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TRANSFORMING CONSTRUCTION DELIVERY IN SOUTH AFRICA THROUGH BUILDING INFORMATION MODELLING: A REVIEW ACROSS THE PROJECT LIFECYCLE

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Abstract

The construction industry is increasingly adopting digital technologies to improve project planning, coordination, productivity and information management. Among these technologies, Building Information Modelling (BIM) has emerged as an important approach for integrating project information throughout the construction lifecycle. BIM extends beyond three-dimensional modelling and incorporates a range of technologies and applications, including four-dimensional scheduling, five-dimensional cost management, clash detection, common data environments, reality capture, augmented and virtual reality, mobile applications and digital twins. In South Africa, BIM adoption has increased as construction organisations seek to respond to growing demands for improved project coordination and digital transformation. However, the application of BIM technologies differs according to project stage, organisational capability and project requirements. This paper presents a critical narrative review of BIM technologies used within the South African construction sector, with particular attention to their application by construction contractors across different project stages. The review discusses BIM applications during planning and design, procurement and pre-construction, construction, handover and operation. The paper argues that BIM adoption should be understood as a lifecycle process rather than as the use of a single software platform. While conventional 3D BIM, design coordination and visualisation have become relatively established applications, advanced applications involving 4D and 5D BIM, reality capture, digital twins and integrated asset management remain less consistently implemented. The paper concludes that greater value can be obtained when contractors integrate BIM technologies with construction planning, cost management, site operations and asset information management. The review provides a conceptual basis for understanding BIM technology application within the South African construction lifecycle and identifies opportunities for deeper digital integration.

Keywords: Building Information Modelling; Construction Contractors; South Africa; BIM Technologies; Construction Lifecycle; Digital Construction; 4D BIM; 5D BIM.

1. INTRODUCTION

Building Information Modelling (BIM) has become an important digital innovation in the global construction industry because it supports the creation, exchange and management of structured information about built assets throughout their lifecycle (Bryde, Broquetas & Volm, 2013; Volk, Stengel & Schultmann, 2014). BIM extends beyond three-dimensional computer-aided design because it combines geometric representations with information relating to materials, quantities, time, cost, performance and asset operation (Eastman et al., 2011; Sacks et al., 2018). It can therefore be understood as an information-centred process that facilitates collaborative planning, design, construction and management of built assets from project inception to operation, maintenance and eventual renewal or demolition (Succar, 2009; Volk et al., 2014). The growing global use of BIM is associated with improved visualisation,

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interdisciplinary coordination and communication among clients, designers, engineers, quantity surveyors, contractors and facilities-management personnel (Azhar, 2011; Bryde et al., 2013). Three-dimensional BIM models can improve design communication and support earlier detection of clashes between architectural, structural and building-services elements, thereby reducing the likelihood of errors and rework during construction (Azhar, 2011; Sacks et al., 2018). Four-dimensional BIM incorporates time-related information to support construction sequencing, programme planning and progress monitoring, while five-dimensional BIM links model elements to quantities and cost information for estimating and cost control (Kassem, Iqbal & Kelly, 2013; Sacks et al., 2018).

BIM can also support operation and maintenance through the management of as-built information, facilities-management data, maintenance histories and asset-performance information (Volk et al., 2014; Pärn, Edwards & Sing, 2017).Despite its documented benefits, BIM implementation remains uneven across national contexts, professional disciplines and construction organisations (Succar & Kassem, 2015; Ghaffarianhoseini et al., 2017). Research on developing-country contexts identifies high software and hardware costs, inadequate technical infrastructure, lack of trained personnel, resistance to organisational change, weak client demand, fragmented procurement arrangements and the absence of supportive standards as common constraints on BIM adoption (Ahuja, Sawhney & Arif, 2018; Matarneh & Hamed, 2017). BIM adoption is therefore not simply a matter of purchasing software; it requires organisational readiness, leadership support, information-management protocols, interoperable workflows and the capacity to collaborate across the construction supply chain (Succar, 2009; Ghaffarianhoseini et al., 2017). The South African construction sector provides an important setting for examining BIM technologies because it faces persistent demands for infrastructure delivery, improved project performance, sustainability and more efficient use of constrained resources (Calitz & Wium, 2022; Venter, Ngobeni & du Plessis, 2021).

South African construction organisations operate in an environment characterised by uneven technological capability, limited specialist digital skills, differing levels of organisational readiness and fragmented participation across the construction value chain (Venter et al., 2021; Calitz & Wium, 2022). BIM may help address some of these challenges by enabling improved multidisciplinary coordination, earlier resolution of design conflicts, more reliable quantity information, enhanced construction planning and better continuity of asset information beyond project handover (Calitz & Wium, 2022; Volk et al., 2014).

Existing South African evidence suggests that BIM uptake remains gradual and uneven, with larger firms and better-resourced professional practices generally more able to adopt BIM than smaller organisations (Venter et al., 2021; Calitz & Wium, 2022). Venter et al. (2021) identify factors such as cost, perceived risk, limited client demand and restricted awareness as barriers to BIM adoption among South African quantity-surveying practices. Calitz and Wium (2022) similarly argue that South Africa requires a coordinated framework for BIM implementation that addresses skills development, standards, stakeholder alignment and industry-wide adoption processes. Although scholarly work has examined BIM adoption and implementation barriers in South Africa, the literature requires further synthesis regarding BIM applications

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across the complete construction project lifecycle (Calitz & Wium, 2022; Venter et al., 2021). Existing studies often concentrate on adoption perceptions, specific professional groups or design-stage implementation, rather than examining the continuity of BIM information from design through construction to operation and maintenance (Pärn et al., 2017; Volk et al., 2014). A lifecycle perspective is necessary because BIM provides its greatest strategic value when information developed during design and construction remains accessible, accurate and useful for facilities management, maintenance planning and long-term asset decision-making (Volk et al., 2014; Pärn et al., 2017). The review addresses the following research questions:

1) What BIM technologies and applications are used across the design, construction, and operation-and-maintenance phases of South African construction projects?
2) What benefits are associated with BIM use across the construction project lifecycle?
3) What technical, financial, organisational, skills-related, and contractual and policy barriers constrain BIM adoption in South Africa?
4) What strategies can support more integrated BIM implementation among South African construction-industry stakeholders?

The remainder of the article presents the conceptual framework and methodology used for the review, followed by an examination of BIM adoption in the South African construction context. The paper then analyses BIM applications across the design, construction and operation-and-maintenance phases, discusses barriers and emerging opportunities, identifies gaps in current research and practice, and concludes with recommendations for industry, government, professional bodies and higher-education institutions.

2. CONCEPTUAL FRAMEWORK AND METHODOLOGY

2.1 Conceptual Framework

Building Information Modelling (BIM) is understood as an integrated digital process for generating, coordinating, exchanging and managing information about the physical and functional characteristics of built assets throughout their lifecycle (Succar, 2009; Sacks et al., 2018). BIM differs from conventional computer-aided drafting because it combines geometric representations with non-geometric information, including material specifications, quantities, costs, schedules, performance data, maintenance requirements and asset-management information (Eastman et al., 2011; Volk, Stengel & Schultmann, 2014). BIM can therefore provide a shared information environment through which project stakeholders make more reliable decisions during the planning, design, construction, operation and maintenance of buildings and infrastructure assets (Succar, 2009; Pärn, Edwards & Sing, 2017).

The scope of BIM in this review extends across three interrelated construction project-lifecycle phases: design, construction, and operation and maintenance. During the design phase, BIM supports three-dimensional modelling, visualisation, multidisciplinary coordination, design reviews, clash detection, quantity take-off and early-stage sustainability analysis (Azhar, 2011; Bryde, Broquetas & Volm, 2013). During construction, BIM can support construction

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sequencing, scheduling, cost estimation, procurement coordination, site-layout planning, progress monitoring, quality management and health-and-safety planning through four-dimensional and five-dimensional model applications (Sacks et al., 2018; Kassem, Iqbal & Kelly, 2013). In the operation-and-maintenance phase, BIM can provide structured as-built information for facilities management, planned maintenance, asset renewal and long-term building-performance monitoring (Volk et al., 2014; Pärn et al., 2017).

The conceptual framework adopted in this study views BIM as an information-management capability rather than merely a modelling technology. The framework proposes that effective BIM application depends on enabling conditions such as organisational readiness, skilled personnel, leadership support, software and hardware capability, interoperable data standards, collaborative procurement approaches and supportive policy or institutional arrangements (Succar & Kassem, 2015; Ghaffarianhoseini et al., 2017).

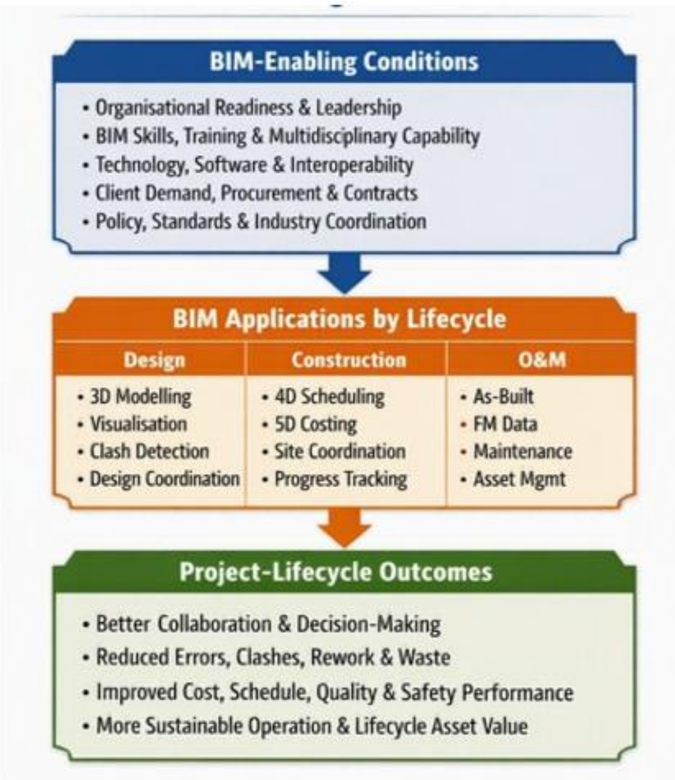

Figure: BIM Asset Management Framework

Figure 1: Conceptual Framework for BIM across the Construction Project Lifecycle

Source: *Author's compilation based on Succar (2009), Bryde et al. (2013), Volk et al. (2014), Venter et al. (2021), and Calitz and Wium (2022).*

These conditions influence the extent to which BIM can be integrated across project phases and used to generate outcomes such as improved coordination, reduced design errors, lower rework, better cost and schedule control, improved safety planning, enhanced facilities management and stronger lifecycle asset value (Bryde et al., 2013; Volk et al., 2014). For the South African context, the framework recognises that BIM use is mediated by financial capacity, digital skills, client demand, organisational maturity, and access to technology and industry-level standards. Research indicates that BIM adoption in South Africa remains uneven, with cost, awareness, perceived risk, insufficient demand and skills limitations influencing implementation among built-environment professionals (Venter, Ngobeni & du Plessis, 2021; Calitz & Wium, 2022). The framework consequently guides the review by examining BIM applications, reported benefits, adoption barriers and recommended interventions at each lifecycle stage.

2.2 BIM in the South African Construction Context

Building Information Modelling (BIM) adoption in South Africa has developed gradually and remains less mature than in many developed construction markets. Early BIM use was largely driven by individual architects, engineers, quantity surveyors and large construction organisations that adopted modelling software to improve design production, visualisation and coordination. This early adoption was generally organisation-specific rather than guided by a nationally coordinated implementation strategy, which resulted in fragmented practices, uneven capability and inconsistent information-management processes across the industry (Calitz & Wium, 2022; Venter, Ngobeni & du Plessis, 2021).

The South African construction industry has used BIM authoring technologies for more than a decade, yet adoption has not become widespread or fully integrated across the architecture, engineering and construction supply chain (Calitz & Wium, 2022; Olugboyega & Windapo, 2023). BIM use has tended to be concentrated in larger, better-resourced organisations and on projects where clients, consultants or contractors recognise the value of digital coordination. Smaller firms may face greater difficulty in acquiring software, upgrading hardware, retaining specialised BIM personnel and funding continuing training, contributing to uneven adoption across the sector (Venter et al., 2021; Calitz & Wium, 2022). Recent evidence suggests that BIM adoption and implementation have increased within the South African architecture, engineering and construction sector, although the level of maturity remains substantially behind that of more digitally advanced construction markets. A 2025 study reported that BIM implementation in South Africa has grown over time, but the sector is estimated to be approximately eight years behind developed countries and remains driven predominantly by private-sector organisations, with limited government support (Olugboyega & Windapo, 2025). This indicates that BIM development has been shaped primarily by market-based decisions rather than coordinated public-sector procurement requirements or a national digital-construction mandate.

2.3 Regulatory Environment and Industry Readiness

South Africa has established legal and regulatory frameworks governing construction quality, health and safety, procurement, professional practice and building standards. However, these frameworks have not historically included a comprehensive national BIM mandate, standardised BIM protocols or compulsory information-management requirements for public

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construction projects (Calitz & Wium, 2022; Olugboyega & Windapo, 2023). The absence of a unified BIM policy can result in organisations developing their own BIM standards, software preferences, model-exchange procedures and contractual arrangements, which may create interoperability challenges and limit collaboration between project participants (Calitz & Wium, 2022). Calitz and Wium (2022) identify leadership, strategy, and clearly defined roles and responsibilities as central requirements for facilitating BIM implementation across the South African construction industry. Their research further categorises the challenges to BIM adoption into educational, cultural, legal, financial and governmental dimensions, indicating that BIM readiness is influenced by more than the availability of software. Similarly, research on stakeholder perspectives suggests that government can facilitate BIM implementation by supporting BIM education and awareness, incentivising BIM use, adapting procurement processes, and enabling shared BIM libraries and data-exchange frameworks (Olawumi, Chan & Wong, 2021).

Industry readiness is therefore uneven. While some organisations possess advanced digital-design, coordination and modelling capabilities, others remain at a basic or exploratory level of BIM use. The readiness gap is associated with disparities in access to technology, software licences, high-performance hardware, reliable connectivity, BIM training and experienced information-management personnel (Venter et al., 2021; Calitz & Wium, 2022). BIM readiness also depends on the willingness of organisations to adjust established workflows, collaborate across disciplinary boundaries and invest in systems whose returns may not be immediate or easily measured (Succar & Kassem, 2015; Ghaffarianhoseini et al., 2017).

The Construction Industry Development Board has recently advanced a BIM implementation roadmap intended to support wider industry adoption, maturity assessment and the development of South African BIM standards and guidelines. The roadmap recognises that sector-wide BIM adoption requires coordinated attention to technology, stakeholder orientation and ecosystem regulation. While this development signals growing institutional recognition of BIM's strategic importance, its practical impact will depend on implementation capacity, industry participation, alignment with public procurement and the establishment of appropriate standards.

2.4 Major Stakeholders and Drivers of BIM Implementation

BIM implementation involves multiple stakeholders because information produced in one project phase must be used, validated and updated by participants in subsequent phases. Key stakeholders include clients and asset owners, architects, engineers, quantity surveyors, project managers, contractors, subcontractors, suppliers, facilities managers, government departments, professional bodies, universities, software providers and industry-development institutions (Succar, 2009; Calitz & Wium, 2022). Clients and public-sector infrastructure owners are particularly influential because they can specify BIM deliverables, information requirements and common data environments during project procurement. Client demand can encourage consultants and contractors to invest in BIM capability, establish collaborative workflows and allocate resources to model-based coordination. However, where clients do not request BIM deliverables or do not understand the lifecycle value of structured asset information,

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organisations may have limited incentive to move beyond basic modelling applications (Venter et al., 2021; Olugboyega & Windapo, 2025).

Professional institutions and industry bodies can support implementation by promoting competency standards, continuing professional development, common protocols and knowledge-sharing platforms. Calitz and Wium (2022) identify the BIM Institute, BIM Academy Africa and software developers as organisations contributing to BIM implementation in South Africa, although they argue that broader coordination is necessary to achieve consistent industry-wide adoption. Universities and higher-education institutions are also important because they can equip future architects, engineers, quantity surveyors, construction managers and facilities managers with multidisciplinary BIM competencies and collaborative digital-work practices. The main drivers of BIM adoption in South Africa include the need to improve project coordination, reduce design conflicts, enhance visualisation, improve quantity and cost information, increase programme certainty and strengthen collaboration between project participants.

2.5 Review of BIM Applications across the Project Lifecycle

BIM supports a continuous flow of coordinated information from early project planning through design, construction, handover, operation and maintenance. Its lifecycle value depends on whether project information is updated, shared and retained for use by subsequent stakeholders, rather than being lost or recreated at each project stage (Succar, 2009; Pärn, Edwards & Sing, 2017). In South Africa, BIM adoption is increasing but remains uneven, with applications often concentrated in the design phase and less consistently extended into construction management, facilities management and lifecycle asset operations (Calitz & Wium, 2022; Venter, Ngobeni & du Plessis, 2021).

Table 1 summarises the principal BIM applications across the design, construction, and operation-and-maintenance phases of the project lifecycle. It further identifies the expected benefits, implementation challenges and implications for the South African construction sector.

Table 1: BIM Applications across the South African Construction Project Lifecycle

Project-lifecycle phase	Core BIM applications	Key benefits	Main implementation challenges	Implications for South Africa
Design phase	3D modelling; architectural, structural and services coordination; visualisation; design reviews; clash detection; quantity take-off; preliminary cost planning; sustainability analysis	Improves design communication; supports early identification of design conflicts; reduces potential errors and rework; improves client understanding; assists early cost and constructability decisions	High software and hardware costs; limited BIM competence; resistance to new workflows; interoperability difficulties; uncertainty over model ownership	BIM can strengthen multidisciplinary coordination and reduce design-related variations, but its value is reduced where consultants use separate systems or do not apply shared modelling standards

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Construction phase	4D scheduling; 5D cost estimation; construction sequencing; site-layout planning; logistics coordination; procurement planning; progress monitoring; quality and safety visualisation	Improves construction sequencing; supports programme and cost control; enhances site communication; assists material and resource coordination; improves transparency when designs change	Limited contractor and subcontractor BIM capability; unreliable model updates; fragmented procurement; low client demand; limited integration with site-management systems	Contractors can use BIM to improve coordination, reduce construction conflicts and plan complex works, but adoption requires investment in site-ready digital systems and training
Operation and maintenance phase	As-built models; digital asset registers; equipment and warranty information; facilities management; maintenance planning; defect tracking; space management; energy-performance monitoring; refurbishment planning	Reduces information loss at handover; improves planned maintenance; supports lifecycle costing; strengthens facilities-management decisions; supports long-term sustainability and asset value	Incomplete as-built models; poorly defined information requirements; weak transfer to facilities teams; limited facilities-management BIM skills; system interoperability challenges	This is the least developed BIM area in South Africa but offers substantial potential for public infrastructure, commercial-property portfolios and long-term asset management
Whole-lifecycle integration	Common data environments; interoperable data standards; BIM execution plans; collaborative workflows; model-based procurement; digital handover; integration with sensors and digital twins	Enables information continuity; improves collaborative decisions; reduces duplicated information; strengthens cost, schedule, quality and asset-performance outcomes	Lack of national BIM standards; uneven organisational maturity; legal and contractual uncertainty; limited public-sector leadership and inconsistent industry protocols	Industry-wide adoption requires coordinated action by government, clients, professional bodies, universities and construction organisations

Source: *Author's compilation based on Succar (2009), Bryde, Broquetas and Volm (2013), Kassem, Iqbal and Kelly (2013), Volk, Stengel and Schultmann (2014), Pärn et al. (2017), Venter et al. (2021), and Calitz and Wium (2022).*

The table demonstrates that BIM's most immediate benefits are often achieved during design, where visualisation, coordination and clash detection can improve the quality of project information before construction starts. However, the strategic value of BIM increases when models are linked to construction sequencing, cost data, procurement planning and site-

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management activities. The operation-and-maintenance phase has the greatest potential for long-term asset value because accurate as-built models can support facilities management, planned maintenance, refurbishment and lifecycle decision-making (Volk et al., 2014; Pärn et al., 2017). Figure 2 presents the conceptual flow of BIM information across the project lifecycle. The figure shows that BIM should not be treated as a series of isolated software applications, but as an integrated information-management process. The quality of information generated in the design phase influences construction planning, while the accuracy of construction-stage updates determines whether the final asset-information model can be used effectively during operation and maintenance.

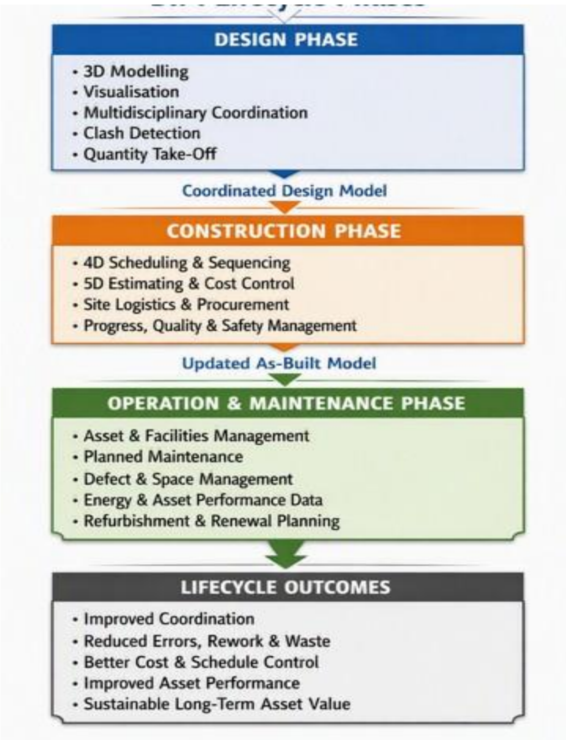

Figure 2: BIM-enabled information flow and outcomes across the construction project lifecycle

Figure 2: BIM-Enabled Information Flow across the Construction Project Lifecycle

Source: *Author's compilation based on Succar (2009), Bryde et al. (2013), Volk et al. (2014), and Pärn et al. (2017).*

3. LIMITATIONS OF CURRENT RESEARCH AND PRACTICE

The literature on Building Information Modelling in South Africa remains limited, fragmented and concentrated mainly on awareness, adoption barriers and stakeholder perceptions rather than measurable project outcomes. Existing studies often examine individual professional groups instead of integrated project teams, limiting understanding of BIM implementation

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across the full project lifecycle. Research on BIM use in facilities management, asset management, maintenance planning and post-construction operations is particularly limited, despite the importance of accurate as-built information for long-term asset performance. BIM adoption also remains unequal, as larger firms are generally better able to afford the technology, specialised skills and training required for implementation than smaller enterprises. Finally, because this review relied mainly on English-language peer-reviewed literature, it may exclude useful evidence from industry reports, government documents and unpublished project records. Future research should therefore use longitudinal, comparative and mixed-method studies to evaluate BIM outcomes across project types, lifecycle phases and organisational contexts in South Africa.

4. CONCLUSION AND RECOMMENDATIONS

This review examined the application of Building Information Modelling technologies across the design, construction, and operation-and-maintenance phases of the project lifecycle in South Africa. The review shows that BIM can improve project visualisation, design coordination, clash detection, quantity take-off, cost estimation, construction scheduling, site management, procurement coordination, facilities management and lifecycle asset decision-making. BIM should therefore be regarded as an integrated information-management process rather than only a three-dimensional modelling tool. The review further indicates that BIM adoption in South Africa is increasing, but its implementation remains fragmented and uneven. BIM use is generally more established in design-oriented activities than in construction management, procurement integration, facilities management and long-term asset operation. The full value of BIM is realised only when information created during design is updated during construction and transferred accurately to asset owners and facilities-management teams at project handover.

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