2025 European Conference on Computing in Construction

CIB W78 Conference on IT in Construction

Porto, Portugal
July 14-17, 2025

BUILDING INFORMATION MODELLING (BIM) INTEGRATION CAPABILITIES FOR SUPPLY CHAIN INTEGRATION IN CONSTRUCTION: A SYSTEMATIC REVIEW

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Abstract

The performance improvements of construction supply chains remain limited because of their fragmented nature. Building Information Modelling (BIM) functions as a digital integration enabler but its precise integration capabilities need further investigation. The study uses a systematic literature review to discover BIM integration capabilities, BIM-enabled integration practices (BEIPs), together with the technical mechanisms which support these practices. The findings demonstrate BIM capabilities which enable information integration together with process, relational, and technology integration. BIM technical mechanisms (BTMs) provide foundational support to integration capabilities but complementary technical mechanisms (CTMs) act as supplementary mechanisms which boost these capabilities.

Introduction

Construction industry faces a persistent problem of fragmentation which researchers have thoroughly studied throughout various academic publications (Dulaimi *et al.*, 2002; Mitropoulos and Tatum, 2000). The fragmentation within construction supply chains revealed the necessity for integration methods (Mitropoulos and Tatum, 2000). Construction supply chain integration (SCI) leads to better cost efficiency, time reduction, quality, and productivity results (Dulaimi *et al.*, 2002; Koolwijk *et al.*, 2018; Power, 2005). The construction industry has made slow progress towards SCI and remains behind other industries (Nguyen and Le, 2022). The lack of development in construction SCI stems from project-based priorities and competitive bidding systems (Doran and Giannakis, 2011).

The construction industry has been discussing technological integration as a solution to achieve better integration since the early 1990s (Mitropoulos and Tatum, 2000; Nam and Tatum, 1992). Integration receives enhancement through the use of information and communication technologies that help streamline delivery processes (Mitropoulos and Tatum, 2000; Nam and Tatum, 1992). Dulaimi *et al.* (2002) demonstrated that compatible information systems play a key role in helping construction project participants exchange information and share knowledge.

Building Information Modelling (BIM) is an information management process which operates through every stage of a built asset lifecycle. It promotes the structured exchange of information alongside collaborative ways of working, which uses digital models with semantic richness. The models serve to enhance design, construction, and operation activities by providing dependable decision support (Ezcan, Isikdag and Goulding, 2013; HM Government, 2015; ISO, 2018). Driven by digital technologies, BIM is increasingly recognised as a potential technological enabler to support SCI in construction (HM Government, 2015). Nonetheless, despite BIM's growing prominence, there remains a notable gap in the literature regarding the specific capabilities through which BIM facilitates SCI. This gap limits both theoretical development and the practical application of BIM to facilitate SCI in construction.

In response to this gap, this study seeks to identify the integration capabilities of BIM for enhancing SCI in construction. Anchored in a pragmatism research philosophy, the study adopts an outcome-oriented perspective, focusing on the effectiveness of BIM in real-world project practices (Creswell and Plano Clark, 2018; Johnson and Onwuegbuzie, 2004). Accordingly, BIM-enabled integration practices (BEIPs) are considered as proxies for BIM integration capabilities. BEIPs represent practices facilitated by BIM that contribute to SCI.

This research is further informed by a technical orientation, examining the BIM technical mechanisms (BTMs) that underpin BEIPs and the broader integration capabilities of BIM, alongside complementary technical mechanisms (CTMs) that enhance both BEIPs and BIM integration capabilities. BTMs encompass native BIM functionalities and internal processes that operate independently within the BIM environment. CTMs, by contrast, denote external tools and technologies that argument or extend BIM integration capabilities by either leveraging BIM functionalities or working interactively with BIM to enhance these capabilities.

Framed by these perspectives, this research addresses four questions: (1) What are the capabilities of BIM to facilitate supply chain integration in construction? (2) What BIM-enabled integration practices demonstrate BIM integration capabilities? (3) What BIM technical mechanisms underpin BIM-enabled integration practices and thus BIM integration capabilities? (4) What complementary technical mechanisms enhance BIM-enabled integration practices and, in turn, BIM integration capabilities?

By advancing understanding of BIM integration capabilities and the technical underpinnings that sustain integration practices, this research aims to contribute both conceptually and practically to the evolving discourse on digital integration within construction supply chains.

Methodology

This research employs a systematic literature review (SLR) methodology, drawing on the framework established by Tranfield, Denyer and Smart (2003), to ensure methodological rigour, transparency, and replicability. The SLR approach is appropriate for synthesising evidence from diverse sources, facilitating the development of a comprehensive and structured understanding of the capabilities of BIM in facilitating SCI. The review process was undertaken in three distinct stages.

Stage 1: Planning the Review

Scopus was selected as the primary database due to its comprehensive coverage of high-quality academic publications in the fields of construction management, digital technologies, and SCI. A search string was developed iteratively to capture relevant literature addressing the intersection of BIM and SCI (see Table 1). Pilot searches were conducted to refine the query and ensure both relevance and specificity.

Table 1: Search query used to retrieve relevant literature

Search Criteria	Search Terms / Parameters
BIM	"BIM" OR "Building Information Model*"
(AND) Integration	"integration" OR "integrating"
(AND) Supply Chain	"supply chain"
(AND) Construction	"construction" OR "building" OR "infrastructure"
(AND) Time Range	2010 - 2025
(AND) Subject	Engineering
(AND) Document Type	Article
(AND) Language	English

Inclusion criteria comprised: (i) peer-reviewed journal articles published between 2010 and 2025; (ii) publications in Q1 or Q2 journals (Scimago classification); (iii) studies in which BIM constitutes a central focus; and (iv) a clear technical orientation, defined as studies that proposed or applied technical frameworks, methods, or mechanisms related to BIM implementation, particularly those involving digital tools, structured processes, or system-based integration. Studies in which BIM was not demonstrably contributing to SCI were excluded.

Stage 2: Conducting the Review

The search yielded 59 articles. A two-step screening process was implemented, comprising an initial review of titles and abstracts, followed by a full-text assessment. This resulted in the selection of 13 articles that satisfied the inclusion criteria. These articles were subjected to in-depth analysis, focusing on extracting data related to BEIPs, BTMs, and CTMs.

Stage 3: Synthesising and Reporting

A thematic synthesis approach was employed to analyse the extracted data, with the aim of identifying recurrent patterns and concepts. This enabled the categorisation of distinct BEIPs, the underlying BTMs that underpin BIM integration capabilities, and the CTMs that operate alongside BIM to enhance SCI. Coding was conducted manually using a structured template, ensuring traceability between integration types, practices, and associated mechanisms. This synthesis provided the foundation for the development of a conceptual framework, which is elaborated upon in the subsequent findings and discussion section.

Findings and Discussion

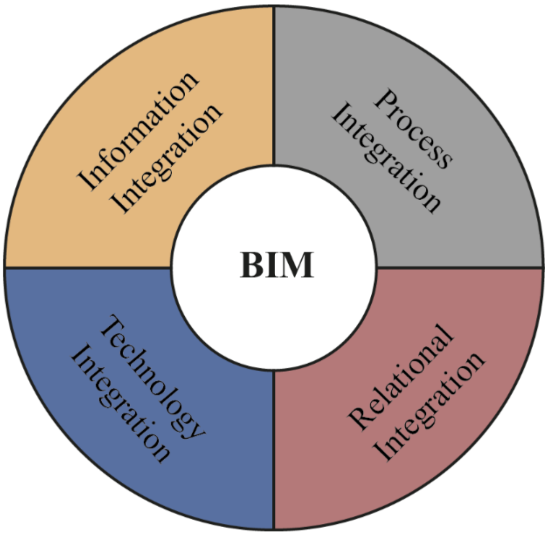

Figure 1: BIM Integration Capability Framework (BICF)

Drawing on the findings of the systematic review, this paper introduces the BIM Integration Capability Framework (BICF) (see Figure 1), which conceptualises the domains through which BIM facilitates SCI. The framework is structured around four pillars: information integration, process integration, relational integration, and technology integration. Each pillar is underpinned by a set of BEIPs that demonstrate BIM capability to enable SCI. The effectiveness of these practices is driven by BTMs and is further augmented by CTMs. The subsequent sections delineate the role of BEIPs, explain how they demonstrate BIM integration capabilities, specify the BTMs underpinning these capabilities, and clarify the ways in which CTMs enhance BIM integration capabilities.

Information Integration

BIM-Enabled Integration Practices:

Tracking Building Element Status through CAD-ERP-BIM Alignment. Supply chain partners receive instant status information about building elements throughout design, prefabrication, and construction phases through this practice. The approach resolves information transfer problems found in CAD to enterprise resource planning (ERP) and BIM systems by establishing coordinated data connections which enhances supply chain visibility and planning precision. BIM information integration capability is demonstrated through the synchronisation of status data between CAD, ERP and BIM systems for connecting production updates with building delivery and construction planning (Čuš-Babič *et al.*, 2014).

Automating Procurement Data Extraction from BIM. The practice uses automation to extract organised procurement details such as material quantities, specifications, and costs from IFC-based BIM models, while avoiding human involvement and ensuring standardised and validated information integration. It improves procurement data exchange and accessibility which cuts down on material planning inefficiencies and enhances decision-making processes. The practice demonstrates BIM information integration capability through its automated process of extracting validated material data from BIM and continuously synchronising it with procurement systems, thus enhancing interoperability and reducing data fragmentation among stakeholders (Kalantari, Taghaddos and Heydari, 2024).

Synchronising Demand Fluctuations with 4D BIM. The practice uses 4D BIM to connect supply chain data and monitor real-time demand changes so it matches materials with current construction progress. Dynamic look-ahead schedules combined with as-built site conditions enable data-driven supply adjustments which reduce dependence on static planning to respond to changing site situations. BIM information integration capability occurs through the real-time connection of contractor-supplier material demand data which provides suppliers with updated site conditions for supply chain decisions (Chen, García de Soto and Adey, 2021).

Standardising Material Data for Sustainability Assessment. The practice makes a standardised framework for material data in BIM systems which allows precise environmental product information transfer between supply chain participants. A standardised approach to embodied recipes together with Environmental Product Declarations (EPDs) improves data interoperability and allows better evaluation of embodied energy in sustainability assessments. BIM information integration capability occurs when material data is organised and connected to guarantee authenticated information transfer between supply chain stakeholders throughout lifecycle assessments (Al-Zrigat, 2025).

Synchronising Lifecycle Product Data with BIM. The practice facilitates the transmission of technical and commercial product details between manufacturers, suppliers, and project teams through the connection of BIM objects to Object Information Pack (OIP) identifiers. The identifiers access current product data to synchronise information within IFC models throughout the product life cycle thus solving fragmented and unchanging product information streams. BIM information integration capability is shown through the process of obtaining current product data while merging it into IFC models through OIP identifiers which enables supply chain participants to obtain standardised information (Nour, 2010).

Mapping Supply Chain Information Flows Using BIM-Integrated Multi-Model Graphs. The practice combines product information together with process data and organisational details to form a unified multi-model graph that shows supply chain information flows. The approach solves construction supply chain information fragmentation through dependency mapping of product components, processes, and actors, thus creating structured information alignment. BIM information integration capability becomes clear when multiple data sources merge into a multi-model graph that shows supply chain actor dependencies to improve information flow transparency (Papadonikolaki, Vrijhoef and Wamelink, 2015).

Synchronising BIM Families with a Blockchain-Enabled Common Data Environment (CDE). The integration of BIM families into a blockchain-enabled CDE provides supply chain stakeholders with a tamper-proof and smooth information transfer system. The system establishes standardised reusable components while providing transparent element tracking and circular economy compliance support for improved supply chain information integration. BIM information integration capability proves through structured immutable information flows that maintain standardised BIM families while providing secure blockchain-based tracking within the CDE (Elghaish *et al.*, 2023).

Automating BIM-Enabled Smart Contract Verification for Information Integrity. The practice uses BIM-generated data to automate smart contract transaction verification which guarantees the traceability and integrity of contractual information in supply chains. The system performs systematic project data and contract term validation within a blockchain that prevents tampering which minimises manual verification mistakes while enhancing transparency. BIM information integration capability proves through automated transaction validation of BIM-generated data and an unalterable verified contractual data record which is distributed throughout the supply chain (Celik, Petri and Rezgui, 2023).

BIM Technical Mechanisms:

IFC Parsing. The core functionality of IFC parsing in *Synchronising BIM Families through Blockchain-Enabled Common Data Environment (CDE)* involves standardising BIM family data exchange across platforms while maintaining geometric and non-geometric attribute synchronisation. Through this system supply chain members can access uniform BIM family data regardless of software limitations to maintain precise information transfer throughout different project stages (Elghaish *et al.*, 2023).

Object Classification. The practice of *Standardising Material Data for Sustainability Assessment* uses BIM to classify material components into standardised categories through digital model object assignment of embodied recipes. The mechanism enables supply chain members to interpret material specifications consistently when conducting embodied energy evaluations, which supports BIM information integration capability through structured material data transfer from project stakeholders to life cycle assessment (LCA) platforms (Al-Zrigat, 2025).

Automated Quantity Takeoff. The automated quantity takeoff function serves as the basis for BIM information integration capability because it performs systematic extractions of material specifications and quantities from parametric BIM models during *Automating Procurement Data Extraction from BIM*. The procurement data maintains its structured format through the automated extraction process which prevents human errors in data transfer between BIM platforms and supply chain participants (Kalantari, Taghaddos and Heydari, 2024).

Automated Data Exchange. *Synchronising Demand Fluctuations with 4D BIM* utilises automated data exchange as the foundation for BIM information integration to insert demand fluctuation data into its structured environment. Real-time material updates are captured digitally through this system to enable supply chain stakeholders to make responsive adjustments to orders which minimises supply-demand imbalance risks (Chen, García de Soto and Adey, 2021).

Complementary Technical Mechanisms:

RFID-Based Material Tracking. *Synchronising Demand Fluctuations with 4D BIM* receives enhancement through Radio Frequency Identification (RFID) and Bluetooth Low Energy which enable the integration of concrete delivery position updates into a common database for accurate and accessible demand information. The supply chain participants can modify their material distribution according to changing demand patterns because of this system which connects supply to demand changes on-site (Chen, García de Soto and Adey, 2021).

Cloud-Based Common Data Environment (CDE). A cloud-based CDE enhances BIM information integration capability through centralised real-time material demand updates which ensures suppliers and contractors obtain synchronised validated data during *Synchronising Demand Fluctuations with 4D BIM*. The system reduces data fragmentation and prevents communication errors so supply adjustments can occur swiftly when demand changes (Chen, García de Soto and Adey, 2021).

IfcOpenShell-Based Data Extraction. The practice of *Automating Procurement Data Extraction from BIM* uses IfcOpenShell as an open-source Python library which automatically extracts procurement data from IFC models to boost BIM information integration capabilities. Through this mechanism the system extracts material quantities and dimensions together with cost attributes from IFC structures using a standardised format that allows consistent procurement data integration across multiple systems (Kalantari, Taghaddos and Heydari, 2024).

ETL Processing. The practice of *Standardising Material Data for Sustainability Assessment* uses Extract, Transform, Load (ETL) processing to improve BIM information integration through model quantity extraction and standardised data transformation before loading into LCA platforms for system compatibility. The supply chain actors benefit from this mechanism because it lets them obtain harmonised BIM material data which ensures consistent information exchange throughout embodied energy assessments (Al-Zrigat, 2025).

Process Integration

BIM-Enabled Integration Practices:

Embedding Look-Ahead Planning in BIM-Enabled Change Coordination. The alignment of material flow processes between design, production, transportation, and installation phases happens through the incorporation of iterative look-ahead planning cycles together with milestone-based decision points in engineer-to-order (ETO) material coordination. Through process integration this method allows stakeholders to modify task sequencing and production schedules because of late-stage design and schedule changes which reduces supply chain disruptions. BIM process integration capability exists because users can perform iterative design-production-transportation-installation schedule alignment through BIM-supported real-time task updates and milestone-based adjustments (Chen *et al.*, 2022).

Automating Production Planning Linked to Site Installation Plan. This practice establishes automated links between production timelines and site installation schedules which enables timely delivery of prefabricated components for assembly purposes. The supply chain processes achieve better integration through factory-site operation synchronisation which reduces scheduling issues. The practice demonstrates BIM process integration capability through automatic coordination between production and installation timelines which maintains continuous workflow operations (Jang, Lee and Son, 2022).

Synchronising Construction Sequences with BIM-Integrated 4D Planning. The process integration method employs BIM-interfaced 4D planning to develop installation sequences and coordinate trade-specific workflow activities. The process of time-based construction modelling through hourly animation allows users to watch task relationships and crew activities while checking safety features which leads to organised sequencing and minimal rework. BIM process integration capability becomes evident by creating organised workflow modifications through progress information and trade information which manages task dependencies and scheduling limitations for optimal execution results (Staub-French *et al.*, 2022).

Automating Procurement Scheduling Using BIM-Driven Multi-Constraint Optimisation. The practice connects procurement schedules with construction zone timelines through a BIM-based optimisation framework which determines appropriate material order amounts along with appropriate zone start dates. The system matches procurement activities with site operations to guarantee materials reach construction areas at optimal times for construction progress which lowers material supply problems and reduces periods of waiting. The practice demonstrates BIM process integration capability through an optimisation model which controls procurement and zone schedules by balancing order quantities alongside timing and cost constraints (Kalantari, Taghaddos and Heydari, 2024)

Automating Concrete Order Adjustments Using 4D BIM-Based Demand Forecasting. The process achieves process integration by modifying concrete orders automatically through 4D BIM-based demand forecasting that tracks current site progress. The system performs automatic order modifications to keep pace with changing schedules so contractors and suppliers can work together better and reduce supply problems from demand changes. BIM process integration capability shows through real-time progress data usage to modify procurement decisions which leads to better order precision and decreased supply mismatch risks (Chen, García de Soto and Adey, 2021).

Synchronising Building Element Identities Using Mapping Algorithms. The system tracks building elements through all phases of design, prefabrication and onsite assembly by connecting CAD and ERP systems with an identity mapping algorithm. The solution resolves fragmented data structures and detail-level variations between these phases to enhance the connection between prefabrication scheduling and onsite installation. Through mapping building element identities between CAD and ERP systems the system proves BIM process integration capability which enables task dependency coordination across supply chain phases (Čuš-Babič *et al.*, 2014).

BIM Technical Mechanisms:

4D Scheduling. The practice of *Synchronising Construction Sequences with BIM-Integrated 4D Planning* relies on 4D scheduling to connect construction models with project timelines for installation sequence planning and scheduling constraint evaluation through progress tracking. The integration achieves optimal task dependency alignment and workforce distribution across supply chain stages which improves coordination while minimising workflow interruptions (Staub-French *et al.*, 2022).

Automated Quantity Takeoff. The automated quantity takeoff functions as the core of BIM process integration capability because it updates the Bill of Materials (BoM) and task schedules automatically when parametric models undergo changes during *Embedding Look-Ahead Planning in BIM-Enabled Change Coordination*. The automated system guarantees that material requirements stay in line with planning changes during look-ahead sessions by matching material quantities to schedule revisions for smooth supply chain plan integration (Chen *et al.*, 2022).

Real-Time Data Exchange. The ability to exchange real-time data underpins BIM process integration capability within *Synchronising Construction Sequences with BIM-Integrated 4D Planning* by linking construction sequences to live project updates which enables immediate workflow adjustments. Real-time data exchange enables teams to make quick adjustments to installation sequences when schedules change and site conditions evolve thus protecting task flow and reducing supply chain phase interruptions (Staub-French *et al.*, 2022).

Complementary Technical Mechanisms:

RFID-Based Material Tracking. The practice of *Embedding Look-Ahead Planning in BIM-Enabled Change Coordination* gains enhanced BIM process integration capability when it uses RFID-based material tracking for real-time tracking of engineer-to-order (ETO) components from production to on-site installation. During iterative planning the mechanism connects material flow updates with BIM-based task adjustments to enable planners to check material progress against developing design, production, and transport schedules during late-stage change coordination (Chen *et al.*, 2022).

Procurement Schedule Optimisation Algorithms (PSO, GA). The implementation of Particle Swarm Optimisation (PSO) and Genetic Algorithm (GA) in *Automating Procurement Scheduling Using BIM-Driven Multi-Constraint Optimisation* enables enhanced BIM process integration by optimising procurement sequences through BIM-derived material quantities, zone scheduling information, and financial constraints. The algorithms coordinate procurement orders to match zone execution schedules and consider cash flow and storage constraints which reduces delivery conflicts while improving supply chain coordination (Kalantari, Taghaddos and Heydari, 2024).

Relational Integration

BIM-Enabled Integration Practices:

Synchronising Decision-Making for Agile Collaboration in BIM-Integrated Supply Chains. The practice enhances collaborative decision-making by integrating iterative planning sessions through BIM workflows which allow supply chain participants to coordinate responses to design, schedule, and material flow changes. The process reduces misalignment through real-time information exchange during planning iterations which enables all parties to make quick adjustments. BIM relational integration capability emerges through agile collaboration when stakeholders work together to improve decisions through shared current BIM data (Chen *et al.*, 2022).

BIM Technical Mechanisms:

Centralised Data Environment for Integrated Planning. BIM relational integration capability relies on a centralised data environment which merges design changes, schedule updates, and material flow data into a single digital platform for *Synchronising Decision-Making for Agile Collaboration in BIM-Integrated Supply Chains*. Stakeholders can coordinate their iterative plans through this mechanism because it provides synchronised and current information which minimises misalignment and supports agile collaboration among supply chain partners (Chen *et al.*, 2022).

BIM-Integrated Digital Workflows for Transparency. The practice of *Synchronising Decision-Making for Agile Collaboration in BIM-Integrated Supply Chains* utilises BIM-integrated digital workflows which enhance BIM relational integration capability through common data environment processing of change requests, order updates, and schedule adjustments. The real-time visibility of project data through this mechanism allows stakeholders to immediately match material flows with design changes and schedule modifications. Enhanced transparency reduces miscommunication while building trust and enabling supply chain actors to work together in decision-making processes (Chen *et al.*, 2022).

Complementary Technical Mechanisms:

Cloud-Based Data Sharing Platforms. The practice of *Synchronising Decision-Making for Agile Collaboration in BIM-Integrated Supply Chains* uses cloud-based data sharing platforms to improve BIM relational integration capability because stakeholders can access synchronised material flow data through real-time updates which enables iterative planning decision revisions based on present project details. The ongoing availability of data creates better collaborative problem-solving because decision-making depends on precise and current digital records which minimises supply chain partner misalignment (Chen *et al.*, 2022).

RFID and IoT-Enabled Material Tracking. The practice of *Synchronising Decision-Making for Agile Collaboration in BIM-Integrated Supply Chains* achieves better BIM relational integration through automated real-time material movement tracking using RFID and IoT technology. The system provides precise material availability and logistics data which allows iterative planning processes to incorporate accurate updates, thus minimising supply uncertainty and helping stakeholders achieve better coordination during planning changes (Chen *et al.*, 2022).

Technology Integration

BIM-Enabled Integration Practices:

Integrating IoT-BIM-Blockchain Layers for Secure Real-Time Data Synchronisation. Real-time data synchronisation across physical and digital operational layers of offsite manufacturing supply chains happens through this practice that combines IoT sensors with BIM platforms and blockchain technology. The method solves technological fragmentation problems through establishing interoperability between IoT-enabled physical data capture with BIM digital models and blockchain-secured data exchange. The practice demonstrates BIM technology integration capability to operate with IoT sensors for live data acquisition while interoperating with blockchain technology to validate data securely in a decentralised manner, thus creating a unified system that improves supply chain visibility and traceability (Brandín and Abrishami, 2024).

Automating BIM-Blockchain Work Package Generation and Execution. The procedure uses blockchain execution verification to create and run work packages that originate from BIM-based structured information. The integration creates consistent data transfer, automated transaction processing, and permanent work progress documentation which enhances work package monitoring and coordination performance. BIM proves its technology capability through automated workflow implementation which facilitates seamless data transfer between BIM and blockchain systems (Celik, Petri and Rezgui, 2023).

Automating BIM-LCA Integration Using ETL for Data Interoperability. The method achieves better supply chain technology integration through automated data transfer between BIM and LCA systems which minimises human data entry errors and solves format incompatibility problems. Through ETL operations the system first extracts then transforms and finally loads material data from BIM tools into LCA applications so users can perform precise energy assessments. This supports material selection, transportation evaluation, and supply chain decision-making. The practice demonstrates BIM technology integration capability to automatically transfer data between BIM and LCA platforms for conducting lifecycle energy evaluations (Al-Zrigat, 2025).

Automating Scan-to-BIM for Digital Component Reuse. The practice combines laser scanning technologies with BIM to automate the digitisation process of reusable building components that maintain their precise digital representation inside supply chain workflows. The method establishes a connection between physical elements and BIM models to improve traceability and reuse planning through deconstruction and design phases and minimise data fragmentation. The connection between reality capture technologies and BIM structured data demonstrates BIM technology integration capabilities which enables automated digital replication of reusable components (Elghaish *et al.*, 2023).

Integrating BIM with AI-Driven Optimisation for Parametric Structural Design. The practice advances technology integration through seamless interoperability between BIM-based parametric modelling, finite element modelling (FEM) and AI-driven optimisation. The system performs automated data exchange together with real-time structural optimisation in BIM workflows to minimise manual work and improve coordination between design and analysis procedures. BIM technology integration capability becomes evident through integrating Dynamo for parametric modelling, Robot Structural Analysis (RSA) for FEM, and genetic algorithms (GA) for structural optimisation, which enables automated data transfer and iterative model refinement between platforms (Yavan, Maalek and Toğan, 2024).

BIM Technical Mechanisms:

Common Data Environment (CDE) Integration. CDE integration serves as the foundation for BIM technology integration by combining IoT sensor data with blockchain system information into a centralised repository in the practice of *Integrating IoT-BIM-Blockchain Layers for Secure Real-Time Data Synchronisation*. The system enables organised storage and dataset retrieval while maintaining interoperability between BIM, IoT, and blockchain platforms through a single digital environment (Brandín and Abrishami, 2024).

Data Federation. The practice of *Integrating IoT-BIM-Blockchain Layers for Secure Real-Time Data Synchronisation* uses data federation as the foundation for BIM technology integration through the process of unifying sensor data from IoT devices with blockchain system data into a single digital model. Through this mechanism users can merge physical supply chain data with BIM geometric and non-geometric information to establish interoperability between real-time IoT data streams and blockchain transaction records inside the BIM environment (Brandín and Abrishami, 2024).

Complementary Technical Mechanisms:

Blockchain. Blockchain enhances BIM technology integration capability within the practice of *Integrating IoT-BIM-Blockchain Layers for Secure Real-Time Data Synchronisation* by enabling BIM to interoperate with distributed ledger platforms including Hyperledger Fabric. The mechanism validates supply chain data automatically through BIM-IoT-blockchain exchanges thus enabling BIM to operate within a distributed digital network for decentralised data coordination between multiple technologies (Brandín and Abrishami, 2024).

IoT Sensors. IoT sensors boost BIM technology integration capability by allowing BIM to automatically acquire live production data, location data, and system status from IoT devices in the *Integrating IoT-BIM-Blockchain Layers for Secure Real-Time Data Synchronisation*. The system automatically sends sensor data to BIM through a manual-free process so BIM operates as a digital hub that links to IoT platforms, blockchain, and other technologies for real-time supply chain monitoring in a unified digital environment (Brandín and Abrishami, 2024).

Smart Contracts. The practice of A*utomating BIM-Blockchain Work Package Generation and Execution* uses smart contracts to improve BIM interoperability with blockchain platforms by enabling automated work package execution. Smart contracts connect BIM-produced completion data with blockchain transaction triggers to enable automatic contract payment initiations at specific milestones. The system minimises human involvement while enabling automatic financial transaction processing from authentic BIM data which strengthens BIM-blockchain technology integration through a single digital operational workflow (Celik, Petri and Rezgui, 2023).

ETL-Based Data Integration. The practice of *Automating BIM-LCA Integration Using ETL for Data Interoperability* employs ETL processes to automate standardisation, transformation, and exchange functions between BIM and LCA platforms which improves BIM technology integration capabilities. The mechanism converts material attributes, energy consumption data, and supplier information into compatible formats to decrease errors which result from manual data handling. The automated data transfers between BIM and LCA systems achieve seamless interoperability which enhances the integration of BIM with external sustainability assessment tools (Al-Zrigat, 2025).

Conclusions

The study defines four main capabilities which demonstrate how BIM facilitates SCI in construction projects through information, process, relational, and technology integration. The study explains the function of BEIPs together with the fundamental technical systems that support these capabilities. The study provides a structured framework which helps advance knowledge about BIM's integrative abilities within fragmented construction supply chains. Future research needs to validate the suggested capabilities through empirical studies across various project settings. The study suggests that researchers need to explore how BIM connects with CTMs to gain better understanding of digital solutions that improve SCI within construction projects.

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