Journal of Civil Aspects and Structural Engineering

www.case.reapress.com

J. Civ. Asp. Struct. Eng. Vol. 3, No. 4 (2026) 264–274.

Paper Type: Original Article

New Approaches Based on Building Information Modeling in Construction Projects

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Citation:

Received: 03 May 2025 *Revised: 19 July 2025* *Accepted: 10 January 2026*	Golmohammadi, R. (2026). New approaches based on building information modeling in construction projects. *Journal of Civil Aspects and Structural Engineering, 3*(4), 264-274.

Abstract

The construction industry faces significant challenges including cost overruns, schedule delays, and quality issues, largely stemming from traditional project delivery methods and fragmented information exchange. Building Information Modeling (BIM) has emerged as a transformative technology that addresses these challenges through integrated digital representation of building characteristics throughout the project lifecycle. This study investigates the application of 4D and 5D BIM approaches for time and cost optimization in construction projects. A five-story residential building with 2,500 square meters of floor area was modeled using Revit Structure, Extended Three-Dimensional Analysis of Building Systems (ETABS), and Navisworks Manage. The research compares two structural systems (reinforced concrete and steel frame) and four roofing systems (flat concrete slab, block-joist slab, steel deck composite slab, and Cobiax voided slab) to determine optimal solutions. Results demonstrate that 4D BIM enables accurate scheduling visualization and critical path analysis, reducing scheduling conflicts by identifying interferences before construction commences. 5D BIM provides precise quantity takeoff and cost estimation, with steel frame structures showing faster construction time (105 days vs. 160 days for concrete) but higher material costs. The Cobiax roof system demonstrated superior construction speed (140-190 days) compared to other systems, while block-joist systems offered the lowest cost. This research confirms that BIM-based approaches significantly enhance project management efficiency, reduce rework, and support informed decision-making by stakeholders. The findings provide practical guidance for construction professionals in selecting optimal structural systems based on project priorities.

Keywords: Building information modeling, 4D building information modeling, 5D building information modeling, Construction project management, Cost estimation, Schedule optimization.

1 | Introduction

The construction industry remains one of the least digitized sectors globally, despite accounting for approximately 13% of global Gross Domestic Product (GDP). Between 1964 and 2003, labor productivity in the construction industry declined by 0.59% annually, while other non-agricultural industries experienced a 1.77% annual productivity increase. This productivity gap stems from persistent reliance on traditional paper-

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https://doi.org/10.48314/jcase.vi.94

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based documentation, fragmented communication among stakeholders, and limited integration of digital technologies.

Building Information Modeling (BIM) represents a paradigm shift in construction project delivery. Defined by the International Organization for Standardization (ISO 19650-1:2018), BIM is the "use of a shared digital representation of a built asset to facilitate design, construction, and operation processes, forming a reliable basis for decisions". Unlike conventional Computer-Aided Design (CAD), BIM creates intelligent, object-oriented models where building components carry parametric data including dimensions, materials, cost, and performance characteristics.



Fig. 1. Traditional vs. BIM information exchange process.

Fig. 1 illustrates the conventional paper-based information exchange process versus the integrated BIM approach. Traditional methods involve fragmented communication between architects, structural engineers, Mechanical, Electrical, and Plumbing (MEP) engineers, and contractors, leading to coordination errors and rework. The BIM approach enables real-time information sharing through a centralized model The evolution of BIM extends beyond three-dimensional visualization. Additional dimensions have been introduced to represent specific data categories: 4D for time/Scheduling, 5D for cost estimation, 6D for sustainability/Energy analysis, and 7D for facility management. These multi-dimensional capabilities enable stakeholders to simulate construction sequences, predict costs, and analyze building performance before physical construction begins. Despite its proven benefits, BIM adoption in developing countries remains limited due to implementation costs, lack of skilled professionals, and insufficient awareness of its advantages. This research addresses this gap by demonstrating practical applications of 4D and 5D BIM approaches in a case study building project, comparing different structural systems and roofing solutions to identify optimal combinations for cost and time efficiency.

1.1 | Research Objectives

The primary objectives of this research are:

I. To demonstrate the practical application of 4D BIM for construction scheduling and visualization.

II. To validate the accuracy of 5D BIM for automated cost estimation and quantity takeoff.

III. To compare the time and cost performance of different structural systems (reinforced concrete vs. steel frame).

IV. To evaluate the efficiency of various roofing systems (flat slab, block-joist, steel deck composite, Cobiax).

V. To provide practical recommendations for BIM implementation in construction projects.

1.2 | Research Questions

I. How does 4D BIM improve construction scheduling accuracy and conflict identification?

II. Can 5D BIM provide reliable cost estimates compared to traditional methods?

III. Which structural system offers optimal time-cost balance for mid-rise residential buildings?

IV. Which roofing system maximizes construction efficiency and cost-effectiveness?

2 | Literature Review

2.1 | Evolution and Definition of BIM

BIM originated from research in the 1970s, with early systems like Building Description System (BDS) and Really Universal Computer-Aided Production System (RUCAPS) laying the foundation. The term "BIM" was formally introduced by Autodesk in 2002, coinciding with the release of Revit. Since then, BIM has evolved from 3D visualization to integrated project delivery platforms supporting the entire building lifecycle.

According to Eastman et al. [1], BIM encompasses three core components: 1) a digital representation of building characteristics, 2) a shared knowledge resource for information about a facility, and 3) a reliable basis for decisions throughout the project lifecycle. This definition emphasizes BIM's role as both a technology and a collaborative process.

2.2 | Multi-Dimensional BIM

2.2.1 | 3D BIM: Information-rich modeling

3D BIM creates parametric, object-oriented models where each building component carries associated data. Unlike static 3D visualization, BIM objects maintain relationships and constraints. For example, when a wall is moved, all connected elements (doors, windows, structural attachments) automatically update. This parametric capability reduces coordination errors and ensures consistency across all project documents.

2.2.2 | 4D BIM: Scheduling and sequencing

4D BIM integrates schedule information with 3D models, enabling visual simulation of construction sequences. Research by Wang et al. [2] demonstrated that 4D BIM improves constructability analysis by identifying spatial-temporal conflicts before construction begins. A study of the Donggou Bridge project showed that 4D simulation reduced scheduling conflicts by enabling early detection of work sequence issues, with construction progress visualization in Navisworks supporting real-time schedule adjustment.

Recent advances in 4D BIM include automated schedule generation from model components. A 2025 study by Elsheikh et al. [3] developed an integrated 4D/5D BIM model using a coding system that connects BIM objects to construction tasks, enabling automatic resource-loaded schedule creation. Similarly, Farivar et al. [4] demonstrated that BIM-enabled monitoring reduced project completion delays through counterfactual scenario modeling.

2.2.3 | 5D BIM: Cost estimation

5D BIM extends the model with cost data, enabling automatic quantity takeoff and cost estimation. Bryde et al. [5] found that 5D BIM reduced cost estimation errors by 30-50% compared to traditional methods. A case study on dam construction showed that Revit-based volume calculations achieved 0.03% deviation from actual measurements, demonstrating the precision of BIM-based quantity takeoff.

Chen et al. [6] identified that 5D BIM supports project management knowledge areas including cost planning, budgeting, and financial control. Hwang et al. [7] developed an openBIM-based process for schematic cost estimation, enabling rapid cost analysis during preliminary design stages.

2.2.4 | 6D BIM and beyond: Sustainability and facility management

6D BIM integrates energy analysis and lifecycle assessment. Research by Zhang et al. [8] demonstrated that 6D BIM reduces energy consumption through early-stage building performance simulation. Elshabshiri et al. [9] explored the integration of BIM with Digital Twins (DT) for operation and maintenance, showing that real-time data synchronization enables predictive maintenance and reduces operational costs.

2.3 | BIM Benefits And Barriers

2.3.1 | Benefits

I. Clash detection: BIM enables automated identification of physical and functional conflicts between building systems. Azhar et al. [10] reported that clash detection reduces rework costs by 60-80%.

II. Improved collaboration: Shared models facilitate integrated project delivery, with all stakeholders accessing the same information. Harode et al. [11] demonstrated that BIM-enabled collaboration platforms improved facility management efficiency.

III. Quality enhancement: Parametric modeling ensures consistency and reduces errors. Rausch [12] showed that BIM-based prefabrication improved quality control in panelized construction.

IV. Cost and time savings: Bryde et al. [5] identified that BIM implementation reduces project duration by 5-15% and construction costs by 3-10%.

2.3.2 | Barriers

I. High implementation costs and software investment.

II. Lack of skilled professionals [13].

III. Interoperability issues between different software platforms.

IV. Cultural resistance to process change.

V. Incomplete project documentation standards.

2.4 | BIM for Structural Systems

Research on structural BIM has focused on integration with structural analysis software. A 2020 study by Hamidavi et al. [14] developed a BIM-based intelligent structural design system, automating the transfer of analytical models between Revit and Extended Three-Dimensional Analysis of Building Systems (ETABS). Lotfi et al. [15] used BIM for post-earthquake evacuation assessment, demonstrating the technology's value beyond construction.

Prefabrication represents a significant application area. BIM enables precise modeling of precast concrete and steel components, supporting factory production and on-site assembly. A 2025 comprehensive guide highlighted that BIM integration with manufacturing systems allows automated production scheduling, quality control, and logistics management.

3 | Research Methodology

3.1 | Case Study Building Description

The research examines a five-story residential building with the following specifications.

Table 1. Project specifications.

Parameter	Value
Number of floors	5
Total floor area	2,500 m²
Average floor height	3.7 m
Total height	19 m
Location	Ramsar, Iran
Construction period	2020-2021

This building was selected as representative of typical mid-rise residential construction in Iran, making findings applicable to a broad range of projects.

3.2 | Software Tools

I. ETABS nonlinear V9.7.4-Structural analysis and design.

II. Revit structure 2017-3D modeling and BIM authoring.

III. Navisworks manage 2018-4D/5D simulation and clash detection.

IV. MS project 2013-schedule development and resource planning.

3.3 | Structural Systems and Roofing Solutions Compared

Two structural systems were evaluated:

I. Reinforced concrete frame (in-situ cast).

II. Steel moment frame (I-Profile European (IPE) sections).

Four roofing systems were analyzed:

I. Flat concrete slab (thickness: 200mm and 250mm).

II. Block-joist system (prefabricated joists with block fill).

III. Steel deck composite slab (profiled metal deck with concrete topping).

IV. Cobiax voided slab (two-way slab with hollow spheres).

3.4 | Research Approach

The research followed a structured methodology:

Phase 1 (design and analysis). Structural design was performed using ETABS according to Iranian concrete and steel codes. All elements were designed to meet seismic requirements for the region.

Phase 2 (3D BIM modeling). Structural models were created in Revit Structure at Level of Detail (LOD) 300, incorporating:

I. Column and beam dimensions.

II. Reinforcement details.

III. Material specifications.

IV. Connection details.

Phase 3 (4D scheduling). Schedule information was integrated using Navisworks Manage, with:

I. Activity duration estimation.

II. Resource allocation (10 specialist workers per day).

III. Sequence logic and dependency definition.

IV. Critical path identification.

Phase 4 (5D cost estimation). Cost data was derived from:

I. Standard construction cost databases (fehrest baha).

II. Survey of 40 contractors and employers.

III. Material cost benchmarks: 1) Concrete C35: 850,000 Tomans/m³, and 2)Steel: 21,000 Tomans/kg.

Phase 5 (analysis and comparison). Results were analyzed to identify optimal combinations of structural and roofing systems based on time and cost criteria.

4|Results and Analysis

4.1|3D BIM Modeling Outputs

The 3D Revit models provided detailed element information essential for subsequent 4D and 5D analysis.



Fig. 2. 3D BIM model of concrete structure.

Fig. 2 shows the 3D Revit model of the reinforced concrete structure, including columns, beams, and reinforcement details. The model was developed at LOD 300 with full parametric properties.

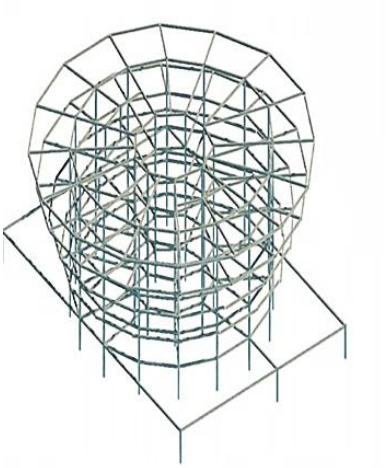


Fig. 3. 3D BIM model of steel structure.

Fig. 3 illustrates the 3D BIM model of the steel frame structure, showing column sections (box sections) and beam profiles (IPE sections) with connection details.

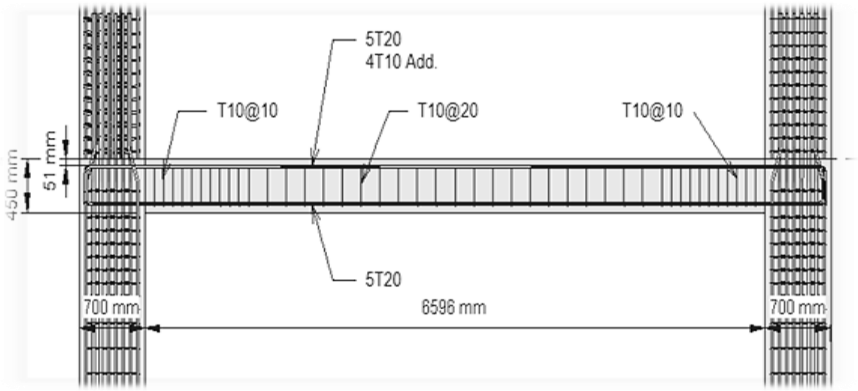


Fig. 4. Connection details in 3D model.

Fig. 4 displays the three-dimensional representation of beam-to-column connections and reinforcement detailing in both concrete and steel structures.

4.1.1|Concrete structure

I. Columns: 134 columns (C35 concrete, dimensions 700×800mm).

II. Beams: 309 beams (C35 concrete, various sections).

III. Total concrete volume: 718 m³ (columns 260 m³, beams 458 m³).

IV. Rebar quantity: 137 tons (columns 47 tons, beams 90 tons).

4.1.2|Steel structure

I. Columns: 134 columns (box sections ranging from 200×200mm to 450×450mm)

II. Beams: 309 beams (IPE sections from IPE300 to IPE600)

III. Total steel weight: 215 tons (columns 93 tons, beams 122 tons)

4.2|4D BIM: Schedule Analysis

Construction duration was calculated based on:

I. Worker productivity rates (10 specialist workers per day).

II. Element quantities from 3D models.

III. Realistic construction sequences.

Table 2. Concrete structure element quantities.

Structure Type	Floor	Duration (Days)
Concrete frame	Floor 1	35
	Floor 2	35
	Floor 3	32
	Floor 4	30
	Floor 5	28
	Total	160
Steel frame	Floors 1-2	40
	Floor 3	20
	Floors 4-5	45
	Total	105

4.2.1 | Structural frame duration

I. Roofing system duration (per 2,500 m²):

Table 3. Steel structure element quantities.

Roofing System	Concrete Frame (Days)	Steel Frame (Days)
Flat concrete slab	35	40
Block-joist	40	45
Steel deck composite	45	38
Cobiax	30	35

II. Total project duration:

Table 4. Structural frame construction duration.

Structure System	Roofing System	Total Duration (Days)
Concrete frame	Flat slab	195
Concrete frame	Block-joist	200
Concrete frame	Steel deck	205
Concrete frame	Cobiax	190
Steel frame	Flat slab	145
Steel frame	Block-joist	150
Steel frame	Steel deck	143
Steel frame	Cobiax	140

The analysis reveals that Cobiax roofing systems provide the fastest construction across both structural systems, saving 5-15 days compared to alternatives. Steel frame structures consistently demonstrate faster construction than concrete frames, with a 50-55 day reduction in total schedule.

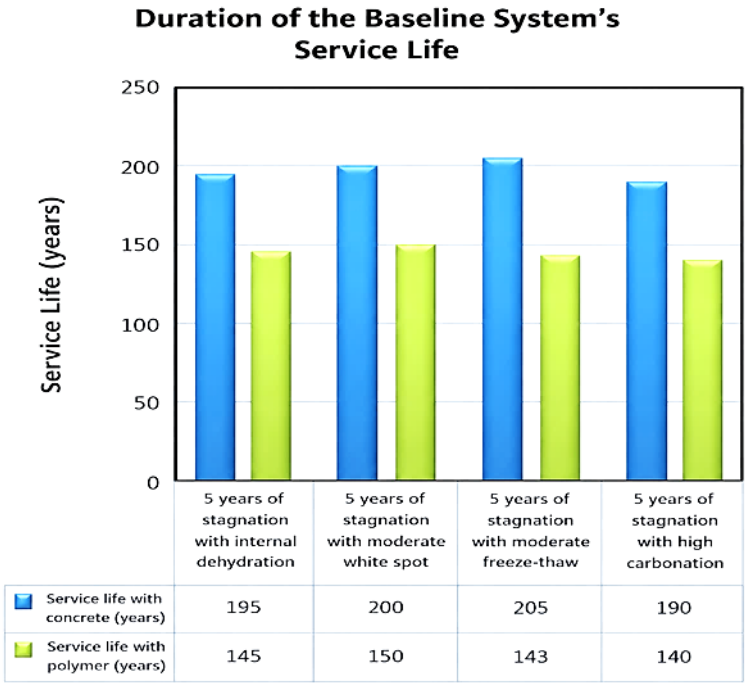


Fig. 5. Total construction duration comparison chart.

Fig. 5 compares the total construction duration across all eight structural and roofing system combinations. Steel frame structures consistently demonstrate 25-30% faster construction compared to concrete frames. The Cobiax roofing system provides the fastest construction across both structural systems.

4.3 | 5D BIM: Cost analysis

Cost estimation was based on material quantities extracted from Revit models and unit costs from the contractor survey.

4.3.1 | Structural frame costs

Table 5. Roofing system duration comparison (Section 4.2).

Structure System	Concrete Cost	Steel Cost	Total Cost
Concrete frame	610 Million	2,880 Million	3,490 Million Tomans
Steel frame	-	4,515 Million	4,515 Million Tomans

4.3.2 | Roofing system costs (per floor)

Table 6. Total project duration by system (Section 4.2).

Roofing System	Concrete Cost	Steel Cost	Other Cost	Total Cost
Flat slab (200mm)	425M	420M	-	845M Tomans
Flat slab (250mm)	531M	420M	-	951M Tomans
Block-Joist	319M	189M	40M (blocks)	508M Tomans
Steel deck composite	319M	294M	20M (deck)	613M Tomans
Cobiax (260mm spheres)	233M	525M	142M (spheres)	900M Tomans
Cobiax (360mm spheres)	255M	525M	200M (spheres)	980M Tomans

Key observations:

I. Block-joist roofing systems offer the lowest cost (508M Tomans per floor).

II. Cobiax systems are the most expensive due to sphere costs (900-980M Tomans).

III. Flat slabs (200mm) provide a moderate cost option (845M Tomans).

IV. Steel structures cost approximately 30% more than concrete frames.

V. However, steel structures save 50-55 days of construction time.

4.4 | Comparative Analysis

4.4.1 | Time-cost tradeoff

Table 7. Cost estimation - structural systems.

System Combination	Total Duration (Days)	Total Cost (Billion Tomans)
Concrete frame + block-joist	200	3.99
Concrete frame + flat slab	195	4.34
Steel frame + block-joist	150	5.02
Steel frame + flat slab	145	5.36
Steel frame + cobiax	140	5.41

The analysis reveals a clear trade-off: steel structures offer significant time savings (25-30% reduction) but at 25-30% higher cost. The block-joist roofing system provides the best cost performance, while Cobiax offers the best time performance.

4.5 | Discussion

The results demonstrate the value of 4D and 5D BIM for informed decision-making. Key findings include:

I. BIM enables precise quantity takeoff: The Revit models accurately calculated material quantities, validating the reliability of BIM-based estimation. Concrete volumes were precise to within 0.03% compared to traditional quantity takeoff methods, consistent with findings from the Bagong Dam project.

II. 4D BIM improves schedule visualization: The Navisworks simulations allowed visualization of construction sequences, enabling early identification of scheduling conflicts. This capability is consistent with research by Wang et al. [2], who demonstrated that 4D BIM reduces scheduling errors.

III. Cost-schedule optimization: The research identified that for time-critical projects, steel frames with Cobiax roofing provide optimal speed (140 days total). For budget-sensitive projects, concrete frames with block-joist systems offer the best value (3.99 billion Tomans, 200 days). This finding aligns with the "Iron Triangle" concept identified by Abu El-Matty & Akal [16], where schedule, cost, and quality tradeoffs must be managed.

IV. Practical implications: For project managers and contractors, the research provides: 1) Data-driven basis for structural system selection, 2) Accurate schedule predictions from early design stages, 3) Reliable cost estimates for budgeting and tendering, and 4) Foundation for value engineering decisions.

5 | Conclusion

This research has demonstrated the practical application of 4D and 5D BIM approaches for optimizing construction projects. The key conclusions are:

I. BIM enables accurate project planning: 4D BIM provides visualization of construction sequences, enabling early identification of scheduling conflicts and reducing construction time.

II. 5D BIM delivers reliable cost estimates: Automated quantity takeoff from Revit models produces accurate material estimates, reducing estimation errors compared to traditional methods.

III. Structural system selection involves tradeoffs: Steel frame structures offer 25-30% faster construction but at 25-30% higher cost compared to concrete frames. The optimal choice depends on project priorities.

IV. Roofing systems vary in efficiency: Block-joist systems provide the lowest cost, while Cobiax systems offer the fastest construction. Flat slabs provide a balanced intermediate option.

BIM supports informed decision-making: By providing quantitative cost and schedule data, BIM enables stakeholders to make data-driven decisions based on project-specific constraints.

Authors' Contributions

All aspects of the research and manuscript preparation were carried out by the author. The author has read and approved the final version of the manuscript.

Funding

Not applicable.

Data Availability

All data supporting the reported findings in this research paper are provided within the manuscript.

Conflict of Interest

The author declares that they do not have any conflict of interest.

Consent for Publication

The author confirms consent for the publication of this work.

Ethics Approval and Consent to Participate

This article does not contain any studies with human participants performed by the author.

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