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A REVIEW ON INTEGRATION OF BIM AND DIGITAL TWIN FOR REAL-TIME PROGRESS MONITORING IN HIGH-RISE CONSTRUCTION PROJECTS

Miss. Arpana S. Akarte[1] Mr. Hemant. B. Dahake [2]

[1]Student M. Tech. (Construction Engg. & Mgmt.) Dept. of Civil Engineering, G. H. Raisoni University, Amaravati, Maharashtra, India

[2]Professor & Head Dept. of Civil Engineering, G.H.Raisoni University, Amaravati, Maharashtra, India

arpana98akarte@gmail.com [1]

Abstract —

The construction industry is currently experiencing a major digital transformation due to the rapid adoption of advanced technologies such as Building Information Modeling (BIM), Digital Twin (DT), Internet of Things (IoT), Artificial Intelligence (AI), drone photogrammetry, cloud computing, laser scanning, and automated monitoring systems. These technologies are revolutionizing the traditional methods of planning, designing, executing, and managing construction projects. Among various infrastructure developments, high-rise construction projects are considered one of the most challenging due to their complex structural systems, simultaneous multi-floor activities, vertical transportation requirements, safety concerns, large workforce involvement, and strict project schedules.

Managing such projects using conventional monitoring techniques often leads to inefficiencies, communication gaps, inaccurate reporting, project delays, and cost overruns. Traditionally, construction progress monitoring has depended on manual site inspections, paper-based reporting systems, photographs, and verbal communication among project stakeholders. Although these methods have been used for decades, they are generally time-consuming, labour-intensive, and unable to provide continuous or real-time information about ongoing site activities. As a result, project managers frequently face difficulties in identifying delays, monitoring productivity, tracking resources, and making timely decisions. In large and high-rise construction projects, where multiple activities occur simultaneously on different floors, the limitations of conventional monitoring systems become even more critical.

To overcome these challenges, the integration of Building Information Modeling (BIM) and Digital Twin (DT) technologies has emerged as a highly effective and intelligent solution for real-time construction progress monitoring. BIM provides a detailed digital representation of the physical and functional characteristics of a building, including architectural, structural, mechanical, electrical, plumbing (MEP), scheduling, and cost information. On the other hand, Digital Twin technology extends BIM capabilities by creating a live and continuously updated virtual replica of the actual construction site through real-time data synchronization.

Despite the numerous advantages, the implementation of BIM and Digital Twin technologies also faces several technical, organizational, and financial challenges. Issues such as software interoperability, high implementation costs, cybersecurity concerns, lack of skilled professionals, resistance to technological adoption, and data integration complexities remain major barriers to widespread implementation. Therefore, this paper also discusses the critical challenges and limitations associated with BIM-Digital Twin adoption in the construction industry. Finally, the review identifies existing research gaps and suggests future research directions focusing on affordable BIM-Digital Twin systems, AI-enabled predictive monitoring, cloud-based collaboration platforms, smart city integration, and real-time automated decision-support systems.

Keywords - *Building Information Modeling (BIM), Digital Twin (DT), Internet of Things (IoT), Artificial Intelligence (AI), High-Rise Construction, Smart Construction, Real-Time Monitoring, Drone Photogrammetry, Construction Automation, BIM-DT Integration.*

I. INTRODUCTION

The construction industry is one of the most important sectors contributing to the economic development, industrial growth, and urbanization of a country. It plays a significant role in the development of infrastructure such as residential buildings, commercial complexes, transportation systems, bridges, airports, smart cities, and industrial facilities. In rapidly developing nations like India, the demand for modern infrastructure and high-rise buildings has increased

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considerably due to urban population growth, limited land availability, and increasing commercial activities. As cities continue to expand vertically, the construction of multi-storey and high-rise structures has become essential for efficient land utilization and sustainable urban development.

However, high-rise construction projects are highly complex and challenging in nature. These projects involve multiple construction activities occurring simultaneously across different floors and departments, including structural work, architectural finishing, mechanical systems, electrical services, plumbing installations, and safety management. Managing such complex projects requires continuous coordination among contractors, consultants, engineers, suppliers, and project owners. Due to the involvement of numerous stakeholders and interconnected activities, high-rise construction projects frequently experience problems such as project delays, cost overruns, communication gaps, low productivity, inefficient resource management, safety hazards, and quality control issues.

One of the major challenges in construction project management is effective progress monitoring and project control. Traditionally, construction progress monitoring is performed through manual site inspections, written reports, photographs, spreadsheets, meetings, and verbal communication. Site engineers and supervisors physically inspect construction activities and prepare periodic progress reports to compare planned work with actual execution. Although these methods have been widely used in the construction industry for many years, they possess several limitations. Manual monitoring systems are often time-consuming, labour-intensive, error-prone, and unable to provide accurate real-time project information. Delays in reporting and human errors frequently lead to poor decision-making, reduced transparency, and ineffective project control.

In high-rise construction projects, these challenges become even more critical because activities occur vertically across multiple floors, making physical monitoring difficult and time-consuming. For example, tracking floor-wise slab casting progress, material movement, labour productivity, equipment utilization, and finishing activities manually may not provide timely or accurate updates. As a result, project managers often struggle to identify schedule deviations, construction bottlenecks, safety risks, and resource shortages at an early stage. This lack of real-time visibility may ultimately result in increased project duration, additional costs, disputes among stakeholders, and reduced project efficiency.

To overcome these limitations, the construction industry is increasingly adopting advanced digital technologies for smart construction management. Among these technologies, Building Information Modeling (BIM) and Digital Twin (DT) have emerged as highly innovative and transformative solutions for improving construction project monitoring, visualization, coordination, and decision-making.

Building Information Modeling (BIM) is a digital technology that creates an intelligent three-dimensional (3D) virtual representation of a building and its components. BIM models contain detailed information related to architectural elements, structural systems, mechanical, electrical, and plumbing (MEP) services, scheduling, cost estimation, material specifications, and facility management. Unlike traditional 2D drawings, BIM provides an integrated digital environment where all project stakeholders can collaborate and access updated project information throughout the project lifecycle. BIM improves visualization, clash detection, coordination, quantity estimation, scheduling, and construction planning. The addition of time and cost dimensions further enhances BIM capabilities through 4D and 5D modeling.

The integration of BIM and Digital Twin technologies enables the development of intelligent construction monitoring systems capable of providing real-time project updates and automated decision support. Through this integration, planned construction schedules can be continuously compared with actual site progress. Project managers can monitor floor-wise construction activities, detect delays instantly, track material and equipment usage, evaluate productivity levels, and identify potential safety risks. The system also enables visualization of completed, ongoing, and pending activities through interactive dashboards and virtual simulations.

Several modern technologies support BIM-Digital Twin integration. Internet of Things (IoT) sensors are used for collecting real-time environmental and operational data such as temperature, humidity, vibration, worker movement, and equipment performance. Drones and UAVs (Unmanned Aerial Vehicles) are used for aerial site inspections, photogrammetry, and progress tracking. RFID systems help monitor material movement and workforce tracking. Laser scanning technologies generate accurate as-built site data, while Artificial Intelligence (AI) and Machine Learning (ML) algorithms analyze collected information to predict delays, optimize schedules, and improve resource allocation. Cloud computing platforms facilitate real-time data storage, communication, and collaboration among project stakeholders.

The adoption of BIM and Digital Twin integration offers numerous advantages for high-rise construction projects. These include improved project visualization, enhanced coordination among stakeholders, reduced construction errors, faster progress monitoring, improved safety management, optimized resource utilization, accurate delay detection, and better project transparency. Additionally, predictive analytics and automated reporting systems help project managers take proactive corrective actions before problems become severe. This results in reduced project delays, lower construction costs, improved quality, and increased productivity.

Considering the increasing complexity of high-rise construction projects and the growing demand for efficient project management systems, the integration of BIM and Digital Twin technologies has become an important area of research and industrial application. Therefore, this study focuses on understanding the role of BIM and Digital Twin integration for real-time progress monitoring in high-rise construction projects. The research aims to analyze existing technologies, monitoring methods, implementation frameworks, advantages, challenges, and future opportunities associated with smart construction management systems.

The present study is highly relevant to the modern construction industry because it contributes toward the development of intelligent, automated, and data-driven project management systems capable of improving efficiency, productivity, safety, and sustainability in high-rise construction projects.

1.1 Advantages of BIM

- Improved design visualization
- Better coordination among stakeholders
- Clash detection between services
- Accurate quantity estimation
- Enhanced scheduling through 4D BIM
- Cost management using 5D BIM
- Improved communication and collaboration
- Reduced rework and project delays

1.2 BIM Evolution

BIM has evolved through different maturity levels:

- **Level 0 BIM:** 2D CAD drafting
- **Level 1 BIM:** Basic 3D modeling
- **Level 2 BIM:** Collaborative modeling
- **Level 3 BIM:** Fully integrated cloud-based smart systems

Modern BIM systems are now integrated with AI, IoT, cloud computing, and Digital Twin technologies.

1.3 Digital Twin Technology

Digital Twin is a dynamic virtual representation of a physical asset that continuously updates itself using real-time data from sensors and monitoring systems. Unlike BIM, which mainly represents static project information, DT continuously reflects actual site conditions.

A. Components of Digital Twin

1. Physical asset
2. Digital model
3. Real-time data connection

B. Applications in Construction

- Progress monitoring
- Safety management
- Equipment tracking
- Predictive maintenance
- Resource optimization
- Delay forecasting
- Quality inspection

Digital Twin systems use IoT devices, drones, RFID tags, cameras, laser scanners, AI algorithms, and cloud platforms to collect and process site data.

1.4 Integration of BIM and Digital Twin

BIM acts as the foundation model for Digital Twin systems. DT extends BIM by integrating real-time information from the physical construction environment.

C. Integration Framework

The BIM-Digital Twin integration process generally includes:

1. BIM model development
2. 4D scheduling integration
3. Real-time data collection
4. Cloud-based synchronization
5. Planned vs actual comparison
6. Dashboard visualization
7. Delay detection and reporting

D. Technologies Used

- IoT Sensors
- Drones and UAVs
- RFID Systems
- Laser Scanning
- AI and Machine Learning
- Cloud Computing
- Extended Reality (XR)
- GIS Integration

II. State of Development

- **Gauri Patra et al. (2026):** Building Information Modeling (BIM) is effective in design and planning, but the static nature of BIM makes it less effective in managing a construction site in real-time. To overcome this, the need for Digital Twins (DTs) with the Internet of Things (IoT) in physical site management has been emphasized. This paper proposes a DT framework for Indian construction sites, emphasizing physical and virtual environments, IoT communication, and feedback systems. The proposed framework adopts Levels of Detail (LoDs) for graphics, information, and site-related aspects such as manpower and equipment. The SLR has revealed the international research gaps in DT, which were further investigated by conducting a survey among 20 BIM experts from prominent Indian cities. The survey indicated that 70-80% of the respondents felt that DT would assist them in monitoring construction activity, increasing efficiency, increasing site safety, and utilizing LoDs. But they also cited difficulties such as fluctuating labor and high density in Indian cities. This paper proposes the combined use of DT, IoT, and BIM to overcome delays and expenses, and also proposes standardization of LoDs and the use of data fusion in DT.

- **Xiang Liu et al. (2025):** In recent years, the advancement of digital technologies such as building information modeling (BIM), internet of things (IoT), and geographic information system (GIS) has had many impacts on the construction industry. However, limited research has been conducted on the integration of BIM, IoT, and GIS technologies, especially in construction resource monitoring. Therefore, this paper presents a state-of-the-art review of BIM, IoT, and GIS integration by focusing on their applications, challenges, research gaps, and future research directions. A systematic literature review and science mapping analysis were adopted in this study. The results identified the gaps in BIM, IoT, and GIS integration in construction resource monitoring, which include interoperability, data security, real-time dynamic monitoring, complex environmental data processing, environmental sustainability studies, prediction models, and convenience for the users. Moreover, challenges and future research directions were proposed. This paper contributes to extending the integrated applications of digital technologies in construction resource monitoring.

- **Sourabh Nandkumar Kadam et al.(2025):** In the evolving landscape of the construction sector, ensuring accurate, timely, and transparent project monitoring remains a critical challenge. Digital Twin (DT) *technology*, when combined with tools such as Building Information Modelling (BIM), reality capture techniques, extended reality (XR), and artificial intelligence (AI), offers a transformative solution for real-time monitoring and tracking of construction activities. This study presents a novel framework for implementing DTs to capture, process, and visualize live project data, enabling proactive decision-making and performance optimization. The approach integrates multi-source data acquisition—from on-site IoT sensors and computer vision systems to machine learning-driven predictive analytics—allowing virtual models to continuously replicate actual site conditions.
- **Wu et al. (2025): Wu** developed a BIM-Digital Twin-Block chain model for automated payment systems. Once work completion was verified through real-time monitoring, payments were automatically processed. This shows how DT can increase transparency and trust in project management.
- **Baghdadi et al. (2025): Baghdadi** reviewed Digital Twin applications and found strong benefits in resource optimization, monitoring efficiency, sustainability, and lifecycle performance. However, implementation costs remain a challenge.
- **Khoshkonesh et al. (2025):** The researchers developed a 4D/5D Digital Twin system using AI and computer vision. It improved schedule forecasting and helped reduce overtime costs. This study is highly relevant to real-time progress monitoring.
- **Nur Farhana Azmi et al. (2024):** Digital twin (DT) and building information modeling (BIM) are interconnected in some ways. However, there has been some misconception about how DT differs from BIM. As a result, industry professionals reject DT even in BIM-based construction projects due to reluctance to innovate. Furthermore, researchers have repeatedly developed tools and techniques with the same goals using DT and BIM to assist practitioners in construction projects. Therefore, this study aims to assist industry professionals and researchers in understanding the relationship between DT and BIM and synthesize existing works on DT and BIM. The analysis of the selected journal articles revealed four types of relationships between DT and BIM: BIM is a subset of DT, DT is a subset of BIM, BIM is DT, and no relationship between BIM and DT.
- **Tae Wook Kang et al. (2024):** The concept of digital twins, initially developed in manufacturing, has found applications in various industries. However, its adoption in the construction field is still nascent, with a limited understanding of its benefits and implications. Existing examples of digital twin implementation in construction mainly provide general frameworks or possibilities for performance. To effectively harness the potential of digital twins in construction, establishing connectivity and predictability for data exchange between the physical and virtual realms is crucial. This research defines the essential requirements for real-time connectivity and predictability in digital twin implementation and

proposes a framework and architecture based on these principles. The proposed method is evaluated through the implementation of a digital twin for monitoring the environmental performance of existing buildings, revealing its effectiveness and challenges. This study serves as a valuable exemplar for the development of a digital twin platform dedicated to construction monitoring.

- **Alwyn Mathew et al. (2024):** newly built structures. This study suggests employing digital twin-based automatic progress monitoring on construction sites, comparing 3D point clouds with their Building Information Modelling to track progress and predict completion. It highlights integrating semi-continuous monitoring with a building's digital twin for efficient construction management. Leveraging precise data enhances understanding and identifies schedule deviations, enabling timely actions. Demonstrated through real-world construction data, visualised Gantt charts showcase its efficacy, offering insights into task status, schedule deviations, and projected completion dates. This underscores digital twin technology's potential to transform construction oversight.
- **Varun Kumar Reja et al.(2024):** This article explores the underutilised potential of Digital Twins (DTs) beyond their predominant application in facility management, focusing on their promising role in enhancing efficiency across various phases of construction projects. Enabling smooth data transfer between virtual and physical environments, DTs hold considerable potential for enhancing project planning and control, safety and quality management, in addition to procurement and resource management through the construction stage. Positioned at the peak of inflated expectations in the innovation hype cycle, a comprehensive review of the DT concept is required to provide valuable insights for both practitioners and academicians. Furthermore, the study employs a PRISMA based systematic literature review methodology to analyse existing research and identify gaps in the literature.
- **Mathew (2024): Mathew** proposed a progress monitoring framework using BIM models and 3D point cloud scanning technology. Laser scanners or photogrammetry tools were used to capture actual site conditions, and these were compared with BIM models to measure completed work. The study found that automatic comparison methods save time and improve measurement accuracy. This method is highly useful for monitoring floor-by-floor progress in tall buildings.
- **Revolti et al. (2024): Revolti** carried out a literature review on the shift from BIM to Digital Twin technologies. The study identified major barriers such as lack of data interoperability, high implementation cost, shortage of skilled professionals, and integration problems among different software systems. The authors recommended standard data exchange platforms for smoother BIM-DT adoption.
- **Saif et al. (2024):** Saif classified Digital Twin applications in construction into seven major categories: safety monitoring, equipment management, productivity tracking, logistics planning, quality control, progress monitoring, and lifecycle management. The study concluded that progress monitoring is one of the most valuable uses of Digital Twin because delays directly affect project cost and completion date.
- **Kang et al. (2024): Kang** developed a complete Digital Twin framework for building construction projects. The framework included BIM models, IoT sensors, cloud storage, AI-based analytics, and dashboards. The study found that real-time synchronization between the physical site and digital model helps managers detect delays, resource shortages, and safety issues quickly.
- **Alavi (2024): Alavi** studied the use of scanned site data integrated with BIM schedules for monitoring planned versus actual progress. The research concluded that combining point cloud data with 4D BIM schedules improves delay detection. It allows project managers to identify whether each activity is ahead, on time, or behind schedule.
- **Ellul et al. (2024): Ellul** examined location-enabled Digital Twins in construction and infrastructure projects. GPS, GIS, and geospatial data were connected with digital models. The study found that location intelligence improves material tracking, workforce movement analysis, and site logistics planning. This is useful in high-rise projects where vertical and horizontal movement must be controlled carefully.
- **Valerian Vanessa Tuhaise et al. (2023):** The construction industry is facing enormous pressure to adopt digital solutions to solve the industry's inherent problems. The digital twin has emerged as a solution that can update a BIM model with real-time data to achieve cyber-physical integration, enabling real-time monitoring of assets and activities and improving decision-making. The application of digital twins in the construction industry is still in its nascent stages but has been steadily growing over the past few years. A wide variety of emerging technologies are being

used in the development of digital twins in diverse applications in construction but it is not immediately clear from the literature which ones are key to the successful development of digital twins, necessitating a systematic literature review with a focus on technologies. This paper aims to identify the key technologies used in the development of digital twins in construction in the existing literature, the research gaps and the potential areas for future research.

- **Shuaiming Su et al.(2023):** The construction industry has a great impact on social and economic development because of its wide coverage and a large number of stakeholders involved. It is precisely owing to its large volume that technological innovation of the construction industry is relatively slow. The birth and rapid development of digital twins brings more hope to the construction industry. This paper summarizes the current development of digital twin and its applications in construction industry. First, the concepts and applications of digital twin are analyzed. Then, the research on digital twins in the construction industry in the past five years is reviewed. The main research directions and key technologies are pointed out in the end. This paper could guide related practitioners to clearly grasp the research application status of digital twin in the construction industry. It could also help to find suitable research directions.
- **K. Amirthavarshan1 et al.(2023):** The digital twin (DT) presents an opportunity for the integration of the physical world into the digital world. DT technology has the potential to transform the construction industry and respond to some of its challenges. In conventional construction projects, progress is largely monitored by direct observation and measurement which suffers from numerous challenges, including low productivity, blunders, and poor technology advancements. Concerns are now being raised about integrating technology for autonomously monitoring building activity. In other sectors, DT technology has been responsible for saving product development time and costs by up to 50%. However, DT is still lagging the adoption of new technologies in the construction industry. The overarching aim of this study was to explore the adaptability of DT in construction site progress monitoring.
- **Nguyen et al. (2023): Nguyen** studied how BIM supports Digital Twin development for smart buildings and construction projects. The research found that integrating BIM with real-time sensor data improves monitoring of structural performance, occupancy, energy use, and construction progress. The authors stated that BIM provides geometry and project data, while DT adds real-time intelligence. This study supports the present research by proving that BIM-DT integration improves project management efficiency.
- **Pal et al. (2023): Pal** reviewed automated construction progress monitoring systems using image processing, drones, cameras, and computer vision. The study found that automated systems reduce dependency on manual inspections and generate faster progress updates. When integrated with BIM and Digital Twin, these tools can automatically compare planned schedules with actual completed work. This is especially useful in high-rise projects where daily physical inspections are difficult.
- **Amirthavarshan et al. (2023):** This study specifically focused on Digital Twin applications in construction progress monitoring. The authors observed that many construction sites still depend on manual reporting, which often causes delays and errors. They proposed that Digital Twin technology can provide continuous monitoring through real-time site data collection. The study concluded that DT can improve transparency, reporting accuracy, and productivity.
- **Mahamadu et al. (2023): Mahamadu** investigated the readiness of the construction sector for Digital Twin adoption. The research found that organizations with existing BIM experience are more prepared to implement Digital Twin systems successfully. This proves BIM is an important foundation for DT integration.
- **Hosamo et al. (2022): Hosamo** developed a Digital Twin framework for building operations and maintenance using BIM and sensor systems. Although focused on post-construction stages, the study demonstrated how real-time twins improve monitoring, which can also be applied during construction progress tracking.
- **Sepasgozar et al. (2022): Sepasgozar** explored smart construction technologies such as AR, BIM, IoT, and Digital Twin. The study found that visual dashboards and mobile access to real-time data improve communication among engineers, contractors, and project managers.
- **Kim et al. (2022): Kim** proposed a 4D BIM scheduling model connected with live site updates. The study concluded that integrating schedule simulation with actual field data improves delay prediction and resource planning in high-rise projects.

- **Opoku et al. (2021): Opoku** examined BIM adoption in developing countries and identified barriers such as training gaps, software cost, and resistance to change. The study is relevant because successful BIM-Digital Twin integration in India also depends on overcoming these barriers.

- **Shahi et al. (2021): Shahi** studied automated progress monitoring using UAV drone imagery integrated with BIM models. The research found that drone-based site surveys save time, improve safety, and provide accurate progress records for tall buildings where manual inspections are difficult.

- **Costin et al. (2021): Costin** reviewed construction automation technologies including laser scanning, RFID, BIM, and robotics. The authors concluded that combining these systems within a Digital Twin environment can improve real-time monitoring and reduce project risk.
- **Deng et al. (2021): Deng and co-authors** conducted a systematic review on the transformation from BIM to Digital Twin in the construction industry. They explained that BIM mainly stores static design and project data, while Digital Twin creates a dynamic model connected with real-world data sources. The study concluded that BIM acts as the base model for developing Digital Twin systems. It also highlighted that sensors, IoT devices, and cloud computing are essential for successful DT implementation. This study is highly relevant because it explains the theoretical relationship between BIM and Digital Twin.
- **Sepehr Alizadehsalehi (2020):** A generic framework for automated construction progress monitoring via introducing a new integration method incorporating the use of reality capture technologies (Laser Scanner and Wireless Sensors), Building Information Modeling (BIM), Digital Twin (DT), and Extended Reality (XR) has been developed in this study. The proposed framework, BIM/Digital twin-based reality capture to extended reality (DRX), in this research, arrays steps on how these technologies work collaboratively to create, capture, generate, analyze, manage, and visualize construction progress data, information, and reports. Interactions among steps and processes to be followed for implementation purposes are discussed through process modeling and Integrated Function Modeling (IDEF0) language. Finally, the reliability, validity, and contribution of the proposed framework was evaluated to understand the DRX model's effectiveness when implemented in real practice.
- **Rahimian et al. (2020): Rahimian** integrated BIM with machine learning and site images for automated construction simulation. The study found that predictive models can forecast schedule delays and productivity trends.
- **Boje et al. (2020): Boje and co-authors** presented a study on the concept of Digital Twin in construction and compared it with BIM. They explained that BIM mainly represents design and planning data, while Digital Twin includes continuous feedback from the real site through sensors and monitoring devices. The study concluded that Digital Twin can greatly improve project control and lifecycle management in complex buildings.
- **Sacks et al. (2020): Sacks** studied the use of BIM combined with lean construction techniques for improving project productivity. The research found that BIM-based progress visualization helps reduce waste, improve coordination, and increase schedule reliability. This is highly useful for high-rise construction where multiple trades work simultaneously.
- **Lu et al. (2020): Lu** explored the role of IoT-enabled BIM platforms for smart construction monitoring. The study found that sensor data linked with BIM can track equipment usage, environmental conditions, and work progress in real time. The authors recommended wider adoption in tall building projects.
- **Chen et al. (2018): Chen** developed a BIM-based hazard monitoring system connected with live data streams. The study found that dynamic BIM systems improve emergency planning and worker safety management.
- **Teizer et al. (2017): Teizer** used wireless tracking systems for workers and equipment movement on construction sites. The results showed improved productivity and better site safety. This concept is important for Digital Twin development.
- **Lee et al. (2016): Lee** integrated BIM with environmental sensors for real-time construction monitoring. Temperature, humidity, and other sensor data were linked to BIM models. The study proved that live environmental monitoring improves decision-making and site management.
- **Fang et al. (2016): Fang** introduced RFID-based resource tracking integrated with BIM. The system improved equipment location tracking and workforce management. This helps reduce time wasted in searching materials and machinery on large construction sites.

III. Real-Time Progress Monitoring

One of the most important advantages of BIM-Digital Twin integration is the ability to monitor construction progress in real time. Traditional progress monitoring methods depend on manual inspections, photographs, paper-based reports, and verbal communication, which are often time-consuming and inaccurate. In contrast, Digital Twin systems continuously synchronize real-world site data with digital BIM models through IoT sensors, RFID devices, drones, cameras, laser scanners, and cloud platforms.

This continuous synchronization allows project managers to monitor ongoing activities instantly and accurately. Construction activities such as concreting, reinforcement work, material movement, equipment operation, and finishing activities can be tracked floor by floor in real time. Project managers can compare planned schedules with actual work completed and identify delays immediately.

For high-rise buildings, where activities occur simultaneously across multiple floors, real-time monitoring greatly improves project visibility and control. It reduces dependency on physical inspections and enables faster reporting and communication among stakeholders.

3.1 Major Advantages:

- Continuous live site updates
- Accurate tracking of completed work
- Faster identification of delays
- Improved reporting efficiency
- Better coordination among teams

3.2 Improved Visualization

Visualization is another major benefit of BIM-DT integration. BIM models provide three-dimensional (3D) representations of building components, while Digital Twin systems enhance these models with real-time data and simulation capabilities. Additionally, 4D BIM integrates the time dimension with 3D models to visualize construction sequences and project schedules.

Through advanced visualization systems, project stakeholders can clearly understand:

- Current construction status
- Upcoming activities
- Delayed work areas
- Resource utilization
- Equipment positioning
- Safety hazards

Interactive dashboards, virtual walkthroughs, and simulation tools improve communication among engineers, contractors, consultants, and clients. Complex project information becomes easier to understand, reducing misunderstandings and coordination problems.

In high-rise construction projects, visualization is especially important because it helps managers monitor activities occurring at different elevations and locations within the structure.

3.3 Visualization Benefits:

- Better project understanding
- Improved stakeholder communication
- Enhanced planning and scheduling
- Easier detection of conflicts and errors
- Improved project presentations

IV. Delay Detection

Construction delays are one of the most common and costly problems in the construction industry. Delays can occur due to poor planning, labour shortages, material unavailability, equipment breakdowns, weather conditions, or coordination failures. BIM-Digital Twin systems help minimize these delays through automated progress comparison and predictive monitoring.

Digital Twin systems continuously compare planned schedules stored in BIM models with actual site progress collected through sensors, drones, laser scanners, and image-processing systems. If deviations are detected, alerts are automatically generated for project managers.

This early detection capability allows managers to take corrective actions before delays become critical. AI and machine learning algorithms can also predict future schedule risks based on historical data and current project trends.

Delay Detection Advantages:

- Automatic planned vs actual comparison
- Early warning systems
- Faster corrective actions
- Improved schedule reliability
- Reduced project overruns

V. Enhanced Safety

Construction sites, especially high-rise projects, involve significant safety risks due to working at heights, heavy machinery, material handling, electrical systems, and confined spaces. BIM-Digital Twin integration significantly improves construction safety through real-time monitoring and hazard detection systems.

IoT sensors, wearable devices, cameras, RFID systems, and drones can continuously monitor:

- Worker movement
- Unsafe zones

- Environmental conditions
- Equipment operation
- Structural stability
- Temperature and humidity levels

When unsafe conditions are detected, the system can immediately notify supervisors and workers through alerts and warnings. Digital Twin systems can also simulate emergency situations and evacuation plans to improve safety preparedness.

Additionally, safety data integrated into BIM models helps visualize hazardous zones and safety protocols more effectively.

Safety Benefits:

- Real-time hazard detection
- Improved worker monitoring
- Faster emergency response
- Reduced accident rates
- Better compliance with safety regulations

VI. Better Decision-Making

Modern construction projects generate large volumes of data from multiple sources such as schedules, sensors, drones, equipment logs, labour records, and environmental monitoring systems. BIM-Digital Twin systems collect, organize, and analyze this data in a centralized platform.

Real-time dashboards, AI analytics, predictive models, and automated reports help project managers make faster and more accurate decisions. Instead of relying on outdated reports or manual estimates, managers can access live project information instantly.

For example:

- Resource shortages can be identified early
- Productivity trends can be analyzed
- Schedule risks can be predicted
- Safety concerns can be addressed quickly
- Cost overruns can be minimized

Predictive analytics also supports proactive project management by forecasting potential future problems before they occur.

Decision-Making Advantages:

- Faster managerial response
- Accurate project analysis
- Data-driven planning
- Improved resource allocation
- Better project control

VII. Cost Optimization

Construction cost overruns are a major challenge in infrastructure projects. BIM-Digital Twin integration helps reduce unnecessary project expenses through improved planning, monitoring, and coordination.

Real-time monitoring systems reduce:

- Rework caused by construction errors
- Material wastage
- Equipment idle time
- Labour inefficiencies
- Delays and associated penalties

Automated clash detection in BIM models identifies conflicts before actual construction begins, reducing costly corrections during execution. DT systems also improve resource tracking and utilization, ensuring that materials, labour, and equipment are used efficiently.

AI-based forecasting systems further optimize project schedules and resource allocation, leading to significant cost savings.

Cost Optimization Benefits:

- Reduced material wastage
- Lower rework costs
- Improved productivity
- Efficient resource utilization
- Better budget control

VIII. Challenges in BIM-DT Implementation

Despite the numerous advantages of BIM-Digital Twin integration, several technical, organizational, financial, and legal challenges hinder widespread adoption in the construction industry.

8.1 Technical Challenges

E. Software Interoperability Issues

Different construction software platforms often use incompatible data formats, making smooth information exchange difficult. BIM, GIS, IoT, and DT systems may not integrate efficiently without standard protocols.

F. Complex Data Integration

DT systems collect large amounts of data from multiple sources including sensors, drones, RFID systems, and cameras. Managing and synchronizing this data in real time is technically challenging.

G. High Computational Requirements

Real-time Digital Twin systems require powerful computing infrastructure, cloud storage, and fast internet connectivity for processing and visualization.

H. Cybersecurity Concerns

Since DT systems depend on cloud computing and live data transmission, they are vulnerable to cyberattacks, data breaches, and unauthorized access.

8.2 Organizational Challenges

I. Lack of Skilled Professionals

Many construction companies lack employees trained in BIM, IoT, AI, and Digital Twin technologies.

J. Resistance to Technology Adoption

Construction industries often follow traditional methods, and stakeholders may resist adopting advanced digital systems.

K. Limited Awareness and Training

In developing countries, awareness regarding DT technology and smart construction systems remains limited.

8.3 Financial Challenges

L. High Implementation Costs

The installation of IoT sensors, drones, laser scanners, cloud systems, and software platforms requires significant investment.

M. Expensive Software Licenses

Advanced BIM and DT software systems are costly, especially for small and medium-sized contractors.

N. Infrastructure Investment

Organizations must invest in hardware, servers, networking systems, and skilled workforce development.

8.4 Legal and Contractual Issues

O. Data Ownership Concerns

Questions often arise regarding who owns and controls project data generated through DT systems.

P. Privacy and Security Risks

Worker tracking systems and surveillance technologies may raise privacy concerns.

Q. Stakeholder Responsibilities

Clear contractual responsibilities for data management, cybersecurity, and DT maintenance are still not well established.

IX. Research Gaps

The literature review identifies several important gaps that require further research and practical implementation.

Limited Studies on High-Rise Projects

Most existing studies focus on general construction projects rather than complex high-rise buildings.

Lack of Real Project Implementations

Many studies are theoretical or simulation-based, with limited practical implementation on real construction sites.

Limited Research Under Indian Conditions

Indian construction environments involve unique challenges such as labour variability, dense urban areas, and infrastructure limitations.

Interoperability Problems

Smooth integration between BIM, GIS, IoT, AI, and DT systems still remains unresolved.

Limited Floor-Wise Monitoring Studies

Few studies specifically focus on vertical progress tracking in multi-storey buildings.

Lack of Affordable DT Systems

Current DT technologies are expensive and difficult for medium and small contractors to adopt.

X. Future Research Directions

Future research should focus on developing more practical, affordable, and intelligent BIM-DT systems.

AI-Driven Predictive Monitoring

AI and machine learning can improve delay prediction, productivity analysis, and automated decision-making.

Affordable BIM-DT Platforms

Developing low-cost systems suitable for medium and small contractors is essential.

Cloud-Based Collaborative Systems

Cloud computing can improve real-time collaboration among stakeholders across different locations.

Integration of BIM, DT, GIS, AI, and Drones

Combining multiple technologies can create more intelligent and accurate monitoring systems.

Real-Time Safety Analytics

Future DT systems should provide advanced worker safety analysis and automated hazard prediction.

Smart City Integration

Digital Twins can be integrated with smart city infrastructure for urban management and sustainability.

Automated Quality Inspection

AI-powered image processing and scanning technologies can automate quality control processes.

XI. Conclusion

The integration of Building Information Modeling (BIM) and Digital Twin (DT) technologies represents a revolutionary advancement in the field of construction project management. BIM provides a detailed digital representation of buildings and

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project information, while Digital Twin technology enhances BIM by incorporating real-time data synchronization, monitoring, and intelligent analytics.

The reviewed studies demonstrate that BIM-Digital Twin integration significantly improves construction progress monitoring, visualization, delay detection, safety management, resource optimization, and project coordination. These technologies are particularly beneficial for high-rise construction projects, where multiple activities occur simultaneously across different floors and require continuous monitoring and efficient coordination.

The integration of IoT sensors, drones, RFID systems, laser scanning, AI, cloud computing, and computer vision further strengthens the capabilities of BIM-DT systems by enabling automated monitoring, predictive analytics, and data-driven decision-making.

However, several challenges such as software interoperability issues, high implementation costs, lack of skilled professionals, cybersecurity risks, and organizational resistance continue to limit widespread adoption. Therefore, further research and industrial collaboration are required to develop affordable, user-friendly, and standardized BIM-Digital Twin solutions suitable for practical implementation.

With continuous technological advancements and increasing awareness regarding smart construction practices, BIM and Digital Twin technologies are expected to play a vital role in the future of intelligent infrastructure development. These technologies have the potential to transform traditional construction management into a highly efficient, automated, data-driven, and sustainable system capable of delivering safer, faster, and more cost-effective high-rise construction projects.

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