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AN INTEGRATED BUILDING INFORMATION MODELING (BIM) FRAMEWORK FOR CONSTRUCTION PROJECT PLANNING AND CONTROL

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ABSTRACT

Building Information Modeling (BIM) has emerged as a transformative technology in the construction industry, enabling efficient planning, coordination, and control of projects. Traditional project management approaches often suffer from poor information integration, schedule delays, and cost overruns. This paper proposes an integrated BIM-based framework to enhance construction project planning and control through centralized data management and real-time collaboration. The framework incorporates 3D modeling, 4D scheduling, and 5D cost estimation to improve decision-making accuracy. Risk identification and progress monitoring are achieved using BIM-based visualization and simulation techniques. The proposed approach enhances communication among stakeholders and minimizes construction conflicts. Experimental validation demonstrates improved project efficiency, reduced rework, and enhanced schedule reliability. The results indicate that BIM integration significantly improves construction project performance and control.

KEYWORDS: Building Information Modeling, Construction Planning, Project Control, 4D BIM, 5D BIM, Cost Management, Scheduling

I. INTRODUCTION

The construction industry is characterized by complex processes, fragmented information flow, and high uncertainty, often leading to delays and cost overruns. Effective planning and control mechanisms are essential to manage construction projects efficiently. Conventional methods rely heavily on 2D drawings and manual scheduling tools, which lack integration and real-time coordination. These limitations necessitate advanced digital solutions for construction management.

Building Information Modeling (BIM) provides a collaborative digital platform that integrates geometric, functional, and financial information throughout the project lifecycle. BIM enables visualization, simulation, and analysis of construction activities before physical execution. This proactive approach helps identify design conflicts and planning inefficiencies at early stages. As a result, BIM significantly improves project predictability and coordination.

The integration of BIM into project planning allows stakeholders to develop accurate schedules and optimize resource allocation. 4D BIM links the construction schedule with the 3D model, enabling time-based simulation of construction activities. This improves understanding of construction sequences and enhances schedule reliability. It also assists project managers in identifying potential delays and resource conflicts.

Project control is another critical aspect where BIM demonstrates substantial benefits. By incorporating cost data into BIM models, 5D BIM supports real-time cost estimation and budget tracking. Variations and design changes can be evaluated instantly, enabling informed decision-making. This reduces financial risks and enhances cost transparency.

This paper presents an integrated BIM framework designed to improve construction project planning and control. The proposed framework combines scheduling, cost management, and progress monitoring within a unified BIM environment. The effectiveness of the framework is evaluated through experimental analysis, demonstrating its applicability in real-world construction projects.

II. LITERATURE REVIEW

Early studies on BIM focused primarily on 3D visualization and clash detection in building design. Eastman et al. demonstrated that BIM improves design coordination and reduces errors during construction. These initial applications highlighted BIM's potential to replace traditional CAD-based approaches. However, early BIM implementations were limited to design phases.

Subsequent research expanded BIM applications into construction planning and scheduling. Researchers introduced 4D BIM by integrating project schedules with 3D models. Koo and Fischer showed that 4D BIM enhances schedule visualization and improves communication among project stakeholders. This approach helped project teams understand construction sequences more effectively.

Cost management using BIM gained attention with the introduction of 5D BIM models. Studies revealed that BIM-based cost estimation improves accuracy and reduces manual calculation errors. Azhar emphasized that 5D BIM enables dynamic cost updates in response to design changes. This capability enhances financial control throughout the project lifecycle.

Several researchers explored BIM-based project control and monitoring systems. Automated progress tracking using BIM and site data has been proposed to enhance project control accuracy. These systems allow comparison between planned and actual progress, enabling early detection of deviations. However, implementation challenges remain due to data integration issues.

Despite significant advancements, existing studies often address BIM applications in isolation rather than as an integrated framework. There is a lack of comprehensive models that combine planning, scheduling, cost control, and monitoring. This research addresses this gap by proposing an integrated BIM framework for holistic construction project management.

III. PROPOSED METHODOLOGY

The proposed methodology introduces an integrated BIM framework for construction project planning and control. The framework begins with the development of a detailed 3D BIM model incorporating architectural, structural, and MEP components. This model serves as a centralized data repository accessible to all stakeholders. Clash detection is performed to eliminate design conflicts.Thesecond phase involves schedule integration using 4D BIM. Construction activities are linked with corresponding BIM components to generate a time-based simulation. This allows visualization of construction sequences and identification of potential scheduling conflicts. The 4D model supports optimized sequencing and resource planning.

In the third phase, cost data is integrated into the BIM environment to create a 5D model. Material quantities are extracted automatically from the BIM model for accurate cost estimation. Cost updates are performed dynamically in response to design changes. This ensures effective budget control and financial transparency.

The fourth phase focuses on project control and monitoring. Actual construction progress is periodically updated in the BIM model. Planned and actual schedules are compared visually to identify deviations. This enables proactive corrective actions to maintain project timelines.

The final phase emphasizes collaborative decision-making. Stakeholders access the BIM platform to review progress, evaluate alternatives, and resolve issues. The integrated framework enhances coordination, reduces rework, and supports data-driven project management.

IV. EXPERIMENTAL SETUP

The experimental study was conducted on a mid-scale commercial building project to validate the proposed framework. A detailed BIM model was developed using industry-standard BIM software. Project drawings, schedules, and cost data were incorporated into the model. The project duration and scope were defined based on real project data.

A baseline project plan was created using traditional planning methods for comparison. The BIM-based planning approach was then implemented following the proposed methodology. Construction schedules were linked to BIM components to generate a 4D simulation. Cost data was integrated to enable real-time cost tracking.Project progress data was collected periodically during the simulation phase. Planned and actual progress were compared using BIM-based visualization tools. Delays and deviations were identified and analyzed. Corrective actions were simulated to evaluate their impact on project performance.

Key performance indicators such as schedule variance, cost variance, and rework percentage were measured. These metrics were used to assess the effectiveness of the BIM-based framework. The results were compared against the traditional planning approach.

The experimental setup demonstrated the practical applicability of the proposed framework. The BIM-based approach provided enhanced visibility, improved coordination, and better control over project execution.

V. RESULTS AND DISCUSSIONS

The results indicate that the integrated BIM framework significantly improves construction project planning accuracy. The 4D BIM model enhanced visualization of construction sequences, reducing scheduling conflicts. Project stakeholders reported improved understanding of project timelines and dependencies.

Cost control performance showed notable improvement using the 5D BIM approach. Automatic quantity take-offs reduced estimation errors and improved cost accuracy. Real-time cost updates enabled effective budget monitoring throughout the project lifecycle.

Project control and monitoring were enhanced through BIM-based progress tracking. Visual comparison of planned and actual schedules facilitated early identification of delays. This allowed timely corrective actions, reducing overall project duration.

The framework also improved communication and collaboration among stakeholders. Centralized data access reduced information silos and enhanced decision-making. Coordination issues between design and construction teams were minimized.

Rework and change orders were significantly reduced due to early clash detection and planning optimization. The BIM-based framework enabled proactive risk mitigation and improved construction quality.Overall, the experimental results confirm that the proposed integrated BIM framework enhances efficiency, reduces costs, and improves project control compared to traditional methods.

VI. CONCLUSION

This research presented an integrated BIM framework for construction project planning and control. The framework combines 3D modeling, 4D scheduling, and 5D cost management within a unified environment. It addresses key challenges associated with traditional construction management practices.

The experimental evaluation demonstrated that BIM integration improves planning accuracy, cost control, and project monitoring. Enhanced visualization and real-time data updates support proactive decision-making. The framework also improves collaboration among project stakeholders.

The findings confirm that BIM-based project management significantly enhances construction project performance. The proposed framework provides a practical and scalable solution for modern construction projects.

FUTURE SCOPE

Future research can integrate AI and machine learning techniques with BIM for predictive project analytics.

IoT-based real-time data collection can enhance automated progress monitoring. Cloud-based BIM platforms can improve scalability for large infrastructure projects. Integration with digital twin technology can further enhance lifecycle project management.

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