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**SUPPLEMENTARY MATERIAL** **OPEN ACCESS**

# Leadership-Driven Pathways to BIM Maturity: Integrating Transformational Dimensions in Latin American AEC Digital Transformation-A Scoping Review

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## PRISMA 2009 Checklist

| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a systematic review, meta-analysis, or both. | Page 1 |
| **ABSTRACT** | | | |
| Structured summary | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | Page 1 |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. | Pages 1-2 |
| Objectives | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | Page 2 |
| **METHODS** | | | |
| Protocol and registration | 5 | Indicate if a review protocol exists, if and where it can be accessed (*e.g.*, Web address), and, if available, provide registration information including registration number. | Page 5 |
| Eligibility criteria | 6 | Specify study characteristics (*e.g.*, PICOS, length of follow-up) and report characteristics (*e.g.*, years considered, language, publication status) used as criteria for eligibility, giving rationale. | Page 4-6 |
| Information sources | 7 | Describe all information sources (*e.g.*, databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | Pages 3 |
| Search | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | Pages 4-6 |
| Study selection | 9 | State the process for selecting studies (*i.e.*, screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | Page 4-6 |
| Data collection process | 10 | Describe method of data extraction from reports (*e.g.*, piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | Pages 4-6 |
| Data items | 11 | List and define all variables for which data were sought (*e.g.*, PICOS, funding sources) and any assumptions and simplifications made. | Page 4-6 |

| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | Not addressed |
| Summary measures | 13 | State the principal summary measures (*e.g.*, risk ratio, difference in means). | Pages 4-9 |
| Synthesis of results | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (*e.g.*, $I^2$) for each meta-analysis. | Page 5 |
| Risk of bias across studies | 15 | Specify any assessment of risk of bias that may affect the cumulative evidence (*e.g.*, publication bias, selective reporting within studies). | Page 8 |
| Additional analyses | 16 | Describe methods of additional analyses (*e.g.*, sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. | Pages 4-8 |
| **RESULTS** | | | |
| Study selection | 17 | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. | Page 5 |
| Study characteristics | 18 | For each study, present characteristics for which data were extracted (*e.g.*, study size, PICOS, follow-up period) and provide the citations. | Page 5 |
| Risk of bias within studies | 19 | Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12). | Not addressed |
| Results of individual studies | 20 | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. | Pages 7-14 |
| Synthesis of results | 21 | Present results of each meta-analysis done, including confidence intervals and measures of consistency. | Pages 7-14 |
| Risk of bias across studies | 22 | Present results of any assessment of risk of bias across studies (see Item 15). | Page 12 |
| Additional analysis | 23 | Give results of additional analyses, if done (*e.g.*, sensitivity or subgroup analyses, meta-regression [see Item 16]). | Pages 7-14 |
| **DISCUSSION** | | | |
| Summary of evidence | 24 | Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (*e.g.*, healthcare providers, users, and policy makers). | Pages 14-15 |
| Limitations | 25 | Discuss limitations at study and outcome level (*e.g.*, risk of bias), and at review-level (*e.g.*, incomplete retrieval of identified research, reporting bias). | Page 15 |
| Conclusions | 26 | Provide a general interpretation of the results in the context of other evidence, and implications for future research. | Page 15 |
| **FUNDING** | | | |
| Funding | 27 | Describe sources of funding for the systematic review and other support (*e.g.*, supply of data); role of funders for the systematic review. | Page 15 |

*From:* Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097
For more information, visit: **www.prisma-statement.org**.

## Supplementary Material A. Qualitative synthesis corpus (N = 14): studies contributing to the conceptual framework.

| # | Author(s) | Year | Context | Method | Sample | Leadership Construct | BIM Maturity Stage | Specific Contribution to Framework |
|---|---|---|---|---|---|---|---|---|
| S1 | Li, T., Helian, Z. & Jin, X. | 2024 | China | SEM | N = 124 construction organizations | Transformational leadership-organizational unlearning- BIM implementation level | Stage 1 | Core empirical validation. Demonstrates that TL contributes to BIM implementation primarily through organizational unlearning ($\beta = 0.31$, $p < .01$). Leaders who stimulate questioning of established routines (intellectual stimulation) enable the abandonment of legacy practices necessary for Stage 1 transition. Confirms that TL's effect is mediated, not direct, and leadership operates through organizational mechanisms. |
| S2 | Vu, T.K.D. & Hsieh, S.-H. | 2025 | Taiwan / Vietnam | CB-SEM | N = 224 BIM projects | Contingent reward leadership-BIM coordination -project performance; BIM maturity as moderator | Stage 2 | Stage 2 boundary condition. Contingent reward (transactional) leadership enhances BIM project performance through coordination effectiveness. Critically, BIM maturity in information management moderates this relationship; higher maturity strengthens coordination effects. Informs the boundary condition that transactional mechanisms may complement TL at Stage 2. |

| # | Author(s) | Year | Context | Method | Sample | Leadership Construct | BIM Maturity Stage | Specific Contribution to Framework |
|---|---|---|---|---|---|---|---|---|
| S3 | Vu, T.K.D. & Hsieh, S.-H. | 2025 | Taiwan / Vietnam | CB-SEM | N = 224 BIM projects | Inspirational motivation- BIM coordination-project performance; appointing party BIM commitment as moderator | Stage 1–2 | Dimension-specific empirical validation. Empirically validates that the *inspirational motivation* dimension of TL specifically enables BIM project coordination and performance. The appointing party's BIM commitment moderates effectiveness when top-level vision is absent; inspirational motivation at the project manager level cannot compensate. Directly supports the idealized influence prescription at Stage 1. |
| S4 | Han, H., Ma, C., Yang, D. & Zhao, W. | 2025 | China | SEM | N = 261 project team members | TL- team reflexivity-project team resilience-project success | Stage 1–3 | Mediating mechanisms. TL positively influences project success through two mediating pathways: team reflexivity (the capacity for collective self-assessment) and team resilience (the capacity to recover from setbacks). These mechanisms map to different maturity stages: reflexivity supports Stage 2 protocol experimentation, while resilience sustains Stage 3 innovation under ecosystem complexity. |
| S5 | Olugboyega, O. | 2022 | Nigeria / Global | Mixed methods (Grounded Theory + AI modeling) | Qualitative interviews + survey data | BIM leadership capacity: orientation, procedures, responsibilities, environment, maturity | Stage 1–3 | BIM-specific leadership theory. Develops the first dedicated BIM Leadership Theory identifying five leadership capacities: developing BIM-friendly orientation, building BIM-focused procedures, performing BIM responsibilities, generating BIM-enabled environment, and reaching maturity. AI modeling validates that coordinating functions, individuals, and transition alignment is the primary leadership requirement. Provides the most direct evidence for stage-dependent leadership configurations. |
| S6 | Omer, M.M. *et al*. | 2022 | Multi-country (AEC) | Systematic review + empirical survey | 12 BIM-based construction projects | Constructive leadership (vision, support, stimulation) *vs*. destructive leadership (authoritarian, passive) in BIM contexts | Stage 1–2 | Behavioral repertoire mapping. Identifies specific constructive behaviors (vision articulation, individual support, intellectual challenge) that enable BIM adoption and destructive behaviors (authoritarian control, passive avoidance) that inhibit maturity progression. Provides the behavioral vocabulary for operationalizing TL dimensions in BIM settings. |
| S7 | Siebelink, S. *et al*. | 2021 | Netherlands | Mixed methods (survey + case studies) | Multi-level organizational data across maturity tiers | BIM barriers differentiated by organizational level and maturity | Stage 1–3 | Stage-contingent barrier differentiation. Core empirical evidence that barriers differ significantly across maturity levels: individual resistance dominates Stage 1, process coordination at Stage 2, and inter-organizational complexity at Stage 3. Directly supports the central argument that leadership emphasis must shift across stages because the *challenges* themselves are qualitatively different. |
| S8 | Shojaei, R., Oti-Sarpong, K. & Burgess, G. | 2023 | UK | Qualitative exploratory (interviews) | 4 large UK contractors | BIM adoption enablers: committed leadership as #1 factor | Stage 1–2 | Leadership operationalization. "Committed leadership and management" was identified as the first and most critical enabler among six key factors. Operationalized as: strategic vision communication, dedicated resource allocation, personal advocacy, and building trust-based supplier relationships. Maps directly to idealized influence (Stage 1) and inspirational motivation (Stage 2). |

| # | Author(s) | Year | Context | Method | Sample | Leadership Construct | BIM Maturity Stage | Specific Contribution to Framework |
|---|---|---|---|---|---|---|---|---|
| S9 | Alankarage, S. *et al.* | 2024 | Australia | Qualitative case studies (Schein's model) | 3 BIM-enabled contractor organizations | Organizational BIM culture at artifact, espoused values, and basic assumptions levels | Stage 2–3 | Cultural depth analysis. Uses Schein's three-layered model to demonstrate that BIM culture operates at artifact (tools, processes), espoused values (collaboration norms), and basic assumptions (beliefs about technology and change) levels. Leadership shapes all three layers, but the deepest layer (assumptions) is most resistant to change and most critical for Stage 2-3 transition. Informs how individualized consideration must address deep cultural beliefs. |
| S10 | Gao, Y. *et al.* | 2024 | China | fsQCA + Survey | N = 312 construction professionals | Configuration pathways to active BIM use: leadership support × training × incentives × culture | Stage 2–3 | Configurational perspective. Demonstrates that leadership support alone is insufficient, active BIM use requires configurations combining leadership with training, incentive structures, and organizational culture. Identifies multiple equifinal pathways, suggesting that leadership's role is necessary but must be contextualized within broader organizational systems. Critical for calibrating framework claims. |
| S11 | Olugboyega, O. *et al.* | 2021 | South Africa | Mixed methods (SEM + interviews) | N = 187 questionnaires; 15 interviews | Top management leadership commitment as strongest BIM success predictor | Stage 1–2 | Developing country empirical evidence. Leadership commitment is identified as the strongest predictor of BIM project success in a developing country context. Operationalized as visible resource allocation, personal advocacy, and strategic communication of BIM value. High power-distance organizational culture amplifies the impact of leader visibility, directly informing the Latin American regional moderation of idealized influence. |
| S12 | Diaz Schery, C. *et al.* | 2024 | Brazil / Global | Bibliometric + systematic review | 576 records-qualitative synthesis | Leadership as transversal critical factor for BIM-based digital transformation | Stage 1–3 | Field-level gap identification. Identifies leadership as a cross-cutting critical factor for BIM digital transformation. Demonstrates that human and organizational factors consistently outweigh purely technical considerations across all maturity stages. Provides the foundational premise for this study's theoretical integration. |
| S13 | Brito, D.M.D. *et al.* | 2021 | Brazil | Framework + survey | Brazilian public organizations | BIM adoption CSFs: leadership commitment among top 3 factors in Brazilian context | Stage 1 | Latin American empirical evidence. Leadership commitment ranked among the top 3 CSFs in Brazilian public organizations. The high power-distance cultural context amplifies the symbolic weight of leader commitment, when leaders visibly endorse BIM, subordinates who expect hierarchical signals respond with greater engagement. Directly informs the regional moderation of idealized influence at Stage 1. |
| S14 | Ozcan-Deniz, G., Ozorhon, B. & Kaya, O.C. | 2025 | Turkey / Developing countries | Systematic review + public client perspective | Multi-country developing context | BIM adoption factors from public clients: leadership and institutional enablers in developing contexts | Stage 1 | Institutional leadership in developing economies. Examines BIM enablers from public client perspective in developing countries. Top management leadership, government policy support, and institutional incentives identified as primary enablers. Validates that in contexts with weak market-driven BIM demand, institutional and hierarchical leadership becomes the decisive adoption trigger, relevant to Latin American government-mandated BIM contexts. |

**Supplementary Material B. Summary of the systematic selection process following PRISMA guidelines.**

| Stage | Action | Exclusion Criteria | Records Excluded | Records Remaining |
|---|---|---|---|---|
| **Identification** | Database search in Scopus | - | - | 576 |
| | Application of temporal, typological, and language filters | Not within the period 2013–2025 | 69 | |
| | | Not an Article or Book | 45 | |
| | | Not in English or Portuguese | 9 | |
| | **Subtotal excluded** | | **123** | **453** |
| **Screening** | Title and abstract verification | Not related to leadership | - | |
| | | Insufficient detail | - | |
| | | Speculative content | - | |
| | **Subtotal excluded** | | **381** | **72** |
| **Eligibility** | Full-text assessment for bibliometric analysis | Documents outside the central themes | **58** | **14** |
| **Included** | Studies included in the final review | - | - | **14** |

**Source:** Elaborated by the authors based on PRISMA guidelines (Page *et al.*, 2021).