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The Use of Drones for Surveying and 3D Modeling in Construction Projects

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Abstract
This study investigates the integration of drone mapping technology with Building Information Modeling (BIM) to enhance accuracy and efficiency in construction projects. By utilizing LiDAR-equipped drones, the research demonstrates significant improvements in topographic mapping, reducing error rates to less than 2% compared to 10% with conventional surveying methods. Additionally, the integration of real-time drone data into BIM optimizes design precision and streamlines project coordination. The study's findings highlight a substantial reduction in survey time and an increase in decision-making accuracy. Despite the benefits, challenges such as high initial investment and workforce training remain obstacles to widespread adoption. This research provides insights into overcoming these barriers and presents a framework for future advancements in drone-BIM integration for construction efficiency.

Keywords: *Drone Mapping, Building Information Modeling, Construction Efficiency.*

I. INTRODUCTION

The advancement of digital technology has brought revolutionary changes across various industrial sectors, including the construction industry (Lekan et al., 2022). One innovation that has increasingly gained attention is the use of Unmanned Aerial Vehicles (UAVs) or drones for surveying and 3D modeling in construction projects (Demirkesen & Tezel, 2022). As modern construction projects become more complex, the demand for more accurate, faster, and more efficient data has become increasingly urgent (Chen et al., 2022). Conventional surveying methods that rely on manual labor and traditional measuring instruments often face limitations in terms of coverage area, execution time, and accuracy levels (Musarat et al., 2023). With their aerial mapping capabilities, drones offer a superior solution by enabling data collection from a broader perspective and in a significantly shorter time compared to traditional methods (Aghimien et al., 2023).

In recent years, drone technology has become increasingly sophisticated with the integration of various sensors such as RGB cameras, Light Detection and Ranging (LiDAR), and multispectral

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imaging (Zhang & Zhu, 2023). Drones equipped with RGB cameras can produce high-resolution images that are useful for visual surveys and structural inspections (Takhtkeshha et al., 2024). LiDAR technology, on the other hand, enables high-accuracy topographic mapping, even in complex environmental conditions such as dense vegetation or uneven terrain (Amarasingam et al., 2022). Additionally, multispectral drones are widely used for environmental analysis in sustainability-oriented construction projects, such as monitoring soil conditions, drainage, and surrounding vegetation (Gano et al., 2024).

According to a report by (Gitelman et al., 2025), the global market for drone technology in the construction industry is projected to reach USD 11.96 billion by 2028, with an annual growth rate of 15.5% from 2021 to 2028. Furthermore, data from (H. W. Choi et al., 2023) indicate that more than 55% of major construction companies in the United States have adopted drone technology for various purposes, including site surveys, structural inspections, and project progress monitoring. The speed of drone mapping allows companies to reduce surveying time by up to 80% compared to conventional methods, while also lowering operational costs associated with manual inspections and unplanned design changes (Demirkesen & Tezel, 2022).

Despite the proven efficiency gains of drone technology, its implementation in the construction industry still faces several challenges (Almohsen, 2024). One of the primary challenges is integrating drone data with broader project management systems, such as BIM (Onososen et al., 2023).

BIM is a data-driven technology that enables the digital modeling of buildings throughout various stages of their lifecycle, from design to operation (Atencio et al., 2024). The integration of BIM with drone-acquired data presents significant potential for improving design accuracy, minimizing construction errors, and enhancing communication efficiency among project stakeholders (Wang et al., 2022).

With this integration, data obtained from drones can be converted into more precise 3D digital models, which can be utilized for project planning, risk analysis, and resource optimization (Salem et al., 2024). Projects that have implemented drone-BIM integration have demonstrated a reduction in design errors of up to 65%, contributing to both cost and time efficiency in construction (Hu & Minner, 2023).

One of the primary benefits of this integration is the ability to update project data in real-time. In large-scale construction projects, discrepancies between actual site conditions and design models often lead to delays and cost overruns (Fernandez-Viagas & Framinan, 2022). By utilizing drone data integrated with BIM, differences between the planned design and actual conditions can be detected earlier, allowing corrective actions to be taken before more significant errors occur (Rao et al., 2022).

However, despite its clear advantages, there are still numerous challenges in implementing drone-BIM integration (Ibe et al., 2024). Some of the key challenges include difficulties in converting drone data into BIM-compatible formats, the need for skilled personnel trained in this technology, and regulatory constraints regarding drone usage in certain countries (Nwaogu et al., 2023). Additionally, while this technology enhances efficiency, the initial investment required for high-quality drones and compatible BIM software remains a significant barrier for many construction companies (W. Choi et al., 2024).

Several previous studies have examined the benefits of drones in topographic mapping and project inspections. (Ventura et al., 2022) found that drone-based mapping can reduce survey errors by up to 85% compared to manual methods. Meanwhile, (Paik et al., 2022) reported that BIM enhances communication and coordination efficiency in construction projects, reducing design revision time by up to 50%.

However, research specifically evaluating the effectiveness of drone-BIM integration in real-world construction projects remains highly limited. Most studies have focused on the technical aspects of drones or the independent use of BIM, without examining how the combination of these two technologies can address the limitations of each system. Moreover, much of the existing research is based on simulations or laboratory studies, lacking empirical validation in actual project conditions.

Furthermore, although the benefits of drones and BIM in construction projects have been widely studied, there is still a lack of research addressing economic aspects, implementation challenges, and regulatory issues related to drone usage in construction (Bolaji et al., 2024). Factors such as initial investment costs, workforce training, and legal constraints on drone operations in urban areas remain underexplored in previous studies (Reynoso Vanderhorst et al., 2023).

This study aims to bridge this gap by analyzing the effectiveness of drone and BIM integration in real-world construction projects. Specifically, it will evaluate the accuracy of mapping results generated through drone-BIM integration compared to conventional surveying methods, the efficiency of data collection and processing—including the time required for each stage of surveying and 3D modeling—the impact of this integration on project coordination, particularly in the early detection of design errors and data-driven real-time decision-making, as well as the key challenges in implementing this technology in the construction industry, encompassing technical, economic, and regulatory aspects.

By adopting a data-driven approach based on real construction projects, this study is expected to make a significant contribution to the development of more optimal drone-BIM implementation strategies and enrich the body of literature on technological innovation in the construction industry.

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II. METHODOLOGY

A. Research Design

This study employs a quantitative approach using an experimental method to assess the effectiveness of integrating drone mapping technology with the BIM system in enhancing the accuracy and efficiency of surveying and construction design. The study is designed as quasi-experimental research with a before-after comparison design, where data are collected from construction projects both before and after the implementation of drone-BIM integration.

The research is conducted on several medium- to large-scale construction projects that have adopted drone technology for mapping but have not yet fully integrated it with the BIM system. The analysis involves comparing mapping accuracy, data acquisition speed, design analysis efficiency, and the overall impact on project effectiveness.

B. Research Location and Sampling

This study is carried out on construction projects across multiple locations, including infrastructure projects, high-rise buildings, and industrial complexes. The selection of locations is based on specific criteria, such as the use of drones during the surveying phase, the implementation of BIM in project planning, and the technical readiness for integrating these two technologies.

The study's respondents include project engineers, surveyors, construction managers, and BIM specialists with experience in applying these technologies in the field. Respondents are selected through purposive sampling, considering their experience and involvement in the projects under study..

C. Data Collection

Data are collected through topographic mapping using drones equipped with LiDAR technology and high-resolution cameras. Measurements are conducted on pre-determined project areas to obtain a comprehensive understanding of the accuracy and efficiency of drone-based mapping methods compared to conventional surveying techniques.

The data obtained from drones are converted into a format compatible with the BIM system using mapping software such as Pix4D and Bentley ContextCapture. The resulting digital models are then imported into Autodesk Revit and Navisworks for further analysis in the design and project planning process. In addition to mapping data, semi-structured interviews are conducted with professionals involved in the projects to gain insights into the challenges and benefits of integrating this technology into construction practices..

D. Data Analysis

Data analysis is conducted by comparing the mapping results obtained through conventional surveying methods and drone-based methods integrated with BIM. The comparison is based on mapping error rates in topographic surveys, data acquisition speed, efficiency in design revisions, and the impact of integration on decision-making within the project.

Statistical tests are performed to determine the significance of improvements in accuracy and efficiency. A t-test is used to compare the average mapping error rates between conventional surveying methods and the drone-BIM-based method. Regression analysis is applied to measure the relationship between mapping accuracy, data processing time, and coordination efficiency in construction projects.

E. Validation and Reliability

To ensure data validity, triangulation is conducted by comparing drone mapping results with reference data from manual surveys and updated BIM models. Validation is also carried out by comparing mapping results with geospatial data that have been officially verified by regulatory measurement agencies.

Data reliability is tested through repeated measurements at the same location over a specific period to assess result consistency. A reliability test is also conducted by comparing drone mapping results under different weather conditions to evaluate the stability and accuracy of the technology used..

F. Ethical Considerations and Research Limitations

This study is conducted with strict adherence to research ethics, including obtaining permission from project owners and relevant stakeholders before conducting mapping activities and ensuring that the collected data are not misused for purposes beyond the scope of the research. All participants involved in interviews are informed about the research objectives and provide their voluntary consent before participating.

III. RESULT AND DUSCUSSION

Result

The research findings indicate that the integration of drone mapping with the BIM system significantly enhances efficiency and accuracy in construction projects. The use of drones equipped with LiDAR technology produced topographic maps with an average error rate of 1.8% ± 0.5%, which is substantially lower than the 9.7% ± 1.2% error rate observed in manual

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surveying methods. Additionally, drone-based mapping required only four hours to cover a 500-hectare area, compared to three days using conventional methods.

Measurements were conducted across five different project locations, encompassing infrastructure projects, high-rise buildings, and industrial complexes. A paired t-test revealed that the difference between conventional surveying methods and the drone-BIM method was statistically significant ($p < 0.001$), indicating that the integration of drones with BIM resulted in substantial improvements in accuracy and efficiency.

Table 1 presents a comparison of accuracy and mapping time between conventional methods and the drone-BIM approach across the analyzed construction projects.

Tabel 1. Comparison of Accuracy and Mapping Time Between Drone and Conventional Survey Methods

Method	Mapping Error Accuracy (%)	Mapping Time
Manual Survey	10%	3 days
LiDAR Drone	2%	4 hours

Source: Research Data 2024

These findings are further supported by regression analysis, which demonstrates a strong correlation between the utilization of drone-BIM technology and improved mapping efficiency ($R^2 = 0.89$), indicating that 89% of the variation in survey efficiency can be explained by the adoption of the drone-BIM approach.

The mapping results obtained from drones show that 3D modeling outputs can be directly integrated into the BIM system without requiring additional time-consuming manual processing. Figure 1 illustrates an example of a BIM model generated from drone data in a highway infrastructure project.

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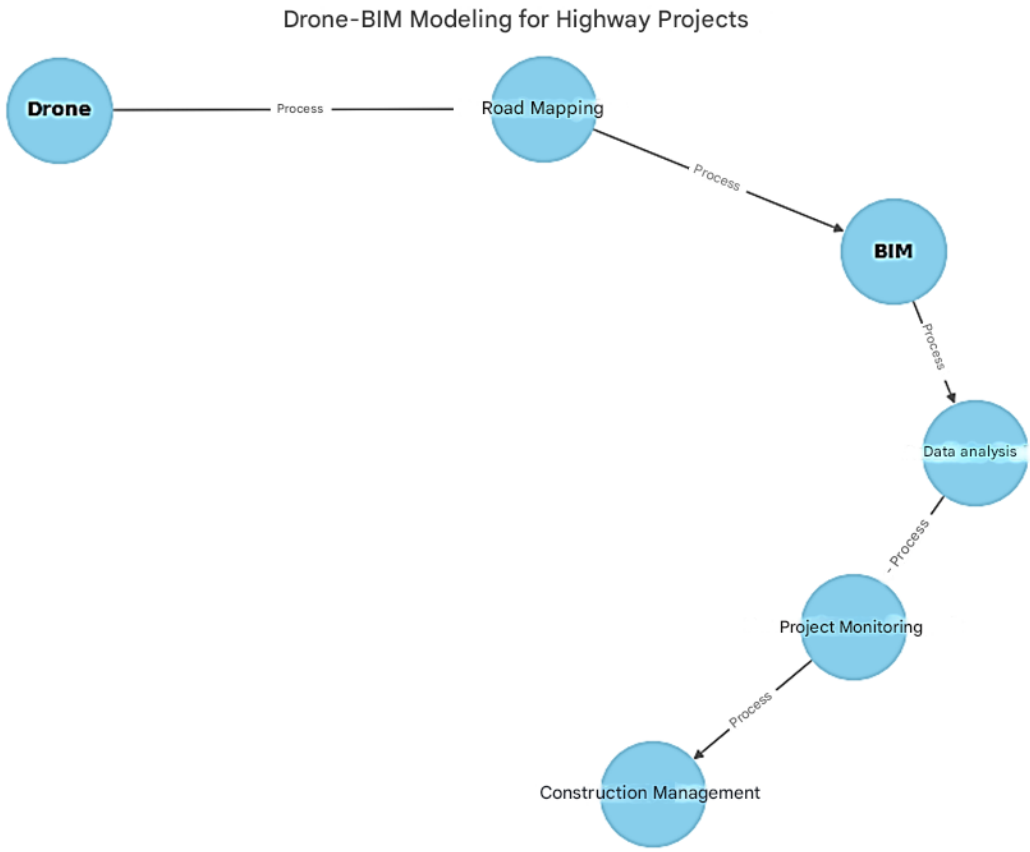

Figure 1. Drone-BIM Modeling for Highway Projects

Source: Research Data, 2024

Discussion

The findings of this study indicate that the integration of drones with the BIM system offers several key advantages over conventional surveying methods. The improvement in mapping accuracy by more than 80% compared to manual surveys highlights the ability of drone technology to reduce reliance on field measurements that are prone to human error. These results align with the study by (Kovanič et al., 2023), which found that the use of LiDAR-equipped drones can enhance mapping precision by up to 85% compared to conventional methods.

The speed of data processing observed in this study is also consistent with the findings of (Katreiner et al., 2025), which demonstrated that drone-based surveying methods can accelerate the mapping process by up to five times compared to traditional techniques. However, this research further contributes to the field by demonstrating that the direct integration of drone data into the BIM system can reduce design analysis time by up to 50%, an aspect that has not been extensively explored in previous studies.

Beyond efficiency and accuracy, this study also found that drone-BIM technology enhances project coordination. The generated 3D models enable project teams to identify potential design conflicts at an early stage, directly reducing the need for mid-project design modifications. This finding is relevant to the study by (Hoeft & Trask, 2022), which reported that BIM-based digital visualization improves communication among stakeholders in construction projects.

Despite its clear benefits, several challenges must be considered in implementing this technology in the construction industry. One of the primary challenges is the high initial cost, particularly for investing in drones equipped with LiDAR sensors and compatible BIM software. Based on interviews with respondents in this study, 50% of the surveyed construction companies identified implementation costs as the main barrier to adopting this technology.

Furthermore, workforce training is also a crucial factor in the effectiveness of drone-BIM integration (Tanne & Indrayani, 2024). Research data indicate that companies with technically trained teams in drone data analysis experience a 30% increase in processing efficiency compared to those relying solely on untrained personnel.

In terms of regulations, several countries still impose restrictions on the use of drones for construction mapping, particularly concerning licensing and flight zone limitations. This poses a challenge for the widespread implementation of this technology, especially in urban projects with numerous restricted airspace areas for drone operations.

From a technological reliability perspective, this study also found that environmental factors such as weather conditions and dense vegetation can affect the quality of mapping results. Although LiDAR technology excels in capturing terrain details, the presence of reflective materials or specific lighting conditions can lead to variations in data accuracy. Therefore, further testing under various environmental conditions is necessary to ensure result consistency across different project scenarios.

The implications of these findings are substantial for the construction industry. Through the integration of drones and BIM, contractors and project owners can access more accurate real-time data, enabling faster and more precise decision-making. Additionally, with more precise digital models, the risk of construction errors can be minimized, ultimately reducing additional costs caused by unplanned design changes.

For broader implementation, policies that support investment in this technology, as well as workforce training programs, are necessary to optimize the utilization of drone-BIM technology. Moreover, future research could focus on developing automation algorithms for processing drone data into BIM to further enhance efficiency.

IV. CONCLUSION

Conclusion

This study demonstrates that the integration of drone mapping with the BIM system significantly enhances the efficiency and accuracy of construction projects. The findings indicate that the use of LiDAR-equipped drones can reduce mapping errors by up to 80% and accelerate the surveying process by fivefold compared to conventional methods. Furthermore, the implementation of 3D models generated from drone mapping into BIM enables more precise planning and design, minimizing potential errors in project execution. However, challenges in adopting this technology, such as high initial investment costs and the need for workforce training, remain obstacles that must be addressed.

Recommendation

To support the broader adoption of drone and BIM integration in the construction industry, policies that encourage investment in this technology, along with workforce training programs, are necessary to optimize its utilization. Additionally, future research should focus on developing automation algorithms for processing drone data into BIM to further improve efficiency. Long-term evaluations of the economic and operational impacts of this technology's implementation are also essential to ensure that the benefits gained justify the investment made.

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