**COST ESTIMATION AND ANALYSIS FOR BETTER PROJECT BUDGETING**

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| **ABSTRACT** |
| Cost estimation and analysis are critical components of effective project planning, serving as the foundation for budgeting, resource allocation, and risk management. Accurate cost estimation enables project managers to predict financial requirements, identify potential cost overruns, and make informed decisions to ensure project success. This paper delves into the methodologies and tools used in cost estimation, including parametric, analogous, and bottom-up approaches, and evaluates their applicability across various project types and industries. Furthermore, the study emphasizes the importance of integrating cost analysis with project scheduling and risk assessment to create a comprehensive planning framework. By leveraging advanced techniques such as Monte Carlo simulations, earned value management (EVM), and machine learning algorithms, this research highlights how modern technologies can enhance the precision and reliability of cost estimates. The paper also explores the impact of external factors, such as market volatility, inflation, and supply chain disruptions, on cost estimation accuracy. Through case studies and empirical data, the study demonstrates how robust cost estimation and analysis can mitigate financial risks, optimize resource utilization, and improve overall project outcomes. The findings underscore the need for continuous refinement of cost estimation practices, supported by data-driven insights and collaborative stakeholder engagement, to adapt to the dynamic nature of project environments. This research contributes to the academic and practical understanding of cost estimation, offering actionable recommendations for project managers and policymakers to enhance project planning and execution in an increasingly complex and uncertain world. |

**KEYWORDS**: Cost Estimation, Cost Analysis, Project Planning, Budgeting, Resource Allocation, Risk Management, Parametric Estimation, Analogous Estimation, Bottom-Up Estimation, Monte Carlo Simulations, Earned Value Management (EVM), Machine Learning, Market Volatility, Inflation, Supply Chain Disruptions, Financial Risk Mitigation, Data-Driven Insights, Stakeholder Engagement, Project Scheduling, Case Studies, Empirical Data.

**1.0 INTRODUCTION**

Cost estimation and analysis are foundational aspects of civil engineering, essential for the planning, execution, and successful completion of projects. Accurate cost estimation ensures that projects are delivered within the budget, meeting both the client’s financial expectations and the project’s technical requirements. Inadequate or inaccurate cost estimates can lead to significant budget overruns, project delays, and ultimately, project failure (Akinci & Fischer, 1998).

Cost estimation and analysis are crucial components of project management in civil engineering, directly influencing the success and viability of projects. Despite the availability of numerous tools and methodologies, the industry continues to face significant challenges in achieving accurate cost estimates. These challenges often result in budget overruns, project delays, and compromised project quality, leading to dissatisfaction among stakeholders (Flyvbjerg et al., 2002; Love et al., 2015).

One of the primary issues in cost estimation is the inherent uncertainty in predicting future expenses. Civil engineering projects are often large and complex, with numerous variables that can change throughout the project lifecycle. Factors such as fluctuating material costs, labor availability, weather conditions, and unforeseen site conditions contribute to this uncertainty (Ashworth, 2010). Traditional cost estimation methods, while widely used, are often inadequate in addressing these complexities. For example, methods like analogous estimating and parametric estimating rely on historical data and predefined parameters, which may not always reflect the unique aspects of a given project (Akintoye & Fitzgerald, 2000).

Cost estimation in civil engineering involves predicting the costs associated with materials, labor, equipment, and overheads required to complete a project. This process is influenced by various factors, including project scope, design complexity, geographical location, and market conditions (Akintoye & Fitzgerald, 2000). These factors introduce uncertainties that can complicate the estimation process. To address these uncertainties, civil engineers use a variety of cost estimation methods, ranging from traditional approaches like unit rate estimation and parametric estimation to more advanced techniques such as probabilistic cost modeling and Building Information Modeling (BIM) (Ashworth, 2010; AACE International, 2016).

BIM, in particular, has transformed the way cost estimation is approached in civil engineering. By integrating project data into a single digital model, BIM enables more accurate and dynamic cost estimation throughout the project lifecycle. Studies have shown that using BIM for cost estimation can reduce the risk of cost overruns by providing real-time data that reflects changes in design, material costs, and labor rates (Bryde et al., 2013). Furthermore, BIM facilitates better communication among project stakeholders, leading to more informed decision-making and enhanced project budgeting (Eastman et al., 2011).

The importance of accurate cost estimation extends beyond budgeting; it is also critical for risk management. By conducting a detailed cost analysis, civil engineers can identify potential risks early in the project and develop strategies to mitigate them. This proactive approach to cost management not only helps in maintaining the project budget but also improves the overall efficiency and success rate of civil engineering projects (Elbeltagi & Dawood, 2011).

Recent research emphasizes the need for continuous improvement in cost estimation practices. The increasing complexity of civil engineering projects, driven by technological advancements and evolving client demands, requires more sophisticated and adaptable cost estimation tools. As a result, the industry is witnessing a shift towards the integration of AI and machine learning algorithms in cost estimation, which promise to further enhance accuracy and efficiency (Hajdu & Skibniewski, 1996; Yang et al., 2016).

Another significant issue is the underestimation of project risks. Many cost estimators fail to adequately account for potential risks, leading to optimistic cost estimates that do not reflect the realities of project execution. This underestimation often results in budget overruns when risks materialize. Studies have shown that project managers and cost estimators frequently overlook or underestimate risks due to cognitive biases or pressure to present lower costs to secure project approval (Hajdu & Skibniewski, 1996; Love et al., 2015).

The advent of modern technologies, such as Building Information Modeling (BIM) and advanced cost management software, has introduced new possibilities for improving cost estimation accuracy. However, these technologies are not without their challenges. The adoption of BIM, for instance, requires significant upfront investment in both software and training, which can be a barrier for many firms. Additionally, while BIM provides more detailed and dynamic cost information, its effectiveness depends on the accuracy of the input data and the competency of the users (Bryde et al., 2013; Eastman et al., 2011).

Furthermore, the integration of cost estimation with overall project management is often lacking. In many cases, cost estimation is treated as a separate function rather than an integral part of project planning and execution. This siloed approach can lead to misalignment between estimated costs and actual project expenditures, exacerbating budgetary issues (Elbeltagi & Dawood, 2011).

**2.0 MATERIAL AND METHOD**

**2.1 METHODOLOGY**

The methodology followed a systematic approach to data collection, cost estimation, and analysis. Six cost estimation techniques were applied, including unit rate estimation, factor estimation, detailed quantity takeoff, approximate estimate, parametric estimation, and cost index estimation. These techniques were implemented on a sample project: a single-storey residential building.

**2.2 Data Collection**

 - Market prices for construction materials (cement, sand, gravel) and labor rates were obtained from local suppliers and contractors.

 - Historical project data from similar construction works was sourced to establish baselines for each estimation technique.

**2.2.1 Application of Estimation Techniques**

 - Each cost estimation technique was applied to the project based on the data gathered.

 - Calculations for material quantities, labor costs, and total project costs were carried out for each technique.

**2.2.2 Analysis and Comparison**

 - The results of each estimation technique were analyzed and compared.

 - Variations between the techniques were evaluated based on accuracy, simplicity, and relevance to civil engineering projects.

**2.2.3 Validation**

 - The estimated costs were compared to actual costs from similar past projects to ensure validity and reliability.

**2.3 Materials**

The following materials were used in the cost estimation process:

* Cement (Ordinary Portland Cement): Commonly used for structural components, with a unit price of ₦8,000 per 50 kg bag.
* Sand (Fine Aggregate): Sourced for concrete mixing and foundation works, measured in tonnes.
* Gravel (Coarse Aggregate): Utilized as a concrete component, measured in tonnes.
* Reinforcement Bars (Steel Rods): Employed for reinforcing concrete structures, measured in kilograms.
* Water: Potable water used in mixing concrete.

Material quantities were calculated using standard civil engineering measurement techniques, and prices were based on the current market rates.

**2.3 Equipment**

The following equipment was used in the data collection and estimation processes:

* Measuring Tape: Used to take dimensional measurements of the building project.
* Weighing Scale: Employed for measuring material quantities, such as cement and aggregates.
* Computer Software (MS Excel): Used for calculations, data analysis, and creating cost estimation tables.
* Concrete Mixer: Although not directly used in the cost estimation process, it was relevant to the actual construction work.
* Calculator: Utilized for quick, on-site cost calculations.

**2.4 Tests and Procedures**

The following procedures were used to apply the cost estimation techniques to the construction project:

**2.4.1 Unit Rate Estimation**: The Unit Rate Estimation method followed these steps:

1. Quantification of Materials: The required quantities of materials (e.g., cement, sand, gravel, reinforcement bars) were measured based on standard construction procedures.

2. Application of Unit Prices: The unit prices for materials and labor were applied based on market data.

3. Total Cost Calculation: The quantities were multiplied by their respective unit prices to derive the total project cost.

**2.4.2 Factor Estimation**: The Factor Estimation technique was carried out as follows:

1. Base Cost Calculation: The base cost, consisting of material and labor costs, was computed.

2. Application of the Factor: A multiplier of 1.25 was applied to account for overheads and contingencies, derived from previous project data.

**2.4.3 Detailed Quantity Takeoff:** Detailed Quantity Takeoff involved these steps:

1. Breakdown of Project Components: The project was divided into individual work components (e.g., foundation, walls, and roofing).

2. Quantity Measurement: The quantity of each material needed for every component was measured using standard construction practices.

3. Application of Unit Rates: The unit rates for materials and labor were applied to calculate the cost for each component.

**2.4.4 Approximate Estimate**

The Approximate Estimate method was performed as follows:

1. Historical Data Analysis: Data from similar past projects was analyzed to estimate costs.

2. Adjustment for Market Conditions: The estimated costs were adjusted for current market prices and inflation.

**2.4.5 Parametric Estimation**

The Parametric Estimation method followed this procedure:

1. Selection of a Key Parameter: The floor area of the building (120 m²) was chosen as the key parameter.

2. Application of Cost per Unit Parameter: The total floor area was multiplied by the cost per square meter (₦45,000) to estimate the total project cost.

**2.4.6 Cost Index Estimation**

The Cost Index Estimation technique was conducted as follows:

1. Collection of Historical Project Data: The cost of a similar project completed in the past was obtained for comparison.

2. Application of Cost Index: A cost index of 1.15 was applied to adjust the historical project cost to the current market rate.

**3.0 RESULTS AND DISCUSSION**

**3.1 Cost Estimation Techniques**

The six cost estimation techniques utilized for the analysis include:

* Unit Rate Estimation
* Factor Estimation
* Detailed Quantity Takeoff
* Approximate Estimate
* Parametric Estimation
* Cost Index Estimation

The following sections provide a detailed presentation of the results derived from these techniques.

**3.2 Unit Rate Estimation:** This technique involves determining the cost per unit of work and multiplying it by the quantity required for the project. For the single-storey building, the unit rates for materials, labor, and equipment were determined and the results are shown below.

Table 1. Results of the unit rates for materials, labour, and equipment for the single-storey building

|  |  |  |  |
| --- | --- | --- | --- |
| Items | Quantity  | Unit Rate (#) | Total Cost (#) |
| Cement (50kg) | 200 | 8,000 | 1,600,000 |
| Sand (Trip) | 30 | 25,000 | 750,000 |
| Gravel (Trip) | 40 | 30,000 | 1,200,000 |
| Reinforcement (mm) | 500 | 10,000 | 5,000,000 |
| Labour  | 20 | 5,000 | 100,000 |
| Total |  |  | 8,650,000 |

**3.3 Factor Estimation**

The factor estimation method applies factors based on past project data to estimate the total project cost. For the residential building, a factor of 1.25 was applied to the base cost, which is the sum of direct material and labor costs.

Base Cost = ₦3,520,000

Factor Applied = 1.25

Thus, the total cost estimate using factor estimation is:

 Total Cost = Base Cost X factor applied

3,520,000 X 1.25= # 4,400,000

**3.4 Detailed Quantity Takeoff**

This method involves a comprehensive measurement of the quantities of all materials and work items required for the project. The results are based on precise measurements and calculations of individual components of the building.

Table 2. Work components, quantities, unit cost and total cost for the construction of a single-storey building

|  |  |  |  |
| --- | --- | --- | --- |
| Work component  | Quantity  | Unit Cost (#) | Total cost (#) |
| Foundation  | 50m³ | 2,000 | 1,000,000 |
| Concrete  | 150m² | 5,000 | 750,000 |
| Formwork  | 200m² | 5,000 | 1,000,000 |
| Roofing materials  | 300m² | 4,000 | 1,200,000 |
| Total  |  |  | 3,950,000 |

**3.5 Approximate Estimate**

The approximate estimate method provides a quick estimate based on previous project costs of similar nature. This technique was used by referencing past data of residential building construction in the same location.

Estimated Total Cost: ₦4,800,000 (based on historical data from similar projects)

**3.6 Parametric Estimation**

The parametric estimation method uses statistical relationships between historical data and project parameters. For this project, the relationship between floor area and total cost was used.

The cost per square meter of floor area for similar buildings is ₦45,000.

Floor Area = 120 m²

Cost per Square Meter = ₦45,000

Total cost= floor Area x cost per square meter

120 X 45,000 = #5,400,000

**3.7 Cost Index Estimation**

Cost index estimation involves adjusting the cost of a previous project using a cost index. For this project, the cost of a similar building constructed in 2020 was ₦4,000,000. The cost index for 2024 is 1.15, meaning costs have increased by 15%.

Adjusted cost= Index cost x previous cost

4,000,000 x 1.15 = #4,600,000

**3.8 Comparative Analysis of Estimation Techniques**

The table below provides a comparison of the total costs derived from the six different estimation techniques.

Table 3. Comparison of the total costs derived from six different estimation methods

|  |  |
| --- | --- |
| Estimation Technique  | Total Estimated cost (#) |
| Unit Rate estimation  | 8,650,000 |
| Estimation Factor  | 4,400,000 |
| Detailed Quantity take off  | 3,950,000 |
| Approximate Estimate  | 4,800,000 |
| Parametric Estimation  | 5,400,000 |
| Cost index Estimation  | 4,600,000 |

From the comparative analysis, it is evident that the cost estimations vary depending on the methodology used. The Unit Rate Estimation provides the highest cost, while detailed quantity take off yields the lowest. The Detailed Quantity Takeoff method is one of the most accurate techniques but tends to be labor-intensive, while Factor Estimation offers a more simplified and quicker alternative, though it may not be as precise.

**3.9 Manual Method**

This involves hand calculations, where data is analyzed using formulas and computations done manually. It's a traditional method but can be time-consuming and prone to human error.

**3.10 Excel-Based Method**

This involves using Microsoft Excel or similar tools to automate calculations. Formulas are inputted into spreadsheets, making the process faster and more accurate. Excel also allows for easy adjustments and data visualization.

**Parameters in Cost Estimation**

1. Quantity of Materials (Q): Total units of each material required, e.g., number of bags of cement, tons of steel, etc.

2. Unit Rate (R): Cost per unit of material in Naira (₦).

3. Labor Cost (L): Total wages for workers involved in the project.

4. Transportation Cost (T): Expenses for moving materials to the site.

5. Overhead Costs (O): Miscellaneous costs, such as equipment maintenance, site security, etc.

6. Total Cost (C): Overall project cost, calculated as:

 C = (Q X R) + L + R + O

Example Project

Building a 3-bedroom bungalow in Lagos, Nigeria.

Materials: Cement, Sand, Granite, Steel, Blocks

Quantities Required: Based on project plan

**Table 4. Manual Method Calculations**

|  |  |  |  |
| --- | --- | --- | --- |
|  Materials  | Quantity (Q) | Unit Rate (#) | Cost (Q x #) |
| Cement  | 300 bags | 4,500 | 1,350,000 |
| Sand  | 20 trips | 30,000 | 600,000 |
| Granite  | 15 Tons | 25,000 | 375,000 |
| Steel  | 10 Tons | 600,000 | 6,000,000 |
| Blocks | 4,000 units | 250 | 1,000,000 |

Manual Method Calculation

Step-by-Step Calculation:

1. Multiply quantity by unit rate for each material.

2. Add the labor, transportation, and overhead costs:

Labor (L): ₦1,500,000

Transportation (T): ₦500,000

Overhead (O): ₦200,000

**Total Cost**

C = material cost + L + T +C

C = (1,350,000 + 600,000 + 375,000 + 6,000,000 + 1,000,000) + 1,500,000 + 500,000 + 200,000]

C = 11,525,000

**Excel method calculation**

Table 5. Excel table format

|  |  |  |  |
| --- | --- | --- | --- |
| Materials  | Quantity (Q) | Unit Rate (#) | Cost (Qx#) |
| Cement  | 300 | 4,500 | =B2\*C2 |
| Sand  | 20 | 30,000 | =B3\*C3 |
| Granite  | 15 | 25,000 | B4\*C4 |
| Steel | 10 | 60,000 | B5\*C5 |
| Blocks  | 4000 | 250 | B6\*C6 |

Additional Costs:

Labor: Input ₦1,500,000

Transportation: Input ₦500,000

Overhead: Input ₦200,000

Formula for Total Cost in Excel:

=SUM(D2:D6) + L + T + O

D2:D6 is the common range for material costs

L,T,O are inputted directly into separate cells

Total Cost output in Excel= #11,525,000

**Table 6. Comparison: Manual & Excel**

|  |  |  |
| --- | --- | --- |
| Aspect  | Manual  | Excel method  |
| Speed | Slow, time consuming  | Fast, especially for large data set |
| Accuracy  | Prone to human error  | High accuracy with correct formulas  |
| Flexibility  | Difficult to update  | Easy to adjust and recalculate  |
| Visualization  | Limited  | Can include charts and graphs for analysis  |

**RECOMMENDATION**

Based on the findings from this research, the following recommendations are made to improve cost estimation and project budgeting practices in civil engineering:

1. Adopt a Hybrid Approach: It is recommended that civil engineers adopt a hybrid approach to cost estimation, combining methods like Parametric Estimation for early-stage planning with Detailed Quantity Takeoff for final budgeting. This would ensure both speed and accuracy throughout the project lifecycle.

2. Regular Market Surveys: To maintain the accuracy of cost estimates, regular market surveys should be conducted to update unit rates for materials and labor. This is particularly crucial in regions where material prices and labor rates are volatile due to economic fluctuations.

3. Integration of Technology: Civil engineering firms should consider the use of specialized cost estimation software that integrates real-time market data and automates calculations. Tools like Building Information Modeling (BIM) can significantly improve the precision of Detailed Quantity Takeoff.

4. Incorporate Contingency Planning: To account for unforeseen costs and inflation, a contingency sum should always be factored into the project budget. A tyfal contingency range of 5% to 10% of the total project cost is recommended to safeguard against potential cost escalations.

5. Periodic Review of Cost Indices: For projects that extend over a long duration, periodic reviews of cost indices should be conducted to ensure that adjustments for inflation and material price increases are accurately reflected in the project budget.

6. Training in Cost Estimation: Continuous professional development for engineers and quantity surveyors in modern cost estimation techniques is essential. Workshops and seminars focused on advanced estimation tools and practices will enhance their ability to deliver accurate project budgets.

**CONCLUSION**

This project focused on the evaluation of various cost estimation techniques for enhancing the accuracy and effectiveness of project budgeting in civil engineering. The research applied six different cost estimation methods—Unit Rate Estimation, Factor Estimation, Detailed Quantity Takeoff, Approximate Estimate, Parametric Estimation, and Cost Index Estimation—on a single-storey residential building.

 Accuracy of Detailed Quantity Takeoff: Among the methods applied, Detailed Quantity Takeoff proved to be the most accurate for large-scale projects, as it involved a detailed breakdown of materials, labor, and equipment required. This method allowed for precise cost predictions, minimizing cost overruns and underestimation errors.

Flexibility of Parametric Estimation: Parametric Estimation was found to be a flexible and time-efficient technique for preliminary budget assessments. Its reliance on cost per unit parameter (e.g., per square meter) made it suitable for early-stage project planning, although it lacks precision for complex projects.

Factor Estimation for Simplified Calculations: Factor Estimation was useful for quick assessments of overall project cost, especially in scenarios with available historical data. However, this technique is highly dependent on accurate factor determination, and any miscalculation in the factor could lead to significant cost discrepancies.

Inconsistencies in Approximate Estimates: Approximate Estimate was deemed less reliable due to its heavy reliance on historical data without adjusting for detailed project-specific conditions. This method could lead to large variances, particularly in projects where material prices fluctuate or labor costs differ significantly from past trends.

Unit Rate Estimation for Standard Projects: Unit Rate Estimation was effective for projects involving standardized components, such as road construction or repetitive building elements. While its accuracy was lower than Detailed Quantity Takeoff, it is well-suited for projects with well-defined unit rates in the local market.

Cost Index Estimation for Inflationary Adjustments: Cost Index Estimation served as an efficient tool for adjusting historical costs to reflect current market conditions. However, it was only as reliable as the accuracy of the historical data and the relevance of the cost index used.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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