of events that may not be observed directly (Afzal et al., 2019). The BBN model is useful for data mining, explicitly exhibiting the link between variables, reflecting expert information, fusing expert knowledge and empirical data, and finding significant uncertainties (Nadali Jelokhani et al., 2021).

However, it is usually difficult to establish causal relationships among variables directly in a complex BBN (Guan et al., 2020).

2.7.6 Fuzzy Arithmetic Risk Analysis

Using traditional deterministic or probabilistic risk analysis approaches, it is difficult to correctly quantify a project's degree of risk exposure due to the uncertainty inherent in risk and the absence of adequate associated historical data on hazards. Alternatives to these strategies include fuzzy logic and expert judgment (Elbarkouky et al., 2016). In this regard, (Madhuri et al., 2014) conducted a study on the introduction of a fuzzy logic-based contingency determination procedure that can handle the experts' subjective uncertainty. A fuzzy arithmetic procedure that addresses the limitations of probabilistic methods such as MCS, including substantial reliance on historical data and a lack of consideration of subjective uncertainty, by employing expert judgment, linguistic scales, and fuzzy numbers to assess risks and opportunities (Fateminia, Siraj, et al., 2020). In the absence of comprehensive and accurate data, fuzzy set theory gives a paradigm for dealing with subjective and linguistically conveyed variables and conveying uncertainty (Sadeghi et al., 2010).

A summary of the methods of risk assessment used in cost estimation and their techniques' advantages and disadvantages are presented in table 2.2 below.

Table 2.2 Methods of risk assessment used in cost estimation

Reference	Method	Technique	Disadvantage	Advantage
(Ökmen & Öztaş, 2015).	Correlated cost risk analysis	MS Excel and @Risk software	slower processing speed	captures the correlation between the costs and risk-factors
(Afzal et al., 2019).	Monte Carlo	@Risk and Excel software.	subjective	Cost contingency estimation, Risk-management plans during the preplanning stage of construction projects.

(Afzal et al., 2019).	Artificial neural network (ANN)	Demonstrate the non-linear relationships between risk factors.	adequate cost-related information is required	produce precise results and it is easy to use
(Afzal et al., 2019) (Guan et al., 2020)	Bayesian belief networks (BBNs)	visually presented in the form of a directed acyclic graph	It can only deal with discrete functions.	Suitable for incomplete data and fast responses.
(Eldosouky et al., 2014) (Islam et al., 2014)	Traditional percentage	a percentage is added as a contingency to the project cost	Easy to use	This approach is unscientific and inadequate in handling risk in a logical way
(Elbarkouky et al., 2016) (Fateminia, Siraj, 2016)	Fuzzy Arithmetic Risk Analysis	Uses software tool, the Fuzzy Contingency Determinate (FCD)	complex It relies on expert knowledge, uncertain	can assess when there is a lack of historical data

2.8 Criteria that are used to choose a method of risk assessment in cost estimation

The usefulness of a specific cost estimating method is determined by the potentiality of a cost estimating method to offer its users a satisfactory degree of accuracy, speed, and, ease of use. The amount of information available at the time of estimation determines the method (Bayram & Al-Jibouri, 2016). The following is a list of criteria that are used to choose a method of risk assessment in cost estimation Degree of accuracy, speed, and ease of use (Kim & Kim, 2010). The degree of accuracy, speed, and ease of use (KarimiAzari et al., 2011) accessibility of the method, and familiarity with the method are factors to be considered in the selection of a risk assessment method. Cost estimation methods are chosen for their familiarity and use instead of their accurate estimates (Xenidis & Stavrakas, 2013). 67% of the consultants in Ethiopia collect and use the company's historical data for the preparation of cost estimation only 1/3 of the consultants in Ethiopia use computer tools for a cost estimate (Zewdu & Aregaw, 2015).

2.9 Research Gap

Academics have given minimal attention to selecting a good risk assessment model (KarimiAzari et al., 2011). To solve this problem, a fuzzy TOPSIS strategy model of risk assessment was presented in a study by (Zavadskas et al., 2010). But the study did not include cost estimation; it aimed to develop a risk assessment model. A study conducted by (Abdou et al., 2004) investigated several methods of modeling risk and uncertainty in building cost estimation and forecasting. However, it did not describe the methods in depth, their benefits, and their drawbacks. Research by (Ökmen & Öztaş, 2015) conducted a detailed evaluation of the Correlated Cost Risk Analysis Model through scenario and sensitivity analyses. Even though the research assessed in great depth the correlated cost risk analysis method, it did not include any other method of cost risk assessment in the study. Research by (Clark, 2019) presents a framework to conduct a quantity take-off (QTO) and cost estimate within the Building Information Modeling (BIM) environment. The research has proposed a model-based cost estimating tool. However, cost-related risks are not cooperated within the model. (Hung, 2018) Proposed a risk assessment framework using the Artificial Neural Network (ANN). The framework is used to assess project risks and their impact on project costs. But it does not incorporate other risk assessment methods used in cost estimation. Research by (Jaskowski & Biruk, 2011) presented a risk analysis and assessment framework by using Monte Carlo simulation. Even though the research assessed in great depth the Monte Carlo simulation method, it did not include any other method of cost risk assessment in the study. (Monzer et al., 2019) has proposed an aggregation-based framework for Construction Risk Assessment with Heterogeneous Groups of experts. The proposed framework provides a systematic, multistep methodology that assesses expertise level in construction risk assessment, and assigns weights to experts' opinions according to their level of expertise.

There are different methods of risk assessment used in cost estimation. Each of the methods has its advantages and disadvantages. Artificial Neural Network (ANN) is a method of risk assessment that requires adequate cost-related information. It produces precise results and it is easy to use (Afzal et al., 2019). Bayesian belief networks (BBNs) are a method of risk assessment that can be used when there is incomplete data. It has a faster processing speed. But it can only deal with discrete functions (Guan et al., 2020). Monte Carlo simulation (MCS) is a method of risk assessment used for cost contingency estimation, but it is subjective (Afzal et al., 2019).

(Ökmen & Öztaş, 2015) Correlated cost risk analysis is a method of risk assessment capable of capturing the correlation between cost and risk factors. It has a slower processing speed (Allahi et al., 2017). A fuzzy arithmetic risk analysis is a method of risk assessment that can be used when there is a lack of historical data. It is complex. It relies on expert knowledge (Elbarkouky et al., 2016).

From the reviewed literature, there are different methods of risk assessment used in cost estimation. Each of the estimation methods has its advantages and disadvantages, and specific areas they can be applied to. However, there is a lack of comprehensive study on the selection of appropriate risk assessment methods for cost estimation depending on project conditions in an organized manner. No such studies are found that have a framework that assists in the selection risk assessment method used in cost estimation. Existing studies are either on only one specific model of risk assessment used in cost estimation (Valipour et al., 2018) or address risk assessment independently from the cost estimation (Fang & Marle, 2013). As a result, a risk assessment framework is required to aid in the selection of the risk assessment method used in cost estimation based on project conditions. Therefore, this study will fill this research gap by assessing risk assessment methods in cost estimation. Comparing their benefit, drawback, applications and proposing a framework that assists in the selection of a suitable deterministic risk assessment method in cost estimation based on a list of selection criteria.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the specific procedures and techniques that are used to identify, select, process, and analyze the research data. The topics covered in detail in this chapter are research design, population and sampling, data collection, and data analysis. A brief illustration of the research design is provided to aid in understanding the structural flow of the study.

3.2. Research Approach

Studies that do not attempt to quantify measurements are classified under the qualitative research approach. In this research approach, informal measurement techniques are used for data gatherings like interviews and observations. It involves asking a broad question and gathering data in the form of words, photographs, and videos (Manual, 2015). On the other hand, the quantitative approach uses statistical analysis to get quantitative results. It involves an empirical investigation of quantitative properties their phenomena and relationships. (Bloomfield & Fisher, 2019). Furthermore, the mixed research approach involves gathering and analyzing both quantitative and qualitative data for a single study. It has the potential to provide a greater depth and breadth of information, which cannot be obtained from a single study approach (Almalki, 2016). A blend of the two (mixed research approach) was used for this study. The qualitative approach was used to identify patterns, averages, predictions, examine causality, and generalize findings to a wider population. The quantitative research approach was used to obtain data on the methods of risk assessment that are used in cost estimation and the criteria that are used to choose the methods.

3.3 Research design

Research design is defined as the framework of procedures and strategies used by researchers to combine components of research in a reasonably logical manner so that research problems are efficiently handled (Bhat et al., 2019). Research design provides a general framework for data gathering, measurement, and analysis (Akhtar, 2016). The research design of this study is illustrated in figure 3.1. It clearly shows the methods and procedures used to collect and analyze data to solve the research problem through specific objectives.

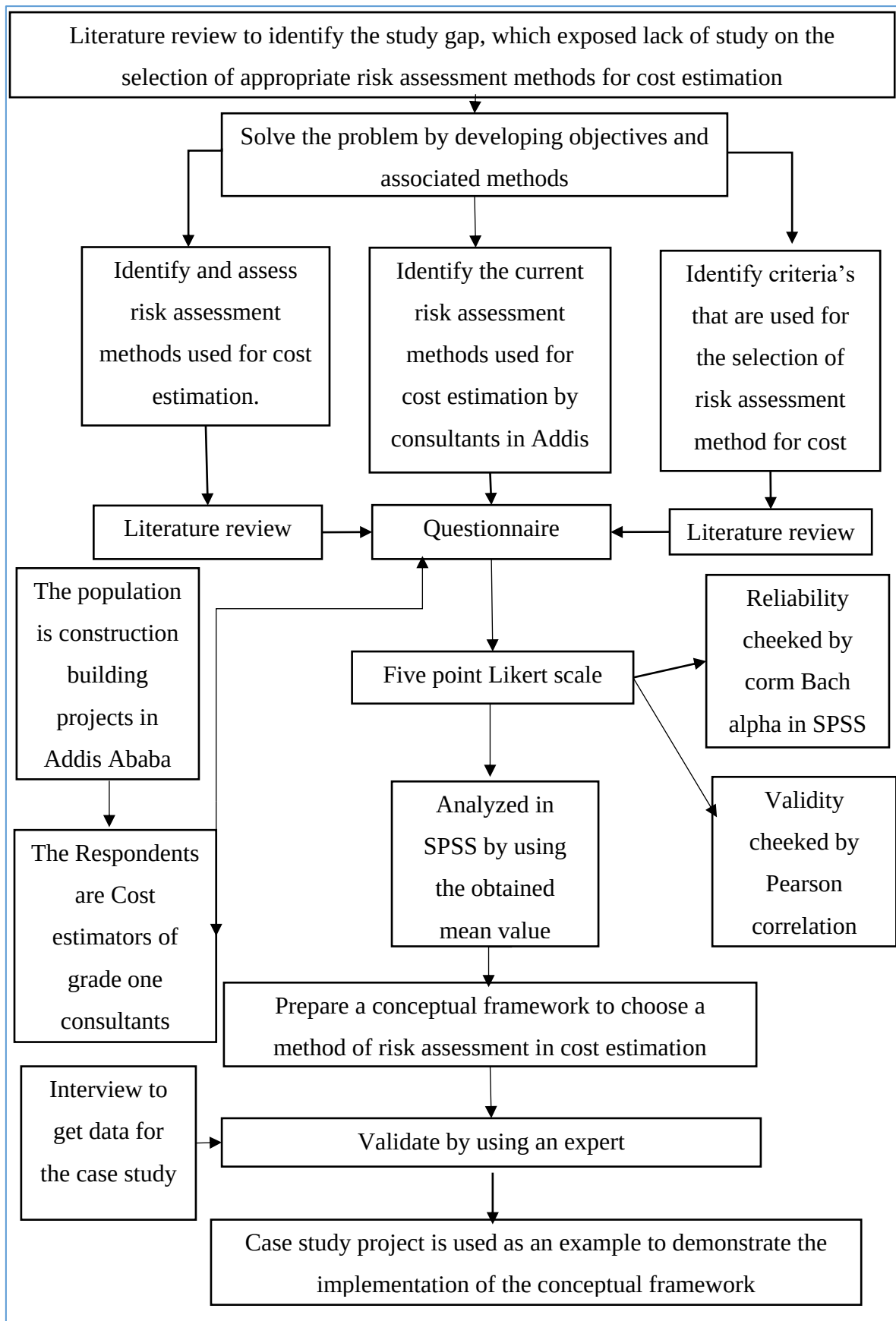


Figure 3.1 Research design

3.4 Population and sampling

3.4.1 Population

The population of this study is construction-building projects that are currently under construction in the city of Addis Ababa. To get the most recent practice projects that have started construction in the past two years 2021-2022GC, were used. Building projects that have five floors or above are taken as the population of this study. Since bigger projects have a higher chance of practicing risk assessment methods in cost estimation (Bakhshi & Touran, 2014). According to the Addis Ababa City Administration Building Permit and Control Office, 60 ground plus five and above construction building projects have begun construction in the last two years, 2021-2022GC. Therefore, 60 building construction projects are the population of this study.

3.4.2 Sampling

Sampling is a method used by researchers to systematically choose a smaller number of representative samples from a pre-defined population to act as a data source (Bagnasco et al., 2014). Random sampling is one of the methods of probabilistic sampling in which every member of the population has an equal probability of being selected as a subject and the sample is representative of the entire population (Sharma, 2017). The sample size determination formula of (Singh & Masuku, 2014) was used to calculate this research's sample size, which is shown in Equation 3.1.

$$\text{Sample size} = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \left(\frac{z^2 \times p(1-p)}{e^2 N} \right)} \text{----- Equation 3.1}$$

Where;

N = population size = 60

e = Margin of error =5% An acceptable margin of error used by most survey researchers typically falls between 4% and 8% at the 95% confidence level (Gilliland & Melfi, 2010)

z = z-score (for Sampling confidence level =95%) is 1.96

P = standard deviation=50%. 50% standard deviation will yield the largest, most conservative standard error(Melzer et al., 2020).

N = 52 sample size obtained

The calculation from Equation 3.1 provided a sample size of $N = 52$ building projects from a population of $N = 60$ building projects. 52 building construction projects are the sample size of this study.

Consultants are the focus of this study. The reason behind choosing consultants as the subject of this study is due to, the fact that consultants are the ones responsible for the estimation of the project's cost (Regd et al., 2015). Grade One consultants are chosen as a target group for the study because they have a properly structured system, organized data set, and better experience. According to the data that was obtained from the ministry of urban development and construction. The head office of the majority of the grade one consultants is located in Addis Ababa. One consulting office is assigned per one building project. 52 grade one consultants were taken as a sample size for the research. Since the main target of this study is risk assessment in cost estimation. The cost estimator is directly responsible for estimating the cost and choosing a risk assessment method for cost estimation. Consulting offices have three main departments and they are the financial department, the contract administration department, and the design department. Under the design department, there are civil engineers, architects, and quantity surveyors. The quantity surveyor is the one responsible for cost estimation. On average one quantity surveyor is assigned for cost estimation per consulting office. Taking on the cost estimator per consulting office, the sample size was calculated to be 52. The pre-requisite requirement for being chosen as a respondent is to work as a cost estimator for a grade one consulting office in Addis Ababa.

3.5 Data collection

Data collection involves gathering information from all relevant sources. To find solutions to the research problems. Data collection methods can be divided into two categories: primary methods of data collection and secondary methods of data collection.

3.5.1 Primary source data

A primary data source is an original data source in which the data is collected firsthand by the researcher for a specific research purpose or project. There are several ways to collect primary data. However, questionnaire surveys and interviews are used in this research. The data obtained from primary sources will often be the primary focus of the data analysis (Pradipta et al., 2016).

3.5.1.1 Questionnaire

A questionnaire is a research tool that consists of a series of questions designed to collect primary data from respondents (Sabrina, 2021). Likert-type questionnaires were chosen as a tool to collect the primary data of this research.

A Likert scale is a psychometric scale often used in survey questionnaire research. Where there are multiple categories from which respondents choose to indicate their opinions, attitudes, or feelings about a particular issue (Barua, 2013). The advantages of Likert-scale questionnaires are that the data can be gathered relatively quickly from large numbers of respondents, is easy and simple to use, and the validity of the interpretations made from the data can be established through a variety of means and produce highly accurate data (Nemoto & Beglar, 2014). Likert-type questionnaires were chosen as a tool to collect the primary data of this research. Because Likert-type questionnaires are easy and simple to use and produce highly accurate data.

This study used a questionnaire to gather data to achieve research objectives 2 and 3. Objective 2 aims to identify the current risk assessment method used for cost estimation by consultants in Addis Ababa. On the other hand, objective 3 deals with criteria that are used to choose a risk assessment method used in cost estimation. The questionnaire used in this study is divided into two main sections. The first section (Part I) is a multiple-choice survey about the respondent's general profile and educational level. The second section (Part II) is a five-point Likert scale survey on the frequency of utilization and importance degree of risk assessment methods used for cost estimation (2.1) and criteria that are used to choose a method of risk assessment used in cost estimation (2.2) (Appendix-A). To help participants gain a basic understanding. A summary of the risk assessment methods utilized in cost estimation is provided in the questionnaire (Appendix-A). The pre-requisite requirement for being chosen as a respondent for this research is to work as a cost estimator for a grade one consulting office in Addis Ababa.

The questionnaire used for data collection in this study was distributed by two mechanisms. The first mechanism is face-to-face distribution. The second mechanism is an online survey using Google Forms. The online survey is used in this research as a data distribution and collection mechanism because it is easily available, has low cost, and consumes less time (Latkovikj & Popovska, 2020).

3.5.1.2 Interview

Interview is a method of data collection that involves two or more people exchanging information through a series of questions and answers (Magnusson & Marecek, 2015). An interview was used in this research to obtain detailed information for the case study project which will be used as an example to demonstrate the implementation of the conceptual framework in a real-life context.

A purposive sampling technique was used to select the case study project. In purposive sampling, the researcher determines what information is necessary and then searches for those who can and are willing to supply it due to their expertise or experience (Etikan et al., 2016). The criteria used to select the case study project are experience, a project that has a similar approach to the theoretical background of the study, and respondents' willingness to answer interview questions. According to the data that was gathered from the questionnaire survey 4.2% of the sample study had experience ranging from 11-15 years. The assumptions that the estimator would apply in the estimate to achieve an accurate estimate are affected by their experience (Hatamleh et al., 2018). The most important factors affecting the accuracy of cost estimates are the consultants' experience and skill level (Alumbugu et al., 2014) And out of this 4.2 % the cost estimator has given a better weight to the importance of the deterministic methods of risk assessment than other respondent is chosen for the interview. The interview conducted was a structured interview with close-ended questions using a face-to-face interaction (Appendix-B).

3.5.1.3 Case Study

The case study project is used as an example to demonstrate the implementation of the conceptual framework in a real-life context. To show how it may assist a decision maker in selecting the appropriate risk assessment method based on its project criteria.

Purposive sampling technique was used to select the case study project in this research. In purposive sampling, the researcher determines what information is necessary and then searches for those who can and are willing to supply it due to their expertise or experience (Etikan et al., 2016). The criteria used to select the case study project are experience, a project that has a similar approach to the theoretical background of the study, and respondents' willingness to answer interview questions.

According to the data that was gathered from the questionnaire survey 4.2% of the sample study had experience ranging from 11-15 years. The assumptions that the estimator would apply in the estimate to achieve an accurate estimate are affected by their experience (Hatamleh et al., 2018).

The most important factors affecting the accuracy of cost estimates are the consultants' experience and skill level (Alumbugu et al., 2014) And out of this 4.2 % the cost estimator has given a better weight to the importance of the deterministic methods of risk assessment than other respondent is chosen for the case study. An interview was used to collect the data for the case study (Appendix-B). The researcher chose a case study project that has a similar approach to the theoretical background of the study (Starman, 2013).

The project that is selected is a 2B+G+10 mixed-use building located in Addis Ababa Jemo 2 which is currently under construction.

3.5.2 Secondary source data

The information that has already been gathered from primary sources and made available for use by researchers in their studies is known as secondary data. Secondary sources offer data that has already been collected or produced by other scholars. (Ajayi, 2017). The secondary data was obtained from the internet, thesis, journals, books, and different articles in published documents.

3.5.2.1 Desk Study

A literature review was used in this research to get an insight into the research problem. To identify the methods used in cost estimation and their advantages, disadvantages, and applications. But all of the reviewed literature was conducted in the past 10 years ranging from 2012 GC–2022 GC because the construction sector advances and changes quickly with the acquisition of new knowledge (Ildarabadi & Alamatian, 2021), so a 10-year range is sufficient to get the latest practice and trends in the construction field. A list of keywords was used to search for research that has been published in peer-reviewed journals in the fields of engineering and the keywords used were: Risk assessment, Cost estimation method, Cost estimation Risk, Cost contingency estimation, List of risk factors in cost estimation, Method of risk assessment used for cost estimation and any types of tools and techniques used in risk assessment for cost estimation that is suitable for building construction projects were also used for this study.

3.6 Data analysis

3.6.1 Method of data analysis.

Data Analysis involves preparing data for analysis, running the analysis, reporting the results, and discussing them (Asaminew, 2021).

The questionnaire that was employed in the study allowed the researcher to collect quantitative data, which was analyzed quantitatively by using descriptive statistics with the help of SPSS version 22 software. The mean, standard deviation, percentage, and frequency were used to find out the summary statistics of the responses. The internal consistency of the questionnaire was checked by using Cronbach's alpha coefficient. Cronbach's alpha is a convenient test used to estimate the internal consistency of a composite score (Foster, 2022). The Likert scale data that is used in this research is a composite score, which is why Cronbach's alpha is used to check the internal consistency.

The reliability of the questionnaire was checked by using the Pearson correlation coefficient. (Stratton, 2018) when using a Likert scale survey to measure the central tendency use the Mean to measure Variability and use standard deviation to measure Associations using Pearson's r (Boone & Boone, 2012).

The Mean Score ranking is One of the most commonly used statistical approaches, mean score (M), uses the average (mean) of a questionnaire survey response that was filled out using a 5-point Likert scale. M is calculated by averaging all responses to an item (Lari et al., 2020).which is shown in equation 3.2.

$$M = \frac{\sum f \times S}{N} \quad (0 < M \leq 5), \text{ -----Equation 3.2}$$

Where S is the score each respondent gave to each characteristic on a scale of 1 to 5, and f is the frequency of replies.

The data obtained from the questionnaire survey part 2.1 on the importance degree of the method of risk assessment used in cost estimation and 2.2 on the importance degree of criteria used to choose a method of risk assessment used in cost estimation (Appendix-A) was analyzed by using the obtained mean value and it was interpreted as follows.

Note: 1 Never .2 seldom, 3 sometimes, 4 often, 5 always

Table 3.1 Five-point Likert scale on usage degree

Mean	Scale	Usage degree
1 - 1.80	1	Never
1.81 - 2.60	2	Seldom
2.61 - 3.40	3	Sometimes
3.41 - 4.20	4	Often
4.21 – 5	5	Always

(Fortunasari et al., 2021)

The data obtained from the questionnaire survey part 2.1 on the importance degree of methods of risk assessment used in cost estimation and 2.2 on the importance degree of criteria used to choose a method of risk assessment used in cost estimation (Appendix-A) was analyzed by using the obtained mean value and it was interpreted as follows.

Note: 1 little importance, 2 some importance, 3 quite important, 4 important, 5 very important

Table 3.2 Five-point Likert scale on importance degree

Mean	Scale	Importance degree
1 - 1.80	1	Little importance
1.81 - 2.60	2	Some importance
2.61 - 3.40	3	Quite important
3.41 - 4.20	4	Important
4.21 – 5	5	Very important

(Fortunasari et al., 2021)

4.6.1.2 Methodology for Conceptual Frame Work

The framework was designed by using a mind map from the methods and criteria that are identified from the literature review and questionnaires as input. The decision-supporting framework shows logical interconnection (flow) between methods' advantages and criteria in such a way that users could select specific methods based on a list of risk assessment selection criteria.

3.6.2 Reliability and validity.

The main objective of a questionnaire in research is to obtain relevant information in the most reliable and valid manner. Thus, the accuracy and consistency of questionnaire survey forms are very significant in research (Taherdoost, 2016).

3.6.2.1 Validity of the questionnaire

Validity is defined as the extent to which a concept accurately measures what it intends to measure and how well the data obtained is relevant to the research (Heale & Twycross, 2015). (Stratton, 2018) argues that parametric tests are more valid when using the survey scale method. To measure associations of a Likert scale, use Pearson's r (Boone & Boone, 2012).

The validity of the questionnaire used in this study is tested by using the Pearson correlation coefficient in SPSS. A Pearson correlation coefficient (PCC) is a statistical metric that measures the strength and direction of a linear relationship between two random variables (Zhou et al., 2016). Pearson's Correlation Coefficient formula is shown in equation 3.3

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \text{-----Equation 3.3}$$

Were,

- r = Pearson Coefficient
- n = number of the pairs of the stock
- $\sum xy$ = sum of products of the paired stocks
- $\sum x$ = sum of the x scores
- $\sum y$ = sum of the y scores
- $\sum x^2$ = sum of the squared x scores
- $\sum y^2$ = sum of the squared y scores

The validity of the questionnaire used in this study is assessed by using the Pearson correlation coefficient in SPSS. The correlation result must meet the following conditions to be a valid questionnaire.

Step 1: The Sig. (2-tailed) value should be less than ($<$) 0.05 it should be checked for every question.

- All of the questions from the questionnaire have a value of Sig. (2-tailed) less than 0.05 this means all of the questions are valid for step 1.

Step 2: Obtained value $>$ critical value in the table

- N =sample size
- Degree of freedom= $N-2$
- Obtained value $>$ critical value in the table
- Sample size is 52 = N
- $DF=N-2=52-2=50$
- See the critical value of 50 DF in the table for 95% confidence interval in table 3.3
- 51DF (0.05) =0.273
- Check all items of the questionnaire one by one
- Example: obtained value is 0.429, which is $>$ 0.273 critical value and is highly significant so it is a valid question.

All of the questions from the questionnaire satisfy step two so all of the questions are valid.

Sample from the Pearson correlation result of the study

Table 3.3 Sample from the Pearson correlation result of the study

Software that is required for the method importance degree	Pearson Correlation	0.324*
	Sig. (2-tailed)	0.025
	N	48
The time that is required to assess the risk usage degree	Pearson Correlation	0.680**
	Sig. (2-tailed)	0
	N	48
The time that is required to assess the risk importance degree	Pearson Correlation	0.382**

	Sig. (2-tailed)	0.007
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The Pearson correlation result obtained from this study's questionnaire satisfies all the parameters to be valid. This means that the questionnaire accurately measured what it set out to measure, and the data collected from it was of better quality, accuracy, and credibility.

Critical values for Pearson's r (Zhou et al., 2016)

Table 3.4 critical values for Pearson's r coefficient table

	Level of significance for a one-tailed test			
Df=N-2	0.05	0.25	0.01	0.05
	Level of significance for a two-tailed test			
	0.10	0.05	0.02	0.01
1	0.988	0.997	0.9995	0.9999
2	0.900	0.950	0.980	0.990
3	0.805	0.878	0.934	0.959
4	0.729	0.811	0.882	0.917
5	0.6690	0.754	0.833	0.874
6	0.622	0.707	0.789	0.834
7	0.582	0.666	0.750	0.798
8	0.549	0.632	0.716	0.765
9	0.521	0.602	0.685	0.735
10	0.497	0.576	0.658	0.708
20	0.360	0.423	0.492	0.537
30	0.296	0.349	0.409	0.449
40	0.257	0.304	0.358	0.393
50	0.231	0.273	0.322	0.354
60	0.211	0.250	0.295	0.325
70	0.195	0.232	0.274	0.302
80	0.183	0.217	0.256	0.284
90	0.173	0.205	0.242	0.267
100	0.164	0.195	0.230	0.254

3.6.2.2 Validity of the frame work

Frameworks are usually validated by experts. The experts can be academicians or practitioners in the field of study (Elangovan & Sundaravel, 2021). The relevance and accuracy of a framework can be validated by experts. To validate framework by using experts (AlHogail, 2015). A reliable consensus of opinions from experts with a wide range of experience about the research subject matter is required. The framework is assessed based on its appropriateness, correctness, comprehensiveness, structure, and its associated elements (Da Veiga & Eloff, 2010). The frame work of this research is validated by an expert. The data that was used to validate the frame work was gathered by using a questionnaire.

3.6.2.3 Reliability

Testing for reliability is important since it refers to the consistency of a measuring instrument. The most extensively used internal consistency statistic is Cronbach's alpha coefficient. When using Likert scales, it is regarded as the most appropriate measure of reliability (Taherdoost, 2016). Cronbach's alpha measures internal consistency, which is, how closely related a set of items are as a group. Cronbach's alpha is a function of the number of test items and the average inter-correlation between them. (Singh, 2017). Cronbach's is the most widely used test for determining an instrument's internal consistency. In this test, the average of all correlations in every combination of split halves is determined (Heale & Twycross, 2015). Cronbach alpha is used to measure the reliability of the Likert scale questionnaire that was used for data collection in this study.

The formula for Cronbach's alpha is shown in equation 3.4

$$\alpha = \frac{N\bar{c}}{\bar{v} + (N-1)\bar{c}} \text{-----Equation 3.4}$$

Where: N is equal to the number of items, $\bar{c}$ is the average inter-item covariance among the items and $\bar{v}$ equals the average variance.

Table 3.5 Coefficient of alpha table

(Taherdoost, 2016)	Coefficient of alpha (α)	Interpretation
	0.90	Excellent
	0.80-0.90	Good reliability

	0.70-0.80	Acceptable reliability
	0.60-0.70	Reliability is questionable
	0.50-0.60	Poor reliability
	0.50	Unacceptable

There are two scales in the questionnaire. The first scale is the usage degree scale, and the second one is the importance degree scale. Two Cronbach alphas are used to show the reliability of the questionnaire on both scales by using SPSS.

Cronbach alpha result for usage degree

Table 3.6 Cronbach alpha result for usage scale

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.770	0.768	13

The result of Cronbach's Alpha (α) for the usage degree scale is 0.770 when interpreted based on Table 3-5. It is considered acceptable reliability because it is in the range of 0.70-0.80.

Cronbach alpha result for importance degree

Table 3.7 Cronbach alpha result for importance scale

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.739	0.758	13

The result of Cronbach's Alpha (α) for the usage degree scale is 0.758 when interpreted based on Table 3-5. It is considered acceptable reliability because it is in the range of 0.70-0.80.

The Cronbach alpha values indicate that the questionnaire used in the study is reliable, implying that if the study is repeated under similar conditions, the results will be consistent.

3.7 Ethical consideration

Research ethics refers to the appropriateness of the researcher's behavior in relation to the rights of those who become the subject of the research work or are affected by it research is a multi-stage process. It needs to take care of various ethical issues at different levels of its

stages (Asaminew, 2021). The ethical considerations in this research were to responsibly cite and acknowledge the professionals whose works were used and reviewed in the literature to avoid distorting and framing data, plagiarizing, and falsely reporting results. In addition, the rights of participants in this research were safeguarded by keeping their identities and responses strictly confidential. The data obtained would be used for academic purposes only.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter deals with the analysis, discussion, and interpretation of the primary data according to the study's objectives. The chapter is classified into three major parts: The first part is about the general profile of the respondents and their response rate. The second part is an analysis of the results and discussion on the methods of risk assessment used in cost estimation and the criteria that are used to choose the methods. The third and most important part is the conceptual framework that is developed to assist in the selection of a risk assessment method for cost estimation.

4.2 Demographic characteristics of the sample

4.2.1. Response rate

For a sample size of 52 cost estimators, 52 questionnaires were distributed. All of the 52 questionnaires were returned. The pre-requisite requirement for being chosen as a respondent is to work as a cost estimator for a grade one consulting office in Addis Ababa. Out of the responses to 52 questionnaires, 48 of them were valid and four were invalid. According to (Fincham, 2018) a response rate of 70% or more can help to draw a very good analysis. The current study response rate is 92.3 %, which means that the response rate is sufficient to draw a very good analysis the response rate of the questionnaire is shown in table 4.1 below.

Table 4.1 Response rate

Number of Questionnaires Distributed	52
Number of Questionnaires Returned	52
Number of accepted questionnaires	48

Number of rejected questionnaires	4
Percentage of Survey Response rate	92.3%

The questionnaire used for data collection in this study was distributed by two mechanisms. The first mechanism is a face-to-face distribution.

The second mechanism is an online survey using Google Forms. The mechanisms used for data distribution in this study are explained in detail in Table 4.2 below.

Table 4.2 Method of questionnaire distribution

Method	Hand in hand	Goggle format
Number of questionnaires distributed	42	10
Number of questionnaires received	42	10
Number of questionnaires rejected	3	1
Percentage of valid questionnaires received	75%	17.3%

4.2.2 General profile of respondent

This section offers general information about the participants in this study, their educational backgrounds, and work experience. The Figure 4.1 below illustrates their educational level.

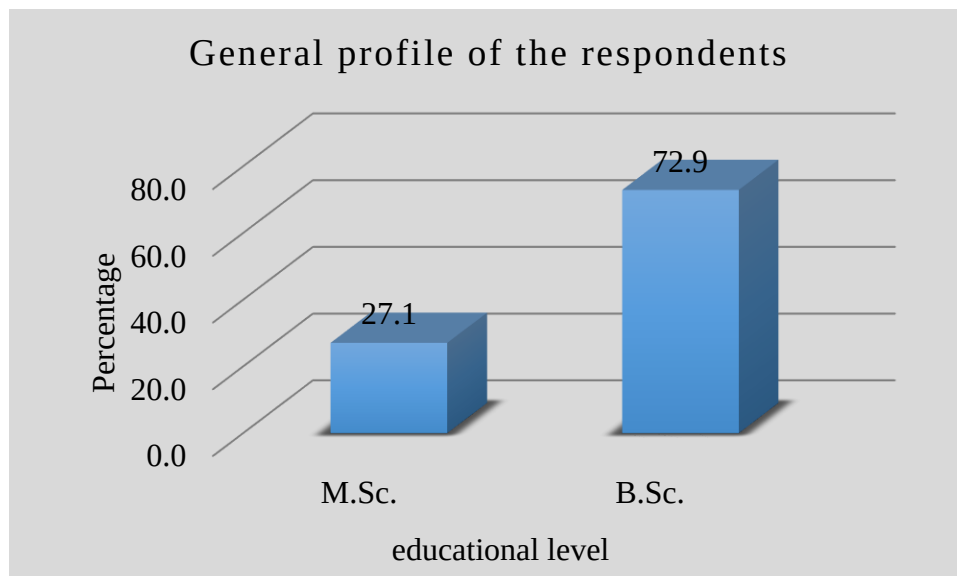


Figure 4. 1 Educational level of the respondent

The educational level of the participants in the study, expressed in percentage, is M.Sc. (27.1%), and B.Sc. (72.9%). Literacy skills and educational qualifications are strongly

intertwined. (Massing & Schneider, 2017). This means that the study's participants are literate. That they have a better understanding and grasp of the research's subject matter, making them excellent participants in this study. The graph below illustrates the work experience of the participants of the study.

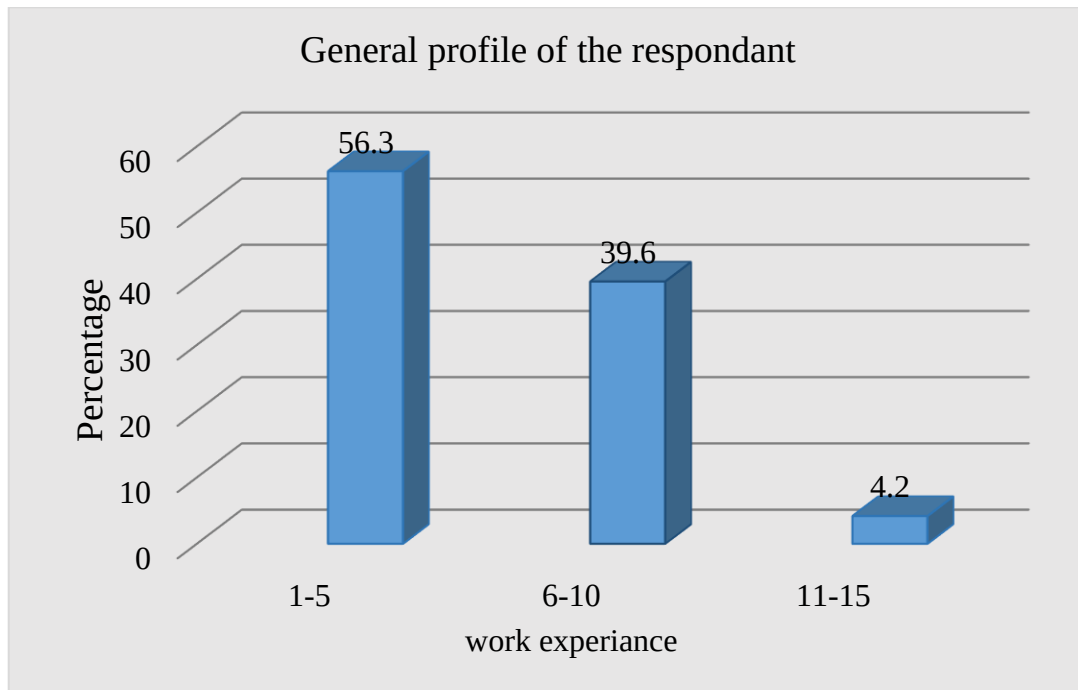


Figure 4. 2 Work experience of the participants of the study

The working experience of the participants in the study, expressed in percentage, is 1-5 years of experience (56.3%), 6-10 years of experience (39.6%), and 11-15 years of experience (4.2%). This means that the majority of cost estimators have little experience, which can affect their cost estimation results and method of risk assessment. The assumptions that the estimator would apply in the estimate to achieve an accurate estimate are affected by their experience (Hatamleh et al., 2018). The most important factors affecting the accuracy of cost estimates are the consultants' experience and skill level (Alumbugu et al., 2014). In this study, 56.3 % of the cost estimator has an experience from 1-5 years. The experience of the cost estimators affects what kind of risk assessment they apply in their cost estimate.

4.3 Methods of risk assessment used in cost estimation

A literature review was conducted to identify the risk assessment methods used for cost estimation around the world. From the conducted literature review, five methods were identified, and they are Traditional Percentage, Monte Carlo simulation (MCS), Artificial Natural Network (ANN), Bayesian belief networks (BBNs), and Fuzzy Arithmetic Risk

Analysis. To identify the current risk assessment methods used for cost estimation by cost estimators in Addis Ababa.

A questionnaire survey was distributed, and the following result was obtained from the five-point Likert scale questionnaire survey of part 2.1, (Appendix A) which was analyzed with the help of SPSS. The data was gathered and analyzed according to the utilization and the relevance of risk assessment methods in cost estimation.

4.3.1 Frequency of using various risk assessment methods in cost estimation

To identify the risk assessment method that is currently practiced in cost estimation a questionnaire survey was used. The questionnaire survey gathered data on the frequency of utilization of risk assessment methods used in cost estimation. Which was analyzed by using the mean value in SPSS.

The following result was obtained from the questionnaire survey that was distributed to get data on the usage degree of the methods of risk assessment used in cost estimation by the cost estimators.

The usage degree shows the frequency in which the cost estimators utilize the methods of risk assessment used in cost estimation. Table 4.3 indicates the frequency of using various risk assessment methods in cost estimation.

Table 4.3 Usage degree of risk assessment methods by study participants

Methods of risk assessment in cost estimation	N	Mean	Std. Deviation
Traditional percentage contingency estimate usage degree	48	4.44	0.712
Monti Carlo simulation usage degree	48	1.26	1.041
Artificial natural network usage degree	48	1.24	0.954
Bayesian belief networks usage degree	48	1.23	1.072
Fuzzy arithmetic risk analysis usage degree	48	1.21	0.850

The mean result that was obtained from the SPSS software was interpreted based on table 3-1. And it has provided the following list of results: The traditional percentage contingency estimate method is used by 97% of the cost estimators. The Monti Carlo simulation method is used by 0.55 % of the cost estimators, the artificial natural network method is used by 0.75

% of the cost estimators, the Bayesian belief networks simulation method is used by 0.80 % of the cost estimators, and the Fuzzy arithmetic risk analysis simulation method is used by 0.90 % of the cost estimators. One of the objectives of the study is to identify the current risk assessment method used for cost estimation by cost estimators in Addis Ababa.

The study results show that 97% of the cost estimators use the traditional percentage or contingency cost method of risk assessment.

A study by (Mesfin, 2014) concluded that the majority of parties involved in Ethiopian building construction projects do not have adequate knowledge of risk management principles. The results from a study by (Buerthey et al., 2013) showed at least 95% of the engineering design actors (EDA) primarily used traditional methods. The deterministic approach is unscientific and inadequate in logically handling risk. This method has several weaknesses. It is overly simplistic and heavily dependent on estimators' faith and experience. Research by (Afzal et al., 2019) stated that due to the limitation of subjective risk data and complex computation, the applications of deterministic methods of risk assessment are limited.

4.3.2 Importance of risk assessment methods in cost estimation

A questionnaire survey was gathered to get data on the importance of risk assessment methods used in cost estimation by the cost estimators. The data that was gathered is presented in table 4.4 below.

Table 4.4 Importance degree of risk assessment method by study participants

Methods of risk assessment in cost estimation	N	Mean	Std. Deviation
Traditional percentage contingency estimate importance degree	48	4.44	0.501
Monti Carlo simulation importance degree	48	1.22	1.444
Artificial natural network importance degree	48	1.24	1.207
Bayesian belief networks importance degree	48	2.25	1.407
Fuzzy arithmetic risk analysis importance degree	48	2.31	1.323

The data that was gathered was analyzed by using its mean value with the help of SPSS software. It was interpreted based on Table 3.2. And it has provided the following list of results: according to the cost estimators' point of view, the traditional percentage

contingency method is very important. The Monti Carlo simulation method has little importance. The artificial natural network method has little importance. The belief networks method has some importance. The Fuzzy arithmetic risk analysis method has some importance.

According to the results, the probabilistic approaches (MCS, ANN, BBNs, Fuzzy arithmetic) have little importance and usage by the cost estimators compared to the traditional percentage or contingency method, even though they are better at assessing risk by identifying risk factors and predicting their outcomes under different scenarios considering various sources of uncertainty. The probabilistic approaches of risk assessment in cost estimation provide a range of potential risks their chance of occurrence and elements that have the greatest impact on the outcomes that can easily be determined. It has several benefits, which include the ability to better manage project schedules, the ability to manage project costs, increased confidence in project decision-making, the ability to make risks explicit, and the capacity to manage risks more effectively (Senesi et al., 2015).

The traditional percentage or contingency cost method of risk assessment is used 97% of the cost estimators and it is considered very important. The Monti Carlo simulation (MCS) method of risk assessment is used by 0.55% of the cost estimators and it is considered to have little importance. The artificial natural network (ANN) method of risk assessment is used by 0.75% of the cost estimators and it is considered to have little importance. The Bayesian belief networks (BBNs) method of risk assessment is used by 0.8% of the cost estimators and it is considered to have some importance. The fuzzy arithmetic risk analysis method of risk assessment is used by 0.90% of the cost estimators and it is considered to have some importance.

Lack of risk management in construction projects is one of the major setbacks for construction project performance in Ethiopia. Construction projects have no routine practices employed to manage risks (Hailu, 2018). There is a lack of proper risk management practices in Ethiopian construction projects. The awareness of risk management is still at a relatively low level in the current Ethiopian construction industry (Yadeta, 2019). Most of the parties involved in the Ethiopian building construction projects have heard of the concept of risk management but lack adequate knowledge about the principles of risk management. The common excuse given for not incorporating risk management techniques into projects was a lack of awareness about their significance (Mesfin, 2014). Ethiopian consultants did

not provide a formal risk management plan for their projects (Mitikie et al., 2017). Failure to adequately deal with risks has been shown to cause higher costs. There is about a 15.33% cost increment beyond the initially estimated cost of construction projects in Ethiopia (Taylan et al., 2014).

4.4 Criteria that are used to choose a method of risk assessment in cost estimation

To identify the criteria that are used for the selection of risk assessment method for cost estimation. A questionnaire was distributed, and the following result was obtained. The results that were obtained from the five-point Likert scale questionnaire part 2.2, (Appendix A) on the criteria that are used to choose a method of risk assessment in cost estimation were analyzed with the help of SPSS. The data was analyzed into two categories: the first category was based on their usage degree and the second category was based on their importance degree.

4.4.1 The frequency of the criteria that are used to choose a method of risk assessment in cost estimation

The following result was obtained from the questionnaire survey that was distributed to get data on the usage degree of criteria that are used to choose a method of risk assessment used in cost estimation by the cost estimators. The usage degree shows the frequency in which the cost estimators utilize the criteria that are used to choose a method of risk assessment used in cost estimation. The following result table 4.5 indicates the usage degree of criteria that are used to choose a method of risk assessment in cost estimation.

Table 4.5 Usage degree of criteria by study participants

List of criteria that are used to choose the methods of risk assessment in cost estimation	N	Mean	Std. Deviation
Amount of information available usage degree	48	1.75	0.944
Accuracy of the output of the method usage degree	48	1.94	0.753
Ease of use usage degree	48	3.54	1.010
Availability of historical data usage degree	48	1.25	1.052
Software that is required for the method usage degree	48	1.70	1.041
The time that is required to assess the risk usage degree	48	3.69	1.035
Accessibility of the method usage degree	48	3.92	0.942

Familiarity with the method usage degree	48	4.83	0.930
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The mean result that was obtained from the SPSS software was defined based on table 3-1. And it has provided the following list of results: The cost estimators never use the amount of information available criteria to choose a method of risk assessment in cost estimation.

The cost estimators never use the accuracy of the output of the method criteria to choose a method of risk assessment in cost estimation. The cost estimators often use ease of use criteria to choose a method of risk assessment in cost estimation. The cost estimators never use the availability of historical data usage criteria to choose a method of risk assessment in cost estimation. The cost estimators never use the software that is required for the method criteria to choose a method of risk assessment in cost estimation. The cost estimators often use the time that is required to assess the risk criteria to choose a method of risk assessment in cost estimation. The cost estimators often use the accessibility of the method criteria to choose the method of risk assessment in cost estimation. The cost estimators always use familiarity with the method criteria to choose the method of risk assessment in cost estimation.

Based on the result obtained the cost estimators use ease of use, time that is required to assess the risk, accessibility of the method, and familiarity with the method criteria to choose a method of risk assessment in cost estimation that is why 97% of the cost estimators use the traditional percentage or contingency cost method of risk assessment.

Degree of accuracy, speed, ease of use, and ease of updating are the criteria that are used for the selection of the method of risk assessment used in cost estimation. (Kim & Kim, 2010). 67% of the consultants collect and use the company's historical data for the preparation of cost estimates only 1/3 of the consultants use computer tools for a cost estimate (Zewdu & Aregaw, 2015).

4.4.2 Importance of the criteria that are used to choose a method of risk assessment in cost estimation

The following result was obtained from the questionnaire survey that was distributed to get data on the importance of the criteria that are used to choose a methods of risk assessment used in cost estimation by the cost estimators. The usage degree shows the frequency in which the cost estimators utilize the criteria that are used to choose a method of risk assessment used in cost estimation. The following result table 4.6 was obtained for the

importance of the criteria that are used to choose a method of risk assessment in cost estimation.

Table 4.6 Importance degree of criteria by study participants

List of criteria that are used to choose the methods of risk assessment in cost estimation	N	Mean	Std. Deviation
Amount of information available importance degree	48	2.46	0.719
Accuracy of the output of the method importance degree	48	2.75	0.934
Ease of use importance degree	48	4.48	0.989
Availability of historical data importance degree	48	1.83	1.044
Software that is required for the method importance degree	48	1.58	1.412
The time that is required to assess the risk importance degree	48	4.79	0.874
Accessibility of the method importance degree	48	3.88	0.841
Familiarity with the method importance degree	48	1.71	0.824

The mean result that was obtained from the SPSS software was interpreted based on table 3-2. And it has provided the following list of results: The amount of information available criteria has some importance in choosing a method of risk assessment in cost estimation. The accuracy of the output of the method criteria is quite important when choosing a method of risk assessment in cost estimation. Ease of use criteria is very important when choosing a method of risk assessment in cost estimation. The availability of historical data criteria has some importance in deciding the method of risk assessment in cost estimation. Software that is required for the method criteria has little importance in choosing a method of risk assessment in cost estimation. The time that is required to assess the risk criteria is very important for choosing the method of risk assessment in cost estimation. Accessibility of the method criteria is important when choosing a method of risk assessment in cost estimation. Familiarity with the method criteria is very important to choose the method of risk assessment in cost estimation.

Based on the results obtained, the following criteria are used to choose a method of risk assessment: Ease of use, the time that is required to assess the risk, the accessibility of the method, and familiarity with the method are more important than the software required for the method, the availability of historical data, the accuracy of the method's output, and the amount of information available.

This explains why the cost estimators use the traditional percentage or contingency estimate method. It is because familiarity and ease of use are more important than accuracy.

Cost estimation methods are chosen for their familiarity and use instead of their accurate estimates. (Xenidis & Stavrakas, 2013).

Criteria that are used to choose a method of risk assessment used in cost estimation. The amount of information available Criteria are never used by most of the cost estimators when choosing a risk assessment method, and they are considered to have little importance.

The accuracy of the output of the method most cost estimators never use risk assessment methods when selecting a risk assessment method, and it is regarded as unimportant. Ease of use Criteria is often used by most of the cost estimators when choosing a risk assessment. Method and it is considered very important. Availability of historical data Criteria are never used by most of the cost estimators when choosing a risk assessment method, and they are considered to have little importance. Software that is required for the method Criteria are never used by most of the cost estimators when choosing a risk assessment method, and they are considered to have little importance. The time that is required to assess the risk Criteria are often used by most cost estimators when choosing a risk assessment method and is considered very important. Accessibility of the method Criteria is often used by most cost estimators when choosing a risk assessment method and it is considered important. Familiarity with the method Criteria is always used by most of the cost estimators when choosing a risk assessment method and is considered very important.

4.5 Conceptual framework for selecting a suitable method of risk assessment for cost estimation

The development of a conceptual framework begins with a deductive assumption that a problem exists, and the application of processes, procedures, functional approaches, models, and other tools are used to solve the problem (Zackoff et al., 2019). A conceptual framework is constructed based on the research objective by using relationships between the particular factors in the research (Regoniel, 2015).

Applications of risk assessment methods are found to be limited. Therefore, a comprehensive risk assessment framework is required (Afzal et al., 2019). At least 95% of Engineering Design Actors (EDA) used traditional methods. The reason why these actors predominantly

used the deterministic method is the unavailability of any tested and approved framework (Buerthey et al., 2013).

From the reviewed literature, there are different methods of risk assessment. Each of the estimation methods has advantages, disadvantages, and specific areas they can apply to. However, there is a lack of study on the selection of suitable risk assessment methods for cost estimation this research will fill this gap by developing a conceptual framework. That helps cost estimators to select a suitable method of risk assessment in cost estimation. The decision-supporting framework was prepared by using the methods and criteria that are identified from the literature review and questionnaires as an input. Only probabilistic risk assessment methods are used in this framework. This is because the probabilistic methods of risk assessment can manage project risks more effectively and effectively (Senesi et al., 2015). The framework was designed by using a mind map that shows logical interconnection (flow) between 8 criteria, 5 methods' and 5 advantages of the methods. It was designed in such a way that users could select specific methods based on a list of risk assessment selection criteria. This framework provides 13 decision scenarios (situations) to help users choose the most appropriate risk assessment methods. 2 of the 13 possibilities lead to the Fuzzy arithmetic risk analysis method, 3 to Monti Carlo simulation, 1 to simulation-based correlation of cost risk analysis model, 4 to artificial neural network (ANN), and 3 to Bayesian belief network (BBN). The framework is presented below in figure 4.3.

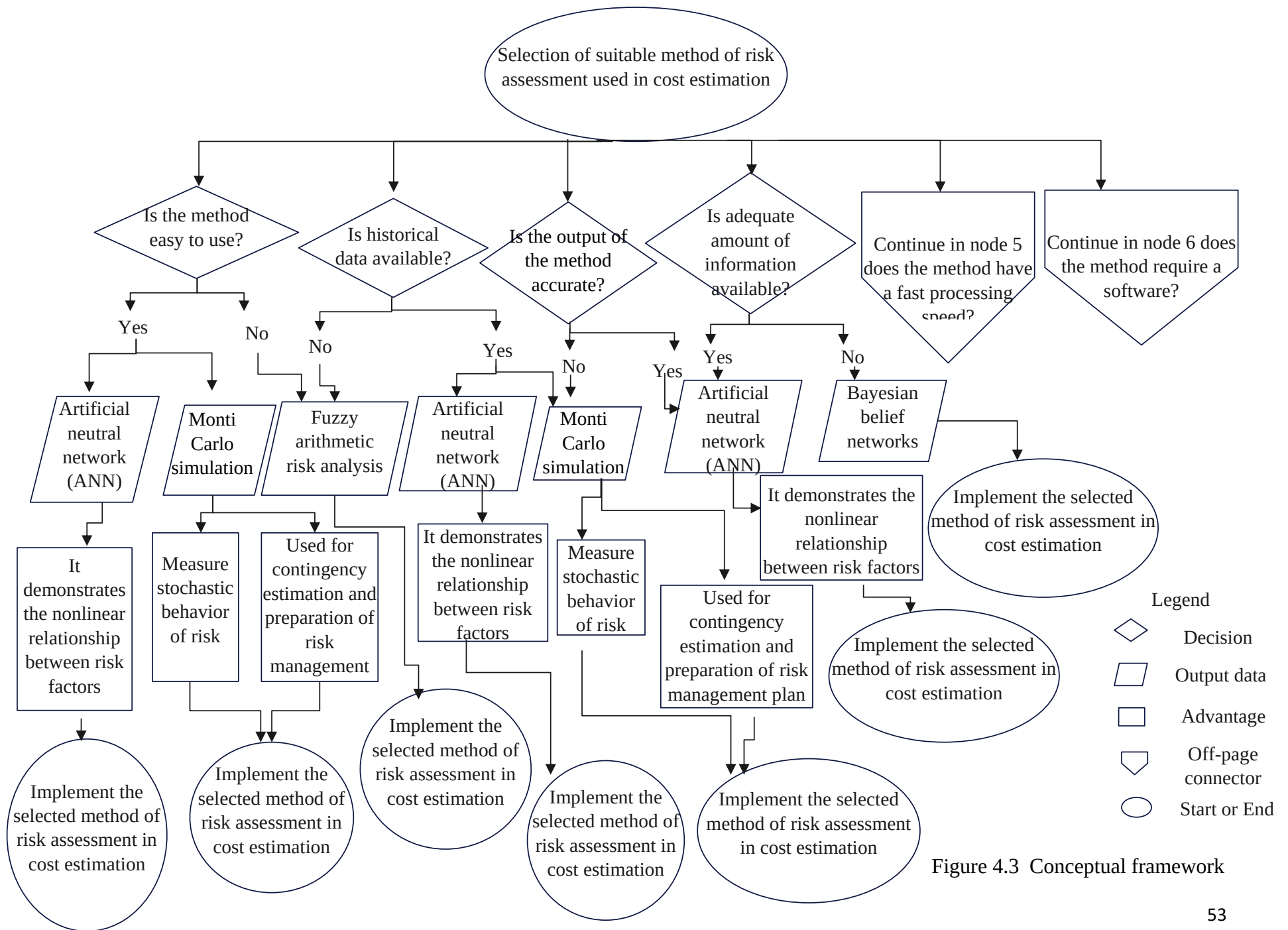


Figure 4.3 Conceptual framework

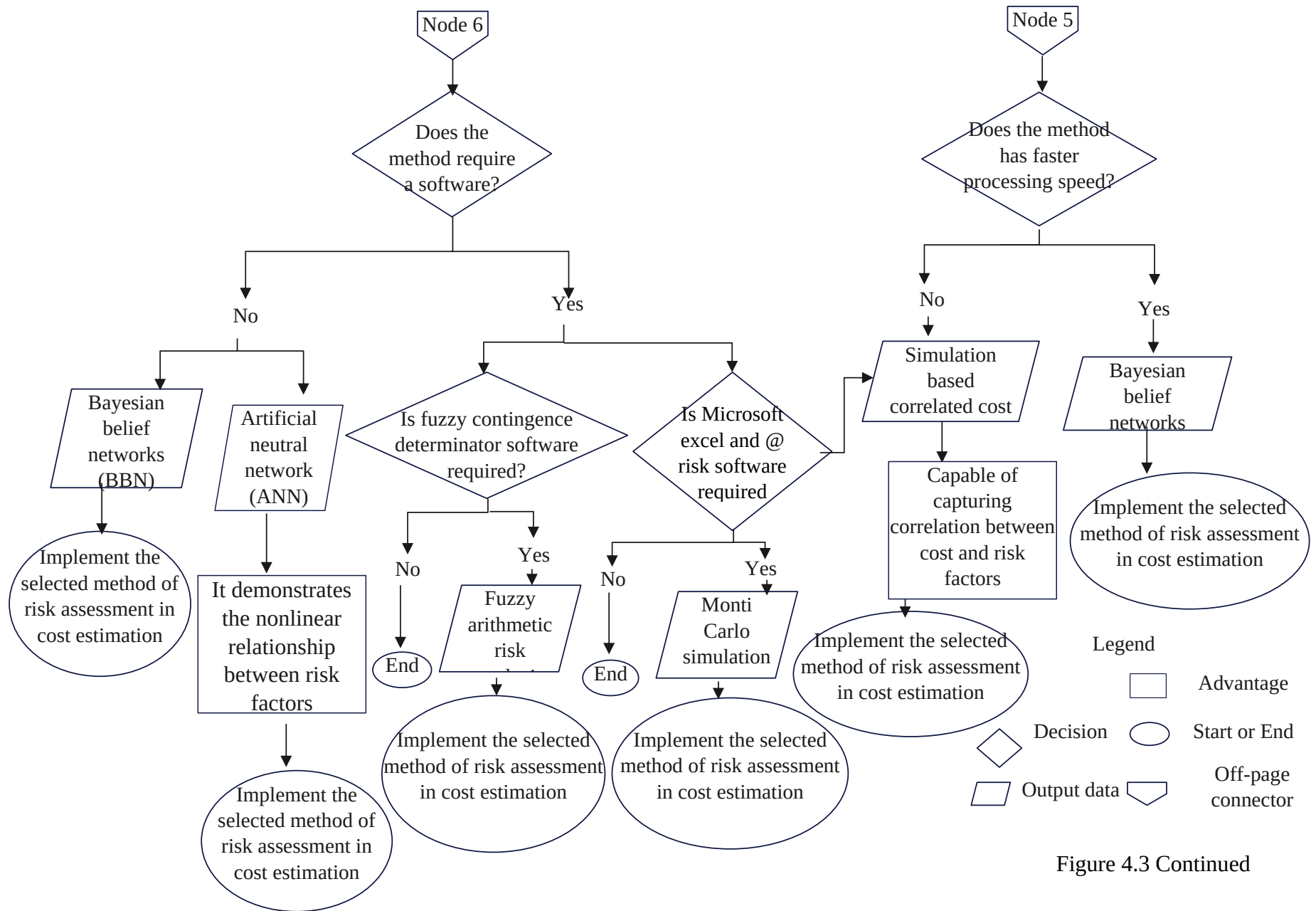


Figure 4.3 Continued

4.5.1 Validation of the Framework

Frameworks are usually validated by experts. The experts can be academicians or practitioners in the field of study (Elangovan & Sundaravel, 2021). The relevance and accuracy of a framework can be validated by experts. To validate framework by using experts (AlHogail, 2015). A reliable consensus of opinions from experts with a wide range of experience about the research subject matter is required. The framework is assessed based on its appropriateness, correctness, comprehensiveness, structure, and its associated elements (Da Veiga & Eloff, 2010). The frame work of this research is validated by an expert. The data that was used to validate the frame work was gathered by using a questionnaire.

The application of the frame work in the industry was assessed based on its ease of use, utilization, logical inter connection flow, clear demonstration, practicality. Relevance in selecting a risk assessment method in cost estimation and Effectiveness in addressing its objective which is helping user's select specific methods based on risk assessment method selection criteria.

1. Have you reviewed/ examined the conceptual frame work.

A. yes ☒

B. No ☐

2. Is the frame work designed in such a way that is easy for users to understand?

A. yes ☒

B. No ☐

3. Is the logical inter connection flow clearly demonstrated?

A. yes ☒

B. No ☐

4. Is the frame work practical?

A. yes ☒

B. No ☐

5. Is the frame work designed in such a way that is easy for users to utilize?

A. yes ☒

B. No ☐

6. Does it help user's select specific methods based on risk assessment method selection criteria?

A. yes ☒

B. No ☐

Company's name Minaret Engineering P.L.C.

Your Job title/position Construction & design department

Signature





4.5.2 Demonstration on the Application of the Framework

The case study project was used as an example to demonstrate the application of the risk assessment method selection supporting framework in a real-life scenario. The validation process provides clues on how the framework helps a decision maker choose a suitable method of risk assessment that best meets his/her criteria.

Case study project

The case study project is a 2B+G+10 mixed-use building located in Addis Ababa Jemo 2.

The steps to follow for selecting a suitable risk assessment method for cost estimation by using the framework are as follows:

1. Is the method of risk assessment easy to use? Yes, artificial neural network (ANN) and Monte Carlo Simulation are selected.
2. Is historical data available for the project? No, Fuzzy arithmetic risk analysis is selected.
3. Is the output of the method accurate? Yes, artificial neural network (ANN) is selected.
4. Is an adequate amount of information about the project available? Yes, artificial neural network (ANN) and Monte Carlo Simulation are selected.
5. Does the method require software? No, Artificial neural network (ANN) and Bayesian belief networks (BBN) are selected.
6. Does the method have a faster processing speed? Yes, Bayesian belief networks (BBN) is selected.

Artificial neural network (ANN) is the selected method of risk assessment in cost estimation for the case study project by using the framework.

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

- The study result shows that 97% of the cost estimators in Addis Ababa use the traditional percentage or contingency estimate method for assessing risk in cost estimation. In this method, the most likely cost of the project is estimated, and a percentage of the likely project cost is added based on experts' best judgment. This approach is unscientific and inadequate in logically handling risk. It has several weaknesses. It is overly simplistic and heavily dependent on estimators' faith and experience.
- The study has identified the following list of criteria that are used for the selection of a risk assessment method for cost estimation and they are: The amount of information available; the accuracy of the output of the method; Ease of use Availability of historical data software that is required for the method, and time that is required to assess the risk, Accessibility of the method, and familiarity with the method.
- Accessibility of the method, and familiarity with the method criteria are given more weight by the cost estimator. Than the software that is required for the method, the availability of historical data, the accuracy of the output of the method, and the amount of information available. This explains why the cost estimators use the traditional percentage or contingency estimate method. It is because familiarity and ease of use are more important than accuracy.
- A conceptual framework that helps cost estimators select a suitable method of risk assessment in cost estimation based on their project condition was designed. It was designed in such a way that users could select specific methods based on risk assessment method selection criteria. This framework provides 13 decision scenarios (situations) to help users choose the most appropriate risk assessment methods. A case study project was used as an example to demonstrate the application of the risk assessment method selection supporting framework in a real-life scenario. For the case study project, artificial neural network (ANN) was the selected method of risk assessment in cost estimation by using the framework. This demonstrated the practical applicability of the framework in supporting decision-makers to choose a suitable risk assessment method.

5.2 Recommendation

Based on the research findings and conclusion, the following recommendations are made to improve the current practice of risk assessment method used for cost estimation by cost estimators in Ethiopia.

- Frequent utilization of probabilistic risk assessment methods in cost estimation should be practiced by cost estimators. Which will lead to a more accurate and precise cost estimate.
- Training and workshops about the advantages of probabilistic risk assessment methods in cost estimation should be provided to cost estimators.
- The accuracy of the output of the risk assessment method for cost estimation should be the number one criteria used to choose a method. Which can lead to an accurate cost estimate.
- Cost estimators use the conceptual framework of this study to select a suitable method of risk assessment in cost estimation based on their project condition. And benefit from the use of risk assessment in their cost estimation.

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APPENDICES

Appendix A- Questionnaire Questionnaire

Letter No:

Date:

Dear Sir/Madam,

Re: Questionnaire for MSc thesis on conceptual framework to select risk assessment method in estimating the cost of building construction project.

My name is soliyana Solomon; I am a student at Adama science and technology university School of Graduate Studies/SGS/ Department of construction engineering and management. I am currently working on research entitled “Framework to Select Risk Assessment Method Used in Cost Estimation in Case of Building Construction Projects” I believe your experience and educational background will greatly contribute to the success of my research. So it is with great respect that I ask you for a little of your time to fill this questionnaire. The questionnaire is prepared to gather information from selected grade-one Building Consultants. The outcome of the research will serve as partial fulfillment of MSC in construction engineering and management. The purpose of the research is to prepare a conceptual framework to select risk assessment method in estimating the cost of building construction project. The questionnaire categorized into three major parts. Part I solicited general information about the respondents. Part II contains questions about the methods of cost estimation and risk assessment used. Your response is highly valuable and contributory to the outcome of the research. All of your responses to any of the question kept strictly confidential and used for this academic research only. No report of the study will ever expose your identity. You kindly requested to answer & fill the questionnaire accurately & with truthfully.

Thank You! Best Regards

Soliyana Solomon, Post graduate student, construction engineering and management

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Addis Ababa, Ethiopia

Introduction

Greetings dear participant I would like to kindly ask you to fill out this questionnaire, I s categorized into three major parts. Part I solicited general information about the respondents. Part II contains questions about the methods of cost estimation and risk assessment used.

Part I General Profile of the Respondent

1). Please tick on the provided box

1.1) what is your educational level?

1) Diploma ☐

3) B.Sc. ☐

2) M.Sc. ☐

4) PhD ☐

3) Other; please specify.....

1.2) Work experience

1) 1-5 years ☐

3) 10-15 years ☐

2) 5-10 years ☐

4) more than 15 years ☐

Part II Methods of risk assessment used in cost estimation.

2.1) below are e list of methods of risk assessment used in cost estimation. Please choose your practice for each specific method by ticking on the appropriate cell.

Short description for each of the methods listed in the table.

- **MCS (Monti Carlo simulation)** is a Simulation-based decision-making tool that uses mathematics to estimate the possible outcomes of an uncertain event.
- **Artificial neural network (ANN)** is a model that uses artificial intelligence (AI). To demonstrate the non-linear relationships that exist between the risk factors based on historical data.

- **Bayesian belief networks (BBNs)** is a probabilistic graphical method (PGM) that represents conditional dependencies between random variables through acyclic the graph.
- **Fuzzy Arithmetic Risk Analysis** enables assessment of risk using a novel and highly flexible fuzzy arithmetic.

Item .no	List of methods of risk assessment used in cost estimation	Usage degree					Importance degree				
		Never	Seldom	Sometimes	Often	Always	Little important	Some important	Quite important	important	Very important
1	Traditional percentage or contingency cost										
2	Monti Carlo simulation (MCS)										
3	Artificial natural network (ANN)										
4	Bayesian belief networks (BBNs)										
5	Fuzzy Arithmetic Risk Analysis										

Other; please specify.....

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2.2) below are a list of criteria that are used to choose a method of risk assessment used in cost estimation. Please choose your practice for each specific criteria by ticking on the appropriate cell.

Item .no	List of Criteria	Usage degree					Importance degree				
		Never	Seldom	Sometimes	Often	Always	Little important	Some important	Quite important	important	Very important
1	Amount of information available										
2	Accuracy of the output of the method										
3	Ease of use										
4	Availability of Historical data										
5	Software that is required for the method										
6	Time that is required to assess the risk										

7	Accessibility of the method										
8	Familiarity with the method										

Other; please specify.....

--	--	--	--	--	--	--	--	--	--	--	--

Thank you for your corporation

Dear Sir/Madam,

My name is Soliyana Solomon; I am a student at Adama science and technology university School of Graduate Studies/SGS/ Department of construction engineering and management. I am currently working on research entitled “Framework to Select Risk Assessment Method Used in Cost Estimation in Case of Building Construction Projects” I believe your experience and educational background will greatly contribute to the success of my research. So it is with great respect that I ask you for a little of your time. The outcome of the research will serve as partial fulfillment of MSC in construction engineering and management. Your response is highly valuable and contributory to the outcome of the research. Which is a conceptual framework that helps cost estimators select a suitable method of risk assessment in cost estimation based on their project condition. It was designed in such a way that users could select specific methods based on risk assessment method selection criteria. I kindly request your view point and opinion on the ease of use, clarity, practicality, relevance and effectiveness of the conceptual framework.

Short description for each of the risk assessment methods. MCS (Monti Carlo simulation) is a Simulation-based decision-making tool that uses mathematics to estimate the possible outcomes of an uncertain event. Artificial neural network (ANN) is a model that uses artificial intelligence (AI). To demonstrate the non-linear relationships that exist between the risk factors based on historical data. Bayesian belief networks (BBNs) is a probabilistic graphical method (PGM) that represents conditional dependencies between random variables through acyclic the graph. Fuzzy Arithmetic Risk Analysis enables assessment of risk using a novel and highly flexible fuzzy arithmetic.

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1. Have you reviewed/ examined the conceptual frame work.

A. yes ☐

B, No ☐

2. Is the frame work designed in such a way that is easy for users to understand and utilize?

A. yes ☐

B. No ☐

3. Is the logical inter connection flow clearly demonstrated?

A. yes ☐

B. No ☐

4. Is the frame work practical?

A. yes ☐

B. No ☐

5. Is the frame work designed in such a way that is easy for users to use?

A. yes ☐

B. No ☐

6. Does it help user's select specific methods based on risk assessment method selection criteria?

A. yes ☐

B. No ☐

Company's name-----

Your Job position/title-----

Signature-----

Appendix B- Interview Questions

Interview questions

Part I General information about the project

1. Where is the location of the building project and its specific area?
2. Function of the building project

Part II Criteria's used to choose a risk assessment method for the building project

1. Do you prefer a method of risk assessment that is easy to use?
2. Is historical data available for the project?
3. Do you prefer a method of risk assessment that has an accurate output?
4. Is an adequate amount of information about the project available?
5. Do you prefer a method of risk assessment that requires software?
6. Do you prefer a method of risk assessment that has a faster processing speed?

Appendix C_ List of grade one consultants in Addis Ababa

	ORGANIZATION NAME	GRADE	TEL	REGION	SUBCITY	WEREDA
1	Alfarow consulting architects & engineers plc	1	911220205	Addis Ababa	bole	1
2	Archsol consulting architects and engineers	1	911239889	Addis Ababa	arada	1
3	Associated engineering consultant's plc	1	93000817	Addis Ababa	bole	3
4	Atcon Eng. arch. consultancy plc	1	936011261	Addis Ababa	bole	6
5	Beza consulting engineer's plc	1	911435027	Addis Ababa	gulelie	10
6	Birnad consultant plc	1	911411652	Addis Ababa	bole	6
7	Biyboneconsultants plc	1	911202961	Addis Ababa	arada	9
8	Clover consulting engineer's plc	1	911428683	Addis Ababa	kirkos	3
9	Colleg consult	1	920900495	Addis Ababa	yeka	7
10	Damra consulting engineering plc	1	929923402	Addis Ababa	bole	4
11	Dawit Semret consultancy plc	1	911262333	Addis Ababa	kirkos	10
12	EF architects & engineers consulting plc	1	920112200	Addis Ababa	yeka	13
13	EPH tec consult	1	911023862	Addis Ababa	akaki kaliti	4
14	ETG designers and consultants share company	1	911225202	Addis Ababa	nifas silk lafto	3
15	Eyob Kinfu consulting architects & engineering plc	1	911795076	Addis Ababa	yeka	3
16	G& Y engineering consultant plc	1	911899905	Addis Ababa	akaki kaliti	1

17	Geretta consult plc	1	911644295	Addis Ababa	bole	10
18	HH consulting architects & engineers plc	1	911126312	Addis Ababa	kirkos	8
19	Hybrid consulting architects & engineering	1	930337330	Addis Ababa	nifas silk lafto	8
20	Image consultancy plc	1	911514239	Addis Ababa	kirkos	8
21	Invent consulting architects' engineers and planners	1	911249323	Addis Ababa	gulelie	1
22	JCB consult plc	1	911265839	Addis Ababa	yeka	8
23	Jdaw consulting architects engineering	1	911513983	Addis Ababa	bole	2
24	KH consulting architect & engineers	1	911210462	Addis Ababa	nifas silk lafto	3
25	K2N architecture & engineering consultancy plc	1	911525848	Addis Ababa	yeka	13
26	Keen consultant's plc	1	911079790	Addis Ababa	yeka	8
27	ITF architects and engineers consulting plc	1	911505419	Addis Ababa	kirkos	7
28	MGM consult plc	1	911675918	Addis Ababa	bole	4
29	Midek consultancy plc	1	911215385	Addis Ababa	yeka	8
30	MTT consulting architecture and engineering plc	1	911405401	Addis Ababa	yeka	8
31	net consult plc	1	930033554	Addis Ababa	bole	4
32	Obon voyage architects & engineers' consultant	1	911215220	Addis Ababa	kirkos	2
33	Omega consulting engineering plc	1	911925758	Addis Ababa	bole	3
34	Paramera architects and engineering cons/plc	1	911222615	Addis Ababa	bole	7

35	Salem architectural & engineering consultants	1	911206539	Addis Ababa	bole	2
36	Salem architectural and engineering consultants	1	911200177	Addis Ababa	lemi kura	8
37	Say consult plc	1	911801013	Addis Ababa	bole	3
38	Seen consulting and architect's plc	1	930077603	Addis Ababa	bole	4
39	SG consulting engineer's plc	1	911651716	Addis Ababa	bole	3
40	Sigor consult plc	1	911232148	Addis Ababa	kirkos	9
41	Sobra consulting service	1	911237706	Addis Ababa	lemi kura	13
42	Stadia engineering work consultant plc	1	911935929	Addis Ababa	kirkos	2
43	Tyas architecture and engineers consult plc	1	911480131	Addis Ababa	yeka	8
44	Walt consulting architects and engineers	1	911154155	Addis Ababa	kirkos	1
45	YBM construction management consult plc	1	930097999	Addis Ababa	kirkos	8
46	Yisakor Wisdom arch. Engineering consulting & trading	1	911203966	Addis Ababa	bole	13
47	Yohannes Abbay cons & arch engineers	1	921239528	Addis Ababa	bole	4
48	Zema consulting architects and engineer's plc	1	920656992	Addis Ababa	nifas silk lafto	3
49	Clover consulting engineer's plc	1	911935929	Addis Ababa	kirkos	2
50	Ethio infra engineering plc	1	911224809	Addis Ababa	bole	6
51	Homeland engineering plc	1	925420439	Addis Ababa	arada	1

52	HH consulting architects & engineers plc	1	921239528	Addis Ababa	bole	4
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