

Improvement of Risk Management in Cost Estimation in the Building Construction Industry in Uganda

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Abstract: The cost performance of construction projects is a crucial success factor. However, risks in construction projects make exact budgetary requirements challenging to forecast accurately, resulting in underestimation and overestimation. Inaccurate cost estimates could further result in unnecessary financial loss to project stakeholders and the 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. However, this method is sometimes unreliable and difficult to justify to project owners. Therefore, there is a need for a reliable and justifiable risk-based cost estimation method. The current study aimed to improve risk management in cost estimation in the building construction industry in Uganda. The specific objectives were to establish the risk factors, assess the effects of the risk factors and develop a reliable model that can be used for risk-based cost estimation in the building construction industry in Uganda. The study adopted a mixed-method approach by utilising quantitative and qualitative research methods. The collection of data was done using a self-administered questionnaire and an interview guide. The data was first sorted, coded and entered for analysis using the Statistical Package for the Social Sciences (SPSS) and Microsoft Excel. The risk factors in cost estimation were identified through a detailed literature review. The study revealed that the top five risk factors influencing cost estimation were: cost of materials, inflation, fraudulent practices and kickbacks, incomplete scope definition, and incomplete design and specification. The study concluded that the risk factors with the most severe effects on cost estimation were inflation, proficiency in estimating, cost of materials, incomplete design and specification, fraudulent practices and kickbacks. The study proposed a model developed using the analytic hierarchy process (AHP). The study recommends more research on the efficiency and effectiveness of risk-based cost estimation models.

Keywords: Ugandan construction industry, Risk management, Cost estimation, Risk-based cost estimation, Analytic hierarchy process (AHP)

INTRODUCTION

The construction industry is one of the major sectors that contributes to the economic transformation of countries worldwide. For example, the development of physical infrastructure can measure the pace of economic growth of a nation. In Uganda, the construction industry contributed 5.2% to the total gross domestic product (GDP) in 2020/2021 compared to 5.5% in 2019/2020 (Uganda Bureau of Statistics, 2021). The construction industry is subjected to more risk and uncertainty than other

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sectors as they cause projects to surpass their estimated budgets (Abdel-Monem, Alshaer and El-Dash, 2022). Uganda's construction industry is diverse and faces the challenges of cost and time overruns (CoST, 2017). Project cost and time overruns put the competence and integrity of construction professionals who plan and predict costs in doubt (Ajator, 2017). Despite all the knowledge and best practices in project management, most projects still do not meet their cost objectives (Herszon and Keraminiyage, 2014). This is evident in recent studies by many researchers.

In another research to investigate the influence of negotiation strategies on construction cost overruns, Kepher, Nyonje and Rambo (2022) stated that even with the engagement of construction professionals, cost overruns still provide a significant challenge in the construction industry. Dlamini and Cumberlege's (2021) study aimed at finding the critical competency skills that project managers must possess found that one of the significant problems in the construction industry is cost overruns which negatively impact contractual stakeholders. Referring to Xie et al. (2022), in a study aimed at developing a fuzzy model for evaluating the critical factors of cost overruns for construction projects, it was concluded that the construction industry has poor cost performance in finishing projects within budget. As described by Kamau, Gesimba and Gichuhi (2022), they sought to establish the influence of cost control on the realisation of government projects and the available data showed that projects are riddled with cost overruns. Furthermore, a study aimed at assessing the critical factors affecting the performance of construction projects stated that cost overruns are one of the challenges construction projects face (Bahati and Kwena, 2023). To an average Ugandan, foul play or corruption is usually suspected given the size of cost overruns.

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 over time (Ojo and Odediran, 2015). Therefore, a model that incorporates risks in cost estimation may be beneficial in addressing this limitation in the building construction industry in Uganda.

LITERATURE REVIEW

Risk Factors in Construction

Many definitions of risk exist in common usage. According to the International Organization for Standardization (2009), risk is the effect of uncertainty on objectives. Project Management Institute (2013a) 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 impact cost, time and quality in varying degrees (Ajator, 2017). Due to inherent risks, construction projects fail to be completed within the agreed time and budget (Chileshe and Kikwasi, 2013). For example, the construction industry in Uganda faces 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% to 10% in building projects are routinely inadequate to contain up to 52% cost overruns.

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 greater than 0% but less than 100% that will affect at least one of the project objectives (Rezakhani, 2012). Therefore, risk factors must be evaluated during cost estimation to develop a more realistic project estimate. According to Umutoni (2014), the 10 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.

In a study aimed at identifying the risk factors affecting construction project performance, Tessema, Alene and Wolelaw (2022), concluded that the risk factors with the highest magnitude of impact were: inflation and price increases, flawed design, poor material quality, delayed payment to the contractor and subpar work. Meanwhile, the study found that those with the most negligible magnitude of impact were labour strikes, lack of a clear scope of work, delays in acquiring site access and lack of site access. In addition, the study further stated that the most significant risk factors for building projects were construction and design risk, poor management, insufficient funding, uncertain political conditions, lack of economics in the project budget, lack of law and order, and an unfavourable climate.

Srinivasan et al. (2022) grouped risk factors into labour risk, material risk, credit risk, execution risk, environmental risk and planning risk. On the other hand, Sankar and Shashikanth (2022) categorised risk factors as cost-related risks, time-related risks, quality-related risks, environmental-related risks, design-related risks, safety-related risks and risks due to unexpected incidents or crises. Ajator (2014) stated that risk factors in construction can be categorised as technological, social, physical, economic and political. They may be internal or external risk factors. Internal risk factors are those within the organisation's control and include its human, financial, physical, technological, and managerial value and ethics. On the other hand, external risk factors are those outside an organisation's control. They are political, macro-economic, environmental, competition and multiple client project risks.

According to Kepher, Nyonje and Rambo (2022), risk factors can be viewed from the perspective of project estimates, project designs, project plans, changes in project scope and administration of projects. The success and failure of construction projects are dependent on many factors. Still, the project manager is considered to directly complete a project within time and budgeted cost (Dlamini and Cumberlege, 2021). While Nguyen et al. (2021) categorised risk factors into five groups: financial risk factors, schedule risk factors, construction risk factors, management risk factors and environmental risk factors, Eja and Ramegowda (2020) concluded that risk factors causing construction project failure include poor financial capacity, corruption, inaccurate costing, frequent design scope changes and errors, sociocultural and political interference, poor contracting and contractor practices, incompetence and lack of knowledge, poor planning, poor leadership and poor communication.

Other researchers have done further categorisation of risk factors. For example, Chapman (2001) grouped risk into environment, industry, client and project. Risk can also be grouped into competition, technical, construction,

operational, market, financial, demand, supply, institutional, regulatory, social acceptability and sovereign risks (Miller and Lessard, 2001). Karim et al. (2012) identified twenty-five risk factors and categorised them into five groups: design, construction, politics and contract provision, finance and environmental.

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. However, achieving project objectives is crucial to the parties involved and, most significantly, the client.

Cost estimating is essential for contracting and making investment decisions. When costs are overestimated, clients 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 result in the incurring of losses and project abandonment. In a study by Ofim et al. (2011), underestimation is considered one of Uganda's leading causes of uncompleted buildings. One of the challenges in estimating for public sector construction projects in Uganda is that bidders make overly optimistic estimates to win the business.

There are different definitions of cost estimation in usage by experts and researchers. Project Management Institute (2013b) defines cost estimation as the development of an approximation (estimate) of costs of the resources needed to complete project activities. It is the basis for project management, business planning, budget preparation and cost and schedule control (AACE [Association for the Advancement of Cost Engineering], 2013). According to Choon and Ali (2008), cost estimating examines a specific scope of work and forecasts 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 influencing cost during a construction project's conception and design stages have mainly been attributed to cost-estimating practices (Doloi, 2012).

The construction industry has a poor reputation for finishing projects on budget. A total of 9 out of 10 projects usually experience cost overruns, with poor cost estimation considered one of the leading causes (Aljohani, Ahiaga-Dagbui and Moore, 2017). In his study, Ssemwogerere (2011) asserted that most projects in Uganda are usually completed with a 25% to 35% increase in the initial cost.

Risk factors in cost estimation

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

Hatamleh et al. (2018) categorised 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 the financial capability of the client, site constraints (access, storage, and 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 detailed drawings and specifications, experience of pricing projects, accuracy and reliability of cost information, project 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 on 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 under the cost estimating group include the 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 human resources, frequent changes in design, contractual procedure, duration of the contract period, fraudulent practices and kickbacks, additional work and contract management. Risk factors related to construction parties include on-site disputes, poor financial control on site, previous contract experience, the relationship between managers and labourers, lack of coordination between construction parties and poor planning. Environmental risk factors in cost estimation include weather effects, 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 rates.

Xie et al. (2022) identified 36 risk factors and classified them into four groups: project management, project macro, project environment and core stakeholders. According to Atapattu, Domingo and Sutrisna (2023), the risk factors with the most significant effect on the cost of construction projects are project management, risk assessment, cost-benefit analysis, construction management, time overrun, decision-making and design/methodology/approach. Meanwhile, Seidu et al. (2022) identified the following risk factors in cost estimation: mistakes in design, unforeseen site conditions, changes in the client's brief, construction cost underestimation, improper planning, inflation, inaccurate or poor estimation, omissions and errors in the bills of quantities, contractual claims, unsuitable construction equipment and methods, force majeure and lack of experience for contractors. As described by Ibrahim and Mohamed (2021), the most significant risk factors affecting cost estimation are clear and detailed drawings, specifications and project documentation, experience and skill level of the estimator, completeness of cost information (accuracy, quality and details), materials (prices, availability, quality and imports) and experience on similar projects.

According to Kwoyigah, Alagidede and Amidu (2021), cost and associated risks are an essential consideration for all construction projects. Their study showed that changes in building material prices remain the key risk factor. In contrast, other factors include changes in project specification and design, inadequate budget analysis and lack of project management skills. Albtoush and Doh (2019)

classified risk factors into 10 main groups, namely: design and contracted-related factors, estimation-related factors, planning and schedule-related factors, project management-related factors, labour-related factors, financial related factors, material and machinery-related factors, construction phase related factors, communication-related factors and external related factors. In addition, 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 the 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) categorised risk factors into physical risk factors, construction risk factors and financial risk factors. Construction risk factors affect a project's equipment/plant and labour. 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 project's physical nature 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 32 risk factors in cost estimation and further grouped them into six categories which are project characteristics, bidding procedure, project design, estimating process, financial and personal factors.

METHODOLOGY

Research Design

The study adopted a mixed-method approach using quantitative and qualitative research methods. Qualitative research seeks to understand underlying reasons, opinions and motivations to uncover trends in thought and ideas. Qualitative data can be collected through in-depth interviews, focus group discussions and key informant interviews (Wyse, 2011). Qualitative data for this study was collected through in-depth face-to-face interviews. A 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 approach helped in understanding the risk factors and their causes.

On the other hand, quantitative research seeks to quantify a problem by generating numerical data that can be transformed into useable statistics. It is used to quantify attitudes, opinions, behaviours and other defined variables to formulate facts and uncover patterns in research. Quantitative data can be collected through face-to-face interviews, telephone, online surveys, paper surveys, online polls and systematic observations (Wyse, 2011). Quantitative data for this study was collected using a self-administered questionnaire.

Target Population

The target population of the current study comprised project managers, architects, civil engineers, quantity surveyors, electrical engineers and mechanical engineers who worked with consultancy and construction firms with vast experience in building construction projects within Kampala City. Based on information from the Architects Registration Board, Engineers Registration Board and Surveyors Registration Board, the number of registered and practising architects with valid practising licenses was 143, civil engineers were 717, electrical engineers were 148, mechanical engineers were 109 and quantity surveyors were 69 in 2021.

Sample Size

Researchers have been using the Kish (1965) formula to determine the sample size for their studies (e.g., Adesi, Owusu-Manu and Boateng, 2019; Bolstein and Crow, 2008; Ashmawi et al., 2018). The Kish Formula was utilised in this study because the formula allowed better results and was more resistant to outliers than other formulas (Akinshin, 2021). The Kish formula is stated as Equation 1 and Equation 2.

$$n_o = \frac{pq}{S^2} \quad \text{Eq. 1}$$

$$n = \frac{n_o}{1 + \frac{n_o}{N}} \quad \text{Eq. 2}$$

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 standard error allowed for the sample mean, N is the target population size and 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 and q , and substituting 0.1 for S , a value of 25 was determined as the first estimate of the sample (n_o).

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

Using this number in Equation 2 and substituting the target population size (N) with different groups, the final estimates of the sample size (n) are shown in Table 1.

Table 1. Sample size

| Study Group | Study Population (N) | Sample Size (n) | % |
|----------------------|----------------------|-----------------|-----|
| 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 |

Data Collection

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

A self-administered questionnaire is a questionnaire that is explicitly designed to be completed by a respondent without the intervention of the researcher and the primary criterion for a well-designed self-administered questionnaire is proper wording (Lavrakas, 2008). A self-administered questionnaire was used to collect both qualitative and quantitative data from project managers, architects, quantity surveyors, civil engineers, electrical engineers and mechanical engineers. 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.

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. The interview method helps the researcher to collect in-depth information on people's opinions, thoughts and experiences (Easwaramoorthy and Zarinpoush, 2006). The following questions were asked concerning 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?" and "Any general comment regarding improving risk management in cost estimation in the building construction industry in Uganda?"

Data collection instruments

A questionnaire and interview guide were used as tools for data collection. An interview guide is used where there is a need for in-depth information from the respondents (Easwaramoorthy and Zarinpoush, 2006). The questionnaire was designed to have two parts: Part 1 and Part 2. Part 1 of the questionnaire was created based on the risk factors in cost estimation identified through the literature review. The respondents were asked to rank them based on their frequency index,

severity index and importance index to obtain the most critical risk factors. Part 2 of the questionnaire was used to obtain weights of the most important risk factors using pairwise comparisons based on Saaty's (1980) scale of the analytic hierarchy process (AHP), as shown in Table 2.

Table 2. Saaty's 1 to 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 to 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)

Data Analysis

Statistical Package for the Social Sciences (SPSS) and Microsoft Excel were used for analysing the data. Data from the collected questionnaires were first sorted, coded and entered into the SPSS software and Microsoft Excel for further statistical analysis. On the other hand, content analysis was manually conducted to analyse

data collected from face-to-face interviews. According to Haggarty (1996), content analysis is a method that allows the qualitative data collected in research to be analysed systematically and reliably so that generalisations can be made from them in relation to the categories of interest to the researcher.

The severity index and frequency index of the risk factors perceived by the respondents were calculated using Equation 3 and Equation 4.

$$SI (\%) = \sum a (n/N) \times 100/5 \quad \text{Eq. 3}$$

where, SI is the severity index, a is the scale given for each option (ranges from 1 to 5), n is the frequency of the response and N is the total number of respondents.

$$FI (\%) = \sum a (n/N) \times 100/5 \quad \text{Eq. 4}$$

where, FI is the frequency index, a is the scale given for each option (ranges from 1 to 5), n is the frequency of the response and N is the total number of respondents.

Importance index (IMPI) was used to determine the importance index of each risk factor to get the most important factors using Equation 5.

$$IMPI (\%) = [FI (\%) \times SI (\%)]/100 \quad \text{Eq. 5}$$

Model Development

Many researchers (e.g., El-Touny, Ibrahim and Amer, 2014; Idrus, Nuruddin and Rohman, 2011; Challal and Tkiouat, 2012; Asal, 2014; Buertey, 2014; Allahaim, Liu and Kong, 2016) have developed and proposed models to deal 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, Ibrahim and Amer, 2014).

Risk-based cost estimation involves using 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 DOT, 2021). The AHP developed by Saaty (1980) was used to develop the model for this research. The AHP is an effective tool for decision-making and may aid the decision-maker in setting priorities and making the best decision. It helps make multi-criteria decisions involving benefits, opportunities, costs and risks. The AHP has also been applied in planning, resource allocation, conflict resolution, and prediction problems (Saaty, 1980). It was selected for its reliability and ease of use. The proposed model was developed using the following steps:

1. Establishing the objectives.
2. Identifying all relevant criteria.
3. Decomposing the risk factors identified by structuring them into a main hierarchy of criteria and sub-criteria as shown in Figure 1.
4. Developing a pairwise comparison matrix by comparing pairs of elements in each level of the hierarchy concerning every element in the higher level to establish priority weights of elements in each level of the hierarchy. The pairwise

- comparison reflects the judgments and relative preferences of different decision-makers based on Saaty's (1980) scale of 1 to 9, as shown in Table 2.
5. Normalising the matrix by totalling the numbers in each column. Each entry in the column was then divided by the column sum to get the normalised score.
 6. Computing priority weights of criteria and sub-criteria by totalling the numbers in each row of the normalised matrix. The sum of each row was then divided by the matrix dimension to get the priority weights.
 7. Checking decision consistency by computing the consistency ratio.

Table 3. Values of random consistency index

| <i>n</i> | Random Consistency Index |
|----------|--------------------------|
| 1 | – |
| 2 | – |
| 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)

$$CI = \frac{(\max - n)}{(n - 1)} \tag{Eq. 6}$$

where, CI is the consistency index, *n* is the number of the matrix dimension and 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 was summed to get the consistency measure.

$$\text{Consistency ratio} = \frac{CI}{RCI} \tag{Eq. 7}$$

where, CI is the consistency index and 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. The risk-based cost estimation model was developed using Equation 8.

$$CR = RW \times FI \times SI \tag{Eq. 8}$$

where, CR represents cost of risk, RW represents the relative weight of the factor/category, FI represents the frequency index of the factor and SI represents the severity index of the factor.

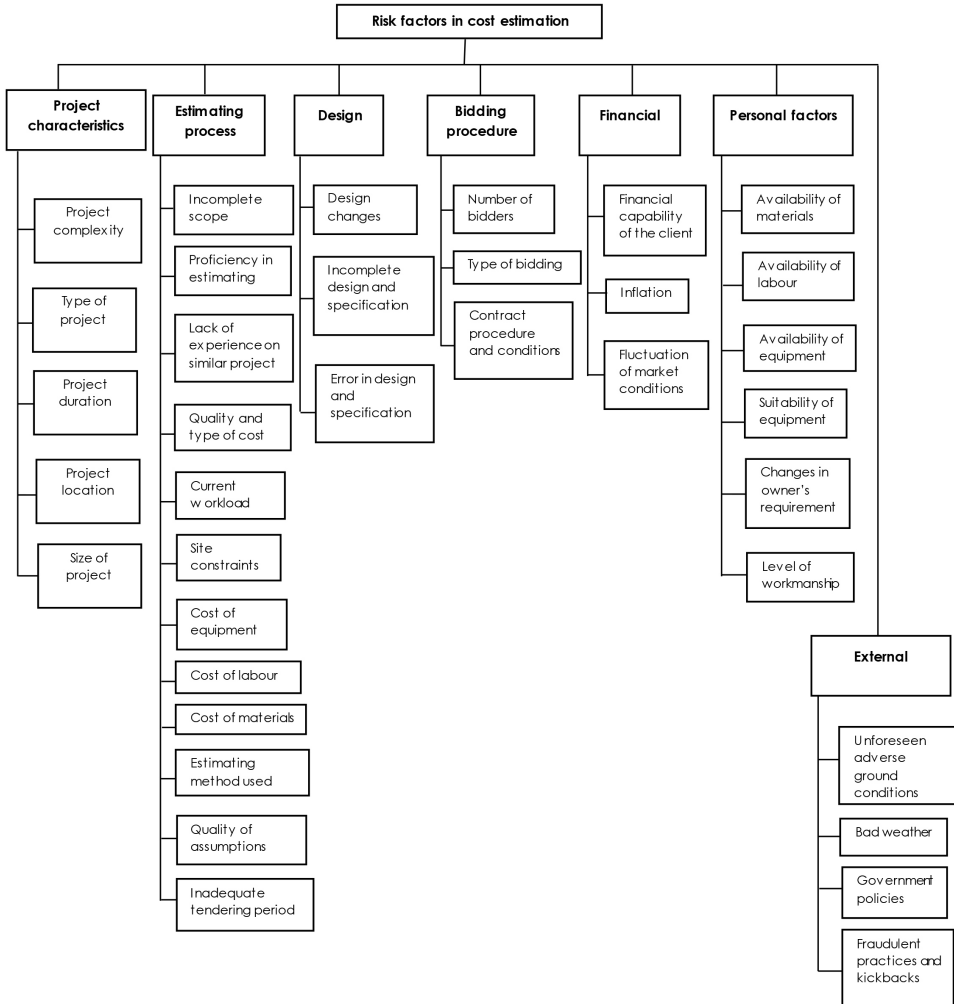


Figure 1. Hierarchy of the 36 risk factors in cost estimation identified through literature review

Model Verification

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, and 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 in the output variables. In the current study, a sensitivity analysis was performed to test the reliability of the developed model.

RESULTS AND FINDINGS

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 recorded in Table 4, which according to Gordon et al. (2002) is a good response rate. The years of experience that the respondents had in the building construction industry are shown in Table 5. The finding in Table 5 demonstrates that the respondents had vast years of experience since a combined total of 89.8% of the respondents had worked for more than five years and therefore believed to have provided reliable data for this study.

Table 4. 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 |

Table 5. Years of experience

| Experience | Frequency | % | Cumulative % |
|----------------------|------------------|----------|---------------------|
| Less than five years | 11 | 10.2 | 10.2 |
| 6 years to 10 years | 39 | 36.1 | 46.3 |
| 11 years to 15 years | 45 | 41.7 | 88.0 |
| 16 years and more | 13 | 12.0 | 100.0 |
| Total | 108 | 100.0 | |

Establishing the Risk Factors in Cost Estimation

Risk factors in construction projects greatly depend on the nature of the project, thus, identifying all the potential risk factors may be challenging. It is however possible to identify the risk factors by analysing previous studies (Riveros et al., 2022). The risk factors in cost estimation were established through a literature review, which guided the questionnaire design for the study. A total of 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 the 36 identified through the literature review.

Assessing the Effects of the Risk Factors on Cost Estimation

Severity index was used to evaluate the impact of the risk factors in cost estimation, and the factors were ranked based on the severity of their effects, as shown in Table 6.

Table 6. Degree of severity of the risk factors in cost estimation

| No. | Risk Factors in Cost Estimation | Degree of Severity | |
|------------|----------------------------------------|---------------------------|-------------|
| | | SI (%) | 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 |

(Continued on next page)

Table 6. Continued

| No. | Risk Factors in Cost Estimation | Degree of Severity | |
|-----|-----------------------------------------------------|--------------------|------|
| | | SI (%) | Rank |
| 9 | Lack of experience in a similar project | 66.67 | 20 |
| 10 | Quality and type of cost data | 70.74 | 14 |
| 11 | Current workload | 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 |

The results in Table 6 show that the most severe risk factors in cost estimation in the building construction industry in Uganda were 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%).

Frequency of Occurrence of Cost Overruns Due to the Risk Factors in Cost Estimation

The frequency index was used to determine the frequency of occurrence of cost overruns because of the risk factors in cost estimation. The factors were ranked as indicated by the respondents and the results are shown in Table 7.

Table 7. Frequency of occurrence of cost overruns due to the risk factors in cost estimation

| No. | Risk Factors in Cost Estimation | Frequency of Occurrence | |
|-----|-----------------------------------------------------|-------------------------|------|
| | | FI (%) | 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 in a similar project | 66.67 | 16 |
| 10 | Quality and type of cost data | 66.67 | 16 |
| 11 | Current workload | 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 |

(Continued on next page)

Table 7. Continued

| No. | Risk Factors in Cost Estimation | Frequency of Occurrence | |
|-----|------------------------------------|-------------------------|------|
| | | FI (%) | Rank |
| 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 |

The findings in Table 7 show that the risk factors with the highest frequency index for the occurrence of cost overruns in the building construction industry in Uganda was 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%).

Importance Index of the Risk Factors in Cost Estimation

Importance index was used to get the most critical risk factors in cost estimation and the findings are presented in Table 8.

Table 8. Importance index of the risk factors in cost estimation

| No. | Risk Factors in Cost Estimation | FI (%) | SI (%) | IMPI (%) | 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 in a 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 workload | 46.67 | 50.19 | 23.42 | 35 |

(Continued on next page)

Table 8. *Continued*

| No. | Risk Factors in Cost Estimation | FI (%) | SI (%) | IMPI (%) | Rank |
|-----|-----------------------------------------------------|--------|--------|----------|------|
| 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 |
| 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 |

The results in Table 8 show that the top 15 risk factors in cost estimation in the building construction industry in Uganda were 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%).

Developing a Reliable Model for Risk-Based Cost Estimation

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

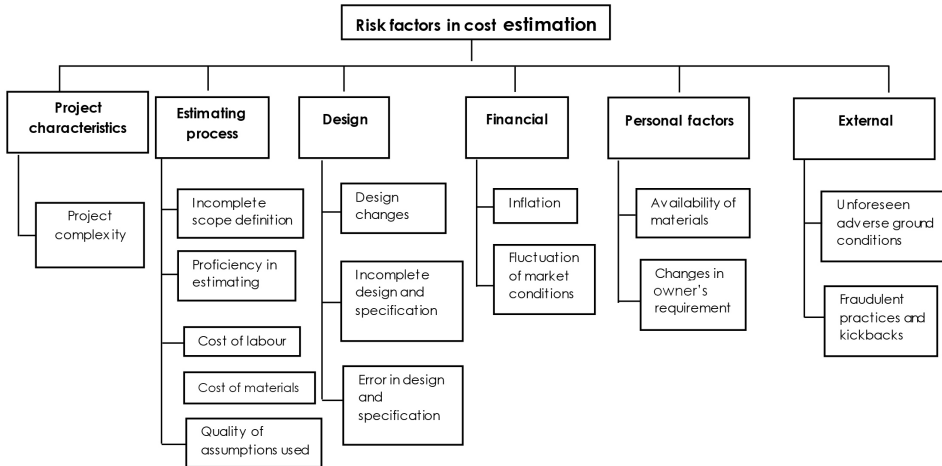


Figure 2. Hierarchy of the 15 most important risk factors in cost estimation

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 9.

Table 9. Summary of priority weights and relative weights of the criteria and sub-criteria

| Criteria | Weight | Sub-Criteria | Weight | Relative Weight (W _i) |
|-------------------------|--------|-----------------------------|--------|-----------------------------------|
| 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 |

(Continued on next page)

Table 9. Continued

| Criteria | Weight | Sub-Criteria | Weight | Relative Weight (W _r) |
|------------------|--------|--------------------------------------|--------|-----------------------------------|
| 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 |

Cost of Risk for the Most Important Risk Factors

The cost of risk for the most critical risk factors was calculated based on the values of the relative weight, frequency index and severity index for each aspect, as shown in Table 10.

Table 10. Cost of risk calculated using the model

| Criteria | Sub-Criteria | W _r | FI | SI | Cost of Risk = W _r × 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 |

(Continued on next page)

Table 10. *Continued*

| Criteria | Sub-Criteria | W_r | FI | SI | Cost of Risk = $W_r \times FI \times SI$ |
|-------------------------------------------------------|--------------------------------------|-------|-------|-------|------------------------------------------|
| 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 = $\sum W_r \times FI \times SI$ | | | | | 0.594 |
| Average cost of risk = $\sum W_r \times FI \times SI$ | | | | | 0.040 |

The results in Table 10 show that the total cost of risk for the 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.

Table 11. Cost percentages of the factors in comparison to the total cost of risk

| Factors | Cost % | Cumulative Cost % | 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 | | |

The results in Table 11 show that the top five factors represent 60.9% of the total cost of risk while other factors represent 39.1%.

Model Verification

According to Salciccioli et al. (2016), sensitivity analysis assesses 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. Sensitivity analysis was performed in Microsoft Excel to test the accuracy and robustness of the model. After the analysis, the risk factors were arranged according to sensitivity to construction project cost as shown in Figure 3. Changes to the input parameters did not vary the final results about the options. Therefore, the developed model proved consistent and sensitive to the considered factors.

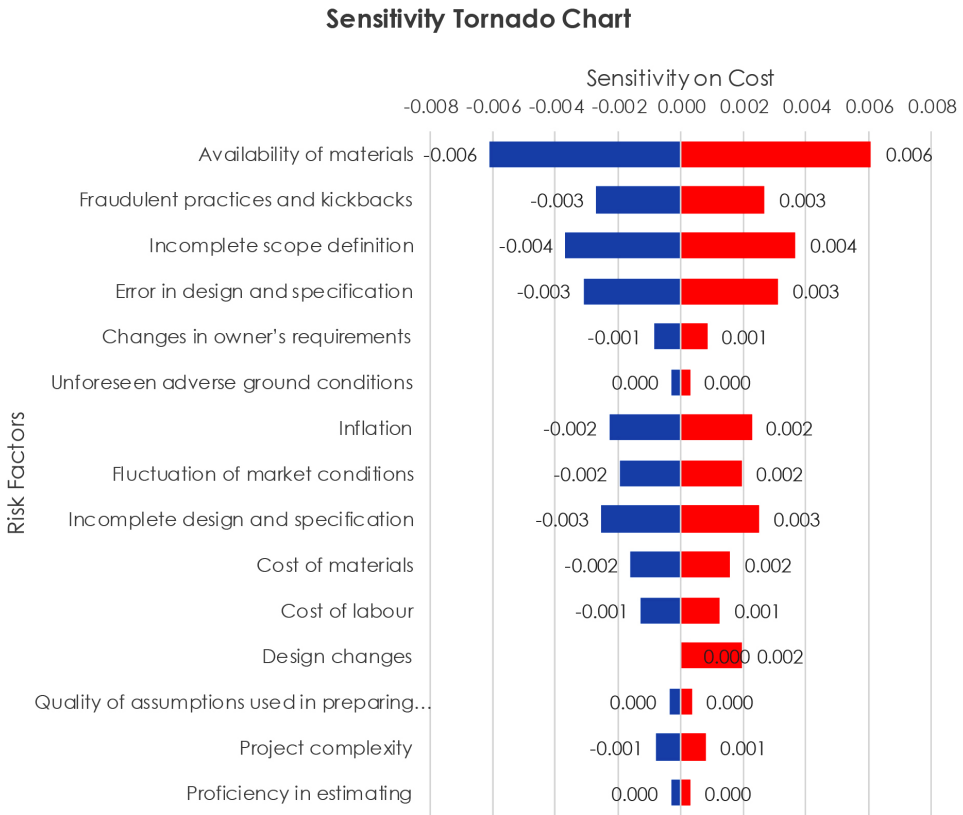


Figure 3. The sensitivity analysis of the developed model

SUMMARY OF FINDINGS AND CONCLUSIONS

Summary of the Findings

The study revealed that the top five risk factors with the most severe effect on cost estimation in the building construction industry in Uganda were inflation, proficiency in estimating, cost of materials, incomplete design and specification, fraudulent practices and kickbacks. The study also revealed that 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 represented 59.4% of the total project cost, with the average cost of risk representing 4.0% of the total project cost. The sensitivity analysis performed on the model proved the reliability of the model for estimating the cost of risk.

Conclusions of the Study

The study aimed to assess the effects of 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 were cost of materials, inflation, fraudulent practices and kickbacks, incomplete scope definition and incomplete design and specification. In addition, the study revealed that the risk factors with the most severe effects on cost estimation were inflation, proficiency in estimating, cost of materials, incomplete design and specification and fraudulent practices and kickbacks.

A reliable model for risk-based cost estimation was developed based on the AHP. The developed model would help estimate the cost of risk on a justifiable basis, thereby eliminating the random and deterministic allocation of 0% to 10% of the project cost to cater for risks.

Contributions of the Study

Previous studies focused on risk factors and cost overruns, but the risk factors have not been studied effectively to estimate risk costs to improve project cost performance. This study has helped to reveal the need for a justifiable and defensible method of estimating the costs of risks involved in a project. Construction professionals can use the developed model to improve the accuracy of cost estimates and the general cost performance of projects. The study has also helped to cover literature gaps by providing empirical evidence and information for further research.

Limitations of the Study

The study was limited to only building construction projects within Kampala. As a result, 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. Furthermore, a more comprehensive testing and model application would also inform whether the findings are generalisable.

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