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# BIM in Public Investment Projects: Adoption, Impact, Policies and Future Directions

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# BIM in Public Investment Projects: Adoption, Impact, Policies and Future Directions

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**Abstract**

The digital transformation of the public construction sector is a strategic imperative for governments seeking to optimize resources and make processes transparent. Building Information Modeling (BIM) emerges as a central methodology in this transition, integrating multidisciplinary data to manage projects throughout their life cycle. Globally, the BIM market reached USD 8.85 billion in 2024, projecting growth of 11.2% annually until 2034. In Latin America, eight countries make up the BIM Network of Latin American Governments, evidencing a regional commitment to accelerate the digitalization of the public sector. Methodology, this study adopts a systematic review approach, analyzing literature indexed in high-impact scientific databases (Scopus Q1-Q2), complemented by technical reports from multilateral organizations such as the IDB and recent sectoral reports (2021-2025). Implementation experiences in Spain, Chile, Brazil and Peru were examined, identifying adoption patterns, persistent barriers and critical success factors through multilevel comparative analysis. Results and Discussion, empirical evidence demonstrates significant quantifiable impacts: reduction of deadlines between 15-25%, reduction of costs of 10-30%, and elimination of design errors by up to 70% through early detection of interferences. Spain recorded a 230% increase in BIM tenders between 2017-2020 after implementing mandatory mandates, while Chile consolidated its regional leadership through the BIM Plan integrated with academia and industry. However, substantial barriers persist in emerging economies: high initial investment, shortage of skilled professionals (affecting 50-65% of organizations), and outdated contractual frameworks that hinder collaboration. 4D/5D BIM applications demonstrate transformative potential, reducing unbudgeted costs by up to 40% and integrating time scheduling with real-time cost estimation. Digital twins represent the technological frontier, with the potential to improve public sector efficiency by 20-30%. Conclusions, the successful adoption of BIM in public investment requires holistic strategies that combine regulatory mandates, economic incentives, professional capacity building, and collaborative contractual frameworks. Context-specific policies, university curriculum integration, and standardization through ISO 19650 are key pillars for overcoming regional disparities and maximizing the return on investment in public infrastructure.

**Keywords:** BIM; public investment projects; policies

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## 1. Introduction

Building Information Modeling (BIM) is increasingly mandatory in public investment projects worldwide, with significant advances in Spanish-speaking countries such as Spain, Chile and Brazil. While these requirements drive improvements in project efficiency, cost management, and quality of outputs, the adoption process is hampered by challenges such as high upfront investments, lack of training, technology interoperability issues, and outdated contractual frameworks. Advanced BIM applications, particularly 4D/5D implementations, as well as enhanced digital integrations such as digital twins and IoT, are emerging to address these challenges. However, there are conflicting views on the severity of financial and organizational readiness issues, creating a dynamic landscape that requires context-specific policy instruments and holistic implementation strategies.

Overview of BIM in public investment

Building Information Modeling (BIM) is a digital methodology that integrates multidisciplinary data to create, manage, and visualize building and infrastructure projects throughout their life cycle. In public investment projects, BIM is increasingly recognized as a strategic tool to improve the efficiency, transparency, and modernization of public works. Governments around the world, particularly Spanish-speaking ones, are demanding BIM to drive industry transformation, improve project outcomes, and align with global digitalization trends. Despite its potential, the adoption of BIM in the public sector faces persistent challenges, such as organizational readiness, technical interoperability, and regulatory adaptation, which condition the pace and effectiveness of its implementation. [1] [15] [17].

**Table 1.** Quantified Impact of BIM on Public Project Performance Indicators.

| **Performance Indicator** | **Improvement with BIM (%)** | **Source/Year** |
|---|---|---|
| Reduction of execution times | 15-25% | Das et al. (2025); Gharaibeh (2024) |
| Reduced project costs | 10-30% | Hosny (2023); Autodesk India (2024) |
| Reduction of design errors | 21-70% | Hosny (2023); IJCRT (2025) |
| Reduction of RFIs (requests for information) | 25-40% | Das et al. (2025); Sompolgrunk (2023) |
| Decrease in rework | 21-25% | Hosny (2023); Ismail (2025) |
| Improved labor productivity | 75-240% | Chowdhury (2024) |
| Reduction of material waste | 11-25% | Autodesk India (2024); Hosny (2023) |
| Positive ROI reported by users | 66-87% | McGraw Hill; Sompolgrunk (2023) |

Global and regional adoption of BIM in public sector projects

Global trends and government mandates

- Mandates and roadmaps: Many governments have established BIM mandates for public projects, with the aim of standardizing processes, improving project execution, and driving digital transformation. These mandates are often accompanied by national roadmaps focusing on digital management, skills development, policies and ecosystems. [1] [3] [15] [21].
- Regional disparities: While adoption is high in countries with strong political support (e.g., UK, Singapore, Spain), developing countries lag behind due to financial, technical, and organizational barriers. [3] [4].

BIM for Peru:

- Improved project performance: BIM improves cost control, quality, and collaboration between stakeholders during the design and construction phases. [89].
- Sustainability and efficiency: BIM supports sustainable practices by integrating multidisciplinary data throughout a project's lifecycle, enabling informed decision-making and efficient management. [90] [91].

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- Collaboration: BIM encourages cooperation between all project participants, including owners, architects, engineers, and contractors. [91] [92].

Challenges in implementation:

- Initial investment: Significant upfront hardware and software costs are a barrier to BIM adoption [89] [93].
- Training and education: Lack of qualified professionals and insufficient investment in training hinder the effective implementation of BIM [93].
- Organizational readiness: Public agencies often face challenges related to organizational and managerial readiness for BIM adoption [94].
- Resistance to change: Reluctance to abandon traditional methods and processes is common in developing countries. [93].

Adoption of BIM in Spain: Frameworks and instruments

- Mandatory requirements: Since 2018 (building) and 2019 (infrastructure), BIM is mandatory in Spanish public tenders. This has led to a 230% increase in BIM-related tenders (2017-2020). [2] [5] [25].
- Implementation Frameworks: Spain employs a framework approach in public procurement, which helps authorities select BIM implementation instruments based on client maturity and project value. Training (especially in Revit) and university integration are key factors. [25] [26] [27].
- Persistent barriers: High upfront investment, lack of training, and insufficient collaboration processes remain significant hurdles, with many organizations planning multi-year adaptation schedules. [2].

Comparative analysis: Brazil and Chile

- Brazil: Federal decrees since 2018 have boosted the adoption of BIM, focusing on professional training and gradual implementation. However, the level of maturity remains low, with most organizations having basic BIM levels and less than 5% adherence in some regions. The main challenges include fragmented information, lack of standardization, and cultural resistance. [28] [29] [30].
- Chile: Since 2015, government mandates and the Plan BIM initiative have integrated the academic, public, and private sectors, leading to greater maturity in public infrastructure (in particular, bridges and railways) and the adoption of advanced methodologies such as BIM and digital twins. [4] [31].
- Lessons learned: Government mandates, multi-stakeholder collaboration, and long-term strategic planning are critical to driving BIM maturity. Brazil can take advantage of Chile's experience to improve its own strategies. [4] [31].

**Table 2.** Status of BIM Adoption in Spanish-Speaking Countries (2024).

| **Country** | **Year of BIM Mandate** | **Adoption Status** | **Main achievements** |
|---|---|---|---|
| Spain | 2018 (building) / 2019 (infrastructure) | Advanced | 230% increase in BIM tenders (2017-2020) |
| Chile | 2015 (initiative) / 2020 (mandatory) | Advanced | Regional leader; Integrated Academia-Industry BIM Plan |
| Brazil | 2018 (decree) / 2021 (mandatory) | In development | Decree 9983/EB-BIM; 3-phase implementation |
| Peru | 2019 (BIM Plan) / 2024 (Law 32069) | In development | General Contracting Law promotes BIM |

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| Country | Year of BIM Mandate | Adoption Status | Main achievements |
|---|---|---|---|
| Colombia | 2020 (National Strategy) | In development | Active member of the BIM Network Latin American Governments |
| Argentina | 2019 (initiative) | Incipient | Founding member of the BIM Gob Latam Network |
| Mexico | 2019 (strategy) | Incipient | Regional initiatives under development |

The role of BIM integration at the university level

- Education as a catalyst: Integrating BIM at university level prepares a skilled workforce and directly supports adoption in the public sector by equipping graduates with practical BIM skills and collaborative competencies. [32] [33] [34].
- Macro-micro linkages: Effective adoption at the macro (public sector) level is influenced by organizational dynamics at the micro level, which is strengthened by university education and professional development. [32] [35].
- Regional impact: In Latin America, greater BIM maturity (supported by education) correlates with greater value generation in public projects, highlighting the importance of academic integration. [33] [36].

Global and regional experiences underscore the importance of policy mandates, tailored frameworks and educational integration to drive BIM adoption. However, persistent barriers, especially in developing economies, require context-sensitive strategies and sustained capacity building.

**Table 3.** Main Barriers and Critical Success Factors for BIM Implementation.

| Category | Main Barriers | Critical Success Factors |
|---|---|---|
| Organizational | Lack of training (45-60%); Resistance to change | Committed leadership; Culture of innovation |
| Technological | Software interoperability (35-50%); Information silos | ISO 19650 standards; IFC Open Formats |
| Financial | High initial investment (40-55%); Training costs | Government incentives; Demonstrable ROI |
| Contractual | Obsolete frames; Ambiguity in BIM roles | IPD Contracts; specific BIM clauses |
| Regulatory | Unclear mandates; Lack of compliance | National roadmaps; Integrated policies |
| Human Capital | Shortage of BIM professionals (50-65%) | University curricular integration; Certifications |

## 2. Methodology

Efficiency, cost, and quality results

- Quantified impacts: Implementing BIM in public projects reduces lead times by ~20%, costs by ~15%, and design errors by ~30%. Requests for information (RFIs) decrease by ~25%, reflecting an improvement in efficiency and quality. [17].
- Collaboration and risk management: BIM improves stakeholder collaboration, design visualization, and risk assessment, leading to more informed decisions and optimized project performance. [17] [37].
- Profitability and Lean Construction: BIM supports Lean principles, eliminating waste, improving productivity and project quality. Empirical evidence attributes approximately 52% of the overall project success to BIM implementation. [19] [20].
- Challenges: High upfront costs, resistance to change, and skills gaps persist, particularly in medium- and low-rise projects and in developing contexts. [37] [38] [39].

Advanced BIM applications: 4D and 5D

- 4D BIM (Scheduling): Improves planning, visualization, and tracking of construction progress, reducing delays and improving coordination. [11] [40].
- 5D BIM (Cost Management): Integrates cost data with 3D/4D models, enabling real-time budget tracking and reducing unbudgeted costs by up to 40% in some cases. [11] [12] [41].
- Combined benefits: 4D/5D BIM facilitates resource allocation, dynamic project control, and proactive risk mitigation, resulting in better schedule and cost performance. [42] [43] [44].
- AI and digital twins: Integration with AI and digital twins further improves accuracy in cost and time predictions and lifecycle management. [13] [14].

BIM Execution Plans and Collaboration

- Role of BEPs: BIM execution plans (BEPs) define roles, workflows, and protocols for data exchange, improving collaboration and information management. [45] [46].
- Risk Management: BEPs support risk mitigation by enabling effective control of progress and costs, and improving safety management. [47] [48].
- Challenges: The inconsistent content of the BEP and limited stakeholder participation, especially in developing countries, hinder the full realization of benefits. [49] [50].

Comparative international experiences

- Developed vs. developing contexts: Developed countries benefit from clear policies, norms, and contractual frameworks, while developing countries face IT literacy gaps, lack of national programs, and socioeconomic constraints. [51] [52] [53].
- Cost-benefit evidence: Czech public sector projects report a cost-benefit ratio >4.5 due to BIM, with reductions in renovations and improved facilities management. [54].
- Legal and contractual risks: The coordination, documentation, and challenges of public agencies require greater legal awareness and management. [55].

BIM demonstrably improves efficiency, cost, and quality in public investment projects, especially when using advanced applications and collaborative frameworks. However, uneven implementation and persistent barriers highlight the need to disseminate best practices and offer tailored support.

## 3. Results

Policy Frameworks, Standards and Guidelines for BIM in Public Projects

Global policy instruments and mandates

- Policy combinations: Governments use regulatory, economic, cooperative and communicative instruments to promote BIM, as seen in Hong Kong and other leading regions. [15].
- Mandates and incentives: Mandates drive adoption, but they can create tiered industry responses; combining mandates with incentives and capacity building is more effective. [56].
- Critical success factors: Frameworks such as Brazil's Decree 10.306/2020 prioritize contractual, regulatory, technological, and procedural aspects. [57] [58] [59].

Guidelines for the operation and maintenance phases

- Current shortcomings: Most guidelines focus on design and construction, with less emphasis on operation and maintenance (O&M). The lack of systematic approaches and BIM-FM integration make it difficult to manage assets throughout their lifecycle. [52] [60] [61].

- Best practices: Owner information requirements, iterative formalization of BIM requirements, and digital-physical integration are recommended for effective operation and maintenance. [62].
- Organizational capabilities: A trained workforce, a supportive culture, and political commitment are essential to the success of the operations and maintenance phase. [63].

Policy Instruments in Low-Income Economies

- Successful strategies: Programs to improve BIM competencies, integration in education, contractual frameworks, and financial aid are effective in overcoming readiness barriers. [59] [64].
- Soft vs. hard strategies: Soft strategies (training, awareness) influence organizational factors, while hard strategies (regulation) mainly impact technology. [64].
- Comprehensive approaches: Policy combinations that combine mandates, incentives, and collaborative environments are the most effective [65].

Combined mandates and incentives in Spanish-speaking countries

- Spain's experience: Legal frameworks, European directives and national laws promote BIM in public procurement, overcoming market maturity barriers [5] [66].
- Economic incentives: Tax breaks and simplified permits incentivize adoption, especially where government support is low. [16].
- SME challenges: Financial constraints and lack of regulatory compliance require tailored support for SMEs. [67] [68].

The effective adoption of BIM in public projects depends on a combination of mandates, incentives, and specific guidelines. Addressing gaps in operations and maintenance, supporting organizational readiness, and designing context-appropriate policies are critical to sustained progress.

## 4. Discussion

Main barriers to BIM adoption

- Organizational and managerial readiness: lack of training, experience, and clear roles; resistance to change; and insufficient standards/guidelines [8] [58] [69] [70] [71].
- Technological barriers: software incompatibility, interoperability issues, and information silos [6] [72] [73] [74].
- Financial and contractual barriers: high costs, outdated contracts, and legal ambiguities, especially in developing countries [8] [9] [75] [76].
- Regulatory ambiguity: Unclear mandates and lack of compliance hinder adoption [9] [77] [78] [79].

Technology interoperability problems and solutions

- Key issues: standards/protocol incompatibility (e.g. BACnet, Modbus), lack of interoperability between BIM, GIS, BAS and other systems, and fragmented data management. [6] [7] [72].
- Effective solutions: Systematic data integration architectures, open/closed source environments, middleware tools, and ontological alignment (e.g., IFC with ontology) [6] [73] [80].
- Organizational solutions: improved collaboration standards, training, and phased implementation strategies [72] [81].

Financial and contractual barriers in developing countries

- Financial constraints: Limited investment in tools, training, and ongoing costs; High upfront and recurring expenses. [8] [76] [82] [83].
- Contractual issues: ambiguity in roles, lack of specific BIM clauses, and reluctance to adopt collaborative contracts [9] [75] [79] [84].
- Legal uncertainties: need for clear protocols, dispute resolution and intellectual property provisions [9] [77] [85] [86].

Evolving contractual frameworks for BIM

- Best practices: Integrated project delivery (IPT), risk and reward sharing, and adaptation of standard contracts with BIM-specific clauses [78] [79].

- Legal evolution: Frameworks should clarify accountability, data integrity, and intellectual property, and be flexible to local contexts. [10] [87] [88].

Future opportunities and recommendations

- Digital integration: Leverage digital twins, AI, and IoT for predictive maintenance, cost forecasting, and lifecycle management. [21] [22] [23] [24].
- Public-private-university collaboration: foster partnerships for training, research and capacity building.
- Customized frameworks: Develop context-specific guidelines and phased implementation strategies.
- SME empowerment: Providing financial incentives and contractual support to accelerate adoption in smaller organizations.

Summary: Overcoming barriers to BIM adoption requires a holistic approach that combines technical solutions, organizational changes, financial support, and legal accommodation. Future opportunities lie in digital inclusion, collaborative frameworks and targeted policy interventions.

## 5. Conclusions

Summary of Perspectives and Implications

BIM is transforming public investment projects by improving efficiency, cost management, and the quality of results. Global mandates and regional initiatives, especially in Spanish-speaking countries, are accelerating their adoption, but significant challenges remain, particularly in organizational readiness, technological interoperability, and contractual adaptation. Advanced BIM applications (4D/5D, digital twins, AI) offer promising solutions; however, its full potential depends on context-appropriate policies, strong training and collaborative frameworks.

For policymakers and practitioners, the evidence underscores the need to:

- Integrated policy approaches: combining mandates, incentives and capacity development.
- Standardized yet flexible guidelines: address all phases of the project, especially operation and maintenance.
- Investment in training and education: leveraging universities and career development.
- Contract Innovation: Update frameworks to reflect the collaborative and digital nature of BIM.
- Integrating digital ecosystems: Adopt emerging technologies for lifecycle asset management.

Future research should focus on standardizing operation and maintenance guidelines, clarifying legal frameworks, and empirically evaluating the impact of digital integration on public sector BIM projects.

The adoption of BIM in public investment projects is a dynamic and multidimensional process. While mandates and advanced technologies drive progress, persistent barriers require holistic and context-sensitive solutions. The way forward lies in integrating policy, education, technology and collaboration to fully harness the transformative potential of BIM in the public sector. [1] [15] [17] [58].

Integrating Digital Twins and Emerging Technologies

Incorporation of an analysis on the convergence between BIM and digital twins in public investment projects. According to McKinsey (2025), digital twins have the potential to improve capital efficiency and public sector operational performance by 20-30%. This integration enables the simulation of complex scenarios, predictive maintenance, and the optimization of investment decisions through digital replicas of physical assets. The global digital twin market, valued at USD 24.97 billion in 2024, is projected to reach USD 155.84 billion by 2030 with a CAGR of 34.2%, evidencing the accelerated technological convergence that will redefine public infrastructure management in the next decade.

## References

1. 1. Perspectives on BIM profession of bim specialists and non-BIM specialists: Case study in Vietnam Le, N.Q., Er, M., Sankaran, S., Ta, N.B. Lecture Notes in Civil Engineering, 2020 https://www.scopus.com/pages/publications/85073691505

2. 2. ANALYSIS OF BARRIERS AGAINST THE ADOPTION OF BIM TECHNOLOGY Villena-Manzanares, F., García-Segura, T., Pellicer, E.
3. Proceedings from the International Congress on Project Management and Engineering, 2021 https://www.scopus.com/pages/publications/85127557495
4. 3. Awareness, Adoption, and implementation of Building Information Modelling in Small and Medium Enterprises in the Moroccan AEC Industry El Asri, H., Benhlima, L. Proceedings of the European Conference on Knowledge Management, ECKM, 2022. https://www.scopus.com/pages/publications/85178515013
5. 4. An Overview of the BIM implementation on Chilean Bridges Valenzuela Saavedra, M.A., Márquez, M., Roca, L., Seguel, J.L. https://www.scopus.com/pages/publications/85182606473
6. 5. Enhancing BIM implementation in Spanish public procurement: A framework approach Pérez-García, A., Martín-Dorta, N., Aranda, J.Á. Heliyon, 2024. https://www.sciencedirect.com/science/article/pii/S2405844024066817
7. 6. BIM-based decision support for building condition assessment Alavi, H., Bortolini, R., Forcada, N. Automation in Construction, 2022 https://www.sciencedirect.com/science/article/pii/S0926580521005689
8. 7. Digitisation in facilities management: A literature review and future research directions Wong, J.K.W., Ge, J., He, S.X. Automation in Construction, 2018 https://www.sciencedirect.com/science/article/pii/S0926580517309020
9. 8. From Barriers to Breakthroughs: A Deep Dive into BIM Integration Challenges
10. Agwa, T.C., Çelik, T. Buildings, 2025 https://www.scopus.com/pages/publications/105002469158
11. 9. Building information modeling (BIM) adoption for enhanced legal and contractual management in construction projects Alotaibi, B., Waqar, A., Radu, D., (...), Almujibah, H. Ain Shams Engineering Journal, 2024 https://www.scopus.com/pages/publications/85191498940
12. 10. Legal framework for the implementation of BIM Klemt-Albert, K., Ritter, N., Hartung, R. Bautechnik, 2018 https://www.scopus.com/pages/publications/85041039115
13. 11. The workability and usefulness of building information modelling based design for building performance Idrissi Gartoumi, K., Aboussaleh, M., Zaki, S. Materials Today: Proceedings, 2022 https://www.sciencedirect.com/science/article/pii/S221478532200342X
14. 12. Blueprint for progress: Understanding the driving forces of BIM adoption in Kingdom of Saudi Arabia (KSA) construction industry Iqbal, Muzaffar, Ullah, Irfan, Abdou, Heba, (...), Yosri, Ahmed M. PLoS ONE, 2025 https://www.sciencedirect.com/science/article/pii/S1932620324133123
15. 13. Opportunities and Adoption Challenges of AI in the Construction Industry: A PRISMA Review Regona, Massimo, Yigitcanlar, Tan, Xia, Bo, Li, Rita Yi Man Journal of Open Innovation: Technology, Market, and Complexity, 2022 https://www.sciencedirect.com/science/article/pii/S219985312201054X
16. 14. Digital Construction and Management the Public's Infrastructures Orsini, G., Piras, G. Urban Book Series, 2023 https://www.scopus.com/pages/publications/85164000967
17. 15. Evolution of Building Information Modelling (BIM) Policy: The Case of Hong Kong Zhang, S., Oti-Sarpong, K., Leiringer, R. Lecture Notes in Operations Research, 2022 https://www.scopus.com/pages/publications/85212480189
18. 16. Driving digital transformation in construction: Strategic insights into building information modelling adoption in developing countries Rinchen, S., Banihashemi, S., AlKilani, S. Project Leadership and Society, 2024 https://www.sciencedirect.com/science/article/pii/S2666721524000231
19. 17. The impact of BIM on project time and cost: insights from case studies Das, K., Khursheed, S., Paul, V.K. Discover Materials, 2025 https://www.scopus.com/pages/publications/85218829025
20. 18. Understanding the effects of BIM implementation in corporation finance: An empirical study in China Wang, Z., Ma, J. Organization, Technology and Management in Construction, 2021 https://www.scopus.com/pages/publications/85120846685
21. 19. Modeling the Relation between Building Information Modeling and the Success of Construction Projects: A Structural-Equation-Modeling Approach Waqar, A., Othman, I., Radu, D., (...), Khan, M.B. Applied Sciences (Switzerland), 2023 https://www.scopus.com/pages/publications/85167887558

22. 20. Building information modeling and lean construction: Technology, methodology and advances from practice Gerber, D.J., Becerik-Gerber, B., Kunz, A. https://www.scopus.com/pages/publications/84866065427
23. 21. BIM adoption and implementation in the civil and transportation infrastructure sector: analysis of governmental roadmaps and action plans Doume Ekale, M., Pavard, A., Benabderrahmane, K.A., Andrew Poirier, E. International Journal of Construction Management, 2025 https://www.scopus.com/pages/publications/105012249346
24. 22. Building Information Modeling (BIM) partnering framework for public construction projects Porwal, A., Hewage, K.N. Automation in Construction, 2013 https://www.scopus.com/pages/publications/84872240863
25. 23. Decoding BIM Challenges in Facility Management Areas: A Stakeholders' Perspective Gordo-Gregorio, P., Alavi, H., Forcada, N. Buildings, 2025 https://www.scopus.com/pages/publications/86000536513
26. 24. Framework for Building Information Modeling Adoption Based on Critical Success Factors from Brazilian Public Organizations Brito, D.M.D., de Andrade Marques Ferreira, E.D.A.M., Costa, D.B. Journal of Construction Engineering and Management, 2021https://www.scopus.com/pages/publications/85105005790
27. 25. Enhancing BIM implementation in Spanish public procurement: A framework approach Pérez-García, A., Martín-Dorta, N., Aranda, J.Á. Heliyon, 2024 https://www.scopus.com/pages/publications/85192088280
28. 26. TRAINING AND TEACHING RESOURCES AVAILABLE FOR BIM MODELING SOFTWARE: ARCHICAD, REVIT AND ALLPLAN Renard-Julián, E.J., Olmos Noguera, J.M. Proceedings from the International Congress on Project Management and Engineering, 2022 https://www.scopus.com/pages/publications/85150361269
29. 27. Implementation of the BIM Methodology in the Architecture Degree: Experience of the Architecture School of San Sebastian Uranga, E.J., León, I., Alberdi, A., (...), Sagarna, M. International Conference on Higher Education Advances, 2021 https://www.scopus.com/pages/publications/85128357804
30. 28. BIM training in Brazil Preparing professionals for BIM adoption by public administration Nardelli, E.S. Proceedings of the International Conference on Education and Research in Computer Aided Architectural Design in Europe, 2019 https://www.scopus.com/pages/publications/85129410036
31. 29. Requirements for BIM implementation in AEC companies: a Brazilian case study de Assis Santos Wanderley, A.K., Lordsleem Júnior, A.C., Rocha, J.H.A. Construction Magazine, 2023 https://www.scopus.com/pages/publications/85172335591
32. 30. Prioritization of risks related to BIM implementation in brazilian public agencies using fuzzy logic Borges Viana, V.L., Carvalho, M.T. Journal of Building Engineering, 2021 https://www.scopus.com/pages/publications/85098949064
33. 31. Resilience in Chilean Railway Infrastructure: Application of BrIM to Historic Metal Bridges Requesens, J., Valenzuela Saavedra, M.A. https://www.scopus.com/pages/publications/105008753088
34. 32. Knowledge graph of building information modelling (BIM) for facilities management (FM) Peng, Y., Au-Yong, C.P., Myeda, N.E. Automation in Construction, 2024 https://www.sciencedirect.com/science/article/pii/S0926580524002280
35. 33. Analyzing the relationship between the level of BIM maturity and the value generated in construction projects in Colombia Giménez, Z., Hernández, H., Leyva Londoño, J.P., (...), Garcia-Lopez, N.P. Ain Shams Engineering Journal, 2025 https://www.sciencedirect.com/science/article/pii/S2090447925000929
36. 34. Building Information Modelling adoption in the European Union: An overview Charef, R., Emmitt, S., Alaka, H., Fouchal, F. Journal of Building Engineering, 2019 https://www.sciencedirect.com/science/article/pii/S2352710218312257
37. 35. Digital transformation through Building Information Modelling: Spanning the macro-micro divide Kassem, M., Ahmed, A.L. Technological Forecasting and Social Change, 2022 https://www.sciencedirect.com/science/article/pii/S0040162522005273
38. 36. A thematic review on Prevention through design (PtD) concept application in the construction industry of developing countries Samsudin, N.S., Mohammad, M.Z., Khalil, N., (...), Che Ibrahim, C.K. Safety Science, 2022 https://www.sciencedirect.com/science/article/pii/S092575352100480X

39. 37. Integrating BIM to Enhance Stakeholder Collaboration and Economic Efficiency in Architecture and Construction Projects Jin, S. E3S Web of Conferences, 2024 https://www.scopus.com/pages/publications/85203788092
40. 38. "Values, Challenges, and Critical Success Factors" of Building Information Modelling (BIM) in Malaysia: Experts Perspective Al-Ashmori, Y.Y., Othman, I., Al-Aidrous, A.-H.M.H. Sustainability (Switzerland), 2022 https://www.scopus.com/pages/publications/85126275209
41. 39. Effectiveness of using BIM in construction: comparative analysis and evaluation methodology Narezhnaya, T., Ovsiannikov, A., Bolgov, V. BIO Web of Conferences, 2024 https://www.scopus.com/pages/publications/85190610812
42. 40. Infrastructure modeling and simulation Zaheer, Qasim, Qiu, Shi, Wang, Wenjuan, (...), Zhang, Xudong Smart Infrastructure Management, 2025 https://www.sciencedirect.com/science/article/pii/B9780443340178000041
43. 41. Building information modeling Casini, Marco Construction 4.0, 2022 https://www.sciencedirect.com/science/article/pii/B9780128217979000027
44. 42. Deep learning-based computer vision in project management: Automating indoor construction progress monitoring Ekanayake, B., Wong, J.K.W., Fini, A.A.F., (...), Thengane, V. Project Leadership and Society, 2024 https://www.sciencedirect.com/science/article/pii/S2666721524000346
45. 43. Advanced site management tools and methods Casini, Marco Construction 4.0, 2022 https://www.sciencedirect.com/science/article/pii/B9780128217979000076
46. 44. Potential features of building information modeling (BIM) for application of project management knowledge areas in the construction industry Raza, M.S., Tayeh, B.A., Abu Aisheh, Y.I., Maglad, A.M. Heliyon, 2023 https://www.sciencedirect.com/science/article/pii/S2405844023069050
47. 45. Methodology for an HBIM workflow focused on the representation of construction systems of built heritage Martinelli, L., Calcerano, F., Gigliarelli, E. Journal of Cultural Heritage, 2022 https://www.sciencedirect.com/science/article/pii/S1296207422000681
48. 46. Building information modeling Casini, Marco Construction 4.0, 2022 https://www.sciencedirect.com/science/article/pii/B9780128217979000027
49. 47. How building information modelling mitigates complexity and enhances performance in large-scale projects: Evidence from China Yang, Y., Zhao, B. International Journal of Project Management, 2025 https://www.sciencedirect.com/science/article/pii/S0263786325000213
50. 48. The role of implementing BIM applications in enhancing project management knowledge areas in Egypt Shaqour, E.N. Ain Shams Engineering Journal, 2022 https://www.sciencedirect.com/science/article/pii/S2090447921002604
51. 49. Unveiling The BIM Execution Plan (BEP): A Comprehensive Review of Global Frameworks and Applications Raduan, S.M.S., Brahim, J., Nordin, R.M., (...), Fajarianto, O. Built Environment Journal, 2025 https://www.scopus.com/pages/publications/105010744303
52. 50. Analyzing the relationship between the level of BIM maturity and the value generated in construction projects in Colombia Giménez, Z., Hernández, H., Leyva Londoño, J.P., (...), Garcia-Lopez, N.P. Ain Shams Engineering Journal, 2025 https://www.sciencedirect.com/science/article/pii/S2090447925000929
53. 51. Investigating the Role of BIM in Stakeholder Management: Evidence from a Metro-Rail Project Gaur, S., Tawalare, A. Journal of Management in Engineering, 2022 https://www.scopus.com/pages/publications/85116539805
54. 52. An Investigation of Contractual Requirements for BIM Adoption in the Brazilian Public Sector Brito, D.M., de Andrade Marques Ferreira, E.A.M., Costa, D.B. Lecture Notes in Civil Engineering, 2021 https://www.scopus.com/pages/publications/85088461685
55. 53. Experiences of Building Information Modelling (BIM) adoption in various countries Mustaffa, N.E., Salleh, R.M., Tajul Ariffin, H.L.B.T. International Conference on Research and Innovation in Information Systems, ICRIIS, 2017 https://www.scopus.com/pages/publications/85029938839
56. 54. A Cost–Benefit Analysis of BIM Methodology Implementation in the Preparation and Construction Phase of Public Sector Projects , Zak, J. Buildings, 2025 https://www.scopus.com/pages/publications/105021557335

57. 55. Legal and Contractual Risks and Challenges for BIM Mohammadi, S., Aibinu, A.A., Oraee, M. Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 2024 https://www.scopus.com/pages/publications/85175469676
58. 56. A Critical Examination of BIM Policy Mandates: Implications and Responses Oti-Sarpong, K., Leiringer, R., Zhang, S. https://www.scopus.com/pages/publications/85096761925
59. 57. BIM Critical Factors-Based Framework Towards Digitalization of Construction in the Public Sector Diaz Schery, C.A.D., Caiado, R.G.G., Vignon, Y.R., (...), Corseuil, E.T. Springer Proceedings in Mathematics and Statistics, 2023 https://www.scopus.com/pages/publications/85180736308
60. 58. Toward a Sustainable and Efficient Design Process: A BIM-Based Organisational Framework for Public Agencies, An Italian Case Study Raj, K., Mastrolembo Ventura, S., Comai, S., Ciribini, A.L.C. Sustainability (Switzerland), 2025 https://www.scopus.com/pages/publications/105013293591
61. 59. Government Initiatives for Enhancing Building Information Modeling Adoption in Saudi Arabia Algahtany, M., Radzi, A.R., Al-Mohammad, M.S., Rahman, R.A. Buildings, 2023 https://www.scopus.com/pages/publications/85172772199
62. 60. Activity theory-based analysis of BIM implementation in building O&M and first response Lu, Q., Chen, L., Lee, S., Zhao, X. Automation in Construction, 2018 https://www.scopus.com/pages/publications/85032807536
63. 61. A Review of Building Information Modelling (BIM) for Facility Management (FM): Implementation in Public Organisations Pinti, L., Codinhoto, R., Bonelli, S. Applied Sciences (Switzerland), 2022 https://www.scopus.com/pages/publications/85123761630
64. 62. Developing owner information requirements for BIM-enabled project delivery and asset management Cavka, H.B., Staub-French, S., Poirier, E.A. Automation in Construction, 2017 https://www.scopus.com/pages/publications/85027396980
65. 63. Factors influencing the organisational capabilities of the public sector for implementation of building information modelling in construction projects Yusuf, A.O., Opawole, A., Musa, N.A., (...), Ebunoluwa, E.I. International Journal of Building Pathology and Adaptation, 2024 https://www.scopus.com/pages/publications/85139426296
66. 64. Optimal Government Strategies for BIM Implementation in Low-Income Economies: A Case Study in Syria Al-Mohammad, M.S., Haron, A.T., Maya, R., Rahman, R.A. Journal of Architectural Engineering, 2024 https://www.scopus.com/pages/publications/85192518447
67. 65. Impacts of Policy Mix Comprehensiveness on BIM Implementation: Moderating Effects of Environmental State and Response Uncertainty Xing, M., Cao, J., Cao, D. Journal of Construction Engineering and Management, 2023 https://www.scopus.com/pages/publications/85143667960
68. 66. Quantity surveying and BIM 5D. Its implementation and analysis based on a case study approach in Spain Baldrich Aragó, A., Roig Hernando, J., Llovera Saez, F.J., Coll Bertran, J. Journal of Building Engineering, 2021 https://www.sciencedirect.com/science/article/pii/S2352710221010925
69. 67. Integration of BIM in project management phases for achieving sustainable success in small construction projects: A SEM-based approach AlSehaimi, A., Baarimah, A.O., Madhusudhan, M.B., (...), Ahmed, W. Ain Shams Engineering Journal, 2025 https://www.sciencedirect.com/science/article/pii/S2090447925003909
70. 68. Knowledge-based decision support for BIM adoption by small and medium-sized enterprises in developing economies Saka, A.B., Chan, D.W.M., Wuni, I.Y. Automation in Construction, 2022 https://www.sciencedirect.com/science/article/pii/S0926580522002801
71. 69. Bim-based research framework for sustainable building projects: A strategy for mitigating bim implementation barriers Manzoor, B., Othman, I., Gardezi, S.S.S., (...), Abdalla, S.B. Applied Sciences (Switzerland), 2021 https://www.scopus.com/pages/publications/85108656734
72. 70. Case Study of Building Information Modeling Implementation in Infrastructure Projects Guo, X., Tian, C., Chen, Y., Zhang, J. Transportation Research Record, 2022 https://www.scopus.com/pages/publications/85125555695

73. 71. Barriers of BIM adoption in Vietnamese contractors Tran-Hoang-Minh, H., Nguyen, T.-Q., Nguyen, D.-P., Pham, Q.-T. AIP Conference Proceedings, 2021 https://www.scopus.com/pages/publications/85119080776
74. 72. Developing a BIM-enabled building lifecycle management system for owners: Architecture and case scenario Li, L., Yuan, J., Tang, M., (...), Cheng, Y. Automation in Construction, 2021 https://www.sciencedirect.com/science/article/pii/S092658052100265X
75. 73. Integration of Industry Foundation Classes and Ontology: Data, Applications, Modes, Challenges, and Opportunities Jia, J., Ma, H., Zhang, Z. Buildings, 2024, https://www.scopus.com/pages/publications/85191403938
76. 74. Integration of BIM and GIS in sustainable built environment: A review and bibliometric análisis Wang, H., Pan, Y., Luo, X. Automation in Construction, 2019 https://www.scopus.com/pages/publications/85062851084
77. 75. BIM inertia: Contracts and behaviours Hooper, M., Widén, K. https://www.scopus.com/pages/publications/85026509806
78. 76. Developing a Model to Assess and Address Challenges in Implementing BIM for Commercial Buildings: A PLS-SEM Analysis in Iran Mehrizi, H.Z., Pourrostam, T., Ramesht, M.H., Rahimi, M. Journal of Architectural Engineering, 2025 https://www.scopus.com/pages/publications/105016393423
79. 77. Latent Provisions for Building Information Modeling (BIM) Contracts: A Social Network Analysis Approach Fan, S.-L., Chong, H.-Y., Liao, P.-C., Lee, C.-Y.KSCE Journal of Civil Engineering, 2019 https://www.scopus.com/pages/publications/85062006783
80. 78. Building Information Modeling in Quebec's Procurement for Public Infrastructure: A Case for Integrated Project Delivery Jobidon, G., Lemieux, P., Beauregard, R.Laws, 2021 https://www.scopus.com/pages/publications/85120330317
81. 79. Proposing bim-related clauses in standard form of Malaysian construction contracts Zainon, N., Vicky, L. Malaysian Construction Research Journal, 2021 https://www.scopus.com/pages/publications/85107684937
82. 80. Integration of BIM and GIS for the Digitization of the Built Environment Piras, G., Muzi, F., Zylka, C. Applied Sciences (Switzerland), 2024 https://www.scopus.com/pages/publications/85211911132
83. 81. BIM-driven sustainable safety management solutions for downstream oil and gas (D-O&G) construction projects Waqar, A., Nisar, S., Qadir, S. Environmental Challenges, 2025 https://www.sciencedirect.com/science/article/pii/S2667010024002245
84. 82. A Holistic Evaluation of BIM Implementation Barriers in the Indian Construction Industry: Pre- and Post-Adoption Perspectives Mishra, A., Hasan, A., Jha, K.N. International Journal of Construction Education and Research, 2024 https://www.scopus.com/pages/publications/85186420167
85. 83. Building information modelling adoption in Uganda's construction industry Acheng, P.O., Kibwami, N., Mukasa, T.J., (...), Manga, M. International Journal of Construction Management, 2023 https://www.scopus.com/pages/publications/85128206728
86. 84. Legal and Contractual Determinants for Further Adoption of Building Information Modelling in the Construction Industry Berema, R.K.R., Ismail, Z., Brahim, J., (...), Preece, C.N. Journal of Engineering, 2025 https://www.scopus.com/pages/publications/105018342280
87. 85. Overview of the Legal Aspects and Contract Requirements of the BIM Practice in Malaysian Construction Industry Jo, T.M., Ishak, S.S.M., Rashid, Z.Z.A. MATEC Web of Conferences, 2018 https://www.scopus.com/pages/publications/85055517038
88. 86. Addressing a Building Information Modeling Ownership Issue Based on DEMATEL Analysis, Chai, C., Chong, H.-Y., Lee, C.K., (...), Fan, L.S.-L. Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 2025. https://www.scopus.com/pages/publications/105008489484
89. 87. A preliminary review on the legal implications of BIM and model ownership. Olatunji, O.A. Journal of Information Technology in Construction, 2011. https://www.scopus.com/pages/publications/79960075352
90. 88. Comparative study for BIM-based contract administration between the cases in Taiwan and China Fan, S.-L. Journal of the Chinese Institute of Engineers, Transactions of the Chinese Institute of Engineers,Series A/Chung-kuo Kung Ch'eng Hsuch K'an, 2020 https://www.scopus.com/pages/publications/85087834377

 doi:10.20944/preprints202511.1967.v1



91. 89. Wang, W.-C., Huang, S.-C., Wang, H.-P. and Cao, M.-T. (2025). Measuring user satisfaction in building information modeling using active interpretable machine learning. *Applied Soft Computing*, *183*(113663), 113663. https://doi.org/10.1016/j.asoc.2025.113663
92. 90. Wei, W., Prasetyo, YT, Belmonte, ZJA, Cahigas, MML, Nadlifatin, R., & Gumasing, MJJ (2025). Application of the Technology Acceptance Model - Theory of Planned Behavior (TAM-TPB) to study the acceptance of Building Information Modeling (BIM) in sustainable building in China. *Acta Psychologica*, *254* (104790), 104790. https://doi.org/10.1016/j.actpsy.2025.104790
93. 91. Lozano, F., Jurado, J.C., Lozano-Galant, JA, de la Fuente, A., & Turmo, J. (2023). Integration of BIM and the Value Model for Sustainability Assessment in bridge projects. Automation in Construction, 152 (104935), 104935. https://doi.org/10.1016/j.autcon.2023.104935
94. 92. Aranda, J. Á., Pérez-García, A., Martin-Dorta, N., & Contero, M. (2025). BIM-based design to improve efficiency and accuracy in cross drainage works. *Journal of Engineering Research* . https://doi.org/10.1016/j.jer.2025.06.008
95. 93. Samsudin, NS, Mohammad, MZ, Khalil, N., Nadzri, ND, and Izam Che Ibrahim, C.K. (2022). A thematic review on the application of the concept of Prevention through Design (PtD) in the construction industry in developing countries. *Safety Science*, *148* (105640), 105640. https://doi.org/10.1016/j.ssci.2021.105640
96. 94. Raj, Kavita, Towards a Sustainable and Efficient Design Process: A BIM-Based Organizational Framework for Public Bodies: An Italian Case Study2025, by https://www.scopus.com/pages/publications/105013293591