



THE ROLE OF BUILDING INFORMATION MODELLING (BIM) IN ENHANCING QUALITY MANAGEMENT ACROSS THE CONSTRUCTION LIFECYCLE: A SYSTEMATIC REVIEW

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Abstract

Building Information Modelling (BIM) has emerged as a key digital innovation in the construction industry, with growing potential to enhance quality management practices across the project lifecycle. While numerous studies report individual BIM applications for quality planning, assurance, and control, a consolidated understanding of how BIM systematically supports quality management in construction remains limited. This paper presents a comprehensive review of the literature on BIM-enabled quality management in construction. Using a structured review methodology, existing studies are synthesized to identify BIM functionalities supporting quality management, classify applications across lifecycle phases, and examine associated benefits and challenges. A conceptual framework is developed to illustrate how BIM capabilities enhance quality planning, assurance, and control from design through operation and maintenance. The findings demonstrate that BIM enables a shift from reactive, document-based quality management toward proactive, data-driven approaches. The paper also identifies key research gaps and proposes directions for future studies to advance BIM-based quality management.

Keywords; Building Information Modelling (BIM), Construction Quality Management, Construction Informatics, Digital Quality Control

1.0 INTRODUCTION

The construction industry continues to face persistent challenges related to quality management, including design inconsistencies, construction defects, excessive rework, and frequent non-conformance with project specifications and regulatory standards. These quality-related issues have been widely recognized as major contributors to cost overruns, schedule delays, disputes, and reduced lifecycle performance of constructed assets. According to Love *et al.* (2016), rework and defect rectification can account for a substantial proportion of project costs, while Hwang *et al.* (2020) further demonstrated the significant impact of rework on overall construction cost performance. These findings underscore the critical importance of effective quality management systems in construction projects. Despite decades of effort to

improve quality performance, however, the industry remains heavily reliant on fragmented and largely reactive approaches to quality control.

Traditional quality management practices in construction are predominantly based on manual inspections, two-dimensional documentation, and paper-based reporting systems. While formal frameworks such as Total Quality Management (TQM) and ISO 9001 have introduced structured procedures for quality assurance, their application in construction projects is often constrained by poor information flow, limited real-time feedback, and weak integration across project phases. Oakland and Marosszeky (2017) argued that the fragmented nature of construction supply chains undermines the effectiveness of traditional quality management systems, particularly when quality-related data are generated and stored in isolated platforms. As a result, inconsistencies, information loss, and delayed identification of errors are common. Consequently, quality management efforts frequently focus on detecting defects after construction activities have commenced, rather than preventing them through early-stage planning and coordination.

In recent years, the increasing digitalization of the construction industry has created new opportunities to address these long-standing limitations. Building Information Modelling (BIM) has emerged as a transformative digital approach that enables the creation and management of integrated, information-rich models throughout the lifecycle of construction projects. Eastman *et al.* (2018) described BIM as a shared knowledge resource that facilitates enhanced collaboration among stakeholders by linking geometric, semantic, and process-related information within a common data environment. Prior research has shown that BIM improves design coordination, reduces clashes, and enhances decision-making, thereby contributing indirectly to improved quality outcomes. More recent studies have moved beyond these indirect benefits to explicitly examine BIM's potential to support quality management processes. For example, Chen and Luo (2014) demonstrated how BIM can enable systematic quality planning and control, while Ma *et al.* (2018) highlighted the role of BIM in improving information accuracy and traceability. Similarly, Panah and Kioumars (2021) emphasized the growing use of BIM-based tools for automated compliance checking and defect management.

Despite the increasing adoption of BIM across the global construction industry, the application of BIM specifically for quality management remains fragmented and uneven. Existing studies tend to concentrate on isolated BIM functionalities or individual project stages, such as design coordination or construction-phase inspections, without offering a holistic understanding of how BIM supports quality management across the entire project lifecycle. Lee *et al.* (2014) noted that BIM applications in infrastructure projects often emphasize coordination and visualization, with limited integration into formal quality management systems. Likewise, Cheng (2018) observed that BIM-based quality management practices are frequently implemented in an ad hoc manner, lacking standardized workflows. More recently, Parsamehr *et al.* (2023) highlighted that while BIM has been widely adopted to improve cost, time, and safety performance, quality management is often treated as a secondary outcome rather than a primary objective. This has resulted in a lack of consolidated knowledge regarding BIM-enabled quality management practices, their benefits, limitations, and implementation challenges. Consequently, practitioners and policymakers continue to lack clear, evidence-based guidance on how BIM can be strategically leveraged to enhance construction quality.

In response to these gaps, the aim of this review paper is to systematically review and synthesize existing research on the role of Building Information Modelling in enhancing quality management in construction projects. Specifically, the study seeks to identify key BIM functionalities that support quality management processes, classify BIM applications across different stages of the construction project lifecycle, analyse the benefits and challenges associated with BIM-enabled quality management, and highlight critical research gaps and future research directions. By adopting a comprehensive and structured review approach, this study integrates dispersed findings from the literature into a coherent and accessible body of knowledge.

The significance of this study lies in its dual academic and practical contributions. From an academic perspective, the review advances understanding by consolidating fragmented research on BIM and construction quality management, thereby providing a clearer conceptual foundation for future empirical and theoretical investigations. From a practical standpoint, the findings offer valuable insights for construction professionals, project managers, and policymakers seeking to improve quality performance through digital transformation. By clarifying how BIM can be effectively integrated into quality management practices, this study supports more proactive, data-driven approaches to achieving quality excellence throughout the construction project lifecycle.

2.0 LITERATURE REVIEW

2.1 Quality Management in Construction

Quality management (QM) in construction refers to the systematic processes employed to ensure that project outcomes meet specified requirements, client expectations, and regulatory standards throughout the project lifecycle. Unlike manufacturing, construction projects are typically characterized by fragmentation, temporary organizational structures, complex stakeholder interactions, and high levels of uncertainty. Oakland and Marosszeky (2017) emphasized that these characteristics significantly contribute to persistent quality-related challenges, including defects, rework, non-conformance, and cost overruns. More recently, Khatatbeh (2023) reaffirmed that such challenges remain prevalent despite ongoing advancements in construction management practices. As a result, effective quality management has long been recognized as a critical determinant of project success in the construction industry.

Quality management in construction is commonly structured around three interrelated components: quality planning, quality assurance (QA), and quality control (QC). Quality planning involves identifying applicable quality standards, defining quality objectives, and establishing procedures, responsibilities, and resources to ensure that these standards are achieved. In construction projects, quality planning is typically formalized through quality management plans, inspection and test plans, and detailed project specifications developed during the pre-construction and design stages. According to ISO (2015), effective quality planning provides the foundation for consistent quality performance; however, traditional approaches in construction rely heavily on static and document-based systems. This reliance limits adaptability and reduces the effectiveness of quality planning in highly dynamic and evolving project environments.

Quality assurance focuses on providing confidence that quality requirements will be fulfilled through systematic and preventive activities. QA emphasizes process-oriented approaches such as standardized workflows, audits, training programs, and continuous improvement mechanisms. In the construction context, QA is often aligned with formal quality management systems (QMS), particularly those based on the ISO 9001 standard. Aburas and Lee (2019) noted that ISO 9001 promotes a process-based and risk-informed approach to quality management, encouraging organizations to embed quality considerations within their operational processes. Nevertheless, empirical evidence suggests that ISO 9001 implementation in construction is frequently driven by contractual or certification requirements rather than genuine performance improvement. Aburas (2020) found that such compliance-oriented implementation often limits the standard's ability to deliver measurable improvements in construction quality outcomes.

Quality control, in contrast, is primarily concerned with the operational techniques used to verify that construction outputs conform to specified requirements. QC activities include inspections, testing, defect identification, and corrective actions, most of which occur during the construction phase. Traditional QC practices in construction are largely reactive, relying on manual inspections, paper-based records, and post-work checks. Oluwatosin (2024) observed that this reactive nature often results in late detection of defects, increased levels of rework, and inefficient transfer of quality-related knowledge across project stages.

Beyond ISO-based systems, Total Quality Management (TQM) principles have also influenced construction quality practices. TQM emphasizes customer satisfaction, leadership commitment, employee involvement, and continuous improvement across organizational processes. While TQM has demonstrated potential benefits in improving construction performance, its implementation remains challenging due to the project-based nature of the industry and limited integration of quality considerations across the project lifecycle. As argued by Oakland and Marosszeky (2017), these limitations highlight the need for more integrated, proactive, and data-driven quality management approaches capable of addressing the inherent complexity of construction projects.

2.2 Overview of Building Information Modelling (BIM)

Building Information Modelling (BIM) has emerged as a transformative digital approach for managing information throughout the lifecycle of a built asset. BIM is commonly defined as a shared digital representation of the physical and functional characteristics of a facility that provides a reliable basis for decision-making from early design through construction and operation. According to ISO 19650-1 (2018), BIM enables structured information management within a collaborative environment, supporting consistency, traceability, and transparency across project stages. Unlike traditional two-dimensional documentation, BIM integrates geometric, semantic, and relational data into a centralized information environment, thereby enhancing collaboration among project stakeholders.

BIM is frequently described through its dimensional extensions, which reflect the progressive enrichment of model-based information. Three-dimensional (3D) BIM represents the geometric and spatial configuration of building elements, enabling improved visualization and clash detection. Four-dimensional (4D) BIM incorporates time-related information to support construction sequencing and schedule optimization, while five-dimensional (5D) BIM

integrates cost data to enhance cost control and forecasting. More advanced dimensions include 6D BIM, which focuses on sustainability and performance analysis, and 7D BIM, which supports facility management and asset lifecycle optimization. Succar (2009) provided one of the earliest frameworks linking BIM dimensions to project outcomes, while Ghansah and Edwards (2024) highlighted the growing relevance of higher BIM dimensions in supporting quality assurance and long-term asset performance.

The concept of BIM maturity further explains variations in the extent and effectiveness of BIM implementation across organizations and projects. BIM maturity models, such as those proposed by Succar (2009), classify BIM adoption into stages ranging from object-based modelling to collaborative and fully integrated practices. Lower maturity levels are typically associated with isolated model use and limited data integration, whereas higher maturity levels enable seamless information exchange, automation, and lifecycle-oriented management. However, empirical evidence suggests that many construction projects continue to operate at intermediate maturity levels, which constrains the full realization of BIM's potential benefits for quality management (Rawdin, 2023).

The value of BIM becomes most apparent when examined across the construction project lifecycle. During the design phase, BIM supports quality planning by enhancing visualization, improving design coordination, and enabling rule-based compliance checking. In the construction phase, BIM facilitates quality control through model-based inspections, clash detection, and real-time issue tracking. During the operation and maintenance phase, BIM contributes to quality assurance by providing accurate as-built information and supporting asset performance monitoring. Araya-Santelices *et al.* (2025) demonstrated that when BIM is integrated with quality management systems, it enables a more holistic and lifecycle-oriented approach to quality management. This lifecycle perspective positions BIM as a critical enabler of integrated quality management, addressing many of the limitations associated with traditional, document-based quality practices.

3.0 RESEARCH METHODOLOGY

This study employs a systematic literature review approach to examine existing research on the role of Building Information Modelling (BIM) in enhancing quality management in the construction industry. A systematic review was selected due to its ability to ensure transparency, reproducibility, and comprehensive coverage of relevant literature, which is particularly important in BIM-related research characterized by methodological diversity and rapid technological development (Tranfield *et al.*, 2003; Page *et al.*, 2021).

A structured literature search was conducted using Scopus, Web of Science, and Google Scholar, chosen for their extensive coverage of peer-reviewed construction and engineering research. The search strategy employed a combination of keywords and Boolean operators to capture studies addressing BIM-enabled quality management. The primary search string included: “*Building Information Modelling*” OR “*BIM*” AND “*quality management*” OR “*quality control*” OR “*quality assurance*” AND “*construction*”. Related terms and synonyms were also used to ensure comprehensive retrieval of relevant studies.

Clear inclusion and exclusion criteria were applied to refine the search results. Only English-language publications from the last ten years were considered to reflect current BIM practices. The review included peer-reviewed journal articles and conference papers, while excluding grey literature, dissertations, and studies lacking a clear focus on BIM applications for quality management. Articles that discussed BIM without explicit relevance to quality-related processes were also excluded.

Data were systematically extracted from the final set of selected studies and analysed using thematic analysis. The literature was classified according to project lifecycle stages (design, construction, and operation), quality management functions (quality planning, assurance, and control), and BIM capabilities (such as clash detection, model-based inspection, automation, and information integration). This analytical framework enabled a structured synthesis of how BIM contributes to quality management across different project phases and contexts.

4.0 RESULT AND DISCUSSION

4.1 BIM Applications in Construction Quality Management

Building Information Modelling (BIM) has increasingly been recognized as a powerful enabler of quality management in construction by embedding quality-related considerations within digital project workflows. Unlike traditional quality management approaches that rely on fragmented documentation and post hoc inspections, BIM facilitates a more proactive, integrated, and data-driven approach to managing quality across the project lifecycle. Chen and Luo (2014) were among the early scholars to demonstrate how BIM can support systematic quality planning and control, while subsequent reviews have confirmed BIM's growing role in improving quality-related processes and outcomes (Panah & Kioumars, 2021). Collectively, existing studies show that BIM supports quality planning, quality assurance, and quality control through a range of model-based applications that enhance information reliability, process transparency, and decision-making.

4.1.1 BIM for quality planning

Quality planning aims to establish quality objectives, standards, and procedures at the early stages of a project to prevent defects before construction begins. BIM plays a critical role in this phase by enabling enhanced design coordination and clash detection, which remain among the most widely adopted BIM applications. By using three-dimensional, information-rich models, designers and engineers can identify geometric, spatial, and system-level conflicts between architectural, structural, and building services components prior to construction. According to Eastman *et al.* (2018), early clash detection significantly reduces design errors and coordination failures, thereby minimizing downstream rework. More recently, Won *et al.* (2023) provided empirical evidence that BIM-based design coordination improves overall design quality in complex building projects.

Beyond clash detection, BIM supports constructability analysis by enabling virtual simulations of construction processes. These simulations allow project teams to evaluate buildability issues related to site constraints, material interfaces, tolerances, and construction sequencing during the planning stage. Ma *et al.* (2018) demonstrated that BIM-based constructability analysis facilitates early identification of potential quality risks that are often overlooked in traditional

two-dimensional planning environments. Similarly, Ghansah and Edwards (2024) highlighted that digital simulations enhance proactive quality planning by enabling early testing of construction scenarios and methods.

BIM also strengthens standardization and specification compliance during quality planning by embedding design standards, codes, and technical specifications directly within the model. Parametric objects and standardized component libraries promote consistency in design application and reduce ambiguity across project documents. Solihin and Eastman (2015) showed that BIM-based rule definitions can automate compliance checking against predefined standards, while Araya-Santelices *et al.* (2025) further demonstrated how BIM-enabled rule systems can be aligned with formal quality management standards such as ISO 9001. These capabilities enhance quality planning by reducing variability and minimizing the likelihood of non-conformance during construction.

4.1.2 BIM for quality assurance

Quality assurance focuses on ensuring that construction processes are capable of consistently delivering the desired quality outcomes. BIM contributes to QA by improving information accuracy and consistency, which are fundamental to effective quality management. In BIM-enabled environments, project information is stored within a centralized or federated model, reducing duplication, inconsistencies, and information loss commonly associated with document-based systems. According to ISO 19650-1 (2018), structured information management within a shared data environment enhances traceability and ensures that stakeholders work with coordinated and up-to-date information.

BIM further supports quality assurance through model-based workflows that replace fragmented, paper-based procedures with integrated digital processes. Activities such as design approvals, inspections, and change management can be linked directly to BIM objects, enabling systematic verification and documentation of quality-related processes. Aburas and Lee (2019) noted that such model-based workflows align closely with the preventive principles underpinning ISO 9001, while Cheng (2018) observed that BIM-enabled workflows improve process transparency and accountability across project teams.

Another critical contribution of BIM to quality assurance lies in its ability to enhance collaboration and communication among project stakeholders. BIM platforms provide a common visual and informational reference point that supports multidisciplinary coordination and reduces misinterpretation. Oakland and Marosszeky (2017) emphasized that effective communication is central to robust quality assurance systems, and more recent studies have shown that BIM-enabled collaboration supports early problem resolution, shared quality responsibility, and continuous improvement (Parsamehr *et al.*, 2023).

In addition, BIM can be integrated with quality assurance documentation systems, including inspection and test plans, method statements, and non-conformance reports. By linking QA documents directly to model elements, BIM enables real-time access to quality records and enhances auditability. Chen and Luo (2014) highlighted that such integration supports systematic monitoring of compliance with quality procedures, while Panah and Kioumars (2021) noted its potential to facilitate organizational learning and knowledge transfer across projects.

4.1.3 BIM for quality control

Quality control focuses on verifying that construction outputs conform to specified requirements through inspection, testing, and corrective actions. BIM enhances quality control by enabling automated rule checking, whereby models are evaluated against predefined rules, codes, and specifications. This automation reduces reliance on manual inspections and enables early detection of non-compliance. Solihin and Eastman (2015) demonstrated that rule-based BIM systems can effectively support dimensional checks and code compliance, while Lee *et al.* (2014) highlighted their applicability in infrastructure projects during design and pre-construction stages.

BIM also supports defect detection and tracking by enabling systematic recording, visualization, and management of quality issues within the model environment. Defects can be linked to specific building elements, assigned responsibilities, and tracked throughout their resolution lifecycle. Ma *et al.* (2018) showed that BIM-based defect management improves transparency and accountability, while Hwang *et al.* (2020) emphasized its value in reducing rework and associated cost impacts through timely corrective actions.

As-built verification represents another significant BIM-enabled quality control application. This process involves comparing constructed elements with design intent to assess compliance and accuracy. BIM models can be updated to reflect as-built conditions, creating reliable digital records that support quality verification and future asset management. Bosché *et al.* (2015) demonstrated the effectiveness of integrating BIM with laser scanning technologies to automate as-built verification, and subsequent studies have reinforced its value in improving inspection accuracy and efficiency (Panah & Kioumars, 2021).

More recently, BIM has been integrated with emerging digital technologies such as Internet of Things (IoT) sensors to support real-time quality monitoring. Tang *et al.* (2023) showed that BIM–IoT integration enables continuous data collection on construction processes and material performance, supporting early detection of quality deviations. While such applications remain at an early stage of adoption, Ghansah and Edwards (2024) argued that they hold significant potential to transform quality control from a reactive activity into a predictive and proactive process. Table 4.1 maps out BIM capabilities to quality management functions.

Table 4.1: Mapping BIM Capabilities to Quality Management Functions

BIM Capability	Quality Planning	Quality Assurance	Quality Control
3D Modelling	✓	✓	✓
4D/5D Simulation	✓	–	✓
Rule-Based Checking	✓	–	✓
CDE	–	✓	✓
Laser Scanning	–	–	✓
IoT Integration	–	–	✓

✓ = strong relevance

The reviewed literature collectively indicates that BIM enhances construction quality management by linking digital capabilities to quality management functions across the project lifecycle, ultimately improving quality outcomes. BIM does not replace traditional quality management systems; rather, it digitally operationalizes quality planning, quality assurance,

and quality control by embedding them within model-based workflows. Table 4.2 summarizes the BIM enabled quality management in construction

Table 4.2: BIM-Enabled Quality Management in Construction

BIM Capability	Quality Management Function	Project Phase	Key Mechanism	Quality Outcomes	Key Sources
3D modelling & clash detection	Quality Planning	Design	Early identification of design conflicts	Error prevention, reduced rework	Eastman <i>et al.</i> (2018); Won <i>et al.</i> (2023)
Constructability simulation (4D BIM)	Quality Planning	Pre-construction	Virtual sequencing and buildability analysis	Improved constructability, fewer site defects	Ma <i>et al.</i> (2018); Ghansah & Edwards (2024)
Standardized object libraries	Quality Planning	Design	Embedded specifications and standards	Design consistency, compliance	Solihin & Eastman (2015)
Common Data Environment (CDE)	Quality Assurance	All phases	Centralized and traceable information	Information accuracy, auditability	ISO 19650-1 (2018); Cheng (2018)
Model-based workflows	Quality Assurance	Design & Construction	Digital approvals and process control	Process consistency, reduced variability	Aburas & Lee (2019)
Rule-based model checking	Quality Control	Design	Automated compliance verification	Early non-conformance detection	Lee <i>et al.</i> (2014); Solihin & Eastman (2015)
BIM-linked issue tracking	Quality Control	Construction	Visualization and tracking of defects	Faster resolution, accountability	Panah & Kioumars (2021)
Laser scanning–BIM integration	Quality Control	Construction	As-built verification	Dimensional accuracy, reduced rework	Bosché <i>et al.</i> (2015)
BIM–IoT integration	Quality Control	Construction	Real-time performance monitoring	Predictive quality control	Tang <i>et al.</i> (2023)

Table 4.2 demonstrates that BIM functions as a digital bridge between quality management theory and construction practice, transforming quality management from:

- i. Reactive → Proactive
- ii. Document-based → Data-driven
- iii. Fragmented → Lifecycle-integrated

4.2 BIM Across the Construction Lifecycle

The literature increasingly recognizes that the value of Building Information Modelling (BIM) for quality management is maximized when it is applied holistically across the entire

construction lifecycle rather than being confined to isolated project stages. BIM enables the continuity of quality-related information from design through construction and into operation and maintenance, thereby supporting more proactive, traceable, and data-driven quality management practices. By integrating quality considerations across lifecycle phases, BIM addresses many of the discontinuities inherent in traditional, document-based approaches to construction quality management.

4.2.1 Design phase: Enhancing design quality and error reduction

During the design phase, BIM plays a critical role in quality planning and defect prevention. One of the most widely reported benefits of BIM at this stage is the reduction of design errors through three-dimensional coordination and clash detection. By enabling early identification of spatial conflicts among architectural, structural, and building services systems, BIM allows design issues to be resolved before construction commences. Eastman *et al.* (2018) emphasized that resolving clashes during design significantly reduces downstream quality problems and costly rework, a finding that has been reinforced by more recent empirical evidence from complex building projects (Won *et al.*, 2023).

Beyond clash detection, BIM enhances overall design quality by supporting constructability analysis and rule-based compliance checking. Designers can use BIM to simulate construction sequences, evaluate alternative design solutions, and embed regulatory requirements and technical specifications directly into model objects. Solihin and Eastman (2015) demonstrated that automated rule checking improves compliance with codes and standards, while Chen and Luo (2014) showed that BIM-based design validation enhances consistency and clarity in project documentation. These capabilities reduce ambiguity in drawings and specifications, ensuring alignment with quality requirements before construction begins.

BIM also facilitates interdisciplinary collaboration during the design phase by providing a shared digital environment in which stakeholders can collectively review and validate quality objectives. Improved collaboration enhances transparency in decision-making and enables early resolution of quality-related concerns. As noted by Parsamehr *et al.* (2023), such collaborative BIM practices reduce the likelihood of design-related non-conformances and contribute to higher overall design quality.

4.2.2 Construction phase: Quality monitoring, rework reduction, and non-conformance management

During the construction phase, BIM shifts quality management from traditional, document-based inspections toward model-driven quality control and real-time monitoring. BIM models serve as digital reference standards against which on-site work can be assessed, improving the accuracy, consistency, and efficiency of inspections. Ma *et al.* (2018) demonstrated that BIM-enabled inspection processes support systematic quality control by linking inspection activities directly to model elements.

BIM further supports the identification and management of non-conformances by enabling defects to be visually located within the model, linked to inspection records, and tracked through structured resolution workflows. Panah and Kioumars (2021) highlighted that this model-based approach improves traceability, accountability, and communication among project participants, reducing delays and misunderstandings associated with quality issues.

The integration of BIM with emerging digital technologies has further enhanced on-site quality monitoring capabilities. Bosché *et al.* (2015) showed that integrating BIM with laser scanning enables automated comparison between as-built conditions and design models, significantly improving the accuracy of dimensional and geometric quality verification. Similarly, Tang *et al.* (2023) demonstrated that BIM–IoT integration allows real-time monitoring of construction processes and environmental conditions, supporting predictive quality control and early intervention. Collectively, these BIM-enabled applications contribute to reduced rework, improved compliance with specifications, and more consistent construction quality outcomes.

4.2.3 Operation and maintenance Phase: Asset quality and facility management integration

In the operation and maintenance (O&M) phase, BIM supports long-term quality management by providing reliable as-built information and structured asset data. BIM models enriched with verified construction data serve as digital asset repositories, ensuring the accuracy and completeness of facility documentation. Arayici and Aouad (2010) were among the first to highlight the potential of BIM to support facility management by maintaining continuity of quality-related information beyond project delivery.

The integration of BIM with facility management (FM) systems further enhances lifecycle quality assurance by supporting maintenance planning, asset performance monitoring, and informed decision-making. Leygonie *et al.* (2022) demonstrated that BIM-based FM systems improve information accessibility, reduce data loss during handover, and enhance long-term asset performance. By enabling continuous access to accurate quality-related information, BIM supports a lifecycle-oriented approach to quality management that extends well beyond the construction phase. Table 4.3 summarizes BIM applications for quality management across project lifecycle phase

Table 4.3: BIM applications for quality management across lifecycle phases

Lifecycle Phase	BIM Applications	Quality Management Function	Representative Sources
Design	Clash detection, constructability analysis	Quality Planning	Eastman <i>et al.</i> (2018); Solihin & Eastman (2015)
Construction	Defect tracking, as-built verification	Quality Control	Bosché <i>et al.</i> (2015); Panah & Kioumars (2021)
Operation & Maintenance	Asset information modeling, FM integration	Quality Assurance	Leygonie <i>et al.</i> (2022); Shahrudin & Zairul (2020)

Despite these benefits, the literature notes that BIM adoption in the O&M phase remains less mature compared to design and construction, highlighting the need for standardized data requirements and stronger integration between BIM and FM systems (Shahrudin & Zairul, 2020).

4.3 Benefits, Challenges, And Limitations of BIM-Enabled Quality Management

4.3.1 Benefits of BIM in construction quality management

The literature consistently reports that BIM delivers substantial benefits to construction quality management by enabling early error detection, improving information reliability, and enhancing process integration. One of the most frequently cited benefits is the reduction of defects and rework through early-stage design coordination, clash detection, and constructability analysis. Love *et al.* (2016) demonstrated that rework constitutes a major source of inefficiency in construction projects, while more recent evidence suggests that BIM-enabled coordination significantly mitigates such quality failures (Won *et al.*, 2023). By identifying potential quality issues before construction begins, BIM shifts quality management from a corrective to a preventive orientation.

BIM also enhances information accuracy, consistency, and traceability, which are fundamental requirements for effective quality assurance. The adoption of a common data environment ensures that stakeholders access coordinated and up-to-date information throughout the project lifecycle. According to ISO 19650-1 (2018), structured information management improves auditability and reduces discrepancies between drawings, specifications, and on-site execution. This capability strengthens compliance with formal quality management systems, including ISO 9001.

Another widely acknowledged benefit of BIM is its capacity to enhance collaboration and communication among project participants. BIM's visual and data-rich environment facilitates interdisciplinary coordination and promotes a shared understanding of quality requirements. Oakland and Marosszeky (2017) emphasized that effective collaboration is central to achieving consistent quality outcomes, while Parsamehr *et al.* (2023) found that BIM-enabled collaboration contributes to fewer disputes, improved decision-making, and increased stakeholder confidence.

In addition, BIM supports automation and data-driven quality control through rule-based checking, defect tracking, and integration with sensing technologies. Panah and Kioumars (2021) highlighted that these capabilities reduce reliance on manual inspections and enable more systematic, efficient, and transparent quality control processes.

4.3.2 Challenges in implementing BIM for quality management

Despite its demonstrated benefits, the implementation of BIM for quality management is associated with several challenges. Technical barriers remain prominent, particularly issues related to interoperability between BIM platforms and inconsistencies in data standards. Solihin and Eastman (2015) noted that poor model quality and incompatible data structures can undermine the effectiveness of automated checking and model-based quality processes.

Organizational and human factors also pose significant obstacles. The effective use of BIM for quality management requires new competencies, revised workflows, and a shift toward collaborative working practices. Succar (2009) argued that low levels of BIM maturity limit the integration of BIM into core management functions, while Rawdin (2023) observed that resistance to change and inadequate training remain persistent challenges in many organizations.

Contractual and legal constraints further complicate BIM-enabled quality management. Traditional procurement and contract arrangements often fail to clearly define responsibilities for model accuracy, data ownership, and liability related to BIM-based decisions. Aburas (2020) highlighted that such ambiguities discourage full reliance on BIM for quality assurance and control, particularly in risk-averse project environments. Table 4.4 summarizes quality management challenges and solutions while table 4.5 summarizes the benefit and challenges of BIM enabled quality management

Table 4.4: Quality management challenges and BIM-based solutions

Quality Challenge	Traditional Approach	BIM-Based Solution	Key Benefit
Design inconsistencies	2D drawings	3D coordinated models	Error prevention
Late defect detection	Manual inspections	Clash detection, rule checking	Reduced rework
Information loss	Paper-based records	Common Data Environment	Data traceability
Poor collaboration	Fragmented communication	Model-based collaboration	Improved quality decisions
Inaccurate as-builts	Manual updates	Laser scanning–BIM integration	Reliable asset data

Table 4.5: Benefits and challenges of BIM-enabled quality management

Dimension	Benefits	Challenges / Limitations
Technical	Automated checking, data accuracy	Interoperability issues
Organizational	Improved collaboration	Resistance to change
Process	Proactive quality management	Lack of standardized workflows
Lifecycle	Improved asset quality	Limited O&M adoption
Economic	Reduced rework costs	High initial investment

4.4 Limitations of Existing Research and Future Research Directions

Although the body of literature on BIM-enabled quality management has expanded significantly in recent years, several limitations continue to constrain a comprehensive understanding of its effectiveness and implementation. A substantial proportion of existing studies adopt case-based or conceptual approaches, with limited large-scale empirical validation across diverse project types, organizational contexts, and geographic regions. This methodological concentration restricts the generalizability of findings and limits the ability to draw robust conclusions regarding the broader impact of BIM on construction quality management.

One of the most prominent gaps identified in the literature is the absence of standardized and empirically validated metrics for assessing quality performance in BIM-enabled projects. The lack of consistent quality indicators complicates cross-study comparison and weakens evidence synthesis, thereby limiting the development of cumulative knowledge in this domain. Future research should therefore focus on the development and validation of BIM-based quality key

performance indicators (KPIs) that align with formal quality management frameworks and lifecycle performance objectives.

Another critical limitation relates to the uneven lifecycle coverage of existing research. Most studies emphasize BIM applications during the design and construction phases, while the operation and maintenance phase remains comparatively underexplored. Given the long-term nature of asset performance and quality assurance, there is a clear need for empirical studies that examine BIM-enabled quality management in facility operation, maintenance, and lifecycle optimization contexts.

Advanced digital applications, including BIM–Internet of Things (IoT) integration, predictive quality analytics, and AI-driven quality control, also remain largely confined to experimental or pilot implementations. While these technologies demonstrate considerable potential to transform quality management from a reactive to a predictive and data-driven process, their large-scale validation in real-world projects is still limited. Longitudinal case studies, cross-country comparisons, and industry-wide implementations are required to assess their technical feasibility, organizational implications, and value contribution.

Finally, organizational, contractual, and governance-related factors represent an underdeveloped area of research. Limited attention has been paid to behavioural aspects, responsibility allocation, data ownership, and contractual mechanisms that enable or constrain BIM-based quality management. Addressing these issues through research on governance models, procurement strategies, and collaborative contracting arrangements is essential to support effective BIM integration across the construction lifecycle. Table 4.6 summarizes the key research gaps identified in the literature and outlines corresponding directions for future research.

Table 4.6: Identified Research Gaps and Future Research Directions

Research Gap	Current Limitation	Suggested Future Research
Quality performance metrics	Lack of standardized indicators	Development of BIM-based quality KPIs
Lifecycle integration	Focus on design and construction	O&M-focused empirical studies
Advanced technologies	Mostly conceptual or pilot studies	Large-scale BIM–IoT validation
Organizational factors	Limited behavioural and governance analysis	Governance and contract model studies
Automation	Limited rule-based quality checking	AI-driven quality analytics

5.0 CONCLUSION AND RECOMMENDATION

Conclusion

This review demonstrates that BIM plays a transformative role in enhancing construction quality management across the project lifecycle. By enabling early error detection, improving information reliability, and supporting integrated quality processes, BIM shifts quality management toward a proactive and preventive paradigm. While significant benefits have been reported in design and construction phases, challenges related to interoperability, organizational readiness, and lifecycle integration persist. The study provides a structured understanding of BIM-enabled quality management and offers a foundation for future empirical research. Continued advancement in BIM integration, standardization, and data-

driven quality analytics is essential to fully realize its potential for improving construction quality outcomes.

Recommendations

Recommendations for Industry Practice

- i. Adopt BIM as a lifecycle quality management platform; Organizations should move beyond using BIM primarily for visualization and coordination and instead integrate it into formal quality management systems (e.g., ISO 9001) to support quality planning, assurance, and control across all project phases.
- ii. Standardize BIM-based quality workflows; The absence of standardized procedures for BIM-enabled inspections, defect tracking, and non-conformance management limits scalability. Industry bodies should develop standardized BIM-QM protocols aligned with ISO 19650.
- iii. Enhance workforce competencies; Effective BIM-enabled quality management requires targeted training that integrates quality management principles with BIM capabilities, rather than treating BIM as a purely technical tool.
- iv. Integrate BIM with site data capture technologies; Construction firms should increasingly adopt BIM integration with laser scanning, mobile inspection tools, and IoT systems to enable real-time and automated quality control.
- v. Strengthen BIM use in operation and maintenance; Clients and asset owners should specify BIM-based quality information requirements at early project stages to ensure reliable asset quality data for facility management.

Recommendations for Policy and Standards Development

- i. Policymakers should mandate quality-related information requirements in BIM execution plans (BEPs).
- ii. Regulatory authorities should encourage model-based compliance checking for building approvals and inspections.
- iii. Public-sector clients can accelerate adoption by linking BIM deliverables to quality performance indicators

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