

TECHNOLOGY IMPLEMENTATION IN CONSTRUCTION PROJECT: A STUDY ON MORDERN DIGITAL TRANSFORMATION

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ABSTRACT:

The construction industry is undergoing a major transformation with the adoption of advanced digital technologies which signifies the transition from traditional manual practices to data driven processes. The study aims to explore the integration of next generation technologies like Building Information Modelling (BIM), Internet of Things (IoT), Artificial Intelligence (AI), Tunnel Boring Machine (TBM) and Digital Twins in a project like Pune Metro. Using the Pune metros Swargate Mandai stretch as a case study, this paper discusses the real-world benefits, integration challenges and overall impact of these technologies on project efficiency, cost management, risk mitigation and sustainability. We adopted a mixed method approach to collect data, using survey data from industry professionals and secondary data from project reports and publications. The findings indicate that while TBM technology achieves advanced rates of 12 m/day exceeding the global average and BIM provides a crucial framework for coordination and lifecycle management, significant challenges such as skill shortages, cultural resistance and high implementation cost. Also, the findings indicate that while technology significantly enhances project outcomes, challenges such as interoperability, resistance to change and data management issues persist.

Key Words: Construction Technology, BIM, IoT, Digital Twin, AI, Pune Metro, TBM, Data Driven, Project Reporting, Smart Construction, Construction 4.0

INDRODUCTION:

The construction sector is rapidly moving away from traditional, labour-intensive methods to smart, data-driven processes and the age of construction 4.0 is characterised by the adoption of digital tools to improve planning, execution and management across the project life cycle. Emerging technologies such as BIM, IoT, RFID, AI, AR & VR, TBM and Digital Twins are transforming the project planning, execution and management. These tools allow for real time data integration, better collaboration and decision making at all phases of the project life cycle. In large-scale metro rail projects, which are often implemented in congested urban landscapes with complex geotechnical conditions, the effective integration of these technologies is not just an advantage, but a necessity. AI and Digital Twin technology combination allows synchronised operations and predictive analysis boosting productivity and sustainability.

This project is on Pune metro project specifically 1.49 km underground stretch from Swargate to Mandai. The segment posed special challenges, including tunnelling through mixed geology (alluvial soil and basalt rock) at depths of 18- 25 meters below a densely populated old city with over 1000 surveyed structures in influence zone. The project employed Earth pressure Balanced (EPB) Tunnel Boring Machines and BIM (3D to 6D) was required to manage this risk. Building Information Modelling (BIM) has become a key platform, especially for bringing design scheduling and cost information together in an integrated digital environment.

Similarly, IoT and smart sensors help in real time monitoring of site conditions that improves safety and operational efficiency. Digital twin technology is changing construction management by creating live virtual replicas of physical assets, allowing for predictive analysis and life cycle management.

The purpose of this study is to analyse the implementation of such technologies in large scale infrastructural projects and reporting, identify the challenges associated with the implementation and evaluate their impact on project performance. The aim of this research is to: a) explore technologies used in the construction industry. b) identify challenges in implementing BIM, IoT, TBM and reporting tools. c) assess solutions and reporting tools used to enhance project coordination and efficiency.

LITERATURE REVIEW:

Previous research shows that digital technologies are becoming increasingly important in construction industry. Rehman et al. (2025) reported that 4D BIM, which adds scheduling information to 3D models, helps in project visualisation and minimises rework. In modular construction, automated systems connect design, fabrication, and assembly, helps in reducing the gap between abstract planning and field operations. Researcher also highlighted the role of IoT in enhancing site safety and operational efficiency through Rehman et al. (2025) showed that 4D BIM, which combines 3D models and scheduling data, significantly enhances project visualisation and reduces rework. Researcher also highlighted the role of IoT in increasing site

safety and operational efficiency by enabling real time monitoring of environmental conditions of equipment and worker activities. Studies by Khan et al. (2024) and Anjum et al. (2025) show that IoT enabled tools reduce injuries and allow teams to catch risk earlier. Digital twin technology has been recognised as a transformative tool that combines real time data with simulation models to optimise construction & maintenance processes. AI driven frameworks were proposed by Mlybari and Elgohary (2025) that employed machine learning to enhance value management and cost benefit review. Problems such as absence of interoperability among systems, high implementation cost, data fragmentation and resistance to technological transition still inhibit the widespread adoption. Also, researcher like Muller et al. (2024) and Singh et al. (2023) stressed that fragmentation and absence of standardised procedures often inhibit smooth technology integration. The literature also indicates the need of skilled professionals and standardised frameworks to fully avail the advantage of digital transformation. However, challenges like lack of interoperability between systems, high implementation costs, data fragmentation, and resistance to technological change still stand in the way of broad adoption of technology. Also, fragmentation and the lack of standardised procedures often pose obstacles to smooth technology integration, as noted by Muller et al. (2024) and Singh et al. (2023). The literature also points out the need for skilled professionals and standardised frameworks for the complete benefit of digital transformation in construction sector.

CASE STUDY: Pune Metro Project (Swargate to Mandai stretch)

The Pune Metro project is an example of implementation of advanced technology in Infrastructure development. The Swargate – Manadi stretch of 1.49km will use both BIM and TMB technologies for efficient execution. The project used 6.61-meter diameter Tunnel Boring Machines (TBMs) at a depth of 18-25 meters. The actual advanced rate of 12 m/day was a critical achievement, exceeding the project baseline of 8 m/day. This efficiency was largely credited to BIM coordination, which allowed to avoid utility relocations and optimised the tunnel alignment under a dense old city zone. BIM was used for various purposes like quantity take-offs, clash detection, scheduling (4D), cost estimation (5D) and lifecycle Management (6D). Further, the use of common data environment (CDE) supported real time collaboration among multidisciplinary teams.

Result:

The implementation of advanced technologies in the Pune metro project resulted in several benefits,

Increased Efficiency: TBM – BIM coordination saved about 21 days on specific drive section leading to saving of support cost of 2.1 crore rupees.

Cost Savings: BIM based planning helped to avoid rework and unnecessary resource use.

Safety enhancement: IoT and monitoring systems allow early detection of risks.

Risk mitigation: BIM visualised an influence zone of around 1000 structures in the old city. Proactive monitoring and avoiding clashes with historical building foundations were possible.

Enhanced Communication: One digital platform enabled better coordination between stakeholders.

Sustainable Design: Good practices in construction resulted in the efficient use of resources and waste reduction.

Lifecycle management: Delivering a “as-built” BIM model to the client ensures long term maintenance efficiency.

Survey Findings on Technology Adoption:

Adoption scale: 60-65% of organisations adopt technology on a large scale, 5-10% have not yet adopted basic digital reporting tools.

Perceived Benefits: A whopping 90-95% of professionals agreed that digital tools increase the accuracy of reports. 100% of respondents agreed that technology allows for faster and more informed decision making for stakeholders, improves cost control, increases transparency and effectively tracks project progress.

Resistance to change: 15-20% of professionals believe that smart techniques will make their jobs harder and another 5-10% are not sure, despite the obvious advantages. Resistance to change this is a strong sign of a major human factor barrier.

Key challenges :

The study identified critical obstacles to technology implementation, The most intense challenges, rated by respondents, were:

1. Skill Shortage (90% intensity): No trained personnel to operate BIM, IoT and Data analytics platforms.

2. High Cost (85% intensity): Large investment in software, hardware and training needed.

3. Cultural Resistance (80% intensity): Comfort with the traditional methods and fear over job losses.

4. Integration Issues (75% Intensity): Problem of interoperability among different software and legacy systems.

Solutions:

In order to overcome the above challenges this study assesses various measures such as onsite training was rated as the most effective solution with the rating of 4.8/5 followed by practical workshops with the rating of 4.5/5. Also, certified courses and online awareness programs, are important solutions, but received

slightly lower ratings of 4/5. Advocating the superior importance of practical, contextual learning over theoretical approaches.

Conclusion:

Digital transformation in construction projects isn't just about adopting new gadgets; it's about reimagining workflows, encouraging collaboration, and strategically managing change to build a more resilient and efficient industry that values sustainability and teamwork. The study concludes that the adoption of technology in construction projects significantly improves efficiency, cost control, safety and sustainability. Tools like BIM, IoT, AI and digital twins are transforming traditional construction practices into data driven intelligent systems. The Pune Metro Swargate-Mandai stretch serve as a benchmark, proving that the digital transformation enables better advance rates, proactive risk management, and lifecycle asset management through as-built BIM models for operations and maintenance (6D).

The study points to ongoing challenges. The “human factor” – skill shortages, cultural resistance and fear of jobless – is as great an obstacle as the technical and financial problems. We recommend a dual pronged strategy to tackle this. First, investment in practical onsite training and workshops to build hands on competence. Second, development of standardised industry framework for reporting measurable BIM KPIs (e.g. clash resolution rates, schedule variance, cost saving). Future research needs to develop standardised frameworks, improve interoperability and promote the development of digital skills to accelerate the adoption of Construction 4.0 technologies. Overall, the construction industry needs to embrace digital transformation to remain competitive and meet the demands of modern infrastructure development.

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