# ENHANCING STRUCTURAL DESIGN EFFICIENCY IN PAKISTAN: A CASE STUDY ON THE IMPACT OF BIM INTEGRATION

***[a]Hassan Tahir* [b]Muhammad Umair***

a: Structure Engineering Department, Designmen Consulting Engineers, Islamabad, Pakistan. hassantahir275@gmail.com*
b: Department of Construction Engineering and Management, National University of Sciences and Technology (NUST), Islamabad, Pakistan. mumair.ms22nice@student.nust.edu.pk

***Abstract-*** This study explores the implementation of Building Information Modeling (BIM) workflow in traditional structural design processes, with a focus on interoperability challenges and comparative analysis. A live project served as the basis for examining both conventional and BIM-based approaches to structure design. The study reveals significant differences in time consumption, coordination, error reduction, and rework between the two methods, with the BIM-based approach demonstrating notable advantages. Through the integration of 3D modeling and project browser features in Revit, stakeholders benefit from enhanced visualization, collaboration, and flexibility in design adjustments. Overall, BIM-based design in Revit proves to be a highly efficient and error-minimizing solution for structural design processes.

***Keywords-*** Automation, BIM, Design Workflow, Structure Design.

## 1 Introduction

The design workflows in construction industry are continuously looking for more efficient methods. The only way is to automate manual processes and utilize better software for reduced cost and time. Introduction of modern technologies in the design workflows is important in achieving these desired efficiencies in the industry. The construction industry is in continuous implementation of new technologies due to ever evolving nature of this field [1], [2]. However, these technologies should facilitate digital building information in construction industry to transform it into dynamic environment [3]. New development in technologies have led to advanced building design tools [4]. BIM methodology is one example of such tools, which has been widely acknowledged and implemented within the construction sector. BIM can help to facilitate communication among design teams to prevent discrepancies in work output by individual team members that can otherwise affect the productivity rates. BIM is based on the idea of having a centralized database which contain digital three-dimensional model of each design parameter. Consequently, data exchange among different participants is easier. Multiple methodologies are being implemented for the use of BIM software in designing structures. These methodologies can help with quick design generation, increase efficiency, and alternatives to cut down discrepancies within design drawings [5]. For this reason, it is suggested that BIM has a significant role in assisting structural designer in their field of activity, and therefore should be adopted by the industry professionals [6]

Structural design is an activity that necessitates proficient management of available software, both in terms of the modelling process and analysis practice [7]. The process of structural design, backed by BIM software, has been extensively researched. A common finding across these studies is the identification of the interoperability capacity of the systems as a primary constraint on BIM implementation in this segment of construction [8], [9]. The percentage of structural projects where BIM software is utilized, revealed an average of 50% in tasks related to inter-discipline coordination, predication of documentation (drawings), and analyses and design [10], [11]. So, interoperability is an essential step that requires careful consideration in project design offices. This study examines and presents the implementation of BIM integration in structural design within a real-world project in Pakistan. The novelty of this study lies in its empirical comparison of BIM and traditional methods, highlighting the practical benefits and efficiency gains of BIM integration. This unique focus provides valuable insights into the implementation of BIM within the local context.

Therefore, this study focusses on two main objectives:

1 Implementation of BIM workflow in the traditional structure design process.
2 Comparison of Traditional and BIM based structure design process.

## 2 Research Methodology

This study follows the methodology as elaborated in Fig. 1. A live project is chosen for study purposes. The structure design of the project has been conducted using the traditional approach practiced in design consultancy. Subsequently, the structure design process is repeated using BIM based approach, resulting into exploration of interoperability compatible BIM methodology for structure design processes and comparison of traditional and BIM based structure design approaches.

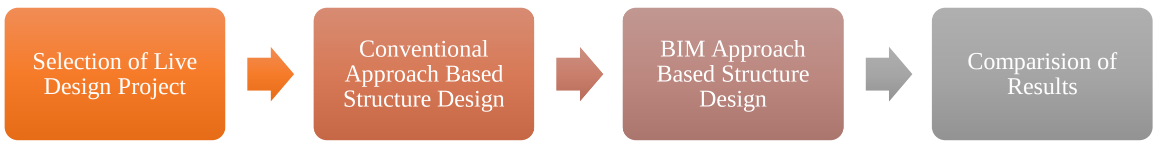


*Figure 1: Research Methodology*

## 3 Case Study

The live project involved the construction of a mosque in the Islamabad region, comprising two floors. The design process commenced with a soil investigation, followed by a site visit to assess soil profile, topography, and other site characteristics. Multiple plans were drafted by the architect according to client's specifications. Upon client's approval, one architectural draft plan was finalized, with column locations marked on for structural design. These architectural plans were then passed to the structural design engineer for framing, analysis, and design of the structure of mosque.

### *1.1 Conventional Design Approach*

The conventional design approach involves the designing of the frame structures on the plans received from the architect. This task is accomplished using specialized software tools such as Etabs, which facilitate detailed and accurate structural analysis and design. The dimensions of the structural members and required steel reinforcements are then provided to the structural draftsmen. Equipped with this information, the draftsmen proceed to create detailed plans in accordance with the provided framing. Despite being time-tested, this methodology necessitates careful coordination and clear communication between all parties involved to ensure the successful completion of the project.

### *1.2 BIM based Design Approach*

In a BIM-based approach, the architect provided CAD files of the architectural plan to the structural engineer for initial column sizing. Simultaneously, the architect began developing an architectural model in Revit for future collaboration and clash detection. The structural engineer linked the CAD file to Revit and created a 3D Structural Framing Model using a Revit structure template. A BIM studio plugin was utilized for automatic column placement based on the linked CAD file, reducing modeling time. Once the framing was verified, the engineer imported the model to CSI ETABS for analysis and design. Following analysis and design, the model was transferred back to Revit for validation. In order to ensure a smooth transferring of model between two software, CSiXRevit plugin was used. Rebar modeling using the CAD Rebar Extension ensued, resulting in the preparation of detailed construction drawings with 3D views and quantity estimation using BIM. Fig 2. shows the workflow begins with an initial framing geometrical model in Revit as shown in fig 2a. this basic 3D model lacks detailed load and boundary condition information. Fig 2b. shows an analytical model which was prepared in Revit incorporating loads and boundary conditions. Fig 2c. demonstrates the results of shear stress distribution after analyzing the analytical model in Etabs, and Fig 2d. represents the final reinforcement model in Revit that was based on the output reinforcement results from Etabs.

## 4 Results

The study showed a big difference in time consumption, coordination issues, errors, and rework between the BIM-based approach and the conventional design-based approach. The results are shown in Table 1 and Table 2. The conventional approach took 8.5 days, while the BIM-based approach only took 3 days.

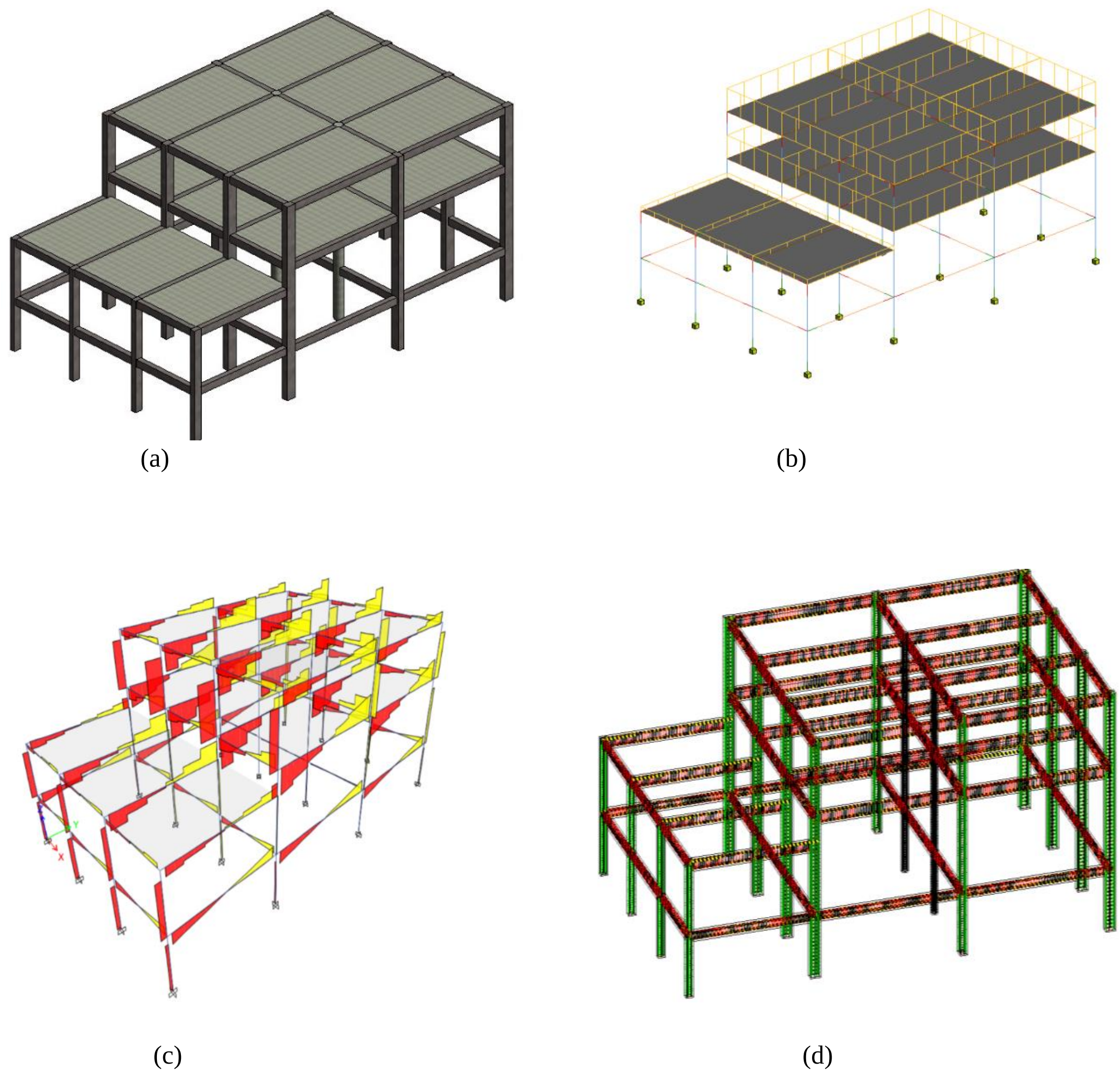


*Figure 2: BIM design approach, a. Initial geometrical model, b. Revit analytical model, c. Etabs analysis model and d. Finalized reinforced model of Revit.*

In the conventional design approach, the architect took 1 day to create the initial concept and CAD plan. Next, the structural draftsman took 1.5 days to prepare the initial structural drawings. Then, the structural engineer needed 2 days for detailed structural analysis and design. After that, the structural engineer spent another 2 days to create detailed structural drawings. Finally, the revision process took 2 more days to finalize the design and drawings. Overall, it took 8.5 days to complete the design and drafting process.

In contrast, with the BIM-based approach, the architect also took 1 day to create the initial CAD plan. After that, the structural engineer completed the design and detailing process using BIM tools in just 2 days. So, the entire process took only 3 days. This shows that the BIM-based process is 2.83 times faster than the conventional process. This significant timesaving highlights the efficiency of using BIM tools in design and drafting.

All in all, the conventional approach is already well established, and users are familiar with its workflow, which results in more predictability in the earlier stages of the project. However, it is time-consuming, as indicated by the results showing that it took 8.5 days for the entire process, and comparatively there is still a high probability of errors and rework. On the other hand, the BIM-based approach is more time-efficient, well-coordinated, and has a comparatively lower probability of errors and rework. However, the initial efforts in terms of setting up a BIM-based design environment, including the hard resources such as systems and soft resources such as software purchasing and recruiting people with the required skills, are comparatively high.

*Table 1: Conventional Design Approach*

| **Sr. no** | **Activity** | **Performed By** | **Time** |
|---|---|---|---|
| 1. | Initial CAD plan | Architect | 1 day |
| 2. | Structural CAD plan | Structure draftsman | 1.5 days |
| 3. | Structure analysis and design | Structure engineer | 2 days |
| 4. | Preparation of structure detailing | Structure draftsman | 2 days |
| 5. | Revisions | Architect and structure engineer | 2 days |

*Table 2: BIM Base Design Approach*

<table>
<tr><th>Sr. no</th><th>Activity</th><th>Performed By</th><th>Time</th></tr>
<tr><td>1.</td><td>Initial CAD Plan</td><td>Architect</td><td>1 day</td></tr>
<tr><td>2.</td><td>CAD to Revit</td><td>Structure engineer</td><td rowspan="2">1 day</td></tr>
<tr><td>3.</td><td>Integration of Revit model to Etabs for analysis and design</td><td>Structure engineer</td></tr>
<tr><td>4.</td><td>Placement of reinforcement in Revit</td><td>Structure engineer</td><td rowspan="2">1 day</td></tr>
<tr><td>5.</td><td>Detailing in Revit</td><td>Structure engineer</td></tr>
</table>

## 5 Conclusion

The study implemented the BIM based structure design process on a live project and drawn comparison with conventional approach. From this study, it is concluded that:

1. BIM-based design in Revit ensures minimal errors and high efficiency due to precise coordinate input and seamless propagation of modifications across all views, saving significant time in the design process.
2. The integration of 3D modeling and project browser in Revit enhances visualization, fosters collaboration, and minimizes inconsistencies across disciplines, further reducing design time.

## References

[1] A. Naamane and A. Boukara, "A Brief Introduction to Building Information Modeling (BIM) and its interoperability with TRNSYS," Renewable Energy and Sustainable Development, vol. 1, no. 1, pp. 126–130, Aug. 2015, doi: 10.21622/RESD.2015.01.1.126.

[2] J. Brozovsky, N. Labonnote, and O. Vigren, "Digital technologies in architecture, engineering, and construction," Autom Constr, vol. 158, p. 105212, Feb. 2024, doi: 10.1016/J.AUTCON.2023.105212.

[3] A. Khudhair, H. Li, G. Ren, and S. Liu, "Towards Future BIM Technology Innovations: A Bibliometric Analysis of the Literature," Applied Sciences 2021, Vol. 11, Page 1232, vol. 11, no. 3, p. 1232, Jan. 2021, doi: 10.3390/APP11031232.

[4] R. Sacks, C. M. Eastman, and G. Lee, "Parametric 3D modeling in building construction with examples from precast concrete," Autom Constr, vol. 13, no. 3, pp. 291–312, May 2004, doi: 10.1016/S0926-5805(03)00043-8.

[5] D. Migilinskas and L. Ustinovichius, "Computer-Aided Modelling, Evaluation and Management of Construction Projects According to PLM Concept," Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), vol. 4101 LNCS, pp. 242–250, 2006, doi: 10.1007/11863649_30.

[6] I. F. Varouqa and M. A. Alnsour, "A method of building information modelling implementation for structural engineering firms," MethodsX, vol. 12, p. 102685, Jun. 2024, doi: 10.1016/J.MEX.2024.102685.

[7] T. Hamidavi, S. Abrishami, and M. R. Hosseini, "Towards intelligent structural design of buildings: A BIM-based solution," Journal of Building Engineering, vol. 32, p. 101685, Nov. 2020, doi: 10.1016/J.JOBE.2020.101685.

[8] "Sequeira, P. (2022) Analysis of BIM Technology Capabilities in the Generation of 4D Models. Master's Thesis, University of Lisbon, Lisbon. - References - Scientific Research Publishing." Accessed: Jul. 16, 2024. [Online]. Available: https://www.scirp.org/reference/referencespapers?referenceid=3548887

[9] A. Z. Sampaio and A. M. Gomes, "BIM Interoperability Analyses in Structure Design," CivilEng 2021, Vol. 2, Pages 174-192, vol. 2, no. 1, pp. 174–192, Feb. 2021, doi: 10.3390/CIVILENG2010010.

[10] "STRUCTURE magazine | BIM and the Structural Engineering Community." Accessed: Jul. 16, 2024. [Online]. Available: https://www.structuremag.org/?p=5359

[11] R. Ren, J. Zhang, and H. N. Dib, "BIM Interoperability for Structure Analysis," Construction Research Congress 2018: Construction Information Technology - Selected Papers from the Construction Research Congress 2018, vol. 2018-April, pp. 470–479, 2018, doi: 10.1061/9780784481264.046.