

A Systematic Review of Multi-Dimensional BIM Applications in Construction Engineering Management: Evidence from Exhibition Center, Metro Station, and Industrial Park Projects

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Abstract: China's construction sector is undergoing rapid digital transformation, with Building Information Modeling (BIM) advancing from a design-focused tool to a lifecycle-oriented management platform. This study examined BIM applications in exhibition center, metro station and industrial park projects through a comparative analysis of operational, quality and schedule management dimensions. Using a combined approach of literature review and case analysis, the paper compares application goals and technical strategies across distinct engineering contexts. Results show that BIM supports spatial and asset integration for efficient facility operation, enables object-based quality tracking and early risk detection in complex underground construction, and enhances scheduling accuracy and resource coordination through 4D simulation. These findings confirm that BIM is evolving toward scenario-specific, full-process solutions. The study offers both theoretical insight and practical guidance for the digital upgrading of construction project management.

Keywords: BIM; Construction Engineering Management; Operation Management; Quality Control; Schedule Optimization

1. Introduction

1.1 Background of Digital Transformation in the Construction Industry

With the growing integration of information technology and the construction sector, China's construction industry is accelerating its transition toward digitalization and intelligent development. National strategic plans have consistently emphasized this transformation. The "14th Five-Year Plan for the Development of the Construction

Industry" calls for the comprehensive application of Building Information Modeling (BIM) across all project phases, aiming to enable fully digital deliverables. The "Digital Housing and Urban-Rural Development Planning Framework" further sets a target of achieving smart construction coverage in over 80 percent of construction sites by 2025, positioning BIM as a central enabling technology. Regional governments are actively responding. For example, Hefei City has mandated the widespread adoption of digital construction practices, including full BIM implementation in major projects. Although information technology investment in the sector currently accounts for less than 0.2 percent of total output, the growth potential remains significant. This creates favorable conditions for the deepening and expansion of BIM applications.

1.2 Fragmentation in Traditional Construction Project Management

Traditional construction projects in China often follow a segmented management approach. Project phases such as design, construction, and operation are typically handled by different stakeholders using separate systems, resulting in fragmented data flows and disconnected processes. This fragmentation leads to inefficiencies, communication breakdowns, and coordination failures. The absence of a unified collaboration platform hampers interdisciplinary cooperation, while delays in feedback and document handovers compromise quality assurance and scheduling accuracy. In one metro project, the lack of an integrated model led to major clashes between reserved structural elements and installed equipment, causing substantial rework and project delays. A similar issue occurred during the expansion of a convention center in Guangzhou, where mismatches between lighting and HVAC

layouts and the original structural model necessitated repeated on-site adjustments and extended the construction timeline by more than 30 percent. Such challenges are particularly acute in complex environments like underground infrastructure and large-scale integrated developments.

1.3 Evolution of BIM's Role

BIM has transformed from a basic modeling tool into a full-fledged platform for lifecycle-wide digital integration. Its formal introduction into national standards by the Ministry of Housing and Urban-Rural Development in 2008 marked the beginning of its institutional adoption in China. Initially used for 3D visualization and design coordination, BIM's functionality expanded around 2015 to encompass 4D scheduling, 5D cost estimation, and 6D facility management. The 2020 release of the "14th Five-Year Plan for Science and Technology Development in Housing and Urban-Rural Construction" reinforced BIM's strategic importance. This policy push, along with progress in industry standardization, has led to the integration of BIM platforms with Project Management Systems (PMS) and Construction Management Systems (CMS), enabling more comprehensive and connected data environments. Looking ahead, BIM is expected to converge with emerging technologies such as artificial intelligence, the Internet of Things, and digital twins. These integrations will support advanced capabilities including intelligent clash detection, predictive analytics, and automated construction simulations, thereby accelerating the implementation of smart construction practices.

1.4 Research Objectives

This paper investigates BIM's application across three typical engineering scenarios, including an exhibition center, a metro station, and an industrial park, focusing respectively on operational management, quality control, and schedule optimization. These scenarios represent key areas where BIM can address complex information demands and management challenges. By conducting a comparative, multi-dimensional analysis, the study explores how BIM adapts to different engineering contexts in terms of objectives, data architecture, and implementation strategies. The research aims to contribute both theoretical

insights and empirical evidence to guide the development of BIM toward greater specialization and scenario adaptability. Unlike previous studies that tend to focus on single case studies, this research adopts a cross-project perspective to uncover differentiated application patterns. It highlights how distinct engineering types prioritize different management functions and deploy specific technical mechanisms. The remainder of the paper is organized as follows: Section 2 presents BIM application strategies for each case across the three management dimensions. Section 3 provides a comparative analysis of the objectives and mechanisms. Section 4 summarizes the findings and outlines future directions.

2. Analysis of BIM Application Effectiveness in Individual Management Dimensions

2.1 Operation Management Dimension: Exhibition Center Project (Typical Facility O&M Scenario)

The exhibition center project illustrates how BIM can enhance facility operation and maintenance by addressing traditional pain points with a unified digital approach. Exhibition centers are characterized by vast floor areas, numerous functional zones, and frequently changing exhibition layouts. For example, the Heze City Exhibition Center spans nearly 90,000 square meters with five large halls, 1,778 standard booths, and extensive outdoor exhibition space, making its operations highly data-intensive and requiring precise spatial scheduling [1]. Traditional facility operation methods, relying on 2D plans, paper logs and manual updates, have proven inefficient in tracking equipment locations or updating maintenance records, and they often suffer from delayed information flow during booth planning, equipment monitoring, and emergency dispatch. This lag in information leads to a reactive "lagged response" pattern in operation management [2].

In this context, BIM provides a comprehensive, object-oriented information framework that transforms how operational data is organized and utilized. Through collaborative modeling of architectural, structural, and MEP systems on a platform like Revit, the exhibition center's BIM model digitizes both spatial geometry and asset attributes into a unified dataset. Disparate

information systems are integrated on a visual, searchable, and interactive platform, establishing a digital foundation for management [3]. Every piece of facility equipment is represented as a component in the model enriched with parameters, real-time status, maintenance schedules, and repair records, converting traditional “file-based” logs into an “object-based” information repository attached directly to each asset. This enables operations staff to precisely locate assets and plan inspection routes via the BIM model, allowing them to reach target equipment quickly and efficiently [4]. When an anomaly occurs, the historical and real-time data linked to that equipment can be retrieved instantly to support fault diagnosis, reducing delays that would occur with experience-driven troubleshooting [5]. Over time, the continuous accumulation of lifecycle data in the model supports analysis of failure rates and identification of potential points of failure, facilitating predictive maintenance planning that shifts facility management from reactive repairs toward proactive prevention. Additionally, the BIM model integrates multi-dimensional operational data such as energy consumption, environmental sensor readings, and safety monitoring information. This integration provides managers with a quantitative overview of energy use patterns and operating costs across different areas, supporting data-informed decision-making for event scheduling and resource optimization. BIM also significantly improves spatial planning and coordination for the exhibition center’s frequently reconfigured layouts. Exhibition events often require rapid reorganization of booth layouts, adjustments to visitor circulation routes, and changes in exhibit installations. Traditional 2D drawings are inadequate for conveying such complex spatial arrangements, often resulting in booth placement conflicts, improperly allocated pathways, or extensive on-site rework. In contrast, the 3D BIM model offers a clear advantage by enabling parametric modeling of hall interiors, functional zone boundaries, and adjustable spatial units. The design team can virtually rehearse space utilization and booth arrangement scenarios within the model before implementation. Three-dimensional views (e.g. plan, perspective, and section) enhance comprehension of the space, transforming the

layout planning process from a flat abstraction into a verified spatial simulation. Within the BIM environment, exhibit components such as booth partitions and displays can be moved, copied, rotated, and aligned as easily as assembling building blocks, greatly improving the efficiency of generating and iterating layout schemes. More importantly, BIM’s automated clash detection continuously checks for spatial conflicts, verifying that minimum clearances are maintained between exhibition installations and building elements like columns, fire sprinklers, or lighting fixtures. Detected issues can thus be resolved digitally in advance, significantly reducing the likelihood of on-site clashes and rework. For scenarios involving multiple teams setting up simultaneously, BIM’s collaborative platform ensures that all teams work on a consistent, up-to-date model. Changes are synchronized in real time, and any interference between teams’ layouts is instantly visualized, guaranteeing information consistency and preventing spatial conflicts during the setup process. Furthermore, BIM can be employed to simulate emergency egress scenarios by running crowd flow simulations in the model [6]. Testing various evacuation plans in the virtual environment provides data-driven support for safety management and emergency planning, extending operational management beyond space optimization into the realm of safety assurance.

In summary, BIM addresses the exhibition center’s operational challenges by deeply integrating asset data with spatial information and enabling proactive management. It provides digital and visual oversight of equipment management, allowing precise tracking of each asset’s location, status, and maintenance history and thereby shifting maintenance practices from experience-driven to data-driven. At the same time, BIM enables intelligent and collaborative space utilization: through 3D layout simulation, clash detection, and coordinated modeling, exhibition planning becomes more efficient and accurate, with far less rework. Consequently, the exhibition center case demonstrates that BIM serves as a unified data platform to support everything from routine facility inspections to complex event reconfigurations and risk preparedness, transforming facility operations from fragmented, reactive workflows into an integrated and predictive management approach.

2.2 Quality Management Dimension: Metro Station Project (Typical Underground Construction Quality Scenario)

The metro station project exemplifies how BIM can support rigorous quality control in an underground construction environment, where traditional methods often fall short. Metro station construction is inherently high-risk for quality management due to deep excavations, dense structural systems, overlapping multi-disciplinary work, and challenging geological conditions. For example, the Qingdao Metro Line 5 Station A extends 470 meters and was built using an open-cut method with an overburden of only 3.5-5.7 meters, resulting in an extremely high-risk construction scenario [7]. In such projects, once critical processes like rebar tying, waterproofing, concrete pouring, or formwork installation are completed, they become hidden and cannot be easily re-inspected. This leads to situations where records for hidden work are missing, creating “information blackouts” in the quality traceability chain. Moreover, the metro station’s mechanical, electrical, and plumbing (MEP) systems are densely packed within the structural confines, and the high degree of spatial coupling means that even a minor local construction deviation can trigger systemic quality defects elsewhere. The dynamic nature of surrounding geology and groundwater adds further uncertainty to quality control. Compounding these issues, numerous contractors and subcontractors participate in metro construction, and the lengthy, paper-based documentation chain often results in incomplete and inconsistent quality information. Traditional manual record-keeping struggles to ensure data integrity and timeliness, leaving quality management in a passive state where problems only surface late and corrective measures are loosely coordinated.

Given these challenges, BIM establishes a centralized information framework that provides a systematic digital foundation for quality management in the metro station project. This approach enables a shift from fragmented, paper-based quality supervision to an integrated, data-driven process encompassing the full construction lifecycle [8]. BIM’s value in this scenario can be articulated in three dimensions: object-oriented quality information management, spatial visualization of quality

issues, and integrated, proactive risk control.

First, an object-oriented approach to quality management makes each physical component in the station a carrier of its own quality data. In the BIM model, every structural or MEP element is linked with detailed attributes including its design specifications, material batch numbers, construction methods, and inspection records (along with timestamps), ensuring that quality information “travels” with the component throughout the project. This mechanism enables full traceability: even if a component becomes concealed after installation (as is common in underground works), all relevant quality records remain associated with that component in the digital model, ready for retrieval when needed.

Second, the BIM model facilitates spatial localization and visualization of quality issues. When a defect or non-conformance is identified, it can be precisely mapped to its location in the 3D model and documented with rich context—photographs, videos, and written descriptions—directly attached to the affected object. This creates a visual, closed-loop workflow for quality management, where issue logging, required remediation, and follow-up inspections are all tracked in the model. As a result, quality control shifts from relying on static paper checklists to a dynamic process of “spatial verification,” in which stakeholders can review and address issues in a virtual replica of the site rather than through purely textual reports.

In the project’s planning and design phases, BIM’s simulation capabilities further strengthen quality assurance. Clash detection routines run on the BIM model can reveal interferences between MEP systems and structural components before construction begins. Identifying these conflicts early allows the team to adjust designs or construction sequences proactively, thereby reducing rework and preventing quality problems that would arise from such clashes in the field. Construction simulations using the BIM model can also pre-validate critical aspects of the work, such as the path for moving large equipment into the station, or the layout of material storage areas, ensuring that the proposed methods are feasible and safe. These pre-construction checks add a layer of quality assurance by verifying that plans can be executed as intended under real-world conditions.

Additionally, BIM enables the integration of

multi-source data for risk management. Geological survey data (borehole logs, rock strata classifications) and hydrological information can be overlaid onto the 3D model of the station. By visualizing these subsurface conditions in relation to the station's structure, the project team can identify potential risk zones (e.g. areas prone to settlement or water ingress) well in advance. This spatially enriched analysis compensates for the shortcomings of traditional 2D drawings in conveying complex subsurface information, thereby improving the reliability of risk assessments and enabling preventive measures to be built into the quality management plan.

During the construction phase, BIM continues to support quality management by improving communication and understanding on site. Three-dimensional, BIM-based work instructions (often called 3D construction method statements) help workers and engineers to visualize complex construction details before execution. For intricate sections like utility tunnels or densely populated service corridors, the 3D model is far more intuitive than traditional 2D drawings, reducing misinterpretation and human error. This enhanced clarity diminishes the likelihood of construction deviations that compromise quality, thereby directly contributing to higher build quality and fewer defects.

In summary, BIM's application in the metro station project demonstrates a clear comparative advantage over traditional quality management methods by enabling both thorough information tracking and proactive control. The objectification and traceability of quality information ensure that every component's quality pedigree is documented and accessible, transforming disjointed inspection reports into a coherent, component-centric record system. Equally, the spatialization and front-loading of risk control mean that potential quality issues are identified and addressed in the model environment before they escalate on site. In effect, BIM serves as the core platform for the project's quality management system, turning quality control from a retrospective, paper-heavy exercise into a transparent, real-time, and precision-driven process. The ultimate outcome is a significant improvement in the overall controllability and reliability of quality for the underground metro project.

2.3 Schedule Management Dimension: Industrial Park Project (Typical Construction Schedule Scenario)

The industrial park project highlights BIM's role in optimizing construction scheduling and resource management, especially in complex projects where traditional scheduling methods struggle. Industrial park constructions usually involve numerous specialized workflows, expansive work areas, frequent overlapping of trades, and tightly compressed timelines. These characteristics create a high-density scheduling environment with many interdependencies. Traditional schedule management—centered on Gantt charts and written reports—has difficulty capturing the reality of such projects. On the one hand, static schedules often fail to reflect the complex spatial conditions on site; they cannot detect when different crews' tasks might clash in the same physical area or account for space constraints that affect task execution. On the other hand, updates from the field are usually slow and retrospective, meaning project managers receive critical information about delays or disruptions only after the fact. This latency makes it hard to promptly reallocate resources or resequence tasks, with the result that the critical path is easily disturbed and the overall plan becomes unstable. In the industrial park case, these shortcomings manifested as difficult spatial coordination, delayed response to plan deviations, and inefficient resource utilization, which are classic pain points of traditional schedule management [9].

BIM technology, particularly 4D BIM which adds the schedule dimension to the 3D model, introduces a proactive and integrated mechanism for managing construction progress. Using the project's BIM model as a base, time data is associated with each building component to create a 4D simulation of the construction process. This transforms the schedule from a static document into a living, visual timeline within the digital model. Through the 4D BIM platform, logical relationships in the construction plan are automatically cross-checked: the sequence of tasks, the feasibility of parallel work, and any spatial conflicts between different crews' activities can be identified and resolved virtually before they manifest in the field. The BIM-based simulation vividly depicts the state of the site at each planned moment, allowing the project team to optimize the sequencing of tasks and the division of work

zones based on how the construction will actually unfold in space and time. In essence, BIM offers an advance spatial validation of the schedule, ensuring that the plan is not only theoretically sound in terms of timing but also practically feasible given the site's constraints. Furthermore, the 4D BIM approach tightly couples the schedule with resource management. As the construction sequence is simulated, the model concurrently adjusts resource allocation needs, aligning the supply of materials, deployment of machinery, and assignment of labor with the project timeline. This dynamic linkage makes it possible to balance resource demand peaks, preventing situations where crews are idle waiting for materials or where equipment sits unused due to sequencing mismatches. By avoiding resource gluts and shortages, the project runs more smoothly and cost-effectively than under traditional scheduling, where such adjustments are often made too late or based on incomplete data. During the execution phase, BIM continues to play a central role: actual progress data (from site reports or IoT sensors) can be fed back into the 4D model in real time. By comparing the real-time status with the original schedule simulation, managers obtain a visual diagnosis of schedule performance, quickly pinpointing any deviations between planned and actual progress. This feedback loop enables timely re-planning, managers can dynamically adjust sequences, add resources, or implement acceleration measures in the model, then communicate updated plans instantly to the teams on site. The schedule thus becomes a continuously optimized plan rather than a static baseline that is only updated after major delays. The effectiveness of this BIM-based schedule management has been borne out in the industrial park project's outcomes. After implementing the 4D BIM model, multiple key construction milestones showed significantly reduced schedule variance, and the overall rate of on-time task completion improved markedly. By using the model to refine the construction sequence, the project team was able to minimize out-of-sequence work and on-site rework, thereby enhancing the stability of the critical path. Resource deployment became more balanced as well: previously, the project experienced periodic surges that led to congestion and idle periods that hindered continuity. With BIM-driven planning, those

peaks and troughs were smoothed into a more continuous and controlled construction rhythm. These practical results validate that 4D BIM improves the coordination and efficiency of construction operations, effectively shifting schedule management from a passive, experience-based practice to an active, visualization- and data-driven discipline.

In summary, BIM adds clear value to schedule management in the industrial park project in two main ways. First, it enables visualization of the schedule and upfront verification of plans. By simulating the construction process in a 3D environment, planners can perform spatial checks on the schedule's feasibility, optimize task ordering, and foresee risks, making schedule control more scientific and reliable. Second, it facilitates coordinated optimization of resource allocation and construction pace. Through the integration of time and resource data, BIM ensures that the deployment of personnel, materials, and equipment remains synchronized with the construction sequence, thereby improving resource efficiency and preventing common bottlenecks. Therefore, the introduction of 4D BIM in the industrial park project provides an integrated digital platform for managing time and resources together, which in turn helps to compress the overall project duration, maintain a steadier construction workflow, and enhance on-site organizational efficiency. The comparison with traditional methods makes it evident that BIM-based schedule management leads to more predictable and controllable project delivery in complex construction scenarios.

3. Multi-Dimensional Comparison of BIM Application Objectives and Adaptation Mechanisms Across Different Project Types

3.1 Differences in BIM Application Objectives Across Project Types

The three project types present distinct management challenges and information needs, which dictate the primary objectives of BIM in each case. In the exhibition center, for example, the core challenge lies in dynamic facility operations. Large public venues have complex spatial layouts and are frequently reconfigured for different events, resulting in high-intensity and high-frequency operational demands. In this context, the value of BIM emerges through a comprehensive digital model that integrates

spatial and asset information. Such a unified model supports digital management of tasks like equipment location tracking, performance monitoring, maintenance logging, and exhibit layout simulation. The main goal of BIM in the exhibition center case is to enhance operational efficiency and decision transparency, ensuring that the facility remains orderly and stable even under heavy usage. In effect, BIM functions as a form of digital operational infrastructure, prioritizing long-term facilities management over traditional construction support.

By contrast, the metro station project, a typical underground construction, faces multiple quality-control challenges. It involves numerous concealed structures, complex geology, dense sequencing, and high cross-disciplinary coordination. Traditional documentation methods struggle to capture hidden work details or resolve interface quality issues. In response, BIM's objective in this context shifts toward comprehensive quality assurance throughout the project lifecycle. BIM is used to bind quality attributes to individual components, digitally record inspection results, incorporate geotechnical and hydrological data, and perform automated clash detection and construction simulations. These combined functions form a proactive digital support system for building the station to high-reliability standards. Quality control shifts from reactive, after-the-fact inspections to proactive risk management and traceable tracking. In short, BIM becomes the core platform of the quality management system in the metro station project, rather than a simple auxiliary tool.

The industrial park project emphasizes construction schedule efficiency and resource coordination. Such projects typically involve many specialized processes, dispersed work areas, and multiple parallel operations, all under a tight schedule. Conventional static scheduling methods struggle to reflect on-site complexity and handle overlapping tasks. Integrating 4D BIM combining the 3D model with the time schedule transforms, the static plan into a dynamic construction simulation. By virtually sequencing construction tasks, space usage, and resource deployment, the BIM model can identify scheduling conflicts early, balance workloads, and enable real-time comparison of planned versus actual progress. This dynamic approach allows continuous schedule adjustment. For the industrial park case, BIM's

application goal is thus to improve schedule control and construction coordination, maintaining a stable construction rhythm and helping to ensure timely project completion.

These examples show that different project types have markedly different core BIM needs: the exhibition center focuses on boosting operational throughput; the metro station focuses on construction quality and reliability; and the industrial park focuses on schedule stability and resource optimization. In each case, the inherent attributes of the project strongly influence the focus of BIM's application, illustrating that engineering context decisively shapes BIM's intended value and goals.

3.2 Differences in Technical Mechanisms

Each project objectives translate into different technical approaches in BIM implementation. In the exhibition center case, the key technical mechanism centers on integrating spatial information and enabling visual facility management. A unified 3D model that combines architectural, structural, and MEP systems is created and enriched with data to support facility tasks such as exhibit layout planning, equipment monitoring, and energy analysis. Within this model, individual components serve as digital carriers of facility information: for example, maintenance logs, performance data, and fault reports are directly attached to the corresponding model elements. The rich spatial capabilities of the BIM model also allow virtual simulations of layout changes, clash detection, and crowd-flow analysis. Together, these mechanisms establish a facility management system focused on unifying space and asset data, which supports proactive planning and visualization of operational strategies.

In the metro station project, the technical mechanisms are best described as component-centric management, spatial coding, and simulation-based verification. Because much of the work is hidden underground, traditional records cannot ensure continuous traceability of quality information. BIM addresses this by treating each building component as an information object: quality records and inspection results are embedded within the component's data. A spatial coding scheme tags model locations so that any quality issue can be precisely located in the 3D model and quickly communicated to teams. Crucially, by

overlaying geological and hydrological data onto the BIM model, potential risks can be identified before construction, enabling data-driven risk control during the build. Functions like automated clash detection and virtual construction path simulation further reduce uncertainty in the complex, multidisciplinary environment. These mechanisms combine to make BIM the core execution tool for the metro station’s quality management. In other words, BIM’s technical focus is on capturing quality information at the component level and using simulation to preempt conflicts and hazards.

For the industrial park project, BIM’s technical mechanism revolves around binding the model to time and coordinating resources. By mapping 3D model elements to the construction schedule, a 4D BIM platform is created for dynamic simulation of the build process. This platform supports optimization of construction sequences, rational division of work areas, and coordinated resource allocation. The 4D model visualizes each phase of construction and can automatically check schedule logic (for example, detecting missing dependencies or unrealistic sequences). During execution, actual progress is fed back into the model to identify any deviations and drive plan adjustments. In very resource-intensive scenarios, the 4D model also serves as a digital tool for scheduling labor and equipment. These mechanisms position BIM as the digital core of schedule control, directly supporting precise coordination of time

and resources.

In summary, the exhibition center’s BIM emphasizes spatial-asset integration for facility management, the metro station’s BIM emphasizes component-level quality tracking and proactive risk identification, and the industrial park’s BIM emphasizes integrated schedule and resource simulation. These differences in technical approach reflect the distinct functional demands of each project type and drive the specialization of BIM solutions in practice.

3.3 Comparative Analysis of Application Objectives and Mechanisms

A structured, side-by-side comparison of the three project types (Table 1) makes these contrasts immediately apparent. This organized comparison highlights the core management challenges, BIM objectives, key technical mechanisms, and tangible benefits for each case. For example, the exhibition center’s rapid operational changes translate into a BIM focus on unifying spatial layout and asset data, whereas the metro station’s hidden works and high-risk environment translate into a focus on object-based quality tracking and preemptive risk management. The industrial park’s complex schedule pressures, by contrast, lead to an emphasis on 4D sequencing and resource coordination [10]. Presenting these factors in parallel underscores that BIM application is highly scenario-dependent.

Table 1. BIM Objectives and Technical Mechanisms Across Project Types

Project Type	Management Focus	BIM Objective	Key Mechanisms	Outcome
Exhibition Center	Dynamic space use, frequent reconfiguration	Unify spatial and asset operations	3D modeling, asset mapping, layout and flow analysis	Improved tracking, fewer reworks, better planning
Metro Station	Concealed work, multi-discipline coordination	Traceable quality control and risk mitigation	Object-level data linkage, spatial feedback, simulation	Enhanced assurance, early warnings, error reduction
Industrial Park	Broad workflows, concurrent tasks	Integrated scheduling and resource control	4D modeling, sequencing, real-time deviation tracking	Shorter timelines, steady pace, improved coordination

Importantly, this comparison yields new insights about BIM’s evolving role. It shows that BIM is no longer a one-size-fits-all tool: instead, its functions and value proposition must be tailored to project-specific needs. In one context BIM enhances operational throughput and visibility, in another it enables proactive quality assurance, and in a third it optimizes schedule control. This recognition of

divergent BIM trajectories suggests a larger trend: BIM implementation is becoming more specialized and contextual. By systematically contrasting these cases, we see that engineering attributes, such as facility complexity, risk profile, and schedule intensity, directly determine how BIM adds value in each scenario. These insights point toward a shift in BIM practice, in which structured, domain-specific

analysis guides more precision-engineered digital solutions for construction management.

3.4 BIM Evolution from a General Tool to Domain-Specific Solutions

The comparative analysis of these cases highlights a core innovation of this study: it demonstrates that BIM's trajectory is determined by the intrinsic attributes of each engineering domain, marking a shift from generic BIM strategies toward precision-engineered digital solutions. Early BIM applications often emphasized general 3D visualization and basic clash detection to support cross-disciplinary collaboration. However, as our comparison shows, diverging project demands now drive BIM to evolve along different paths. In the exhibition center, BIM effectively becomes an operational management platform that integrates all facility data. In the metro station, BIM evolves into the foundation of the quality control system. In the industrial park, BIM transforms into the central scheduling and resource-management tool.

These trends indicate that BIM's value has expanded from a simple "modeling platform" to an adaptive digital solution for full-lifecycle project management. Rather than applying a uniform approach, practitioners must now "engineer" BIM implementations to match the specific context. In practice, this means tailoring data structures, analysis workflows, and functional modules to fit each domain's needs. For example, BIM deployments may increasingly incorporate specialized modules, such as IoT integration for facility monitoring or advanced simulation for hazard prediction that directly address project-specific challenges. By explicitly linking engineering attributes to BIM outcomes, our study provides both a theoretical framework and practical guidance for this transition. The result is a more mature BIM paradigm in which digital tools are precisely calibrated to optimize performance in each construction context.

4. Conclusion and Future Directions

This study examined BIM applications in exhibition center, metro station and industrial park projects through a comparative analysis of operational, quality and schedule management dimensions. These cases exemplify distinct engineering contexts involving high-frequency facility operations, risk-intensive underground

construction, and complex multi-trade scheduling. Together, they illustrate how project attributes fundamentally shape BIM's functional deployment and management value.

The comparative findings demonstrate that BIM is no longer a one-size-fits-all modeling tool. Instead, it is evolving into a scenario-responsive digital management solution. In exhibition centers, BIM facilitates the integration of spatial and asset data to improve operational efficiency. In metro stations, it enables traceable quality control and early-stage risk identification through object-based modeling and spatial analytics. In industrial parks, BIM leverages 4D simulation to synchronize scheduling and resource flows, promoting more stable construction execution.

From a technical perspective, BIM systems have become increasingly differentiated. They support operational databases, quality traceability chains, and time-bound construction simulations across respective project types. This shift reveals a deeper transition from geometry-centric models toward semantically enriched, management-driven platforms. The trend reflects BIM's movement from visualization support to data-centric infrastructure enabling real-time decision-making.

Looking ahead, several development priorities emerge. Cross-phase integration of design, construction, and operations will ensure continuity and reusability of model data. Deeper alignment with intelligent technologies, such as AI, IoT, and digital twins, will empower predictive analytics, autonomous control, and adaptive planning. Finally, scenario-specific BIM standards must be developed to define modeling depth, attribute schemas, and collaboration protocols that align with project-specific demands. These efforts will improve BIM's scalability and interoperability across the industry.

In summary, BIM is becoming a core digital infrastructure for contemporary construction management. Its multi-dimensional adaptability is reshaping traditional engineering workflows. This research contributes both a theoretical framework and empirical reference for advancing BIM toward more intelligent, integrated, and domain-specialized applications in the digital era of construction.

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