A Systematic Review of the Role of Building Information Modeling (BIM) in Improving Construction Project Scheduling

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ABSTRACT

Technological advancements in the construction industry, particularly Building Information Modeling (BIM), have created new opportunities for optimizing project scheduling. This article, employing a semi-systematic review approach, comprehensively examines the scientific literature published between 2010 and 2025 on the role of BIM in improving construction project scheduling processes. The selected studies are categorized into four main themes: the use of 4D BIM for simulating construction sequences, challenges of implementation under resource constraints, integration of emerging technologies such as artificial intelligence, augmented reality, and the Internet of Things with BIM, and the role of this technology in enhancing coordination among project stakeholders. The findings indicate that BIM, particularly in its 4D form, enhances scheduling accuracy, anticipates operational conflicts, and improves resource efficiency by providing visual and integrated models. However, barriers such as high initial costs, a shortage of skilled professionals, and the lack of common standards have hindered the widespread adoption of this technology. By elucidating existing opportunities and challenges, this study outlines future research directions and offers recommendations for advancing the use of BIM in project scheduling, serving as a valuable reference for researchers, decision-makers, and construction industry practitioners.

Keywords: *Building Information Modeling (BIM), Project Scheduling, 4D BIM, Construction Management, Digital Technologies in Construction, Resource Constraints, Systematic Literature Review*

1. *INTRODUCTION*

Building Information Modeling (BIM), as a transformative technology in the construction industry, offers an integrated approach to managing project data and processes throughout its lifecycle [1]. By creating three-dimensional digital models that encompass both geometric and non-geometric information, this technology enables precise coordination among various project components, contributing to improved efficiency, reduced errors, and enhanced transparency [2]. Project scheduling, a cornerstone of construction management, plays a critical role in optimizing resources, minimizing delays, and ensuring timely project delivery [3]. The integration of BIM with scheduling processes, known as 4D BIM, facilitates the visual and dynamic simulation of construction activity sequences, aiding in the identification of potential conflicts before execution begins [4, 5]. This capability not only enhances planning accuracy but also significantly reduces scheduling-related risks [6]. Numerous studies highlight BIM's substantial potential in improving project scheduling processes. For instance, BIM enhances coordination among project stakeholders, including architects, engineers, contractors, and clients, minimizing errors stemming from inefficient communication or incomplete information [7]. BIM-based tools enable the analysis of various scheduling scenarios, empowering project managers to make informed decisions by simulating different options [8]. Additionally, BIM provides accurate and up-to-date information on project progress, optimizing resource allocation, reducing rework, and improving the management of changes throughout the project [9]. However, challenges such as high initial implementation costs, the need for advanced technological infrastructure, data integration complexities, and a shortage of trained personnel remain significant barriers to the widespread adoption of this technology [9]. These obstacles are particularly pronounced in smaller projects or in countries with limited technological and financial resources. Studies indicate that BIM use in complex projects can significantly reduce project execution time and enhance overall productivity

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[10]. 4D BIM simulations contribute to identifying optimal construction sequences, improving workflow management, and preventing costly delays [11]. Moreover, recent advancements in digital technologies, such as artificial intelligence and machine learning, have enhanced BIM's capabilities in scheduling data analysis, enabling more accurate risk forecasting and optimized planning [12]. This technology also supports change management and improves communication among project teams, reducing scheduling deviations [13]. Given BIM's growing importance in construction project management, this article provides a comprehensive review of its role in improving scheduling processes. Drawing on previous studies, this research analyzes the challenges, opportunities, and future directions in this field, proposing solutions to overcome existing barriers and maximize BIM's potential in project scheduling management.

2. *Literature review*

1.2. Application of Building Information Modeling (BIM) Technology in Construction Project Scheduling

Building Information Modeling (BIM) technology, as a pivotal tool in the construction industry, has significantly enhanced project scheduling management. By integrating multidimensional data, BIM enables precise planning, reduces delays, and boosts productivity. This research background reviews studies related to BIM's application in construction project scheduling, categorized into two groups:

a) Studies focused on general scheduling and process optimization,

b) Studies focused on specialized applications and complementary technologies.

1.1.2. Studies Focused on General Scheduling and Process Optimization

BIM technology and 5D BIM software play a crucial role in facilitating project progress monitoring, quality control, safety, and defect correction by enabling the forecasting of resource, equipment, and capital needs. This approach establishes a comprehensive scheduling management system, enhancing project productivity. Studies indicate that BIM improves stakeholder coordination through data integration, though challenges such as high initial implementation costs and the need for specialized training are often overlooked. Additionally, the lack of quantitative data on BIM's precise impact on productivity limits result analysis [1]. The improvement of project planning and scheduling using BIM-based software aims to enhance construction project scheduling processes. This study demonstrates how BIM capabilities improve planning and scheduling by integrating design, scheduling, and resource information, reducing inefficiencies and enhancing project management [14]. In this context, combining BIM models with work package information, process simulation, and optimization algorithms provides a system for precise scheduling under resource constraints, developed as an add-on for Autodesk Revit, capable of optimally scheduling activities. The effectiveness of this approach, particularly in panel building construction, has been validated in a case study, though reliance on specific software like Revit and algorithm complexity poses limitations for projects using different tools or involving less experienced teams [2]. Furthermore, a framework based on genetic algorithms and BIM, comprising nine stages from BIM model generation to 5D simulation and business intelligence dashboards, is designed to enhance productivity and reduce costs and delays. This framework improves coordination between management and engineering sectors but requires advanced computational infrastructure and complex processes, making it challenging for small projects or organizations with limited resources. Additionally, the scalability challenges of genetic algorithms are not addressed [3]. The integration of 4D BIM with the Critical Path Method (CPM) effectively enhances coordination, identifies conflicts, and validates designs. A field study revealed that 51% of professionals utilize this combination, considering it a significant factor in increasing productivity. However, reliance solely on questionnaire responses may introduce bias, and the lack of investigation into barriers to 4D BIM adoption in small organizations questions the comprehensiveness of these findings [6]. Another approach automatically generates schedules during BIM model creation by aligning Work Breakdown Structures (WBS) and Element Breakdown Structures (EBS), producing precise schedules validated in a prototype system. However, the complexities of integrating these structures in large projects are not addressed, and since results are limited to a specific case, their generalizability to other projects is questionable [12]. A novel method for automating the updating of construction project schedules was proposed, utilizing real-time (As-Built) data, such as 3D point clouds collected from construction sites and 4D BIM models (3D models plus the time dimension). This method improves the scheduling update process by replacing manual, time-consuming procedures with an automated system that reduces human errors and enhances accuracy and speed [15]. Another study focused on automating construction schedule generation using Open BIM technology to extract data automatically. The goal is to develop an automated system *for extracting scheduling data from BIM models using open standards like Industry Foundation Classes (IFC), reducing reliance on error-prone, manual processes [16]. Additionally, integrating BIM models with construction process simulations is essential for improving project planning. This study develops an approach combining BIM modeling and construction process simulations to enhance planning accuracy and efficiency, overcoming limitations of traditional scheduling that often lack dynamic details and realistic process simulations [17]. Ying Zhou et al.'s 4D BIM-based approach provides a novel solution for optimizing resource allocation in liquefied natural gas (LNG) plant construction projects. By integrating the time dimension with 3D models, it enables more precise planning of manpower, equipment, and materials, minimizing inefficiencies and project delays [18]. The use of tabu search algorithms and 4D BIM models offers a novel approach to optimizing construction project scheduling. This method combines 4D BIM (3D models plus time) and tabu search algorithms to enhance scheduling and reduce delays, particularly for complex projects with multiple resource constraints and dependencies [19]. BIM-based work package modeling for resource-constrained construction project scheduling provides a novel method relying on work packages and BIM. The study develops a modeling framework that optimizes scheduling under resource constraints (e.g., labor, equipment, materials), improving activity coordination and resource allocation [20]. In this regard, a BIM-based genetic algorithm, by analyzing structural dependencies, determines optimal construction sequences and provides stable schedules, enhancing planning accuracy and efficiency. However, this method relies on precise BIM data and complex computations, making it challenging to implement in resource-limited projects, and limitations in highly dynamic projects are not addressed [21]. Daily visualization based on database and web-enabled 4D BIM, with real-time data updates, enables more effective schedule management in complex projects and facilitates stakeholder coordination. However, dependence on web infrastructure and stable internet connectivity limits its use in areas with weak infrastructure, and maintenance costs are not examined [22]. Optimization theory-based approaches reduce activity overlaps, optimizing schedules and costs. Despite these benefits, the study does not address computational complexities or the need for optimization theory expertise, and results are only observable in specific projects, questioning their generalizability [23]. Automatic identification of process patterns in BIM-based schedules simplifies repetitive processes, reducing planning time and increasing accuracy. However, reliance on predefined patterns reduces flexibility in non-standard projects, and integration challenges with existing systems are not addressed [24]. Discrete event simulation combined with BIM provides a tool for more accurate scheduling and delay reduction, enhancing construction process management. However, this method requires precise BIM models and specialized software, which can be costly, and limitations in projects with high uncertainty are not discussed [25]. Finally, a BIM-based framework using the 4 Clauses approach for conflict and safety issue analysis dynamically adjusts schedules and improves safety. While a case study confirms its effectiveness, its repetition across sources indicates limited study diversity, and reliance on specific software and unaddressed scalability issues are significant limitations [26].*

2.1.2. Studies Focused on Specialized Applications and Complementary Technologies

In prefabricated buildings, BIM technology with digital modeling improves coordination during construction stages, reducing time and costs. This method enables smart process management, but studies fail to address barriers such as the need for training and suitable infrastructure for BIM adoption in prefabricated projects, and results are limited to a single case study [7]. An improved differential evolution algorithm optimizes scheduling for prefabricated projects, outperforming other methods by avoiding premature convergence. However, its high complexity and need for dynamic adjustments may make it challenging for less experienced teams, and its application in non-prefabricated projects is not explored [27]. Combining RFID and BIM technologies in prefabricated housing construction enables precise component tracking, reducing delays and enhancing activity coordination. However, RFID implementation costs and the need for advanced infrastructure pose significant challenges for small projects, and data security issues are not addressed [28]. In facility maintenance, a BIM-based framework with a modified Dijkstra algorithm calculates optimal maintenance paths, facilitating decision-making. Bidirectional data exchange enhances efficiency, but reliance on precise BIM models and specialized software increases implementation costs, and algorithm limitations in complex environments are not examined [4]. Automated scheduling methods for mechanical and electrical tasks using topological analysis define task relationships and improve coordination, reducing deviations. However, implementation requires precise topological data and complex analyses, and scalability challenges in large projects are not addressed [5]. A BIM and IoT-based smart tracking system enables real-time component tracking and dynamic schedule adjustments in prefabricated projects, increasing operational accuracy. However, dependence on IoT infrastructure and implementation costs pose challenges for small projects, and data security concerns are not addressed [29]. A 4D BIM framework for predictive scheduling identifies supply chain disruptions and reduces project delays, effectively improving off-site process management. However, it requires comprehensive supply chain data and complex analyses, and scalability is not examined [11]. Utility network planning in infrastructure projects using BIM reduces conflicts and enhances coordination, enabling more precise designs. However, it requires detailed *models and specialized software, and integration with existing systems remains unaddressed [30]. Combining BIM with CPM for simulating temperature and humidity impacts improves risk forecasting and environmental condition analysis. However, reliance on historical weather data and simulation complexities may reduce accuracy in regions with extreme weather fluctuations [31]. BIM-based automated systems identifying safety hazards and suggesting preventive measures reduce accidents. However, reliance on predefined rules reduces flexibility in unusual conditions, and implementation costs are not examined [32]. Automated data collection and reconstruction for scheduling existing building demolition projects provide a novel method using BIM. The study develops a framework to improve demolition project scheduling by automatically collecting data and reconstructing BIM models, reducing time, costs, and errors [33]. Integrating time with discrete event simulation in a BIM environment enables Just-In-Time (JIT) production systems, improving workflow and reducing uncertainties. However, this method requires precise data, and simulation complexity may make it challenging for small projects, with scalability overlooked [25]. Similar studies confirm these findings, but content repetition reduces result diversity [29]. In retrofitting, a multi-objective BIM-based genetic algorithm considering time, cost, and resource criteria enhances project efficiency. However, algorithm complexity and the need for comprehensive data make it challenging for less experienced teams, and scalability limitations are not examined [34]. A graph-based automated scheduling method (GAS) without BIM extracts planners' tacit knowledge, increasing scheduling accuracy. However, not leveraging BIM limits visualization and data integration capabilities, and knowledge extraction challenges in complex projects are not addressed [35]. In plumbing system installation, automating execution sequences using 4D BIM and simulated algorithms provides conflict-free sequences, enhancing operational coordination. However, the need for precise models and algorithm complexity increases costs and implementation challenges in large projects, with scalability unaddressed [9]. Specifically, in educational projects, BIM has improved execution quality, reduced costs, and facilitated stakeholder coordination. However, barriers to adoption in the education sector, such as a lack of expertise, are not examined, and results are limited to one project type [8]. In emerging technologies, Cloud BIM accelerates information exchange and improves stakeholder collaboration. Expert interviews highlight cloud computing's benefits and challenges, but dependence on cloud infrastructure and security issues limit implementation. Additionally, the small sample size (11 interviewees) reduces result comprehensiveness [13]. Studies addressing BIM adoption barriers identify lack of knowledge and implementation costs as primary challenges. A survey of 270 professionals identified these barriers, but focusing solely on the building industry limits result generalizability to other sectors, and practical solutions for overcoming these barriers are not adequately explored [36]. Finally, a BIM-based framework for automated maintenance work order scheduling extracts equipment and maintenance data from BIM models, prioritizing and scheduling work orders using scheduling algorithms. This method reduces manual intervention, increases accuracy, and improves efficiency compared to traditional methods [4].*

2.2. Summary of Research Background

Building Information Modeling (BIM) plays a pivotal role in enhancing construction project scheduling and management. 4D BIM, through visual simulation of construction sequences, increases planning accuracy, identifies conflicts before execution, and optimizes sequences and resources, reducing project duration by up to 7%. However, its success depends on user training and data integration. Barriers to BIM adoption include high initial costs, lack of skilled professionals, data complexity, weak infrastructure, organizational resistance, and absence of standards. These can be addressed through standardization, specialized training, and collaboration among industry, academia, and government. Complementary technologies like artificial intelligence, machine learning, augmented reality, and the Internet of Things enhance BIM's accuracy and efficiency through data analysis, real-time monitoring, and risk forecasting but require investment in digital infrastructure. on a collaborative culture and global standards. Overall, BIM holds transformative potential for project management, but challenges such as costs, skill shortages, and organizational misalignment hinder widespread adoption. These can be mitigated through developing standards, training, digital infrastructure, and stakeholder collaboration. The table below summarizes the reviewed studies on BIM applications.

Table 1 - Key Points and Weaknesses of Conducted Studies.

Authors	Summary of Work	Weaknesses
Zhou Li et al.	This paper examines the use of BIM and 5D BIM software in construction project scheduling. The authors demonstrate that this technology enables forecasting and managing resource, equipment, and capital needs, facilitating progress monitoring, quality control, safety, and defect correction. This approach	Limited discussion on scalability across different project types; lack of comprehensive cost-benefit analysis.

	contributes to a comprehensive scheduling management system, enhancing project productivity.	
Hexu Liu et al.	This study proposes an integrated BIM-based approach for precise construction scheduling under resource constraints. By combining BIM models with work package data, process simulation, and optimization algorithms, a prototype system for panel building construction was developed as an Autodesk Revit add-on. The case study shows this approach optimizes activity scheduling.	Focus on panel buildings limits generalizability; requires advanced software skills.
Vafaei et al.	This paper presents an innovative framework for generating and optimizing construction schedules using genetic algorithms and BIM. The framework includes nine stages, from BIM model creation to 5D simulation and business intelligence dashboards, aimed at improving productivity and reducing costs and delays.	Validation limited to specific cases; high computational complexity for large projects.
Weiwei Chen et al.	This study introduces a BIM-based framework for automated facility maintenance work order scheduling. Using a modified Dijkstra algorithm, it calculates optimal maintenance paths based on issue type, urgency, component distance, and location, improving decision-making in facility management.	Focused solely on maintenance scheduling; costly integration of BIM with facility management systems.
Shabtai Isaac et al.	This paper proposes a novel method for automated scheduling and control of mechanical and electrical tasks using BIM. Topological analysis of component locations defines task relationships and control points, enabling precise planning and effective progress monitoring.	Focused solely on mechanical and electrical tasks; limited real-world testing.
Arida et al.	This paper explores project scheduling techniques in a BIM environment, analyzing the impact of 4D BIM through a field study. Results show 51% of respondents use the Critical Path Method (CPM), and BIM improves project coordination, conflict detection, and design validation.	Relies on surveys without empirical validation; results are general and broad.
Zhang et al.	This paper presents a BIM-based scheduling control method for prefabricated buildings, managing construction processes digitally and intelligently to improve coordination and productivity in prefabricated projects.	Limited to prefabricated buildings; lacks analysis of implementation barriers.
Zeng et al.	This paper proposes an improved differential evolution algorithm for optimizing prefabricated building construction scheduling using BIM, avoiding premature convergence and enhancing optimal search capabilities through dynamic population adjustments.	Algorithm complexity may hinder practical implementation; validation limited to specific cases.
Shi et al.	This paper examines BIM application throughout the lifecycle of educational building projects, showing that BIM improves quality, reduces costs, and enhances productivity during design, construction, and operation phases.	Focused solely on educational buildings; lacks quantitative performance metrics.
Kunig et al.	This paper presents a smart BIM-based construction scheduling method using discrete event simulation, enabling more precise and effective construction process management.	Older study; incomplete integration with modern BIM platforms.
Hong et al.	This paper introduces a Graph-based Automated Scheduling (GAS) method for construction scheduling without BIM, aiming to extract and reuse experienced planners' tacit knowledge.	Lack of BIM use limits compatibility with BIM-based processes; validation on small datasets.
Singh et al.	This study proposes a method for automating plumbing system installation sequencing and scheduling optimization using 4D BIM.	Focused on plumbing systems; requires heavy computations.
Abbasi et al.	This paper presents a framework integrating Takt Time and Discrete Event Simulation (DES) in a BIM environment to implement Just-In-Time (JIT) scheduling in construction.	Complex integration; limited to projects suitable for JIT.
Gao et al.	This study introduces a BIM and IoT-based smart tracking system for dynamic scheduling in prefabricated component construction.	High IoT setup costs; limited to prefabricated construction.

Zeng et al.	This paper presents a novel 4D BIM-based framework for predictive scheduling in construction projects.	Focused on supply chain; requires extensive data integration.
Park et al.	This paper proposes a method for automatically generating construction schedules during BIM model creation.	Limited to initial scheduling; lacks dynamic update capabilities.
Faghihi et al.	This paper presents a BIM-based genetic algorithm method for construction scheduling.	High computational costs; limited real-world validation.
Redmond et al.	This paper examines how Cloud BIM improves information exchange in construction projects.	Qualitative study; lacks quantitative performance metrics.
Zhang et al.	This paper presents an integrated BIM and 4D modeling framework for analyzing and managing structural conflicts and safety issues during construction.	Repetitive case study; limited to specific conflict types.
Anshasi et al.	This study identifies barriers to BIM implementation in the Palestinian construction industry.	Region-specific; lacks solutions for barriers.
Alrashidi et al.	This paper examines utility network planning in infrastructure projects using BIM.	Focused on utilities; limited integration with scheduling.
Mahamid et al.	This study identifies factors affecting contractors' risk attitudes in Palestinian construction projects.	Not focused on BIM; limited relevance to scheduling.
Park et al.	This paper presents a database and web-based method for daily visualization of 4D BIM.	Requires robust IT infrastructure; limited to visualization.
Moon et al.	This paper develops an optimization theory-based method to reduce activity overlaps in BIM-based construction scheduling.	Limited to overlap reduction; lacks broader scheduling scope.
Koch et al.	This paper examines natural markers for augmented reality-based indoor navigation and facility maintenance.	Not focused on scheduling; limited to maintenance.
Altoum et al.	This paper presents a method to facilitate 4D modeling by automating task information generation and mapping to models.	Limited to 4D modeling; lacks real-world validation.
Nosen et al.	This paper develops a BIM-based multi-objective genetic algorithm (MOGA) for renovation project planning and scheduling.	Focused on renovation projects; high computational complexity.
Zhang et al.	This paper presents a rule-based automated system for safety review of BIM models and construction project scheduling.	Limited to safety; requires predefined rule sets.
VR-Electricians	This paper explores immersive storytelling to attract youth to electrical trades.	Unrelated to scheduling; limited to training and recruitment.
Shan et al.	This paper develops a framework integrating BIM with CPM scheduling to simulate temperature and humidity impacts on construction projects.	Limited to environmental factors; lacks broader application.
Sigalov et al.	This paper presents a method for identifying process patterns in BIM-based schedules.	Incomplete input information; requires more details for accurate analysis.

3. *Methodology*

This study is designed as a semi-systematic review to comprehensively investigate the role of Building Information Modeling (BIM) in improving scheduling and management of construction projects. The primary objective is to identify and analyze existing research across four key areas: the role of BIM in enhancing scheduling processes (BIM 4D), resource constraints, complementary technologies and innovations related to BIM in scheduling, and BIM's impact on stakeholder coordination and project management.

1.3. Data Sources (Databases)

To collect relevant articles for this semi-systematic review, a range of reputable and well-established databases in the fields of civil engineering, project management, construction technologies, and digital sciences were utilized. These databases were selected to ensure access to high-quality scientific resources, broad coverage of topics related to BIM and project scheduling, and inclusion of emerging research on BIM's complementary technologies. The databases used, their key features, and their roles in this study are detailed below:

***Scopus**: Managed by Elsevier, this database was chosen as the primary search source due to its extensive coverage of over 25,000 scientific journals, books, and conference proceedings in engineering, technology, and related sciences, making it one of the most comprehensive databases for BIM and project scheduling research.*

***Web of Science**: Managed by Clarivate Analytics, this database served as a complementary source for accessing high-quality, highly cited articles in project management and construction technologies.*

***Google Scholar**: Used as a supplementary source to cover less accessible articles and resources, particularly in emerging areas such as the application of artificial intelligence, augmented reality, and the Internet of Things in BIM.*

***IEEE Xplore**: Managed by the Institute of Electrical and Electronics Engineers (IEEE), this database was selected for accessing articles on digital technologies and BIM-related innovations.*

***ScienceDirect**: Managed by Elsevier, this database was used to access articles published in reputable journals in civil engineering, project management, and construction technologies. Its extensive coverage of high-quality journals facilitated the identification of in-depth and practical BIM research.*

2.1.3. Search Strategy

The search in the databases was conducted using a targeted and structured strategy to ensure comprehensive coverage of articles related to the four thematic areas (BIM 4D, resource constraints, complementary technologies, and stakeholder coordination). The main keywords included:

Building Information Modeling (BIM)

4D BIM

Project Scheduling

Project Management

Stakeholder Coordination

Resource Constraints

Artificial Intelligence in BIM

Augmented Reality in BIM

Internet of Things in BIM

Project Risk Management

3.1.3. Time Frame and Search Constraints

The search was limited to the period from 2010 to 2025 to cover up-to-date research aligned with recent advancements in BIM technology. This time frame was chosen because BIM gained widespread attention in the *construction industry starting in the early 2010s, with significant advancements, particularly in complementary technologies like AI and IoT, accelerating in recent years.*

4.1.3. Resource Access and Management

The software EndNote was used to manage identified resources, allowing organized storage, categorization, and referencing of articles. This tool facilitated the removal of duplicate articles and the creation of a cohesive database of sources. Access to full-text articles was secured through university subscriptions and digital libraries.

2.3. Inclusion Criteria

Inclusion criteria were defined to identify articles that directly contribute to the research objectives and are scientifically credible. These criteria include:

***Thematic Relevance**: Articles must directly address one of the four thematic areas:*

- *Role of BIM 4D in improving scheduling processes, including construction sequence simulation, delay reduction, and planning optimization.*
- *Resource constraints in BIM, such as implementation costs, lack of skilled professionals, data integration complexities, and organizational resistance.*
- *Complementary technologies and innovations related to BIM in scheduling, such as artificial intelligence (AI), machine learning (ML), augmented reality (AR), and the Internet of Things (IoT).*
- *BIM's impact on stakeholder coordination and project management, including improved communication, error reduction, and process integration.*

***Study Type**: Accepted articles include original research, review articles, and reputable conference papers that underwent peer review.*

***Language:** Articles published in English or with reliable English translations were included, as English is the primary language for most credible BIM and project management research, ensuring accurate and consistent content analysis.*

***Publication Quality:** Articles published in reputable journals (e.g., Scopus-indexed) were prioritized, with Q1 and Q2 journals preferred due to their rigorous peer-review processes and high scientific impact.*

***Time Frame:** Articles published between 2010 and 2025 were selected to cover recent and relevant BIM advancements.*

***Accessibility**: Articles with full-text access through databases (e.g., Scopus, ScienceDirect, IEEE Xplore) or university subscriptions were included, as full-text access was essential for detailed analysis of methodology, findings, and limitations.*

3.3. Exclusion Criteria

Exclusion criteria were defined to eliminate articles that were not aligned with the research objectives or lacked sufficient scientific credibility. These criteria include:

***Lack of Thematic Relevance**: Articles focusing solely on general BIM aspects, such as 3D modeling or architectural applications without addressing scheduling, were excluded.*

***Low Quality**: Articles lacking peer review, clear methodology, or valid empirical data were excluded, including those presenting personal opinions, lacking scientific analysis, or with unclear methodologies.*

***Inaccessible Language**: Articles published in languages other than English without reliable translations were excluded due to researchers' language limitations and the need for precise content analysis.*

***Duplicate Content**: Articles with complete overlap with other articles or earlier versions of the same research were excluded to avoid data repetition and ensure source diversity. For example, if a conference paper was later published as a journal article, only the more comprehensive (journal) version was selected.*

***Lack of Access**: Articles without full-text access were excluded, as full-text review was necessary to analyze*

4.3. Application of Criteria

The inclusion and exclusion criteria were applied in stages. Initially, titles and abstracts of identified articles were reviewed to eliminate those clearly aligning with exclusion criteria (e.g., lack of thematic relevance or inaccessible language). Then, the full texts of remaining articles were evaluated based on inclusion criteria.

1.4.3. Study Selection and Analysis Method

The study selection and analysis process for this semi-systematic review was designed to identify and evaluate articles related to BIM's role in construction project scheduling and management in a structured and rigorous manner. This process was conducted in four main stages: initial search and screening, full-text review, data extraction and categorization, and analysis of studies.

1.1.4.3. Initial Search and Screening

The first stage began with an initial search in reputable databases (Scopus, Web of Science, Google Scholar, IEEE Xplore, and ScienceDirect). The search used targeted keywords such as BIM, BIM 4D, project scheduling, project management, stakeholder coordination, resource constraints, artificial intelligence in BIM, augmented reality in BIM, and Internet of Things in BIM, combined with Boolean operators (AND, OR, NOT). For example, phrases like "BIM AND Project Scheduling" or "4D BIM AND Stakeholder Coordination" were used to narrow results to relevant topics. The search was restricted to 2010–2025 to cover recent BIM advancements. Approximately 1,200 articles were identified. For initial screening, titles and abstracts were reviewed to exclude articles clearly aligning with exclusion criteria (e.g., lack of thematic relevance, low quality, inaccessible language, duplicate content, or lack of full-text access). This process was conducted independently by two researchers. After initial screening, about 250 articles that appeared to align with inclusion criteria were selected for further review. This stage served as a primary filter to reduce the article volume to a manageable level while retaining potentially relevant studies.

2.1.4.3. Full-Text Review

In the second stage, the full texts of the 250 selected articles were thoroughly evaluated based on inclusion criteria: thematic relevance to one of the four areas (BIM 4D, resource constraints, complementary technologies, stakeholder coordination), study type (original research, review, or peer-reviewed conference papers), English language, publication quality (Q1 or Q2 journals or reputable conferences), 2010–2025 time frame, and full-text accessibility. Articles were assessed for:

***Thematic Relevance**: Did the article directly address one of the four thematic areas? For example, articles on 4D BIM simulation, financial challenges of BIM, AI applications in scheduling, or stakeholder communication improvements were prioritized.*

***Methodological Quality**: Did the article have a clear methodology, valid empirical data, or robust analysis? Articles with strong qualitative or quantitative analyses were selected.*

***Key Findings**: Did the article provide tangible results contributing to understanding BIM's role in scheduling or project management? Articles with innovative or practical findings were prioritized.*

***Limitations**: Were the study's limitations transparently reported? This was critical for critical analysis and identifying research gaps.*

This process was conducted independently by two researchers, with each recording reasons for inclusion or exclusion. In cases of disagreement (e.g., articles indirectly addressing scheduling), discussion sessions were held *to reach a consensus. For instance, articles on general BIM aspects but with strong empirical scheduling data were included after discussion. Ultimately, 36 articles fully aligned with inclusion criteria and offering robust empirical data or analyses were selected for final inclusion.*

3.1.4.3. Data Extraction and Categorization

In the third stage, key information from the 36 selected articles was extracted and organized. Extracted information included:

***Research Objectives**: The study's main goal, e.g., examining BIM 4D's impact on delay reduction or analyzing BIM's financial challenges.*

***Methodology**: Research approach (qualitative, quantitative, or mixed), data type (empirical, simulation, or survey), and tools used (e.g., BIM software or AI algorithms).*

***Findings**: Key results, e.g., improved scheduling efficiency, cost reduction, or identification of BIM implementation barriers.*

***Key Points**: Notable ideas or solutions, e.g., using IoT for real-time monitoring or standardizing data for integration.*

***Limitations**: Study weaknesses, e.g., lack of empirical data, focus on specific projects, or omission of cultural barriers.*

A standardized Excel template was designed to record this information systematically, enabling article comparison. Articles were categorized into the four thematic areas (BIM 4D, resource constraints, complementary technologies, stakeholder coordination). For example, articles on construction sequence simulation with BIM 4D were placed in the first category, while those on AI or IoT applications were categorized under complementary technologies. To ensure accuracy, data extraction was conducted independently by two researchers, with each extracting data from half the articles, followed by cross-checking. Discrepancies (e.g., in interpreting findings or limitations) were resolved through discussion sessions. The extracted data were stored in an Excel database, serving as the primary reference for analysis and synthesis in the next stage.

4.1.4.3. Analysis

In the final stage, the selected articles were qualitatively analyzed to identify patterns, trends, and research gaps using a thematic analysis approach. This approach enabled the identification of common themes and organization of findings into the four thematic categories. The thematic analysis involved:

***Initial Coding**: Findings and key points from each article were coded, e.g., "delay reduction with BIM 4D" or "BIM financial challenges."*

Theme Identification: Codes were grouped into broader themes, e.g., "improved scheduling efficiency," "BIM implementation barriers," or "role of complementary technologies."

***Theme Organization:** Themes were organized under the four thematic categories to ensure a cohesive review structure.*

***Findings Synthesis**: For each thematic category, key findings, such as BIM's positive impacts, implementation challenges, and proposed solutions, were synthesized.*

For each thematic category, the analysis focused on:

***Positive Impacts of BIM**: E.g., improved scheduling accuracy, error reduction, and increased transparency.*

***Challenges**: E.g., lack of skilled professionals, organizational resistance, or data integration complexities.*

***Proposed Solutions**: E.g., specialized training, cost-effective technologies, or standard development.*

***Research Gaps**: E.g., lack of empirical data from small projects or unexplored cultural barriers.*

5.3. Tools and Additional Considerations

To ensure a comprehensive and organized process, resource management tools were used:

***EndNote**: For storing, organizing, and referencing articles, enabling duplicate removal and creating a cohesive database.*

***Excel**: For recording extracted data and creating comparative tables, facilitating data filtering by thematic categories and rapid analysis.*

***NVivo (Optional):** Used for advanced qualitative analysis, such as coding and theme identification, if needed. To avoid bias, the selection and analysis processes were conducted independently by two researchers, with results reviewed in regular coordination meetings. Articles on the boundary of inclusion and exclusion criteria were scrutinized carefully to assess their potential value to the review.findings, methodology, and limitations.*

4. Conclusion

This semi-systematic review analyzed 36 articles to explore the role of Building Information Modeling (BIM) in enhancing construction project scheduling and management, focusing on four key areas: BIM 4D, resource constraints, complementary technologies, and stakeholder coordination. The findings indicate that BIM holds significant potential to transform the construction industry but faces notable challenges. BIM 4D, through construction sequence simulation, reduces project duration by up to 7% and improves coordination in complex projects, though its success relies on user training and precise data integration. Resource constraints, including high initial costs, a shortage of skilled professionals, and the lack of global standards, limit BIM adoption, particularly in small projects and less developed regions. Complementary technologies such as artificial intelligence, machine learning, augmented reality, and the Internet of Things enhance scheduling accuracy and efficiency through complex data analysis and real-time monitoring, but their implementation is hindered by high costs and the need for advanced infrastructure. In terms of stakeholder coordination, BIM improves collaboration among design, construction, and client teams by providing a single source of information, reducing communication errors, and increasing transparency, with significant impacts in large, international, and sustainable projects. However, this requires a collaborative culture and adoption of global standards like IFC. Overall, BIM is a critical tool for improving project management, but barriers such as implementation costs, skill shortages, and organizational misalignment hinder its widespread adoption. Complementary technologies like AI and IoT can mitigate these challenges and enhance BIM capabilities, provided strategic investments and planning are in place. To fully harness BIM's potential, recommendations include developing specialized training programs, establishing global data exchange standards, offering cost-effective solutions for small projects, and fostering collaboration among industry, academia, and governments. This study identified research gaps, such as the lack of empirical data from small projects and unexplored cultural barriers, and outlined future research directions. Future studies could focus on developing BIM models for small projects, examining cultural influences on technology adoption, and assessing the long-term impact of complementary technologies. This review not only provides a comprehensive understanding of BIM's current role in scheduling and project management but also serves as a foundation for future research and strategic decision-making in the construction industry.

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