

## Research Article

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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emerging economies: high initial investment, shortage of skilled professionals (affecting 50-65% of organizations), and outdated contractual frameworks that hinder collaboration. 4D/5D BIM applications demonstrate transformative potential, reducing unbudgeted costs by up to 40% and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.

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### 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. [1-17].

**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 [1-21].
- **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].
- **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. [25-27].

- **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 [28-30].
- **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
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 [32-34].
- **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
Mexico	2019 (strategy)	Incipient

### 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 [37-39].

### 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 [42-44].
- **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 [51-53].
- **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.

### 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 [57-59].

### 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.

## 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 [6-74].
- **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 [9-79].

### 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. [6-72].
- **Effective Solutions:** Systematic data integration architectures, open/closed source environments, middleware tools, and ontological alignment (e.g., IFC with ontology) [6-80].
- **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. [8-83].
- **Contractual Issues:** ambiguity in roles, lack of specific BIM clauses, and reluctance to adopt collaborative contracts [9-84].
- **Legal Uncertainties:** need for clear protocols, dispute resolution and intellectual property provisions [9-86].

### 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. [10-88].
- Future opportunities and recommendations
- **Digital Integration:** Leverage digital twins, AI, and IoT for predictive maintenance, cost forecasting, and lifecycle management. [21-24].
- **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.

## Conclusion

### 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. [1-58].

### 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.

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