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Identifying Critical Barriers to BIM-Driven Design–Construction Integration in Xi'an Building Projects: A Questionnaire Study

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Abstract: Building information modelling (BIM) can provide a common digital basis for coordinating design decisions and construction activities, yet the presence of modelling software does not ensure that information, authority and workflows remain aligned across the design–construction interface. This study identifies and prioritises perceived barriers to BIM-driven design–construction integration in building projects in Xi'an, China. A literature-informed questionnaire covered 42 barrier statements allocated in advance to eight candidate domains. Of 280 returned questionnaires, 262 were retained after screening. Descriptive statistics, internal-consistency analysis, item-level severity ranking and comparisons of pre-established domain scores were undertaken. Cronbach's alpha was 0.802 for the complete 42-item scale. Using the study-specific criterion of a mean severity rating of at least 3.50, 22 items were classified as critical. These items occurred exclusively within four candidate domains: information management, process, responsibility and governance, and collaboration and relational conditions. Information management had the highest domain mean (4.003), followed by process (3.883), responsibility and governance (3.783), and collaboration and relational conditions (3.624). The highest-ranked individual issue concerned the absence of clear rules for BIM naming, classification, information exchange and delivery (mean 4.084). Inconsistent versions and the absence of a standardised issue-closure process followed. The findings suggest that the main perceived impediments in this sample lie in the controlled use and cross-stage coordination of digital information rather than solely in software capability. This paper provides an empirically bounded diagnosis for Xi'an building projects; it does not test causal relationships, identify latent statistical factors or validate a management intervention.

Keywords: Building Information Modelling; Design–Construction Integration; Barrier Identification; Information Management; Collaboration; Questionnaire Survey; Xi'an

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1. Introduction

Digital transformation in the architecture, engineering and construction (AEC) sector has enlarged the opportunities for information sharing, coordinated design and construction planning. Building information modelling is commonly expected to

connect geometry with classifications, quantities, technical decisions and the records needed to coordinate project activities. This expectation is significant because construction projects are delivered by several organisations whose responsibilities and information requirements change as a project moves from design development to site execution. A model created to support the designer's interpretation of a project may not be immediately usable for procurement, trade coordination, constructability checking or construction detailing. Accordingly, the practical question is not simply whether a BIM model exists. It is whether information can be identified, checked, authorised, communicated and acted upon by the next responsible participant in time for the relevant decision.

The design–construction interface is especially exposed to discontinuity because technical information crosses both stage boundaries and contractual or professional boundaries. Model authors may assume that an object is sufficiently developed while downstream contractors need additional information about materials, tolerances, sequences, temporary works and construction access. Changes approved through established drawing procedures may not be reflected promptly in the model, or a model revision may be made without a corresponding formal decision. These discrepancies create a risk that apparently shared information is not shared in meaning, status or authority. Previous research has reported that BIM-enabled collaboration depends on contractual arrangements and perceptions of coordination as well as technology adoption (Gao et al., 2022). The present study therefore approaches BIM as an information-enabled management practice rather than an isolated software activity.

The literature identifies a broad range of BIM adoption and implementation barriers, including costs, skills, organisational readiness, interoperability, contractual uncertainty and inter-organisational coordination. A review of collaboration and risk in BIM research demonstrates the importance of the social and managerial context of implementation (Ali et al., 2022). Comparative evidence from developing countries also shows that the relevance of barriers varies with organisational and institutional conditions (Ariono et al., 2022). Nevertheless, lists drawn from different settings cannot establish which specific impediments are most severe at the interface between design and construction in a particular local project environment. Nor does a list of widely discussed barriers tell a practitioner whether the immediate priority should be upgrading software, clarifying decision rights or strengthening model-release procedures.

Xi'an provides a bounded and relevant setting in which to investigate this distinction. The city participates in China's intelligent-construction policy context, yet policy attention to digital construction should not be equated with uniform implementation at the project level. Building projects involve design institutes, clients, contractors, specialist trades and BIM service organisations, and these actors may have different work sequences, information rights and digital capacities. Rather than treating the designation of Xi'an as a pilot city as evidence of successful integration, this study examines the severity assessments reported by professionals with relevant BIM-project experience in Xi'an. Its unit of analysis is the practitioner's rating of a specific barrier condition associated with a reference project, not a measured causal effect on a project's cost or duration.

The objective is to identify and rank the major barriers affecting BIM-driven design–construction integration in building projects in Xi'an. Three focused research questions guide the paper: Which of 42 literature-informed barrier conditions receive the highest severity ratings from eligible respondents? How do their ratings compare across eight fixed candidate domains? What does the distribution of higher-priority barriers imply for understanding design–construction information and management discontinuities? The study does not seek to construct a new latent-factor solution, estimate structural relationships or test the performance of a proposed BIM management framework. These tasks would require additional designs and evidence. Its contribution is a transparent, local, descriptive barrier diagnosis that can be compared with the international literature and can inform subsequent research without being confused with that subsequent work.

The article follows a format broadly comparable to a conventional empirical construction-management paper. Section 2 reviews BIM collaboration, design–construction information continuity and barrier evidence. Section 3 describes the questionnaire, respondents, screening, statistics and the pre-established priority rule. Section 4 presents respondent characteristics, reliability statistics, item rankings and domain comparisons. Section 5 interprets the findings against prior research and discusses their methodological and practical boundaries. Section 6 provides conclusions and directions for future

investigation. This separation of method, results and discussion is intended to keep the findings auditable and to avoid turning the present diagnosis into an unsupported claim that a management solution has already been validated.

2. Literature Review

2.1 BIM-Enabled Collaboration and the Design–Construction Interface

BIM involves coordinated management of structured information, not simply the production of three-dimensional illustrations. It can create a shared spatial reference for multidisciplinary review, quantities, project sequencing and coordination of construction tasks. However, the informational value of a model depends on its intended uses, data quality and the ability of recipients to distinguish tentative working information from formally accepted information. ISO 19650-1 and ISO 19650-2 provide a widely used information-management vocabulary for collaborative production and exchange. These standards support the principle that information needs to be controlled across delivery processes, although the standards do not themselves determine which local impediments will be ranked most severely by practitioners.

Collaboration also includes the human ability and organisational authority to make and implement decisions. In an empirical study of the Chinese construction market, Gao et al. (2022) separated cooperation from coordination and found that BIM application related positively to both, with particular contractual and relational conditions moderating the associations. This evidence is valuable because the technical capacity to circulate models does not remove the possibility that a coordination request is delayed, that responsibilities overlap or that a formal decision is communicated through parallel channels. Design–construction integration consequently requires a consistent relation between current information, the activity requiring it and the party authorised to approve its use.

The interface is not a single instant at which a designer transfers files to a contractor. It includes early participation by construction specialists, review of constructability, controlled release of information for construction, subsequent detailing, management of site questions and incorporation of approved changes. At each of these points, information may change purpose and ownership. A technically readable exchange does not necessarily guarantee continuity if it omits the status of a design decision or the conditions governing subsequent use. A research focus limited to file interoperability is therefore narrower than the management problem of cross-stage integration.

2.2 Information Management, Workflows and Governance

Recent work on common data environments (CDEs) has drawn attention to the gap between a proposed single source of information and the multiple repositories used in real projects. Jaskula et al. (2024) combined a literature review with expert interviews and identified project complexity and simultaneous CDE use as practical challenges to accountability, transparency and reliability. Seyis and Ozkan (2024) likewise analysed construction-stage CDE benefits and challenges, emphasising the value of accurate and up-to-date information alongside difficulties of implementation. These studies support the relevance of information-management issues, but they do not establish the relative ratings of specific barriers in Xi’an. That requires data from the local research sample.

Management discontinuity can occur even when all participants have access to adequate software. For example, one party can place a revised model in a common folder while another party continues to use an earlier file because the release status is not apparent. A design change can be technically correct but not usable on site until it is linked to the formal documentation and an authorised release decision. The distinction between access and authority is particularly important in multi-organisational projects: permission to upload information is not necessarily permission to approve engineering decisions. These recurring situations motivate treating information management and responsibility/governance as separate diagnostic domains rather than a single undifferentiated technology category.

Workflow arrangements are a related but distinct concern. Design review may identify a clash or a constructability issue, but identification alone does not show that the issue was assigned, answered, verified and closed. A process can therefore generate many digital records while providing little assurance that the relevant decision has been completed. Formal integration of BIM coordination into approval and project-management procedures matters because work cannot be governed solely through informal messages or visually compelling federated models. Treating process continuity as an analytical category helps differentiate late, inconsistent or disconnected work from defective model content.

2.3 Broader BIM Barriers and the Need for Local Prioritisation

BIM barriers have been organised in several ways. Ali et al. (2022) identified recurring themes of collaboration, risk and adoption in their systematic review. Ariono et al. (2022) considered drivers, barriers and enablers in developing-country contexts. Mishra et al. (2024) differentiated pre-adoption and post-adoption barriers in the Indian construction sector using practitioner surveys. This distinction is useful: organisations may overcome initial access and awareness problems while continuing to face information, governance or coordination problems during routine BIM use. It would nevertheless be inappropriate to assume that the ranking of Indian barriers is directly transferable to a sample of Xi'an building projects.

The barrier literature also varies in terminology. Lack of top-management support may be identified as organisational readiness, managerial commitment or a resource constraint. Unclear approval rights may be treated as an organisational, contractual or governance issue. Similarly, model inconsistency may reflect technological limitations but can also be caused by weak naming rules, uncontrolled document states and incomplete workflows. For the present survey, the value of a domain framework is its ability to organise questions by their principal management mechanism, not to claim the existence of eight distinct statistical factors. The eight domains were specified before analysis, and their use supports transparent item coverage and descriptive comparison.

In this study, organisational factors cover strategy, leadership and resources; responsibility and governance cover roles, rights and decision authority; collaboration and relational conditions cover trust, communication and joint working; process factors cover the sequencing of review, coordination and transition activities; information management covers coding, status, versions, exchange, completeness and delivery acceptance; technological factors cover software and infrastructure capabilities; human and competency factors cover relevant training and professional skills; and institutional and contractual factors cover external rules, procurement and legal/formal arrangements. The distinctions are pragmatic rather than ontologically absolute. A single management problem may involve more than one domain, but the questionnaire assigns each statement to one primary category to avoid double counting in descriptive summaries.

A local severity study also contributes a different kind of knowledge from the mere frequency with which terms appear in published research. A highly cited technological problem may be less severe for a particular group of practitioners than an ordinary but persistent issue of version control. Conversely, a low mean rating does not prove that a problem is absent. Mean severity indicates the reported average assessment under a specific instrument, time and respondent mix. Accordingly, this paper uses literature to explain why the chosen barrier statements matter, while relying on sample statistics—not literature prominence—to determine their relative priority in Xi'an.

Evidence from the Chinese construction sector is especially relevant when positioning the present work. Ma et al. (2022) studied BIM implementation barriers using 166 valid professional responses and reported that the most critical issues varied in their relative order across national settings. Their research included additional multivariate analysis that is not reproduced here, but the descriptive implication matters: rankings ought to be interpreted in their own project and respondent context. The present survey examines a narrower problem, the design–construction interface in Xi'an building projects, rather than all forms of BIM adoption. As a result, differences between findings should not automatically be treated as contradictions. A survey that asks whether a company can adopt BIM for the first time measures a different practical concern from one asking whether already shared digital information is correctly approved and handed over.

International comparison sharpens this distinction. Waqar et al. (2023) examined barriers affecting the deployment of BIM in small Malaysian construction projects, while Mishra et al. (2024) explicitly separated pre- and post-adoption issues in India. Their settings are informative precisely because they differ from the current Xi'an sample in project size, institutional context, maturity and respondent recruitment. The literature therefore contributes conceptual coverage, not replacement data. This is also why the eight survey domains are deliberately broad: the instrument needed to allow technical, capability, organisational and contractual problems to register as severe if respondents experienced them as such. The fact that other categories scored higher emerged from the returned questionnaires; it was not imposed by excluding technology items during instrument preparation.

3. Research Methodology

3.1 Study Design and Questionnaire Development

A cross-sectional, questionnaire-based quantitative design was used because the immediate purpose was to describe and compare practitioners' perceptions of the severity of predefined obstacles. It was not necessary to elicit interview narratives or infer unobserved causal mechanisms in order to answer the ranking objective. The instrument had three parts. Section A contained eligibility and BIM-activity screening questions; Section B described professional and project background; and Section C consisted of 42 negatively worded barrier statements. The instrument instructed each participant with experience of multiple BIM-enabled projects to use the most recent or most familiar eligible building project in Xi'an as a consistent reference. This helped anchor ratings to actual practice rather than general beliefs about the BIM industry.

The 42 barrier statements were drawn from the study's literature-informed candidate structure and refined for the design–construction interface. They were internally mapped to eight a priori domains: organisational (OR, six items); responsibility and governance (GV, five); collaboration and relational (CR, five); process (PR, six); information management (IM, six); technological (TE, five); human and competency (HC, four); and institutional and contractual (IC, five). One version of the formal questionnaire presented all items in a continuous Q1–Q42 sequence, while the researcher's grouped version organised equivalent content by code. These are alternative presentations of the same 42-item content, not separate data sources or independent scales.

Section C employed a five-point severity scale anchored from 1 (not a barrier), through 3 (moderate barrier), to 5 (very serious barrier). An additional "not sure/not applicable" option permitted respondents to decline ratings outside their experience; these responses were treated as missing for item-level descriptive analysis, not as a neutral midpoint. The study's priority convention was an item mean of 3.50 or above. This value was chosen as an operational distinction between the moderate rating of 3 and the major rating of 4; it is a study-specific reporting threshold and should not be represented as an internationally validated cut-off for BIM criticality. The precise wording and scale anchors matter because the reported statistics represent ratings of hindrance, not frequencies or objective project-performance outcomes.

The questionnaire's two presentations deserve clarification because they affect reproducibility. The continuous version displayed Q1–Q42 in a mixed sequence to reduce the likelihood that consecutive answers would be shaped by visible conceptual headers. The grouped researcher version used the OR, GV, CR, PR, IM, TE, HC and IC labels to describe the same substantive statements by domain. For example, the continuous Q21 is IM3 in the internal coding and represents the lack of common information-management rules; Q20 is PR3 and concerns issue closure. Analyses used consistent item correspondence rather than treating the two layouts as separate forms. Maintaining this code dictionary is important for matching item-level descriptive output, thesis tables and any future reanalysis of the underlying responses.

3.2 Eligibility, Sample Composition and Screening

The target population comprised professionals who had participated in BIM-enabled building projects in Xi'an and undertaken at least one BIM-related activity such as modelling, design review, coordination, constructability checking, construction planning, information exchange, change management or BIM/project management. Background questions captured primary professional role, organisation type, total professional experience, BIM experience, number of BIM projects, building type, delivery arrangement and main stage of involvement. These variables provide a descriptive view of the retained respondent pool. Because a complete probability sampling frame and total invitation count were not established in the supplied statistical tables, the retained percentage is reported as a proportion of returned questionnaires, not as a response rate for all practitioners contacted.

Of 280 returned questionnaires, 18 were removed before the main analysis. Four failed the initial project eligibility screen, three reported no BIM-related activity, six had at least 12 missing core items, and five had straight-line response patterns. The final sample contained 262 questionnaires, representing 93.6% of returns. These steps were applied before estimating scale reliability or ranking the barrier items. Item-specific valid sample sizes varied from 260 to 262 because certain items contained missing or not-applicable responses. The total-scale reliability calculation used 254 complete cases. These denominators must remain distinct: neither the 262 retained questionnaires nor the 254 reliability cases should be substituted uncritically for each item's valid N.

The sample included client/developer representatives, designers, structural and building-services engineers, contractors, project managers, BIM coordinators and specialists. Multiple project types and delivery arrangements were reported. These features provide several perspectives on the transition from design information to construction use; however, the distribution does not prove that the sample statistically represents all building-project professionals or projects in Xi'an. The study accordingly avoids city-wide population estimates and causal generalisation. Its claims concern priorities perceived in the retained analytical sample under the specified questionnaire conditions.

3.3 Statistical Treatment and Reporting Decisions

The reported SPSS analysis comprised questionnaire screening, frequency and percentage summaries for respondent characteristics, internal-consistency reliability, descriptive statistics for each barrier item and descriptive comparison of the eight pre-established candidate domains. For the item-ranking table, severity means were the primary statistic. Standard deviations describe response dispersion and were also consulted where equal means arose at the level of reporting precision. Results are displayed to three decimal places in most journal tables, with more precision used in the text where needed to distinguish close values. The item-level analysis retained the actual valid N, mean and standard deviation for each statement; the full list contains 42 rows and is condensed in the main paper to keep the narrative readable.

Cronbach's alpha was used as a diagnostic of internal consistency for the full barrier instrument and for the predetermined item groupings. It was not used as evidence that eight latent constructs had been independently discovered. The literature-informed grouping provides a practical classification for comparison, but a descriptive survey alone cannot establish construct independence or causal effects. Similarly, the presence of KMO, Bartlett or exploratory-factor-analysis tables in a software output does not make those procedures part of the present study's analysis. In accordance with the fixed RO1 method, this paper does not report factor loadings, extracted factors, rotated matrices or a newly inferred empirical factor structure.

For domain-level comparison, the supplied SPSS composite scores for the eight fixed categories were reported as means and standard deviations; their relative ranks express descriptive differences in perceived severity. The individual-item criticality rule was then applied independently to each of the 42 questions. An average domain mean above 3.50 does not, by itself, prove that every item within that domain is critical. In the present data, all item means within each of the four highest domains happened to meet the threshold, but this is an observed distribution rather than a definitional requirement. No inferential comparison between occupational groups, confidence interval for the Xi'an population or project-level impact coefficient is claimed in this paper.

4. Results

4.1 Screening and Respondent Characteristics

The respondent screening results are summarised in Table 1. The 262 retained cases constitute the analytical dataset for the item-level severity analysis, subject to the item-specific missing values described above. The exclusions were documented by type so that the transition from returned questionnaires to retained cases can be examined. The valid fraction of returned questionnaires is high, but without a verified sampling denominator it must not be interpreted as a population response rate.

Table 1. Questionnaire screening and analytical retention

Outcome	Number	Percentage of 280 returns
Initial questionnaires received	280	100.0%
Ineligible: S1 screen	4	1.4%
No BIM-related activity	3	1.1%
At least 12 missing items	6	2.1%
Straight-line responses	5	1.8%
Total excluded	18	6.4%
Retained analytical sample	262	93.6%

Professional roles were varied within the retained sample. BIM managers and coordinators were the largest identified group

(54, 20.6%), followed by contractors/construction managers (47, 17.9%) and client/developer representatives (37, 14.1%). Designers numbered 26 (9.9%), structural or MEP engineers 20 (7.6%), project managers and consultants 29 (11.1%), specialist contractors six (2.3%), and respondents coded as other 43 (16.4%). The relatively substantial BIM-coordination and construction representation is relevant to a study of information release, version discrepancies and construction-stage interface handling. At the same time, the heterogeneous "other" category is a limitation for highly detailed role-level interpretation.

General contractors formed the largest organisation-type category (69, 26.3%). Clients/developers and design institutes each contributed 50 respondents (19.1% each), while project management/consultancy contributed 22 (8.4%), BIM consultancy 28 (10.7%), and other organisations 43 (16.4%). The most frequently reported professional-experience category was six to ten years (85, 32.4%), followed by 11–15 years (64, 24.4%). BIM experience was distributed across one to three years (29.8%), four to five years (28.2%), six to ten years (24.0%), over ten years (10.3%) and below one year (7.6%). These distributions indicate a mix of newer and more established BIM practitioners rather than only novice respondents.

Public buildings represented the largest reported project-type category (75, 28.6%), followed by residential projects (65, 24.8%), mixed-use developments (52, 19.8%), commercial projects (37, 14.1%), industrial buildings (29, 11.1%) and other projects (four, 1.5%). Engineering–procurement–construction (EPC) was the most frequently indicated delivery arrangement (91, 34.7%), while design–bid–build was reported by 69 respondents (26.3%) and design–build by 62 (23.7%). Regarding stage involvement, 81 respondents (30.9%) worked across multiple stages, 78 (29.8%) mainly in construction, 52 (19.8%) in design and 51 (19.5%) at the design-to-construction transition. This distribution makes the selected topic substantively relevant to the reported practitioner activities.

Table 2. Selected respondent and project characteristics

Characteristic	Largest or focal category	n	%
Professional role	BIM manager / coordinator	54	20.6
Professional role	Contractor / construction manager	47	17.9
Organisation	General contractor	69	26.3
Professional experience	6–10 years	85	32.4
BIM experience	1–3 years	78	29.8
Project type	Public building	75	28.6
Delivery arrangement	EPC	91	34.7
Stage involvement	Multiple stages	81	30.9
Stage involvement	Construction stage	78	29.8

4.2 Reliability and Analytical Adequacy

The total 42-item scale produced Cronbach's alpha of 0.802 from 254 complete records. Alpha coefficients for the eight pre-established domains ranged from 0.789 to 0.876. The process domain had the highest coefficient (0.876), followed by information management (0.860), organisational factors (0.853), institutional and contractual factors (0.841), collaboration and relational factors (0.840), responsibility and governance (0.837), technological factors (0.820), and human and competency factors (0.789). All eight coefficients indicate reasonably consistent response patterns within the corresponding item groups under the reported reliability procedure.

Internal consistency is useful but does not answer every question about measurement validity. A high coefficient does not show that a domain is causally decisive, nor does it prove that the domain is one-dimensional under a confirmatory measurement model. The present paper therefore interprets the reliability output conservatively, as support for reporting the fixed descriptive groupings rather than as validation of an eight-factor empirical structure. Because the grouping was specified before the survey was analysed, the domain labels remain "candidate" or "a priori" in results and discussion.

Table 3. Internal-consistency reliability for fixed candidate domains

Measure	Number of items	Valid N	Cronbach's α
Overall barrier instrument	42	254	0.802
Organisational (OR)	6	260	0.853
Responsibility & governance (GV)	5	262	0.837
Collaboration & relational (CR)	5	262	0.840
Process (PR)	6	261	0.876
Information management (IM)	6	260	0.860
Technological (TE)	5	260	0.820
Human & competency (HC)	4	262	0.789
Institutional & contractual (IC)	5	261	0.841

4.3 Item-Level Critical Barriers

Of the 42 evaluated barriers, 22 met or exceeded the study-specific mean severity threshold of 3.50. The highest-ranked item, IM3, concerned the absence of clear and consistent project BIM information-management rules covering model naming, classification/coding, exchange and delivery requirements (mean 4.0840, SD 0.87571). The next two reported item means were both 4.0153: IM1 concerned inconsistent versions of BIM models or related information (SD 0.82569), while PR3 concerned the lack of a standardised workflow for identifying, assigning, resolving, confirming and closing coordination issues (SD 0.86201). Using standard deviation as the secondary reporting criterion places IM1 immediately ahead of PR3 in a deterministic order, while preserving their equality in rounded mean severity. This is not an inferential claim that the two means differ significantly.

The next group of severe barriers described the continuity of authorised information. IM5 concerned insufficient synchronisation and traceability between BIM models and formal project documents following design or construction changes (mean 4.0038). IM4 described design-delivered model detail and information that did not adequately support construction detailing or site use (mean 3.9847). IM6 addressed the absence of consistent quality checking and acceptance before delivery to construction teams (mean 3.9809). IM2 concerned unclear model status and permitted use of working, coordination or issued versions (mean 3.9542). These four findings indicate that respondents distinguished several failure modes within the broad theme of information management: the need for usable content, an authorised state, consistent change records and a quality gate before formal handover.

Process-related items followed closely. PR6 addressed discontinuity in transforming design BIM into construction, specialist or fabrication information (mean 3.8931); PR2 addressed discontinuity between coordination in design and construction (mean 3.8855); and PR5 addressed inadequate constructability review during design (mean 3.8779). These statements relate to different points in the same cross-stage transition. An accepted design deliverable can still require interpretation and transformation for downstream use, while even a technically coherent model may not incorporate buildability constraints if construction experience arrives too late. Importantly, the survey demonstrates that respondents considered these conditions severe; it does not demonstrate that introducing a particular review mechanism would reduce rework by a measured percentage.

Responsibility and governance appeared throughout the critical set. GV2, concerning unclear ownership, use rights and management responsibility for BIM information, had a mean of 3.8626. GV5, concerning priority and resolution rules when BIM models conflict with approved drawings or other authorised documents, scored 3.8092. GV3 addressed approval authority (3.7634), GV1 the clarity of roles (3.7443), and GV4 the responsibility for model updating after changes (3.7366). The coexistence of these barriers suggests that the role of digital information is difficult to separate from decision authority. It is possible to manage filenames consistently while leaving unresolved the authority to approve a technical change or determine which document takes precedence.

Table 4. Critical barriers meeting the mean ≥ 3.50 threshold

Order	Code	Barrier description (abbreviated)	Valid N	Mean	SD
1	IM3	Inconsistent BIM information-management rules	262	4.084	0.876
2	IM1	Inconsistent versions among participants	262	4.015	0.826
3	PR3	No standardised coordination issue-closure workflow	262	4.015	0.862
4	IM5	Weak model–document revision synchronisation	261	4.004	0.857
5	IM4	Design BIM content insufficient for construction use	261	3.985	0.850
6	IM6	No consistent model delivery quality gate	262	3.981	0.855
7	IM2	Unclear model status and permitted use	262	3.954	0.879
8	PR6	Poor transition into downstream detailing	262	3.893	0.846
9	PR2	Discontinuous design–construction BIM coordination	262	3.885	0.915
10	PR5	Insufficient design-stage constructability review	262	3.878	0.849
11	GV2	Unclear digital-information rights and duties	262	3.863	0.856
12	PR1	Late contractor/specialist involvement	262	3.813	0.897
13	PR4	BIM coordination outside formal review procedures	261	3.812	0.854
14	GV5	No clear precedence for model–document conflicts	262	3.809	0.854
15	GV3	Unclear BIM technical review/approval authority	262	3.763	0.870
16	GV1	Unclear BIM roles and responsibilities	262	3.744	0.897
17	GV4	Unclear responsibility for updating after changes	262	3.737	0.916
18	CR4	Unaligned project goals and BIM priorities	262	3.672	0.892
19	CR3	Limited willingness to share BIM information	262	3.641	0.863
20	CR1	Insufficient trust for open information sharing	262	3.641	0.872
21	CR2	Untimely / ineffective design–construction communication	262	3.622	0.917
22	CR5	Slow resolution of cross-organisational disagreements	262	3.546	0.969

All five collaboration and relational items also exceeded the threshold, although their means were lower than the strongest information-management and process items. CR4 concerned misaligned project goals and BIM collaboration priorities (3.6718). CR3 and CR1 concerned unwillingness to share information and insufficient inter-organisational trust (both 3.6412, with marginally different standard deviations). CR2 involved ineffective or untimely communication (3.6221), while CR5 concerned the slow resolution of cross-organisational disagreements (3.5458). These ratings show that relationship and joint-working conditions remain important in the sample even where digital information controls are the most highly rated problems. The presence of both procedural and relational barriers cautions against interpreting coordination as an exclusively technical issue.

Taken together, the 22 critical items represented exactly the six information-management items, six process items, five responsibility/governance items and five collaboration/relational items in the questionnaire. None of the 20 remaining items in the organisational, technological, human/competency and institutional/contractual groups reached the chosen mean threshold. The lowest-rated critical item, CR5, remained above it at 3.5458. The highest-rated non-critical item, OR2, was close to it at

3.4809. This boundary is useful for transparent classification but also reveals why the analysis should not be over-interpreted: a difference between 3.481 and 3.546 reflects the adopted operational threshold, not evidence of a fundamental qualitative divide between two real-world problems.

A closer reading of the item order illustrates why a simple "technology versus management" opposition would be misleading. The strongest problem, IM3, describes missing rules that could be implemented in digital systems but require institutional agreement among project participants. IM1 similarly requires technical access to current models as well as management decisions about what counts as the current release. PR3 is operationally procedural, yet a model-linked issue register could provide supporting digital functionality. These categories are distinct for questionnaire coding, not isolated in practice. The useful finding is therefore the consistent concentration of high-rated conditions around the governance of already existing information and around control of coordination work, rather than an assertion that management and technology have no interactions.

4.4 Comparing the Eight a Priori Domains

Table 5. Descriptive ranking of the eight a priori barrier domains

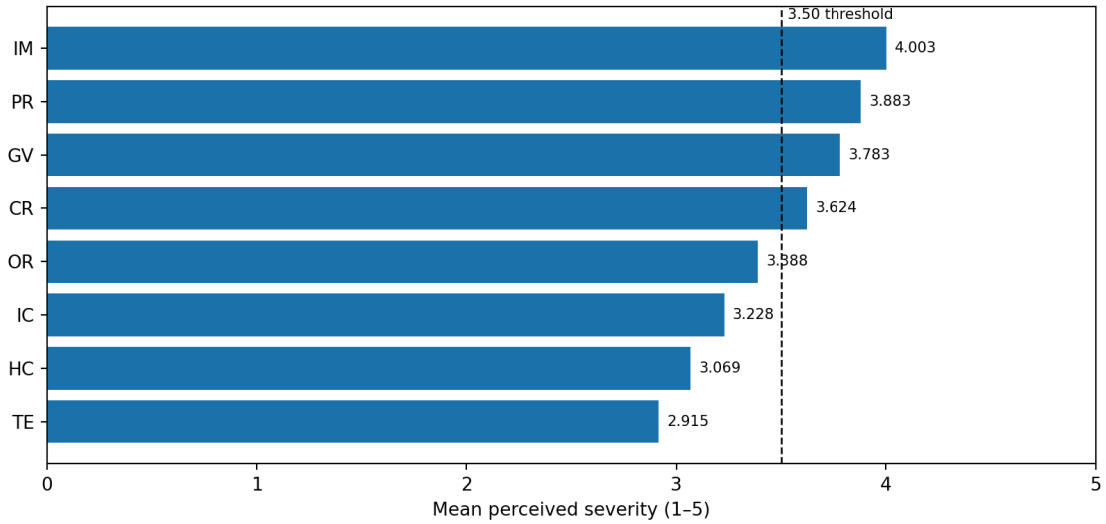
Rank	Domain	Mean	SD	Items	Items ≥ 3.50
1	Information management	4.003	0.659	6	6
2	Process	3.883	0.684	6	6
3	Responsibility and governance	3.783	0.684	5	5
4	Collaboration and relational	3.624	0.706	5	5
5	Organisational	3.388	0.687	6	0
6	Institutional and contractual	3.228	0.724	5	0
7	Human and competency	3.069	0.710	4	0
8	Technological	2.915	0.688	5	0

The composite domain ratings reinforce the item-level pattern. Information management was first (mean 4.0033, SD 0.65858), followed by process (3.8827, SD 0.68400), responsibility and governance (3.7832, SD 0.68371), and collaboration and relational factors (3.6244, SD 0.70576). These four categories had means above the study-specific threshold, and each of their constituent items also met the item-level criterion. Organisational factors ranked fifth (3.3882), followed by institutional and contractual (3.2284), human and competency (3.0687), and technological factors (2.9153). These results describe the sample's relative perception of severity; they do not demonstrate that one domain causally determines the others.

The contrast between information management and technology is particularly noteworthy. Respondents rated information naming, status, revision consistency, delivery quality and downstream usability substantially higher, on average, than problems of software compatibility or digital infrastructure. This does not imply that technical interoperability is solved in Xi'an. The technological domain includes five distinct statements, and their reported mean ratings ranged from approximately 2.831 to 3.000. Rather, the result suggests that within this particular sample, the more immediate management difficulties were associated with rules and practices governing information already being produced, exchanged and used. A technically accessible model can still be incomplete, unapproved or contradictory.

The four lower-scoring domains should remain part of the interpretation. OR2, concerning variation in BIM capability across organisations, had a mean of 3.4809, only marginally below the threshold. Some institutional and training concerns likewise had means above 3.0, indicating that they were assessed as more than negligible problems. The ranking therefore supplies a pragmatic priority order, not a binary statement about whether a problem exists. The original eight-domain design remains useful for observing what was not highly rated as well as what was. This prevents the analysis from selectively reporting only statements that reinforce a preferred information-management explanation.

Figure 1. Mean perceived severity across the eight pre-established barrier domains (N = 262).



The dashed line in Figure 1 marks the study-specific 3.50 reporting threshold. The chart displays domain descriptive means only; the critical-item classification was applied to individual statements. Therefore, the figure must not be interpreted as an exploratory-factor-analysis result or as proof that the eight domains are statistically independent.

5. Discussion

5.1 Information Governance as the Leading Perceived Problem

The first contribution of this study is its more specific account of what "information fragmentation" meant to the surveyed professionals. The top-rated item was not simply that digital tools fail to connect, but that clear rules for naming, classification, exchange and delivery were lacking. Related high-rated problems concerned inconsistent model versions, uncertain information status, poor synchronisation with formal records and inadequate delivery checking. These conditions form a coherent managerial interpretation without requiring that the study treat them as a statistically extracted factor. A shared model becomes operationally valuable when participants can establish which information is current, which use is permitted, who is responsible for revisions and whether the release has passed the intended quality gate.

This pattern can be read alongside the CDE literature. Jaskula et al. (2024) reported challenges related to accountability, reliability and working with multiple information environments; Seyis and Ozkan (2024) emphasised access to accurate and up-to-date information as a principal benefit of effective CDE use. The Xi'an results are consistent with the general significance of controlled information, but their distinct empirical contribution is the ordering of 42 specifically worded interface obstacles in a local building-project sample. The literature explains why information controls matter; the questionnaire shows that respondents assigned relatively high severity to these particular failures in their reference projects.

One implication is that future BIM implementation reviews should not equate successful information management with simply providing a shared repository. A repository can hold a current version, an obsolete copy, an approved drawing and an unapproved model simultaneously. Unless the project establishes classification rules, naming consistency, approval states and document precedence, broad access may increase ambiguity rather than reduce it. The survey findings support giving such controls serious attention, while the precise procedures, staffing and technologies needed to establish them remain subjects for later design or implementation studies.

5.2 Workflow Discontinuity and the Role of Earlier Construction Input

The second prominent pattern concerns transitions within and between project stages. Lack of a standard issue-closure process was among the top three barriers, and the process group also contained highly rated issues of early constructability input, continuity of design–construction coordination and transformation into downstream detailing. This distribution suggests that the surveyed practitioners experienced BIM shortcomings not only as information defects but also as breakdowns in the timing and accountability of work. Identifying a coordination issue digitally is not equivalent to resolving it; similarly, delivering a file does not establish that the downstream organisation received the information needed for

construction planning.

The finding warrants a distinction between “design complete” and “ready for a particular construction use”. A design model may contain the geometry and information appropriate for one approval event while remaining incomplete for a trade-level fabrication or logistics decision. If construction specialists become involved late, the incompatibility may only become visible after formal design decisions have been made. The severe ratings for PR1, PR5 and PR6 make these interfaces sensible priorities for additional field inquiry. They do not imply that a single collaboration protocol would be sufficient for all project procurement forms. The sequencing and authority of reviews depend on the contractual context, which was not experimentally varied in this study.

The process findings also strengthen the rationale for separating issue management from general communication. Communication may be frequent while unresolved issues circulate among disciplines without an owner, response due date, authorised decision or verified closure. Conversely, a formal issue register without a practical escalation path can produce comprehensive documentation but little operational progress. The survey establishes that practitioners perceived missing formal issue closure as highly obstructive. A later implementation study could determine whether introducing ownership, status and verification controls changes measured response time or rework, but the present analysis does not measure those outcomes.

5.3 Governance and Relational Barriers Remain Interdependent

Governance and collaboration were also prominent. Unclear model-use rights, approval authority and responsibility for updates had high mean severity, while all five relational items passed the reporting threshold. These findings underline an important difference between knowing where information is stored and knowing who may act upon it. A model coordinator can maintain access, but technical approval may belong to a qualified designer, a client representative or an authorised project decision-maker depending on the contract and applicable requirements. The risk of mistaking tool administration for professional decision authority persists even in digitally mature project teams.

Gao et al. (2022) showed that contractual specificity and fairness perceptions interact with BIM-associated collaboration in the Chinese construction market. The Xi’an survey addresses a different question: it evaluates the perceived severity of particular governance and relational shortcomings. The studies are compatible in the general sense that collaboration involves formal and informal arrangements, but their numerical results are not directly comparable. The present sample does not include a causal model linking trust to version consistency or authority to project performance. Interpretation must therefore remain at the level of plausible organisational mechanisms suggested by the pattern of rated items.

The governance findings also resist a simplistic explanation in which appointing a BIM manager would solve every interface problem. Participants rated uncertainty over ownership, approval and precedence separately from role clarity, implying that multiple rules may need to coexist. A clear role name is insufficient if nobody knows whether the role is authorised to change technical information; a contractual authority clause may be insufficient if update responsibility and information delivery routes remain operationally unclear. Similarly, trust and willingness to share information may strengthen cooperation but cannot replace formal review or release requirements where construction safety and professional liability are involved.

Chen et al. (2022), studying effective collaborative behaviours in BIM-enabled construction projects, emphasised the importance of integrated coordination and collaborative conduct. Liu et al. (2022) specifically examined contractual and relational governance in relation to BIM collaboration and implementation. Their research reinforces the conceptual basis for including both responsibility/governance and collaboration/relational questions in the questionnaire. Yet the present findings do not demonstrate which of these two domains is causally prior. For instance, a respondent may report weak trust because update responsibilities are vague, or report unclear responsibilities because cross-organisational willingness to communicate is low. A cross-sectional severity instrument cannot establish the direction of these relationships. Any subsequent causal hypothesis would require a separate theoretical specification and an appropriate research design rather than relying on the descriptive rank alone.

5.4 Why Technology and Competency Scored Lower

The relative position of technological and human/competency domains is an important counterpoint to common technology-

first accounts of BIM barriers. Every technological item mean was below 3.50, with the domain mean 2.9153. Human and competency factors ranked seventh, at 3.0687. International adoption studies, including Mishra et al. (2024), have highlighted skills, costs and implementation challenges, but barrier prominence is sensitive to adoption stage, organisational context, question wording and sample composition. The surveyed Xi'an practitioners were selected for prior BIM-project experience, so it is plausible that basic software and training difficulties were less salient to them than problems encountered during routine cross-organisational information use. This explanation is a reasoned interpretation, not a tested causal finding.

Several alternative explanations remain possible. The items might reflect differences in respondent familiarity with technology, variations between organisation types, or the perception that technical problems can be handled more routinely than unclear approvals. The threshold itself influences the number of items labelled critical. Moreover, the sample contained many BIM coordinators, contractors and managerial respondents, potentially foregrounding operational control issues. Because the present paper does not report subgroup tests or a sensitivity analysis based on alternative thresholds, it cannot confidently distinguish among these explanations. A careful discussion acknowledges them rather than presenting low technological means as proof that interoperability or skills are unimportant.

The findings nonetheless suggest a useful priority for project diagnostics: assess information-control and workflow arrangements before assuming that a new software purchase will remove interface barriers. This recommendation does not require rejecting advanced technologies or uniform training. It recognises that software availability and information authority are different dimensions of coordination. Further studies could test whether the priority pattern changes between projects with different procurement routes, levels of BIM use, institutional arrangements or stage responsibilities.

5.5 Contribution, Practical Implications and Limitations

The study contributes a local, transparent ranking of predefined BIM design–construction barriers rather than a general catalogue assembled from international studies. Its strengths include a defined reference-project instruction, a fixed 42-item instrument, explicit screening decisions, item-specific denominators, reliability statistics and consistent priority criteria. Presenting all eight candidate domains alongside the 22 higher-rated items limits selective reporting and makes the relative position of non-critical statements visible. This evidence can support more focused consultation with practitioners, review of BIM information-management protocols and the design of subsequent management research, but it does not constitute evaluation of a finished model.

For project managers, a reasonable first diagnostic is to ask whether the delivery chain can identify the authoritative information state for each use, whether coordination issues retain an owner and closure record, and whether construction detailing requirements are introduced early enough. Clients and design organisations may also review how approval authority, model use rights, change responsibilities and document precedence are communicated to downstream teams. These are implications derived from perceived severity and existing scholarship, not measured remedies whose performance has been validated in the sample. An organisation should therefore adapt any response to its own procurement documents, project type, professional responsibilities and current BIM information arrangements.

Several limitations constrain interpretation. The available material documents returned and retained questionnaires but not a complete population sampling frame, so statistical representativeness and an invitation-based response rate cannot be established. The cross-sectional data measure perceived severity rather than direct cost, quality, rework or schedule outcomes. The eight domains were defined a priori; the reliability coefficients support internal consistency but do not establish independent latent factors. The threshold of 3.50 is a declared analytical convention and should not be treated as an externally validated boundary. Differences in item-specific valid N, reliance on self-reported reference projects and possible occupational variation may also affect results. No independent replication of the SPSS calculations from original respondent-level files is claimed here beyond the supplied statistical tables.

The study deliberately stops at RO1 barrier diagnosis. It does not derive or validate a final set of collaborative management requirements, demonstrate that BIM-based measures resolve the identified obstacles, or report expert consensus. Later research could examine the robustness of the rankings under alternative cut-offs, compare professional or procurement groups where sample sizes permit, and use richer process evidence to understand why high-priority barriers arise. A separate

requirements-mapping exercise could then design control responses, followed by expert appraisal and field testing. Keeping these stages distinct is essential for preserving the boundary between an empirical diagnosis, a proposed solution and verified management outcomes.

The reproducibility of priority selection can be improved further by retaining the full item-level dataset, codebook, missing-value definitions and the SPSS syntax used to generate the original tables. The present manuscript reports the exact screening counts and uses the supplied descriptive output, but readers cannot reconstruct every individual response from the summary tables alone. Accordingly, the author should preserve the source SAV dataset and original SPSS output as controlled research records and make a de-identified dataset or complete summary available only where ethics, participant consent and institutional rules permit. The publication should not claim public data access unless a genuine repository or authorised request route exists. These controls are particularly important when a later paper uses the same participant dataset to derive requirements or assess the proposed management framework.

6. Conclusions

This study identified the barriers most severely perceived to obstruct BIM-driven design–construction integration among 262 retained respondents with relevant building-project experience in Xi'an. From a 42-item literature-informed questionnaire, 22 items met the predetermined study-specific mean severity threshold of 3.50. The most severe barriers concerned inconsistent BIM information-management rules, inconsistent model and information versions, and the lack of standard procedures for coordination-issue closure. High ratings also covered model–document synchronisation, suitability of design information for construction, delivery acceptance, cross-stage coordination and decision responsibility. These findings draw attention to how BIM information is governed and used after its technical production.

All 22 critical items belonged to four of the eight pre-established candidate domains: information management, process, responsibility and governance, and collaboration and relational conditions. Information management ranked highest by domain mean, while technology ranked lowest. The comparative pattern suggests that the principal reported difficulty in this sample was not simply the absence of BIM tools, but the incomplete management alignment of information states, workflows, responsibilities and cross-organisational interaction. This is a descriptive and contextual conclusion, not proof of a causal hierarchy or absence of technical constraints in Xi'an as a whole.

The article provides an evidence-based starting point for future investigation of design–construction coordination in Xi'an building projects. Subsequent work should retain the distinction between critical-barrier identification, requirements development, model construction, expert appraisal and project-level performance evaluation. In particular, the practical effectiveness of interventions inspired by the present rankings remains to be tested. The main contribution of this paper is therefore a bounded and reproducible diagnosis of perceived priorities that can inform—but does not predetermine—later BIM collaborative-management research.

The study's implications are best expressed as priorities for investigation and management attention, not as a prescriptive universal checklist. The high severity of information-management statements supports careful examination of naming rules, controlled status, model–document linkage and delivery acceptance; the high ratings for process statements support further study of issue closure, formal review participation and downstream detailing interfaces. The governance and relational findings point to the need to understand who makes decisions, how conflicting records are resolved and how participants cooperate across organisational boundaries. None of these implications requires claiming that BIM cannot help unless a specific vendor platform is adopted. Future studies should distinguish project-configurable practices from legally required approvals and should quantify any claimed improvement only after implementation evidence is collected.

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Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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