

Leveraging on digital technologies for assessing cost estimation accuracy in renovation and refurbishment projects towards improved project delivery

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Abstract

This study investigates the impact of digital technologies on improving cost estimation accuracy in refurbishment projects, with the aim of enhancing project delivery through cost certainty. Conducted in Bloemfontein, Free State, South Africa, the research utilized a mixed-methods approach, combining quantitative data from 30 structured questionnaires with qualitative insights from 4 semi-structured interviews with construction professionals. Descriptive statistics were employed to evaluate the effectiveness of various estimation tools, while thematic analysis identified key barriers and enablers influencing digital technology adoption. Single coding was applied due to the study's small, pilot nature and interpretive focus. Findings reveal that advanced tools such as Building Information Modelling (BIM) and Laser Scanning Technology (LST) significantly improve estimation accuracy; however, their use is limited by high costs, lack of technical expertise, and insufficient as-built data. Despite the superior precision of these digital solutions, manual estimating methods remain dominant due to resource constraints and resistance to change. The study contributes original insight by linking digital tool adoption directly to cost estimation inaccuracies in R&R projects, rather than only examining adoption barriers as in prior BIM research. It highlights an “effectiveness-adoption gap,” where advanced technologies like BIM and Laser Scanning/LiDAR are highly valued but underused, while simpler tools such as QTO are more widely adopted due to practical constraints. Integrating digital tools with traditional estimation practices is recommended to enhance accuracy, reduce project risks, and improve project cost outcomes in the construction sector.

Keywords: Digital technologies, Construction Project Management, Renovation and Refurbishment, Cost Estimation

1. Introduction

Accurate cost estimation is widely recognised as a critical factor in achieving successful construction project outcomes (Doloi, 2012; Ahiaga-Dagbui and Smith 2014). However, it continues to present significant challenges, particularly in renovation and refurbishment (R&R) projects where incomplete project information and uncertain site conditions increase estimation complexity (Abdelsalam et al. 2026). Conventional cost estimation methods are often unable to adequately account for such uncertainties, resulting in estimation inaccuracies that frequently lead to cost overruns and project delays, thereby affecting overall project performance and stakeholder satisfaction (Mokhojane, and Makgoe 2025). Cost overruns remain one of the most prevalent risks in construction projects worldwide. In the South African context, inaccurate material quantification and unforeseen site conditions have been identified as major causes of budget increases and schedule disruptions in infrastructure projects (Mokhojane et al. 2024).

Emerging digital technologies such as Building Information Modelling (BIM), Laser Scanning Technology (LST), Artificial Intelligence (AI), and advanced Quantity Take-Off (QTO) systems have demonstrated considerable potential to improve estimation accuracy through enhanced visualisation, automated quantity measurement, and real-time data integration (Khafiso and Tjebane 2026). BIM, in particular, facilitates centralised project information management and enables the generation of more accurate 5D cost data linked to digital models, thereby reducing uncertainty and supporting informed decision-making (Mokhojane et al. 2024; Mehdiipoor et al. 2026). The selection of these three technologies for purposes of de-risking cost estimation in R&R projects is because of their possible interoperability, BIM digital process that creates and manages a shared 3D model containing detailed information about a building's physical and functional characteristics throughout its lifecycle (Odeyinka, and Yusif, 1997; Azhar, 2011). LST is a data-capture method that uses laser beams to measure and record the geometry of physical structures, producing highly accurate three-dimensional point cloud models. In refurbishment projects, LST is

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commonly used to document existing conditions and generate reliable as-built information for planning and cost estimation (Eastman et al. 2011). AI refers to computer systems capable of performing tasks that typically require human intelligence, such as learning, pattern recognition, prediction, and decision-making. In construction, AI can be used to automate cost estimation, analyse project data, identify risks, and improve forecasting accuracy (Mokhojane et al. 2024; Mokhojane et al. 2024). Although the benefits of these technologies are well documented, their practical adoption remains relatively low. Existing studies attribute this slow uptake to factors such as high implementation costs, limited technical expertise, organisational resistance to change, and inadequate model data quality, challenges that are particularly evident in developing countries such as South Africa (Azhar, 2011).

Against this backdrop, this study investigates the role of digital technologies in enhancing cost estimation accuracy within R&R projects. Specifically, it explores the effectiveness of available digital tools, examines the barriers constraining their adoption, and identifies strategies that can facilitate wider implementation. In doing so, the study contributes to ongoing efforts to advance the digitalisation of cost estimation practices and improve project delivery performance in complex construction environments.

2. Literature Review

Cost estimation in rehabilitation and refurbishment (R&R) projects is widely regarded as more challenging than in new-build construction because of the high levels of uncertainty associated with incomplete information, concealed defects, and changing site conditions (Akintoye, 2000; Abdelsalam et al. 2026; Mehdiipoor et al. 2026). These projects frequently involve undocumented alterations, uncertain structural conditions, and material deterioration, which complicate the estimation process and increase the risk of inaccuracies in projected costs. The literature indicates that such uncertainties often lead to cost overruns, as preliminary estimates are typically based on assumptions that may require revision as project conditions become clearer during implementation (Flyvbjerg, 2009; Love et al. 2016; Abdelsalam et al. 2026). Furthermore, the fluid nature of R&R projects, where design requirements and project scope are regularly adjusted during construction, further undermines the reliability of cost estimates (Khabisi, 2013).

The reliability of cost estimates depends heavily on the availability and quality of project information during the pre-construction phase. Inadequate site investigations, outdated or incomplete documentation (including as-built records and drawings), and ineffective information management practices often

lead to inaccurate assumptions and unforeseen changes during project execution (Neupane and Jaisi 2025). Previous studies have consistently identified poor data management and limited site assessment as major contributors to estimation inaccuracies and subsequent cost overruns (Sanusi 2024; Abdelsalam et al. 2026). Similarly, insufficient project planning and weak scope definition limit project teams' ability to anticipate and mitigate project-specific risks and uncertainties, increasing estimation errors (Gilbert, 2024). These findings highlight the need for thorough site assessments, effective data collection processes, and accurate record management to improve estimation reliability.

Despite the complexity of refurbishment projects, traditional estimation techniques, including manual quantity take-offs and estimator experience-based methods, remain widely used. Although these approaches are valued for their simplicity and relatively low implementation costs, they are susceptible to human error and often fail to adequately address the complexities and uncertainties associated with R&R projects (Taherdoost 2024). Recent studies suggest that digital technologies such as Building Information Modeling (BIM), Artificial Intelligence (AI), and Laser Scanning Technology (LST) can substantially enhance cost estimation accuracy by facilitating improved data integration, visualization, and real-time project analysis. However, the adoption of these technologies remains constrained, particularly in developing countries, due to factors such as high investment costs, limited technical capabilities, and resistance to organisational change (Díaz-Arancibia et al. 2024; Barkley and Jokonya 2024. Oyenuga et al. 2025).

3. Research Methodology

The study adopted a mixed methods design to comprehensively investigate cost estimation accuracy in R&R projects in Bloemfontein, Free State, South Africa. Ethical clearance was obtained from the Faculty Research and Innovation Committee (FRIC). Purposive sampling was used to identify suitable respondents. Quantitative data were collected through structured questionnaires administered to construction professionals consisting of consultants and contractors. Qualitative data were analyzed using descriptive statistics to determine frequencies, mean values, and rankings of key factors influencing estimation precision. This analysis allowed for the identification of prevailing patterns and the relative significance of variables affecting project outcomes. Simultaneously, qualitative data were obtained through semi-structured interviews with selected industry experts, providing deeper insights into their experiences and perspectives. Thematic analysis was applied to the qualitative responses, coding and categorizing them into key themes such as barriers to adopting digital technologies and challenges in project planning. Single coding was

adopted given the study being profiled as small, a pilot and relying on the researcher's interpretive lens. By integrating descriptive and thematic analyses, the study employed methodological triangulation, enhancing the reliability and validity of the findings by linking statistical trends with practitioner insights.

4. Findings and Discussion

4.1. Quantitative Data Analysis

The survey participants were professionals in roles related to cost estimation and construction project delivery. Quantity surveyors formed the largest group of respondents (63%), followed by project managers (21%) and contractors (16%). Most respondents possessed considerable industry experience, with 72% reporting more than five years of professional practice, while 28% had between one and five years of experience. In terms of project involvement, 68% of participants were primarily engaged in private-sector renovation projects, whereas the remaining respondents worked across both public and private sectors. The strong representation of experienced quantity surveyors suggests that the study findings are informed by practitioners directly involved in critical activities such as cost planning, tender preparation, and financial management. Furthermore, the high proportion of private-sector respondents provides valuable insight into a segment of the construction industry that is generally less regulated but often more receptive to innovation and technological advancement. Table 1 below presents a summary of the demographic profile of the quantitative respondents.

4.1.2 Causes of Estimation Inaccuracies

The findings presented in Table 2 indicate that unforeseen site conditions (83%) and inadequate pre-project investigations (76%) are the most significant contributors to inaccuracies in cost estimation. This highlights the importance of thorough site assessments and effective planning during the early stages of a project. These results are consistent with the findings of Sheikhalishahi et al. (2025), Afana et al. (2024), and Alfasi and Khan (2026), who argue that insufficient front-end planning and optimism bias often result in unrealistic cost forecasts and subsequent project overruns. Likewise, incomplete or outdated project documentation (64%) emerged as a major source of estimation errors, supporting previous studies that link poor-quality information to inaccurate estimates, rework, and diminished project performance (Nnadi and Najjabyo 2025; Jayana et al. 2025; Adamu, 2020). The influence of inflation and material price volatility (53%) further reflects the impact of external economic conditions on project cost performance, corroborating the findings of Ezzat et al. (2025), AlTalhoni et al. (2026), and Raghieb et al. (2023) who identify market fluctuations as a key driver of cost deviations in construction projects. In addition, weak scope definition (48%) and continued dependence on manual or outdated estimation techniques (41%) reinforce existing calls for improved project scoping and greater adoption of digital technologies, particularly BIM, to enhance the reliability and accuracy of cost estimates (Fazeli et al. 2021; Shen and Issa 2010). Overall, the results suggest that estimation inaccuracies stem from a combination of technical uncertainties and managerial deficiencies, both of which remain critical challenges in construction project delivery.

Table 1: Summary of Questionnaire Respondents' Profiles

Demographic Category	Response Options	Frequency (n=30)	Percentage (%)
Professional Role	Quantity Surveyor	19	63%
	Project Manager	6	21%
	Contractor	5	16%
Years of Experience	1–5 years	8	28%
	More than 5 years	22	72%
Sector Focus	Private Sector	20	68%
	Public Sector	3	10%
	Both Public and Private	7	22%

Table 2: Leading Causes of Cost Estimation Inaccuracies

Cause of Inaccuracy	% Ranked as Top 3
Unforeseen site conditions	83%
Inadequate pre-project investigations	76%
Incomplete or outdated documentation	64%
Inflation and material price volatility	53%
Poor scope definition	48%
Use of manual/outdated estimation techniques	41%

4.1.3 Risk Factor Rankings by Respondents

The findings in Table 3 below indicate that cost estimation inaccuracies and project risks are primarily influenced by technical uncertainties, inadequate planning, and external economic conditions. Hidden defects, unforeseen site conditions, and limited pre-project investigations highlight the importance of thorough front-end planning and reliable site information to reduce uncertainty. Regulatory compliance requirements and the integration of existing and modern systems further complicate project delivery, creating additional coordination and technical challenges. Economic factors, particularly inflation and fluctuating material prices, contribute significantly to cost deviations. Similarly, incomplete documentation and continued reliance on traditional estimation methods reveal weaknesses in information management and limited digital technology adoption. These findings support previous studies that identify inadequate planning, incomplete project information, and volatile market conditions as major causes of cost overruns and project inefficiencies (Nnadi and Najjobyo 2025, Gurumayum 2025, Amini et al. 2023, Afana et al. 2024, Alshihri et al. 2022). Overall, the results underscore the need for comprehensive investigations, greater digitalisation, and robust project management practices to improve cost estimation accuracy and project performance.

4.1.4 Quantitative Assessment of Tool Usage

The results in Table 4 highlight a clear disparity between the perceived effectiveness of digital cost estimation technologies and their actual adoption in practice. Building Information Modelling (BIM) (Mean

= 4.42) and Laser Scanning/LiDAR (Mean = 4.35) were rated as highly effective for improving estimation accuracy and project visualisation; however, their adoption levels remain relatively low at 36% and 18%, respectively. This suggests that barriers such as high implementation costs, limited technical expertise, and inadequate as-built information continue to constrain their use, particularly in developing-country contexts (Khafiso et al. 2026). In contrast, Quantity Take-Off (QTO) software demonstrates both strong perceived effectiveness (Mean = 4.20) and comparatively high adoption (67%), indicating that accessible and user-friendly digital tools are gaining wider acceptance despite their reliance on accurate project documentation. AI-assisted estimation records a low adoption rate (15%) despite a moderate effectiveness rating (Mean = 3.87), reflecting challenges related to data availability and technical capacity. Conversely, manual estimation methods remain the most widely used approach (82%), despite lower effectiveness (Mean = 3.65), supporting findings that traditional practices persist due to familiarity, affordability, and ease of use, even though they are more susceptible to errors and inefficiencies (Sikka and Bhayana 2024, Pirzada et al. 2026).

4.2. Qualitative Findings

The qualitative phase included four experienced professionals actively involved in private-sector R&R projects. Participants comprised three quantity surveyors and one quantity surveyor who also served as a contracts manager, with professional experience ranging from five to over fifteen years. CCS Candy emerged as the dominant cost estimation software, used

Table 3: Impact of Specific Risk Factors on Estimation Accuracy (N = 30)

Risk Factor	Mean Rating (1–5)	% Rated “4” or “5”
Latent Defects (hidden/unseen conditions)	4.64	91%
Regulatory Constraints	4.48	85%
Integration of Old & New Systems	4.36	82%
Inadequate Pre-project Investigation	4.21	79%
Inflationary Pressures	4.03	73%
Documentation Gaps	3.94	70%

Table 4: Usage and Effectiveness of Estimation Tools (N = 30)

Tool	% Usage (Always/Often)	Mean Effectiveness Score (1–5)	Notable Barriers
Building Information Modelling (BIM)	36%	4.42	High cost, low skills, poor as-built records
QTO Software (e.g., Bluebeam)	67%	4.20	Relies on accurate base drawings
AI-Assisted Estimation	15%	3.87	Limited datasets, low technical expertise
Laser Scanning / LIDAR	18%	4.35	Equipment cost, low availability, training gaps
Manual Estimation Methods	82%	3.65	Prone to error, slow, lacks automation

by three participants, while CostX and DimX were employed by two respondents alongside CCS Candy. Notably, none of the interviewees reported using advanced technologies such as Building Information Modelling (BIM) or Artificial Intelligence (AI) for cost estimation. These findings indicate that, despite considerable industry experience, the adoption of emerging digital estimation technologies remains limited within the private R&R sector (Table 5).

enhance the reliability and accuracy of cost estimates in refurbishment projects.

Theme 3: Reliance on Traditional Estimation Methods

Interview findings revealed continued reliance on manual cost estimation methods because they are familiar, affordable, and easy to use, despite their

Table 5: Summary of Questionnaire Respondents' Profiles

Interviewee	Role	Years of Experience	Sector	Tools Used	Used BIM /AI?
Interviewee 1	QS	10+ years	Private	CCS Candy	No
Interviewee 2	CM	5+ years	Private	CostX, CCS Candy	No
Interviewee 3	QS	15+ years	Private	CCS Candy only	No
Interviewee 4	QS & CPM	5+ years	Private	CCS Candy, DimX	No

Theme 1: Barriers to Adopting Digital Technologies for Cost Estimation in R&R Projects

Participants recognised that BIM and LST can improve cost estimation accuracy and project visualisation, but their adoption remains limited by high costs, insufficient technical skills, and poor availability of reliable as-built data. Respondents also highlighted the lack of accurate drawings and training as reasons for the continued reliance on manual methods. These findings align with studies identifying cost, skills shortages, and poor information quality as major barriers to BIM adoption (Shah et al. 2026). Organisational resistance and low digital maturity further restrict technology uptake (Siewe et al. 2026). Similarly, limited AI adoption reflects challenges related to inadequate datasets and technical expertise (Nikiforova et al. 2025). Overall, financial, technical, organisational, and data-related barriers continue to hinder digital transformation in R&R projects.

Theme 2: Challenges in Project Planning and Scope Definition

The participants reported that unclear project scopes and inadequate planning are major obstacles to accurate cost estimation. Uncertainties about existing building conditions, undocumented alterations, and changing project requirements often lead to differences between initial estimates and actual project costs. Respondents noted that frequent scope changes and poorly documented previous modifications make early stage estimates less reliable and complicate planning efforts. These observations are consistent with previous studies showing that weak scope definition and insufficient pre-project investigations contribute significantly to estimation inaccuracies and cost overruns (Afana et al. 2024, Rahim et al. 2025, Onalaja 2023, Barani Shikhrobat et al. 2025). The findings highlight the importance of thorough site investigations, accurate documentation, and effective planning procedures to

susceptibility to errors and inefficiencies. This supports earlier studies showing that traditional estimation practices remain prevalent in developing countries because of limited resources and inadequate digital skills (Salmi et al. 2025, Fietz and Lay 2023, Ndibalema 2025, Ramabodu et al. 2026). Although based on a small sample, the qualitative findings identified three key factors affecting estimation accuracy: barriers to digital technology adoption, including cost, skills shortages, and poor data quality; uncertainties arising from weak planning and scope definition; and persistent dependence on manual methods. Improving accuracy therefore requires stronger planning, better information management, skills development, and organizational support for digital transformation.

5. Triangulation synthesis

Integrating quantitative and qualitative findings provides a comprehensive understanding of cost estimation challenges in refurbishment projects. The results show that estimation inaccuracies arise from a combination of technical uncertainties, inadequate front-end planning, poor information quality, economic volatility, and limited digital technology adoption. Quantitative findings identified unforeseen site conditions (83%), insufficient pre-project investigations (76%), and incomplete documentation (64%) as major contributors to cost overruns, while qualitative evidence highlighted deficiencies in site assessments and fragmented project information. The findings further reveal a gap between the perceived effectiveness and actual use of digital technologies. Although BIM (Mean = 4.42) and Laser Scanning/LiDAR (Mean = 4.35) are recognised for improving estimation accuracy, their adoption remains low due to cost, skills shortages, and organisational constraints. In contrast, Quantity Take-Off (QTO) software shows higher adoption because of its affordability and ease of integration. Manual estimation methods remain dominant despite lower effectiveness,

reflecting entrenched practices and limited digital capability. Similarly, AI-assisted estimation remains underutilised due to insufficient datasets and low digital maturity.

Overall, the evidence suggests that improving cost estimation accuracy requires stronger pre-project investigations, better information management, targeted skills development, wider adoption of appropriate digital tools, and improved project governance. Effective digital transformation depends not only on technology adoption but also on reliable project data, standardised documentation, and enhanced organisational capacity.

6. Conclusion and Further Research

This study found that cost estimation accuracy in refurbishment projects is shaped by a combination of technical uncertainties, managerial shortcomings, economic pressures, and limited digital technology adoption. Factors such as unforeseen site conditions, latent defects, incomplete documentation, weak scope definition, and continued reliance on manual estimation methods contribute significantly to estimation errors. Although technologies such as BIM, LST, AI-assisted estimation, and QTO software can improve accuracy and project visualization, adoption remains constrained by high implementation costs, skills shortages, poor data quality, and organizational resistance. Integrating quantitative and qualitative findings highlights the

interconnected nature of these challenges. To address these issues, organizations should prioritize comprehensive pre-project investigations, accurate as-built documentation, and robust front-end planning. Capacity-building initiatives are also required to enhance practitioners' digital competencies and reduce dependence on manual methods. Given their affordability and ease of use, accessible digital tools such as QTO software can serve as a practical entry point for digital transformation. Furthermore, stronger project planning, clear scope definition, systematic risk management, and early stakeholder engagement are essential for improving estimate reliability. Organizational support is equally important. Firms should allocate resources for technology adoption, strengthen data management practices, and foster a culture that embraces innovation. In South Africa, professional bodies such as the CIDB, SACQSP, and ASAQS can support digital transformation through standards, guidelines, CPD programmes, and incentives that promote BIM, QTO, and AI-enabled estimation practices. Implementing these measures can improve estimation accuracy, strengthen financial control, reduce project delays, and enhance the competitiveness of the South African construction sector.

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