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ADVANCING BIM-ENABLED MULTIDISCIPLINARY COORDINATION FOR SUSTAINABLE BUILDING DELIVERY: A COMPREHENSIVE REVIEW OF DIGITAL INTEGRATION ACROSS ARCHITECTURAL, STRUCTURAL, AND MEP SYSTEMS

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ABSTRACT

Building Information Modeling (BIM) has become the principal digital infrastructure for coordinating the architectural, structural, and mechanical, electrical, and plumbing (MEP) disciplines that jointly determine whether a building is delivered efficiently and sustainably. Research on BIM-enabled coordination remains fragmented across discipline-specific silos, with interoperability, MEP clash management, sustainability, and emerging technologies typically examined in isolation. This paper presents a comprehensive review synthesizing 50 peer-reviewed studies published between 2015 and 2026 to build an integrated account of how BIM supports multidisciplinary coordination for sustainable building delivery. Using a hybrid narrative-systematic method, literature was retrieved from major databases, screened against explicit criteria, and synthesized thematically across six domains: BIM fundamentals and collaboration; architectural-structural integration; MEP coordination; interoperability and data standards; sustainability performance; and emerging technologies and adoption barriers. Results show that geometric clash detection, long treated as the primary coordination mechanism, is necessary but insufficient, since unresolved semantic, temporal, and organizational issues persist even where automated detection is mature; machine-learning resolution methods are emerging to close this gap. Interoperability losses at the Industry Foundation Classes boundary continue to undermine architectural-structural exchange, and sustainability gains from BIM-linked energy, life-cycle, and certification workflows remain constrained by the same data-continuity problems limiting design coordination. Digital twins, artificial intelligence, and augmented reality extend BIM's coordinating capacity but inherit its standardization and skills gaps. The review concludes that sustainable delivery depends on aligning data standards, collaboration practices, and sustainability metrics within one integrated environment, and proposes a research agenda.

Keywords: Building Information Modeling, Multidisciplinary coordination, Sustainable building delivery, Interoperability, MEP coordination, Structural BIM, Digital twin, Literature review

1 INTRODUCTION

The delivery of a modern building is an exercise in reconciling the competing logics of at least three disciplines: architecture, which organizes space and form; structural engineering, which ensures the safety and stability of the physical frame; and mechanical, electrical, and plumbing (MEP) engineering, which embeds the systems that make a building habitable, efficient, and resilient (Akponeware & Adamu, 2017; Ali et al., 2022). Historically, these disciplines have exchanged information through drawings, specifications, and periodic coordination meetings, a process that is slow, error-prone, and poorly suited to the demands of contemporary sustainable construction (Oraee et al., 2017; Akponeware & Adamu, 2017). Building Information Modeling (BIM) was introduced, in large part, as a response to this fragmentation: a shared, object-based digital representation of a building intended to allow architects, structural engineers, and MEP designers to work from a common model rather than from disconnected, discipline-specific drawings (Ali et al., 2022).

Nearly two decades after BIM entered mainstream practice, its promise of seamless multidisciplinary coordination remains only partially realized. Empirical studies continue to document unresolved design-coordination issues even on BIM-mature projects (Mehrbod et al., 2019), persistent interoperability losses when models move between architectural and structural software (Gerbino et al., 2021; Colajanni et al., 2025), and organizational and cultural barriers that limit collaboration regardless of technological capability (Oraee et al., 2019; Kineber et al., 2023). At the same time, BIM is now expected to do more than prevent geometric clashes: it is expected to underpin sustainable building delivery by enabling accurate energy simulation, life-cycle carbon accounting, and green-certification workflows that themselves depend on reliable, discipline-spanning data (Soust-Verdaguer et al., 2017; Alhammad et al., 2024). Procurement policies such as Buy Clean, which rely on Environmental Product Declarations (EPDs) to verify embodied carbon, are adding further demand for accurate, model-linked material data (Dauda et al., 2026). Sustainability performance and multidisciplinary coordination are therefore not separate research problems; they are two expressions of the same underlying requirement for coherent, interoperable, and well-governed building information.

The literature addressing these issues, however, has developed largely along disciplinary lines: reviews of BIM-MEP clash detection, BIM-structural interoperability, BIM-based sustainability assessment, and digital-twin or artificial-intelligence extensions of BIM each synthesize a narrow slice of the field but rarely connect their findings across disciplinary boundaries (Fernández-Mora et al., 2022; Berges-Alvarez et al., 2024; Deng et al., 2021). This fragmentation obscures cross-cutting patterns that only become visible when the literature is read across these boundaries. This paper addresses that gap through a comprehensive review that deliberately spans architectural, structural, and MEP coordination together with the interoperability standards, sustainability applications, and emerging technologies that connect them. The review pursues three objectives: to synthesize the evidence on how BIM supports coordination within and across the three core disciplines; to trace how coordination quality shapes BIM's contribution to sustainable building delivery; and to evaluate whether emerging digital technologies and documented adoption barriers are likely to resolve, or merely relocate, the coordination problems identified in the earlier literature. The remainder of the paper describes the review methodology, presents the thematic results, discusses their integration into a proposed framework and research agenda, and concludes.

2 METHODOLOGY

This review adopts a hybrid narrative-systematic approach, combining the transparent search and screening procedures associated with systematic reviews with the interpretive, cross-thematic synthesis characteristic of narrative reviews, because the aim was to construct a coherent, cross-disciplinary account of literature that is topically fragmented across architectural, structural, MEP, sustainability, and emerging-technology subfields rather than to answer a single narrowly bounded question. Literature was identified through structured searches of Scopus, Web of Science, ScienceDirect, the ASCE Library, MDPI journal platforms, and Google Scholar, using combinations of the terms "BIM," "multidisciplinary coordination," "clash detection," "interoperability," "IFC," "structural," "MEP," "sustainability," "life cycle assessment," "digital twin," and "adoption barriers," organized into six parallel thematic search streams corresponding to the major result themes below. Studies were included if they were peer-reviewed journal articles published between 2015 and 2026, addressed BIM in the context of at least one theme, and reported empirical findings, a validated framework, or a systematic synthesis; conference proceedings, non-peer-reviewed industry sources, and studies focused exclusively on infrastructure or heavy-civil applications were excluded. This process yielded 50 studies, which were read against one another and synthesized thematically, with later studies positioned as extending, contesting, or empirically substantiating earlier findings, and explicit cross-references drawn between themes wherever the literature itself suggested a connection.

3 RESULTS

The 50 studies included in this review are distributed across six thematic domains, summarized in Table 1 and organized here to move from the conceptual foundations of BIM-enabled coordination, through discipline-specific integration with structural and MEP systems, to the standards infrastructure, sustainability applications, emerging technologies, and adoption barriers that connect them. Table 2, presented after the discipline-specific themes, collects the quantified outcomes reported across studies that measured coordination or sustainability performance directly, to illustrate the magnitude of effects documented in the literature.

Table 1: Thematic Distribution of the 50 Studies Included in the Review

Theme	k	Primary Focus	Representative Studies
BIM fundamentals, maturity, and multidisciplinary coordination	12	Collaboration theory, coordination-issue taxonomies, clash-detection and clash-resolution computation	Oraee et al. (2017, 2019); Wang et al. (2016); Mehrbod et al. (2019); Koo et al. (2026)
Architectural-structural integration	8	Structural-analysis interoperability, parametric and precast optimization	Shin (2017); Sherif et al. (2022); Lao et al. (2023); Yavan et al. (2024)
MEP systems coordination	7	Clash avoidance, automated and generative MEP design, prefabrication, facility handover	Akponeware & Adamu (2017); Wang et al. (2022); Pestana et al. (2024); Wijeratne et al. (2023)
Interoperability and data standards	5	IFC exchange fidelity, openBIM adoption, Common Data Environments	Lai & Deng (2018); Sibenik & Kovacic (2020); Seyis & Ozkan (2024)
Sustainable building delivery	10	Energy simulation, LEED/BREEAM automation, life-cycle assessment, waste and carbon reduction	Jalaei & Jrade (2015); Soust-Verdaguer et al. (2017); Akinade et al. (2018); Lou & Hsieh (2024)
Emerging technologies and adoption barriers	8	Digital twins, artificial intelligence, augmented reality, cross-national barrier ranking	Tang et al. (2019); Deng et al. (2021); Kineber et al. (2023); Alshibani et al. (2024)

Source: Author's construct, 2026 *Note.* IFC = Industry Foundation Classes; MEP = mechanical, electrical, and plumbing. Themes reflect each study's primary focus; several studies also contribute evidence to other themes, as noted in the narrative synthesis.

3.1 BIM Fundamentals, Maturity, and Multidisciplinary Coordination

The theoretical case for BIM-enabled coordination rests on the observation that traditional, drawing-based information exchange between architects, structural engineers, and MEP designers is inherently lossy: each discipline typically maintains its own representation of the building, and reconciling these representations depends on manual cross-checking that scales poorly with project complexity (Ali et al., 2022). Bibliometric analysis of the BIM-collaboration literature by Oraee et al. (2017) confirmed that this problem has attracted sustained research attention but also revealed an important imbalance: the field is dominated by studies of technology and process, while the organizational and human dimensions of collaboration are comparatively under-theorized. Their subsequent conceptual synthesis of 73 studies (Oraee et al., 2019) made this imbalance explicit, identifying 26 discrete collaboration barriers distributed across process, contextual, actor, team, and task categories, and showing that organizational and behavioral barriers outnumber purely technical ones. This finding reframes multidisciplinary coordination as a socio-technical rather than purely technical problem, a distinction that recurs throughout the literature reviewed in this paper.

Empirical work on design coordination substantiates this reframing. Mehrbod et al. (2019) developed an issue taxonomy from real BIM-coordinated projects and found that 28% of identified coordination issues remained unresolved by the end of the design-coordination process, with temporal and functional issues, as distinct from purely geometric clashes, proving hardest to close (see Table 2). A complementary result comes from Wang et al. (2016), who developed a coordination framework for integrating MEP layout with constructability review and found that 78% of software-flagged clashes were, on inspection, non-actionable, while designers still manually identified 102 genuine collisions the software had missed. These two studies point to an early finding that shapes the rest of this review: automated clash detection, as originally implemented, over-generates irrelevant conflicts while under-detecting functionally significant ones, so raw clash counts are a poor proxy for coordination quality.

This diagnosis has driven a discernible methodological progression, moving from rule-based detection toward relevance-aware and resolution-oriented computation. Hu et al. (2021) reframed the problem from detection to resolution, using graph-based modeling of BIM component relationships to predict which elements require modification

once a clash is identified, and Hu et al. (2023) extended this graph-convolutional approach specifically to MEP disciplines. Most recently, Koo et al. (2026) proposed a risk- and relevance-based triage method that prioritizes clashes for resolution, directly operationalizing the false-positive problem identified nearly a decade earlier by Wang et al. (2016). This sequence is one of the clearest examples of cumulative progress in the coordination literature.

A parallel strand asks why coordination outcomes remain uneven despite this technical progress. Jones's (2020) longitudinal survey of UK architectural practices across 2011, 2014, and 2018 found that BIM utilization rose steadily, yet training costs, limited client demand, and process complexity remained persistent barriers throughout. Ahankoob et al. (2026) offered a theoretical account of this lag, reviewing 104 studies to show that BIM's organizational-learning benefits depend on seven enabling factors operating through experience accumulation, knowledge articulation, and knowledge codification, arguing that BIM functions as a socio-technical platform whose value is realized only when organizations convert model-based experience into codified practice. Ali et al.'s (2022) bibliometric mapping of 88 core studies corroborates this picture, identifying six thematic clusters while explicitly flagging the intersection of collaboration and risk as understudied.

3.2 Architectural-Structural BIM Integration

Coordination between architectural design and structural engineering depends on reliably translating a geometry-focused BIM model into an analytical model suitable for structural analysis, and this translation has proven a persistent point of failure. Shin (2017) argued early that Open BIM standards and application programming interfaces were necessary to enable exchange up to a workable Level of Development. Subsequent benchmarking largely confirms this precondition remains unmet: Gerbino et al. (2021) conducted a three-year benchmark of IFC-based exchange between architectural and structural tools and found persistent element disconnection, geometry misinterpretation, and loss of parametric relationships, concluding that IFC implementation still favors expert users over mainstream practice. Colajanni et al. (2025) reached a consistent conclusion in a more recent case study, finding that direct, software-specific links preserved geometry more reliably than IFC-mediated transfers, which required manual correction. Together, these studies indicate that the architecture-structure interoperability gap has narrowed only marginally.

A related strand treats the architecture-structure interface as a design-optimization opportunity rather than only a translation problem. Sherif et al. (2022) developed a BIM framework automating structural layout and design while optimizing cost, achieving material-cost reductions of up to 15% across eleven case studies (Table 2). Lao et al. (2023) extended this optimization logic to precast construction, balancing structural performance against constructability using a hybrid metaheuristic. Ajtayné Károlyfi and Szép (2023) pushed this further upstream, screening 48 alternative structural configurations against embodied environmental impact at the conceptual stage, while Yavan et al. (2024) combined evolutionary algorithms with life-cycle-assessment tools to optimize steel truss designs for both material minimization and environmental impact. These four studies show that structural BIM integration has matured from an interoperability challenge into a multi-objective optimization capability that increasingly incorporates sustainability criteria directly, a convergence revisited in the sustainability results below.

A third strand addresses the data-exchange mechanics more directly. Sibenik et al. (2021) proposed an open-source framework using centralized data storage and transparent interpretation rules to automate conversion between architectural and structural models, validated on three buildings, while Shoieb et al. (2020) developed a web-based tool to exchange data across structural-analysis applications, addressing the proprietary fragmentation that leads practitioners toward the point-to-point workarounds documented by Colajanni et al. (2025). Fernández-Mora et al.'s (2022) review situates these technical solutions within a broader account of the structural project's place in the BIM paradigm, confirming that interoperability, optimization, and sustainability are increasingly overlapping rather than separate research trajectories.

3.3 BIM-Enabled MEP Systems Coordination

MEP coordination has historically been BIM clash detection's most visible application, because mechanical, electrical, and plumbing systems occupy dense, spatially constrained zones. Akponeware and Adamu (2017) offered an influential distinction between reactive "clash detection," in which software identifies conflicts after they occur in the model, and proactive "clash avoidance," in which coordination protocols prevent conflicts from arising, arguing that software alone cannot deliver the latter without deliberate process change. This distinction directly anticipates the false-positive problem documented by Wang et al. (2016): a coordination process built solely around automated detection is destined to generate excess, low-value alerts unless paired with proactive process design.

The methodological response has followed the trajectory identified above, extended here with MEP-specific evidence. Hu et al. (2021, 2023) applied graph-based methods to predict which components require modification to resolve a clash, with the MEP-specific model finding that clash-relational context is the strongest predictor of the correct resolution. The most recent contribution, Ailem and Boton (2026), proposes a machine-learning pipeline that automatically filters clash relevance across architecture-structure-MEP coordination, directly targeting the reduction

in coordinator review burden that Wang et al. (2016) identified. This progression marks a clear evolution from rule-based geometric detection through graph-based resolution prediction to automated relevance filtering, though none of this literature reports evidence that automation has reduced the underlying rate of temporal and functional issues documented by Mehrbod et al. (2019).

Beyond clash management, BIM-MEP coordination increasingly extends into design generation and offsite production. Wang et al. (2022) developed an automated framework for HVAC design that reduced design time from approximately 23 hours to approximately 1 hour in office-building case studies. Pestana et al. (2024) pursued a complementary generative approach to optimize MEP layouts, validated through Monte Carlo simulation with an estimated 99% success rate; the contrast between Wang et al.'s (2022) rule-based automation and Pestana et al.'s (2024) generative, exploratory approach illustrates two converging computational strategies for accelerating MEP design. On the production side, Jang and Lee (2018) provided rare project-level evidence that BIM-enabled multi-trade prefabrication, despite initially lengthening MEP coordination time, shortened overall project duration and reduced person-hours by 40% via learning effects. Guo et al. (2020) closed the loop with a 3D laser-scanning method for inspecting prefabricated MEP modules against their BIM design models, extending BIM's coordinating role into quality assurance.

Finally, MEP coordination has consequences beyond construction. Wijeratne et al. (2023) reviewed 33 real projects and found recurring data-continuity failures at the handover between design/construction and operations. This is the same information-loss problem documented at the model-translation scale by Gerbino et al. (2021) and Colajanni et al. (2025) in the architecture-structure context, and it suggests that data loss recurs wherever information crosses an organizational, software, or lifecycle boundary.

3.4 Interoperability, Data Standards, and Common Data Environments

The discipline-specific interoperability problems documented above are symptoms of a more general challenge. Lai and Deng (2018) systematically tested IFC-based transfer across heterogeneous BIM platforms and identified parametric, relational, and attribute-level data loss that closely mirrors the findings reported by Gerbino et al. (2021) for structural exchange specifically. Sibenik and Kovacic (2020) quantified this loss more precisely, finding that information degrades cumulatively across each conversion stage rather than being lost at a single identifiable point. Singh et al. (2024) responded with a proposed technical remedy, an automated IFC-based workflow that derives structural analytical models directly from architectural BIM, though this remains one of several competing technical proposals rather than a converged solution.

At the field level, Gao et al.'s (2024) systematic review of openBIM research across the global construction industry confirms that interoperability remains a live research and practice problem notwithstanding IFC's maturity as a published standard. This technical literature is complemented by research on governance: Seyis and Ozkan (2024) examined Common Data Environments (CDEs) during the construction phase and identified clear benefits, including version control, a single authoritative source of information, and reduced rework, alongside persistent challenges around standardization and training that parallel the barriers identified in the collaboration literature above. Model-level coordination problems therefore cannot be resolved by improved software translation alone; they also require governance structures, of which the CDE is the most developed example.

3.5 BIM for Sustainable Building Delivery

If the preceding themes establish that BIM's coordinating function depends on reliable cross-disciplinary data exchange, this theme shows that BIM's sustainability function depends on precisely the same reliability. Alhammad et al.'s (2024) systematic review of methods for coupling BIM with energy-simulation engines identifies interoperability problems, specifically geometry simplification and data gaps during export, as the primary barrier to simulation accuracy, directly extending the interoperability diagnosis above into the sustainability domain.

A parallel application concerns green-building certification. Jalaei and Jrade (2015) proposed an early automated framework linking BIM to LEED at the conceptual design stage, reducing rework from late-stage certification checks. Cascone (2023) revisited this integration nearly a decade later, concluding that plug-in development offers the greatest functional power but demands programming expertise, while visual-scripting approaches are more usable but less powerful. Parisi et al.'s (2026) systematic review broadens this picture by mapping how BIM automates credit calculation across multiple rating systems, including LEED and BREEAM, confirming that certification automation is converging toward standardized workflows even as underlying interoperability constraints persist.

A third application, life-cycle assessment (LCA), reveals the same pattern in sharper relief. Soust-Verdaguer et al.'s (2017) foundational review identified methodological gaps in linking BIM data to LCA databases, gaps that Berges-Alvarez et al. (2024) found remain the dominant constraint on the field's progress nearly a decade later. Yang et al. (2018) grounded this literature in a concrete case, applying a BIM-LCA workflow to quantify the carbon footprint of a residential building in China and finding that material production and operational energy jointly dominate emissions.

Akinade et al. (2018) extended BIM's sustainability application to construction-waste minimization, identifying clash detection, quantity takeoff, and design optimization as the functionalities practitioners expect to reduce waste, linking the coordination functions above directly to a sustainability outcome.

The most recent contributions point toward computational acceleration rather than new conceptual ground. De Paula et al. (2026) combined BIM-extracted design parameters with machine-learning models to predict energy use and carbon performance considerably faster than conventional simulation. Lou and Hsieh (2024) reviewed strategies for achieving net-zero-energy and net-zero-carbon buildings and noted a persistent disconnect between energy-focused and carbon-focused approaches, a gap that BIM-integrated, multi-metric workflows are only beginning to close. This body of work supports a central proposition of this review: BIM's contribution to sustainable building delivery is a direct function of coordination quality, since energy, certification, and life-cycle-assessment workflows all depend on the same reliable, discipline-spanning data shown above to remain incompletely achieved.

3.6 Emerging Digital Technologies Extending BIM Coordination

A rapidly growing literature examines how emerging technologies extend BIM's coordinating capacity beyond static, design-stage models. Tang et al.'s (2019) widely cited review synthesized the BIM-Internet of Things (IoT) integration literature into a taxonomy of monitoring, controlling, and optimizing purposes, identifying interoperability and data-format gaps as the principal barrier to real-time sensor-BIM fusion. This literature is widely treated as the technical precursor to digital twins. Deng et al.'s (2021) systematic review of 123 studies constructed a five-level taxonomy tracing the evolution from static BIM through IoT integration to digital twins, finding that most implementations stop at simulation or sensor integration, with genuine closed-loop digital-twin capability still rare. Radzi et al.'s (2023) systematic review offers a complementary taxonomy emphasizing conceptual overlaps between BIM and digital twins rather than a maturity ladder; the divergence between these two framings illustrates that the field has not yet converged on a single conceptual model of what distinguishes a digital twin from an advanced BIM model.

Table 2: Quantified Coordination and Sustainability Outcomes Reported in Representative Studies

Study	Discipline Focus	Method	Reported Outcome
Wang et al. (2016)	MEP-structural clash detection	BIM coordination framework, real project audit	78% of software-flagged clashes were non-actionable; 102 genuine collisions were missed by software
Mehrbod et al. (2019)	Multidisciplinary design coordination	Issue taxonomy from two case-study projects	28% of identified coordination issues remained unresolved by the end of design coordination
Sherif et al. (2022)	Structural design and cost	Automated BIM structural optimization, 11 case studies	Up to 15% reduction in structural material cost
Jang & Lee (2018)	MEP multi-trade prefabrication	Longitudinal case study	40% reduction in person-hours through learning effects across repeated modules
Wang et al. (2022)	HVAC design automation	Automated BIM design framework, office case studies	HVAC design time reduced from approximately 23 hours to approximately 1 hour
Pestana et al. (2024)	Generative MEP layout design	Monte Carlo-validated generative design	Approximately 99% estimated design-success rate in early-stage residential layouts
Alshibani et al. (2024)	BIM adoption barriers	Interpretive Structural Modeling, Saudi Arabia	Lack of skilled personnel identified as the most structurally influential root barrier
Kineber et al. (2023)	BIM adoption for sustainable construction	Exploratory factor analysis / SEM, Nigeria	Weak designer-supply-chain collaboration ranked the most influential barrier among seven categories

Source: Author's Construct *Note.* Figures are as reported in the cited primary studies and are not directly comparable across projects, building types, or national contexts; they are presented to illustrate the range of measured effects rather than to support pooled estimates.

Translating this research into practice depends on organizational conditions that mirror those identified for BIM adoption generally. Manzoor et al.'s (2025) systematic and bibliometric review of critical success factors for digital-twin implementation identified four persistent gaps: interoperability with emerging technologies, integration with lifecycle and sustainability objectives, human-centered stakeholder collaboration, and policy and regulatory frameworks.

Artificial intelligence and immersive visualization extend this pattern further. Marović et al.'s (2026) cross-country survey of 199 professionals found that BIM adoption correlates more strongly with sustainability-related outcomes than artificial-intelligence adoption alone, with the strongest outcomes occurring when artificial intelligence augments BIM under skilled human oversight rather than substituting for it. Bhatarai et al.'s (2025) review found that augmented-reality-BIM integration reduces design errors and construction rework through real-time visualization, while flagging hardware cost, software interoperability, and cultural adoption resistance as continuing barriers. Each new technology therefore extends what BIM can do for coordination without independently resolving the interoperability and organizational-readiness problems documented earlier.

3.7 Barriers and Critical Success Factors

The organizational barriers first identified conceptually by Oraee et al. (2019) and traced longitudinally by Jones (2020) have been examined more recently through quantitative, cross-national studies. Kineber et al. (2023) applied exploratory factor analysis and structural equation modeling to survey data from Nigeria and identified seven barrier categories to BIM implementation for sustainable construction, with weak collaboration between designers and downstream supply-chain actors emerging as the most influential impediment (Table 2). Alshibani et al. (2024) applied Interpretive Structural Modeling to survey data from Saudi Arabia and found that a lack of skilled personnel functions as the most structurally influential root barrier, driving downstream awareness and communication gaps.

The methodological contrast between Kineber et al.'s (2023) factor-analytic ranking and Alshibani et al.'s (2024) structural root-cause modeling is instructive: two studies, conducted in different national contexts using different analytical techniques, converge on the conclusion that Ahankoob et al. (2026) reached through a purely theoretical lens, namely that BIM's collaboration benefits depend on human capability and skills development at least as much as on software capability. This convergence across bibliometric synthesis, longitudinal survey, organizational-learning theory, and cross-national quantitative modeling is one of the most robust findings in the literature reviewed in this paper, and it has direct implications for the emerging-technology literature above, where critical-success-factor studies of digital twins and augmented reality identify the same human-centered and organizational barriers.

4 DISCUSSION

4.1 Toward an Integrated Framework

The synthesis above supports three integrative conclusions that extend beyond what any single stream of the literature establishes on its own. The clearest of them is that one underlying problem, the loss of information whenever it crosses a boundary, presents itself differently in each domain while remaining the same problem throughout. It appears as false positive clash rates and unresolved temporal issues in design coordination (Wang et al., 2016; Mehrbod et al., 2019), as parametric and geometric loss in the translation between architecture and structure (Gerbino et al., 2021; Colajanni et al., 2025), as cumulative degradation across IFC exchange steps (Sibenik & Kovacic, 2020; Lai & Deng, 2018), as a loss of simulation accuracy in energy and life-cycle assessment workflows (Alhammad et al., 2024; Soust-Verdaguer et al., 2017), and as data loss at the handover between construction and operations (Wijeratne et al., 2023). No study reviewed here proposes a mechanism that resolves the problem across all of these manifestations at once. Instead, the field has developed point solutions specific to a discipline or an application, each addressing one manifestation while leaving the others largely untouched.

The synthesis also indicates that sustainable building delivery is best understood as a downstream consequence of coordination quality rather than as an independent application of BIM. Every sustainability mechanism reviewed above depends on data that originates in the architectural, structural, and MEP coordination processes examined earlier. Where those processes generate incomplete or degraded information, sustainability outputs inherit the same limitations, as the parallel diagnoses of Alhammad et al. (2024) and Soust-Verdaguer et al. (2017) demonstrate. Design-stage material selection, which recent reviews identify as a key lever for reducing the embodied carbon of buildings (Dauda & Gate, 2026), depends in the same way on the quantity and specification data that coordination produces.

A final conclusion concerns the pace of technological change. The trajectory visible across the structural, MEP, and emerging technology results has consistently improved the efficiency with which information is processed without resolving the organizational and skills barriers identified above. Manzoor et al.'s (2025) finding that the success of digital twins depends on collaboration centered on people, together with Marović et al.'s (2026) finding that artificial intelligence adds most value when it augments rather than replaces skilled human oversight, suggests that this pattern will persist as new technologies are layered onto the BIM foundation.

As shown in Figure 1, these conclusions integrate into a three-layer framework. The technical layer comprises the data standards, model-translation tools, and computational methods that determine how much information survives as it moves between disciplines and software platforms. The organizational layer comprises the collaboration practices,

skills, and governance structures that determine whether surviving information is used to resolve coordination issues. The outcome layer comprises the sustainability and delivery performance metrics that this review argues are best understood as emergent properties of the interaction between the technical and organizational layers rather than as independently optimizable targets. This framework implies that interventions targeting only one layer (for example, adopting a more capable clash-detection algorithm without addressing collaboration culture, or mandating a sustainability certification without addressing interoperability) are unlikely to achieve their intended outcomes.

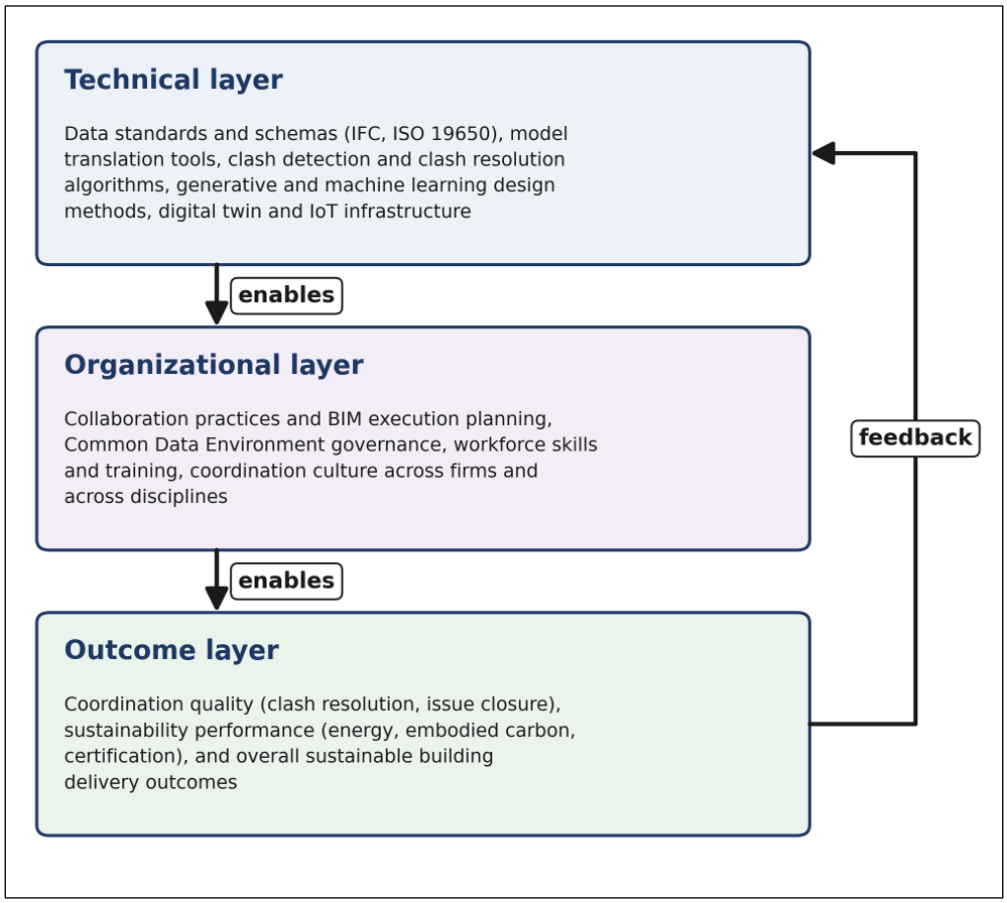

Figure 1: Integrated Framework for BIM-Enabled Multidisciplinary Coordination and Sustainable Delivery

Source: Authors' construct (2026). *Note.* The technical layer enables the organizational layer, which in turn enables the outcome layer; outcomes feedback to inform technical and organizational practice. The synthesis in this review indicates that interventions targeting only one layer are unlikely to achieve their intended coordination or sustainability outcomes.

4.2 Research Gaps and Future Directions

Five research gaps emerge from this synthesis. The most pressing concerns interoperability. The problem documented across the translation from architecture to structure, across IFC-based exchange, and across sustainability data pipelines has attracted a proliferation of point solutions specific to a discipline or a vendor, rather than convergence toward a shared and robust standard. Future research should therefore prioritize comparative evaluation of competing interoperability frameworks over the continued proposal of new and narrowly validated ones.

A related weakness concerns risk. Ali et al. (2022) identified the intersection of collaboration and risk as understudied, and this synthesis extends that observation. The literature has not systematically examined how information loss at model translation boundaries propagates into project risk, whether cost overrun, schedule delay, or safety, in a way that would allow the economic case for investment in interoperability to be quantified. Isolated cost and productivity figures do exist within single studies (Sherif et al., 2022; Jang & Lee, 2018), but they have not been connected to risk exposure.

Evidence on emerging technologies presents a different difficulty, in that it remains predominantly conceptual or drawn from small samples. Deng et al. (2021) found that few of the digital twin implementations they reviewed achieve genuine closed-loop feedback, and longitudinal studies tracking digital twins, artificial intelligence, and augmented reality across multiple projects, from implementation through to measured outcomes, are largely absent.

The sustainability literature, for its part, remains fragmented across energy, certification, waste, and carbon sub-themes that are rarely integrated within a single BIM workflow. Lou and Hsieh's (2024) observation of a persistent gap between strategies focused on energy and those focused on carbon suggests that multi-metric sustainability assessment frameworks built into BIM represent a significant and, at present, underdeveloped opportunity. Reviews of material decarbonization point to the same need from the supply side: inconsistent EPD methodologies and the absence of standardized embodied-carbon benchmarks limit the data available to such workflows (Dauda et al., 2026), and emerging life-cycle evidence on low-carbon construction materials derived from organic waste (Gate et al., 2026) has yet to be linked to BIM-based design workflows.

The final gap follows from the organizational barriers discussed above. Literature offers comparatively little guidance on how to design the training, incentive, and governance interventions that would close the skills and collaboration gaps identified by Kineber et al. (2023), Alshibani et al. (2024), and Ahankoob et al. (2026). Work grounded in organizational behavior and implementation science, rather than in technology development, may be needed to complement the largely technical solutions that dominate the current literature.

5 CONCLUSION

This review has synthesized 50 peer-reviewed studies to construct an integrated account of how Building Information Modeling supports multidisciplinary coordination across architectural, structural, and MEP systems, and how that coordination shapes sustainable building delivery. The synthesis shows substantial technical progress, evident in the progression from rule-based clash detection to graph-based and machine-learning-enabled clash resolution, from manual to automated architecture-structure translation, and from static energy audits to BIM-linked, machine-learning-accelerated sustainability prediction. At the same time, the cross-thematic reading in this review reveals that this technical progress has consistently outpaced progress on the organizational, standards-governance, and skills dimensions of coordination, such that unresolved information loss and collaboration barriers documented in the earliest studies reviewed here reappear, in updated form, in the most recent studies on digital twins and artificial intelligence. The central implication is that sustainable building delivery cannot be engineered through technical BIM capability alone; it requires the joint development of interoperable data standards, organizational collaboration practices, and integrated sustainability metrics within a shared digital environment. Realizing BIM's full potential for multidisciplinary coordination and sustainable delivery will depend on treating these technical and organizational dimensions as inseparable, rather than sequential components of a single coordination system.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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