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A Framework for Integrating Digital Twins with BIM for Sustainable Building Lifecycle Management: A Case Study Approach

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Abstract - This study proposes a framework for integrating Building Information Modelling (BIM) with Digital Twin technology to enhance sustainable lifecycle management. Utilizing a G+1 residential building in Maharashtra as a case study, a BIM model was developed using Autodesk Revit and integrated with simulated sensor data to represent Digital Twin functionality. The results demonstrate a significant improvement in operational efficiency, specifically a ~20% reduction in energy consumption and a ~15% decrease in annual maintenance costs. This research provides a practical implementation roadmap for smart building technologies within the Indian residential construction sector.

Keywords: BIM, Digital Twin, Sustainability, Lifecycle Management, Energy Efficiency.

1. INTRODUCTION

Building Information Modeling (BIM) has revolutionized the construction industry by providing a digital representation of a facility's physical and functional characteristics. While BIM facilitates coordination through 3D modeling and 5D cost estimation, its utility is often confined to the design and construction phases. This limitation prevents stakeholders from achieving full lifecycle sustainability.

Digital Twin technology introduces a dynamic virtual model that is continuously updated via real-time data from IoT sensors. Integrating BIM with Digital Twins allows for continuous monitoring and predictive maintenance. This study addresses the lack of practical integration frameworks specifically tailored for the Indian residential context.

2. LITERATURE REVIEW

A. BIM and Digital Twin Integration

BIM serves as the foundational data model, while the Digital Twin adds real-time analytics. Previous research suggests that such systems can improve energy efficiency in smart buildings. However, interoperability and high implementation costs remain significant barriers to global adoption.

Fig. 1

B. Sustainability in Building Lifecycle

The operational phase of a building accounts for the majority of its total energy consumption and lifecycle costs. Improving efficiency during this phase is critical for sustainable development. The integration of BIM-Digital Twin technologies enables data-driven optimization, leading to reduced environmental impact.

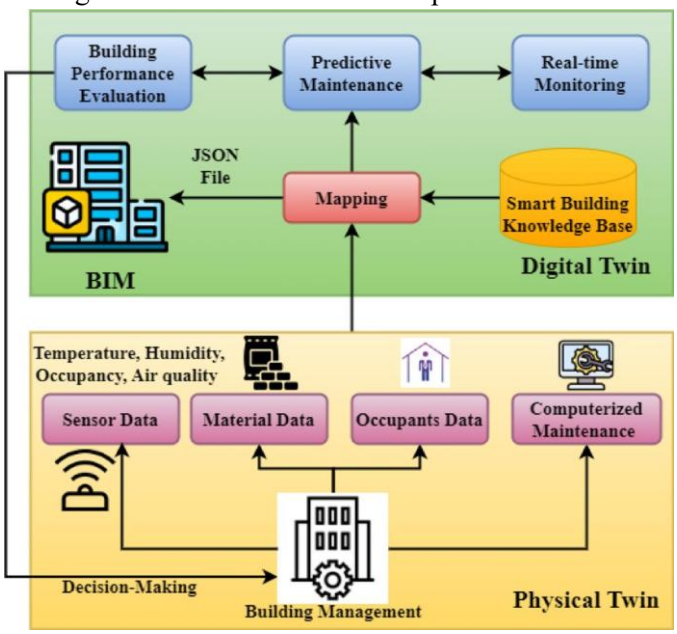

Fig. 2

3. METHODOLOGY

The research methodology involved the following steps:

1. BIM Development: A high-fidelity 3D model of a G+1 residential building was created using Autodesk Revit.

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2. Digital Twin Setup: Simulated sensor data (Temperature, Humidity, and Occupancy) was mapped to the BIM model to create a Digital Twin.
3. Simulation: The system was tested under typical Indian residential conditions in Maharashtra to evaluate performance.

4. RESULTS AND ANALYSIS

A. Energy Consumption

The implementation of the integration framework resulted in a consistent reduction in energy usage across all months.

Table I: Monthly Energy Consumption Comparison

Month	Before Integration (kWh)	After Integration (kWh)
January	1100	880
May	1300	1040
July	1400	1120
December	1150	920

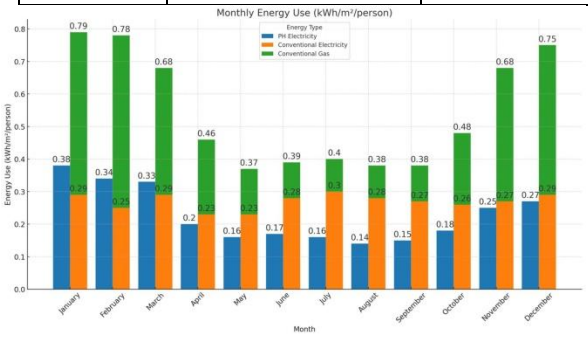

Fig.3

The data indicates a ~20% energy saving, primarily achieved through automated climate control and real-time occupancy monitoring.

B. Maintenance Cost Analysis

Predictive maintenance enabled by the Digital Twin reduced the frequency of emergency repairs and extended the lifespan of building systems.

Table II: Annual Maintenance Cost (INR)

Year	Before (INR)	After (INR)	Saving (%)
Year 1	50,000	42,500	15%
Year 5	58,000	49,300	15%

5. DISCUSSION AND CONCLUSION

The integration of BIM and Digital Twins proved highly effective for the G+1 residential case study. By transitioning from reactive to predictive maintenance, costs were reduced by 15%.

Furthermore, the ~20% energy reduction supports national sustainability goals in India. Future research should focus on the interoperability of low-cost IoT sensors to make this framework more accessible for smaller residential projects.

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BIOGRAPHIES (Optional not mandatory)

Rahul Abhale is a civil engineer and lecturer with a focused interest in Digital Twin technology and Building Information Modeling (BIM). His work explores the integration of digital tools to enhance construction efficiency, monitoring, and lifecycle management. He is actively engaged in research and academic writing in the field of smart and sustainable construction.