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BIM-GIS Integration for Improving Cost and Time Management in Construction Projects – A Review

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Abstract

Construction projects continue to be affected by constant problems like unforeseen delays, growing expenses, and disorganized information flow throughout project phases. Since both Geographic Information Systems (GIS) and Building Information Modelling (BIM) have enriched digital construction management on their own, their respective applications limit efficient coordination and sound decision-making. Planning efficiency is increased, 4D scheduling is strengthened, and 5D cost analysis is improved when BIM and GIS work together to provide a unified understanding of detailed building information and broader spatial context. Despite these benefits, interoperability problems, semantic discrepancies between IFC and CityGML, and geometry loss during data conversion continue to limit practical implementation. Although more advanced organisational and technical frameworks are needed for wider adoption, the review generally shows that BIM-GIS integration increases schedule reliability and lowers rework.

Keywords: *BIM-GIS integration; 4D/5D BIM; construction project management; cost and time management; interoperability;*

1. Introduction

Managing construction projects is inherently complex due to the involvement of multiple stakeholders, parallel workflows, and diverse digital platforms. Even with increasing digitalization, construction projects frequently experience delays, cost overruns, and coordination problems. One major cause of these issues is the fragmented nature of project data. Along with 3D visualization, Building Information Modeling (BIM) has grown into a rich information digital model of a facility throughout its lifecycle. BIM helps with coordinated planning, 4D scheduling, and 5D cost control by integrating geometry, quantities, time, and cost knowledge. Early dispute detection, better communication, and more predictable project outcomes were rendered possible by these capabilities. However, BIM's value in site-sensitive projects is limited when used in isolation since it is unaware of real-world spatial conditions like terrain, surrounding infrastructure, and regulatory constraints. GIS platforms primarily focus on spatial, environmental, and regulatory information that influences site feasibility. When these data environments remain disconnected, project teams struggle to fully understand how design decisions interact with real-world site conditions [15,17,19]. BIM-GIS integration addresses this gap by enabling building and infrastructure models to be visualized and analyzed within their geographic context. This integrated perspective supports improved site assessment, clearer identification of risks, and more informed decision-making related to time and cost planning. In large-scale infrastructure projects like tunnels, transportation corridors, and urban developments, where terrain, utilities, and regulatory constraints significantly impact project feasibility, the advantages of integration are especially clear [14,18].

2. Methodology

For reasons of transparency and reproducibility, this review takes a methodical approach based on

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PRISMA principles. Scopus, Web of Science, and Google Scholar were used for collecting appropriate research, with a focus on works published between 2014 and 2025. The dominant themes in BIM-GIS research, such as integration strategies, issues with interoperability, cost and time performance, and IFC-CityGML data exchange, were identified in the search terms chosen. Studies were included if they addressed BIM-GIS integration workflows, data exchange mechanisms, or demonstrated impacts on project scheduling or cost management. Papers focusing exclusively on BIM or GIS without integration were excluded to maintain a clear research focus. For each selected study, information was extracted regarding data types, standards used, conversion processes, and visualization or simulation platforms, particularly those supporting 4D and 5D applications [6,7,10]. A PRISMA-style flow representation is used to summarize the study selection procedure. A structured BIM-GIS integration workflow that is frequently documented in the literature is shown in Figure 1. It begins with a structured review to identify relevant building and infrastructure data for effective time and cost management. To overcome interoperability issues, building data (location, mapping, and project status) and infrastructure data (cost, planning, quality, and duration) are processed independently before being combined through a data conversion stage. IFC and COBie standards are used to handle BIM data, and CityGML is used to manage GIS data so that platforms can exchange data consistently. The transformed datasets are incorporated into a central BIM model that facilitates advanced analysis, visualization, and simulation using programs like Unity and Unreal Engine, as well as BIM execution planning. Overall, the figure shows how integrated modeling and standardized data conversion facilitate 4D/5D analysis, improve coordination, and improve decision-making for efficient construction time and cost management.

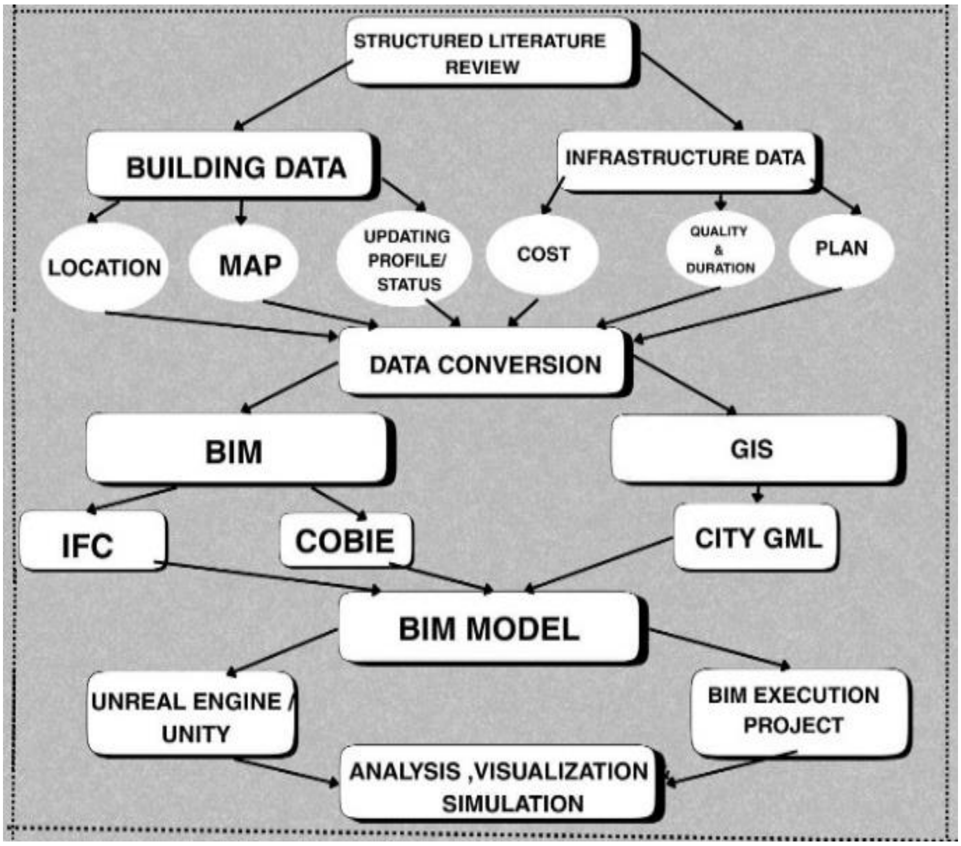

Figure 1 **BIM-GIS Workflow Showing Data Collection, Conversion, Model Integration, and Simulation Steps.**

3. Analysis of Methodology

The use of multiple scientific databases significantly increased the breadth and diversity of the reviewed literature, aligning with established bibliometric practices in BIM-GIS research [4]. The structured keyword strategy ensured that the selected studies were closely connected to current developments in semantic mapping, lifecycle integration, and geospatial modeling. The methodology's focus on the technical and conceptual aspects of BIM-GIS integration is one of its main advantages. Instead of staying purely theoretical, the review captures how integration is implemented in real-world scenarios by looking at workflows involving data conversion, georeferencing, and interoperability. However, the methodology also has limitations. Industry reports and proprietary project documentation were excluded due to limited public availability. Furthermore, reliance on published methodologies means that issues such as geometry distortion, attribute loss, and performance constraints in large-scale models may not be fully reported [12]. Despite these limitations, the methodology provides a reliable overview of current research while highlighting the need for stronger industry-based evidence.

4. BIM-GIS Integration Workflow

BIM-GIS integration is typically carried out using a structured workflow that includes data collection, standardisation, conversion, model integration, and visualisation, according to the reviewed literature. The goal of this workflow is to enable more thorough project analysis by bridging the gap between specific building-level data and a larger geospatial context. In most studies, BIM data are created and managed using standards such as IFC and COBie, which store detailed information related to geometry, materials, quantities, and construction schedules. GIS data, on the other hand, are typically represented using CityGML and related spatial formats that capture terrain, land use, infrastructure networks, and regulatory layers [5]. Standardization at this stage is essential to reduce semantic inconsistencies and ensure compatibility between BIM and GIS datasets. In the integration workflow, the data conversion stage is crucial. According to a number of studies, if the proper transformation rules are not used, direct conversion between IFC and CityGML frequently leads to geometry distortion, attribute loss, or coordinate misalignment. Therefore, to maintain spatial accuracy and information integrity during data exchange, meticulous georeferencing and semantic mapping techniques are needed [12]. Once converted, BIM and GIS datasets are combined into an integrated model that enables multi-scale spatial analysis. These integrated models allow project teams to evaluate terrain conditions, underground utilities, regulatory constraints, and spatial compatibility between design elements and the surrounding environment. Such capabilities are particularly valuable in infrastructure and urban projects, where spatial constraints significantly influence constructability and feasibility. Visualization and simulation represent the final stage of the BIM-GIS integration workflow. Platforms such as Unity, Unreal Engine, and WebGIS are frequently used to support interactive visualization, 4D scheduling, and 5D cost analysis. By linking spatial data with time and cost information, these platforms enhance coordination, improve communication among stakeholders, and support more informed decision-making throughout the project lifecycle [3,10].

5. Recent Research Advancement

Since 2015, research on BIM-GIS integration has grown dramatically, reflecting broader trends towards infrastructure automation, smart cities, and digital construction. Geographically, integrated workflows are being used more and more in transport networks and urban infrastructure projects in China, Europe, the UK, and Southeast Asia. Emerging research directions include semantic mapping between IFC and CityGML, cloud-based WebGIS platforms enabling real-time collaboration, and tighter coupling of spatial data with 4D scheduling and 5D cost estimation. More recent studies also explore early-stage digital twin concepts that integrate BIM, GIS, and sensor data to support monitoring and predictive planning [2,5].

6. Integration Approaches

The literature identifies three primary levels at which BIM and GIS can be integrated, namely data-level, process-level, and application-level integration. Each level differs in technical complexity, accuracy, and

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suitability for construction management objectives. Data-level integration focuses on direct data exchange between BIM and GIS formats such as IFC, COBie, and CityGML. This approach aims to preserve geometric detail and semantic attributes during conversion and is particularly important for infrastructure projects requiring high spatial accuracy. However, several studies report challenges related to geometry loss, semantic mismatches, and coordinate transformation during IFC-CityGML conversion [11,12]. Process-level integration links GIS-based site analysis with BIM-driven design, scheduling, and quantity takeoff processes. This level of integration supports coordinated 4D scheduling and 5D cost management by combining spatial constraints with construction sequences and resource planning and has been shown to improve coordination across project stages [8,9]. Application-level integration emphasizes visualization, communication, and decision support rather than detailed data exchange. WebGIS platforms and simulation environments are frequently used to support site logistics planning, safety analysis, and stakeholder engagement (Table 1). Although this level provides lower geometric precision than data-level integration, it is highly effective for collaborative planning and scenario evaluation [20].

Table 1 Comparison of BIM-GIS Integration Approaches

Integration Approach	Benefit	Limitation	Most Suitable Application
Data-Level Integration	Provides highly detailed and accurate model representation; preserves geometry and attributes closely to the original design	Risk of geometry loss during conversion; semantic mismatches between IFC, CityGML, and other formats	Infrastructure projects that require precise spatial and geometric accuracy
Process- Level Integration	Enables stronger 4D/5D simulation; improves planning, scheduling, and coordination across project stages	Requires clear workflow standardisation and consistent processes across software platforms	Projects focused on construction sequencing, time– cost planning, and lifecycle coordination
Application-Level Integration	Enhances visualisation for stakeholders; supports decision-making in logistics, safety, and site planning	Lower geometric detail compared to data-level integration; may not capture full semantic richness	Site logistics management, safety zoning, and context-based decision-support systems

7. Challenges in BIM-GIS Integration

Coordinate mismatches, geometric distortion during data exchange, and semantic differences between IFC and CityGML continue to be major obstacles to BIM and GIS interoperability. Limited native interoperability between widely used BIM and GIS software platforms and performance problems when managing large-scale models are examples of technological limitations. Organizational barriers further complicate adoption, as practitioners often have limited experience with integrated workflows and varying levels of digital maturity. Resistance to workflow changes and training requirements can slow long-term implementation [16].

8. Contribution to Cost and Time Efficiency

The reviewed literature consistently demonstrates

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that BIM-GIS integration contributes significantly to improving both cost and time efficiency in construction projects. One of the most frequently reported benefits is improved scheduling reliability, achieved by linking BIM-based construction sequences with GIS-derived spatial constraints. This integration enables planners to consider terrain conditions, site access, and spatial dependencies during schedule development, resulting in more realistic and reliable construction timelines [12,13]. Another major contribution of BIM-GIS integration is the reduction of rework through early detection of spatial conflicts. By combining detailed BIM models with GIS layers such as topography, underground utilities, and regulatory zones, potential clashes can be identified during early project stages. This early visibility is particularly valuable in infrastructure, tunneling, and urban projects, where late-stage design changes often lead to significant cost overruns and schedule delays [1]. By enabling project teams to visualize site-specific risks like unstable terrain, restricted access zones, and environmentally sensitive areas, GIS-based risk assessment further improves time efficiency. Teams can reduce delays caused by unanticipated site conditions by proactively adjusting construction sequences and resource allocation when these risk layers are integrated with BIM scheduling information. From a cost management perspective, BIM-GIS integration supports improved logistics planning and material handling. Linking BIM-based quantity information with GIS-derived spatial analysis enables optimized site layout planning, equipment routing, and material storage strategies. These improvements help minimize unnecessary material movement, reduce idle equipment time, and improve overall site productivity, leading to more accurate cost forecasting and better cost control [20]. Additionally, through interactive visualization platforms, application-level BIM-GIS integration improves stakeholder communication. Faster decision-making, fewer approval cycles, and fewer change orders during construction are all made possible by a clear visualization of schedule-cost relationships, all of which improve time and cost performance. Overall, research shows that BIM-GIS integration offers a solid basis for construction project management that is more effective, predictable, and data-driven.

9. Practical Implications for Construction Project Management

Early inspection of terrain, underground utilities, access routes, and regulatory constraints within a single spatial environment is made viable through BIM-GIS integration, which enables more precise scheduling and cost estimation during planning. Planners can evaluate constructability before deployment by placing BIM models within actual geographic contexts, which avoids late-stage revisions. Construction sequences can be assessed in the real site context by connecting BIM schedules with GIS-based spatial data. This strengthens 4D planning and increases schedule realism during execution by exposing access conflicts, workspace overlaps, and sequencing constraints related to terrain. Material planning, equipment routing, and site layout decisions are improved by combining BIM quantities with logistics and accessibility data derived from GIS. These features minimize idle resources, cut down on needless material movement, and improve 5D cost control. Rework is decreased by early detection of spatial conflicts between design elements, terrain, subterranean utilities, and regulatory zones, especially in infrastructure and urban projects where late modifications are expensive. Stakeholder communication is improved, approvals are expedited, and well-informed decision-making is supported by integrated visualization using WebGIS, Unity, or Unreal Engine. According to the review, projects with high geometric accuracy have the greatest potential for data-level integration, whereas time-cost planning and site management have greater backing by process- and application-level integration. This distinction enables practitioners to choose suitable integration strategies according to the complexity and size of the project.

Conclusion

By combining exact building data with real spatial context, BIM-GIS integration offers a useful and effective approach for enhancing time and cost management in construction projects. Using a PRISMA-guided methodology, this review systematically examined how BIM-GIS integration is structured, implemented, and evaluated across recent research. Better coordination between project phases,

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early detection of site constraints, and more precise planning are all made possible by this integration. The review demonstrates that integrating BIM schedules and quantities with GIS-based terrain, access, and utilities data increases schedule reliability, strengthens 4D and 5D workflows, and minimizes rework, particularly in infrastructure and urban projects where performance is dominated by spatial constraints. Despite all of these benefits, complications with interoperability, including coordinate inconsistencies, geometry loss during data exchange, and semantic confusion between IFC and CityGML remain to delay widespread adoption. These limitations emphasize the necessity of more reliable, automated, and standardized integration frameworks. A clear path toward more dependable and scalable integration is shown by developments in cloud-based platforms, AI-assisted semantic mapping, and digital twin environments. BIM-GIS integration is anticipated to be crucial in enabling data-driven, predictable, and effective construction project delivery as these technologies develop and are verified in actual projects. Real-world pilot projects in infrastructure and smart city environments should be used in future work to validate these frameworks.

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