ASSESSMENT OF RISK MANAGEMENT IN COST ESTIMATION IN THE BUILDING CONSTRUCTION INDUSTRY IN UGANDA: A CASE OF KAMPALA CITY

BY

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by Kyambogo University a dissertation titled **"Assessment of Risk Management in Cost Estimation in the Building Construction Industry in Uganda",** in fulfilment of the requirements for the award of a degree of Master of Science in Construction Technology and Management of Kyambogo University

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DECLARATION

I, **Draleti Gerald,** do hereby declare that this dissertation is my own original work and to the best of my knowledge has never been submitted to any institution or university for any academic award.

Signed……………………………………… Date………………………………….

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DEDICATION

This dissertation is dedicated to my father and mother, Mr. Ebevura Maurice and Mrs. Pauline Ebevura, my siblings, friends and colleagues who assisted in diverse ways to make this work and my studies in general a success.

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A dissertation of this nature cannot be written without the grace of God Almighty. It is through his mercy that I had the strength and wisdom to write this piece of work.

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ACR	Average Cost of Risk
AHP	Analytic Hierarchy Process
CI	Consistency Index
CR	Consistency Ratio
FI	Frequency Index
GDP	Gross Domestic Product
IMPI	Importance Index
PERT	Program Evaluation and Review Technique
RCI	Random Consistency Index
RW	Relative Weight
SI	Severity Index
TCR	Total Cost of Risk
UNABCEC	Uganda National Association of Building and Civil Engineering Contractors

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ABSTRACT

The cost performance of construction projects is a key success factor. However, risks in construction projects make exact budgetary requirements difficult to forecast accurately resulting in underestimation and overestimation. Inaccurate cost estimates have further resulted in unnecessary financial loss to the project stakeholders and loss of reputation and trustworthiness of construction professionals. In Uganda, risk factors are either ignored or subjectively taken care of by simply allowing a contingency figure ranging from 0% to 10% of the project cost. This method is sometimes unreliable and difficult to justify to the project owners. Therefore, there is need for a risk-based cost estimation method that is reliable and justifiable. The purpose of this study was to improve risk management in cost estimation in the building construction industry in Uganda. The risk factors in cost estimation were identified through detailed literature review and then their effect in cost estimation was assessed using severity index. The study revealed that the risk factors with the most severe effects in cost estimation were: inflation, proficiency in estimating, cost of materials, incomplete design and specification, fraudulent practices and kickbacks. The importance index of all the risk factors was computed based on their severity index and frequency index so as to rank them. The study further revealed that the five most important risk factors were: cost of materials, inflation, fraudulent practices and kickbacks, incomplete scope definition, incomplete design and specification. The study proposes a model for risk-based cost estimation that was developed using the Analytic Hierarchy Process (AHP). The total cost of risk estimated by the model for the fifteen most important risk factors in cost estimation in the building construction industry in Uganda represents 59.4% of the total project cost while the average cost of risk represents 4.0% of the total project cost. Sensitivity analysis was used to validate the robustness and consistency of the developed model in calculating the cost of risk. The developed model was verified to be consistent and reliable in calculating the cost of risk.

Keywords: *Risks, Risk management, Cost estimation, Risk based cost estimation, Analytic Hierarchy Process (AHP).*

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

The construction industry is one of the largest sectors that contributes to the transformation of the economy of countries all over the world. The pace of economic growth of a nation can be measured by the development of physical infrastructure. In Uganda, the construction industry contributed 5.2% to the total gross domestic product (GDP) in the financial year 2020/2021 compared to 5.5% in the financial year 2019/2020 (UBOS, 2021). The construction industry is subjected to more risk and uncertainty than many other industries causing projects to surpass their estimated budgets (Abdel-Monem, Alshaer and El-Dash, 2022). The construction industry in Uganda is diverse and also faced with challenges of cost and time overruns (CoST, 2017). Project cost and time overruns put the competence and integrity of construction professionals that plan and predict costs in doubt (Ajator, 2017). Even with all the knowledge and best practices in project management today, most projects still do not meet their cost objectives (Herszon & Keraminiyage, 2014). To an average Ugandan, foul play or corruption is usually suspected given the size of cost overruns.

A construction project is a mission, undertaken to create a unique facility, product or service within the specified scope, quality, time, and cost (Chitkara, 2004). The development of construction projects involves different phases and stages of work. Each stage of the activities has a different timescale and necessary cost estimates. Project cost estimates are required to set the financial commitment of the client and also create an avenue for cost control. Cost estimation is one of the most critical tasks in the stages of a building construction project and is done under great uncertainty. Improved risk management in cost estimation therefore, requires an understanding of the risk factors and their impact on project cost. This is the purpose of the current study.

1.2 Statement of the problem

Construction project goals are traditionally directed towards time, cost and quality. The cost performance of construction projects is a key success factor for their funding and the development of a comprehensive cost estimate is critical for a project to be considered successful on completion. The uncertainties in construction projects make exact budgetary requirement difficult to forecast accurately and as a result, projects deviate from plans. Increasing uncertainties in projects reduce the reliability of cost estimates and overall project success (Ullah *et al.*, 2021).

The inability to arrive at a reliable project cost estimate has resulted in project cost overruns and sometimes subsequent abandonment. Risk factors affecting cost estimation are either ignored or done subjectively by simply allowing for a contingency figure. Risks associated with cost estimation have not been managed effectively or accurately determined overtime (Ojo and Odediran, 2015).

There is strong evidence of inconsistent performance of Ugandan construction projects by both international and local firms. Projects are reportedly failing across all the key performance measures of cost, time and quality (Muhwezi, Acai and Otim, 2014). The growth of the Ugandan building construction industry over the years warrants a systematic analysis to improve risk management in cost estimation within the industry. Also according to Project Management Institute (2012), the traditional cost estimation processes do not take into consideration the dynamic nature of risks. Therefore, a model that incorporates risks in cost estimation may be beneficial in addressing this limitation in the building construction industry in Uganda.

1.3 Objectives of the study

1.3.1 Main objective

The main objective of the study was to assess risk management in cost estimation in the building construction industry in Uganda.

1.3.2 Specific objectives

The specific objectives of the study were:

i) To establish the risk factors in cost estimation in the building construction industry in Uganda.

ii) To assess the effects of the risk factors in cost estimation in the building construction industry in Uganda.

iii) To develop a reliable model that can be used for risk-based cost estimation in the building construction industry in Uganda.

1.4 Research questions

The guiding research questions were:

i) What are the risk factors in cost estimation in the building construction industry in Uganda?

ii) What are the effects of the risk factors in cost estimation in the building construction industry in Uganda?

iii) What model can be used for risk-based cost estimation in the building construction industry in Uganda?

1.5 Justification of the study

Inaccurate cost estimation is one of the most common problems facing the building construction industry in Uganda and if this problem is not addressed, it may lead to project abandonment, project delays and cash flow problems. In order to solve these problems, a reliable model for risk based cost estimation could be the solution.

1.6 Significance of the study

Cost estimation being one of the most critical tasks in the stages of a building construction project, there is need to carry out extensive research on this element. Information from this study will help consultants and contractors who could use the findings to make improvements of the cost estimation system. This information will also be useful to academicians and researchers in carrying out further research in the areas of risk management and cost estimation.

1.7 Scope of the study

1.7.1 Content scope

The study focused on the risk factors and their effects in cost estimation of building construction projects in the construction industry in Uganda. In addition, it was limited to public and private building construction projects having the engineer’s estimate. The engineer’s estimate acts as a benchmark and helps in reflecting the amount that the client or the procuring and disposing entity considers fair and is willing to pay for the works. The review of the contractor’s estimate also depends on the reliability of the engineer’s estimate.

1.7.2 Geographical scope

The study was carried out within Kampala which is the capital city of Uganda. Among the cities and districts in Uganda, Kampala has one of the highest concentration of building construction projects both completed and ongoing. In terms of general infrastructural development, Kampala is considered to be one of the fastest growing cities in Africa (DW, 2019).

1.7.3 Time scope

The time scope of this study was from September 2019 to June 2020 starting with research proposal development and ending with final dissertation submission.

1.8 Conceptual framework

The conceptual framework shows the relationships among the variables in order to achieve the set objectives. It illustrates how the independent variable (risk factors in cost estimation) relate to the dependent variable (improved risk management in cost estimation). The framework further demonstrates that the relationship between the independent and dependent variables can be altered by a moderator or mediating variable as illustrated in Figure 1.1.

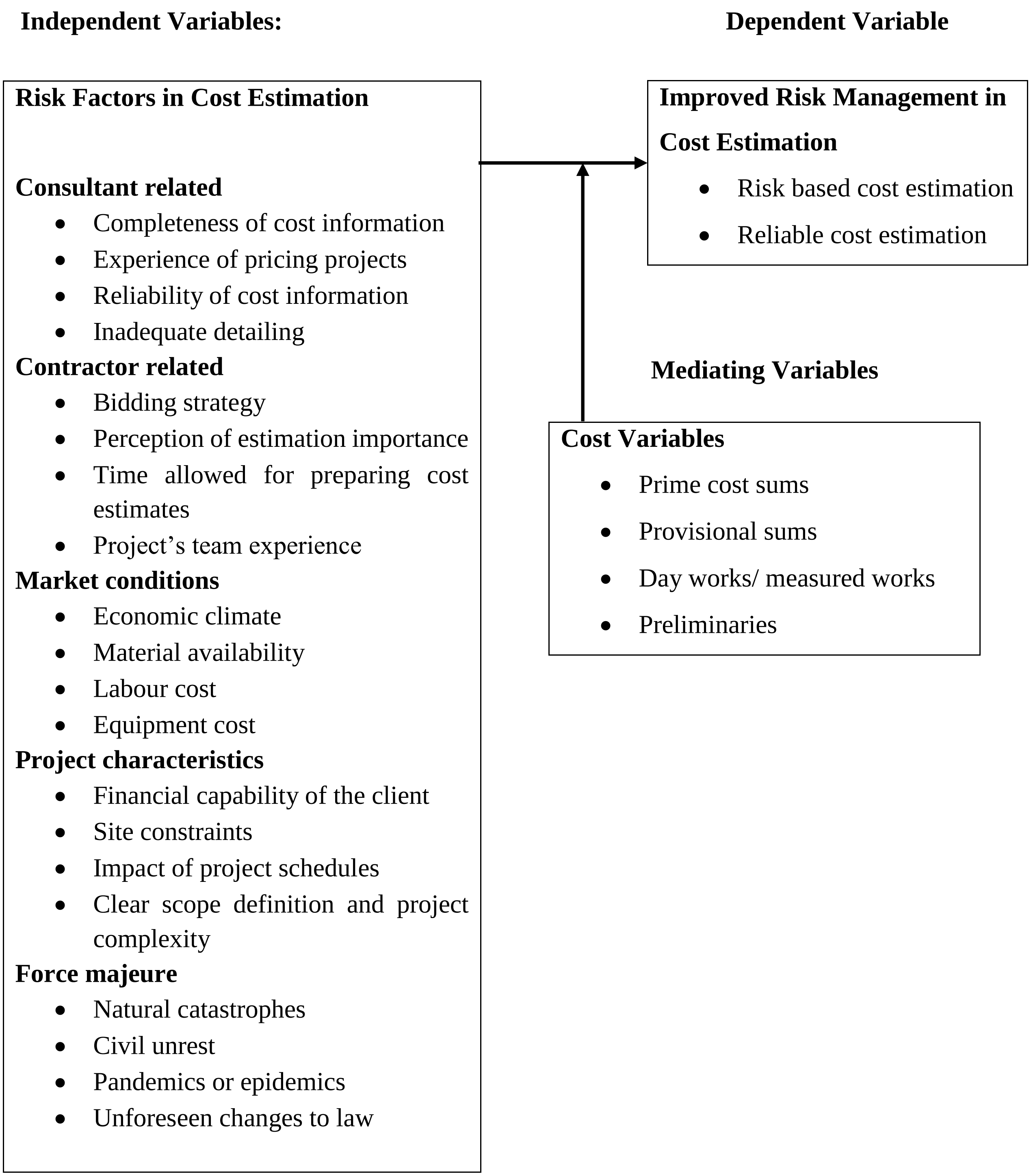

Figure 1. 1: Conceptual framework (Researcher's own work, 2022)

As demonstrated by the framework, the independent variables related to the consultant are:

Completeness of cost information: Cost information is an important part of activities involved during cost estimation. According to RIBA (2013), cost information refers to all of the project costs including the cost estimate and life cycle costs where required. A complete cost information helps in setting prices, making decisions and producing reliable estimates. The consultant should always ensure that the cost information used in preparation of estimates is well detailed and accurate.

Experience of pricing projects: The reliability of cost estimates is highly dependent on the consultant's experience of pricing projects. The consultant must also have the necessary skills and knowledge required for the task. Overestimation causes inefficiency in the use of funds as funds that the client could invest in other projects are tied up to a particular project for a given period of time yet they will not be utilized. On the other hand, underestimation of project costs may cause unnecessary delays and project abandonment while the client arranges for additional funding to meet the extra costs.

Reliability of cost information: Given the uniqueness of every construction project, sometimes budgetary requirements may not be met and the consultant will have to find all possible ways of improving functionality and quality while keeping costs low. To effectively carry out value engineering, the consultant must have up to date and reliable cost information. There are various sources of cost data that differ in reliability and accuracy and therefore caution must be exercised on the choice of cost data to use. The sources include: old estimates from previous projects, quotations from suppliers, in-house cost models, information from industry experts and market surveys. The reliability of cost estimates will highly be dependent on the source of cost data used.

Inadequate detailing: The accuracy of cost estimates of building construction projects is highly dependent on the quality and level of detailing. Inadequate detailing makes it difficult to prepare reliable cost estimates thereby causing unnecessary variations.

The independent variables related to the contractor are:

Bidding strategy: The building construction industry is very competitive and contractors use different strategies to win bids. In Uganda, public procurements are characterized by the low bid price approach. Contractors tend to bid low and sometimes abnormally low depending on the competitiveness of the tender so as to be successful. This has greatly affected the reliability and performance of cost estimates.

Perception of estimation importance: The importance that a contractor attaches to cost estimation will define its reliability and performance during project execution. Cost estimates define the future of the construction company and its ability to win projects. The use of inaccurate cost estimates for a construction project result into financial loss and loss of credibility of the contractor. According to Mumela and Ngari (2015), inaccurate cost estimation has resulted into insolvency and liquidation of many contractors.

Time allowed for preparing cost estimates: Dependable cost estimates require adequate time to prepare. The contractor should always allocate reasonable time for preparation of cost estimates as hurriedly prepared estimates tend to be inaccurate due to mistakes.

Project's team experience: Cost estimates are dependent on the project's team general and specific experience. A team with extensive experience is likely to produce more reliable estimates than an inexperienced team.

Market conditions refer to the economic environment for doing business or the state of the economy. These conditions are unpredictable and are used as an indicator to influence decisions.

The independent variables related to market conditions are:

Economic climate: This is one of the factors that affect the reliability of cost estimates due to the constant variation. Both the engineer's and contractor's estimates must be firm to take care of price fluctuations during the construction period. Favourable climate makes it easier to do business while unfavourable climate makes it challenging as budgets are distorted.

Material availability: Cost estimation is highly influenced by the availability of materials. According to Danso and Manu (2013), materials account for about 60% to 70% of the total construction cost for a project. Therefore, using locally available materials instead of importing considerably reduces construction costs. This is because of the reduced transportation costs, reduced taxes and reduced handling costs among others.

Labour cost: In the construction industry, labour represents 30% of the total construction costs (Bah *et al*., 2018). The cost of labour is highly dependent on its availability and skill sets. The construction industry is labour intensive and uses both skilled and unskilled labour. The composition of the labour to be used on a particular project will greatly determine its cost.

Equipment cost: This is associated with ownership and operation costs of the equipment (Assakkaf, 2003). Equipment costs will differ for every project and it is important to determine the right kind and size of equipment to be used and the equipment should be provided at the right time. Fixed costs and variable costs of the equipment to be used should be considered when preparing estimates for the project. Fixed costs consist of the initial purchase cost and depreciation of the equipment while variable costs consist of maintenance and operating costs of the equipment.

Given that construction projects are unique in nature, the independent variables related to project characteristics are:

Financial capability of the client: This is the capacity of the client to provide financial support for the successful execution of the project. When funding for a project is not enough, some clients request contractors to do works at extremely low rates which in turn affects quality performance. On the other hand, some desperate contractors adjust or produce unrealistic cost estimates so as to fit within the clients' low budgets in order to increase their chances of winning projects.

Site constraints: As defined by Lau and Kong (2006), a constraint is a condition, agency or force that impedes progress on objective or goal. Site constraints could include; access, neighboring properties, boundaries, existing services, available space for workers, available space for storage among others. These constraints can have a huge impact on project cost and should therefore be identified early enough and considerations made for them during cost estimation.

Impact of project schedules: Construction cost is highly influenced by schedules and scope. A project schedule is a list of activities to be carried out and their associated timeline or start and finish dates. The project schedule also outlines the resources needed for each task. It is therefore an important part of the construction planning phase and must be considered when preparing cost estimates.

Clear scope definition and project complexity: Scope outlines the responsibilities and tasks for each party involved in a contract. APM (2021), defines scope as the totality of the outputs, outcomes and benefits and the work required to produce them. Scope should be well detailed and clearly defined during the early stages as project cost depends on it. Complexity is one of the characteristics of construction projects. The degree of complexity will determine how a project is approached in terms of the work methods, required resources, tools and equipment (Brockmann and Kähkönen, 2012). Complexity should be measured and its value determined when preparing cost estimates.

Force majeure is an event or effect that can neither be anticipated nor controlled (Dictionary, 1990). It also refers to unpredictable events beyond anyone's reasonable control, which hinder any of the parties involved in a contract from fulfilling the agreed terms (Burton, 2020). The following are the independent variables related to force majeure:

Natural catastrophes: These are considered to be an act of God and are beyond human control. Examples include; floods, earthquakes, volcanoes, exceptionally adverse weather, landslides among others. Occurrence of these disasters affect the reliability of cost estimates.

Civil unrest: This involves wars, riots, rebellions, invasions, terrorism among others. The whole world is currently experiencing the effects of political unrest between Russian and Ukraine. The cost of construction materials is continuing to rise and the current energy crisis will only add to the industry's distresses, as its dependence on materials manufactured through energy intensive processes will continue to take a financial toll (McArdle, 2022).

Pandemics or epidemics: The most recent pandemic of Covid-19 significantly affected the whole world and businesses unexpectedly came to a standstill. With the construction industry being no exception, it suffered a shortage of both materials and labour which further resulted in high costs of doing business. In Uganda, the government put up measures to contain and slow the spread of Covid-19 which included; closing hardware shops and construction sites that wished to continue were required to provide accommodation for workers on site. The government further issued Standard Operating Procedures (SOPs) which required construction sites to have Covid-19 management plan in place such as; providing hand washing facilities, masks, clinic, temperature guns, adequate signage on site and observing social distancing among others. Implementation of these SOPs came with cost implications on construction projects.

Unforeseen changes to law: This can adversely affect construction costs as a result of the increase in costs of doing business. For example, at the start of the Covid-19 pandemic, the government of Uganda issued restrictive measures that included closing down most businesses. Construction sites were allowed to continue but on condition that workers were accommodated at the sites and prohibited from moving out of the sites. These unexpected changes come with a financial burden to the parties involved in a contract.

Furthermore, the framework demonstrates that the relationship between the independent and dependent variables can be moderated by cost variables which include:

Prime cost sums: Prime cost sums are allowances for works to be carried out by nominated subcontractors. Such allowances are calculated by the cost estimator and the main contractor is only paid for attendance. Prime cost sums can increase the contract sum if the provisions made are not reasonable causing the nominated subcontractor's actual cost to be higher than what was allowed for. On the other hand, prime cost sums can also decrease the contract sum if the nominated subcontractor's actual cost is lower than what was allowed for.

Provisional sums: Provisional sums are also known as best guess allowances. They are included in the bills of quantities to cater for items of work that cannot be accurately priced because they lack enough detail at the time of tendering or entering a contract. Provisional sums are utilized after getting the project manager's approval. As works progress, the actual works done are measured and valued which may cause the contract sum to increase or decrease.

Day works: For works that cannot be measured and priced in a normal way, the contractor is paid for costs incurred on materials, labour, plant and equipment. A mark-up is then added to cater for the contractor's profit and overheads. Benge and Davidson (2012), define day works as the method of valuing work on the basis of time spent by the contractor's work people, the materials used and the plant employed. Accordingly, day works may also increase or decrease the contract sum of a given construction project.

Preliminaries: Preliminaries are necessary for the successful execution of a construction project but do not form part of the works. According to Flanagan and Jewell (2018), preliminaries refer to the cost of administering a project and providing general plant, site staff, facilities, site based services and other items not included in the rates. In construction, preliminaries can include provision of the following: temporary access, temporary structures for the contractor's use, hoarding, scaffolding, water, electricity, telephone, insurance, advance payment and performance guarantees, site security, statutory requirements and obligations, protection of works, health and safety among others. Where a construction project is prolonged or delayed, the contractor may claim for additional preliminaries. The extent of the preliminaries may also depend on the nature of the project.

1.9 Chapter summary

This chapter has presented the background to the study, the problem statement and the objectives of the study. Research questions were formulated to arrive at the objectives of the study and the need for the research also justified. Finally, the chapter was concluded with discussions on the significance of the study, scope of the study and the conceptual framework.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The chapter presents the review of relevant existing literature on the improvement of risk management in cost estimation in the building construction industry. The contents of this chapter will assist in the overall understanding of the study as it looks at risk factors, cost estimation, types of cost estimates and risk management.

2.2 Risk factors in construction

There are many definitions of risk that exist in common usage. According to International Organization for Standardization (2009), risk is the effect of uncertainty on objectives. Project Management Institute (2013), defines risk as an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives. Risks in construction projects may be external, design, commercial, construction and operational factors that have an impact on cost, time and quality in varying degrees (Ajator, 2017). Construction projects fail to complete in the agreed time and budget due to the inherent risks (Chileshe and Kikwasi, 2013). In Uganda, the construction industry is faced with various risks resulting in poor performance of projects with cost and time overruns (Umutoni, 2014). Kibwami (2020) also stated that in Uganda, the arbitrary and deterministic contingencies of 0% - 10% in building projects are routinely inadequate to contain cost over-runs of up to 52%.

A risk factor is a potential complication or problem which can affect project completion and the achievement of its objectives. It is an uncertain future event or condition with an occurrence rate that is greater than 0% but less than 100% that will have an effect on at least one of the project objectives (Rezakhani, 2012). These risk factors must be evaluated during cost estimation so as to come up with a more realistic project estimate. According to Umutoni (2014), the ten most significant risk factors in the construction industry in Uganda are: financial failure, inflation, awarding the design to an unqualified designer, quality of work and time constraints, delayed payment on contract, lack of consistency between bills of quantities, drawings and specifications, change order negotiations, not coordinated design, changes in work and defining scope of work.

Risk factors in construction can be categorized as technological, social, physical, economic and political (Ajator, 2014). They may be internal or external risk factors. Internal risk factors are those within the organization's control and include its human, financial, physical, technological and managerial value and ethics. On the other hand, external risk factors are those outside the organization's control. They are political, macro-economic, environmental, competition and multiple clients project risks.

Further categorization of risk factors has been done by many other researchers. Chapman (2001), grouped risk into environment, industry, client and project. Risk can also be grouped into competition risk; technical, construction, operational; market risk; financial, demand, supply and institutional risk; regulatory, social acceptability and sovereign risks (Miller and Lessard, 2001). Karim *et al.*, (2012) identified a total of twenty five risk factors and categorized them into five groups namely: design, construction, politics and contract provision, finance and environmental as shown in Table 2.1.

Table 2. 1: Risk factors and their categories

Category of risk	**Risk factor**
Design	Improper design
	Change in scope
Construction	Shortage of material
	Shortage of equipment
	Land acquisition
	Poor quality of workmanship
	Site safety
	Late delivery of materials
	Inadequate planning
	Weather
	Insolvency of subcontractors
	Insolvency of suppliers
Politics and contract provision	Delay in project approval and permit
	Excessive contract variation
	Change in law and regulation
	Inconsistencies in government policies
	Poor supervision
	Compliance with government
	Bureaucracy
Finance	Lack of financial resources
	Cash flow difficulties
	Delay in payment for claims
Environmental	Pollution
	Compliance with law and regulation for environmental issue
	Ecological damage

Source: Karim *et al.* (2012)

2.3 Cost estimation

A cost estimate must address risks and uncertainties in the project. These risks and uncertainties affect the determination of the probable construction cost of a given project. It is a challenge for most construction projects in Uganda to be completed within the initial estimates yet achieving project objectives is very crucial to the parties involved and most especially the client.

Cost estimating is essential for contracting and making investment decisions. When costs are overestimated, the client may decide not to proceed with the project and contractors are also likely to lose out in competitive bidding. While on the other hand, underestimation could equally result into the incurring of losses and project abandonment. In a study carried out by Otim *et al.* (2011), underestimation is considered as one of the top leading causes of uncompleted buildings in Uganda. One of the challenges in estimating for public sector construction projects in Uganda, is that bidders make overly optimistic estimates in order to win the business.

According to Choon and Ali (2008), cost estimating is the procedure of examining a specific scope of work and forecasting the cost of completing the work. While Butcher and Demmers (2003), see cost estimating as a well formulated prediction of the likely cost of a specific construction project. Factors that influence cost during the conception and design stages of a construction project have been largely attributed to cost estimating practices (Doloi, 2012). World over, the construction industry has a poor reputation in terms of finishing projects on budget. Nine out of ten projects normally experience cost overruns and poor cost estimation is considered as one of the leading causes (Ahiaga-Dagbui and Moore, 2017). In his study, Ssemwogerere (2011) asserted that most projects in Uganda are usually completed at a cost of about 25-35 percent increase of the initial cost.

Realistic cost estimation is vital for the successful planning and completion of any construction project (Shabniya, 2017). Further, according to Bayram and Al-Jibouri (2016), accurate cost estimation is a key factor for project success. There are different definitions of cost estimation in usage by experts and researchers. PMBOK (2013), defines cost estimation as the development of an approximation (estimate) of costs of the resources needed to complete project activities. It's the basis for project management, business planning, budget preparation and cost and schedule control (AACE, 2013).

2.4 Cost overruns

Cost is one of the key performance indicators of a successfully completed project. However, most projects world over face substantial cost overruns and the problem mainly occurs in developing countries (Durdyev, 2020).

A cost overrun is an unanticipated increase in a budgeted project cost agreed by the project stakeholders (Shehu *et al.*, 2014). A cost overrun can also be defined as a percent difference (positive) between the final cost of the project and the contract award amount (Emhjellen *et al*., 2003). There are various causes of project cost overruns and this subject has attracted considerable attention from researchers globally (Durdyev, 2020). In his study to review construction journals on causes of project cost overruns that have been reported since 1985, Durdyev (2020) identified 79 causes of cost overruns. However, the top ten causes that received the highest number of citations are: design problems and incomplete design, inaccurate estimation, poor planning, weather, poor communication, stakeholder's skill, experience and competence, financial problems/poor financial management, price fluctuations, contract management issues and ground/soil conditions.

Table 2. 2: Causes of project cost overruns

No.	Cause
1	Design problems and incomplete design
2	Inaccurate estimation
3	Poor planning
4	Weather
5	Poor communication

	Table 2.2 (continued)
No.	**Cause**
6	Stakeholders’ skill, experience and competence
7	Financial problems/poor financial management
8	Price fluctuations
9	Contract management issues
10	Ground/soil conditions
11	Project duration issues
12	Additional works
13	Political/social problems
14	Project delays
15	Construction errors/mistakes
16	Drawings/specifications
17	Payment
18	Project size/complexity
19	High cost of resources (man, machinery, material)
20	Project location
21	Unforeseen events
22	Lack of skilled/unskilled manpower
23	Material shortage
24	Scope change
25	Fraudulent practices and kickbacks
26	Inspection/testing delay
27	Poor site management
28	Contract awarded to the lowest bidder
29	Conflicts/disputes
30	Labour productivity
31	Managerial and technical difficulties
32	Delay in material delivery
33	Differing site condition
34	Procurement/delivery method
35	Poor coordination/supervision
36	Inflation
37	Lack of/frequent breakdown of plant/equipment
38	Subcontractor
39	Exchange rate
40	Poor schedule control/monitoring
41	Imported materials
42	Construction method
43	Delay in permits/approvals
44	Poor resource allocation
45	Type of work
46	Administrational issues
47	Decision making
48	Insurance

	Table 2.2 (continued)
No.	**Cause**
49	Poor cost planning/control
50	Material quality
51	Risks/uncertainties
52	Waste on site
53	Bidder stage
54	Change orders
55	Market conditions
56	Unclear/change in owner's brief
57	Cash flow
58	Re-measurement of provisional works
59	Reworks
60	Variations
61	Laws/regulations
62	Transportation cost
63	Delay in information issue
64	Interest rates
65	Contractor's workload
66	Security issues
67	Delay due to land acquisition process
68	Inadequate review
69	Deficiencies in the infrastructure
70	Economic stability
71	BOQ issue
72	Contractor's financial status
73	Monopoly
74	Fuel shortages
75	Front end loading of rate
76	Adjustments of prime cost and provisional sums
77	High quality expectation from owner
78	Patching quantity adjustment
79	Liquidated damages

Source: Adapted from Durdyev (2020)

2.5 Elements of cost estimation

The elements of cost estimation are: direct cost, indirect cost and mark-up.

Direct cost is the cost of completing work that is directly attributable to its performance and is necessary for its completion. In construction, it is the cost of installed equipment, material, labour and supervision directly involved in the physical construction of the permanent facility (AACE, 2013).

Indirect cost is the cost that is not directly attributable to the completion of an activity which is typically allocated or spread across all activities on a predetermined basis. In construction, it is a cost which does not become a final part of the installation but which is required for the orderly completion of the installation and may include field administration, capital tools, start-up costs, insurance, taxes, contractor’s fees among others (AACE, 2013).

Mark-up includes such percentage applications as general overhead, profit and other indirect costs (AACE, 2013).

2.6 Cost estimation methods

There are four different cost estimation methods used by Project Management Professionals (Snyder, 2013). The methods are: Analogous estimation, parametric estimation, three-point estimation and bottom up estimation.

2.6.1 Analogous estimation

This method is also known as the top-down estimation. It is used at the start of the project when there is limited detail about the project. The cost of the project is estimated by comparing it with past similar projects. It is a quick and relatively easy method but does not provide accurate estimates.

2.6.2 Parametric estimation

It is used for quantitatively based estimates. For example, dollar per square foot, number of installations per day, cost of concrete per cubic meter, etc. The requirement for the current project is obtained and multiplied with the cost obtained from the previous project. This method is more accurate than the analogous estimation since it employs more than one data set.

2.6.3 Three-point estimation

It accounts for uncertainties and biases associated with estimation. It is employed to reduce uncertainties and biases in estimation assumptions. It involves determining three estimates instead of finding one estimate and then their average is taken. Taking their average helps in reducing the uncertainties and biases. The three estimates are optimistic (represented by O), most likely (represented by M) and pessimistic (represented by P). The most commonly used method in three-point estimation is the Program Evaluation and Review Technique (PERT).

The PERT formula is:

E = (O + 4M +P) / 6 (Equation 2. 1)

Where: E is the expected cost.

The optimistic cost (O) considers the best case and concludes that everything goes better than presumed.

The most likely cost (M) considers a typical case and everything goes as usual. The most likely cost is weighted most heavily.

The pessimistic cost considers the worst case and assumes that almost everything goes wrong.

2.6.4 Bottom-up estimation

This method is also known as the definitive method. It is used when there is significant detail about the activity. It involves breaking down the total project work into the smallest work components. The cost of completing each activity is determined at the bottom level and then rolled up to calculate the total cost of the project. It's a time consuming and costly method but gives the most reliable and accurate result.

2.7 Cost estimation software

Manual cost estimation is time consuming and given the current nature of the construction industry where some cost decisions are quickly taken and in very short periods of time with stakeholders expecting cost information within the shortest time possible, cost estimation software is necessary to enable prompt responses.

Over the years, several technological advancements have taken place in the construction industry with one of them being the innovation of cost estimation software. Some of the popular cost estimation software in use include: ProEst, Clear Estimates, SimPro, ConEst, Buildertrend, PlanSwift, WinQS, STACK, CostX, PriMus and QSPlus and QSCAD.

According to Gerardi (2021), cost estimation software has positively changed the way professionals conduct their business and achieve their goals by providing a streamlined approach that gives forward-thinking firms an edge over their competitors. Cost estimation software have become increasingly more intuitive allowing construction professionals to choose task specific programs and personalized platforms to create estimates. Gerardi (2021) further stated that, research has also shown that the majority of today's contractors are using software more than the traditional forms of estimating, such as manual documentation. Firms are recognizing the value of using construction estimation software, even if it adds an additional cost to their expenditures in terms of purchasing annual licenses.

Similarly, a research carried out in Uganda by Sebanenya (2018) among contractors registered with the Uganda National Association of Building and Civil Engineering Contractors (UNABCEC), revealed that majority of the contractors are using cost estimation software with WinQS being very popular.

Some of the benefits of using cost estimation software include: accuracy, better project management, consistency, convenience, efficiency, integration of work with other software solutions and elevation of the firm's level of professionalism.

2.8 Types of cost estimates

The project life cycle has five different stages namely: initiation, planning, execution, monitoring and control, and closure (PMBOK, 2021). Each of these stages has a cost estimate and according to Project Management for Construction (2013), construction cost estimates can be categorized into: design, bid and control estimates. The different categories are discussed in detail below:

2.8.1 Design estimates

These are provided to the client during the planning and design stages of the project by the consultant. It involves the following types of cost estimates:

- Screening estimates (order of magnitude estimates);
- Preliminary estimates (conceptual estimates);

- Detailed estimates (definitive estimates);
- Engineer's estimates based on plans and specifications (Project Management for Construction, 2013).

The amount of design information available, typically increases for each of the different estimates. The screening estimate is usually made at the very early stages before the facility is designed. It relies on the historical cost data of similar projects done in the past. The preliminary estimate is based on the conceptual design of the facility at the time when the basic technologies for the design are known. The detailed estimate is made at the state when the detailed design is in progress so that the essential features of the facility are identifiable and the scope of the work is clearly defined. An engineer's estimate is made when the client wants to solicit bids from contractors. The estimate is based on the completed plans and specifications and will also include expected amounts for the contractor's overhead and profits.

2.8.2 Bid estimates

These are provided by the contractor to the client for purposes of either negotiation or competitive bidding. It consists of direct construction cost, field supervision cost and a mark-up to cover general overhead and profits. For bid estimates, the direct cost of construction is usually derived from subcontractor quotations, quantity take-offs or provided blank bills of quantities and construction procedures. The desire of the contractor to secure the job is often reflected by the bid estimate. If the contractor intends to use specialty subcontractors, it may solicit quotations from them for the various tasks to be subcontracted. In this case the contractor shifts the burden of cost estimation to the subcontractors. Where all the construction work is to be undertaken by the contractor, the quantity take-offs from the drawings or blank bills of quantities provided may be used as a basis to prepare the bid estimate. The construction procedures proposed by the contractor may also be used to develop bid estimates. In this case, the parameters for the cost estimate will be labour, materials and equipment needed to perform the various tasks.

2.8.3 Control estimates

These are derived from available information to establish the budget estimate for financing, budget cost after contracting but prior to construction and the estimated cost to completion during progress of construction. Both the client and the contractor must adopt a base line for project cost control. The budget estimate should be adopted by the client early enough to enable planning for long term project financing. The budget estimate adopted by the client is the engineer's estimate. It must be updated periodically as work progresses to reflect the estimated completion cost. The bid estimate is on the other hand regarded as the budget estimate by the contractor. It will be used for control purposes and planning construction financing. The contractor's budget estimate must also be revised periodically to reflect the estimated completion cost.

2.9 Risk factors in cost estimation

In Uganda, the most severe risk factors on the cost of a construction project are: poor communication between the parties, financial failure of the contractor, defective design, awarding the design to an unqualified designer, rush design, unmanaged cash flow, delayed payment on contract, inflation, occurrence of accidents because of poor safety procedures and undocumented change orders (Umutoni, 2014).

From previous studies, many researchers have categorized risk factors in cost estimation. For purposes of this research, the categorization of risk factors in cost estimation as given by Hatamleh *et al.*, (2018), Oyedele (2015), Ojo and Odediran (2015), Mahamid (2014), and Chapman (2001), have been adopted.

Hatamleh *et al.*, (2018), categorized the risk factors in cost estimation as constituting consultant and contractor related factors, factors related to market conditions and those related to project characteristics. Risk factors related to project characteristics include: financial capability of the client, site constraints (access, storage, services), impact of project schedules, clear scope definition and project complexity. Risk factors related to market conditions include: material availability, labour cost, labour availability, equipment cost, equipment availability, equipment performance, economic climate, level of competition and level of workmanship (productivity and performance). Risk factors related to consultant and contractor were explained to include: clear and detail drawings and specification, experience of pricing projects, accuracy and reliability of cost information, project's team experience, completeness of cost information, estimating method used, quality of assumptions used in preparing the estimate, time allowed for preparing cost estimates, contractor bidding strategy and the perception of estimation importance.

In a study carried out among building contractors by Mahamid (2014), he grouped the risk factors in cost estimation into five groups: cost estimating, construction items, construction parties, environmental and financing. Risk factors in the cost estimating group include: cost of materials, cost of labour, cost of machinery, transportation cost, high machinery maintenance cost, high interest rates by bankers, wrong estimation method, cost of insurance, fluctuation of prices of materials, long period between design and time of implementation, bureaucracy in tendering method and waste on site. Risk factors related to construction items include: lack of adequate manpower, frequent changes in design, contractual procedure, duration of contract period, fraudulent practices and kickbacks, additional work and contract management. Risk factors related to construction parties include: disputes on site, poor financial control on site, previous experience of contractor, relationship between managers and labourers, lack of coordination between construction parties and poor planning. Environmental risk factors in cost estimation include: effects of weather, poor productivity, economic instability, level of competitors, number of ongoing projects, number of competitors, project location, social and cultural impacts, inadequate raw materials, absence of construction cost data and government policies. Financial risk factors include: inflationary pressure, project financing and fluctuation in currency exchange rate.

Oyedele (2015) explained that the risk factors in cost estimation include: political factors, economic factors (interest rate, inflation and forces of demand and supply), time of construction, location of the project, government policy, security, legal factors (litigation, taxes and other statutory payments), year of project, nature of project, experience of the contractor, complexity of the job, detail of project brief given to consultants by the client and corruption.

Chapman (2001), categorized the risk factors into: physical risk factors, construction risk factors and financial risk factors. Construction risk factors are those that affect equipment/plant and labour involved in a project. They include: equipment/plant availability, suitability of equipment/plant, labour productivity level, availability of materials, unforeseen adverse ground conditions, familiarity with such work, equipment breakdown, availability of experienced and skilled labour, defects resulting from poor workmanship, maintenance facilities of plant and level of supervision. Physical risk factors are related to the physical nature of the project and they include: incomplete design/specification, design changes, bad weather, operative accidents, theft of materials and loss due to fire outbreaks. Financial risk factors include: inflation, fluctuation and cash flow stability.

Ojo and Odediran (2015) in their study, identified a total of thirty two (32) risk factors in cost estimation and further grouped them into six (6) categories which include: project characteristics, bidding procedure, project design, estimating process, financial and personal factors.

Table 2. 3: Risk factors in cost estimation

Category	**Risk factor**
Project characteristics	Type of project
	Size of project
	Project location
	Project duration
	Project information
	Project complexity
Estimating process	Proficiency in estimating
	Incomplete scope definition
	Lack of experience on similar project
	Type of cost data
	Quality of cost data
	Current work load
	Sheer quantitative experience
	Access to the consultants
	Access to site
	Inadequate tendering period
Design	Error in design and specification
	Incomplete design and specification
	Availability of design information
Bidding procedure	Type of bidding
	Contract conditions
	Contract period
	Number of bidders
Financial	Unforeseeable changes in material prices
	Fluctuation in labour prices
	Market requirements
	Stability of market conditions
Personal factors	Contractor’s efficiency
	Changes in owner’s requirements
	Availability of labour
	Availability of materials
	Error in judgement

Source: Ojo and Odediran (2015)

Table 2. 4: Summary of risk factors in cost estimation from different literature review

No.	Risk factors in cost estimation	Sources
1	Project complexity	Hatamleh *et al.*, (2018), Ojo and Odediran (2015), Oyedele (2015)
2	Type of project	Ojo and Odediran (2015), Oyedele (2015)
3	Project duration	Ojo and Odediran (2015), Mahamid (2014), Oyedele (2015)
4	Project location	Ojo and Odediran (2015), Mahamid (2014), Oyedele (2015)
5	Size of project	Ojo and Odediran (2015)
6	Incomplete scope definition	Hatamleh *et al.*, (2018), Ojo and Odediran (2015)
7	Proficiency in estimating	Hatamleh *et al.*, (2018), Ojo and Odediran (2015)
8	Unforeseen adverse ground conditions	Chapman (2001)
9	Lack of experience on similar project	Ojo and Odediran (2015), Oyedele (2015), Mahamid (2014), Chapman (2001)
10	Quality and type of cost data	Hatamleh *et al.*, (2018), Ojo and Odediran (2015)
11	Current work load	Ojo and Odediran (2015), Mahamid (2014)
12	Site constraints (access, storage, services)	Hatamleh *et al.*, (2018), Ojo and Odediran (2015)
13	Financial capability of the client	Hatamleh *et al.*, (2018), Mahamid (2014), Chapman (2001)
14	Availability of materials	Hatamleh *et al.*, (2018), Mahamid (2014), Chapman (2001), Ojo and Odediran (2015)
15	Availability of labour	Hatamleh *et al.*, (2018), Chapman (2001), Ojo and Odediran (2015), Mahamid (2014)
16	Availability of equipment	Hatamleh *et al.*, (2018), Chapman (2001)
17	Suitability of equipment	Hatamleh *et al.*, (2018), Chapman (2001)
18	Cost of equipment	Hatamleh *et al.*, (2018), Mahamid (2014)
19	Cost of labour	Hatamleh *et al.*, (2018), Mahamid (2014), Ojo and Odediran (2015)
20	Cost of materials	Mahamid (2014), Ojo and Odediran (2015)
21	Level of workmanship (productivity and performance)	Hatamleh *et al.*, (2018), Mahamid (2014), Chapman (2001)
22	Design changes	Mahamid (2014), Chapman (2001), Ojo and Odediran (2015)
23	Bad weather	Mahamid (2014), Chapman (2001)
24	Estimation method used	Hatamleh *et al.*, (2018), Mahamid (2014)

	Table 2.4 (continued)	
No.	**Risk factors in cost estimation**	**Sources**
25	Quality of assumptions used in preparing estimates	Hatamleh *et al.*, (2018), Ojo and Odediran (2015)
26	Incomplete design and specification	Ojo and Odediran (2015), Chapman (2001), Hatamleh *et al.*, (2018)
27	Error in design and specification	Ojo and Odediran (2015)
28	Inadequate tendering period	Hatamleh *et al.*, (2018), Ojo and Odediran (2015)
29	Number of bidders	Mahamid (2014), Ojo and Odediran (2015)
30	Government policies	Mahamid (2014), Oyedele (2015)
31	Inflation	Mahamid (2014), Ojo and Odediran (2015), Chapman (2001)
32	Fluctuation of market conditions	Mahamid (2014), Ojo and Odediran (2015), Chapman (2001), Oyedele (2015)
33	Type of bidding	Mahamid (2014), Ojo and Odediran (2015)
34	Contract procedure and conditions	Mahamid (2014), Ojo and Odediran (2015)
35	Changes in owner's requirements	Ojo and Odediran (2015)
36	Fraudulent practices and kickbacks	Mahamid (2014), Oyedele (2015)

Source: Researcher's own work (2022)

2.10 Risk management

According to Srinivas (2019), risk management may be described as a planned and structured process aimed at helping the project team make the right decision at the right time to identify, classify, quantify the risks and then to manage and control them. Risk management involves planning, identifying, analysing, developing risk handling strategies, monitoring and control (Aduma and Kimutai, 2018). Risk management in the cost estimation process helps to reduce uncertainties and ensures better estimates.

Over the years, multitude of risk management software have been developed to enable decision makers in the construction sector in processing, assessing, categorizing and organizing information on risk (Oduoza *et al*., 2017). According to Hillson (2003), a risk management software should be able to recommend the appropriate approach for risks avert, transfer, mitigate and retain or opportunities (exploit, share, enhance and ignore).

Table 2. 5: Risk management software

No.	Software	Developer
1	TDRM	HVR Consulting Services
2	Predict Risk Controller	Risk Decisions
3	Risk Radar	Software Program Managers Network
4	Decision Pro	Vanguard Software
5	iDecide	Decisive tools
6	Risk RisGen	Line International
7	SRE	Software Engineering Institute
8	Nickleby KIT	Nickleby HFE
9	Risk Tools	Carma

Source: Oduoza *et al*., (2017)

2.10.1 Risk identification

This is the first step in the risk management process and also the first step to a successful risk management. Risk identification will vary depending on the nature of the project and the skills of the team members in risk management. This being a preliminary stage, it mostly relies on past experience and study of similar executed projects. The purpose of risk identification is to obtain a list of risks and apply different techniques to manage/mitigate them. Different techniques may be applied in risk identification but the project team should use a method that they are familiar with for the exercise to be effective. The risk identification techniques are: brainstorming, checklist analysis, cause and effect diagram, Delhi technique, expert judgement, SWOT analysis and questionnaires (Srinivas, 2019). Conducting risk identification is regarded as one of the risk mitigation measures in cost estimation (Sharma, 2014). This can be achieved by use of a risk breakdown structure. A risk breakdown structure is a tool that can be used to group project risks and organize them in categories. It’s an analogy to the work breakdown structure. A structure to the work that needs to be done is created in a work breakdown structure where as a structure to the risks in cost estimation is created in the risk breakdown structure.

2.10.2 Risk assessment

This is the second stage in the risk management process. Under this stage, the identified risks are short listed according to those with high and low impact on cost estimation. It consists of quantitative and qualitative risk assessment.

Qualitative risk assessment involves registering the identified risks in a risk register. A risk register consists of the following: classification and reference of the risk, description of the risk, relationship of the risk to other risks, potential impact of the risk on cost estimate, likelihood of occurrence and risk response/mitigation strategy (Srinivas, 2019).

Quantitative risk assessment is done for those risks which are considered as having high impact on cost estimation. This assessment is done to find the amount of contingency to be added to the estimate of the risks. In case the risks occur, the contingency is used to cover the additional expenditure. Quantitative risk assessment involves a lot of analysis to determine the potential impact of the risk on cost estimation. The impact is quantified in terms of cost and divided into two namely: base estimate and contingency allowance. The base estimate is for items that are known and a degree of certainty exists whereas the contingency allowance is for uncertain elements. Using a rule of thumb on a risk free base estimate, contingencies are normally calculated varying from 5 to 10%. Using a risk management approach will ensure that contingencies are set up to realistically reflect the risks. Quantitative risk assessment methods are: Monte Carlo simulation, decision tree, sensitivity analysis and multi estimating using risk analysis (Srinivas, 2019).

2.10.3 Risk response and control

Risk identification and assessment are not enough. The main idea is to manage the risks. Srinivas (2019) states four ways of managing risks which are discussed under; risk avoidance, risk transfer, risk reduction and risk acceptance.

2.10.3.1 Risk avoidance

Risk avoidance involves changing the project scope to eliminate the threat entirely. This can be done by changing the strategy or by de-scoping the portion of the project that contains the risk elements. De-scoping might disappoint the stakeholders since it changes the reason for performing the project (Srinivas, 2019).

2.10.3.2 Risk transfer

Risk transfer involves moving the risk to a third party that is more cable of handling it (such as an insurance company). Risks transferred to the insurance company may include: security of materials on site, unforeseen risks, fire hazards, safety of electrical rooms, among others (Srinivas, 2019).

2.10.3.3 Risk reduction

This involves lessening the likelihood that the risk will occur or lessening the impact of the risk to be within acceptable limits. Risk reduction measures include: detailed site investigation upon which an estimate can be prepared, preparedness to tackle any natural disaster, contingency planning, designing as per standards, removal of engineering/structural barriers and strengthening the quality assurance procedures. (Srinivas, 2019).

2.10.3.4 Risk acceptance

After trying to avoid, transfer and reduce the risks in a project, risk acceptance should be adopted as a strategy to deal with the remaining risks. In this case, the project team deals with the risks as they occur. (Srinivas, 2019).

2.10.4 Knowledge gaps

In a study carried out on risk analysis and management of construction projects in Uganda by Umutoni (2014), it was concluded that contractors and consultants still depend on traditional methods of risk analysis and there is need for them to adopt more specialized techniques such as expert systems, sensitivity analysis and simulation analysis for risk management so as to ensure better performance of projects.

From the reviewed literature, it is clear that risks greatly affect project completion and achievement of its objectives. Hence, there is need for the risk factors to be evaluated during cost estimation so as to produce more realistic estimates. Risk factors can be grouped into: project characteristics, estimating process, design, bidding procedure, financial and personal factors. This chapter also clearly shows the methodological issues and knowledge gaps regarding previous studies. This study will contribute in resolving the identified issues by developing a risk based model for cost estimation based on the Analytic Hierarchy Process (AHP).

2.11 Chapter summary

This chapter has discussed the introduction, risk factors in construction, cost estimation, risk factors in cost estimation and risk management. The purpose of this chapter was to review relevant published literature in relation to improvement of risk management in cost estimation in the building construction industry.

Furthermore, the conclusions and findings cited in this chapter will guide in choosing the right tools and methodology for the study.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The chapter presents the methodology that was adopted during the study. It describes and discusses; the research design, sample size and selection, data collection method, validity and reliability of data collection instruments, data analysis procedure, model development and verification.

3.2 Research design

According to Kirshenblatt (2006), a research design refers to the overall strategy that the researcher chooses to integrate the different components of the study in a coherent and logical way to ensure that the research problem is effectively addressed. The design adopted in this study was a mixed method approach where both quantitative and qualitative research methods were used. The quantitative method was used to assess the effects of the risk factors and quantify data required for the model development using the Analytic Hierarchy Process. The qualitative method helped in understanding the risk factors and their causes.

Qualitative research seeks to gain an understanding of underlying reasons, opinions and motivations to uncover trends in thought and opinions. Qualitative data can be collected through in-depth interviews, focus group discussions and key informant interviews (Wyse, 2011).

Quantitative research seeks to quantify a problem by way of generating numerical data that can be transformed into useable statistics. It is used to quantify attitudes, opinions, behaviours and other defined variables so as to formulate facts and uncover patterns in research. Quantitative data can be collected through face to face interviews, telephone interviews, online surveys, paper surveys, online polls and systematic observations (Wyse, 2011).

3.3 Target population

A population is defined as the complete set of subjects from which a sample may be obtained (Shao and Steel, 1999). The target population comprised project managers, architects, civil engineers, quantity surveyors, electrical engineers and mechanical engineers working with consultancy and construction firms that have vast experience in building construction projects within Kampala City. Based on information from the Architects Registration Board, Engineers Registration Board and Surveyors Registration Board, registered and practicing architects for the year 2021 were 143, civil engineers were 717, electrical engineers were 148, mechanical engineers were 109 and quantity surveyors were 69.

Table 3. 1: Target population

Study Group	**Study Population**
Project Managers	143
Architects	143
Quantity Surveyors	69
Civil Engineers	717
Electrical Engineers	148
Mechanical Engineers	109
Total	**1,329**

Source: Primary data (2022)

3.4 Sample size

Sampling is the process of selecting a number of elements from a population of interest so that by studying the sample we may fairly generalize the results back to the population (Trochim, 2006).

Having defined the target population, the Kish (1965) formula was used to determine the sample size for each group of this study. The Kish formula has been used by other researchers to determine the sample size for their studies (Adesi *et al*., 2019; Bolstein & Crow, 2008 and Ashmawi *et al.*, 2018). The Kish formula is stated as:

$$\mathbf{n_o} = \frac{\mathbf{pq}}{\mathbf{S^2}} \qquad \textbf{(Equation 3. 1)}$$

$$\mathbf{n} = \frac{\mathbf{n_o}}{\mathbf{1} + \frac{\mathbf{n_o}}{\mathbf{N}}} \qquad \textbf{(Equation 3. 2)}$$

Where:

n_o is the first estimate of the sample size.

p is the proportion of the characteristics being measured.

q is 1- p.

S is the maximum percentage of the standards error allowed for the sample mean.

N is the target population size.

n is the final estimate of the sample size.

Using a confidence interval of 95% and standard error of distribution at 10%, substituting 0.5 for p, q becomes 0.5 and substituting 0.1 for S gives a value of 25 as the first estimate of the sample (n_o).

$$\mathbf{n_o} = \frac{\mathbf{0.5 \times 0.5}}{\mathbf{0.1^2}} = \mathbf{25}$$

Using this number into the second equation (3.2) and substituting the target population size (N) for the different groups, gives the final estimate of the sample size (n) as shown in table 3.2.

Table 3. 2: Sample size

Study Group	**Study Population (N)**	**Sample Size (n)**	**Percentage (%)**
Project Managers	143	21	17
Architects	143	21	17
Quantity Surveyors	69	18	14
Civil Engineers	717	24	19
Electrical Engineers	148	21	17
Mechanical Engineers	109	20	16
Total	**1,329**	**125**	**100**

Source: Primary data (2022)

3.5 Sampling technique

Purposive sampling technique was used in data collection. The key informants were purposively sampled because they had technical and specialized knowledge about the research topic.

3.6 Data collection methods

3.6.1 Questionnaire method

A self-administered questionnaire was used to collect both qualitative and quantitative data from the project managers, architects, quantity surveyors, civil engineers, electrical engineers and mechanical engineers. A self-administered questionnaire is a questionnaire that is designed specifically to be completed by a respondent without the intervention of the researcher and the major criterion for a well-designed self-administered questionnaire is proper wording (Lavrakas, 2008). The questionnaire was designed to contain open ended and closed ended questions. The self-administered questionnaire was preferred because of its low cost, saving of time and respondent's convenience.

3.6.2 Interview method

An interview is a conversation for gathering information where the interviewer who coordinates the process of the conversation asks questions and the interviewee responds to the questions. Interview method helps the researcher to collect in-depth information on people's opinions, thoughts and experiences (Easwaramoorthy and Zarinpoush, 2006).

3.7 Data collection instruments

A questionnaire and interview guide were used as tools for data collection. An interview guide is used where there is need for in-depth information from the respondents (Easwaramoorthy and Zarinpoush, 2006). The questionnaire was designed to have two parts, namely: Part I and Part II. Part I of the questionnaire was designed basing on the risk factors in cost estimation that were identified through literature review and the respondents were asked to rank them based on their frequency index, severity index and importance index so as to obtain the most important risk factors. Part II of the questionnaire was used to obtain weights of the most important risk factors using pairwise comparisons based on Saaty (1980) scale of the Analytic Hierarchy Process (AHP) as shown in Table 3.4. An unstructured interview guide was also used to collect in-depth information from the respondents. A sample questionnaire and interview guide are attached in appendices 1 and 2 respectively.

3.8 Validity and reliability of the research instruments

The accuracy and consistency of the questionnaire forms a significant aspect of the research methodology known as validity and reliability (Taherdoost, 2016). Before the commencement of data collection, a pre-test was done on 10 respondents who were not part of the final study. This helped to determine the clarity of the questions given that proper wording is a major criterion for a well-designed self-administered questionnaire (Lavrakas, 2008).

3.9 Ethical considerations

The respondents were informed about the purpose of the study and their consent was sought before participating in the study. The identity of the respondents and the information given were treated with utmost confidentiality.

Integrity was demonstrated by acknowledging the contributions of others.

3.10 Procedure for data collection

The questionnaire was administered after approval from the supervisors at Kyambogo University. The respondents were informed about the purpose of the research and their consent was sought before administering the questionnaires. The questionnaires were administered through email and drop-off and pick-up method. Where there was need for in-depth information, the interview method was conducted after securing an appointment with the respondents.

3.11 Data analysis

Statistical Package for the Social Sciences (SPSS) and Excel were used for analyzing the data. Data from the collected questionnaires were first sorted, coded and entered into the SPSS software and Excel for further statistical analysis.

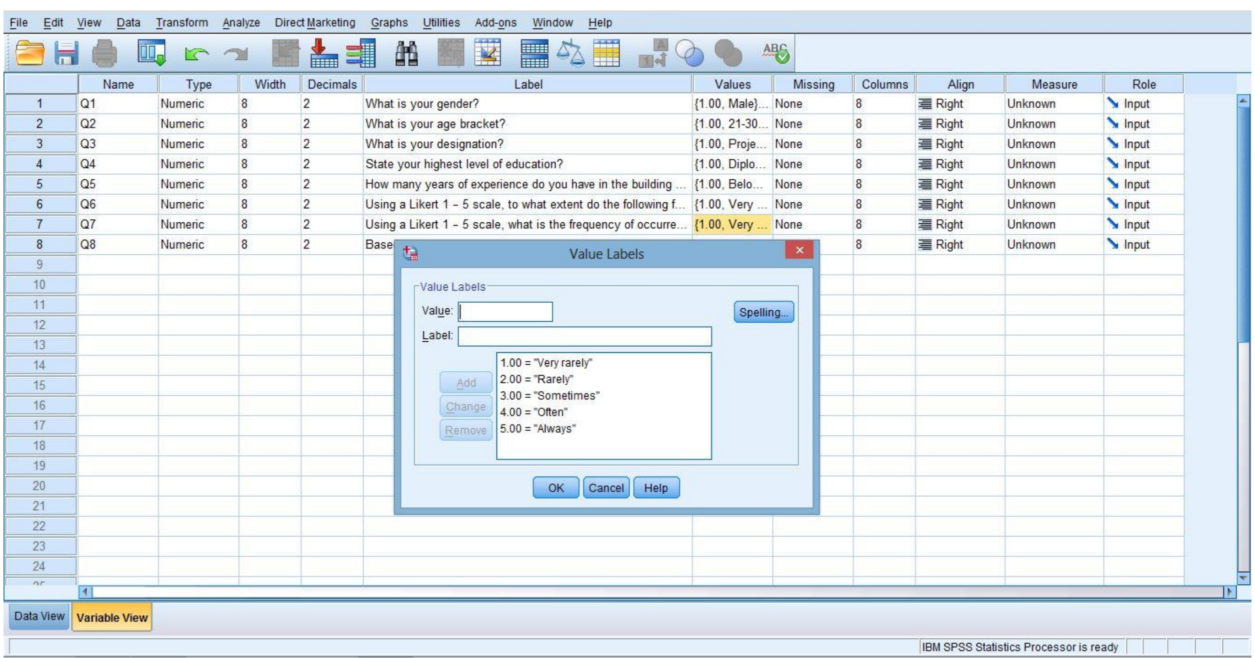

Figure 3. 1: SPSS window showing the questionnaire coding process

Severity index and frequency index of the risk factors as perceived by the respondents were calculated using the following statistical formulas:

Severity Index (S.I) (%) = $\Sigma a (n/N) * 100/5$ (Equation 3. 3)

Where:

S.I is the Severity Index.

a is the scale given for each option (it ranges from 1 – 5).

n is the frequency of the response.

N is the total number of respondents.

Frequency Index (F.I) (%) = $\Sigma a_1 (n_1/N) * 100/5$ (Equation 3. 4)

Where:

F.I is the Frequency Index.

a_1 is the scale given for each option (it ranges from 1 – 5).

n_1 is the frequency of the response.

N is the total number of respondents.

3.12 Model development

(El-Touny *et al*., 2014; Idrus *et al*., 2011; Challal & Tkiouat, 2012; Asal, 2014; Buertey, 2014 and Allahaim *et al*., 2016), have developed and proposed models for dealing with risks in cost estimation. However, most of these models are very complex, have limited and high mathematical treatment and therefore difficult to apply. As a result, they are usually neglected by construction professionals (El-Touny *et al*., 2014). Risk based cost estimation involves the use of simple or complex modelling based on inferred and probabilistic relationships among project events. The risk factors are identified and then applied to the base cost estimate through modelling (Nevada, 2021). The Analytic Hierarchy Process (AHP) developed by Saaty (1980) was used to develop the model for this research. It was selected for its reliability and ease of use.

The AHP is an effective tool for decision making and may aid the decision maker to set priorities and make the best decision. It is useful for making multi-criteria decisions involving benefits, opportunities, costs and risks. The AHP has also been applied in planning and resource allocation, conflict resolution, and prediction problems (Saaty, 1980). Therefore, the AHP was used in this research to assess the weights of the various risk factors in cost estimation through pairwise comparison matrices. The pairwise comparison judgments of the decision makers were based on the general personal experience. The proposed model was developed using the following steps as guided by Saaty (1980).

3.12.1 Establishing objectives

The objective was to improve risk management in cost estimation of building construction projects.

3.12.2 Identifying all relevant criteria

This was carried out in two stages. The first stage involved identifying the relevant criteria (risk factors in cost estimation) through literature review and interviews. The second stage involved getting views from professionals through the use of questionnaires so as to get the most important factors that affect cost estimation from those identified through literature review. Two questions were asked for each factor and respondents rated them on a scale of 1 – 5 as shown in Table 3.3 and 3.4. The most important factors were then identified by using the statistical methods for severity index, frequency index and importance index.

Severity Index (S.I) was used to determine the degree of severity of the risk factors and rank the factors based on their severity as indicated by the respondents using equation (3.3).

Frequency Index (F.I) was used to determine the frequency of occurrence of cost overruns arising from the risk factors and also rank the factors as identified by the respondents using equation (3.4).

Importance Index (IMP.I) was used to determine the importance index of each risk factor so as to get the most important factors using the following formula:

Importance Index (IMP.I) (%) = [F.I (%) * S.I (%)]/100 (Equation 3. 5)

Where:

IMP.I is the Importance Index.

F.I is the Frequency Index.

S.I is the Severity Index.

Table 3. 3: Frequency index table

Description	Very rarely	Rarely	Sometimes	Often	Always
Scale	1	2	3	4	5

Source: Primary data (2022)

Table 3. 4: Severity index table

Description	Very small	Small	Medium	High	Extreme
Scale	1	2	3	4	5

Source: Primary data (2022)

3.12.3 Decomposing the risk factors

All the risk factors identified through literature review were decomposed by structuring them into a main hierarchy of criteria and sub criteria as shown in Figure 3.1. Another hierarchy was developed for only the most important risk factors from which pairwise comparisons was developed.

3.12.4 Developing a pairwise comparison matrix

Pairwise comparisons were made by comparing pairs of elements in each level of the hierarchy with respect to every element in the higher level to establish priority weights of elements in each level of the hierarchy. A comparison matrix was then developed based on the values of the pairwise comparisons as illustrated in Figure 3.2.

Element	**C1**	**C2**	**C3**	**C4**
C1	C_{11}	C_{12}	C_{13}	C_{14}
C2	C_{21}	C_{22}	C_{23}	C_{24}
C3	C_{31}	C_{32}	C_{33}	C_{34}
C4	C_{41}	C_{42}	C_{43}	C_{44}

Figure 3. 2: Pairwise comparison matrix

The pairwise comparison reflects the judgments and relative preferences of different decision makers based on (Saaty, 1980) scale of 1-9 as shown in Table 3.5 and Figure 3.2. The diagonal elements of the matrix are all equal to one because they represent the comparison of a criterion against itself. The upper triangular values of the matrix were first filled using the following rules: If the judgment value was on the left side of the scale, the actual judgment value was considered and if the judgment value was on the right side of the scale, the reciprocal value was considered. The lower triangular values are the reciprocal of the upper triangular values (i.e. aij = 1/aji). All numbers in the matrix are positive.

Table 3. 5: Saaty's 1-9 scale of pairwise comparison

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	Intermediate value
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	Intermediate value
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	Intermediate value
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	Intermediate value
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	A reasonable assumption
1.1-1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities

Source: Saaty (1980)

Element 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Element 2

Figure 3. 3: Saaty scale

3.12.5 Normalizing the matrix

This was done by totalling the numbers in each column. Each entry in the column was then divided by the column sum to get the normalized score. The sum of each column of the normalized matrix is equal to 1.

3.12.6 Computing priority weights of criteria and sub criteria

This was done by totalling the numbers in each row of the normalized matrix. The sum of each row was then divided by the matrix dimension to get the priority weights.

3.12.7 Checking decision consistency

This was done by computing the consistency ratio (CR). The CR was obtained by dividing the consistency index (CI) by the random consistency index (RCI) as shown in equation 3.7. The consistency index was calculated using equation 3.6 and the values of the random consistency index are provided in Table 3.5.

Table 3. 6: Values of random consistency index

n	RCI
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

Source: Saaty (1980)

$$\mathbf{CI} = \frac{(\boldsymbol{\lambda}\mathbf{max} - \mathbf{n})}{(\mathbf{n} - \mathbf{1})} \qquad \textbf{(Equation 3. 6)}$$

Where “n” is the number of the matrix dimension.

Where “λmax” is the consistency measure.

The consistency measure was calculated by multiplying every value in each row of the pairwise comparison matrix and then powering the values by 1/n (where n is the matrix dimension) to obtain the total row value. The total row value of all the rows were summed to obtain the consistency measure.

$$\mathbf{CR} = \frac{\mathbf{CI}}{\mathbf{RCI}} \qquad \textbf{(Equation 3. 7)}$$

Where “CR” is the consistency ratio.

Where “CI” is the consistency index.

Where “RCI” is the random consistency index.

The acceptable value of the consistency ratio should be smaller or equal to 0.10. If the consistency ratio is larger than 0.10, it indicates that the judgements require re-examination.

3.12.8 Developing risk-based cost estimation model

After determining the weights of each factor in the hierarchy, the risk-based cost estimation model was developed using the following equation;

CR = RW * FI * SI (Equation 3. 8)

Where, **CR** represents the cost of risk, **RW** represents the relative weight of the factor; relative to the weight of its category; **FI** represents the frequency index of the factor; and **SI** represents the severity index of the factor.

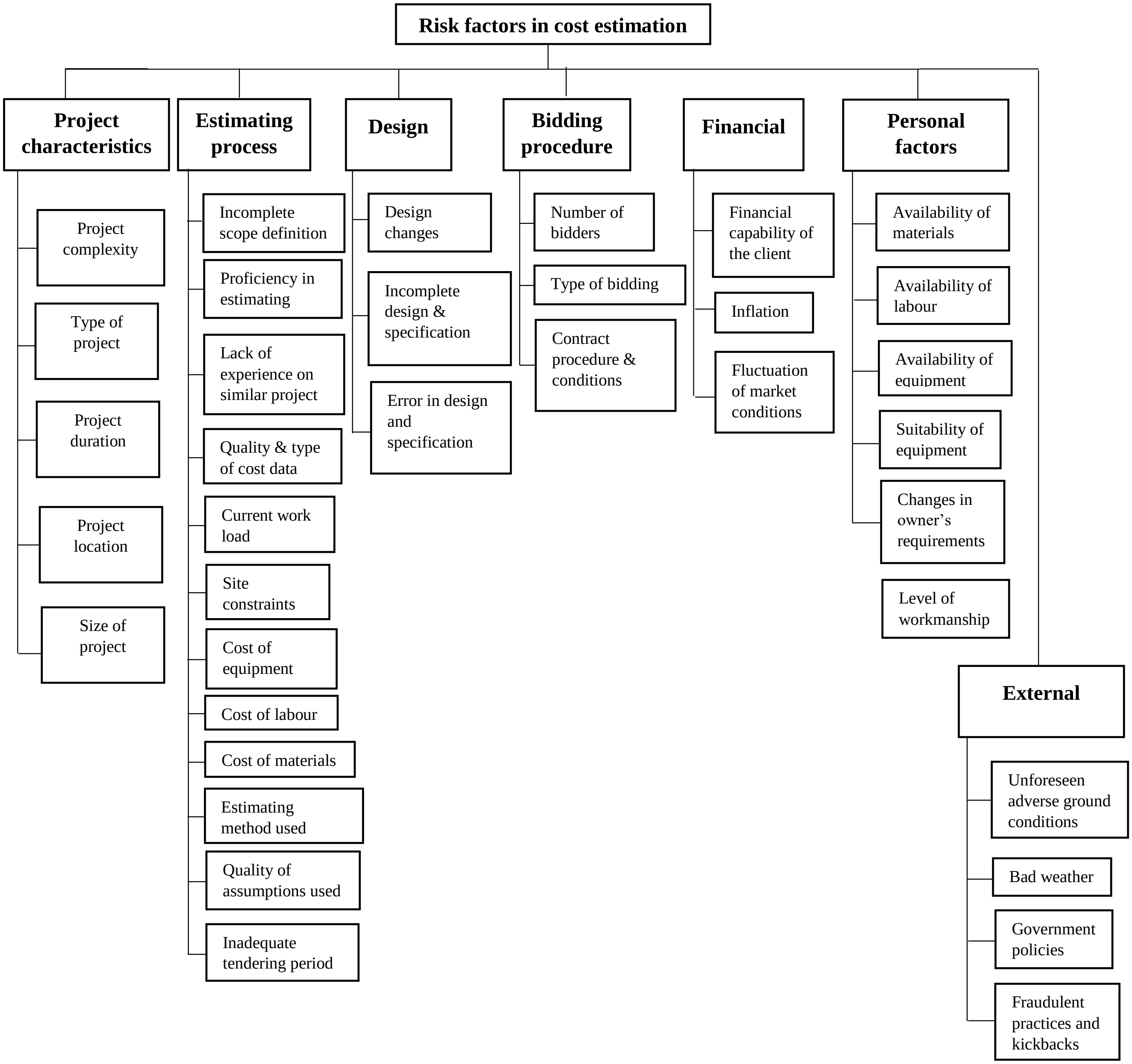

Figure 3. 4: Hierarchy of the thirty six (36) risk factors in cost estimation identified through literature review

3.13 Model verification

Sensitivity analysis was performed to test the reliability of the developed model. Sensitivity analysis is a method used to determine the robustness of an assessment by examining the extent to which results are affected by changes in methods, models, values of unmeasured variables or assumptions (Schneeweiss, 2006). Pichery (2014) defines sensitivity analysis as a method used to measure how the impact of uncertainties of one or more input variables can lead to uncertainties on the output variables.

3.14 Comparison of the Analytic Hierarchy Process based model with other existing models

Accurate cost estimation of construction projects still remains a difficult and complex problem which continues to attract considerable research attention. Many researchers have studied and developed different models to help solve this problem. Some of the existing models are based on regression analysis, artificial neural networks and case-based reasoning. A comparison of the different techniques is provided in Table 3.7.

Table 3. 7 Comparison of different models

Model	Advantages	Disadvantages
Analytic Hierarchy Process (AHP)	- It provides an easy applicable decision making methodology that assists the decision maker to precisely decide the judgments (Oguztimur, 2011). - It provides a simple and very flexible model for a given problem (Oguztimur, 2011).	- AHP allows only triangular fuzzy numbers to be used (Oguztimur, 2011). - The computational requirement is quite time-consuming even for a small problem (Oguztimur, 2011). - Rank reversal fact has to be carefully considered during application as it defines the

	- Any level of detail about the main focus can be listed or structured in AHP (Oguztimur, 2011). - It can take into consideration the relative priorities of factors or alternatives (Oguztimur, 2011). - It is possible to measure the consistency of decision maker's judgment (Oguztimur, 2011). - Decision makers can analyze the elasticity of the final decision by applying sensitivity analysis (Oguztimur, 2011). - AHP relies on the judgments of experts from different backgrounds and therefore the problem can be easily evaluated from different aspects (Oguztimur, 2011).	changes of the order of judgment alternatives when a new judgment alternative is added to the problem (Oguztimur, 2011). - There is not always a solution to the linear equations (Oguztimur, 2011). - AHP is based on probability and possibility measures (Oguztimur, 2011). - When the number of the levels in the hierarchy increases, the number of pairwise comparisons also increases. This increases the time and effort required to build the AHP model (Oguztimur, 2011). - The methodology cannot guarantee the decisions as definitely true due to the subjective nature of the modeling process (Oguztimur, 2011).
Regression Analysis (RA)	- Powerful statistical tool that can be used for both predictive and analytical techniques in examining the impact of items to the reliability of estimates (Skitmore and Patchell, 1990). - Have well defined mathematical basis and measures of how well a curve matches a given data set (Kim, An and Kang, 2004).	- They don't support the use of a large number of input variables (Garza, 1995), (Adeli and Wu, 1998), (Bode, 1998), (Hegazy, Fazio and Moselhi, 1994), and (Smith and Mason, 1997). - They have no clearly defined approach that will help estimators in choosing the cost model that best fits historical data to a given cost estimation application (Garza, 1995), (Adeli and Wu, 1998), (Bode, 1998), (Hegazy, Fazio and

		Moselhi, 1994), and (Smith and Mason, 1997). - Certain types of multiple equations and their data are assumed to be suitable for the regression equation (Garza, 1995), (Adeli and Wu, 1998), (Bode, 1998), (Hegazy, Fazio and Moselhi, 1994), and (Smith and Mason, 1997).
Artificial Neural Network (ANN)	- The number of inputs and outputs are not restricted (Garza, 1995), (Smith and Mason, 1997). - Information is stored on the entire network, not on a database. The disappearance of a few pieces of information in one place does not prevent the network from functioning (Maad, 2018). - Has numerical strength that can perform more than one job at the same time (Maad, 2018). - It has the ability to work with incomplete knowledge. The ANN model can be trained so that the data may produce output even with incomplete information (Maad, 2018). - It is fault tolerant and corruption of one or more cells does not prevent it from generating the required output (Maad, 2018).	- Requires considerable time in determining the number of neurons (Bode, 1998), (Hegazy, Fazio and Moselhi, 1994), (Yeh, 1998), and (Wang, Stockton and Baguley, 2000). - ANN requires processors with parallel processing power (Maad, 2018). - Problems have to be translated into numerical values before being introduced to ANN (Maad, 2018). - There is no specific rule for determining the structure of artificial neural networks (Maad, 2018). - When it produces a probing solution, it does not give a clue as to why and how. This reduces trust in the network (Maad, 2018).

Case Based Reasoning (CBR)	- It can easily be updated and the variables stored are consistent (Kim, An and Kang, 2004). - It allows a system to avoid past errors and exploit past successes (Aamodt, 1993), (De Mantaras *et al.*, 2005), (Watson, 1999) and (Budimac and Kurbalija, 2001). - Appropriate indexing strategies add insight and problem solving power (Aamodt, 1993), (De Mantaras *et al.*, 2005), (Watson, 1999) and (Budimac and Kurbalija, 2001). - It has the ability to encode historical knowledge directly (Aamodt, 1993), (De Mantaras *et al.*, 2005), (Watson, 1999) and (Budimac and Kurbalija, 2001). - It allows for shortcuts in reasoning. If an appropriate case can be found, new problems can be solved in much less time (Aamodt, 1993), (De Mantaras *et al.*, 2005), (Watson, 1999) and (Budimac and Kurbalija, 2001). - Extensive analysis of domain knowledge is not required (Aamodt, 1993), (De Mantaras *et al.*, 2005), (Watson, 1999) and (Budimac and Kurbalija, 2001).	- Cases do not often include deeper knowledge of the domain. This allows the possibility that cases may be misapplied (Aamodt, 1993), (De Mantaras *et al.*, 2005), (Watson, 1999) and (Budimac and Kurbalija, 2001). - A large case base can suffer from storage/compute trade-off problems (Aamodt, 1993), (De Mantaras *et al.*, 2005), (Watson, 1999) and (Budimac and Kurbalija, 2001). - It is difficult to determine good criteria for indexing and matching cases (Aamodt, 1993), (De Mantaras *et al.*, 2005), (Watson, 1999) and (Budimac and Kurbalija, 2001).

Source: Researcher's own work (2023)

3.15 Chapter summary

This chapter discussed the research design and approach, target population and sample, data collection methods, data analysis and model development.

CHAPTER FOUR

PRESENTATION, ANALYSIS AND INTERPRETATION OF RESULTS

4.1 Introduction

The chapter presents the field findings of the study based on the questionnaire, interviews and primary data in order to achieve the objectives of the study.

4.2 General information about the respondents

The background information of the respondents was established by assessing their gender, age, designation, level of education and years of experience in the building construction industry in Uganda.

4.2.1 Response rate

Self-administered questionnaires were used to get the required information from respondents. A total of 125 questionnaires were distributed but only 108 were returned giving a response rate of 86.4% as seen in Table 4.1, which according to Gordon *et al.*, (2002) is a good response rate.

Table 4. 1: Response rate

Category	Sample size	Responses received	Response rate
Project Managers	21	19	90.5%
Quantity Surveyors	18	18	100.0%
Architects	21	17	81.0%
Civil Engineers	24	24	100.0%
Electrical Engineers	21	16	76.2%
Mechanical Engineers	20	14	70.0%
Total	**125**	**108**	**86.4%**

Source: Primary data (2022)

4.2.2 Gender of the respondents

This subsection presents the gender of the respondents and the findings are shown in Table 4.2.

Table 4. 2: Gender of the respondents

Gender	Frequency	Percentage	Cumulative percentage
Male	87	80.6	80.6
Female	21	19.4	100.0
Total	**108**	**100.0**	

Source: Primary data (2022)

The findings in Table 4.2 indicate that majority of the respondents, 87 (80.6%) were male while 21 (19.4%) were female. This finding reflects that the building construction industry in Uganda is still a male dominated field.

4.2.3 Age of the respondents

The findings about the age of the respondents are presented in Table 4.3.

Table 4. 3: Age of the respondents

Age bracket	Frequency	Percentage	Cumulative percentage
21 – 30 years	17	15.7	15.7
31 – 40 years	56	51.9	67.6
41 – 50 years	21	19.4	87.0
Over 50 years	14	13.0	100.0
Total	**108**	**100.0**	

Source: Primary data (2022)

Table 4.3 shows that majority of the respondents, 56 (51.9%) were of the age between 31-40 years, 21 (19.4%) were of the age between 41-50 years, 17 (15.7%) were of the age between 21-30 years and 14 (13.0%) were of the age above 50 years. This finding reveals that 84.3% of the respondents were above 30 years of age and could therefore use their professional experiences, maturity and better sense of judgement to give reliable information required for the study.

4.2.4 Designation of the respondents

The respondents were requested to indicate their designations and the findings in this regard are presented in Table 4.4.

Table 4. 4: Designation of the respondents

Designation	**Frequency**	**Percentage**	**Cumulative percentage**
Project Managers	19	17.6	17.6
Quantity Surveyors	18	16.7	34.3
Architects	17	15.7	50.0
Civil Engineers	24	22.2	72.2
Electrical Engineers	16	14.8	87.0
Mechanical Engineers	14	13.0	100.0
Total	**108**	**100.0**	

Source: Primary data (2022)

Table 4.4 shows that majority of the respondents, 24 (22.2%) were Civil Engineers, 19 (17.6%) were Project Managers, 18 (16.7%) were Quantity Surveyors, 17 (15.7%) were Architects, 16 (14.8%) were Electrical Engineers and 14 (13.0%) were Mechanical Engineers. This finding reveals that data was collected from a selection of professionals believed to have good knowledge of cost estimation and risk factors in cost estimation in the building construction industry and could therefore give reliable data required for this study.

4.2.5 Education level of the respondents

This subsection presents the education level of the respondents and the findings regarding their highest level of education are shown in Table 4.5.

Table 4. 5: Highest education level of the respondents

Highest Education level	Frequency	Percentage	Cumulative percentage
Diploma	13	12.0	12.0
Degree (Bachelors)	72	66.7	78.7
Post graduate	21	19.4	98.1
Others	2	1.9	100.0
Total	**108**	**100.0**	

Source: Primary data (2022)

The findings in Table 4.5 show that majority of the respondents, 72 (66.7%) had attained degrees as their highest level of education, 21 (19.4%) had attained post graduate, 13 (12.0%) had attained diplomas while 2 (1.9%) had attained other qualifications. The finding shows that the respondents had reasonable level of education and since education background is critical in understanding cost estimation and the risk factors involved, the information that was collected from the respondents is highly reliable for this study.

4.2.6 Experience of the respondents

This subsection presents the years of experience that the respondents have in the building construction industry and the findings are shown in Table 4.6.

Table 4. 6: Experience of the respondents

Experience	Frequency	Percentage	Cumulative percentage
Below 5 years	11	10.2	10.2
6 – 10 years	39	36.1	46.3
11 – 15 years	45	41.7	88.0
16 years and above	13	12.0	100.0
Total	**108**	**100.0**	

Source: Primary data (2022)

The findings in Table 4.6 show that majority of the respondents, 45 (41.7%) had worked for 11-15 years, 39 (36.1%) had worked for 6-10 years, 13 (12.0%) had worked for 16 years and above while 11 (10.2%) had worked for less than 5 years. This finding demonstrates that the respondents had vast years of experience since a combined total of 89.8% had worked for more than 5 years and therefore believed to have provided reliable data for this study.

4.3 Empirical findings

The study sought to improve risk management in cost estimation in the building construction industry in Uganda. Three specific objectives were set to guide the study and the analysis was done on an objective by objective basis. The specific objectives of the study were: to establish the risk factors in cost estimation in the building construction industry in Uganda; to assess the effects of the risk factors in cost estimation in the building construction industry in Uganda and to develop a reliable model that can be used for risk based cost estimation in the building construction industry in Uganda.

4.3.1 Interview findings

Interviews were held with targeted key informants to get in-depth information based on their opinions, thoughts and experiences. Out of the total of 20 targeted key informants, only 13 offered the researcher the opportunity to be interviewed representing 65% response rate under this category. The following questions were asked in relation to the main objective: “what risk management techniques do you use on construction projects?”, “how effective are these techniques in risk management?”, “what risk management software do you use?”, “how do you manage risks during cost estimation?”, “what cost estimation methods do you use?”, “what cost estimation software do you use?", "any general comment with regard to improvement of risk management in cost estimation in the building construction industry in Uganda?"

(a) Risk management techniques used on construction projects

Following the interview, the risk management techniques used on construction projects are: contingency plan, risk exploitation, risk avoidance, risk transfer, risk reduction and risk acceptance.

(b) Effectiveness of risk management techniques used on construction projects

Risk management techniques are effective as they lead to project success, helps in maintaining profit margins since the possibility of risk occurrence and its potential impacts are reduced, provide a basis for sound decision making, helps in preparing for eventualities that may happen, aids in preparing more accurate project budgets and improves the project teams' focus when members are assigned the responsibility of risk monitoring.

(c) Risk management software used on construction projects

The information that was gathered from the interview indicates that none of the key informants uses risk management software. They however mentioned the use of risk management tools such as brainstorming, risk register, SWOT and risk assessment.

(d) Risk management during cost estimation

Based on the key informants' views, the following are the ways of managing risks during cost estimation: use of cost estimation software, use of contingency amount, reviewing historical data, verification of project scope, using work breakdown structures, using clearly defined assumptions and use of risk management tools and techniques.

(e) Cost estimation methods used on construction projects

The following are the cost estimation methods used on construction projects: floor area method, elemental method, unit cost method and approximate quantities method.

(f) Cost estimation software used on construction projects

The interview revealed that the cost estimation software in use are: WinQS, QSPlus, PlanSwift and PriMus.

(g) General comments with regard to improvement of risk management in cost estimation in the building construction industry in Uganda

The following were suggested towards the improvement of risk management in cost estimation in the building construction industry in Uganda: understanding the project external environment during cost estimation; practicing value engineering; using risk factors in previous projects to determine the cost of risk; clearly identifying and defining the unknown elements at the cost estimation stage and embracing the use of tools and techniques to determine the likelihood of risk.

4.3.2 Establishing the risk factors in cost estimation

Risk factors in construction projects greatly depend on the nature of the project and identifying all the potential risk factors may be challenging. It is however possible to identify the risk factors through analysing previous studies (Riveros *et al.*, 2022). The risk factors in cost estimation were established through literature review and this guided in the design of the questionnaire for the study. A total of thirty-six (36) risk factors were used in the questionnaire design. The respondents were further asked to list down other risk factors based on their experience and to the best of their knowledge. However, the responses from the respondents did not provide any additional risk factors different from those (36) already identified through literature review.

Table 4. 7: Risk factors in cost estimation

No.	Risk factors in cost estimation
1	Project complexity
2	Type of project
3	Project duration
4	Project location
5	Size of project
6	Incomplete scope definition
7	Proficiency in estimating
8	Unforeseen adverse ground conditions
9	Lack of experience on similar project
10	Quality and type of cost data
11	Current work load
12	Site constraints (access, storage, services)
13	Financial capability of the client
14	Availability of materials
15	Availability of labour
16	Availability of equipment
17	Suitability of equipment
18	Cost of equipment
19	Cost of labour
20	Cost of materials
21	Level of workmanship (productivity and performance)
22	Design changes
23	Bad weather
24	Estimation method used
25	Quality of assumptions used in preparing estimates
26	Incomplete design and specification
27	Error in design and specification
28	Inadequate tendering period
29	Number of bidders
30	Government policies
31	Inflation

32	Fluctuation of market conditions
33	Type of bidding
34	Contract procedure and conditions
35	Changes in owner's requirements
36	Fraudulent practices and kickbacks

Source: Primary data (2022)

4.3.3 Assessing the effects of the risk factors in cost estimation

Severity Index (S.I) was used to assess the effects of the risk factors in cost estimation and the factors were ranked based on the severity of their effects as shown in Table 4.8.

Table 4. 8: Degree of severity of the risk factors in cost estimation

No.	Risk factors in cost estimation	Degree of severity	
		Severity Index (%)	Rank
1	Project complexity	72.22	12
2	Type of project	69.26	17
3	Project duration	63.89	22
4	Project location	73.52	11
5	Size of project	69.63	15
6	Incomplete scope definition	79.81	5
7	Proficiency in estimating	83.89	2
8	Unforeseen adverse ground conditions	67.78	19
9	Lack of experience on similar project	66.67	20
10	Quality and type of cost data	70.74	14
11	Current work load	50.19	30
12	Site constraints (access, storage, services)	62.59	23
13	Financial capability of the client	60.00	26
14	Availability of materials	77.41	7
15	Availability of labour	73.52	11
16	Availability of equipment	68.33	18
17	Suitability of equipment	60.00	26
18	Cost of equipment	67.78	19
19	Cost of labour	70.93	13
20	Cost of materials	82.96	3
21	Level of workmanship (productivity and performance)	69.44	16
22	Design changes	74.63	10
23	Bad weather	54.81	27
24	Estimation method used	61.30	25

25	Quality of assumptions used in preparing estimates	74.81	9
26	Incomplete design and specification	82.59	4
27	Error in design and specification	75.93	8
28	Inadequate tendering period	64.07	21
29	Number of bidders	46.67	31
30	Government policies	61.48	24
31	Inflation	84.26	1
32	Fluctuation of market conditions	78.70	6
33	Type of bidding	51.67	29
34	Contract procedure and conditions	53.52	28
35	Changes in owner’s requirements	70.93	13
36	Fraudulent practices and kickbacks	82.59	4

Source: Primary data (2022)

The results in Table 4.8 show that the risk factors with the highest degree of severity in cost estimation in the building construction industry in Uganda are; inflation (84.26%), proficiency in estimating (83.89%), cost of materials (82.96%), incomplete design and specification (82.59%), fraudulent practices and kickbacks (82.59%), incomplete scope definition (79.81%), fluctuation in market conditions (78.70%), availability of materials (77.41%), error in design and specification (75.93%), quality of assumptions used in preparing estimates (74.81%) and design changes (74.63%).

(a) Frequency of occurrence of cost overruns due to the risk factors in cost estimation

Frequency Index (F.I) was used to determine the frequency of occurrence of cost overruns due to the risk factors in cost estimation and the factors were ranked as indicated by the respondents and the results are shown in Table 4.9.

Table 4. 9: Frequency of occurrence of cost overruns due to the risk factors in cost estimation

No.	Risk factors in cost estimation	Frequency of occurrence	
		Frequency Index (%)	Rank
1	Project complexity	76.11	9
2	Type of project	60.19	23
3	Project duration	69.44	13
4	Project location	61.48	21
5	Size of project	58.52	24
6	Incomplete scope definition	82.96	2
7	Proficiency in estimating	73.52	11
8	Unforeseen adverse ground conditions	70.74	12
9	Lack of experience on similar project	66.67	16
10	Quality and type of cost data	66.67	16
11	Current work load	46.67	29
12	Site constraints (access, storage, services)	61.11	22
13	Financial capability of the client	50.93	28
14	Availability of materials	63.70	19
15	Availability of labour	65.19	18
16	Availability of equipment	62.59	20
17	Suitability of equipment	57.41	25
18	Cost of equipment	66.48	17
19	Cost of labour	78.70	7
20	Cost of materials	85.19	1
21	Level of workmanship (productivity and performance)	68.33	15
22	Design changes	82.59	3
23	Bad weather	57.41	25
24	Estimation method used	61.11	22
25	Quality of assumptions used in preparing estimates	69.07	14
26	Incomplete design and specification	76.11	9
27	Error in design and specification	81.11	5
28	Inadequate tendering period	56.11	26
29	Number of bidders	40.00	31
30	Government policies	57.41	25
31	Inflation	81.48	4
32	Fluctuation of market conditions	74.81	10
33	Type of bidding	46.48	30
34	Contract procedure and conditions	53.52	27
35	Changes in owner's requirements	77.41	8
36	Fraudulent practices and kickbacks	80.19	6

Source: Primary data (2022)

The findings in Table 4.9 show that the risk factors with the highest Frequency Index for occurrence of cost overruns in the building construction industry in Uganda are; cost of materials (85.19%), incomplete scope definition (82.96%), design changes (82.59%), inflation (81.48%), error in design and specification (81.11%), fraudulent practices and kickbacks (80.19%), cost of labour (78.70%), changes in owner's requirements (77.41%), project complexity (76.11%), incomplete design and specification (76.11%) and fluctuation of market conditions (74.81%).

(b) Importance Index of the risk factors in cost estimation

Importance Index (IMP.I) was used to get the most important risk factors in cost estimation in the building construction industry in Uganda and the findings are presented in Table 4.10.

Table 4. 10: Importance Index of the risk factors in cost estimation

No.	Risk factors in cost estimation	F.I (%)	S.I (%)	IMP.I (%)	Rank
1	Project complexity	76.11	72.22	54.97	11
2	Type of project	60.19	69.26	41.69	24
3	Project duration	69.44	63.89	44.37	22
4	Project location	61.48	73.52	45.20	19
5	Size of project	58.52	69.63	40.75	25
6	Incomplete scope definition	82.96	79.81	66.21	4
7	Proficiency in estimating	73.52	83.89	61.68	6
8	Unforeseen adverse ground conditions	70.74	67.78	47.95	15
9	Lack of experience on similar project	66.67	66.67	44.45	21
10	Quality and type of cost data	66.67	70.74	47.16	18
11	Current work load	46.67	50.19	23.42	35
12	Site constraints (access, storage, services)	61.11	62.59	38.25	26
13	Financial capability of the client	50.93	60.00	30.56	32
14	Availability of materials	63.70	77.41	49.31	14
15	Availability of labour	65.19	73.52	47.93	16
16	Availability of equipment	62.59	68.33	42.77	23
17	Suitability of equipment	57.41	60.00	34.45	30
18	Cost of equipment	66.48	67.78	45.06	20
19	Cost of labour	78.70	70.93	55.82	10
20	Cost of materials	85.19	82.96	70.67	1

	Table 4.10 (Continued)				
No.	**Risk factors in cost estimation**	**F.I (%)**	**S.I (%)**	**IMP.I (%)**	**Rank**
21	Level of workmanship (productivity and performance)	68.33	69.44	47.45	17
22	Design changes	82.59	74.63	61.64	7
23	Bad weather	57.41	54.81	31.47	31
24	Estimation method used	61.11	61.30	37.46	27
25	Quality of assumptions used in preparing estimates	69.07	74.81	51.67	13
26	Incomplete design and specification	76.11	82.59	62.86	5
27	Error in design and specification	81.11	75.93	61.59	8
28	Inadequate tendering period	56.11	64.07	35.95	28
29	Number of bidders	40.00	46.67	18.67	36
30	Government policies	57.41	61.48	35.30	29
31	Inflation	81.48	84.26	68.66	2
32	Fluctuation of market conditions	74.81	78.70	58.88	9
33	Type of bidding	46.48	51.67	24.02	34
34	Contract procedure and conditions	53.52	53.52	28.64	33
35	Changes in owner's requirements	77.41	70.93	54.91	12
36	Fraudulent practices and kickbacks	80.19	82.59	66.23	3

Source: Primary data (2022)

The results in Table 4.10 show that the top fifteen (15) risk factors in cost estimation in the building construction industry in Uganda are; cost of materials (70.67%), inflation (68.66%), fraudulent practices and kickbacks (66.23%), incomplete scope definition (66.21%), incomplete design and specification (62.86%), proficiency in estimating (61.68%), design changes (61.64%), error in design and specification (61.59%), fluctuation of market conditions (58.88%), cost of labour (55.82%), project complexity (54.97%), changes in owner's requirements (54.91%), quality of assumptions used in preparing estimates (51.67%), availability of materials (49.31%) and unforeseen adverse ground conditions (47.95%).

(c) Most important risk factors in cost estimation

The fifteen (15) most important risk factors in cost estimation in the building construction industry in Uganda are shown in Table 4.11.

Table 4. 11: Ranking of the most important risk factors in cost estimation

No.	Risk factors in cost estimation	F.I (%)	S.I (%)	IMP.I (%)	Rank
1	Cost of materials	85.19	82.96	70.67	1
2	Inflation	81.48	84.26	68.66	2
3	Fraudulent practices and kickbacks	80.19	82.59	66.23	3
4	Incomplete scope definition	82.96	79.81	66.21	4
5	Incomplete design and specification	76.11	82.59	62.86	5
6	Proficiency in estimating	73.52	83.89	61.68	6
7	Design changes	82.59	74.63	61.64	7
8	Error in design and specification	81.11	75.93	61.59	8
9	Fluctuation of market conditions	74.81	78.70	58.88	9
10	Cost of labour	78.70	70.93	55.82	10
11	Project complexity	76.11	72.22	54.97	11
12	Changes in owner's requirements	77.41	70.93	54.91	12
13	Quality of assumptions used in preparing estimates	69.07	74.81	51.67	13
14	Availability of materials	63.70	77.41	49.31	14
15	Unforeseen adverse ground conditions	70.74	67.78	47.95	15

Source: Primary data (2022)

4.3.4 Developing a reliable model for risk based cost estimation

The model was developed based on the fifteen (15) most important risk factors in cost estimation in the building construction industry in Uganda.

(a) Decomposing the most important risk factors in cost estimation

The most important risk factors in cost estimation were decomposed by structuring them into a hierarchy of criteria and sub criteria as shown in Figure 4.1.

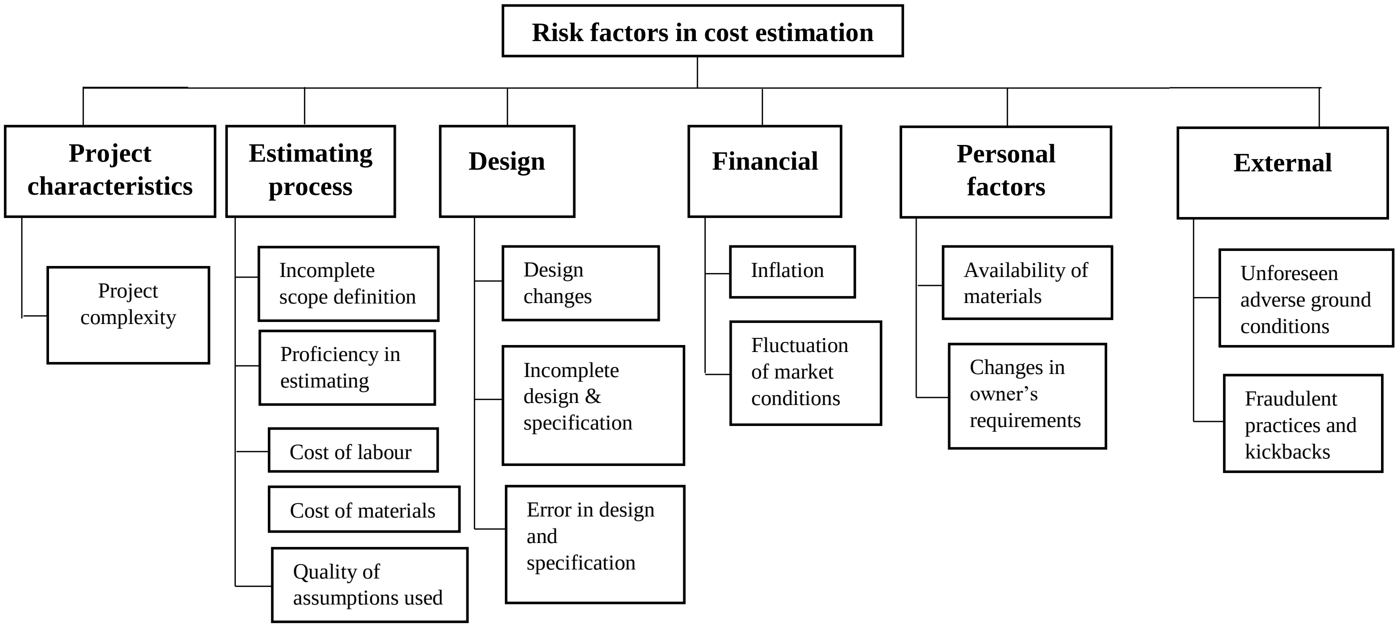

Figure 4. 1: Hierarchy of the fifteen (15) most important risk factors in cost estimation

(b) Developing pairwise comparison matrices

Pairwise comparison matrices were developed by comparing pairs of elements in each level of the hierarchy of the fifteen (15) most important risk factors in cost estimation. The matrices were then normalized to compute the priority weights of the elements.

(i) Pairwise comparison matrix, normalized matrix and priority weights of the criteria

The pairwise comparison matrix, normalized matrix and priority weights of the criteria are shown in Table 4.12, Table 4.13 and Table 4.14 respectively. The symbols used denote the following words:

PC: Project Characteristics.

EP: Estimating Process.

D: Design.

F: Financial.

PF: Personal Factors.

E: External.

Table 4. 12: Pairwise comparison matrix of the criteria

Factor	PC	EP	D	F	PF	E
PC	1.000	0.111	0.143	0.167	0.200	0.167
EP	9.000	1.000	1.000	1.000	1.000	3.000
D	7.000	1.000	1.000	3.000	1.000	3.000
F	6.000	1.000	0.333	1.000	0.167	2.000
PF	5.000	1.000	1.000	6.000	1.000	3.000
E	6.000	0.333	0.333	0.500	0.333	1.000

Source: Primary data (2022)

Table 4. 13: Normalized matrix of the criteria

Factor	PC	EP	D	F	PF	E
PC	0.029	0.025	0.038	0.014	0.054	0.014
EP	0.265	0.225	0.263	0.086	0.270	0.247
D	0.206	0.225	0.263	0.257	0.270	0.247
F	0.176	0.225	0.087	0.086	0.045	0.164
PF	0.147	0.225	0.263	0.514	0.270	0.247
E	0.176	0.075	0.087	0.043	0.090	0.082

Source: Primary data (2022)

Table 4. 14: Priority weights of the criteria

Factor	Weight	
PC	0.029	Consistency measure (“λmax) = 6.491
EP	0.226	Consistency index (CI) = 0.098
D	0.245	
F	0.131	Random consistency index (RCI) = 1.24
PF	0.278	
E	0.092	Consistency ratio (CR) = 0.079

Source: Primary data (2022)

(ii) Pairwise comparison matrix, normalized matrix and priority weights of the sub criteria under the estimating process criteria

The pairwise comparison matrix, normalized matrix and priority weights of the sub criteria under the estimating process criteria are shown in Table 4.15, Table 4.16 and Table 4.17 respectively. The symbols used denote the following words:

ISD: Incomplete Scope Definition.

PE: Proficiency in Estimating.

CL: Cost of Labour.

CM: Cost of Materials.

QAU: Quality of Assumptions Used.

Table 4. 15: Pairwise comparison matrix of the sub criteria under the estimating process criteria

Factor	ISD	PE	CL	CM	QAU
ISD	1.000	8.000	5.000	3.000	5.000
PE	0.125	1.000	0.143	0.143	1.000
CL	0.200	7.000	1.000	1.000	4.000
CM	0.333	7.000	1.000	1.000	3.000
QAU	0.200	1.000	0.250	0.333	1.000

Source: Primary data (2022)

Table 4. 16: Normalized matrix of the sub criteria under the estimating process criteria

Factor	ISD	PE	CL	CM	QAU
ISD	0.538	0.333	0.676	0.548	0.357
PE	0.067	0.042	0.019	0.026	0.071
CL	0.108	0.292	0.135	0.183	0.286
CM	0.179	0.292	0.135	0.183	0.214
QAU	0.108	0.042	0.034	0.061	0.071

Source: Primary data (2022)

Table 4. 17: Priority weights of the sub criteria under the estimating process criteria

<table>
<tr><td>Factor</td><td>Weight</td><td rowspan="6">Consistency measure (“λmax) = 5.291

Consistency index (CI) = 0.073

Random consistency index (RCI) = 1.12

Consistency ratio (CR) = 0.065</td></tr>
<tr><td>ISD</td><td>0.491</td></tr>
<tr><td>PE</td><td>0.045</td></tr>
<tr><td>CL</td><td>0.201</td></tr>
<tr><td>CM</td><td>0.201</td></tr>
<tr><td>QAU</td><td>0.063</td></tr>
</table>

Source: Primary data (2022)

(iii) Pairwise comparison matrix, normalized matrix and priority weights of the sub criteria under the design criteria

The pairwise comparison matrix, normalized matrix and priority weights of the sub criteria under the design criteria are shown in Table 4.18, Table 4.19 and Table 4.20 respectively. The symbols used denote the following words:

DC: Design Changes.

IDS: Incomplete Design and Specification.

EDS: Error in Design and Specification.

Table 4. 18: Pairwise comparison matrix of the sub criteria under the design criteria

Factor	DC	IDS	EDS
DC	1.000	1.000	0.500
IDS	1.000	1.000	1.000
EDS	2.000	1.000	1.000

Source: Primary data (2022)

Table 4. 19: Normalized matrix of the sub criteria under the design criteria

Factor	DC	IDS	EDS
DC	0.250	0.333	0.200
IDS	0.250	0.333	0.400
EDS	0.500	0.333	0.400

Source: Primary data (2022)

Table 4. 20: Priority weights of the sub criteria under the design criteria

Factor	Weight	Consistency measure (“λmax) = 3.054
DC	0.261	Consistency index (CI) = 0.027
IDS	0.328	Random consistency index (RCI) = 0.58
EDS	0.411	Consistency ratio (CR) = 0.047

Source: Primary data (2022)

(iv) Pairwise comparison matrix, normalized matrix and priority weights of the sub criteria under the financial criteria

The pairwise comparison matrix, normalized matrix and priority weights of the sub criteria under the financial criteria are shown in Table 4.21, Table 4.22 and Table 4.23 respectively. The symbols used denote the following words:

INF: Inflation.

FMC: Fluctuation of Market Conditions.

Table 4. 21: Pairwise comparison matrix of the sub criteria under the financial criteria

Factor	INF	FMC
INF	1.000	1.000
FMC	1.000	1.000

Source: Primary data (2022)

Table 4. 22: Normalized matrix of the sub criteria under the financial criteria

Factor	INF	FMC
INF	0.500	0.500
FMC	0.500	0.500

Source: Primary data (2022)

Table 4. 23: Priority weights of the sub criteria under the financial criteria

Factor	Weight	Consistency measure (“λmax) = 2.000
INF	0.500	Consistency index (CI) = 0.000
FMC	0.500	Random consistency index (RCI) = 0.00
		Consistency ratio (CR) = 0.000

Source: Primary data (2022)

(v) Pairwise comparison matrix, normalized matrix and priority weights of the sub criteria under the personal factors criteria

The pairwise comparison matrix, normalized matrix and priority weights of the sub criteria under the personal factors criteria are shown in Table 4.24, Table 4.25 and Table 4.26 respectively. The symbols used denote the following words:

AM: Availability of materials.

CR: Changes in Owner’s Requirements.

Table 4. 24: Pairwise comparison matrix of the sub criteria under the personal factors criteria

Factor	AM	CR
AM	1.000	8.000
CR	0.125	1.000

Source: Primary data (2022)

Table 4. 25: Normalized matrix of the sub criteria under the personal factors criteria

Factor	AM	CR
AM	0.889	0.889
CR	0.111	0.111

Source: Primary data (2022)

Table 4. 26: Priority weights of the sub criteria under the personal factors criteria

Factor	Weight	Consistency measure (“λmax) = 2.000
AM	0.889	Consistency index (CI) = 0.000
CR	0.111	Random consistency index (RCI) = 0.00 Consistency ratio (CR) = 0.000

Source: Primary data (2022)

(vi) Pairwise comparison matrix, normalized matrix and priority weights of the sub criteria under the external criteria

The pairwise comparison matrix, normalized matrix and priority weights of the sub criteria under the external criteria are shown in Table 4.27, Table 4.28 and Table 4.29 respectively. The symbols used denote the following words:

UGC: Unforeseen Ground Conditions.

FPK: Fraudulent Practices and Kickbacks.

Table 4. 27: Pairwise comparison matrix of the sub criteria under the external criteria

Factor	UGC	FPK
UGC	1.000	0.143
FPK	7.000	1.000

Source: Primary data (2022)

Table 4. 28: Normalized matrix of the sub criteria under the external criteria

Factor	UGC	FPK
UGC	0.125	0.125
FPK	0.875	0.875

Source: Primary data (2022)

Table 4. 29: Priority weights of the sub criteria under the external criteria

Factor	Weight	
UGC	0.125	Consistency measure (“λmax) = 2.000 Consistency index (CI) = 0.000 Random consistency index (RCI) = 0.00 Consistency ratio (CR) = 0.000
FPK	0.875	

Source: Primary data (2022)

(c) Priority weights and relative weights of the criteria and sub criteria

The priority weights and relative weights of the criteria and sub criteria are shown in Table 4.30.

Table 4. 30: Summary of priority weights and relative weights of the criteria and sub criteria

Criteria	Weight	Sub criteria	Weight	Relative weight (Wr)
Project characteristics	**0.029**	Project complexity	**1.000**	0.029
Estimating process	**0.226**	Incomplete scope definition	**0.491**	0.111
		Proficiency in estimating	**0.045**	0.010
		Cost of labour	**0.201**	0.045
		Cost of materials	**0.201**	0.045
		Quality of assumptions used	**0.063**	0.014
Design	**0.245**	Design changes	**0.261**	0.064
		Incomplete design and specification	**0.328**	0.080
		Error in design and specification	**0.411**	0.101
Financial	**0.131**	Inflation	**0.500**	0.066
		Fluctuation of market conditions	**0.500**	0.066
Personal factors	**0.278**	Availability of materials	**0.889**	0.247
		Changes in owner's requirements	**0.111**	0.031
External	**0.092**	Unforeseen adverse ground conditions	**0.125**	0.012
		Fraudulent practices and kickbacks	**0.875**	0.081

Source: Primary data (2022)

(d) Cost of risk for the most important risk factors

The cost of risk for the most important risk factors was calculated based on the values of the relative weight, frequency index and severity index for each factor as shown in Table 4.31.

Table 4. 31: Cost of risk calculated using the model

Criteria	Sub criteria	Relative Weight (RW)	Frequency Index (FI)	Severity Index (SI)	Cost of Risk (CR = RW*FI*SI)
Project characteristics	Project complexity	0.029	0.761	0.722	0.016
Estimating process	Incomplete scope definition	0.111	0.830	0.798	0.074
	Proficiency in estimating	0.010	0.735	0.839	0.006
	Cost of labour	0.045	0.787	0.709	0.025
	Cost of materials	0.045	0.852	0.830	0.032
	Quality of assumptions used in preparing estimates	0.014	0.691	0.748	0.007
Design	Design changes	0.064	0.826	0.746	0.039
	Incomplete design and specification	0.080	0.761	0.826	0.050
	Error in design and specification	0.101	0.811	0.759	0.062
Financial	Inflation	0.066	0.815	0.843	0.045
	Fluctuation of market conditions	0.066	0.748	0.787	0.039
Personal factors	Availability of materials	0.247	0.637	0.774	0.122
	Changes in owner's requirements	0.031	0.774	0.709	0.017
External	Unforeseen adverse ground conditions	0.012	0.707	0.678	0.006
	Fraudulent practices and kickbacks	0.081	0.802	0.826	0.054
Total Cost of Risk (TCR) = ∑ RW * FI * SI					**0.594**
Average Cost of Risk (ACR) = ∑ RW * FI * SI / 15					**0.040**

Source: Primary data (2022)

The results in Table 4.31 show that the total cost of risk for the fifteen (15) most important risk factors represents 59.4% of the project cost while the average cost of risk represents 4.0% of the project cost which is the maximum cost of risk in a project. This maximum cost of risk is dependent on the occurrence of all the considered factors and could therefore be lower if the risk factors are properly dealt with from project onset. Risk factors should be effectively managed during the early phases of the project as this will ensure that there is enough information for use in the cost estimation process thereby increasing the accuracy of cost estimates. This will also ensure low financial risks due to reliable cost estimates.

Table 4. 32: Cost percentages of the factors in comparison to the total cost of risk

Factors	Cost percentage	Cumulative cost percentage	Rank
Project complexity	2.7	2.7	11
Incomplete scope definition	12.5	15.2	2
Proficiency in estimating	1.0	16.2	13
Cost of labour	4.2	20.4	9
Cost of materials	5.4	25.8	8
Quality of assumptions used in preparing estimates	1.2	27.0	12
Design changes	6.6	33.6	7
Incomplete design and specification	8.4	42.0	5
Error in design and specification	10.4	52.4	3
Inflation	7.6	60.0	6
Fluctuation of market conditions	6.6	66.6	7
Availability of materials	20.5	87.1	1
Changes in owner’s requirements	2.9	90.0	10
Unforeseen adverse ground conditions	1.0	91.0	13
Fraudulent practices and kickbacks	9.1	100.0	4
Total	**100.0**		

Source: Primary data (2022)

The results in Table 4.32 show that the top five factors with the highest cost of risk are; availability of materials (20.5%), incomplete scope definition (12.5%), error in design and specification (10.4%), fraudulent practices and kickbacks (9.1%) and incomplete design and specification (8.4%). The top five factors represent 60.9% of the total cost of risk while other factors represent 39.1%.

4.4 Sensitivity analysis

Sensitivity analysis was performed in Microsoft Excel to determine the most sensitive factors that affect cost estimation. According to Salciccioli *et al.*, (2016), sensitivity analysis assess how the uncertainty in the output of a model is related to the uncertainty in its inputs. Sensitivity analysis is used to quantify the uncertainty in a model, test the model and calculate the sensitivity of the model. Changes made to the input parameters varied the final results about the options as shown in Figure 4.2. Therefore, the developed model proved to be consistent and sensitive to the considered factors.

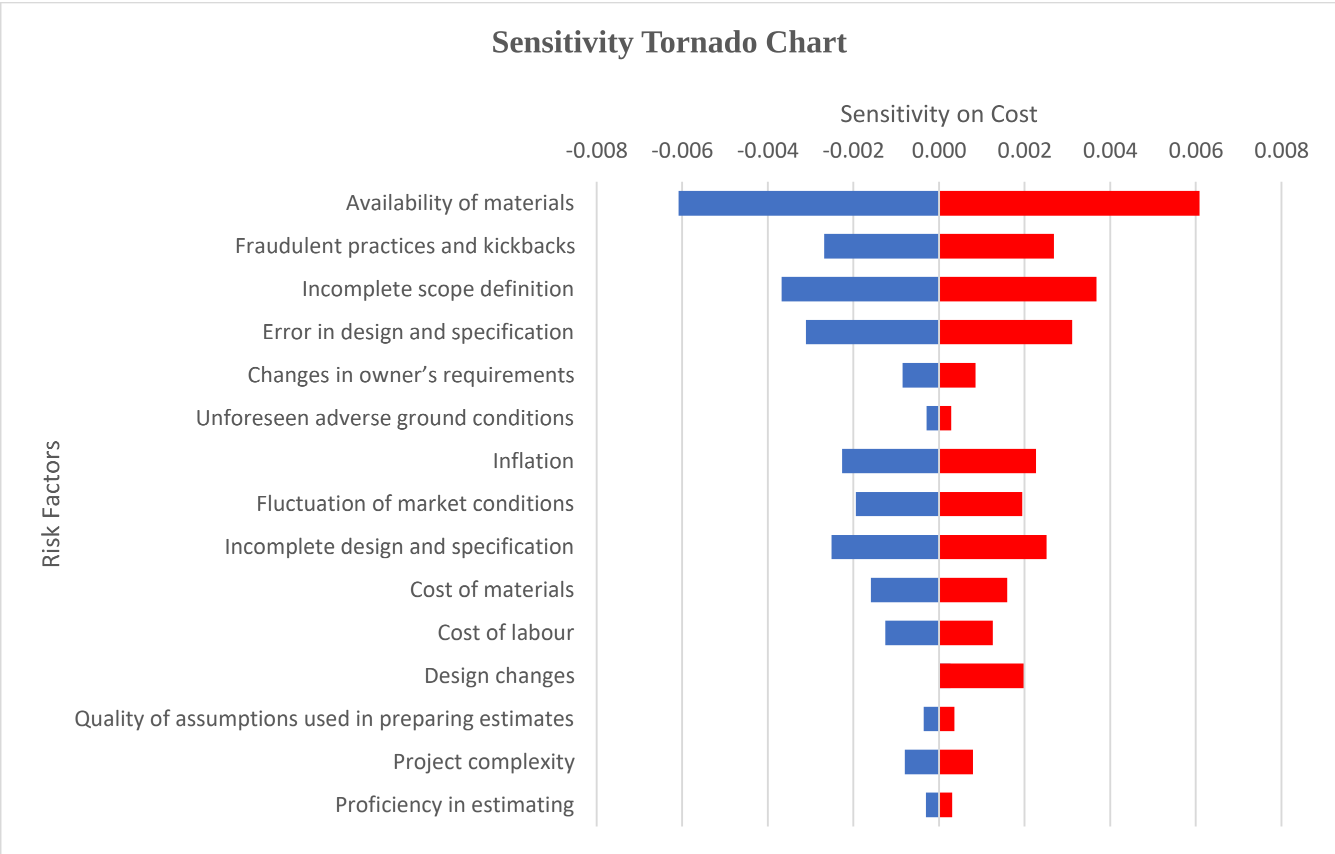

Figure 4. 2: Sensitivity analysis of the developed model

4.5 Model validation and applicability

The first step of validation involved comparing the predicted model value with real values from completed projects so as to check the accuracy and applicability of the average cost of risk (4.00%) that was obtained from the model. Historical data for ten completed projects that have both estimated and actual costs were obtained from the key informants. The cost of risk for the projects was calculated by subtracting the estimated cost from the actual cost. The difference obtained was then divided over the estimated cost to obtain the percentage cost of risk for the completed projects as shown in Table 4.33. The results show that the cost of risk ranged from 1.04% to 7.38% and the average cost of risk for the ten projects is 4.51%. Therefore, the model validation demonstrated acceptable discrepancies.

Table 4. 33: Cost of risk for ten completed building construction projects

Project	Actual cost (Ugx)	Estimated cost (Ugx)	Cost of risk (Ugx)	Percentage cost of risk
Completion of Busega Market at Busega, Kampala District	13,532,256,158	12,887,963,424	644,292,734	5.00
Proposed Royal Palms Housing Estate on Plot No. 26, Butabika Road, Kampala	11,740,931,851	11,322,100,000	418,831,851	3.70
Proposed Construction of Uganda Allied Health Examinations Board Office Block Complex at Kyambogo	878,954,034	869,891,044	9,062,990	1.04
Proposed Barracks Lane Serviced Apartments on Plot No. 20, Barracks Drive, Nsambya, Kampala	22,193,046,190	21,525,000,000	668,046,190	3.10
Specialized Maternal & Neonatal Health Care Unit, Mulago	90,968,311,000	85,610,017,500	5,358,293,500	6.26
Proposed Construction Works on Plot 684, Bbunga – Kawuku, Victoria View Apartments	117,438,615	111,846,300	5,592,315	5.00
Construction of Facilities at Luzira Secondary School	1,590,520,625	1,557,022,599	33,498,026	2.15

Proposed Office Development on Plot No.78, Luthuli Avenue, Bugolobi	13,288,753,205	12,394,873,820	893,879,385	7.21
Proposed External Works at Plot 228, Block 253, Lukuli Makindye	714,769,089	685,315,587	29,453,502	4.30
Proposed Apartment Development on Plot No. 47 & 49, Kanjokya Street, Kamwokya	12,689,497,418	11,817,083,157	872,414,261	7.38
Average				**4.51**

Source: Primary data (2022)

The second step of validation was based on a mathematical model adopted from Zayed and Halpin (2005). The model was used to calculate the average invalidity percentage and average validity percentage as follows:

$$\mathbf{AIP} = \frac{\sum_{i=1}^{n} |1 - (E_i/C_i)|}{n} \qquad \textbf{(Equation 4. 1)}$$

$$\mathbf{AVP = 1 - AIP} \qquad \textbf{(Equation 4. 2)}$$

Where "AIP" is the average invalidity percentage. The value ranges from 0 to 1.

Where "AVP" is the average validity percentage.

Where "E_i" is the estimated/predicted value.

Where "C_i" is the actual value.

Where "n" is the number of observations.

Applying real values from the completed projects and the developed model to the equations shows that, AIP is 0.099 and AVP is 0.901. The value of AVP shows the accuracy of the developed model as 90.1%, which is satisfactory. Therefore, the developed model is robust in predicting the cost of risks.

4.6 Chapter summary

This chapter discussed the presentation of results, analysis of results, interpretation of results, model development and verification.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The chapter presents a summary of the findings, conclusions, recommendations and limitations of the study in relation to the objectives and reviewed literature.

5.2 Summary of the findings

The study revealed that the top five risk factors with the most severe effect in cost estimation in the building construction industry in Uganda are: inflation, proficiency in estimating, cost of materials, incomplete design and specification, fraudulent practices and kickbacks.

Furthermore, based on the frequency of occurrence and severity of the factors, the study also revealed that the top five most important risk factors in cost estimation in the building construction industry in Uganda are: cost of materials, inflation, fraudulent practices and kickbacks, incomplete scope definition, incomplete design and specification.

The total cost of risk estimated by the model for the fifteen most important risk factors in cost estimation in the building construction industry in Uganda represents 59.4% of the total project cost while the average cost of risk represents 4.0% of the total project cost. Sensitivity analysis was performed on the model and it was found to be reliable for use in estimating the cost of risk.

5.3 Conclusions of the study

This subsection presents the conclusions of the study on the improvement of risk management in cost estimation in the building construction industry in Uganda.

5.3.1 Risk factors in cost estimation

The study set out to establish the risk factors in cost estimation in the building construction industry in Uganda. The study concluded that the top five most important risk factors in cost estimation are: cost of materials, inflation, fraudulent practices and kickbacks, incomplete scope definition and incomplete design and specification.

5.3.2 Effects of the risk factors in cost estimation

The study aimed to assess the effects of the risk factors in cost estimation in the building construction industry in Uganda. Therefore, according to the study, the risk factors with the most severe effects in cost estimation are: inflation, proficiency in estimating, cost of materials, incomplete design and specification and fraudulent practices and kickbacks.

5.3.3 Developing a reliable model for risk-based cost estimation

A reliable model for risk-based cost estimation was developed based on the Analytic Hierarchy Process (AHP) and taking into account the most important risk factors in cost estimation in the building construction industry in Uganda. Considerable research has focused on the risk factors but these factors have not been used effectively to estimate the cost of risk. The developed model would help in estimating the cost of risk on a justifiable basis thereby eliminating the random and deterministic allocation of 0% - 10% of the project cost to cater for risks.

However, using the developed model to estimate the cost of risk does not discharge the project stakeholders namely, the client, consultant and contractor of their responsibilities to properly manage the risk factors involved so as to reduce their likelihood of occurrence and effect on a project.

5.4 Recommendations and further research

More research needs to be done on the efficiency and effectiveness of models for risk-based cost estimation. This will help in establishing a reasonable and standard system for estimating the costs of risk so as to deal with the challenges of under estimation and over estimation in Uganda's building construction industry.

Clients should always endeavour to seek the services of reputable construction professionals to manage their projects right from the initiation phase to the closing phase. Furthermore, construction professionals should properly identify and reduce risk factors during the early phases of a project and ensure that there is sufficient information for use in the cost estimation process. This will result in good cost performance and low financial risks due to reliable cost estimates.

5.5 Limitations of the study

The study was limited to only building construction projects within Kampala. Carrying out similar research in different regions of the country and also on civil engineering projects would help to understand the variation in risk factors and their associated costs. Wider testing and application of the model would also inform whether the findings are generalizable.

5.6 Contributions of the study

Previous studies have focused on risk factors and cost overruns but the risk factors have not been used effectively to estimate the costs of risk in order to improve cost performance of projects. This study has helped to reveal the need for a justifiable and defendable method of estimating the costs of risks involved in a project. The developed model can be used by construction professionals to improve accuracy of cost estimates and general cost performance of projects.

The study has also helped in covering literature gaps by providing empirical evidence and information for further research.

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APPENDICES

APPENDIX 1: QUESTIONNAIRE

INTRODUCTION

Dear Respondent,

I am a student of Kyambogo University conducting a research on the **“Assessment of risk management in cost estimation in the building construction industry in Uganda”** in partial fulfilment for the award of a Master’s degree in Construction Technology and Management.

The specific objectives of the study are:

i) To establish the risk factors in cost estimation in the building construction industry in Uganda.

ii) To assess the effects of the risk factors in cost estimation in the building construction industry in Uganda.

iii) To develop a reliable model that can be used for risk based cost estimation in the building construction industry in Uganda.

I wish to let you know that you have been selected as one of the key respondents to assist in providing essential data required for this activity. I kindly request you to spare a few minutes and answer the attached questionnaire. The information obtained will be used for academic purposes only, will be treated with utmost confidentiality and respondents will not in any way be identified.

Thank you for your support.

Yours faithfully,

Draleti Gerald

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PART I

SECTION A: General Information

1. What is your gender?

Male ( ) Female ( )

2. What is your age bracket?

21 – 30 ( )

31– 40 ( )

41 – 50 ( )

Over 50 years ( )

3. What is your designation?

Project Manager ( )

Quantity Surveyor ( )

Architect ( )

Civil Engineer ( )

Electrical Engineer ( )

Mechanical Engineer ( )

4. State your highest level of education?

Diploma ( )

Degree ( )

Post graduate ( )

Others ( )

If others please specify …………………………………………….....

5. How many years of experience do you have in the building construction industry?

Below 5 years ( )

6-10 years ( )

11-15 years ( )

16 years and above ( )

SECTION B: Effect of risk factors in cost estimation

6. Using a Likert 1 – 5 scale, to what extent do the following factors influence cost estimation in the building construction industry in Uganda? Please tick the most appropriate to indicate your position.

No.	Factors	Very small (1)	Small (2)	Medium (3)	High (4)	Extreme (5)
1	Project complexity					
2	Type of project					
3	Project duration					
4	Project location					
5	Size of project					
6	Incomplete scope definition					
7	Proficiency in estimating					
8	Unforeseen adverse ground conditions					
9	Lack of experience on similar project					
10	Quality and type of cost data					
11	Current work load					
12	Site constraints (access, storage, services)					
13	Financial capability of the client					
14	Availability of materials					
15	Availability of labour					

16	Availability of equipment					
17	Suitability of equipment					
18	Cost of equipment					
19	Cost of labour					
20	Cost of materials					
21	Level of workmanship (productivity and performance)					
22	Design changes					
23	Bad weather					
24	Estimation method used					
25	Quality of assumptions used in preparing estimates					
26	Incomplete design and specification					
27	Error in design and specification					
28	Inadequate tendering period					
29	Number of bidders					
30	Government policies					
31	Inflation					
32	Fluctuation of market conditions					
33	Type of bidding					
34	Contract procedure and conditions					
35	Changes in owner's requirements					
36	Fraudulent practices and kickbacks					

SECTION C: Frequency of cost overruns arising from risk factors

7. Using a Likert 1 – 5 scale, what is the frequency of occurrence of cost overruns arising from risk factors in the building construction industry in Uganda? Please tick the most appropriate to indicate your position.

No.	Factors	Very rarely (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
1	Project complexity					
2	Type of project					
3	Project duration					
4	Project location					
5	Size of project					
6	Incomplete scope definition					
7	Proficiency in estimating					

8	Unforeseen adverse ground conditions					
9	Lack of experience on similar project					
10	Quality and type of cost data					
11	Current work load					
12	Site constraints (access, storage, services)					
13	Financial capability of the client					
14	Availability of materials					
15	Availability of labour					
16	Availability of equipment					
17	Suitability of equipment					
18	Cost of equipment					
19	Cost of labour					
20	Cost of materials					
21	Level of workmanship (productivity and performance)					
22	Design changes					
23	Bad weather					
24	Estimation method used					
25	Quality of assumptions used in preparing estimates					
26	Incomplete design and specification					
27	Error in design and specification					
28	Inadequate tendering period					
29	Number of bidders					
30	Government policies					
31	Inflation					
32	Fluctuation of market conditions					
33	Type of bidding					
34	Contract procedure and conditions					
35	Changes in owner’s requirements					
36	Fraudulent practices and kickbacks					

8. Based on your experience and to the best of your knowledge, which other factors influence cost estimation in the building construction industry in Uganda and yet not covered in this questionnaire?

………
………
………
………

PART II

In this part of the questionnaire, the risk factors have been disintegrated by structuring them into a hierarchy of criteria and sub criteria as shown in the table below. You are required to make pairwise comparisons of the factors in each level of the hierarchy using a Saaty scale of 1 – 9 where;

1 means equal importance.

2 means weak or slight importance.

3 means moderate importance.

4 means moderate plus importance.

5 means strong importance.

6 means strong plus importance.

7 means very strong importance.

8 means very, very strong importance.

9 means extreme importance.

Summary of criteria and sub-criteria of risk factors

Criteria	**Sub-criteria**
Project characteristics	Project complexity
	Type of project
	Project duration
	Project location
	Size of project
Estimating process	Incomplete scope definition
	Proficiency in estimating
	Lack of experience on similar project
	Quality & type of cost data
	Current work load
	Site constraints
	Cost of equipment
	Cost of labour
	Cost of materials
	Estimating method used
	Quality of assumptions used
	Inadequate tendering period
Design	Design changes
	Incomplete design & specification
	Error in design & specification
Bidding procedure	Number of bidders
	Type of bidding
	Contract procedure & conditions
Financial	Financial capability of the client
	Inflation
	Fluctuation of market conditions
Personal factors	Availability of materials
	Availability of labour
	Availability of equipment
	Suitability of equipment
	Changes in owner's requirements
	Level of workmanship
External	Unforeseen adverse ground conditions
	Bad weather
	Government policies
	Fraudulent practices and kickbacks

SECTION A: Pairwise comparisons of the criteria

1. Using a Saaty 1 – 9 scale, which criterion is more important in each pairwise comparison and by how much? Please make check marks at the numbers representing the intensity of importance to indicate your position.

Project characteristics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Estimating process**

Project characteristics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Design**

Project characteristics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Bidding procedure**

Project characteristics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Financial**

Project characteristics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Personal factors**

Project characteristics	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**External**

Estimating process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Design**

Estimating process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Bidding procedure**

Estimating process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Financial**

Estimating process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Personal factors**

Estimating process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**External**

Design	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Bidding procedure**

Design	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Financial**

Design	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Personal factors**

Design	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**External**

Bidding procedure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Financial**

Bidding procedure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Personal factors**

Bidding procedure	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**External**

Financial	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Personal factors**

Financial	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**External**

Personal factors	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**External**

SECTION B: Pairwise comparisons of the sub-criteria in terms of project characteristics

2. Using a Saaty 1 – 9 scale, which sub-criterion is more important in each pairwise comparison and by how much? Please make check marks at the numbers representing the intensity of importance to indicate your position.

Project complexity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Type of project**

Project complexity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Project duration**

Project complexity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Project location**

Project complexity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Size of project**

Type of project	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Project duration**

Type of project	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Project location**

Type of project	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Size of project**

Project duration	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Project location**

Project duration	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Size of project**

Project location	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Size of project**

SECTION C: Pairwise comparisons of the sub-criteria in terms of estimating process

3. Using a Saaty 1 – 9 scale, which sub-criterion is more important in each pairwise comparison and by how much? Please make check marks at the numbers representing the intensity of importance to indicate your position.

Incomplete scope definition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Proficiency in estimating**

Incomplete scope definition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Lack of experience on similar project**

Incomplete scope definition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Quality & type of cost data**

Incomplete scope definition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Current work load**
Incomplete scope definition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Site constraints**

Incomplete scope definition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of equipment**

Incomplete scope definition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of labour**

Incomplete scope definition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of materials**

Incomplete scope definition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Estimating method used**

Incomplete scope definition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Quality of assumptions used**

Incomplete scope definition	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inadequate tendering period**

Proficiency in estimating	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Lack of experience on similar project**

Proficiency in estimating	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Quality & type of cost data**

Proficiency in estimating	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Current work load**

Proficiency in estimating	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Site constraints**

Proficiency in estimating	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of equipment**

Proficiency in estimating	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of labour**

Proficiency in estimating	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of materials**

Proficiency in estimating	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Estimating method used**

Proficiency in estimating	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Quality of assumptions used**

Proficiency in estimating	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inadequate tendering period**

Lack of experience on similar project	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Quality & type of cost data**

Lack of experience on similar project	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Current work load**

Lack of experience on similar project	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Site constraints**

Lack of experience on similar project	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of equipment**

Lack of experience on similar project	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of labour**

Lack of experience on similar project	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of materials**

Lack of experience on similar project	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Estimating method used**

Lack of experience on similar project	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Quality of assumptions used**

Lack of experience on similar project	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inadequate tendering period**

Quality & type of cost data	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Current work load**

Quality & type of cost data	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Site constraints**

Quality & type of cost data	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of equipment**

Quality & type of cost data	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of labour**

Quality & type of cost data	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of materials**

Quality & type of cost data	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Estimating method used**

Quality & type of cost data	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Quality of assumptions used**

Quality & type of cost data	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inadequate tendering period**

Current work load	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Site constraints**

Current work load	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of equipment**

Current work load	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of labour**

Current work load	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of materials**

Current work load	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Estimating method used**

Current work load	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Quality of assumptions used**

Current work load	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inadequate tendering period**

Site constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of equipment**

Site constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of labour**

Site constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of materials**

Site constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Estimating method used**

Site constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Quality of assumptions used**

Site constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inadequate tendering period**

Cost of equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of labour**

Cost of equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of materials**

Cost of equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Estimating method used**

Cost of equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Quality of assumptions used**

Cost of equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inadequate tendering period**

Cost of labour	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Cost of materials**

Cost of labour	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Estimating method used**

Cost of labour	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Quality of assumptions used**

Cost of labour	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inadequate tendering period**

Cost of materials	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Estimating method used**

Cost of materials	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Quality of assumptions used**

Cost of materials	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inadequate tendering period**

Estimating method used	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Quality of assumptions used**

Estimating method used	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inadequate tendering period**

Quality of assumptions used	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inadequate tendering period**

SECTION D: Pairwise comparisons of the sub-criteria in terms of design

4. Using a Saaty 1 – 9 scale, which sub-criterion is more important in each pairwise comparison and by how much? Please make check marks at the numbers representing the intensity of importance to indicate your position.

Design changes	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Incomplete design & specification**

Design changes	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Error in design & specification**

Incomplete design & specification	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Error in design & specification**

SECTION E: Pairwise comparisons of the sub-criteria in terms of bidding procedure

5. Using a Saaty 1 – 9 scale, which sub-criterion is more important in each pairwise comparison and by how much? Please make check marks at the numbers representing the intensity of importance to indicate your position.

Number of bidders	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Type of bidding**

Number of bidders	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Contract procedure & conditions**

Type of bidding	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Contract procedure & conditions**

SECTION F: Pairwise comparisons of the sub-criteria in terms of financial factors

6. Using a Saaty 1 – 9 scale, which sub-criterion is more important in each pairwise comparison and by how much? Please make check marks at the numbers representing the intensity of importance to indicate your position.

Financial capability of the client	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Inflation**

Financial capability of the client	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Fluctuation of market conditions**

Inflation	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Fluctuation of market conditions**

SECTION G: Pairwise comparisons of the sub-criteria in terms of personal factors

7. Using a Saaty 1 – 9 scale, which sub-criterion is more important in each pairwise comparison and by how much? Please make check marks at the numbers representing the intensity of importance to indicate your position.

Availability of materials	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Availability of labour**

Availability of materials	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Availability of equipment**

Availability of materials	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Suitability of equipment**

Availability of materials	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Changes in owner’s requirements**

Availability of materials	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Level of workmanship**

Availability of labour	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Availability of equipment**

Availability of labour	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Suitability of equipment**

Availability of labour	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Changes in owner's requirements**

Availability of labour	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Level of workmanship**

Availability of equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Suitability of equipment**

Availability of equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Changes in owner's requirements**

Availability of equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Level of workmanship**

Suitability of equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Changes in owner's requirements**

Suitability of equipment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Level of workmanship**

Changes in owner's requirements	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Level of workmanship**

SECTION H: Pairwise comparisons of the sub-criteria in terms of external factors

8. Using a Saaty 1 – 9 scale, which sub-criterion is more important in each pairwise comparison and by how much? Please make check marks at the numbers representing the intensity of importance to indicate your position.

Unforeseen adverse ground conditions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Bad weather**

Unforeseen adverse ground conditions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Government policies**

Unforeseen adverse ground conditions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Fraudulent practices and kickbacks**

Bad weather	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Government policies**

Bad weather	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Fraudulent practices and kickbacks**

Government policies	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Fraudulent practices and kickbacks**

Thank you for your time and cooperation

APPENDIX 2: INTERVIEW GUIDE

Dear respondent, this research is aimed at **"Assessment of risk management in cost estimation in the building construction industry in Uganda"**. You are kindly requested to be part of it by expressing your views in this interview.

The information obtained will be used for academic purposes only, will be treated with utmost confidentiality and respondents will not in any way be identified.

Thank you for your support.

Yours faithfully,

Draleti Gerald

1. What risk management techniques do you use on construction projects?

   ………

   ………

   ………
2. How effective are these techniques in risk management?

   ………

   ………

   ………
3. What risk management software do you use?

   ………

   ………

   ………
4. How do you manage risks during cost estimation?

   ………

   ………

   ………
5. What cost estimation methods do you use?

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6. What cost estimation software do you use?

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7. Any general comment with regard to improvement of risk management in cost estimation in the building construction industry in Uganda?

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.....………………………………………………...……

……………………………………………..

Thank you for your time and cooperation