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# Integrated use of BIM Tools for Structural Retrofitting: Design Development and Clash Detection to Project Management

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**Abstract- This study presents a comprehensive framework for applying Building Information Modelling (BIM) tools to retrofit existing structures with improved accuracy and efficiency. BIM platforms such as Autodesk Revit are used to develop precise 3D as-built models that capture geometric, structural, and material details of existing buildings. By incorporating point-cloud data and field measurements, these models provide a reliable digital representation of actual site conditions, reducing uncertainties and enhancing visualization for informed decision-making during retrofit planning. This paper present, the focus was on developing accurate BIM-based models and performing structural analysis and optimization. Tools such as Autodesk Revit 2025, SketchUp, and STAAD Pro were integrated to enable detailed modelling, simulation, and performance evaluation. The as- built BIM models served as a foundation for structural assessment in STAAD Pro, facilitating the identification of deficiencies and the selection of appropriate strengthening strategies. This integrated workflow ensured safe, coordinated, and cost-effective retrofit design while improving overall project efficiency. The outcomes of this phase demonstrate the effectiveness of BIM in supporting retrofit design through accurate modelling and structural analysis. Focus on clash detection, design coordination, and synchronized model updates to further enhance project integration. Overall, the proposed BIM-based workflow establishes a structured approach to retrofitting that integrates 3D modelling, analysis, and cost/schedule management, contributing to reduced errors and more efficient, data-driven delivery in civil and infrastructure engineering.**

**Keywords— BIM, retrofitting, point cloud, Revit, STAAD Pro, structural analysis, 3D modelling, scan-to-BIM, design coordination, clash detection, cost efficiency, workflow, lifecycle management.**

## I. INTRODUCTION

Retrofitting involves upgrading existing buildings by integrating modern technologies to improve functionality, energy efficiency, and overall performance. However, the process is often constrained by incomplete documentation and limited knowledge of existing conditions. This study addresses these challenges by leveraging Building Information Modelling (BIM) methodologies combined with digital technologies and non-destructive testing (NDT). A case study of a 2,404.5 m² building in Brasília demonstrates a structured five-stage approach, including 3D laser scanning for point cloud generation, pathology mapping, construction system assessment, BIM-based modelling, and final retrofit model development. The findings highlight the effectiveness of BIM in improving collaboration, transparency, and interdisciplinary coordination, despite challenges such as limited data availability and difficulty in assessing concealed systems (Volk et al., 2014; Murphy et al., 2013; Dore & Murphy, 2012).

The research also builds on the concept of “BIMification,” which provides a systematic approach to modelling existing buildings using standardized frameworks such as IFC. This process consists of two key stages: anamnesis, which focuses on data collection and building assessment, and diagnosis, which involves analysis and interpretation to support retrofit decision-making. The integration of NDT techniques further strengthens the framework by enabling accurate evaluation of material properties and structural conditions while minimizing invasive testing. These combined approaches support better structural health monitoring, maintenance planning, and lifecycle extension of existing buildings(Volk et al., 2014; Murphy et al., 2013).

A key problem identified in retrofit is the reliance on conventional practices such as manual surveys and 2D documentation, which often lead to design inconsistencies, poor coordination, and increased costs and timelines. BIM addresses these limitations by providing an integrated digital platform for 3D visualization, clash detection, quantity estimation, and performance simulation. However, challenges such as data acquisition, interoperability between software tools, and the absence of standardized workflows for retrofit applications continue to hinder widespread adoption. This study proposes a structured BIM-based framework that incorporates data capture techniques such as laser scanning and photogrammetry, model development, and performance analysis to enhance project efficiency and accuracy (Volk et al., 2014; Barazzetti et al., 2015).

The study aims to develop a data-driven BIM framework that improves retrofit design, structural safety, and coordination. Key objectives include creating precise 3D as-built models, performing structural analysis and optimization, enabling interdisciplinary collaboration, detecting design conflicts, and improving planning and monitoring through BIM-based data integration. The significance of this work lies in its ability to enhance design accuracy, reduce risks, optimize costs and resources, and support sustainability through lifecycle management and energy analysis. Additionally, BIM facilitates improved communication among stakeholders and ensures better compliance with regulatory standards (Eastman et al., 2011; Volk et al., 2014).

The scope of the study focuses on applying BIM to retrofit projects with emphasis on design optimization, cost estimation, sustainability, and lifecycle performance. It also identifies existing technological gaps, including interoperability issues, limited real-time analytics, and insufficient integration with emerging technologies such as IoT, AI, and digital twins. The research outlines a comprehensive BIM-based workflow that includes reality capture, scan-to-BIM modelling, structural assessment, retrofit design, coordination, and implementation. Overall, the study demonstrates that BIM-enabled retrofitting provides a structured, efficient, and sustainable approach to upgrading existing buildings while enhancing long-term performance and asset management (Murphy et al., 2013; Barazzetti et al., 2015).

## II. METHODOLOGY

The methodology adopts a systematic approach for the integrated use of BIM tools in structural retrofitting, encompassing stages such as data collection, modelling, simulation, evaluation, and optimization. It focuses on improving design accuracy, clash detection, and project management to ensure efficient and sustainable outcomes. A hybrid research approach is employed, combining qualitative methods such as literature review, sustainability assessment, and regulatory considerations—

with quantitative analysis, including simulation results and performance evaluation. This integrated methodology enables a comprehensive understanding of retrofit design while ensuring practical implementation with measurable and optimized results.

### 1. Research Framework

The research framework provide a structured approach for integrating BIM technologies in the structural retrofitting of existing buildings to enhance accuracy, coordination, and efficiency. It begins with the development of precise 3D as-built models using laser scanning or LiDAR data processed in Autodesk ReCap Pro and modeled in Revit. Structural analysis and optimization are performed using STAAD.Pro, while interdisciplinary coordination is achieved through IFC-based interoperability in a federated BIM environment. Clash detection using Navisworks ensures model consistency, and 4D/5D BIM simulations support scheduling, cost estimation, and progress monitoring. Overall, the framework enables data-driven decision- making, reduces design conflicts, and improves collaboration throughout the retrofit project lifecycle.

## 2. Precise 3D As-Built BIM Modeling for Retrofit Design

The development of precise 3D as-built BIM models for retrofit design begins with defining project requirements, including the intended use of the model, Level of Detail (LOD), and selected software such as Revit, Navisworks, and Recap. This is followed by detailed site data acquisition using laser scanning/LiDAR, photogrammetry, and manual surveys to capture accurate existing conditions. The collected point cloud data is then processed through registration, noise removal, and coordinate alignment before being imported into BIM software for modeling. Architectural, structural, and MEP components are systematically developed and continuously validated against the point cloud to ensure accuracy. Quality control procedures, including clash detection and deviation analysis, are performed to verify model reliability. The validated as-built model then serves as a foundation for integrating retrofit interventions and assessing design feasibility. Finally, the model is used for visualization, documentation, and stakeholder review, enabling informed decision-making and supporting efficient retrofit planning and execution.

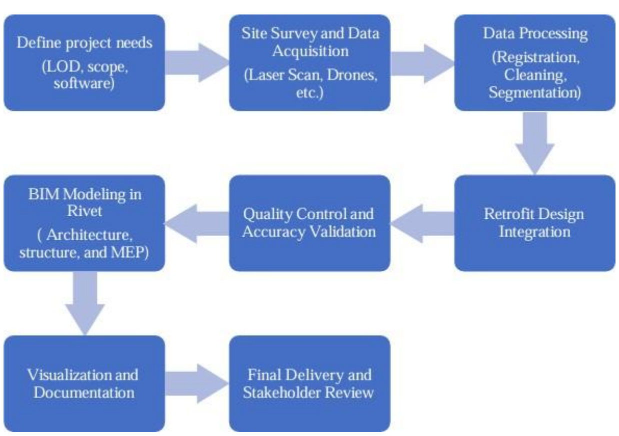


Figure 1. 3D As-Built BIM Process

## 3. Structural Analysis and Optimization for Safe Retrofit Design using STAAD.Pro

The structural retrofitting process using STAAD.Pro begins with a detailed preliminary assessment of the existing structure through drawing review, site inspection, and Non-Destructive Testing (NDT) to evaluate material condition, damage, and load requirements. Based on this, an accurate 3D structural model is developed in STAAD.Pro by defining geometry, material properties, boundary conditions, and relevant load combinations as per design codes. Structural analysis is then performed using appropriate methods such as linear static or response spectrum analysis to identify critical stresses, deflections, and weaknesses in the system. Based on the analysis results, suitable retrofitting techniques such as jacketing, FRP wrapping, shear walls, or bracing are selected to improve structural performance. An iterative optimization process is carried out within STAAD.Pro to achieve a balance between safety, cost-effectiveness, and material efficiency by testing different retrofit configurations. Finally, detailed design drawings, reinforcement details, and cost estimates are prepared, followed by proper site execution and quality control to ensure the retrofitted structure meets required safety and performance standards.

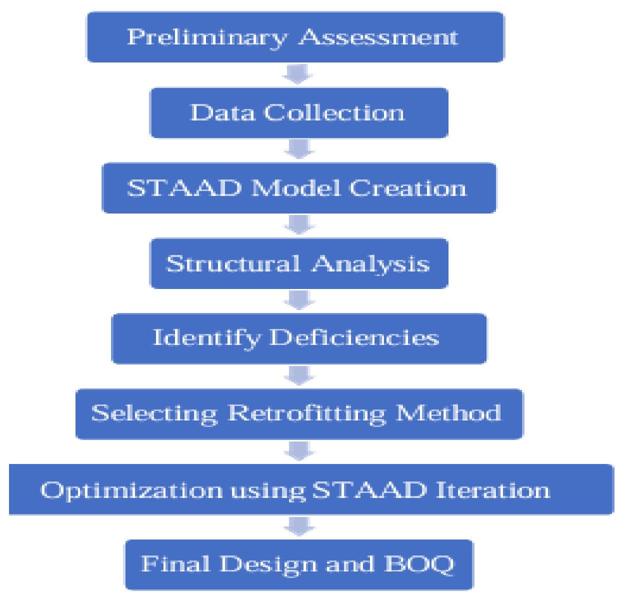


Figure 2. Retrofitting Design and Optimization Flowchart

**4. Interdisciplinary BIM Coordination for Structural,**

Architectural, and MEP Integration The interdisciplinary BIM coordination process integrates architectural, structural, and MEP teams through a structured workflow that begins with a BIM Execution Plan (BEP) to define standards and collaboration procedures. Each discipline develops its model, which is shared via a Common Data Environment (CDE) and combined into a federated model for integrated review. Clash detection is used to identify and resolve spatial conflicts through iterative coordination and regular team reviews. This continuous collaboration ensures design consistency, minimizes conflicts, and improves overall project efficiency. Once fully coordinated and validated, the BIM model supports the generation of construction documentation and facilitates smooth paper execution

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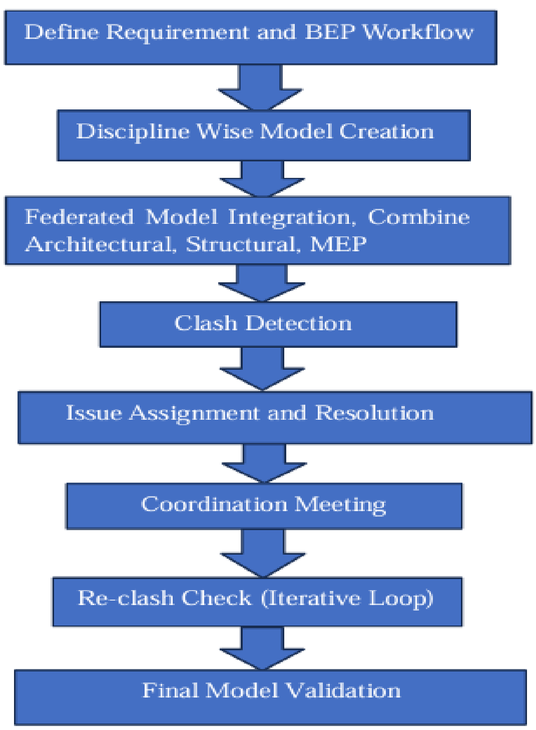


Figure 3 Multidisciplinary BIM Process

## III. RESULTS AND DISCUSSIONS

This chapter presents the overall analytical results and interpretation of the BIM-based methodologies applied in the study, including 3D as-built modeling, structural analysis and optimization, interdisciplinary coordination, and sustainable system integration. The findings are evaluated in terms of accuracy, efficiency, structural performance, and sustainability improvements using simulation outputs, clash detection reports, and comparative analyses. The results are organized into two main categories:

- as-built BIM development and structural optimization using tools like Revit and STAAD.Pro.
- interdisciplinary BIM coordination along with 4D/5D planning and sustainable design implementation such as rainwater harvesting.

Together, these outcomes demonstrate how BIM enhances design accuracy, coordination efficiency, and overall paper performance.

**1. Development of Precise 3D As-Built Models Using BIM**

The development of precise 3D as-built BIM models involves defining project requirements and selecting appropriate software such as Revit, Navisworks, and Autodesk Recap. Site data is collected using LiDAR, drone photogrammetry, and manual surveys to generate accurate point cloud information. This data is then processed through registration, noise removal, and segmentation to support efficient modeling of architectural, structural, and MEP elements in Revit. The model is continuously validated against the point cloud, followed by quality checks and clash detection to ensure accuracy and coordination. The finalized as-built model serves as a reliable foundation for integrating and evaluating retrofit design solutions in terms of feasibility and spatial compatibility.

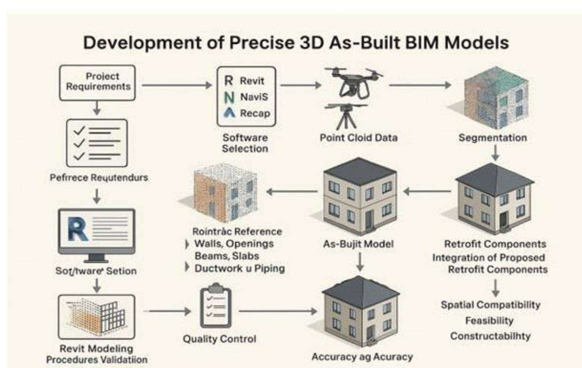


Figure 4. Workflow for Developing Accurate 3D As-Built BIM Models

Source: Marlapalle, P., et al. (2012)

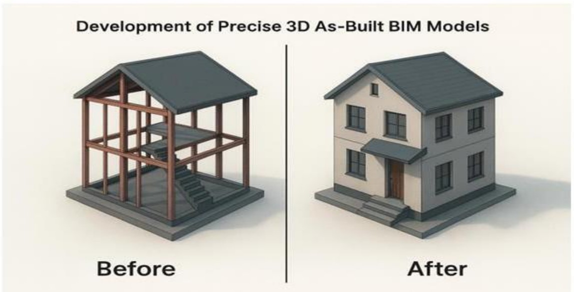


Figure 5. Before and After: Generation of Accurate 3D As-Built BIM Models

Source: Marlapalle, P., et al. (2012)

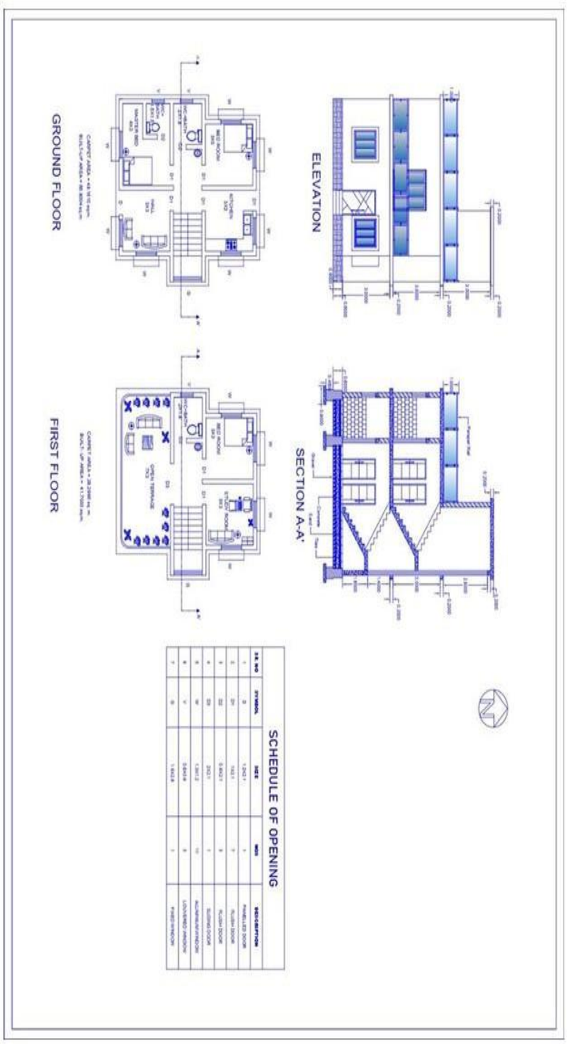


Figure. 6. Prepared 2D Plan of an Existing Building

Figure. 7. Precise 3D Modeling of an Existing Building Using Revit Architecture

**2. Structural Analysis and Optimization Using STAAD.Pro**

The structural retrofitting process starts with a detailed assessment of the existing building using drawings, site inspections, and NDT to evaluate material condition and structural capacity. Accurate data on geometry, materials, soil conditions, and loads is then collected to develop a reliable analytical model in STAAD.Pro. A 3D structural model is created and analyzed using appropriate load combinations and design codes, helping identify critical weaknesses through analysis outputs such as stresses, deflections, and forces. Based on these results, suitable retrofitting techniques like jacketing, FRP wrapping, shear walls, or bracing are selected and optimized to ensure safety, efficiency, and cost-effectiveness. Finally, detailed drawings, cost estimates, and construction guidelines are prepared, followed by quality- controlled implementation and post-retrofit monitoring to ensure long-term structural performance.

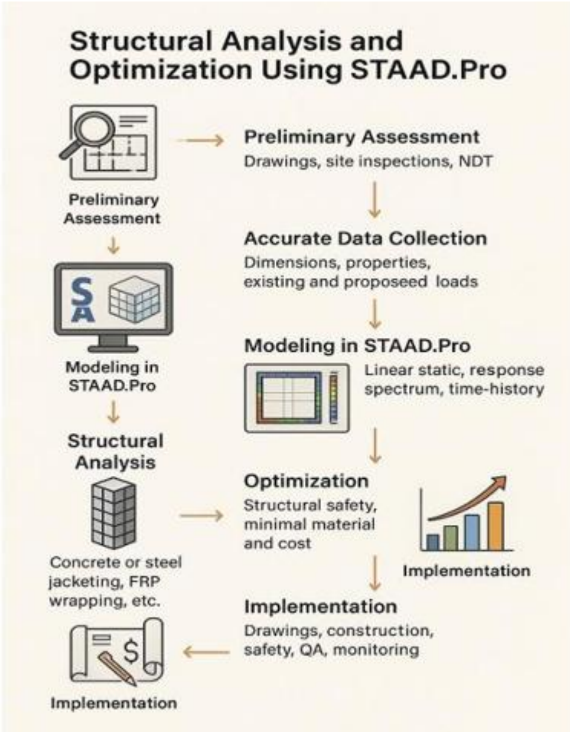


Figure.8. Comprehensive Structural Layout for Building Retrofitting

Source: Kulkarni, P., & Bhusare, A. (2016)

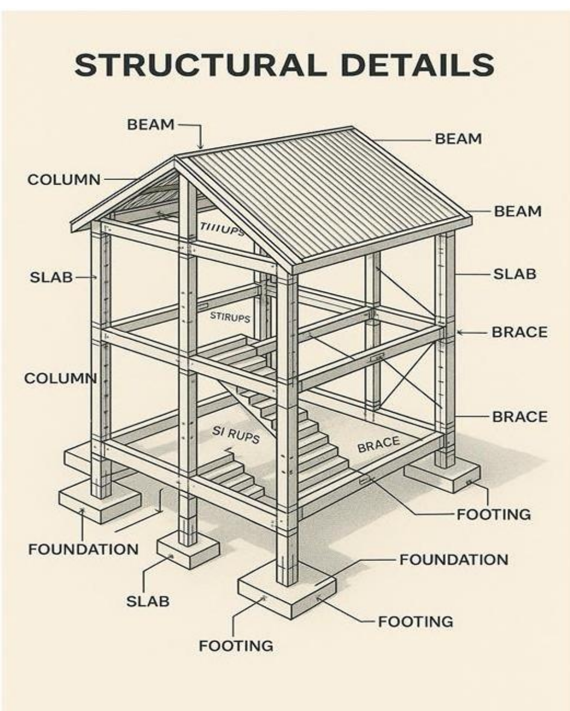


Figure.9. Structural Details of a Two-Storey RC Frame Building

Source: Marlapalle, P., et al. (2012)

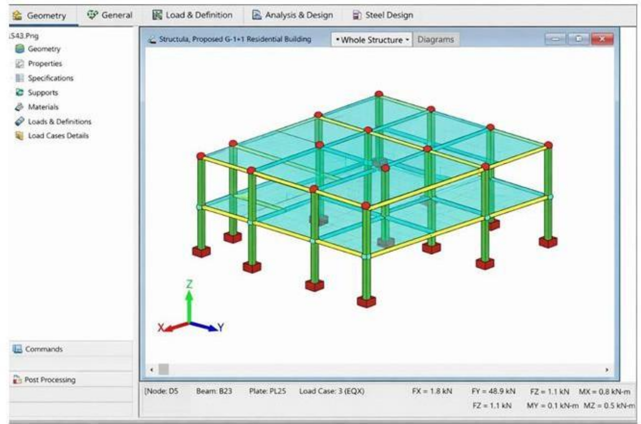


Figure.10.Structural Analysis and Modeling Using STAAD Pro Based on Non-Destructive Testing Data

**3. Integration of Structural, Architectural, and MEP Models Using BIM**

Interdisciplinary coordination among structural, architectural, and MEP teams was effectively achieved using a centralized BIM- based federated model of the existing building. Discipline-specific models were developed and integrated into a single coordinated platform, enabling consistent data sharing and collaboration. Clash detection identified multiple conflicts, most of which were resolved digitally through iterative coordination, significantly reducing on-site issues. BIM also supported retrofit planning by enabling accurate assessment of structural conditions, optimized MEP rerouting, and simulation of construction sequences. The approach improved design accuracy, reduced rework and coordination errors, shortened project timelines, and enhanced overall efficiency, demonstrating the strong impact of BIM in managing complex retrofit projects.

**4. Clash Detection and Synchronized Conflict Resolution**

BIM-based clash detection and synchronized conflict resolution in retrofitting projects significantly improve overall project performance by enabling early identification and mitigation of design conflicts. The approach reduces on-site clashes by 70–90%, decreases rework by up to 60%, and achieves time savings of 15– 25% along with cost reductions of 10–20%. It also enhances interdisciplinary coordination through a centralized visual platform, improving communication, transparency, and decision- making among structural, architectural, and MEP teams. Additionally, BIM supports better planning, safety, and risk reduction by allowing simulation of design alternatives and improving workflow efficiency through structured conflict resolution. Overall, this methodology ensures more efficient, accurate, and reliable execution of complex retrofitting projects.

**5. Improved BIM-Based Retrofit Planning and Progress Tracking**

BIM significantly enhances retrofit planning and progress tracking by providing a detailed digital model that integrates both geometric and project data. Using information from surveys, drawings, and technologies like laser scanning, a 3D as-built model is developed to represent existing conditions accurately. This model supports the integration of architectural, structural, and MEP systems for early identification of constraints and coordination issues. With 4D BIM, construction sequencing and scheduling can be simulated to optimize planning and resource allocation. During execution, real- time updates to the model enable continuous progress monitoring by comparing planned and actual work, helping detect delays and deviations early. Overall, BIM improves coordination, accuracy, communication, and decision-making, making retrofit projects more efficient, controlled, and reliable.

The comparative analysis shows that BIM-based retrofitting outperforms traditional methods across all key parameters, including clash reduction, rework reduction, time savings, cost savings, and coordination efficiency. BIM achieves higher efficiency by enabling early clash detection through 3D modeling and integrated coordination, whereas traditional methods often identify issues only during construction, leading to delays and rework. The integration of 4D BIM improves scheduling and sequencing, resulting in significant time savings, while accurate quantity estimation and reduced errors contribute to lower costs. Additionally, BIM enhances coordination by providing a centralized platform for real-time collaboration among all disciplines, unlike traditional fragmented workflows. Overall, BIM-based retrofitting is more efficient, accurate, and reliable due to its integrated and data-driven approach.

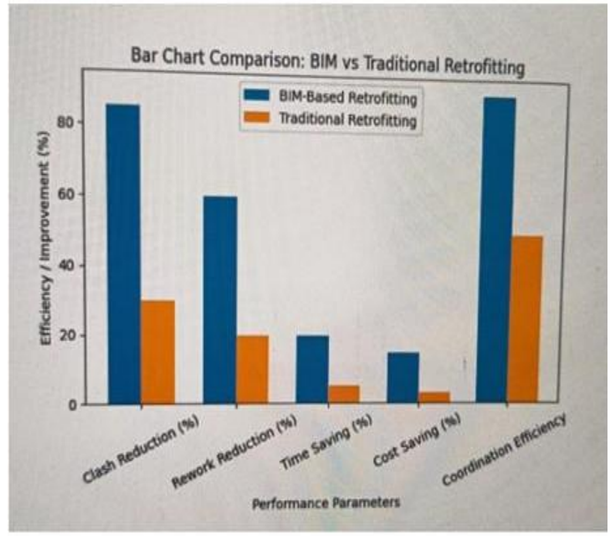


Figure.11. Bar Chart Comparison: BIM vs Retrofiting

## IV. CONCLUSION

The project concludes that the integrated use of BIM significantly improves the effectiveness of structural retrofitting by enhancing accuracy, coordination, and overall project efficiency. The development of precise 3D as-built models provides a reliable digital foundation for analysis and retrofit design, while structural assessment and optimization ensure safe, stable, and cost-effective strengthening solutions.

Furthermore, BIM enables strong interdisciplinary coordination among architectural, structural, and MEP systems through a unified digital platform, improving communication and reducing coordination errors. Clash detection and synchronized conflict resolution help identify issues early, minimizing rework, saving time and cost, and improving project execution. In addition, BIM-based planning and progress tracking support better scheduling, real-time monitoring, resource optimization, and informed decision-making throughout the lifecycle.

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