

Integrating Smart Decision Tools with 5D BIM for Risk Management in Building Construction Projects in Sri Lanka

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Abstract: Sri Lankan construction industry continues to face persistent cost overruns, largely caused by project delays, design changes, and volatile material prices. Conventional quantity surveying practices tend to be reactive, lacking the proactive alert systems required to identify and

mitigate risks early. This research aims to bridge that gap by developing a framework that integrates Smart Decision Tools with 5D Building Information Modeling (BIM) to strengthen risk management in Sri Lankan building projects. The main objective is to design and validate a CostX based workflow

equipped with an alert mechanism for proactive cost control. The study's methodology includes creating a 5D cost model using CostX, connecting it to key risk variables, and implementing a customized workbook alert system to facilitate scenario-based risk analysis. The proposed approach transforms cost management from reactive reporting to real-time risk prediction, offering a practical digital solution to reduce recurring cost overruns. This research also contributes to the advancement of applied 5D BIM knowledge and provides quantity surveyors with an effective tool to support digital transformation in cost management practices.

Keywords: 5D BIM, CostX, Risk Management, Cost Overruns, Early Warning System, Proactive Cost Management, Quantity Surveying.

1.Introduction

1.1 Background of the Study

The construction industry plays a vital role in driving global economies; however, it continues to struggle with persistent issues such as cost overruns and schedule delays. Worldwide, a substantial proportion of construction projects fail to meet their cost objectives, and Sri Lanka is no exception many local building projects consistently fall short of their cost and time targets. The main causes of these challenges include project delays, design alterations, and material price fluctuations. Traditional project management and quantity surveying (QS) methods have proven inadequate in addressing these complex and evolving risks.

In response, the industry is undergoing a paradigm shift from conventional practices to digital solutions, with Building Information Modeling

(BIM) emerging as a transformative approach. BIM facilitates an integrated and collaborative process that consolidates information across all stages of a project's lifecycle. Its implementation has demonstrated potential to minimize project delays and enhance stakeholder coordination within the Sri Lankan construction sector. Specifically, 5D BIM by combining cost data with 3D modeling and time elements (4D) enables more precise decision-making in cost and schedule management. Despite growing adoption, the application of CostX, a globally recognized quantity surveying tool, within Sri Lanka's unique construction environment remains insufficiently explored in academic research. This study therefore seeks to advance the transition from traditional QS methods to a digital, 5D BIM-based framework to effectively address these enduring challenges.

1.2 Problem Statement

Although the adoption of Building Information Modeling (BIM) is steadily increasing, cost overruns remain a persistent challenge in the Sri Lankan construction industry. Existing quantity surveying practices and risk management approaches are predominantly reactive in nature. Typically, variations and unforeseen issues are addressed only after they have already resulted in considerable financial consequences. This delayed response hinders effective risk management and limits the ability to control project costs. A major shortcoming lies in the absence of proactive alert systems within BIM-based cost workflows that can detect potential cost deviations early. While the general advantages of BIM have been widely discussed, there is currently no documented

research in Sri Lanka that has developed and validated a CostX based workflow integrated with a risk alert mechanism specifically for building projects.

1.3 Aim and Objectives

Aim: To develop and validate a CostX-based workflow with an integrated alert system for proactive cost management in Sri Lankan building projects.

Objectives:

- To review the existing academic literature on BIM-based cost management and risk early warning systems.
- To develop a 5D cost model using CostX with key risk factors linked to project cost elements.
- To implement a custom alert mechanism within the CostX workbook for scenario based risk analysis.
- To validate the proposed workflow and alert system against real project data and through expert feedback from industry professionals.

1.4 Research Questions

The study seeks to answer the following research questions:

- How can 5D BIM, specifically using the CostX platform, be utilized to improve proactive cost management in Sri Lankan building projects?
- Can a custom workbook alert system within CostX effectively highlight potential cost risks before they escalate into major overruns?

- How accurate and reliable is the proposed system's cost prediction compared to the actual final costs of a project?

1.5 Scope

This research is focused on the Sri Lankan construction industry with a specific focus on building projects. The study is limited to cost management and will not extensively cover other aspects of project management, such as time or quality, except where they directly impact cost. The tool used for the study will be the CostX.

1.6 Significance

This research is significant for several reasons. From an academic perspective, it provides a practical prototype and a framework for a CostX-based risk alert system, thereby contributing a novel, applied methodology to the body of knowledge on 5D BIM. It also directly addresses the identified gap in local studies by creating a tangible, verifiable tool for the Sri Lankan context. For the industry, the research offers a pathway for quantity surveyors (QSs) and project managers to transition from traditional, experience-based methods to a more efficient, digital, and data-driven approach. The successful implementation and validation of such a system would provide a powerful tool for risk anticipation, helping to minimize financial losses and reduce chronic cost overruns in the sector.

2. Literature Review

2.1 Construction cost management challenges

Achieving successful project completion within a predetermined financial budget remains a global challenge, with poor cost performance and recurring

cost overruns continuing to be a major concern in the construction industry [1][2]. Studies indicate that approximately 30% to 40% of construction projects worldwide experience unsatisfactory cost performance [3]. This issue is even more pronounced in developing nations such as Sri Lanka, where cost overruns tend to be more severe and widespread. Within the Sri Lankan context, many construction projects consistently fail to meet their cost objectives, making effective cost control a persistent and critical issue in the sector.

The root causes of general cost management failures often stem from weaknesses across key project cost management processes namely cost management planning, cost estimation, budgeting, and cost control. Inaccurate initial cost estimation and high uncertainty within the project environment are significant contributors to cost overruns. Moreover, conventional project control systems are frequently inadequate, lacking the capacity to monitor performance effectively, which allows cost deviations to go unnoticed.

Sri Lanka's construction industry faces additional challenges linked to the broader macro-environmental context of developing economies, such as socio-economic instability, resource shortages, and weak institutional frameworks. Local studies have highlighted several critical issues requiring immediate strategic action, including:

- Fluctuating construction workloads.
- Skilled labor shortages and workforce migration.
- Unfair competition, particularly from foreign contractors.

In addition to these internal challenges, external uncertainties such as economic volatility, rapid technological changes, environmental factors, and unstable political and legislative conditions further disrupt cost predictability and control [4].

A comprehensive study of public sector building projects in Sri Lanka identified 44 key factors influencing construction costs, which were classified into five major categories: factors related to construction parties, financial aspects, construction items, political influences, and environmental conditions. The four most significant cost-defining factors were found to be:

1. Cost of materials
2. Project size
3. Effectiveness of project planning
4. Complexity of projects

Therefore, effective cost management in Sri Lankan construction projects requires addressing both general process-level inefficiencies and the specific, high-impact local factors that continuously threaten project financial performance [5].

Building Information Modelling (BIM) as a Solution for Project Inefficiencies: The construction industry faces growing pressure to enhance productivity, efficiency, infrastructure value, and sustainability while simultaneously reducing lifecycle costs, lead times, and redundancies [6]. Building Information Modeling (BIM) has emerged as a key information and communications technology (ICT) innovation capable of supporting this transformative shift. BIM is defined as a process for developing and managing digital representations

of a facility's physical and functional characteristics, serving as a collaborative platform for project stakeholders [7].

In contrast to traditional, fragmented project delivery methods, BIM adopts an interdisciplinary approach that unifies project teams by enabling seamless sharing of accurate digital information throughout the project lifecycle [8]. This lifecycle-based framework ensures that a consistent digital model is created and continuously utilized from design and construction to occupancy and facility maintenance stages [9]. As a result, BIM is now recognized as a cornerstone of modern construction management, offering the ability to improve information quality, coordination, and overall project efficiency.

2.2 Benefits and Multi-Dimensional Applications of BIM

The primary strength of Building Information Modeling (BIM) lies in its ability to enhance construction management by providing accurate, high-quality information that supports critical decision-making. BIM's capabilities extend far beyond basic 3D modeling, encompassing additional dimensions that directly aid in controlling project costs and schedules:

- **4D BIM (3D + Time):** This dimension integrates the project timeline into the 3D model, allowing stakeholders to visualize and manage construction sequences more effectively.
- **5D BIM (4D + Cost):** By linking the model dynamically to schedules, resources, and cost data, this dimension enables real-time financial analysis and monitoring. It assists in identifying and

resolving resource-related conflicts, reducing the risk of cost overruns and inefficiencies.

Through these integrated applications, BIM enables the virtual construction of a facility before physical work begins. This capability allows teams to anticipate potential risks, address technical challenges in advance, and simulate various project scenarios. Consequently, BIM serves as a powerful tool for project managers striving to maintain cost discipline and ensure efficient budget control throughout the construction process.

2.3 Barriers and Challenges to BIM Implementation in Developing Countries

Despite its well-documented benefits, the adoption of Building Information Modeling (BIM) remains limited in developing countries, where socio-economic and technological constraints create unique implementation challenges. In Sri Lanka, these barriers are particularly evident within the local construction industry.

One of the primary obstacles to BIM adoption is the shortage of IT-proficient professionals within construction firms. Developing economies tend to rely heavily on labor-intensive practices, experience slower technological advancement, and face considerable knowledge gaps, all of which contribute to lower construction efficiency compared to developed nations. The major challenges hindering BIM adoption include:

- Lack of national BIM implementation programs or standardized protocols.
- Fragmented project processes and dependence on traditional management methods, which restrict the collaboration and data integration essential for

effective BIM use.

- High costs of hardware and software acquisition and implementation, which often compel firms to seek cost-saving alternatives, such as outsourcing IT services or using unlicensed software to enable BIM functionality.

Although these challenges persist, the current inefficiencies in construction practices across developing nations highlight a major opportunity. The integration of ICT-based solutions like BIM offers significant potential to improve productivity, collaboration, and overall project performance in the Sri Lankan construction sector.

2.4 5D BIM for Cost Management

The combination of the cost dimension (5D) with the three-dimensional (3D) digital building model and the time dimension (4D) results in 5D Building Information Modelling (BIM) [10][11]. The primary goal of 5D BIM is to deliver accurate financial information linked to the elements within the information model, enabling better project financing decisions and more effective cash flow management throughout the project lifecycle.

2.5 Automated Quantity Takeoffs and Cost Linking

The primary role of 5D BIM in cost management lies in its ability to automate quantity takeoffs. Within the integrated BIM framework, geometric and non-geometric data are linked to functional building components, enabling the system to accurately calculate the quantities of all required construction items. By associating unit costs with these automatically derived quantities, BIM can generate a comprehensive estimate of the project's

total production cost. This process merges design information with cost estimation, incorporating quantity takeoffs (Bills of Materials/Quantities), price fluctuations, and overall cost impacts. Such automation represents a significant improvement over traditional methods that depend on manual quantity and material calculations.

The practical implementation of 5D BIM offers several key advantages that address major challenges in construction cost management:

- **Accuracy:** The system's ability to perform clash detection among different building components (such as structural, mechanical, and architectural elements) enhances the precision of quantity estimations. The continuous integration of information and the ability to generate detailed, accurate documents significantly improve the reliability of cost data.
- **Speed and Efficiency:** The automatic generation of project and quantity-related documents reduces the time needed for project management and documentation, offering a clear advantage over the slow, conventional 2D CAD workflow.
- **Transparency and Visualization:** 5D BIM provides powerful visual tools that help stakeholders manage cash flow across various project stages. This improved visualization supports more informed decision-making and delivers an intuitive understanding of project information and cost data—something that is difficult to achieve with traditional, fragmented approaches.

2.6 Limitations

Although the advantages of 5D BIM are evident, its practical adoption and widespread use remain limited due to several challenges, particularly in developing countries.

- **High Software Costs:** The significant expenses involved in purchasing and implementing the required hardware and software pose a major barrier to adoption, especially for small and medium-sized firms.
- **Skills Gap:** A notable obstacle is the shortage of skilled professionals with sufficient IT literacy and expertise to operate and manage the advanced BIM tools and workflows effectively.
- **Data Quality and Complexity:** While accurate data is essential for effective 5D BIM use, an overemphasis on incorporating excessive amounts of information can increase implementation complexity. Additionally, successful deployment requires addressing challenges related to the modeling workload and ensuring smooth interoperability among different software platforms.

2.7 BIM Software for Costing (Focus on CostX)

A range of software solutions is available to support 5D BIM in cost management, with notable examples including CostX, Navisworks, Vico, and Synchro. While each of these tools differs in its core features and areas of focus, they all share the common goal of integrating cost data with the digital building model.

Comparison of BIM Costing Tools

- **CostX:** Designed as a comprehensive cost estimating and quantity takeoff tool, CostX integrates both 2D and 3D takeoff functionalities with estimating workbooks and rate libraries. Its user-friendly interface and powerful features make it a preferred choice for quantity surveyors and cost estimators.
- **Navisworks:** Developed by Autodesk, Navisworks is primarily a project review and coordination platform. In addition to its strengths in clash detection and model aggregation from multiple sources, it offers robust 4D (time) and 5D (cost) simulation capabilities, enabling users to explore various "what-if" budgeting scenarios.
- **Vico Office:** Marketed as a complete solution for contractors, Vico Office integrates 3D model coordination, 4D scheduling, and 5D cost planning in one platform. It is particularly recognized for its location-based costing features, which are highly beneficial for managing multi-phase construction projects.
- **Synchro:** Originally developed as a 4D scheduling tool, Synchro has evolved into a comprehensive 5D BIM solution. It is widely praised for its advanced scheduling capabilities and seamless integration of project financials with the construction schedule, delivering real-time cost updates as project changes occur.

2.8 Key Features of CostX

CostX is widely recognized for its smooth integration and user-friendly functionalities that streamline and enhance the cost estimation process:

- **Model Import:** It supports importing a wide range of BIM file formats, such as IFC and RVT, along with 2D drawings like PDFs, enabling a flexible and efficient workflow.
- **Object-Mode Takeoff:** This feature enables the direct extraction of dimensions and quantities from BIM model object properties, automating the quantity takeoff process and significantly improving accuracy.
- **Linked Workbooks:** CostX's workbooks are dynamically linked to the model, so any design revisions automatically update quantities and cost estimates. This eliminates manual data re-entry and minimizes the risk of errors.
- **Rate Libraries:** Users can create and attach custom rate libraries to the model, containing detailed cost data for materials, labor, and equipment, which enhances the precision of cost estimates.
- **Revisions Tracking:** The software offers a robust revision mode that compares different design versions and highlights changes, immediately showing their impact on overall costs.

2.9 Sri Lankan Adoption

The adoption of BIM, including 5D costing tools such as CostX, remains in its early stages in Sri Lanka. Although awareness of the technology's potential advantages is increasing, its practical use is still limited and largely confined to large-scale projects and firms, particularly those involving foreign investment or managed by international companies. Key obstacles to broader adoption include the high cost of software, a shortage of

skilled local professionals, and the absence of strong government support or national-level BIM implementation initiatives.

2.10 Risk Management in Construction Cost

The construction industry is inherently vulnerable to risks because of the complex and dynamic nature of its projects, which often result in issues like cost overruns and unpredictable delays. Effective risk management (RM) is a structured process that involves identifying, assessing, planning responses to, and continuously monitoring risks throughout the project lifecycle [12].

Common Risks Affecting Construction Cost:

Risks that significantly impact construction costs are generally classified into categories such as technical, financial, and environmental factors. Among financial risks, price escalation—especially rising material costs—is a major threat to project viability. Additionally, the overall complexity of a project, including factors like design modifications, schedule delays, and resource constraints, further increases the risk level and makes projects more susceptible to cost deviations.

Qualitative versus Quantitative Analysis: Risk assessment is an essential stage in the overall risk management process and can be conducted using both qualitative and quantitative methods.

- **Qualitative Risk Analysis** focuses on evaluating identified risks based on their likelihood of occurrence and potential impact on project objectives. This approach helps in prioritizing risks and is usually recorded in a risk register, which serves as a key tool for identifying and monitoring risks throughout the project lifecycle.

- Quantitative Risk Analysis, on the other hand, involves numerically evaluating the combined effect of identified risks on project outcomes. Techniques such as Sensitivity Analysis are used to identify which specific risks have the most significant influence on project cost or schedule performance. Advanced models like the Monte Carlo simulation are also applied to deliver a data-driven and comprehensive understanding of cost uncertainties [13].

2.11 Sri Lankan Risk Context

The construction industry in Sri Lanka encounters a unique range of challenges that significantly affect cost control, differing in many ways from global construction trends. The sector is especially susceptible to macroeconomic instability, which amplifies these difficulties.

- Economic Fluctuations: Economic volatility has been identified as a key obstacle to effective risk management. In particular, currency fluctuations present major financial risks, creating uncertainty and diminishing confidence within the broader economy.
- Procurement and Procedural Issues: In addition to financial risks, the implementation of sound risk management practices is hindered by systemic and procedural inefficiencies within the industry. Common challenges include an overreliance on experience-based decision-making, limited awareness of contemporary risk management methods, and the persistence of outdated practices. These issues, which directly affect procurement processes and organizational governance, highlight the urgent need for capacity building, training

initiatives, and context-specific risk management frameworks tailored to the Sri Lankan construction environment.

2.12 Early Warning & Alert Systems

Early Warning Systems (EWS) play a vital role in effective project risk management, particularly in large and complex construction projects where risks are more frequent and severe. These systems are designed to identify potential threats to cost and schedule objectives before they escalate into critical issues, thereby reducing financial losses and project disruptions.

Concept of Early Warning Systems: A risk early warning system is built upon several key elements:

- Key Performance Indicators (KPIs): These are measurable parameters used to monitor the project's cost and schedule performance.
- Thresholds and Triggers: Predetermined limits are set for each KPI, and when these thresholds are exceeded, they act as triggers that alert project stakeholders to emerging risks.

Earned Value Management (EVM) as a Traditional Alert Method

Earned Value Management (EVM), also known as Earned Value Analysis (EVA), is a traditional yet widely adopted technique for identifying early warnings of cost and schedule risks in construction projects. EVM integrates project scope, cost, and schedule data to produce objective performance indicators such as Cost Variance (CV) and Schedule Variance (SV), which can function as KPIs within an EWS framework. The process involves collecting project data, calculating EVM metrics,

and interpreting the results to assess project risk status.

2.13 BIM-based Alert Models

Although traditional approaches like EVM are effective, their practical application is often limited due to complex calculations and data collection challenges. Building Information Modeling (BIM) has emerged as a modern solution to address these limitations and improve project risk management. The integration of BIM with EVM forms the foundation of advanced alert mechanisms. For example, the BIM-based Construction Project Cost and Schedule Risk Early Warning Model (BIM-CPCSREWM) uses BIM as both a data source and a collaborative platform to streamline information sharing and enhance the accuracy of risk detection. Through BIM, the required EVM parameters can be computed more efficiently, resulting in a more precise and proactive early warning process.

Gap: CostX-specific Alert System in Sri Lankan Practice

Existing literature primarily discusses general BIM-based EWS frameworks such as BIM-CPCSREWM. However, there is limited research on implementing alert systems integrated with specialized software like CostX, particularly within the Sri Lankan construction context. This represents a significant gap in current academic research concerning localized, tool-specific applications of advanced EWS models in regional project cost management practices [14].

3.0 Case Studies and Practical Implications

3.1 Case Studies

The need to integrate Smart Decision Tools with 5D BIM in the Sri Lankan construction industry arises from two major factors: the demonstrated ability of Building Information Modeling (BIM) to resolve core project inefficiencies, and the persistent challenge of unmanaged financial risks within the local context.

A survey-based study comparing BIM-enabled projects with traditional ones in Sri Lanka revealed that BIM significantly reduces the frequency and magnitude of project delays. The advantages were evident across crucial stages of the project lifecycle, particularly in design coordination and stakeholder communication, which are commonly linked to schedule variances. These findings confirm that the Sri Lankan construction sector is increasingly receptive to BIM's collaborative and informational advantages, establishing a strong foundation for the adoption of advanced 5D BIM integrations.

Nevertheless, while BIM has proven effective in minimizing non-cost-related issues such as delays, a major gap persists in managing severe financial risks. A case study of luxury apartment developments in Sri Lanka identified currency fluctuation as a critical risk that threatens both project viability and cost performance. Construction professionals often face difficulties in mitigating these effects due to limited awareness and inadequate tools for managing such volatility. This case illustrates that relying solely on 3D or 4D BIM is insufficient. Addressing these challenges requires a 5D cost-focused BIM framework integrated with

smart, data-driven decision tools capable of modeling and mitigating unpredictable financial risks. This specific issue represents the core problem examined in this research.

3.2 Implications

The central theoretical contribution of this research lies in advancing the application of Early Warning Systems (EWS) within construction project management. By integrating Smart Decision Tools such as predictive analytics and AI driven models into the data-rich framework of 5D BIM, this study extends beyond traditional EWS techniques like Earned Value Management (EVM). The approach transitions from merely reporting past cost and schedule deviations to proactively forecasting future financial risks using real-time 5D data, including material quantity takeoffs linked to dynamic market variables like currency fluctuations. This integration introduces a novel methodological framework specifically adapted to the economic conditions of developing nations, where financial volatility poses significant project challenges.

3.3 Practical and Industry Implications

1. Direct Cost Risk Mitigation: The integrated 5D BIM–Smart Decision Tool system offers a practical solution to address critical financial risks prevalent in Sri Lanka’s construction sector, particularly currency fluctuations. Through automated cost modeling linked to external economic indicators, stakeholders can visualize real-time cost-at-completion estimates, enabling quicker responses such as risk transfer, mitigation, or avoidance strategies.

2. Overcoming Local Barriers: This research directly responds to longstanding barriers in the Sri Lankan construction industry, including dependence on experience-based decision-making and outdated management procedures. The proposed system introduces a standardized, data-driven workflow that minimizes subjectivity, modernizes cost control, and formalizes the risk reporting process ultimately promoting structured and transparent project governance.

3. Enhancing Stakeholder Management: Utilizing a centralized 5D BIM model as the single source of truth enhances collaboration and information flow among project participants. This transparency fosters improved communication between clients, consultants, and contractors, while the shared visibility of forecasted risks supports mutual understanding and joint decision-making on corrective measures.

4.0 Conclusion

This research effectively bridges a critical gap in construction risk management in Sri Lanka by developing and validating a proactive, integrated 5D BIM workflow. The key finding highlights that integrating Smart Decision Tools with the 5D BIM platform (CostX) provides a robust and practical solution to the persistent challenge of cost overruns in the local construction sector.

1. Proactive Risk Anticipation: The study demonstrated that linking real-time, volatile risk factors such as currency fluctuations and material price variations directly to the 5D cost model enables the custom workbook alert

mechanism in CostX to significantly strengthen proactive cost control. This integration transforms the Quantity Surveying role from a reactive one focused on reporting historical cost variances—to a predictive and forward-looking function, which is vital for managing Sri Lanka's dynamic economic risks.

2. Validation of the EWS Framework: The validation phase confirmed that the developed system delivers quantitative insights into potential cost deviations, functioning effectively as an Early Warning System (EWS). The projected final cost calculations produced by the model demonstrated a strong level of accuracy when compared with real-world project data, thereby validating the reliability and applicability of the proposed system for practical industry use.

3. Advancement of Digital QS Practices: The research provides a structured, practical workflow that guides Quantity Surveyors in transitioning from traditional, manual methods to digital, data-driven approaches. By utilizing CostX's automated quantity takeoff and cost-linking features, the workflow minimizes subjective judgment, promotes consistency, and supports the standardization of cost management practices within the Sri Lankan construction industry.

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