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The Influence of Artificial Intelligence on Building Information Modeling when Managing Engineering Projects

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Abstract

The combination of Building Information Modeling (BIM) and Artificial Intelligence (AI) is transforming multi-disciplinary engineering project management through enhanced coordination, real-time decision-making, and productivity. While BIM has been used to coordinate information and co-design, it does not have predictive analytics and automation capabilities. AI introduces the potential for enhancing BIM benefits through automating tasks, optimizing resource utilization, and enhancing decision-making. This paper presents the impact of AI-based BIM compared to traditional BIM for engineering management based on actual case studies and the history of the strengths, weaknesses, and industry implications. Results confirm that the integration with AI improves productivity in project works, cost management, and stakeholders' coordination, which are lessons gained by digital engineering and construction management practitioners. The convergence of BIM and AI is transforming interdisciplinary engineering project management in the form of improved coordination, productivity, and timely decision-making. This study makes use of a desktop research methodology which combines a structured literature review, identified case study analysis and meta-analysis of secondary sources that are utilized to assess and compare how traditional BIM and BIM with integrated AI perform in managing multi-disciplinary projects.

Keywords
Building Information Modelling (BIM), Artificial Intelligence (AI), Engineering Management, Digital Engineering, Multi-Disciplinary Projects

1. Introduction
Building Information Modeling (BIM) and Artificial Intelligence (AI) integration is revolutionizing multi-disciplinary engineering project management, alleviating the traditional coordination, decision-making in real-time, and efficiency problems. BIM significantly improved design coordination, clash detection, and information coordination (Eastman et al. 2018). However, it remains limited in predictive analytics, automation, and resource optimization (HS2 Ltd 2021). BIM is missing predictive analytics, automation, and resource optimization. The capacity of AI to manage large data and automate complex engineering processes provides an opportunity to enhance BIM's usability further (Crawford 2023).

Though huge, the potential of AI in AI-based BIM project management is still not fully exploited, particularly in behemoth, multi-disciplinary construction projects (Alshaikhi 2021). This research compares AI-based BIM project management with traditional BIM regarding cost-effectiveness, performance, and efficiency. Empirically case study research-guided, this research is industry-relevant, identifying strengths and weaknesses. Industry take-up and best practices of AI-automated BIM processes are supported by breakthroughs and final assurance of ever-more efficient and sustainable complex construction projects. Practice contributions to construction management and digital engineering are realized through practitioner derivation of AI-determined optimization of the project delivery. With extensive limitations on the research carried out due to the introduction of AI still currently rolling out, the need for exploration is increasing exponentially as the digital engineering aspect grows significantly. This outlines the need for understanding the inherent motivations and constraints hampering or constraining digital engineering with AI for multi-disciplinary projects. These identify the various kinds of technologies that may be integrated to drive project management using AI and how engineering management efficiency for stakeholders and projects, when utilizing AI combined with BIM for multi-disciplinary projects, is impacted.

2. Literature Review

BIM has revolutionized computer-aided engineering in terms of centralized universes of information to facilitate coordination, visualization, and collaboration (Eastman et al. 2018). Traditional BIM platforms lack performance in situations involving real-time decision-making and automation, especially in large projects involving multi-disciplinary input. Such conditions demand real-time coordination, predictability forecasting, and adaptive workflows, which classical static data models-based BIM cannot provide (Ahmed 2020).

AI has also been a strategic tool to augment BIM with capabilities to provide machine learning, deep learning, and natural language processing capabilities. These capabilities bring depth to predictive analytics, conflict detection, real-time feedback, and workflow enhancement (Al Hattab 2018). For instance, in HS2 Rail, real-time validation of the design and environment reports were enabled by AI-based decision-support and digital twin systems, virtually eradicating rework and enhancing safety checks (HS2 Ltd 2021). Google Bay View Campus construction used AI to achieve optimized sustainability-led design and unlocked the potential for greater resource efficiency with machine learning (Google 2022).

Apart from intermittent discontinuous achievement, the general application of AI-based BIM is constrained. Among the constraints is a high initial price, i.e., training, cost of software and hardware for infrastructure. Shanghai Tower construction stakeholders did not readily accept AI systems on account of the expense of new acquisitions and personnel for retraining (China Construction 2018). Small and medium-sized enterprises (SMEs) cannot absorb the high costs, reducing augmented use throughout the industry (Alshaikhi 2021).

Interoperability is another imperative problem. Multi-disciplinary projects consist of different platforms for software, and AI-enhanced BIM models will generally face issues of data format compatibility. The Riyadh Metro project is one such instance where data model discrepancies among global teams were a hindrance to AI integration (Arriyadh Development Authority 2019).

Organizational and cultural resistance are drivers of some issues. The Doha Metro project, for instance, refused to drop outdated BIM practices because of managerial conservatism as well as the temptation of tried formulas (Dobrucali et al. 2024). Change resistance, job replacement, and uncertainty regarding the value of AI benefits are drivers of resistance to evidence presented by international case studies of AI value (Dobrucali et al. 2024).

Theoretically, all published literature until now talks about BIM and AI independently or some definite certain applications like scheduling or costing. Very few studies have been conducted to explore the ways in which AI can transform BIM as a whole in various areas of projects, such as stakeholder coordination, resource planning and sustainability and risk management, in real-world engineering settings. Also, while previous studies would indicate the ability of AI to save resources and be less error-prone, long-term economic and environmental impact has not been researched extensively (Miettinen and Paavola 2014; Huang 2023).

This research will fill this gap by integrating practical and theoretical findings from real projects to investigate the performance of AI-enabled BIM in five key areas of project performance: efficiency, clash detection, cost management, resource planning and scheduling. Further digital engineering practice and decision-making supported by evidence, will be advanced to make appropriate arrangements for adoption in the future.

3. Methods

The research conducted herein used a desktop research approach by way of a structured literature review, case study centered analysis, and meta-analysis in examining mechanisms by which AI enhances BIM use in multi-disciplinary engineering practice. The mixed-methods approach was used, drawn from the application of qualitative and quantitative information to the level of achieving performance comparison against conventional and AI-solved BIM platforms.

Figure 1 presents the research methodology in a flow chart.

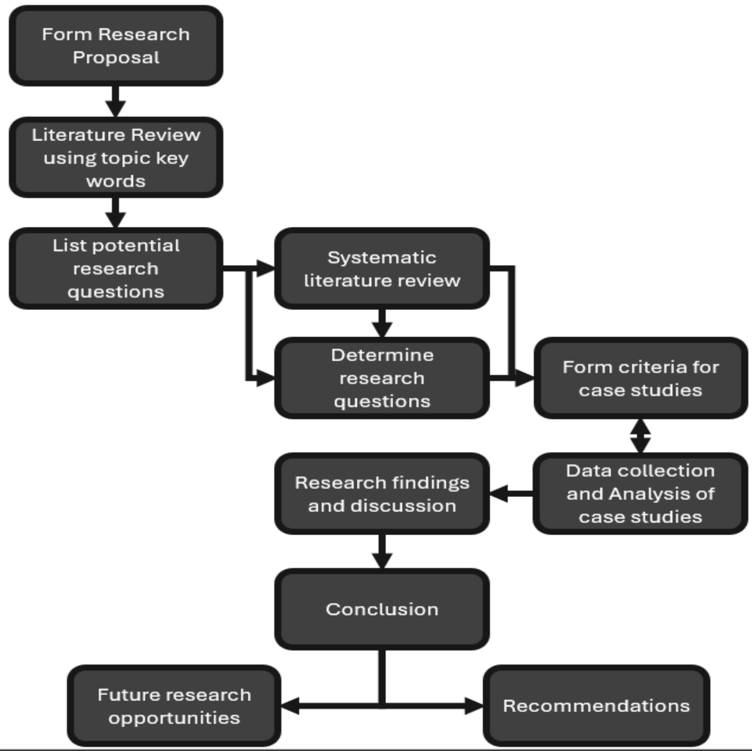

Figure 1. Research methodology flow chart

The research was executed in three stages:

1. Reviewing available literature to analyze theoretical frameworks, industry trends, and novel applications of AI and BIM in infrastructure, transportation and construction sectors.

2. Analyzing case studies using secondary published project reports to compare KPIs for two types: AI-based BIM and conventional BIM.

3. Doing a meta-analysis to pool trends and measure differences in terms of cost saving, schedule management, clash detection and coordination.

Desk-based research was prioritized as the projects in question are worldwide and there are enough secondary datasets to work with and, therefore, best placed to undertake a comparative analysis of digital technologies in actual contexts.

3.1 Research Setting and Sampling Strategy

The study was focused on multi-disciplinary engineering projects worth an amount above USD 50 million. Purposive sampling was utilized in the selection of case studies using the parameters set out below:

- Projects employing conventional BIM or AI-driven BIM.
- Accessibility to publicly available project performance metrics, i.e., cost benefits, time saved and decreased errors.
- Allocation across a selection of industries, i.e., infrastructure, commercial high-rise buildings and transportation (Arriyadh Development Authority 2019).

The sources of data in this research include peer-reviewed journals of construction research (e.g., Automation in Construction, Journal of Construction Engineering and Management), case study databases of the engineering industry (e.g., Autodesk, Bentley Institute's ProjectWise, global databases of global engineering projects) and technical reports and white papers from engineering companies that are publicly available.

Each data source was selected based on verifiable performance data to which it had access and relevance to BIM-AI integration for high-value engineering projects.

Consistency and reliability of case study selection were controlled by requirements of systematic inclusion and exclusion processes as presented in Table 1.

To ensure appropriateness and consistency of approach, inclusion and exclusion criteria were used to choose case studies to be analyzed. Inclusion criteria were built on the principles below:

- Projects incorporating traditional or AI-capable BIM
- Having publicly available performance data
- Engineering, multi-discipline projects of more than USD 50 million
- Cross-section representation in transport, commercial and infrastructure sectors

Exclusion was used wherever projects:

- Were not implementing BIM or integrated digital systems
- Were single-discipline or otherwise too specialized in nature
- Had no publicly available performance data
- Were unverifiable or anecdotal in nature

This systematic screening ensured that there was only high-quality, case-relevant case study evidence to consider, as is optimal practice when synthesizing evidence-based studies (Miettinen and Paavola 2014; Alahaikhi 2021).

Table 1. Inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
BIM Methodology	Projects using AI-enhanced or traditional BIM systems	Projects using only CAD or lacking BIM integration
Project Type	Multi-disciplinary projects involving ≥3 engineering disciplines	Single-discipline projects (e.g., purely architectural)
Project Scale	Medium-to-large scale with high complexity (>USD 50 million)	Small-scale or low-complexity projects
Data Availability	Publicly available, detailed performance data (cost, time, collaboration)	Projects without sufficient data or performance metrics
Sector Representation	Infrastructure, commercial buildings, transport	Projects in niche sectors with low transferability
Geographic Distribution	Global representation across diverse contexts	Regionally restricted projects without broad insights
Publication Type	Peer-reviewed sources or validated institutional publications	Anecdotal or unverified sources

Requirements of theoretical sampling were set to increase the diversity of the sample as well as ensure the research addresses multi-disciplinary engineering project environments.

4. Data Collection and Analysis

Extensive reading of peer-reviewed journals, industry reports and studies on BIM-AI integration provided insight into how AI boosts the connectivity of projects, predictive modeling and decision-making (Davahli 2020).

For further evaluation of these findings, a comparative analysis was made between real engineering projects and how top performance metrics of the traditional BIM and the AI-aided BIM compare (Taylor 2018). Performance evidence was categorized into five coded themes: project efficiency, clash detection, cost control, resource planning, and time management, based on frequency and prominence across case study findings. While the majority of findings were qualitative, where quantitative figures (e.g., percentage improvements or cost/time savings) were available in the literature, these were noted and used to support comparisons. All the chosen cases were benchmarked against five areas of excellence in performance: project efficiency, clash detection, cost control, resource planning and time management.

In addition to the above, a meta-analysis was also performed where quantitative information from different case studies was aggregated to examine trends and measure the overall effect of AI integration in project management (Sacks et al. 2020).

4.1 Data Analysis Approach
Descriptive statistics were employed to take into account significant project parameters such as cost-effectiveness, time and error detection.

Comparative analysis was performed to determine differences between traditional BIM and AI-based BIM approaches.

Identifying trends centered on applying AI to automate decision-making, workflow control and enhancing collaboration among the stakeholders (Holzmann and Lechiara 2022).

4.2 Justification of Methodology
This approach offers a combined, evidence-based assessment of the influence of AI on BIM with both qualitative and quantitative results. Case study and meta-analysis approaches offer the prospect of the findings of true-world issues and advantages that can be used by engineering professionals, project managers and business executives in the construction sector (McArthur and Bortoluzzi 2018).

5. Results
The research highlights the comparative benefits of AI-facilitated BIM over traditional BIM practices in the administration of multi-disciplinary engineering projects. The research examines real case studies and compares sizeable differences in project performance, cost savings and decision-making factors (HS2 Ltd 2021).

5.1 Comparison of Traditional BIM vs AI-enhanced BIM
A comparison of project case studies is found in Table 2, showing the effect of AI-facilitated BIM on major project performance measures.

To contextualize the comparison in Table 2, the shortlisted case studies were compared against five categories of performance from the literature: project efficiency, clash detection, cost management, resource allocation and time management (Sacks et al. 2020). A data coding sheet was used to code qualitative descriptions and quantitative values whenever possible. Triangulation used descriptive statistics, peer-reviewed project results and case histories to provide comparative values in the table (McArthur and Bortoluzzi 2018). Performance descriptions where there was no relevant numerical data were derived from qualitative results that were elaborated in detail.

Table 2. A comparative analysis of case studies

Category	Traditional BIM	AI-Enhanced BIM
Project Efficiency	Improved coordination but manual adjustments required	Automated scheduling and decision-making
Clash Detection	Manual issue identification and resolution	AI-driven predictive clash detection
Cost Management	Higher risk of budget overruns	Predictive cost estimation reduces overruns
Resource Allocation	Engineer-driven adjustments	AI-optimized resource distribution
Time Management	Longer project timelines due to human input	Accelerated schedules with AI interventions

The outcome is that conventional BIM enhances design coordination and stakeholder coordination but is extremely dependent on human decision-making, hence less effective in the scenario of real-time project changes and risk management (Taylor 2018). This contrasts with AI-powered BIM which encompasses machine learning, automation and predictive analysis, resulting in improved efficiency in project scheduling, cost control and resource management (Google 2022).

5.2 Key Findings
The results of this research establish the persuasive benefits of AI-based BIM over conventional BIM in key aspects of project management. In clash detection and error minimization, conventional BIM is dependent on manual detection and correction, which is bound to lead to delays and rework. In contrast, AI-based BIM detects clashes automatically

in real time, reducing errors and enhancing construction schedules (China Construction 2018).

Similarly, in scheduling and time management, traditional BIM depends on manual scheduling, which subsequently results in inefficiencies and poor coordination. Predictive models of scheduling in AI-driven BIM allow for efficient workflows with less delay, by far (HS2 Ltd 2021).

In addition, cost-cutting and management receive an appreciable impetus with AI. Whereas conventional BIM is most probably to be outsmarted by cost overruns due to erroneous costing and inefficient resource utilization, AI-facilitated costing forecasting models ensure decreased monetary risk by optimizing material and manpower planning (Infrastructure Intelligence 2020).

All the above tips the scale in favor of the prospect of AI-facilitated BIM in streamlining project execution and enhancing overall efficiency in multi-disciplinary engineering projects.

6. Discussion

The results of the study confirm that BIM enhanced by AI improves the efficiency of the project, cost control and multi-disciplinary coordination on engineering projects far better. Classical BIM enhances coordination and integration of design but does not support real-time decision-making and predictive analysis (Sacks et al. 2020). These limitations are avoided by combining BIM and AI through the automation of the scheduling, collision detection and resources management, thus improving future project performance (Holzmann and Lechiara 2022). Table 3 provides a summary of the key findings concerning the research questions.

Table 3. Summary of research questions and findings

Research Question	Key Findings
What are the motivations and constraints affecting AI-enhanced BIM adoption?	Motivations include improved scheduling, cost savings, and stakeholder coordination. Constraints include high setup cost, interoperability challenges and skills gaps.
What AI technologies enhance BIM in coordination and management?	Predictive analytics, machine learning and digital twins were commonly adopted. These support clash detection, risk forecasting and design simulation.
How does AI-integrated BIM affect project delivery?	AI-enhanced BIM improves time management, reduces design errors, supports real-time decision-making and improves resource utilization.

The observed improvements in clash detection, scheduling efficiency, and cost management using AI-enhanced BIM are consistent with previous findings in literature. For instance, Crawford et al. (2023) and Alshaikhi and Khayyat (2021) similarly report measurable improvements in scheduling accuracy and decision support when AI models were integrated into BIM platforms for software engineering and project management applications. This convergence validates the present research outcomes and demonstrates alignment with emerging industry trends.

6.1 Implications for Theory, Practice and Management

Theory contribution: This paper contributes to digital engineering literature by explaining how AI transforms BIM into a forward-looking decision system rather than a fixed one.

Practice application: BIM with AI expands automation of workflows, cost estimation and provides real-time updates of the project to the benefit of the construction company as well as consulting engineers (Google 2022).

Impact on project management: AI-powered BIM brings instant insights into data, enabling project managers to make decisions instantly to avoid risk and waste in dynamic engineering environments (Hendy 2022).

From a theoretical perspective, the study proposes a conceptual lens where AI transforms BIM from a static coordination platform into a dynamic, predictive decision-support tool, enhancing its value in complex engineering environments. The comparative findings in this study are supported by earlier investigations into AI-enabled construction management, particularly those by Fridgeirsson et al. (2021), McArthur and Bortoluzzi (2018), and Holzmann and Lechiara (2022), validating the applicability and generalizability of AI-BIM integration benefits across project environments.

6.2 Limitations

This study is limited by its reliance on secondary data sources, which vary in depth and objectivity. Although cases were selected from peer-reviewed or industry-validated sources, potential biases in reporting performance benefits may influence interpretation. The lack of access to raw project data and the diversity of project contexts also limit the generalizability of specific findings.

6.3 Recommendations for Future Research

The subsequent research should be focused on the standardization of the platforms to enhance the integration and compatibility of AI-BIM in the construction of buildings. More research is required to be done to explore real-time applications of AI in BIM, for instance, developing autonomous decision-making and proactive planning of projects. Long-term cost factors and sustainability factors of AI-based BIM systems also have to be developed to ascertain profitability and environmental advantages (Arsiwala et al. 2023). Future research could benefit from longitudinal case tracking to assess the evolving impact of AI tools throughout the project lifecycle. Experimental BIM environments with embedded AI for design validation, cost forecasting, and stakeholder engagement should also be tested. Establishing benchmarks for AI-BIM performance metrics would further enable cross-project comparisons.

As AI has evolved to revolutionize the world of engineering, it is necessary to build knowledge regarding the application of AI in education and skill acquisition so that industry professionals can be empowered with skills to install and operate AI-based BIM technology effectively (McArthur and Bortoluzzi 2018).

7. Conclusion

This research acknowledges the potential of AI in making BIM-managed project management leaner, less expensive and enhancing engineering project decision-making. Despite the failure of adoption, AI-based BIM projects can be a sound foundation for future building management and digital engineering development.

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Biographies

Jason Naidoo holds a Bachelor of Technology (Civil Engineering - Water) from the University of Johannesburg. He is a Senior Engineering Technologist Consultant with over 7 years of experience in the civil engineering industry. Jason’s industry experience includes the design of pump stations, pipelines and reservoir water engineering, bulk water and wastewater conveyance system designs, site monitoring, investigation reporting, design reports, tender documentation, contract management and administration, construction management, procurement and delivery of work packages utilizing BIM for multi-disciplinary projects. Jason is currently working towards registering as a professional engineering technologist. Countries of work experience include South Africa, the Democratic Republic of Congo, Botswana, Saudi Arabia, the United Arab Emirates and the United Kingdom. Jason has reputable public relations skills and is easily adaptable to different situations. Jason has been involved in numerous presentations to the design team, project team and private and public clients, including the Deputy Mayor of the City of Cape Town. He is currently enrolled as a master’s student at the Postgraduate School of Engineering Management in the Faculty of Engineering and the Built Environment.

Jan Harm Christiaan Pretorius earned his MSc (Laser Engineering and Pulse Power) at the University of St Andrews in Scotland (1989), the latter of which was cum laude, and his BSc Hons (Electrotechnics) (1980), MIng (1982), and DIng (1997) degrees in Electrical and Electronic Engineering at the Rand Afrikaans University. During his fifteen years of service, he was a Senior Consulting Engineer at the South African Atomic Energy Corporation (AEC). In addition, he was employed by the Council for Scientific and Industrial Research (CSIR) as the Technology Manager at the Satellite Applications Centre (SAC). Since 1998, he has held the position of Professor in the Postgraduate School of Engineering Management within the Faculty of Engineering and the Built Environment. In addition to supervising 80 PhD and more than 400 master's students, he has co-authored more than 300 research articles.