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Stage-Conditioned Organization–Data Connections in Collaborative Decision Events: Evidence from a Supertall Building Project

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Abstract

Process-oriented BIM research has documented coordination workflows and design decisions, but project records rarely show how technical evidence becomes a basis for joint judgment and how confirmed outcomes become controlled project information for subsequent tasks. This study develops an auditable event-level framework and applies a retrospective explanatory embedded single-case design to a 266 m mixed-use supertall building. It reconstructs 31 collaborative decision events from 266 evidence fragments across 41 archival records. Within the case, scheme decision-making and specialist design centered on establishing a defensible design basis; design development linked joint review, responsibility assignment, and controlled updates of models, drawings, and issue records to establish a shared cross-disciplinary baseline; and construction detailing and implementation emphasized translating site and procurement changes into the current executable project state. Changed conditions could reopen joint judgment before controlled project information was updated. Comparable events revealed distinct evidentiary discontinuities: analytical outputs were sometimes retained without traceable use in joint judgment, decisions without traceable controlled write-back, and updated records without documentation of the preceding judgment process. Separating these transitions clarifies why similar digital tools and organizational arrangements produce different information outcomes and provides a traceable, stage-conditioned basis for design justification, baseline formation, implementation control, and cross-stage continuity.

Keywords: supertall building project; organization–data connections; collaborative decision events; BIM coordination; common information objects; controlled write-back

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1. Introduction

Large mixed-use supertall buildings provide an important means of accommodating offices, retail, hotels, public services, and transport interchanges in high-density cities [1,2]. They integrate structural, mechanical, electrical, and plumbing (MEP), façade, fire-protection, vertical-transportation, and smart-building systems. These systems share constrained spaces such as the core, shafts, and plant floors, while disciplinary interfaces and information dependencies become more complex as functions are integrated [3–5]. A local adjustment may affect several disciplines and subsequently influence procurement, site implementation, and operations and maintenance. Project teams must therefore bring together relevant disciplinary knowledge and information, reach a joint judgment, assign responsibility for action, and retain the resulting information in a form that can be recognized and used in later stages [6]. These interdependent technical systems, disciplinary interfaces, and implementation activities continually generate collaborative decision events during design, construction, and handover. Resolving such events generally requires participants to identify the problem, exchange and interpret relevant information, compare alternatives, confirm responsibilities, and translate the resulting decision into a project outcome that can be implemented and traced in subsequent work.

At the individual-event level, collaborative decision making generally involves both organizational action and data responses. Research on digital knowledge collaboration in complex engineering projects indicates that participants' knowledge boundaries, interaction patterns, and approaches to information openness affect how knowledge is shared, interpreted, and jointly used across organizations [7]. Research on building information management further shows that the structured exchange, integration, and linkage of multidisciplinary information can provide a shared information base for option analysis and engineering decisions [8,9]. The organizational dimension therefore examines how disciplinary knowledge, decision authority, and implementation responsibility shape problem resolution through stakeholder involvement, joint interpretation, formal confirmation, responsibility assignment, and outcome verification. The data dimension examines how dispersed project records are transformed into shared, controlled project information that remains usable over time through information collection and integration, option analysis and comparison, version and status control, and formal documentation of decisions. Connections between organizational action and data responses may vary with coordination conditions and project stage. Accordingly, organizational and data responses constitute the two analytical dimensions used in this study.

Existing research on organizational coordination can be organized into three main strands. The first examines information exchange, joint review, collaborative problem solving, and action coordination, showing that combinations of collaborative behaviors and the distribution of knowledge among participants affect the handling of specific tasks [10,11]. The second focuses on specialist coordination roles, such as BIM managers, and examines their interface functions in model review, information-requirement coordination, issue assignment, and delivery management [12]. The third adopts a project-governance perspective to investigate how leadership, client involvement, contractual arrangements, relational trust, and responsibility allocation shape joint judgment and authorization for action [13,14]. Together, these strands explain the foundations for joint judgment and implementation in multi-organizational projects through collaborative behavior, coordination roles, and governance conditions.

Research on digital information management can be grouped into four areas. The first examines how BIM functions differ across design, construction, and operation as information requirements, model maturity, and users change over the project life cycle [15]. The second considers how models, option analyses, and simulations support design decisions, showing that common information objects help participants inspect problems, compare alternatives, and verify decisions [16]. The third investigates version control and common data environments (CDEs), emphasizing how versions, baselines, approval status, access rights, and data responsibilities affect the identification and exchange of valid information [17,18]. The fourth examines design-decision records and links decision rationales, evaluation criteria, and applicable constraints to model objects to improve the interpretability and later reuse of design outcomes [19]. Together, these areas explain how digital information supports stage deliverables, option appraisal, status control, and decision documentation.

Some studies have also begun to examine the relationship between organizational action and digital information directly. Research on BIM-supported decision making shows that the use of digital information changes participants' roles, capability requirements, and decision processes [20]. Organization–information network studies reveal structural relationships between project participants and digital objects by jointly analyzing actor relations and information exchange [21]. Research on digital implementation further indicates that platform workflows, information permissions, and patterns of use are shaped by contractual arrangements, organizational routines, and participant strategies [22,23].

Alongside these perspectives, process-oriented BIM research has examined coordination workflows, decision documentation, and digital activity traces. Zahedi et al. organize design explanations through design episodes and connect them to model elements, while Shim et al. model iterative BIM-based construction coordination [19,24]. Jang et al. examine the information available in BIM logs and identify limitations in their object-level detail [25]. These studies provide foundations for examining coordination within project processes. Building on them, the present study addresses a more specific question: how can heterogeneous project records be used to assess separately whether technical evidence entered joint judgment and whether a confirmed outcome entered controlled project information, while retaining cases in which either connection remains undocumented?

To address this gap, this study develops an event-level analytical framework for organization–data connections. C1 is the evidence-to-judgment connection, through which technical evidence enters joint interpretation, option selection, formal confirmation, or responsibility determination. C2 is the decision-to-controlled-information connection, through which a confirmed decision, assigned responsibility, or verification finding enters controlled project information through controlled write-back. Their combinations define four connection states: C1 + C2, C1 only, C2 only, and no identifiable documented connection. C1 and C2 are assigned only when the corresponding connection is documented; the co-occurrence of organizational and data responses alone is insufficient.

A retrospective embedded single-case design was used to examine a 266 m mixed-use supertall building in Xiamen, China. The analysis extracted 266 traceable evidence fragments from 41 project records and reconstructed 31 collaborative decision events. The study addresses two research questions.

RQ1. *What coordination conditions arise in different engineering stages of a complex supertall building project, what organizational and data responses are adopted, and what stage-conditioned coordination functions do they serve?*

RQ2. *How does technical evidence enter joint judgment through C1, and how do confirmed decisions, assigned responsibilities, or verification findings enter controlled project information through C2?*

The study makes three contributions. First, it operationalizes two documented organization–data connections within collaborative decision events: the evidence-to-judgment connection (C1) and the decision-to-controlled-information connection (C2). Second, by assessing C1 and C2 separately, it distinguishes four connection states and locates specific evidentiary gaps within coordination processes. Third, comparisons across engineering stages and representative evidence chains provide a within-case explanation of how stage-conditioned coordination functions relate to formation of a defensible design basis, establishment of a shared cross-disciplinary baseline, and maintenance of the current executable project state. The framework complements process-oriented BIM research by linking event interpretation to explicit evidence requirements while retaining uncertainty arising from incomplete records.

2. Literature Review and Analytical Framework

2.1. Coordination Problems and Event Conditions in Complex Building Projects

Coordination problems in complex building projects arise from multiple dependencies among technical systems, disciplinary tasks, participating organizations, and delivery stages. As the number of objectives, interfaces, and participants increases, project relationships become more susceptible to systemic risk [26,27]. Local decisions and their effects may propagate across technical, contractual, and organizational boundaries to other disciplines, projects, or stages [28,29]. Studies of systems integration and design coordination also show that interface conditions and integration responsibilities change throughout design, construction, testing, and operational readiness, with primary responsibility potentially shifting among the client, design team, contractors, and suppliers [30,31].

Stage transitions also change information requirements, deliverables, and users. Models and documents produced in one stage must be filtered, validated, and reorganized before they can support subsequent tasks [32]. Research on digital transformation shows that platform use changes information exchange, organizational boundaries, and work routines, while workflows are continually adapted to the project context [33]. Consequently, the same organizational arrangement or digital tool may serve different functions across stages, including evidence generation, joint review, implementation control, and information delivery for operations [34].

The literature identifies four sources of coordination conditions: insufficient or discontinuous information, interpretive ambiguity or differences in judgment, task or disciplinary interdependence, and contextual change. These conditions were operationalized as conditions U1–U4 so that they could be identified in project records. Insufficient or discontinuous information (U1) includes missing records, unsynchronized models and drawings, unclear versions or status, and information loss during stage transitions; this condition concerns the availability, validity, and continuity of event evidence [9,35,36]. Interpretive ambiguity or differences in judgment (U2) arise when participants differ in their understanding of the problem, the priority of objectives, evaluation criteria, or the effects of alternatives. Digital visualization can provide a common information object, but disciplinary backgrounds and cognitive differences still shape its interpretation [37,38]. Task, technical, or disciplinary interdependence (U3) occurs when a local adjustment requires coordinated analysis, confirmation, and modification by several disciplines or organizations, and interface connections may amplify the effects of the change [30]. Changes in schedule, site, or external conditions (U4) include shifts in procurement or supply status, site conditions, review requirements, or operational requirements that prompt revisions to options, plans, or implementation arrangements [39,40]. U1–U4 are non-exclusive coordination conditions that may co-occur. They were coded from direct archival evidence, with the collaborative decision event serving as the embedded unit of analysis.

2.2. Organizational Responses in Collaborative Decision Events

Research on organizational coordination first considers participating actors and the conditions for collaboration. Complex construction projects are delivered jointly by organizations with different disciplinary expertise, contractual responsibilities, and decision authority. The timely identification and involvement of key actors, together with appropriate disciplinary-interface arrangements, affect whether a coordination problem can be interpreted adequately [41–43]. Studies of BIM collaboration networks and standardized information management further show that clearly defined roles, responsibilities, information requirements, and coordination positions establish basic pathways for interorganizational action [44–46]. This research explains which actors participate in collaboration and what knowledge, authority, and responsibility they bring.

Building on this foundation, recent research has shifted toward the collaborative actions that participants undertake around specific tasks. Project knowledge must be captured, shared, and integrated to develop shared understanding, while information sharing, joint work, adaptive adjustment, and trust jointly affect task outcomes [47–49]. This line of research supports examination of whether relevant knowledge actually enters a collaborative event and whether participants develop a shared interpretation through joint review, negotiation, and problem solving.

Once a shared interpretation has been established, coordination must convert judgment into authorized, implementable action. The limits of project managers' authority, the combination of vertical and shared leadership, and incentive mechanisms influence decision formation, resource commitment, and responsibility assignment [50,51]. Research on contractual governance, trust and conflict, and interorganizational risk propagation further indicates that issues beyond existing responsibilities or authority may need to be referred to another organization or a higher decision level [52–54]. Studies of reliable collaboration, performance monitoring, and delivery management also emphasize that assigned tasks should be followed by review, verification, or acceptance of the resulting action [55,56].

Accordingly, six organizational responses were defined to capture the functional sequence from actor involvement and joint interpretation to implementation and closure. O1 denotes relevant-actor involvement or early participation; O2 denotes joint interpretation, cross-disciplinary review, or negotiation; O3 denotes a decision, approval, or formal authorization; O4 denotes responsibility assignment and commitment to act; O5 denotes issue escalation and cross-level resolution; and O6 denotes outcome verification, review, and acceptance. Routine events may progress through O1–O4 and then to O6. When the participating actors or current authorization level cannot resolve the issue, O5 provides an escalation route. The codes capture organizational responses identifiable in the records. Multiple codes may occur within one event, and events are not assumed to follow the entire sequence.

2.3. Data Responses and Controlled Project Information

Research on data coordination first addresses how heterogeneous records are acquired, transformed, and integrated into a shared project data foundation. Studies integrating BIM with the Internet of Things (IoT), big data, and geographic information systems (GIS) show that sensor, model, schedule, and spatial data must be extracted, cleaned, semantically mapped, and linked before they can be queried and processed within a unified context [57,58]. Building on this work, studies of federated CDEs and cross-domain knowledge graphs connect disciplinary models, issue records, and external knowledge into identifiable common information objects, enabling participants to view and exchange information about the same component, issue, or data relationship [59–61].

Common information objects must also be converted into analytical evidence that supports judgment. Research on machine-learning-assisted design, multi-objective optimization, and BIM-based sustainability assessment generates comparable evaluation results through performance prediction, simulation, and option comparison, thereby providing quantitative evidence for design selection [62–64]. As project data evolve, coordination must also identify model differences, design changes, and their effects while controlling versions, baselines, and metadata status [65,66]. A CDE can provide a common channel for storage and access; however, reliable use of that information still depends on permissions, standardization, validity status, and verifiable provenance [67,68].

Research on formal documentation further examines traceability after information moves across actors, platforms, and stages. Studies of data provenance, blockchain-based linkage, and contractual information management indicate that structured retention of information sources, responsible actors, timestamps, permissions, and change relationships can improve the reliability and accessibility of project records [69,70]. Research on design intent and information requirements also emphasizes that later users need to identify the rationale for option selection, the alternatives considered, applicable constraints, and delivery requirements. Confirmed outcomes should therefore be explicitly linked to model objects or formal deliverables [71,72].

Data responses were divided into five functions: information input, common information objects, analytical evidence, validity control, and formal documentation. D1 denotes information collection, extraction, and integration across sources; D2 denotes the formation of a traceable common information object for joint viewing, querying, or discussion; and D3 denotes analysis, simulation, calculation, and option comparison [59,73]. D4 denotes the setting or updating of versions, baselines, approval status, and issue status. D5 denotes the entry of confirmed outcomes, decision rationales, or responsibility information into formal, retrievable project records [69,74]. D1–D5 are parallel functional codes and may co-occur within an event. The mere existence of a document, simply opening a model, or one-way transmission of information does not by itself constitute a data response.

2.4. From Response Co-Occurrence to Documented Organization–Data Connections

Beyond the separate literatures on organizational coordination and data management, recent studies have examined interactions between organizational conditions and digital practices. Research on human–organization–technology fit, collaboration among BIM professionals, and leadership for digital innovation shows that professional capability, role configuration, management support, and governance arrangements shape both the adoption of digital technologies and collaborative processes [75–77]. Research on front-end knowledge collaboration, two-layer information collaboration networks, and dynamic BIM collaboration networks further links participant relationships to information exchange, model operations, and knowledge openness [7,78]. These studies can identify the structure and evolution of relationships between actors and information, but project- or network-level aggregates cannot directly show whether a particular data object entered a specific judgment or whether a decision subsequently triggered an update to that object [21].

Research on the use of technical evidence in joint judgment shows that three-dimensional visualization mediates participants' perceptions of site conditions and model content, while immersive collaborative environments and BIM-based multicriteria evaluation turn model information into evidence for joint inspection, discussion, and comparison [79,80]. On this basis, C1 is defined as the evidence-to-judgment connection: a documented organization–data connection through which technical evidence enters joint judgment. C1 is identified where records show that relevant actors viewed, cited, compared, or interpreted a specific model, drawing, parameter, analytical result, or issue record during joint interpretation, option selection, formal confirmation, or responsibility determination [81]. The mere presence of a model on a platform, attachment of a file to meeting records, or confirmation that information was transmitted does not establish C1. Failure to identify C1 means only that the available archive does not document this connection.

Research on organizational decisions that change digital objects focuses on design change, collaborative workflows, and closed-loop information feedback. Studies of BIM–VR design change, cross-domain digital-twin collaboration, and closed-loop manufacturing information show that confirmed adjustments, instructions, and verification findings may alter model content, workflow status, version relationships, and production information [82,83]. Research on synchronized construction management and process mining also uses timestamps, operation sequences, and event logs to reconstruct the order of activities, providing a methodological basis for identifying information-update processes [84,85].

However, because recording granularity differs across systems and digital traces do not necessarily contain explicit links among objects, issues, and decisions, temporal or digital co-occurrence alone does not establish a documented organization–data connection [25,86]. C2 is therefore defined as the decision-to-controlled-information connection: a documented organization–data connection through which a confirmed decision, assigned responsibility, or verification finding enters controlled project information. C2 is identified where records link such a confirmed outcome to an update of a specific controlled project object, such as a drawing, model, report, issue status, or version baseline [25]. Controlled write-back is the traceable action that incorporates the confirmed outcome into that object together with its validity or status information. C1 and C2 produce four connection states: C1 + C2, C1 only, C2 only, and no identifiable documented connection. The final state denotes cases in which the available archive does not support either connection, including cases where organizational and data responses co-occur without sufficient linkage evidence or where essential information on object identity, evidence use, judgment content, or update status is unavailable.

In summary, the event-level analytical framework comprises coordination problems and event conditions, organizational responses, data responses, two documented organization–data connections, and controlled project information. U1–U4 identify coordination conditions; O1–O6 and D1–D5 identify organizational and data responses; C1 identifies the evidence-to-judgment connection; and C2 identifies the decision-to-controlled-information connection. A controlled project object is the specific model, drawing, report, issue status, or version baseline updated through C2; controlled write-back is the updating action; and controlled project information is the resulting information with identifiable content and validity status for subsequent tasks. As shown in Figure 1, RQ1 examines stage-conditioned coordination functions across engineering stages and contextual comparison events. RQ2 compares connection states and representative evidence chains to trace how technical evidence, joint judgment, and controlled project information are linked. The arrows indicate documented temporal and evidential ordering.

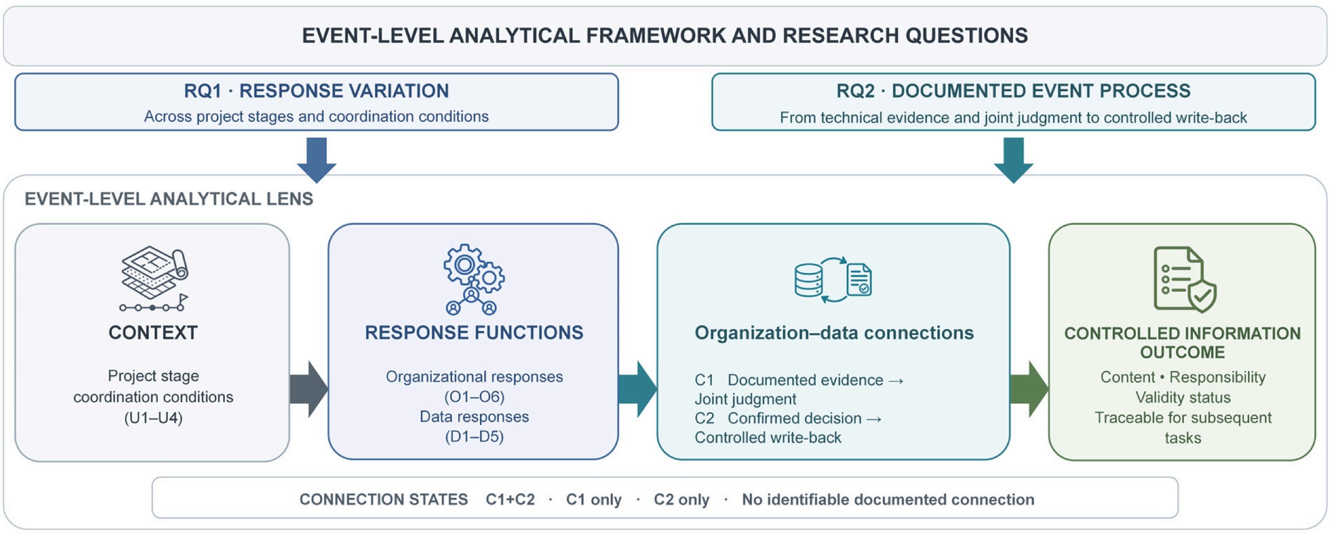

Figure 1. Research and analytical framework.

3. Materials and Methods

3.1. Research Design, Case, and Data

This study adopted a retrospective explanatory embedded single-case design. Case studies are appropriate for examining context-dependent, process-oriented research questions in real project settings, while an embedded design permits comparison among clearly bounded units within the overall case boundary [87]. Research on complex engineering projects also shows that retrospective analysis of historical project records can reconstruct activities and relationships across stages and identify changes in project processes over time [88]. Because this study examines the evidence-to-judgment connection (C1) and the decision-to-controlled-information connection (C2), the project as a whole constitutes the case boundary and collaborative decision events constitute the embedded units of analysis. This design preserves the process relationships among specific actions, information objects, and the project context.

The case was selected purposively using four criteria: project complexity and relevance to the research questions; the density of multidisciplinary and multi-organizational interfaces; continuity of digital-information activities; and the completeness and traceability of records across stages. The case is the Xiamen Hemei Center, a mixed-use supertall building approximately 266 m high. The project involved architects, structural and MEP engineers, façade specialists, contractors, equipment suppliers, operations consultants, and regulatory authorities. Disciplinary interfaces were dense; knowledge, decision authority, and implementation responsibility were dispersed across organizations; and design and construction information changed continually. The completed project spanned scheme design, design development, procurement, construction, and operational readiness. These characteristics generated a high density of observable collaborative events and made the case suitable for identifying C1 and C2 and comparing them across stages within one project setting. Figure 2 presents the overall building form, multidisciplinary BIM models, and representative coordination records.

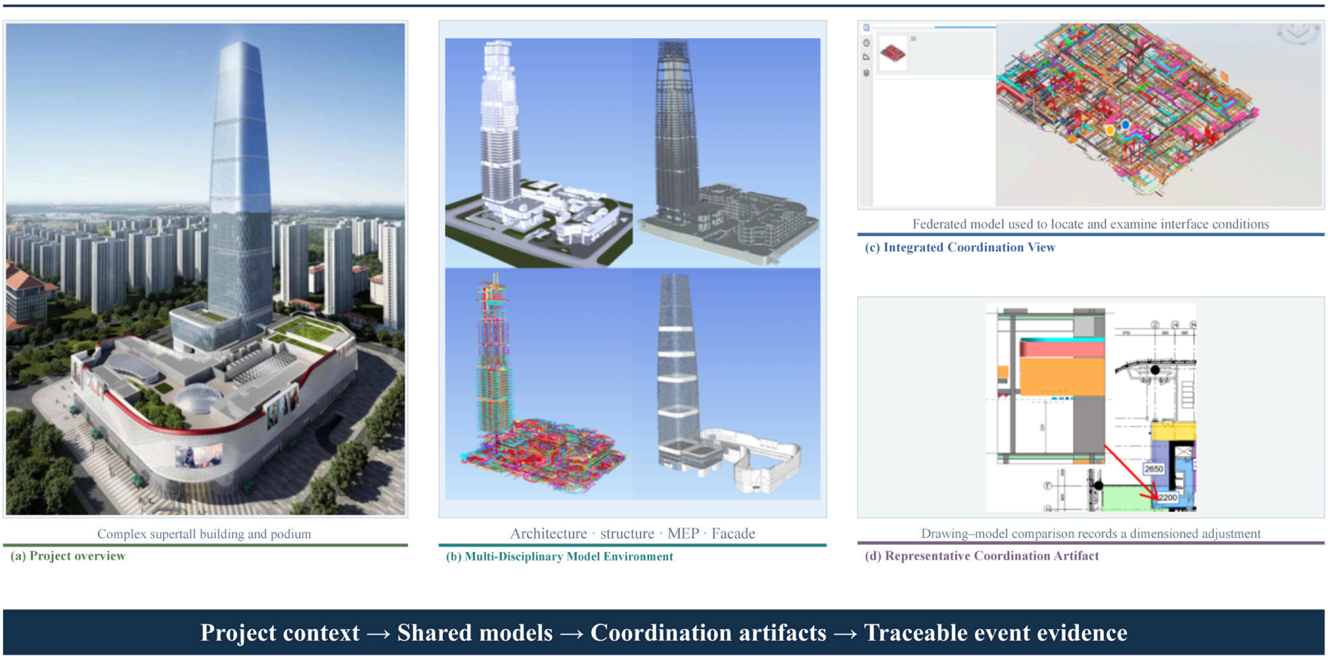

Figure 2. Case project and BIM-based coordination context.

Previous research on the same project examined project governance and value creation through the F + EPC + O model and a dynamic-capabilities perspective. The earlier work addressed governance and value creation at the project level, whereas the present study uses collaborative decision events as embedded units to analyze documented organization–data connections. Accordingly, the two studies differ substantially in their research questions, coding frameworks, units of analysis, and reported results [6].

According to the group's audited data for 2024, the project generated approximately CNY 71 million in combined economic benefits over its life cycle, including approximately CNY 12.8 million attributed in the project audit to digital collaboration and concurrent decision making. The magnitude of these audited benefits indicates that digital collaboration constituted a materially important component of project delivery rather than a peripheral technical activity. This practical significance makes the project a valuable empirical setting for examining how digital collaboration and concurrent decision making were organized and documented in practice. The present study therefore investigates the event-level connections among disciplinary actors, technical evidence, joint judgment, responsibility assignment, and controlled write-back across the project stages.

3.2. Event-Based Coding, Aggregation, and Classification

The data came from the internal project archives of the collaborating organization, CCCC Xiamen Investment Co., Ltd., and covered 2012–2025. Records that directly documented coordination processes were produced mainly between 2019 and 2024. In total, 41 project records were catalogued, including BIM coordination and issue records; design–construction coordination minutes; option-comparison materials; specialist analyses and technical reports; model-analysis outputs; specialist consultation and verification documents; and operations, acceptance, and project-summary materials. These sources were used to identify coordination conditions, participating actors, joint reviews, option comparisons, responsibility assignments, changes in versions and issue status, and technical verification. Triangulation across sources supported reconstruction of the event processes. Table 1 summarizes the composition and principal uses of the data.

Table 1. Data sources.

Archive Record Category	Number of Records	Principal Analytical Use
BIM coordination and issue-management records	15	Identify issues, joint reviews, responsibility assignments, and changes in versions and issue status
Design–construction coordination minutes	6	Identify site constraints, design changes, procurement interfaces, and adjustments to implementation responsibilities
Option studies, specialist analyses, and technical verification records	11	Identify option comparisons, parameter calculations, simulations, and specialist verification
Operations, acceptance, and summary records	5	Supplement project context, outcome status, operational readiness, and summary information
Project technical reports	4	Provide stage-specific context and cross-check findings in each section; verify statements that an outcome was finally determined against the latest available document
Total	41	Composite files and duplicate scans were excluded

The analysis proceeded in five steps: archive indexing and evidence extraction; evidence-fragment coding; reconstruction of collaborative decision events; extraction of event-level attributes; and cross-event comparison and pattern identification. The procedure is shown in Figure 3.

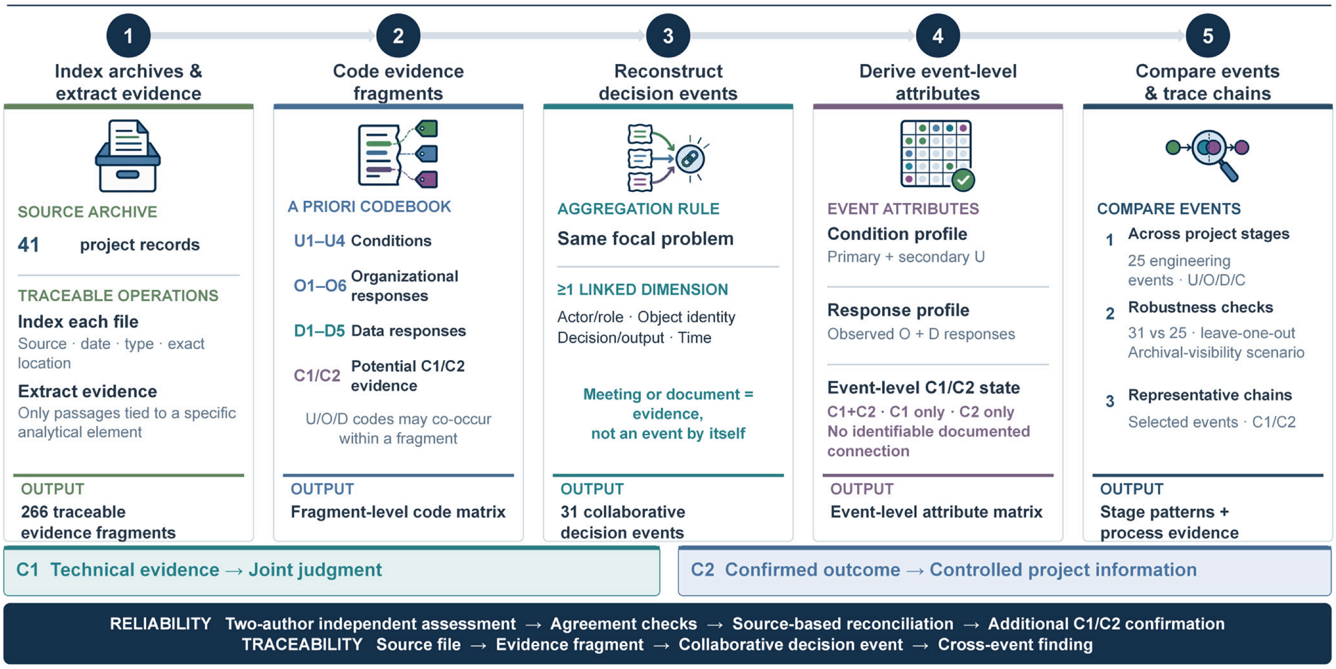

Figure 3. Five-step workflow for evidence coding and event-level analysis.

First, each of the 41 project records was indexed by source file, date, record type, and location within the source. A discrete passage was extracted as an evidence fragment when it independently described a coordination condition, organizational action, data action, common information object, or outcome and could be traced to a specific source location. This process produced the primary analytical dataset of 266 traceable evidence fragments. General background descriptions, attendance lists alone, procedural statements not tied to a specific issue, and material without a traceable source location were not coded as independent evidence fragments.

Second, the analytical framework developed in Section 2 was used as an a priori coding scheme for the 266 evidence fragments. Fragment-level codes covered coordination conditions U1–U4, organizational responses O1–O6, and data responses D1–D5. Fragments containing evidence potentially relevant to C1 or C2 were additionally flagged for subsequent event-level assessment. Multiple codes were permitted when a fragment contained more than one analytical element, thereby preserving the concurrent conditions, actions, information objects, and outcomes within complex events.

Third, evidence fragments distributed across different dates and documents were aggregated into collaborative decision events, primarily on the basis of problem continuity and with reference to links among principal participants, common information objects, and outcomes. Fragments were assigned to the same event only when they addressed the same focal problem and formed a traceable continuity in at least one additional dimension: actor responsibility, information-object identity, decision or output, or temporal sequence. A single meeting or document constituted only part of the evidence and was not automatically treated as a collaborative decision event. Adjacent fragments were kept separate when they concerned different focal problems, different controlled objects, or independent decisions, even if they appeared in the same meeting or on the same date. Event-reconstruction reproducibility was assessed through independent reconstruction and subsequent reconciliation, as described in Section 3.3.

Fourth, fragment codes were aggregated into event-level attributes to identify the primary and secondary coordination conditions, organizational responses, data responses, and connection state of each event. C1 and C2 were assessed using the definitions in Section 2.4. C1 required identification of the technical evidence used, the actors involved, and the joint judgment or responsibility determination informed by that evidence. C2 required identification of the confirmed outcome, the controlled project object updated, and evidence of controlled write-back. Co-occurring organizational and data responses were recorded only as response co-occurrence and were insufficient to establish either connection. Fifth, cross-event comparison and pattern identification were conducted using the event-level attribute matrix. The comparison covered the distribution of coordination conditions and organizational and data responses across engineering stages, together with the four connection states: C1 + C2, C1 only, C2 only, and no identifiable documented connection. Cross-event analysis also compared the evidence chains linking common information objects, joint judgment, formal confirmation, and controlled write-back to identify how organizational action and data responses were connected in different engineering stages. Complete code definitions, inclusion and exclusion rules, positive and negative examples, event-aggregation criteria, and boundary cases are provided in Appendixes A and B.

3.3. Independent Coding and Event-Reconstruction Validation

Two authors independently analyzed the archive using predefined coding and event-reconstruction protocols and without access to each other's classifications. Coding agreement and reconstruction consistency were assessed separately for three analytical tasks.

First, fragment-level agreement for U1–U4, O1–O6, and D1–D5 was evaluated using code-specific agreement tables, exact agreement, and Cohen's kappa. Both coders applied these codes to the aligned 266-fragment analytical dataset.

Second, event-reconstruction consistency was assessed independently from code assignment. Because the two researchers independently segmented the same archival sources at different levels of granularity, their reconstruction datasets contained 266 and 290 evidence fragments, respectively. Agreement between the two independently reconstructed event structures was evaluated using the adjusted Rand index.

Third, C1 and C2 were independently assessed at the event level. Agreement was evaluated separately for the binary C1 and C2 classifications and for the resulting four-category connection-state classification (C1 + C2, C1 only, C2 only, and no identifiable documented connection). Before agreement statistics were finalized, notation inconsistencies and clerical entry errors identified during the confirmatory review were checked against the original coding records and corrected. These corrections concerned transcription or notation only; substantive differences in analytical judgment remained unreconciled at this stage.

All substantive coding disagreements and discrepant event boundaries were subsequently reconciled against the original archival sources and the operational rules in Appendixes A and B before the final classifications were adopted. An additional researcher then confirmed the reconciled C1/C2 classifications against the evidentiary requirements and the traced evidence chains.

3.4. Stage and Cross-Event Comparisons

Stage analysis used event-level descriptive statistics to compare primary coordination conditions, major organizational and data responses, their event coverage within each engineering stage, and the four connection states: C1 + C2, C1 only, C2 only, and no identifiable documented connection. Because an event could contain several conditions and responses, U, O, and D were coded non-exclusively. Event counts and within-stage distributions were used to identify stage patterns; no tests of statistical significance were performed. Cross-event analysis then compared evidence chains linking the common information object, joint judgment, formal confirmation, and controlled write-back. Representative events with relatively complete project records were selected from all four connection states. The comparison was used to explain why similar organizational and data responses produced different connection states and information outcomes.

To assess whether heterogeneity among the six contextual comparison events affected the interpretation, the C1/C2 distribution was recalculated after excluding these events and compared with that for all 31 events. Two additional robustness checks examined the principal stage patterns. First, a leave-one-event-out analysis recalculated the proportion of design development events classified as C1 + C2 and the proportion of construction detailing and implementation events containing documented C2 after removing each engineering event in turn. Second, an archival-visibility scenario treated one, two, and all four construction detailing and implementation events classified as C2 only as potentially containing an undocumented C1 process.

Throughout the analysis, source-to-fragment-to-event traceability was retained, and event boundaries and process relationships were checked through triangulation across project records. Connections unsupported by the available archive were classified as no identifiable documented connection. Detailed procedures are provided in Appendixes A and B.

4. Results

4.1. Coding Agreement and Event-Reconstruction Consistency

Fragment-level coding agreement was assessed for U, O, and D before substantive reconciliation. Across the aligned 266-fragment coding dataset, exact agreement was 77.4% for coordination conditions (U), 75.9% for organizational responses (O), and 81.6% for data responses (D). Cohen's kappa was 0.83 (95% CI 0.79–0.87) for U, 0.77 (95% CI 0.71–0.82) for O, and 0.87 (95% CI 0.84–0.90) for D, with a combined kappa of 0.82 (95% CI 0.80–0.84) across the three coding dimensions. All three aggregate coding dimensions therefore reached substantial or almost perfect agreement. The two coders assigned identical code sets across all four dimensions (U, O, D) for 75 of the 266 fragments (28.2%); identical code sets across the three dimensions U, O, and D were found for 115 fragments (43.2%).

Event-reconstruction consistency was examined independently from fragment-level code agreement. The two researchers reconstructed 31 and 32 provisional collaborative decision events, respectively. The two event reconstructions yielded an adjusted Rand index of 0.802; the segmentation procedure is described in Section 3.3.

The substantive event-boundary disagreement was confined to one case: whether the temporally separated façade and thermal-comfort optimization analyses following completion of the tower-crown scheme selection represented a continuation of an existing event or a new event associated with changed design conditions. After source-based reconciliation using the predefined aggregation rules, 31 collaborative decision events were retained for the final analysis.

Event-level C1/C2 agreement was assessed on the independent ratings after correction of one notation inconsistency and three clerical entry errors, but before reconciliation of substantive disagreements. Exact agreement was 90.3% for C1 and 93.5% for C2, with Cohen's κ of 0.795 and 0.859, respectively. Agreement for the four-category connection-state classification was $\kappa = 0.739$. Remaining substantive disagreements were subsequently reviewed against the original archival sources and the operational criteria before the final classifications were adopted. Table 2 reports the code-specific agreement results.

Table 2. Code-specific agreement between the two independent coders.

Code	Raw Agreement (Per Code Unit)	Cohen's κ
U1	0.974	0.815
U2	0.936	0.809
U3	0.925	0.843
U4	0.932	0.775
O1	0.902	0.333
O2	0.966	0.798
O3	0.921	0.727
O4	0.955	0.878
O5	0.989	0.567
O6	0.981	0.879
D1	0.974	0.707
D2	0.985	0.887
D3	0.925	0.85
D4	0.936	0.855
D5	0.929	0.857
C1	0.903	0.795
C2	0.935	0.859

Note: U/O/D rows are based on the 266 aligned evidence fragments; C1/C2 rows are based on the 31 shared events.

4.2. Event Overview and Stage Groups

The analysis extracted 266 traceable evidence fragments from 41 project records and reconstructed 31 collaborative decision events. Twenty-five engineering events were assigned to three engineering stages according to where the principal decision was made, the event's primary work content, and the stage in which its information outcome was mainly used: scheme decision-making and specialist design, design development, and construction detailing and implementation. The remaining six were retained as contextual comparison events to provide evidence on continuity over time and archival visibility. Table 3 presents the four stage groups.

Table 3. Coordination conditions, responses, and connection states by stage group.

Stage Group	*n*	Main Conditions	Main Organizational Responses	Main Data Responses	Connection State
Scheme decision-making and specialist design	8	U2 primary in 5; U2 and U3 each in 6	O3 in 5; O2 in 3	D3 in 8; D4 in 7; D5 in 5	C1 + C2: 3; C1 only: 2; C2 only: 1; no identifiable documented connection: 2
Design development	8	U3 primary in 4; U3 in 6; U1 and U2 each in 4	O3 in 7; O4 in 6; O2 and O6 each in 5	D3, D4, and D5 each in 7	C1 + C2: 7; no identifiable documented connection: 1
Construction detailing and implementation	9	U3 primary in 5; U4 primary in 4; U3 in 8; U4 in 6	O4 in 8; O3 in 6; O6 in 4	D5 in 8; D3 and D4 each in 6	C1 + C2: 4; C2 only: 4; no identifiable documented connection: 1
Contextual comparison events	6	U1–U4 distributed across events	No stable combination	D5 in 5; D3 and D4 each in 4	C1 + C2: 1; C1 only: 1; no identifiable documented connection: 4

An event could contain multiple coordination conditions and multiple organizational and data responses; U, O, and D were therefore coded non-exclusively. The following comparisons use event counts and within-stage distributions to identify descriptive patterns among the observed events, without tests of statistical significance. C1 and C2 refer to the evidence-to-judgment and decision-to-controlled-information connections defined in Section 2.4. Co-occurrence of organizational and data responses does not by itself establish either connection.

4.3. Scheme Decision-Making and Specialist Design: Observed Conditions, Responses, and Connection States

The principal coordination task during scheme decision-making and specialist design was to establish a design basis that could be developed further under multiple objectives and constraints. U2 was the primary condition in five of the eight events; when secondary conditions were included, U2 and U3 each occurred in six events. Structural safety, architectural expression, MEP requirements, energy consumption, occupant comfort, cost, constructability, and review requirements generally had to be considered together. This stage was therefore characterized by the interpretation of alternatives and multi-objective trade-offs.

Among the data responses, analysis, simulation, and option comparison were the most prominent. D3 occurred in all eight events, D4 in seven, and D5 in five. Among the organizational responses, O3—decision, approval, or formal authorization—occurred in five events, while O2—joint interpretation and cross-disciplinary review—occurred in three. At this stage, data responses primarily produced calculation results, performance metrics, option matrices, and stage-specific parameters, whereas organizational responses determined whether these outputs became design conditions for subsequent development.

Comparison across the events indicates that a specialist analysis must be followed by a clear record of the technical conclusion's authorization status and scope of applicability. In EVT-020, comparison of structural schemes A, B, and C for the banquet hall produced a recommendation to develop Scheme A, which was subsequently used in comfort verification and integrated MEP layout; the available records did not retain formal approval by the client or architect. In EVT-021, an ETABS (v 2017.0.1) model, period and displacement results, quantities, construction duration, and an evaluation matrix were reviewed at a coordination meeting. They informed an interim selection of the structural system, which was recorded in later documents as the final implementation baseline. EVT-027 delivered wind-tunnel pressure measurements, wind-induced response checks, and version-controlled reports, but the records did not show how the design team used the load data or updated the model.

These events show that scheme decision-making and specialist design can generate substantial quantities of technically detailed data. The usability of stage outcomes also depends on clear documentation of the selected option, the limits of approval, and the stage baseline. Information outcomes at this stage included interim technical judgments, parameter rules, specialist reports, and option baselines.

4.4. Design Development: Observed Conditions, Responses, and Connection States

The principal coordination task during design development was to integrate dispersed disciplinary proposals into a design baseline that could be jointly revised and used in subsequent work. U3 was the primary condition in four of the eight events and occurred as either a primary or secondary condition in six; U1 and U2 each occurred in four. Disciplinary interfaces, information completeness, and option interpretation overlapped at this stage.

Organizational and data responses were particularly frequent among the observed design development events. O3 occurred in seven events, O4 (responsibility assignment and commitment to act) in six, and O2 (joint review) and O6 (outcome verification) in five each. D3, D4, and D5 each occurred in seven events. Seven of the eight events showed a traceable evidence chain in which technical evidence entered joint judgment and a confirmed decision was linked to a subsequent update of a controlled project object.

EVT-004 illustrates how a shared cross-disciplinary baseline was established. Delayed issue responses, missing attachments, and repeated revisions across versions led the project team to establish deadlines for written responses, WSP review, issue escalation, and status updates. The issue list, response records, and open/resolved status together preserved each issue, the assigned responsibility, and the outcome for use in subsequent reviews and version control. EVT-005 arose from repeated major changes that were not fully marked. The resulting duplicate modeling and baseline drift led the client to designate the 0718 version as the model baseline, freeze the structural and MEP versions, and restrict subsequent changes to local review and limited updates.

EVT-024 produced clash statistics, disciplinary examples, and benefit estimates, but the archive did not contain item-level responsibilities, disposition dates, closure status, or independent verification. The records confirm that analytical outputs were produced, but they do not show how the statistics were converted into item-level design decisions. Compared with EVT-004 and EVT-005, the key distinction was whether the issue record, responsible actor, version status, and write-back outcome formed a continuous, traceable chain.

Information outcomes documented during design development included cross-disciplinary control parameters, issue-list status, frozen versions, construction-drawing delivery requirements, and shared cross-disciplinary baselines. Joint review, authorization, responsibility assignment, version control, and formal documentation frequently co-occurred in these records. The pattern is consistent with the interpretation that joint judgment and controlled baselines were often linked within the same observed decision process.

4.5. Construction Detailing and Implementation: Observed Conditions, Responses, and Connection States

The principal coordination task during construction detailing and implementation was to maintain the current executable project state as site conditions, procurement constraints, and construction sequences changed. Among the nine events, U3 was the primary condition in five and U4 in four; when secondary conditions were included, U3 occurred in eight events and U4 in six.

O4, responsibility assignment and commitment to act, was the most frequent organizational response, occurring in eight events; O3, decision or formal authorization, occurred in six, and O6, outcome verification, in four. Among the data responses, D5, formal documentation and structured recording, was the most frequent, occurring in eight events; D3 and D4 each occurred in six. Eight of the nine events showed C2, and four of these also showed C1. These frequencies should be interpreted as documented patterns within the available records for construction detailing and implementation.

EVT-012 documents rework caused by inconsistencies among base-build (primary) MEP drawings, fit-out (secondary) MEP drawings, installed work, and acceptance criteria. The project team compared drawings, change records, equipment power ratings, and site conditions; reassigned responsibilities between the base-build and fit-out MEP scopes; revised the controlled drawings and versions; and used the updated information in subsequent construction briefings and acceptance inspections. EVT-013 illustrates how site feedback can invalidate an earlier decision. In December, the drawing-coordination approach agreed in October conflicted with the installed services and the available clear height below the finished ceiling. The team reassessed the constraints, selected a change to the interior fit-out, and prepared a low-clearance issue list for further review at subsequent drawing-overlay meetings.

Construction changes also affected procurement and safety responsibilities. In EVT-014, changes to the interior layout and already-installed risers invalidated the original exhaust-equipment scheme. The project team decided not to alter completed floors and immediately stopped procurement of the original equipment. In EVT-015, a pump foundation was classified as a major safety hazard; the project specified a 150 mm foundation and required the main contractor to rectify the work. The available records did not document completion or verification of the rectification.

Information outcomes at this stage included structural change orders, detailed design drawings, procurement instructions, revised drawing versions, site issue lists, and rectification requirements. The distribution of events during construction detailing and implementation indicates that responsibility, version status, and controlled write-back were the principal points at which organizational and data responses converged.

4.6. Cross-Stage and Contextual Comparison Events

The six contextual comparison events concerned an investment-value baseline, market and operations reviews, organizational arrangements extending across time, an operations platform, and an enterprise-level collaboration system. They differed substantially in objectives, time span, and record type. Their analytical role was limited to examining long-term information continuity and the visibility of processes in the archive.

EVT-016 established value parameters including the internal rate of return, land price per unit floor area, functional mix, and cash flow. These parameters continued to be referenced in reviews conducted in 2018 and 2025, but formal approval documents were absent from the archive. EVT-017 and EVT-018 show that market changes prompted revisions to early assumptions and positioning parameters, although the available records were insufficient to fully identify the approved object and its controlled write-back. EVT-030 documented requirement confirmation, pilot feedback, functional updates, and acceptance for an enterprise-level system. Its direct correspondence with the case project was limited, so it was used only to describe the external digital-collaboration environment and not to infer connection mechanisms within the project's engineering stages.

The contextual comparison events suggest that long-term information continuity requires records of parameter baselines, the basis for their formation, the approving actor, transfers of responsibility, version changes, and subsequent use. Four events showed no identifiable documented connection, primarily because the records were heterogeneous and the underlying processes had limited visibility. A report or system output confirms the existence of a result; specific project records are still needed to establish how that result entered judgment, authorization, and subsequent tasks.

4.7. Cross-Stage Synthesis

Across the 31 events, C1 and C2 were both identified in 15, C1 only in three, C2 only in five, and no identifiable documented connection in eight. Stage comparison was based on the 25 engineering events. Connection states varied during scheme decision-making and specialist design; seven of eight design development events were classified as C1 + C2; and eight of nine construction detailing and implementation events contained C2. The six contextual comparison events were used only to clarify continuity and evidential boundaries.

Analysis of U, O, D, the formal status of information, and subsequent use identified three stage-conditioned coordination functions. During scheme decision-making and specialist design, the main conditions were interpretive differences and multi-objective trade-offs. Organizational responses centered on option selection and formal confirmation, while data responses centered on calculation, simulation, and option comparison. The resulting information outcome was a defensible design basis. During design development, disciplinary interdependence was the dominant condition; joint review, responsibility assignment, verification, version control, and formal documentation together established a shared cross-disciplinary baseline. During construction detailing and implementation, disciplinary interdependence interacted with changing site conditions; responsibility assignment, formal authorization, and controlled write-back together maintained the current executable project state.

Because U1–U4 were non-exclusive, their overlap was also examined. The most frequent combinations were U2 + U3 (8 events) and U3 + U4 (7 events). U2 + U3 occurred most frequently in scheme decision-making and specialist design and in design development, whereas U3 + U4 was concentrated in construction detailing and implementation (5 of 9 events). This pattern indicates that interpretive differences often coincided with disciplinary interdependence earlier in the project, while construction detailing and implementation more often combined disciplinary interdependence with changing site or implementation conditions.

Table 4 further shows that similar project records may remain as stand-alone analytical outputs, inform joint judgment through C1, or enter controlled project information through C2. The representative evidence chains therefore distinguish the four connection states and their information outcomes.

Table 4. Evidence chains in representative collaborative decision events.

Event and Stage Group	Problem and Common Information Object	Evidence Supporting C1: Technical Evidence Used in Joint Judgment	Evidence Supporting C2: Confirmed Outcome Incorporated into Controlled Project Information	Connection State and Information Outcome
EVT-020/Scheme decision-making and specialist design	Banquet-hall structural schemes A/B/C, metric comparison, comfort verification, and integrated MEP-layout records	Comparison of Schemes A, B, and C yielded a recommendation to develop Scheme A; the recommendation continued to inform subsequent verification and layout work	No formal approval by the client or architect, or baseline write-back, was identified in the available archive	C1 only; an interim basis for further development was established, although its authorization status remains uncertain
EVT-004/Design development	Issue list, response attachments, WSP review records, and open/resolved status	Relevant actors reviewed the completeness of each response and interpreted and escalated overdue or unresolved issues	Response deadlines, responsibilities, and resolution status were entered in the controlled issue list and updated continually	C1 + C2; an issue state usable in subsequent work was established
EVT-005/Design development	Multiple disciplinary-model versions, change marks, and baseline discrepancies	After comparing the scope of modifications and baseline drift, the client confirmed the 0718 version as the common model baseline	Structural and MEP versions were frozen, with local review and limited updates thereafter	C1 + C2; a shared cross-disciplinary model baseline was established
EVT-024/Design development	Clash statistics, disciplinary examples, and benefit estimates	The available archive did not show how the statistics entered item-level joint judgment	Item-level responsibilities, disposition dates, closure status, and independent verification were absent	No identifiable documented connection; analytical outputs were documented, but evidence for the evidence chain was insufficient
EVT-012/Construction detailing and implementation	Base-build (primary) and fit-out (secondary) MEP drawings, change records, equipment power ratings, installed work, and acceptance criteria	Relevant actors compared the discrepancies and reassigned responsibilities between the base-build and fit-out MEP scopes	Versions and drawings were revised, and the updates were used in construction briefings and acceptance	C1 + C2; a controlled basis for construction and acceptance was established
EVT-013/Construction detailing and implementation	Drawing-coordination approach and new site conditions involving installed services and finished-ceiling clearance	New site evidence invalidated the existing basis; the relevant actors reassessed the constraints and selected a change to the interior fit-out	A low-clearance issue list and a revised interior-fit-out scope were produced	C1 + C2; changed site conditions prompted renewed joint judgment and controlled write-back
EVT-015/Construction detailing and implementation	Pump-foundation safety hazard, 150 mm rectification parameter, and site issue record	The available archive did not fully retain the process by which hazard evidence entered joint judgment	The 150 mm foundation requirement and the main contractor's rectification responsibility were entered in the rectification record; completion verification was absent	C2 only; a rectification requirement was established, but closure and verification remained undocumented

4.8. Robustness and Sensitivity Checks

Three checks examined whether the reported connection-state patterns were sensitive to sample composition, individual events, or archival visibility. First, a sample-composition sensitivity analysis examined whether the six heterogeneous contextual comparison events affected the overall C1/C2 distribution. After excluding these events, the remaining 25 engineering events comprised 14 C1 + C2 events, two C1-only events, five C2-only events, and four events with no identifiable documented connection, compared with

15, three, five, and eight events, respectively, in the full set of 31 events. Excluding the contextual comparison events reduced the relative frequency of cases with no identifiable documented connection but did not alter the stage-conditioned interpretation, because the stage comparisons were based on the 25 engineering events.

Second, a leave-one-event-out analysis examined whether the principal stage patterns depended on any single engineering event. The proportion of design development events classified as C1 + C2 remained between 85.7% and 100%, compared with 87.5% in the full stage sample. The proportion of construction detailing and implementation events containing documented C2 remained between 87.5% and 100%, compared with 88.9% in the full stage sample. The principal stage patterns were therefore not driven by a single event.

Third, an archival-visibility scenario analysis examined the four construction detailing and implementation events classified as C2 only. If one, two, or all four were assumed, for sensitivity purposes, to contain an undocumented C1 process, the C2-only count would decrease from 4/9 to 3/9, 2/9, or 0/9, while the potential C1 + C2 count would increase correspondingly. Eight of the nine construction detailing and implementation events would retain documented C2 in every scenario. The robust inference is therefore the frequent documentation of C2 during construction detailing and implementation, whereas the exact division between C1 + C2 and C2-only remains sensitive to archival visibility.

5. Discussion

Among the 25 engineering events, three stage-conditioned coordination functions were observed in a complex supertall building project. Given the limited number of engineering events in each stage (8, 8, and 9), these patterns are interpreted as within-case descriptive tendencies. Scheme decision-making and specialist design tended to establish a defensible design basis; design development tended to establish a shared cross-disciplinary baseline; and construction detailing and implementation focused on maintaining the current executable project state. The connection-state distribution for all 31 events also shows that co-occurring organizational and data responses indicate only that both forms of action were present. Under the C1/C2 definitions, project records must show whether technical evidence entered joint judgment and whether a confirmed outcome entered controlled project information. Previous research has shown that BIM use varies with the project life cycle, organizational conditions, and work practices [15,89]; the present case adds an event-level account of the stage-conditioned coordination functions associated with these variations.

5.1. Stage-Conditioned Coordination Functions of Organization–Data Connections

5.1.1. Scheme Decision-Making and Specialist Design: Establishing a Defensible Design Basis

Among the eight observed events, coordination during scheme decision-making and specialist design centered on establishing a defensible design basis. Multi-objective trade-offs and differences in disciplinary judgment had to be translated into technical evidence that participants could compare on a common basis. Morin and Romero-Torres (2024) found that BIM can provide information and visualization for design decisions, although decision quality still depends on how participants interpret the information, organize the decision process, and use its outputs [16]. The present case suggests that comparable technical evidence became most useful when it was coupled with disciplinary interpretation and identifiable authority for formal confirmation. More complete evidence chains combined specialist knowledge and decision authority around explicitly defined alternatives, evaluation dimensions, assumptions, and analytical versions. The resulting defensible design basis constrains subsequent development and establishes the stage baseline.

The combination of organizational and data responses during scheme decision-making and specialist design reflects the need for dynamic systems integration in complex projects. Whyte and Davies (2021) conceptualized systems integration as an adaptive process that continually addresses technical and organizational uncertainty, and Muruganandan et al. (2022) showed that large projects must balance stability and change among systems at different levels of maturity [88,90]. The building-design events examined here were consistent with this logic: analytical tools expanded the option space and revealed system-wide effects, whereas common evaluation criteria and authorization arrangements narrowed the range of feasible choices. Where either the analytical basis or confirmation authority remained incomplete, the available records were more likely to retain a technical recommendation than a fully confirmed project baseline. At this stage, data capability is therefore needed to produce comparable evidence, and organizational capability is needed to support cross-disciplinary interpretation and stage confirmation.

5.1.2. Design Development: Establishing a Shared Cross-Disciplinary Baseline

Among the eight design development events, coordination most often centered on establishing a shared cross-disciplinary baseline. The frequent combination of C1 and C2 suggests that disciplinary-interface judgments and formal information updates often needed to occur together. Chen et al. (2022) showed that information sharing, joint problem solving, coordination, and adaptation have different effects on collaboration in BIM-enabled projects [10]. Cao and Shao (2024) likewise found different structures in formal task-communication and informal knowledge-advice networks [91]. The event evidence adds that these interactions became consequential for cross-disciplinary continuity when their outcomes were reflected in a shared model, drawing, parameter table, or issue list. Confirmation, responsibility assignment, and version updates then establish a baseline that each discipline can continue to use.

The high proportion of C1 + C2 events during design development reflects the stage's interface density and delivery responsibilities. Architectural, structural, MEP, façade, and other specialist systems require continual adjustment within constrained space, and a change in one discipline may alter the design conditions of others. Hu and Dossick (2024) found that BIM-use practices change with project conditions and may shift toward hybrid working arrangements; continued use requires alignment among organizational arrangements, technical functions, and work practices [20]. The present findings suggest a more specific event-level interpretation: during design development, the model or coordination drawing provides a common information object for cross-disciplinary interpretation, while the version baseline and issue status record the confirmed interface outcomes. The case therefore highlights the importance of keeping the object used for discussion aligned with the formal deliverable so that issues resolved through coordination are also incorporated into controlled disciplinary information.

5.1.3. Construction Detailing and Implementation: Maintaining the Current Executable Project State

Among the nine construction detailing and implementation events, coordination centered primarily on maintaining the current executable project state. Four events exhibited C1 + C2, and another four exhibited C2 only. This distribution suggests that the observed events during construction detailing and implementation frequently emphasized responsibility for action, responses to site changes, authorized information updates, and the recording of implementation status. Ozkan and Seyis (2024) showed that CDEs can support information and communication management during construction but face implementation challenges associated with data structures, responsibilities, and workflows [92]. Radzi et al. (2025) likewise identified team management, coordination, and model and data management as important challenges to BIM project construction readiness [93]. Within the present case, data management during construction detailing and implementation was particularly concerned with keeping implementation information current and identifiable: site personnel must be able to identify the drawings, models, change instructions, and issue status that govern construction, procurement, acceptance, and review.

Within this case, the larger number of C2-only events can be interpreted in relation to implementation demands during construction detailing and implementation, while also reflecting the greater archival visibility of controlled write-back. Some events inherited a basis for judgment established upstream; their main task was to carry out assigned actions and update controlled project objects, making C2 more readily observable in the archive. This pattern does not necessarily indicate an absence of joint judgment. If site, procurement, or review conditions invalidate an existing assumption, the relevant actors need to reconvene, interpret the new evidence, and complete a new C1 before C2 is completed through controlled write-back.

The construction-coordination process proposed by Shim et al. (2024) similarly emphasizes the links among continuing review, issue resolution, and progress updates [24]. In the present case, the C1/C2 distinction identifies whether renewed joint judgment and controlled write-back are both documented within such iterations. Where project records show that changed conditions prompted reassessment of the decision basis, a new C1 can be identified alongside subsequent C2. Where only controlled write-back is documented, however, the archive may not establish whether the event relied on an earlier judgment or involved an unrecorded reassessment. C2-only events during construction detailing and implementation therefore require interpretation in relation to both the task performed and the archival visibility of the judgment process.

5.1.4. Cross-Stage Transition: Continuity of the Decision Basis, Responsibility, and Information Status

The six contextual comparison events were retained primarily to examine cross-stage continuity in the decision basis, responsibility, and information status. They covered investment and financing judgments, organizational arrangements extending over time, preparation of an operations platform, and enterprise capability development; four had no identifiable documented connection. This result primarily reflects heterogeneous project records and limited process visibility in matters spanning long periods and does not establish that coordination failed to occur. Zhang et al. (2024) noted that the transition of large projects to operations requires deliberate connections across strategy, structure, processes, and people [94]. Abdelkarim et al. (2024) likewise showed that information loss at handover must be controlled by organizing and coordinating information around facility-management requirements [56]. The case evidence indicates that cross-stage continuity depends on retaining the decision basis, confirmation status, transfers of responsibility, version changes, and receipt outcomes. Models and platforms alone cannot substitute for explicit project records of these connections.

Overall, organizational and data responses served different stage-conditioned coordination functions as the project progressed. Life-cycle studies have identified differences in BIM capabilities and levels of digitalization across stages [15,89], and systems-integration research emphasizes the need to adapt continually to changing technical and organizational conditions [90]. At the event level, the coordination function shifted from establishing a defensible design basis to establishing a shared cross-disciplinary baseline, maintaining the current executable project state, and preserving cross-stage continuity. This stage-conditioned perspective explains how the same digital tool or organizational arrangement may serve different coordination functions over the project life cycle.

5.2. Evidence Chains Linking Technical Evidence, Joint Judgment, and Controlled Project Information

The representative evidence chains trace two documented organization–data connections within a collaborative decision event. C1 is the evidence-to-judgment connection: it shows whether technical evidence entered joint judgment. C2 is the decision-to-controlled-information connection: it shows whether a confirmed outcome entered controlled project information through controlled write-back. C1 and C2 are assessed separately because evidence for one connection does not establish the other.

The comparison events demonstrate why this separation matters. In EVT-020, the multi-option comparison informed subsequent joint judgment, but formal approval and controlled write-back could not be established from the available records. EVT-024 retained clash statistics and benefit estimates, but the archive did not show how these outputs entered item-level joint judgment or controlled issue closure. EVT-015 showed the reverse configuration: the rectification requirement and assigned responsibility were retained in a project record, whereas the technical evidence used in joint judgment and the participating actors were insufficiently documented. Thus, events involving similar models, meetings, and formal documents may exhibit different documented connection states and information outcomes.

Connection states should be interpreted in relation to both stage-conditioned coordination functions and evidential boundaries. Scheme decision-making and specialist design involved diverse connection states because their principal function was to establish comparable and confirmable design conditions. Design development commonly connected joint review with responsibility assignment and shared-baseline formation, whereas construction detailing and implementation more often emphasized controlled write-back of site, procurement, and implementation changes. When changed conditions invalidate existing technical evidence or assumptions, a new C1 may be required before C2 updates the corresponding controlled project information. A C1-only or C2-only state may therefore reflect the task boundary of an event, its position within a continuing process, limited archival visibility, or a combination of these factors. It should not be interpreted as incomplete collaboration or used as a maturity or performance ranking.

The contribution can be positioned more precisely in relation to process-oriented BIM research. Zahedi et al. provide a means of documenting design explanations and associating them with model elements [19]. The extension offered here is not the association of a decision with a model element itself, but the separate evidentiary assessment of whether identified technical evidence was used by identified actors in joint judgment (C1) and whether a confirmed outcome was traceably written back to an identified controlled project object (C2). Shim et al. model iterative BIM-based coordination workflows; the C1/C2 framework complements this approach by assessing whether these two connections are documented within individual collaborative decision events [24]. Jang et al. identify limitations in the model-element-specific information available in native BIM logs [25]. Consistent with this limitation, the present study links meeting records, issue lists, analytical reports, design changes, and verification documents through focal problems, object identities, and documented actions, while leaving unsupported connections unresolved.

This separation provides additional interpretive value by locating different evidentiary discontinuities within an event process. Analytical outputs may be documented without evidence that they entered joint judgment; joint judgment may be documented without evidence that the confirmed outcome entered controlled project information; and controlled write-back may be traceable without documentation of the preceding judgment process. C1 and C2 therefore connect process interpretation with the evidence required to substantiate each transition, rather than treating the presence of models, meetings, or decision records as evidence of a complete process. Together with the stage comparison, this event-level distinction explains how different organization–data configurations contribute to a defensible design basis, a shared cross-disciplinary baseline, and the current executable project state [10,20,95]. Figure 4 illustrates these functions through EVT-020, EVT-004, and EVT-012.

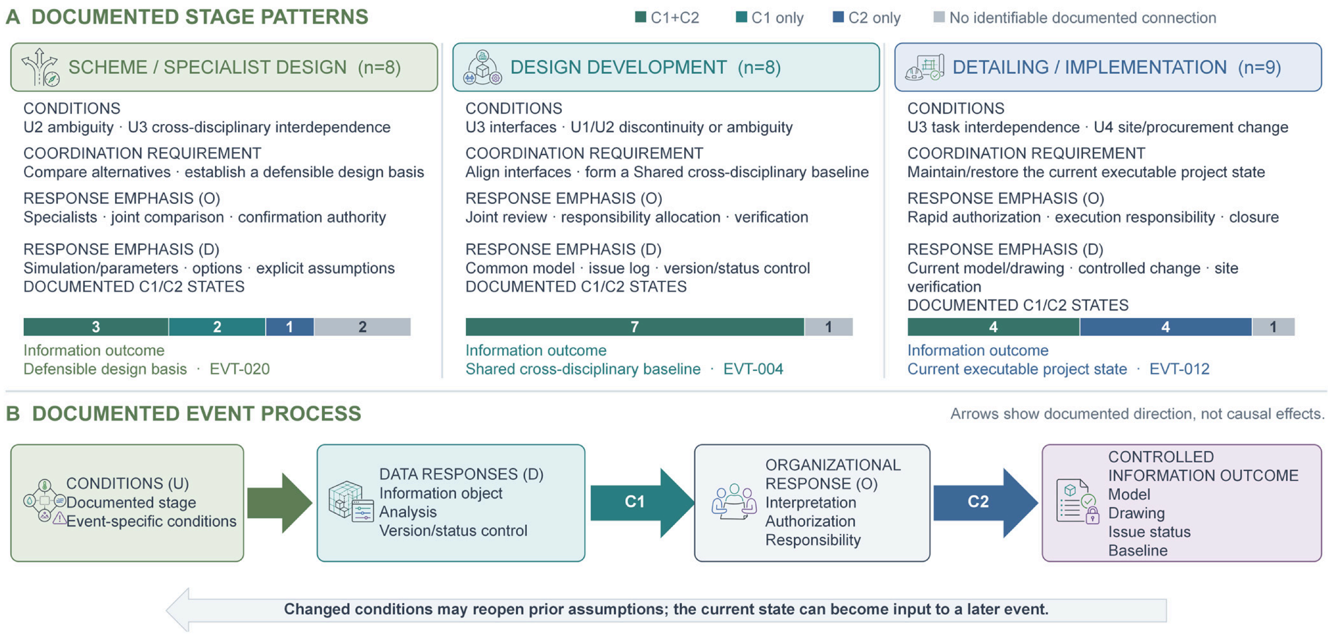

Figure 4. Stage-conditioned coordination functions and organization–data connections across collaborative decision events.

5.3. Managerial Implications

During scheme decision-making and specialist design, projects should apply a defensible-design-basis checkpoint. Before a major option comparison, the evaluation dimensions, analytical assumptions, valid data version, required disciplines, and final approving authority should be specified. Each analysis should be linked to a specific joint judgment and should record its conditions of applicability. Once an outcome is confirmed, controlled write-back should incorporate it into the stage model, drawing, parameter table, or formal report to define clear boundaries for design development.

Design development requires a shared-cross-disciplinary-baseline checkpoint. For each cross-disciplinary interface event, the team should identify the common information object under discussion, interface owner, approving actor, object to be modified, version status, and review method. After joint review, the model, drawings, issue list, and parameter table should be updated together, and the recorded closure status should match the completed modification.

Construction detailing and implementation should use a current-executable-project-state checkpoint. Site issue records, design changes, procurement instructions, and acceptance records should refer to the currently valid drawing or model and identify the responsible organization, completion deadline, reviewing actor, and basis for closure. If site conditions, equipment parameters, or review requirements invalidate an existing assumption, the team should establish a new C1. If the existing basis remains valid, the priority may shift to completing assigned actions and C2 through controlled write-back.

Matters spanning project stages can be supported by a cross-stage continuity checkpoint. Records should preserve the decision basis, formal approval, transfers of responsibility, version changes, outstanding matters, and confirmation of receipt across design, construction, and operational handover. The client or project-management team should define the handover object, receiving party, and subsequent maintenance responsibility at each stage and assume overall responsibility for continuity. Platforms store and transmit the information; governance arrangements determine its validity and define the boundaries of responsibility [34,94].

These recommendations translate the event-level findings into four control checkpoints that can be used diagnostically in practice. A well-developed analysis that remains unimplemented may indicate that the required participants or approval authority are missing. Continued use of outdated information after a meeting decision points to a problem with responsibility, version control, or controlled write-back. Changed site conditions require the joint judgment process to be revisited. The checkpoints primarily target decision traceability, baseline consistency, information validity, and cross-stage continuity; improvements in cost, schedule, quality, or rework would depend on how these controls interact with broader project conditions.

By reducing ambiguity in decision bases, inconsistencies in shared cross-disciplinary baselines, use of superseded information, and loss of continuity across stages, the four checkpoints provide practical mechanisms through which the digital collaboration and concurrent decision-making practices identified in this study can support project-level value. These mechanisms are consistent with the types of benefits reflected in the audited project-level gains reported in Section 3.1 and provide a basis for transferring those practices into repeatable project controls.

5.4. Limitations and Future Research

The findings are most applicable to complex building projects involving multiple actors, dense disciplinary interdependencies, continually changing information, and controlled delivery requirements. The single supertall case provides fine-grained event evidence but limits comparison across contractual arrangements, governance structures, project types, and levels of digital maturity. Its high technical complexity, F + EPC + O delivery arrangement, extensive cross-organizational coordination, and relatively complete multi-year records may also have made formal coordination and controlled write-back more observable than in projects with fewer interfaces, more fragmented delivery arrangements, or less complete archives. The 25 engineering events had relatively clear stage boundaries, whereas the six contextual comparison events differed substantially in objectives, time span, and record density and therefore supported only a contextual interpretation.

Archival visibility constrained complete identification of C1 and C2. Formal decisions, responsibility assignments, change documents, and version updates are generally retained, whereas informal discussions, immediate interpretations, and site actions are more easily omitted. Undocumented C1 processes may therefore have occurred in events classified as C2 only or as having no identifiable documented connection.

Evidence-fragment segmentation, event reconstruction, and analytical coding relied partly on manual interpretation. Although explicit coding rules, independent review, source-based reconciliation, and source-to-event traceability improved consistency, human judgment remained necessary when defining event boundaries and assigning connection states. These classifications may therefore remain sensitive to analytical granularity and archival visibility.

Future research can test transferability through multiple-case comparisons across delivery models, client involvement, digital maturity, and project complexity, including traditional design–bid–build projects. These comparisons can examine whether formation of a defensible design basis, establishment of a shared cross-disciplinary baseline, and maintenance of the current executable project state recur under different interface and responsibility conditions. Collaboration-platform logs, model versions, issue status, and meeting records can also support continuous tracing of C1 and C2, including whether one connection is documented after an initially single-connection event. Finally, outcome measures such as decision time, rework, change-cycle duration, information-retrieval time, and handover-information quality can examine how the documented connections relate to project outcomes.

6. Conclusions

This study reconstructed 31 collaborative decision events from 266 traceable evidence fragments concerning a 266 m mixed-use supertall building. The 25 engineering events suggest three stage-conditioned coordination functions. Scheme decision-making and specialist design centered on establishing a comparable and defensible design basis. Design development frequently centered on establishing a shared cross-disciplinary baseline for models, drawings, parameters, and issue status. Construction detailing and implementation focused on maintaining the current executable project state in line with site conditions, procurement, and implementation responsibilities. The six contextual comparison events highlighted the need to preserve decision bases, responsibility, and information status across stage boundaries.

The evidence chains identify two documented organization–data connections. C1, the evidence-to-judgment connection, shows whether technical evidence entered joint judgment. C2, the decision-to-controlled-information connection, shows whether a confirmed decision, assigned responsibility, or verification finding entered controlled project information. C2 is completed when controlled write-back incorporates the confirmed outcome into a specific controlled project object, thereby preserving its content, responsibility, and validity status for subsequent tasks. The four connection states show whether both connections, either connection, or neither connection can be identified in the available archive. If site, procurement, or review conditions invalidate the existing basis, a new C1 may be needed before C2 is completed. This stage-conditioned explanation translates project-level digital collaboration into traceable event processes linking technical evidence, joint judgment, and controlled project information.

In practice, projects can establish four control checkpoints: defensible design basis, shared cross-disciplinary baseline, current executable project state, and cross-stage continuity. C1 and C2 can be used within these checkpoints to assess whether technical evidence informed joint judgment and whether confirmed outcomes entered controlled project information. The checkpoints provide a practical means of strengthening traceability, information validity, and continuity in digital collaboration. The single-case design and archival visibility limit transferability; future research can examine these connections across projects using continuous process records and outcome measures.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/buildings16183676/s1, Table S1: De-identified codebook.

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Data Availability Statement: The data supporting the findings of this study are contained within the article and its Supplementary Materials. A de-identified codebook is provided in the Supplementary Materials. The original project records cannot be made publicly available because they contain commercially confidential information and materials subject to third-party rights. Subject to authorization from the relevant rights holders, the evidence index and event-comparison matrix may be obtained from the corresponding author upon reasonable request.

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Appendix A.

Table A1. Codebook.

Analytical Dimension	Code	Code Name	Operational Definition	Inclusion Criteria	Exclusion Criteria	Positive Example	Negative Example	Potentially Confusable Code	Decision Note
Coordination condition	U1	Insufficient or discontinuous information	Information required for judgment or action is missing, incomplete, unsynchronized, unavailable, or unconfirmed	Missing parameters; incomplete records; incomplete drawing, model, or site information; supplier data unavailable; design and construction information not linked	Merely stating that information exists; background description without an information gap	"Missing information is listed by discipline"	"Basement architectural work is 100% complete"	Versus U4: U1 concerns missing information; U4 concerns changed conditions	The location of the gap must be specified
Coordination condition	U2	Interpretive ambiguity or differences in judgment	Different interpretations of the problem, objective priority, option evaluation, applicable standard, or responsibility boundary	Different disciplinary judgments; multi-objective trade-off; option superiority cannot be determined from data alone; disagreement	Merely having several options; parameter calculations without interpretive conflict	"The steel elevation was clarified: the slab is lowered, not the steel beam"	Only "four schemes were proposed"	Versus U3: U2 concerns interpretation or trade-off; U3 concerns task dependence	Interpretation, trade-off, or disagreement must be present
Coordination condition	U3	Task, technical, or disciplinary interdependence	A decision concerning one discipline, component, or system affects another and requires coordination across boundaries	Disciplinary interface; dependency involving clearance or openings; cascading effects of a design adjustment	Multiple disciplines participate, but no specific dependency is identified	"The smoke-exhaust duct requires an interior-finish enclosure, while the façade team addresses the steel beam"	Only a list of attending organizations	Versus U2: U3 is an objective dependency chain; U2 is a subjective difference	This was the most frequent coordination condition
Coordination condition	U4	Changes in schedule, site, or external conditions	Change in site status, construction progress, procurement status, operational requirements, review comments, regulations, or time window	Site measurement differs from design; some work already completed; procurement status changed; new requirement introduced	Routine stage description; time information that did not change the judgment	"Site services have been installed close to the core; available clearance must be reassessed"	For example, only "the model is based on the 0430 version"	Versus U1: U4 is a state change that triggers reassessment	A trigger for change must be present
Organizational response	O1	Relevant-actor involvement or early participation	An actor with relevant knowledge, responsibility, authority, or downstream experience is actively involved in resolving the issue	BIM, construction, suppliers, or operations involved before design completion; consultant, supplier, or contractor provides input	Only a participant list; only stating that an organization belongs to the project	"The client involved the hotel operator and interior designer in the joint work"	Only "attendees: client and ECADI"	Versus O2: O1 is actor involvement; O2 is the joint-review action	An action verb is required
Organizational response	O2	Joint interpretation, cross-disciplinary review, or negotiation	Two or more actors interpret, review, compare, or negotiate the same issue or common evidence	Joint review of models, drawings, or options; multidisciplinary joint judgment; comparison around a common object	One-way transmission; unilateral analysis; meeting notice without joint interpretation	"Both parties reviewed and answered each issue in turn"	Only "a meeting was held"	Versus O6: O2 is the joint-review process; O6 is outcome verification	A common object is essential

Table A1. *Cont.*

Analytical Dimension	Code	Code Name	Operational Definition	Inclusion Criteria	Exclusion Criteria	Positive Example	Negative Example	Potentially Confusable Code	Decision Note
Organizational response	O3	Decision, approval, or formal authorization	An authorized actor selects an option, confirms a judgment, approves a change, or formally establishes a baseline	Explicit option selection; formal confirmation by the client or another authorized actor; acceptance of version-specific technical conditions	General recommendation; personal preference; agreement in principle without defined scope; only "continue the study"	"The client requires a 2600 mm ceiling and recommends routing services through the beam"	"The report recommends that the client decide"	Versus O4: O3 is a decision; O4 is responsibility assignment	Flag for review when the authorized actor or degree of formality is unclear
Organizational response	O4	Responsibility assignment and commitment to act	Specifies who will make a modification, provide information, issue confirmation, implement an action, or follow up	Design institute assigned to revise drawings; BIM team required to compile information; supplier confirms parameters; completion date specified	Only mentioning the relevant organization	"ECADI to clarify the acceptance criteria with the quality-supervision authority by 1 November"	Only "the duties of participating organizations are involved"	Versus O3: O4 specifies who does what and when	Responsible actor plus deadline or deliverable
Organizational response	O5	Issue escalation and cross-level resolution	An issue is referred to a higher level or specialist mechanism when routine coordination cannot resolve it, time is constrained, or authority is insufficient	Overdue issue escalated; dispute referred to the client; specialist approval initiated	Routine forwarding or normal transmission	"The client requires the design team to conduct a further internal review, including the B1M corridor"	"WSP asks ECADI to review the issue list"	Versus O4: O5 raises the organizational level; O4 allocates responsibility at the same level	Escalation requires a higher level or specialist judgment
Organizational response	O6	Outcome verification, review, and acceptance	A formal, identifiable review of the resolution, modified output, implementation status, or technical performance	Review of the modified model or drawings; supplier confirmation; consultant verification; formal sign-off	Only "completed," without verification; automatic system closure without an identified actor	"WSP's review of the 0529 response identified deficiencies"	"The issue summary is marked resolved"	Versus O2: O6 verifies an outcome; O2 concerns the review process	The verifying actor and basis must be identifiable
Data response	D1	Information collection, extraction, and cross-source integration	Information is collected from and linked across disciplines, documents, models, the site, or suppliers	Disciplinary information compiled; supplier parameters mapped item by item; measured, design, and equipment information integrated	Merely sending or receiving a file; only mentioning a filename	"The air-conditioning contractor provides equipment loads and a discrepancy list"	Only "the report was prepared by . . ."	Versus D2: D1 is an integration action; D2 forms an object	An integration action is required
Data response	D2	Formation of a common information object	Dispersed information is organized into an object that participants can jointly identify, view, compare, and discuss	BIM model; overlay drawing; coordination drawing; parameter table; issue list; option matrix	General drawing or model description; not used in collaborative resolution	"Elevator identifiers in the construction drawings serve as common reference objects for checking"	Only "the model was displayed"	Versus D3: D2 is the object; D3 is analysis based on that object	The object must carry the collaborative resolution process

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Table A1. *Cont.*

Analytical Dimension	Code	Code Name	Operational Definition	Inclusion Criteria	Exclusion Criteria	Positive Example	Negative Example	Potentially Confusable Code	Decision Note
Data response	D3	Analysis, simulation, calculation, and option comparison	Models, tests, calculations, simulations, or metrics convert a problem into analyzable and comparable information	Structural calculation; energy simulation; wind-tunnel test; clearance analysis; clash detection; multi-option comparison	Merely displaying a model or stating option names	"Simulation of three options shows differences in COP"	Only "four types of scheme were proposed"	Versus D2: D3 is the analytical action; D2 is the carrier	An actual analysis or comparison process is required
Data response	D4	Version, baseline, and issue-status control	Versions, dates, freezes, revision clouds, status fields, or issue identifiers are used to control currently valid information	Working baseline established; version frozen; modification scope marked; issue status recorded	A file merely has a date; the latest version is mentioned without a control action	"The structural model is frozen at the 0718 version"	Only "the model is based on the 0430 version"	Versus D5: D4 controls information validity; D5 creates a formal record	A control rule or action is required
Data response	D5	Formal documentation, structured recording, and accessibility	Decisions, parameters, rules, responsibilities, or verification findings are retained in a traceable, retrievable record	Formal issue response; controlled report; responsible actor and result retained; accessible history	Informal chat; untraceable information; file known to exist but content unknown	"Common requirements are frozen in a signed requirements-confirmation form"	Only "minutes were prepared"	Versus D4: D5 emphasizes traceable recording and access	The record content or location must be identifiable
Organization–data connection	C1	Evidence-to-judgment connection	A model, drawing, parameter, analysis, or record is used by relevant actors during joint interpretation, option selection, formal confirmation, or responsibility determination	Can answer: what technical evidence was used, who used it, and what joint judgment or responsibility determination it informed	Model only displayed; report only submitted; effect cannot be explained	"The client selects the third scheme on the basis of the simulation results"	"The model was displayed during the meeting"	Versus response co-occurrence: all three evidence requirements must be met for C1	Flag for review if any of the three elements is missing
Organization–data connection	C2	Decision-to-controlled-information connection	A confirmed decision, assigned responsibility, or verification finding enters controlled project information through an explicit update to a model, drawing, report, parameter table, issue status, or version baseline	Can answer: what outcome was confirmed, what controlled project object was updated, and what evidence demonstrates controlled write-back	Only "follow-up action" after a decision; modification requested without evidence of write-back	"After the option is confirmed, the design institute issues a change"	Only "an organization was asked to modify it"	Versus D5: C2 is the connection established through controlled write-back; D5 is the formal record	Write-back must be traceable to a specific object

Appendix B. Coding, Event Reconstruction, and Trustworthiness

Appendix B.1. Local Evidence Fragments and Coding

Each project record was read and indexed. The smallest textual unit that independently expressed an information gap, difference in judgment, disciplinary interdependence, contextual change, participant action, common information object, or outcome was extracted as an evidence fragment. Each fragment had to be traceable to a source identifier and its original location. Multiple codes were permitted when a fragment contained a coordination condition, organizational response, data response, or connection evidence concurrently. General technical descriptions, procedural statements, lists of organizations, and lessons-learned summaries that could not be linked to a specific project issue were not coded separately. Appendix A provides the operational definition, inclusion and exclusion criteria, positive and negative examples, codes that could be confused, and decision notes for each code.

Appendix B.2. From Local Actions to Collaborative Decision Events

After the evidence fragments had been coded, they were aggregated primarily on the basis of problem continuity and with reference to relationships among the principal actors, common information objects, and outcomes. Fragments were combined into the same event only when they could be interpreted as a continuous process addressing the same problem; different issues occurring on similar dates or in the same meeting were not combined automatically. An event could span several dates and documents and could include renewed handling after conditions changed. A fragment without a verifiable date was marked as missing time information and was not used to infer sequence. After each adjustment to an event boundary, the relevant sources and other events were rechecked to ensure that comparable records were aggregated at a consistent level. For the reconstruction-consistency assessment, the two researchers independently reviewed the same archival source set and applied the same event-aggregation rules without access to the other's event assignments. Evidence segmentation was performed independently and resulted in 266 and 290 fragments, respectively, reflecting differences in segmentation granularity. Consistency between the independently reconstructed event structures was assessed using the adjusted Rand index. Disputed event boundaries were reconciled only after the independent reconstruction and agreement assessment had been completed.

Appendix B.3. Event-Level Aggregation and Classification Rationale

After event reconstruction, fragment codes were aggregated and interpreted in relation to the event process to determine the primary and secondary coordination conditions, the coverage of organizational and data responses, and the connection state. C1 required identification of the technical evidence used, the actors who used it, and the joint judgment or responsibility determination that it informed. C2 required identification of the confirmed outcome, the controlled project object updated, and evidence of controlled write-back. Co-occurring organizational and data responses were recorded only as response co-occurrence; C1 and C2 were classified separately. Changes in site or external conditions were treated as coordination conditions and were not assigned an additional connection code.

Appendix B.4. Traceability, Factual Verification, and Evidential Boundaries

Traceability was maintained from source files through evidence fragments and collaborative decision events to cross-event findings. Before reconciliation, two authors independently applied the analytical framework to the archival evidence. U/O/D agreement was evaluated on the aligned 266-fragment coding dataset, event-reconstruction consistency was assessed separately using the independently segmented reconstruction datasets, and C1/C2 classifications were independently evaluated at the event level. They then reconciled fragment- and event-level differences and jointly reviewed event reconstruction, event boundaries, and connection classifications against the original sources and operational rules. Evidence chains were triangulated across meeting minutes, issue lists, analytical reports, design changes, and verification documents. An enterprise project manager confirmed final event occurrence, project attribution, source traceability, technical facts, and outcome boundaries. The research team retained responsibility for analytical coding based on the archival evidence and operational rules. Cases without sufficient records were classified as having no identifiable documented connection.

The independent analytical datasets were compared at three levels. U/O/D coding agreement was evaluated using the 266 aligned evidence fragments, code-specific 2×2 contingency tables, exact agreement, and Cohen's kappa. Event-reconstruction consistency was assessed separately for the independently reconstructed datasets using the adjusted Rand index. C1 and C2 were independently rated by both authors across the 31 shared events and compared using binary agreement statistics and the four-category connection-state classification. Notation and clerical entry errors were checked against the original coding records before agreement statistics were finalized; substantive disagreements were reconciled only afterward. The results are reported in Section 4.1 and Table 2.

References

1. Ahlfeldt, G.M.; Baum-Snow, N.; Jedwab, R. The Skyscraper Revolution: Global Economic Development and Land Savings. *SSRN* **2023**. [CrossRef]
2. Gong, J.; Fang, T.; Zuo, J. A Review of Key Technologies Development of Super High-Rise Building Construction in China. *Adv. Civ. Eng.* **2022**, *2022*, 5438917. [CrossRef]
3. Omrany, H.; Ghaffarianhoseini, A.; Chang, R.; Ghaffarianhoseini, A.; Rahimian, F.P. Applications of Building information modelling in the early design stage of high-rise buildings. *Autom. Constr.* **2023**, *152*, 104934. [CrossRef]
4. Lafhaj, Z.; Rebai, S.; AlBalkhy, W.; Hamdi, O.; Mossman, A.; Alves Da Costa, A. Complexity in construction projects: A literature review. *Buildings* **2024**, *14*, 680. [CrossRef]
5. Brozovsky, J.; Labonnote, N.; Vigren, O. Digital technologies in architecture, engineering, and construction. *Autom. Constr.* **2024**, *158*, 105212. [CrossRef]
6. Pan, J.; Zhang, Q.; Su, Y.; Lin, H.; Xu, Q.; Yao, M. From capability integration to value co-creation: A case study on the dynamic capability mechanisms of the F+ EPC+ O model in super-high-rise projects. *Buildings* **2025**, *15*, 4258. [CrossRef]
7. Korotkova, N.; Lilliesköld, J.; Hetemi, E. Pursuing openness in the digital age: Insights from client–contractor knowledge collaboration at the project front end. *Int. J. Proj. Manag.* **2024**, *42*, 102564. [CrossRef]
8. Khudhair, A.; Li, H.; Ren, G. Knowledge-based OpenBIM data exchange for building design. *Autom. Constr.* **2023**, *156*, 105144. [CrossRef]
9. Bucher, D.F.; Hunhevicz, J.J.; Soman, R.K.; Pauwels, P.; Hall, D.M. From BIM to Web3: A critical interpretive synthesis of present and emerging data management approaches in construction informatics. *Adv. Eng. Inform.* **2024**, *62*, 102884. [CrossRef]
10. Chen, G.; Chen, J.; Tang, Y.; Li, Q.; Luo, X. Identifying effective collaborative behaviors in building information modeling–enabled construction projects. *J. Constr. Eng. Manag.* **2022**, *148*, 04022026. [CrossRef]
11. Yang, C.; Lin, J.-R.; Yan, K.-X.; Deng, Y.-C.; Hu, Z.-Z.; Liu, C. Data-driven quantitative performance evaluation of construction supervisors. *Buildings* **2023**, *13*, 1264. [CrossRef]
12. Sampaio, A.Z.; Azevedo, G.; Gomes, A. BIM Manager Role in the Integration and Coordination of Construction Projects. *Buildings* **2023**, *13*, 2101. [CrossRef]
13. Doan, D.T.; Ghaffarianhoseini, A.; Naismith, N.; Ghaffarianhoseini, A.; Tookey, J. Developing a framework for building information modelling (BIM) adoption in New Zealand. *Built Environ. Proj. Asset Manag.* **2024**, *14*, 490–506. [CrossRef]
14. Kussl, S.; Wald, A. The role of construction clients in digital innovation: Insights from scenario analysis. *Constr. Manag. Econ.* **2025**, *43*, 381–404. [CrossRef]
15. Wang, T.; Chen, H.-M. Integration of building information modeling and project management in construction project life cycle. *Autom. Constr.* **2023**, *150*, 104832. [CrossRef]
16. Morin, X.; Romero-Torres, A. How does building information modeling influence decision-making process in the project design? An input, process and output analysis. *Proj. Leadersh. Soc.* **2024**, *5*, 100160. [CrossRef]

17. Jaskula, K.; Kifokeris, D.; Papadonikolaki, E.; Rovas, D. Common data environments in construction: State-of-the-art and challenges for practical implementation. *Constr. Innov.* **2025**, *25*, 1522–1541. [CrossRef]
18. Esser, S.; Vilgertshofer, S.; Borrmann, A. Graph-based version control for asynchronous BIM collaboration. *Adv. Eng. Inform.* **2022**, *53*, 101664. [CrossRef]
19. Zahedi, A.; Abualdenien, J.; Petzold, F.; Borrmann, A. BIM-based design decisions documentation using design episodes, explanation tags, and constraints. *J. Inf. Technol. Constr.* **2022**, *27*, 756–780. [CrossRef]
20. Hu, Y.; Dossick, C.S. Decoding the dynamics of BIM use practice in construction projects. *Constr. Manag. Econ.* **2024**, *42*, 451–475. [CrossRef]
21. Chen, X.; Shi, Q.; Xiao, C.; Zhao, D.; Tang, K. Unveiling and evaluating the collaboration in engineering projects through a two-layer information collaboration network model. *J. Manag. Eng.* **2024**, *40*, 04024014. [CrossRef]
22. Abdirad, H. Managing digital integration routines in engineering firms: Cases of disruptive BIM cloud collaboration protocols. *J. Manag. Eng.* **2022**, *38*, 05021012. [CrossRef]
23. Celoza, A.; de Oliveira, D.P.; Leite, F. Qualitative analysis of the impact of contracts on information management in AEC projects. *J. Constr. Eng. Manag.* **2023**, *149*, 04022185. [CrossRef]
24. Shim, J.-H.; Ham, N.-H.; Kim, J.-J. Collaborative BIM-based construction coordination progress modeling using extended collaborative process modeling (exCPM). *Buildings* **2024**, *14*, 358. [CrossRef]
25. Jang, S.; Lee, G.; Shin, S.; Roh, H. Lexicon-based content analysis of BIM logs for diverse BIM log mining use cases. *Adv. Eng. Inform.* **2023**, *57*, 102079. [CrossRef]
26. Moussa, A.; El-Dakhakhni, W. Managing Interdependence-Induced Systemic Risks in Infrastructure Projects. *J. Manag. Eng.* **2022**, *38*, 04022048. [CrossRef]
27. Shen, W.; Xue, J. Managing project-to-project interfaces for large-scale programmes: A network study in world expo 2020. *Int. J. Proj. Manag.* **2023**, *41*, 102438. [CrossRef]
28. Abdulfattah, B.S.; Abdelsalam, H.A.; Abdelsalam, M.; Bolpagni, M.; Thurairajah, N.; Perez, L.F.; Butt, T.E. Predicting implications of design changes in BIM-based construction projects through machine learning. *Autom. Constr.* **2023**, *155*, 105057. [CrossRef]
29. Shen, W.; Wang, Y.; Lee, S. Formation of inter-project ties from the sender–recipient perspective: Roles of task interdependence and functional interdependence. *Int. J. Proj. Manag.* **2022**, *40*, 577–586. [CrossRef]
30. Pan, W.; Parker, D.; Pan, M. Problematic interfaces and prevention strategies in modular construction. *J. Manag. Eng.* **2023**, *39*, 05023001. [CrossRef]
31. Zani, C.M.; Denicol, J.; Broyd, T. Organisation design in megaprojects: A systematic literature review and research agenda. *Int. J. Proj. Manag.* **2024**, *42*, 102634. [CrossRef]
32. Zhang, J.; Luo, H.; Xu, J. Towards fully BIM-enabled building automation and robotics: A perspective of lifecycle information flow. *Comput. Ind.* **2022**, *135*, 103570. [CrossRef]
33. Çıdık, M.S.; Boyd, D. Value implication of digital transformation: The impact of the commodification of information. *Constr. Manag. Econ.* **2022**, *40*, 903–917. [CrossRef]
34. Nyqvist, R.; Peltokorpi, A.; Lavikka, R.; Ainamo, A. Building the digital age: Management of digital transformation in the construction industry. *Constr. Manag. Econ.* **2025**, *43*, 262–283. [CrossRef]
35. Sacks, R.; Wang, Z.; Ouyang, B.; Utkucu, D.; Chen, S. Toward artificially intelligent cloud-based building information modelling for collaborative multidisciplinary design. *Adv. Eng. Inform.* **2022**, *53*, 101711. [CrossRef]
36. Pauwels, P.; van den Bersselaar, E.; Verhelst, L. Validation of technical requirements for a BIM model using semantic web technologies. *Adv. Eng. Inform.* **2024**, *60*, 102426. [CrossRef]
37. Johansson, M.; Roupé, M. Real-world applications of BIM and immersive VR in construction. *Autom. Constr.* **2024**, *158*, 105233. [CrossRef]
38. Aladağ, H.; Demirdöğen, G.; Demirbağ, A.T.; Işık, Z. Understanding the perception differences on BIM adoption factors across the professions of AEC industry. *Ain Shams Eng. J.* **2023**, *14*, 102545. [CrossRef]
39. Baghalzadeh Shishehgarkhaneh, M.; Moehler, R.C.; Fang, Y.; Aboutorab, H.; Hijazi, A.A. Construction supply chain risk management. *Autom. Constr.* **2024**, *162*, 105396. [CrossRef]
40. Bonilla, M.; Castelblanco, G.; Rasdorf, W. The Paradox of Project Performance: The Role of Procurement, Contextual, and Contractor-Related Factors. *J. Constr. Eng. Manag.* **2026**, *152*, 04026062. [CrossRef]
41. Prebanić, K.R.; Vukomanović, M. Exploring stakeholder engagement process as the success factor for infrastructure projects. *Buildings* **2023**, *13*, 1785. [CrossRef]
42. Abdul Nabi, M.; Elsayegh, A.; El-adaway Islam, H. Understanding Collaboration Requirements for Modular Construction and Their Cascading Failure Impact on Project Performance. *J. Manag. Eng.* **2023**, *39*, 04023043. [CrossRef]
43. Al Qasem, D.; El-Sayegh Sameh, M. Design–Construction Interface Problems in Sustainable Construction Projects. *J. Archit. Eng.* **2025**, *31*, 04024044. [CrossRef]

44. Oraee, M.; Hosseini, M.R.; Edwards, D.J. Quantitative insights into collaboration in BIM-enabled projects: A PLS-SEM approach. *Eng. Constr. Archit. Manag.* **2026**, *33*, 2538–2563. [CrossRef]
45. Kaya, U.; Özener, O.Ö. A strategic evaluation of BIM-driven information management in the context of ISO 19650-2 standard. *Eng. Constr. Archit. Manag.* **2025**, *32*, 7857–7886. [CrossRef]
46. Ling Florence Yean, Y.; Yapary, M. Impact of Leaders' Organizational Behavior on the Satisfaction and Well-Being of Project Managers. *J. Manag. Eng.* **2024**, *40*, 04024048. [CrossRef]
47. Chen, G.; Chen, J.; Yuan, J.; Tang, Y.; Xiahou, X.; Li, Q. Exploring the impact of collaboration on BIM use effectiveness: A perspective through multiple collaborative behaviors. *J. Manag. Eng.* **2022**, *38*, 04022065. [CrossRef]
48. Deng, H.; Xu, Y.; Deng, Y.; Lin, J. Transforming knowledge management in the construction industry through information and communications technology: A 15-year review. *Autom. Constr.* **2022**, *142*, 104530. [CrossRef]
49. Wei, F.; Hwang, B.-G.; Zainal Nur Syafiqah, B.; Zhu, H. Trust, Team Effectiveness, and Strategies: A Comparative Study between Virtual and Face-to-Face Teams. *J. Constr. Eng. Manag.* **2024**, *150*, 04024065. [CrossRef]
50. Vu Thi Kim, D.; Hsieh, S.-H. Impact of Project Managers' Contingent Reward Leadership Style on Performance of BIM Construction Projects. *J. Manag. Eng.* **2025**, *41*, 04025009. [CrossRef]
51. Zhang, Y.; Ma, G.; Pan, X.; Liu, T.; Jia, J. Resolving the Tension between Vertical and Shared Leadership in Construction Project Teams: A Congruence Perspective. *J. Manag. Eng.* **2025**, *41*, 04025013. [CrossRef]
52. Yan, L.; Pan, Y.; Chen, Y. Understanding the Double-Edged Sword Effect of Contract Flexibility on Contractor's Opportunistic Behavior in Construction Project: Moderating Role of BIM Application Degree. *J. Constr. Eng. Manag.* **2024**, *150*, 04024124. [CrossRef]
53. Xue, Y.; Le, Y.; Jiang, K.; Gan, X. Collaborative Management Framework for Interorganizational Risk in Megaprojects Based on Metanetwork. *J. Manag. Eng.* **2024**, *40*, 04024038. [CrossRef]
54. Wang, J.; Zhang, S.; Fenn, P.; Luo, X.; Liu, Y.; Zhao, L. Adopting BIM to Facilitate Dispute Management in the Construction Industry: A Conceptual Framework Development. *J. Constr. Eng. Manag.* **2023**, *149*, 03122010. [CrossRef]
55. Chen, G.; Liu, M.; Li, H.; Hsiang Simon, M.; Jarvamard, A. Motivating Reliable Collaboration for Modular Construction: Shapley Value–Based Smart Contract. *J. Manag. Eng.* **2023**, *39*, 04023042. [CrossRef]
56. Abdelkarim Shimaa, B.; Ahmad Ahmad, M.; Naji, K. A BIM-Based Framework for Managing Handover Information Loss. *J. Manag. Eng.* **2024**, *40*, 04024030. [CrossRef]
57. Sompolgrunk, A.; Banihashemi, S.; Golzad, H.; Le Nguyen, K. Strategic alignment of BIM and big data through systematic analysis and model development. *Autom. Constr.* **2024**, *168*, 105801. [CrossRef]
58. Liu, X.; Antwi-Afari, M.F.; Li, J.; Zhang, Y.; Manu, P. BIM, IoT, and GIS integration in construction resource monitoring. *Autom. Constr.* **2025**, *174*, 106149. [CrossRef]
59. Werbrouck, J.; Schulz, O.; Oraskari, J.; Mannens, E.; Pauwels, P.; Beetz, J. A generic framework for federated CDEs applied to Issue Management. *Adv. Eng. Inform.* **2023**, *58*, 102136. [CrossRef]
60. Teclaw, W.; O'Donnel, J.; Kukkonen, V.; Pauwels, P.; Labonnote, N.; Hjelseth, E. Federating cross-domain BIM-based knowledge graph. *Adv. Eng. Inform.* **2024**, *62*, 102770. [CrossRef]
61. Seidenschnur, M.; Kücükavci, A.; Fjerbæk, E.V.; Smith, K.M.; Pauwels, P.; Hviid, C.A. A common data environment for HVAC design and engineering. *Autom. Constr.* **2022**, *142*, 104500. [CrossRef]
62. Singh, M.M.; Deb, C.; Geyer, P. Early-stage design support combining machine learning and building information modelling. *Autom. Constr.* **2022**, *136*, 104147. [CrossRef]
63. Alothaimeen, I.; Arditi, D.; Türkakın, O.H. Multi-objective optimization for LEED—New construction using BIM and genetic algorithms. *Autom. Constr.* **2023**, *149*, 104807. [CrossRef]
64. Akbari, S.; Sheikhkhoshkar, M.; Pour Rahimian, F.; El Haouzi, H.B.; Najafi, M.; Talebi, S. Sustainability and building information modelling: Integration, research gaps, and future directions. *Autom. Constr.* **2024**, *163*, 105420. [CrossRef]
65. Chuang, T.-Y.; Yang, M.-J. Change component identification of BIM models for facility management based on time-variant BIMs or point clouds. *Autom. Constr.* **2023**, *147*, 104731. [CrossRef]
66. Wang, L.; Lee, J.; Nimawat, J.; Han, K.; Gupta, A. Integrated 4D Design Change Management Model for Construction Projects. *J. Constr. Eng. Manag.* **2024**, *150*, 04024023. [CrossRef]
67. Brelih, A.; Klinc, R. Building digital trust in CDE-based BIM workflows: Key strategies. *J. Inf. Technol. Constr.* **2025**, *30*, 524. [CrossRef]
68. Celik, Y.; Petri, I.; Barati, M. Blockchain supported BIM data provenance for construction projects. *Comput. Ind.* **2023**, *144*, 103768. [CrossRef]
69. Brandín, R.; Abrishami, S. IoT-BIM and blockchain integration for enhanced data traceability in offsite manufacturing. *Autom. Constr.* **2024**, *159*, 105266. [CrossRef]
70. Torkanfar, N.; Azar, E.R.; McCabe, B. Decentralized and Collaborative Information Management System in Construction Contract Administration: A change management case study. *J. Inf. Technol. Constr.* **2025**, *30*, 1123.

71. Akbas, E.; Bolpagni, M.; Borrmann, A.; Boeykens, S.; Mellenthin Filardo, M.; Liu, L.; Beetz, J. A holistic approach to information requirements: Integration of level of information need and information delivery specification. *J. Inf. Technol. Constr.* **2025**, *30*, 731–744. [CrossRef]
72. Menezes-Firmino Maria, J.; Alencar Luciana, H.; Olbina, S. Contract Management of BIM-Based Projects in the Brazilian Public Sector: Contractors' and Owners' Perspectives. *J. Manag. Eng.* **2026**, *42*, 04026011. [CrossRef]
73. Huang, X.; Liu, Y.; Huang, L.; Onstein, E.; Merschbrock, C. BIM and IoT data fusion: The data process model perspective. *Autom. Constr.* **2023**, *149*, 104792. [CrossRef]
74. Wyke, S.; Lindhard, S.M. Understanding Design Rationale and Intent through Natural Language Processing analysis: A search for Consensus. *J. Inf. Technol. Constr.* **2025**, *30*, 631–649. [CrossRef]
75. Xu, J.; Lu, W.; Papadonikolaki, E. Human-Organization-Technology Fit Model for BIM Adoption in Construction Project Organizations: Impact Factor Analysis Using SNA and Comparative Case Study. *J. Manag. Eng.* **2022**, *38*, 04022004. [CrossRef]
76. Wang, K.; Zhang, C.; Guo, F.; Guo, S. Toward an Efficient Construction Process: What Drives BIM Professionals to Collaborate in BIM-Enabled Projects. *J. Manag. Eng.* **2022**, *38*, 04022033. [CrossRef]
77. Bastidas, V.; Oti-Sarpong, K.; Nochta, T.; Wan, L.; Tang, J.; Schooling, J. Leadership for responsible digital innovation in the built environment: A socio-technical review for re-establishing competencies. *J. Urban Manag.* **2023**, *12*, 57–73. [CrossRef]
78. Pan, Y.; Zhang, L. Modeling and analyzing dynamic social networks for behavioral pattern discovery in collaborative design. *Adv. Eng. Inform.* **2022**, *54*, 101758. [CrossRef]
79. Voordijk, H.; olde Scholtenhuis, L. Technological mediation and 3D visualizations in construction engineering practice. *AI Soc.* **2024**, *39*, 207–220. [CrossRef]
80. Prabhakaran, A.; Mahamadu, A.-M.; Mahdjoubi, L.; Boguslawski, P. BIM-based immersive collaborative environment for furniture, fixture and equipment design. *Autom. Constr.* **2022**, *142*, 104489. [CrossRef]
81. Lozano, F.; Jurado, J.C.; Lozano-Galant, J.A.; de la Fuente, A.; Turmo, J. Integration of BIM and Value Model for Sustainability Assessment for application in bridge projects. *Autom. Constr.* **2023**, *152*, 104935. [CrossRef]
82. Panya, D.S.; Kim, T.; Choo, S. An interactive design change methodology using a BIM-based Virtual Reality and Augmented Reality. *J. Build. Eng.* **2023**, *68*, 106030. [CrossRef]
83. Jiang, Y.; Liu, X.; Wang, Z.; Li, M.; Zhong, R.Y.; Huang, G.Q. Blockchain-enabled digital twin collaboration platform for fit-out operations in modular integrated construction. *Autom. Constr.* **2023**, *148*, 104747. [CrossRef]
84. Martinez Lagunas Araham, J.; Nik-Bakht, M. Process Mining, Modeling, and Management in Construction: A Critical Review of Three Decades of Research Coupled with a Current Industry Perspective. *J. Constr. Eng. Manag.* **2024**, *150*, 04024158. [CrossRef]
85. Gao, W.; Lu, S.; Zhang, X.; He, Q.; Huang, W.; Lin, B. Impact of 3D modeling behavior patterns on the creativity of sustainable building design through process mining. *Autom. Constr.* **2023**, *150*, 104804. [CrossRef]
86. Ni, X.-R.; Pan, P.; Lin, J.-R. What makes a good BIM design? Quantifying the link between design behavior and quality. *Autom. Constr.* **2025**, *171*, 105992. [CrossRef]
87. Martinsuo, M.; Huemann, M. Designing case study research. *Int. J. Proj. Manag.* **2021**, *39*, 417–421. [CrossRef]
88. Muruganandan, K.; Davies, A.; Denicol, J.; Whyte, J. The dynamics of systems integration: Balancing stability and change on London's Crossrail project. *Int. J. Proj. Manag.* **2022**, *40*, 608–623. [CrossRef]
89. Begić, H.; Galić, M.; Dolaček-Alduk, Z. Digitalization and automation in construction project's life-cycle: A review. *J. Inf. Technol. Constr.* **2022**, *27*, 441–460. [CrossRef]
90. Whyte, J.; Davies, A. Reframing systems integration: A process perspective on projects. *Proj. Manag. J.* **2021**, *52*, 237–249. [CrossRef]
91. Cao, D.; Shao, S. Colleagues or friends? Comparing communication and advice networks for building information modeling (BIM) implementation in construction projects. *Proj. Manag. J.* **2024**, *55*, 232–246. [CrossRef]
92. Ozkan, S.; Seyis, S. Benefits and challenges of implementing the common data environments in the construction phase of BIM-based projects. *J. Constr. Eng. Manag.* **2024**, *150*, 04024091. [CrossRef]
93. Radzi, A.R.; Azmi, N.F.; Kamaruzzaman, S.N.; Algahtany, M.; Rahman, R.A. Challenges in construction readiness for BIM-based building projects. *J. Asian Archit. Build. Eng.* **2025**, *24*, 1689–1704. [CrossRef]
94. Zhang, X.; Denicol, J.; Chan, P.W.; Le, Y. Designing the transition to operations in large inter-organizational projects: Strategy, structure, process, and people. *J. Oper. Manag.* **2024**, *70*, 107–136. [CrossRef]
95. Liu, T.; Chong, H.-Y.; Zhang, W.; Lee, C.-Y.; Tang, X. Effects of contractual and relational governances on BIM collaboration and implementation for project performance improvement. *J. Constr. Eng. Manag.* **2022**, *148*, 04022029. [CrossRef]

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