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Review Article

Benefits of Implementing the 4D and 5D BIM Methodology in Infrastructure Projects: A Literature Review (2015-2025)

Luis Mayo-Alvarez[1], Gustavo Baldera-Gutiérrez[2], Arturo Casas-López[3], Marco García-Mena[4]

[1,2,3,4]*Escuela de Posgrado, Universidad Tecnológica del Perú, Lima, Perú.*

[1]*Corresponding Author : c21050@utp.edu.pe*

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Abstract *- Building Information Modeling (BIM), particularly its 4D and 5D dimensions, plays a significant role in improving infrastructure project management by enabling simulation of schedules and budgets, thereby supporting planning, execution, and data-driven decision-making. This study aims to identify and synthesize the benefits of BIM 4D and 5D. A systematic review was conducted using the Scopus database, covering publications from 2015 to 2025 and following the PRISMA 2020 guidelines. From an initial set of 2,317 records, 53 peer-reviewed articles were selected for analysis. The results were classified into five main categories: Technical and Quality Benefits (24.54%), Innovation and Emerging Trends (22.63%), Sustainability and Risk Management (20.75%), Economic Benefits (15.10%), and Scheduling, Planning Benefits (15.10%). The findings indicate that BIM 4D and 5D enhance time and cost control, coordination, and overall project efficiency. However, platform interoperability issues and limited studies in developing countries indicate future research opportunities. This study contributes to the 2030 Agenda for Sustainable Development by Strengthening Research and Innovation in Resilient Infrastructure (SDG 9) and Supporting Sustainable Urban Planning (SDG 11). It also enhances productivity and efficiency in the construction sector through Digital Transformation (SDG 8), promotes responsible resource use and emission reduction (SDGs 12 and 13), and supports capacity building in digital skills and international academic collaboration within the BIM domain (SDGs 4 and 17).*

Keywords *- Building Information Modeling (BIM), Infrastructure Project Management, Project Efficiency, Time and Cost Control, Sustainable Development Goals (SDGs).*

1. Introduction

Globally, we are immersed in a Building Information Modeling (BIM) environment, where the methodology's interface enhances software interoperability (75%-time reduction) [1] and project execution. This context requires companies and project stakeholders to strengthen their BIM management practices, where effective coordination and optimization of resources play a decisive role in cost reduction and the mitigation of project delays [2, 3]. New modeling practices, more versatile software, and infrastructure projects have absolutely transformed into a major necessary step in construction, shifting away from traditional models and generating resource coordination and optimization [2]. We can mention Earned Value Management (EVM) in relation to 5D BIM, which provides the earned value between the planned cost and the total project cost, and the theory of construction process simulation in relation to 4D BIM, which allows us to perform real-time simulation of the project throughout its lifecycle, among other technologies and tools. In this context, the adoption of this environment is a major advance for the optimization of infrastructure project management, requiring national regulations such as those in Chile, Brazil, and Peru, creating specialists committed to the expansion of BIM implementation [4, 5-10, 11].

In this global context, companies have made progress in using BIM in projects, increasing their design productivity, improving planning accuracy, and fostering collaboration in multidisciplinary teams [1].

In Peru, BIM has been used successfully in a small number of flagship projects, with the 2019 Pan American Games being a prime example [11]. However, the application of this methodology is not very common in the Peruvian construction sector. That is, there is limited use of, or a lack of understanding of, BIM in the project planning and programming phases, often with a preference for traditional methods [11]. This situation reveals a lack of commitment to migrating to BIM and a reluctance to digitize projects despite the promise of significant savings in public and private resources, as well as a reduction in execution time by allowing activities to be performed only once instead of repeatedly [8]. Instead, there is a slow adaptation to digitization, which reduces competitiveness in an increasingly virtual environment [5].

However, a significant research gap persists in current knowledge. While the global adoption of BIM is well-documented in the residential and commercial construction sectors, there is a notable lack of systematic evidence integrating the multidimensional benefits of 4D and 5D BIM specifically for large-scale infrastructure projects. Most existing studies focus on isolated technical aspects, leaving a gap in the comprehensive understanding of how these dimensions (cost, time, and sustainability) converge to optimize public works in emerging economies like Peru. To address this fragmentation, this research develops a structured synthesis of the evidence-based benefits that justify digital migration.

Various tools have been developed for project planning and control, which are used to monitor activities related to execution and to generate real-time project reports. When implemented correctly, these tools facilitate management through key performance indicators, including overall project performance, thereby improving productivity and reducing construction timelines. According to Liao et al. [5], the benefits of BIM in railway projects show an average savings of USD 41,000 and a reduction of 49 days.

From the same perspective, the use of 4D and 5D construction simulation facilitates the optimization of project execution time by improving planning, scheduling, coordination, cost control, and proper management of the project baseline. It also efficiently aids in the early identification and resolution of constraints. However, the current fragmentation and lack of specificity regarding the integrated benefits of 4D and 5D BIM methodologies, specifically within the infrastructure sector, constitute the problem addressed by this research. There is a clear absence of a systematic framework that correlates scheduling (4D) and cost (5D) with sustainability objectives and risk management in large-scale civil works projects. The originality of this study stems from providing a novel, multidimensional synthesis of evidence-based benefits from 2015 to 2025, offering a precise diagnosis for decision-makers in emerging economies. Consequently, the following research question is formulated: What are the specific multidimensional benefits of implementing 4D and 5D BIM in infrastructure projects, and how do they align with current global sustainability trends?

In this context, the implementation of BIM methodologies with a 4D and 5D approach becomes the necessary focus of study. Even now, traditional information is being migrated to digital information, with parameters for quality, costs, and time. That is to say, the methodology aims to simulate the construction process more accurately, generating real-time economic estimates during design and construction, thus supporting the entire project lifecycle.

The main objective of this article is to identify the benefits of implementing 4D and 5D BIM methodologies in infrastructure projects. Moreover, as specific objectives, to identify the economic benefits of implementing the BIM 4D and 5D methodology in infrastructure projects, to identify the programming and planning benefits of implementing the BIM 4D and 5D methodology in infrastructure projects, to identify the technical and quality benefits of implementing the BIM 4D and 5D methodology in infrastructure projects, to identify the sustainability and risk management benefits of implementing the BIM 4D and 5D methodology in infrastructure projects, and to identify the innovation and trend benefits of implementing the BIM 4D and 5D methodology in infrastructure projects.

2. Materials and Methods

This review adopted the PRISMA 2020 framework to ensure a systematic and transparent selection of the study sample. The eligible sample for the research was determined through the application of three sequential phases: (a) identification; (b) screening; and (c) final inclusion. For this purpose, inclusion and exclusion criteria were defined, classified as search filters and thematic eligibility criteria, which are detailed in Table 1. While the former was applied directly within search engines, the latter involved a multi-stage qualitative review that began with a rigorous analysis of titles and abstracts, followed by a comprehensive evaluation of the full text.

The workflow for sample selection is detailed in the PRISMA diagram shown in Figure 1. During the initial data collection stage, the Scopus database was selected as the primary source of information. To extract relevant records, a search strategy was designed based on the following technical terms:

("BIM" or "Building Information Modeling") and ("Infrastructure" or "Infrastructure").

This initially identified 2,317 articles. Subsequently, the predefined search filters (FB-01, FB-02, FB-03, and FB-04) were applied, excluding 2,111 articles. Other records (duplicates, unsuitable due to automation tools, and/or other reasons) were not removed.

In the screening phase, 206 records were examined. Of these, 82 were excluded for not meeting predefined thematic relevance criteria at the title and abstract levels, leaving 124 records for retrieval. No records were found to be unretrieved, leaving 124 records evaluated for eligibility. Of these, 71 records were excluded for not meeting predefined full-text thematic relevance criteria.

In the inclusion phase, 53 articles were considered for review, forming the eligible sample for the study.

On the other hand, for thematic analysis of the articles included in this review, categories and subcategories were identified and organized to systematize the approaches addressed in relation to the research objective. This thematic coding was developed inductively, considering the main recurring discursive lines in the analyzed studies and grouping them into five main axes: (1) Economic Benefits, (2) Programming and Planning Benefits, (3) Technical and Quality Benefits, (4) Sustainability and Risk Management Benefits, and (5) Innovation and Trends Benefits.

First, an Economic Benefits category was identified, within which two subcategories were recognized: (a) Savings and Optimization of Operational Productivity and (b) Refined Financial Control and Risk Mitigation through 5D BIM Governance.

Table 1. Inclusion and exclusion criteria

Type	Criterion	Code	Inclusion	Exclusion
Search Filter	Year of publication	FB-01	Articles published between 2015 and 2025	Articles published before 2015
	Language	FB-02	Publications in Spanish or English	Publications in other languages
	Document type	FB-03	Peer-reviewed scientific articles (Journals)	Theses, book chapters, conference proceedings, reviews, editorials
	Access to the document	FB-04	Documents available in full text (Open access)	Documents without access to the full text
Thematic Relevance: Eligibility	Thematic area	RT-01	Studies related to the BIM 4D and 5D Methodology	Studies from other unrelated disciplines
	Related sector	RT-02	Studies related to infrastructure projects	Studies from other unrelated sectors
	Type of study	RT-03	Empirical studies, systematic reviews, or case studies	Theoretical essays without empirical evidence or practical application

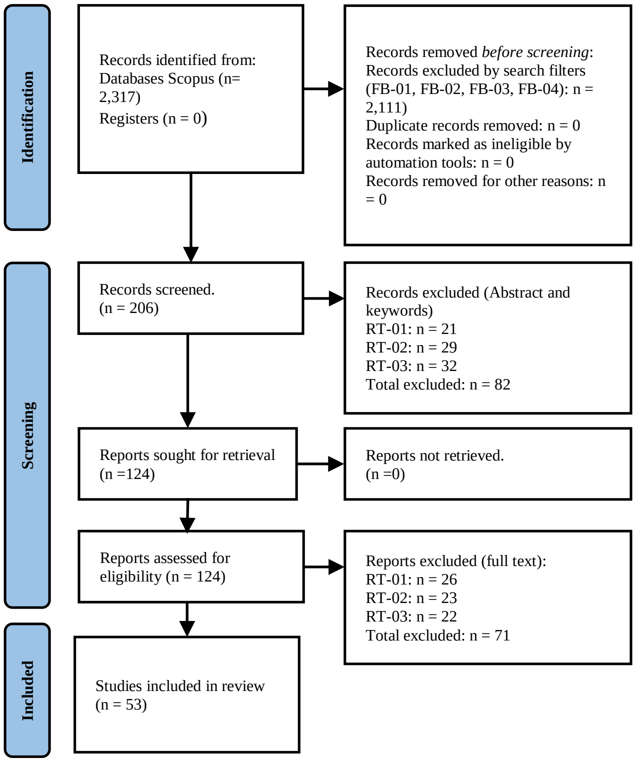

Fig. 1 PRISMA diagram

Second, the category focused on Scheduling and Planning Benefits, within which two subcategories were recognized: (a) Workflow and Logistics Optimization, and (b) Financial Control and Performance Evaluation.

Third, the category focused on Technical and Quality Benefits, within which two subcategories were recognized: (a) Process Optimization and Economic Efficiency, and (b) Advanced Simulation and Quality Management.

Fourth, the category focused on Sustainability and Risk Management Benefits, within which two subcategories were recognized: (a) Optimization of Sustainability and Project Lifecycle, and (b) Risk Management and Threat Assessment.

Finally, the fifth category related to Benefits in innovation and trends, which comprised two subcategories, namely (a) Advanced Technologies and (b) Digitalization and Efficiency in Construction.

3. Results

Table 2 shows the distribution of scientific output by continent and country. Europe accounts for 52.83% of the studies, with Germany as the main contributor (5 articles, 9.43%), followed by Spain, Italy, and Norway (3 articles each, 5.66%). Asia contributes 41.51%, led by China (12 articles, 22.64%) and followed by South Korea, Japan, and India. In contrast, South America accounts for only 3.77%, with Peru being the sole contributor, and North America accounts for 1.89%, represented by the United States. Advanced technological infrastructure, public policies that strongly promote the use of BIM, and a solid culture oriented toward applied research drive greater scientific productivity in Europe and Asia.

A greater emphasis on quantitative approaches (50.94%), followed by mixed methods (28.30%) and qualitative methods (13.21%), is evident in the methodological approach of scientific production, while the development of literature reviews and systematic reviews represents only 7.55% (Table 3). This preference for quantitative methods demonstrates the maturity of the field and the need to validate 4D and 5D BIM digital models empirically, consolidating their practical application in infrastructure project management.

Table 2. Scientific production by continent and country

Continent	Total	%	Country	Total	%
Asia	22	41.51	China	12	22.64
			South Korea	4	7.55
			Japan	3	5.66
			India	2	3.77
			Singapore	1	1.89
Europe	28	52.83	Germany	5	9.43
			Spain	3	5.66
			Italy	3	5.66
			Norway	3	5.66
			Austria	2	3.77
			Netherlands	2	3.77
			United Kingdom	2	3.77
			Sweden	2	3.77
			Portugal	1	1.88
			Poland	1	1.89
			Ireland	1	1.89
			Finland	1	1.89
			Denmark	1	1.89
			Switzerland	1	1.89
North America	1	1.89	USA	1	1.89
South America	2	3.77	Peru	2	3.77
Total	53	100		53	100

Figure 2 shows the annual distribution of publications by quartiles (Q1, Q2, Q3, and Q4) between 2015 and 2025. Of the 53 articles identified, the highest concentration is in Q2 (17), followed by Q3 (15), Q4 (14), and Q1 (7). The years with the highest output (2021 and 2022) show no balance between the quartiles, while in the recent period (2023–2025), publications are concentrated in Q3 and Q4, reflecting a slight reduction in impact diversity. This trend toward mid-quartiles demonstrates a growing interest.

Table 3. Scientific production according to methodological approach (scopus)

Approach	Articles	%
Qualitative approach	7	13.21%
Quantitative approach	27	50.94%
Mixed approach	15	28.30%
Literature review	3	5.66%
Systematic review	1	1.89%
Total	53	100.00%

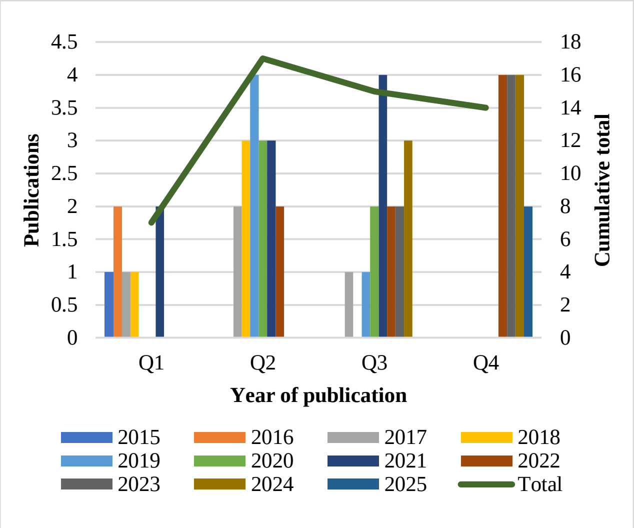

Fig. 2 Annual scientific production by indexing quartile (2015–2025)

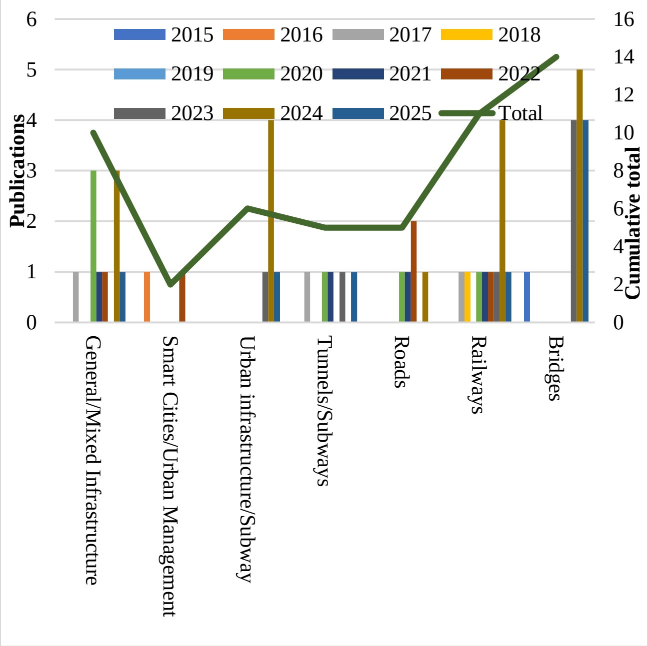

Fig. 3 Annual evolution of scientific production according to type of infrastructure (2015-2025)

Figure 3 shows the annual distribution of publications by infrastructure type between 2015 and 2025. Fifty-three articles were identified, with the highest concentration on bridges (14), followed by railways (11), general or mixed infrastructure (10), urban infrastructure or subways (6), tunnels/subways (5), roads (5), and smart cities or urban management (2). The years with the lowest production were 2015, 2016, and 2018, with no publications recorded in 2019, while 2024 stood out with a significant increase in all typologies. The results show a sustained trend of growth and thematic diversification, with a greater emphasis on large-scale infrastructure projects, where the application of 4D and 5D BIM is relevant for optimizing planning, cost control, and construction simulation.

The keyword co-occurrence network, presented in Figure 4, reveals two main clusters. The red cluster groups terms related to BIM management and modeling (building information modeling, project management, architectural design, information management), while the green cluster links BIM to transportation infrastructure and digital technologies, highlighting railways, rail transport, and digital twins. Two dominant approaches in the literature stand out: (a) project management and collaborative design; (b) digitization and intelligent infrastructure monitoring. However, no relevant connection with economic and sustainability factors is evident, revealing a gap that needs to be addressed in the integration of 5D BIM and life cycle assessment.

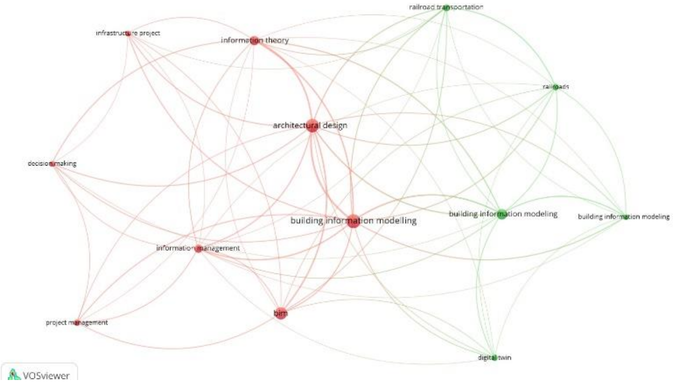

Fig. 4 Visualization of the co-occurrence network by cited keywords

The results in Figure 5 show 53 articles, predominantly on 4D BIM (30), followed by 5D (14) and combined 4D-5D approaches (9). A lower level of scientific output is evident in 2015, 2016, and 2018, while 2019 saw no publications. Conversely, 2024 registered the highest activity, with 8 studies in 4D, 5 in 5D, and 4 integrated, reflecting sustained growth, albeit with less thematic diversity. The limited development of publications integrating 4D and 5D highlights the need to address the interoperability of time and cost data, as well as the lack of standardized metrics, factors that hinder the consolidation of integrated models within the scientific community.

The results in Table 4 show a greater development of studies focused on technical and quality benefits (13 articles; 24.54%), followed by innovation and trend benefits (12; 22.63%) and sustainability and risk management benefits (11; 20.75%). Economic benefits (9; 16.98%) and programming and planning benefits (8; 15.10%) are less frequent. In general, the reviewed literature focuses primarily on technical and innovation aspects as central to BIM 4D and 5D, while the economic and planning components are theoretically related to Earned Value Management (EVM), which facilitates the evaluation of the financial and temporal performance of infrastructure projects.

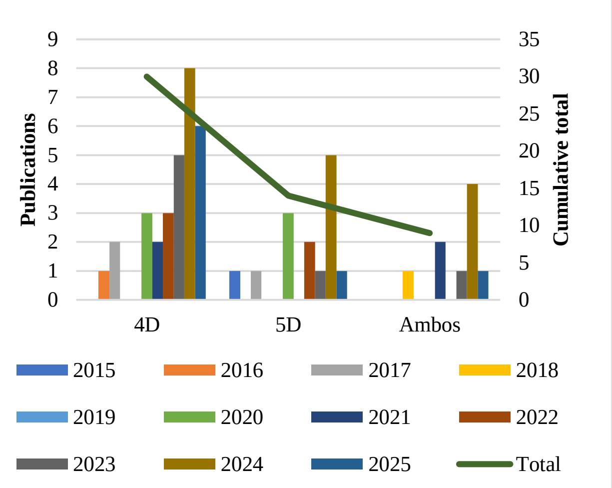

Fig. 5 Annual scientific production by BIM approach (2015–2025)

4. Discussion

Scientific production is geographically concentrated in China and a few other countries (Table 2), a finding reinforced by previous studies highlighting that countries benefiting most from the application of 4D and 5D BIM tend to generate a higher volume of publications [12, 13]. Significant differences are also evident between continents. In Asia and Europe, production is largely dependent on a single country (China and Germany, respectively), reflecting the risk of knowledge centralization in specific national contexts. North and South America, on the other hand, exhibit low levels of production, with publications concentrated in the United States and Peru, suggesting the presence of isolated research centers and limited regional representation. In light of this evidence, the need to promote policies of international collaboration and geographical diversification is emphasized to reduce dependence on a few countries and broaden the scientific visibility of emerging contexts.

Most of the reviewed publications are concentrated in Q2 and Q3 journals (Figure 2), demonstrating interest in this topic among mid-impact journals. Greater accessibility and academic recognition could be associated with the predominance of Q2 journals. The stability of Q3 and Q4 journals during the 2015–2025 period demonstrates the consolidation of a broad and continuous scientific base. These results open the opportunity for potential growth in publications in Q1 journals, which would boost the visibility and international impact of findings on 4D and 5D BIM.

Table 4. Scientific production according to benefits by categories

Categories	Subcategories	Articles	Percentage	Total
Economic benefits	Savings and Optimization of Operational Productivity	4	7.55%	16.98%
	Refined Financial Control and Risk Mitigation Through 5D BIM Governance	5	9.43%	
Benefits of programming and planning	Workflow and Logistics Optimization	4	7.55%	15.10%
	Financial Control and Performance Evaluation	4	7.55%	
Technical and quality benefits	Process optimization and economic efficiency	8	15.11%	24.54%
	Advanced Simulation and Quality Management	5	9.43%	
Benefits of sustainability and risk management	Optimizing the project's sustainability and life cycle	7	13.20%	20.75%
	Risk management and threat assessment	4	7.55%	
Benefits of innovation and trends	Advanced technologies	5	9.43%	22.63%
	Digitalization and efficiency in construction	7	13.20%	
Total		53	100%	100%

A predominance of quantitative studies (50.94%) is noted, demonstrating an interest in the use of empirical, measurable, and comparable data. Mixed and qualitative approaches (28.30% and 13.21%, respectively) provide a valuable perspective for understanding the interpretive and contextual dimensions of BIM use. The development of literature reviews and systematic reviews (7.55%) reveals a limited interest in synthesizing and analyzing existing knowledge, which would strengthen and broaden the theoretical basis of publications.

4.1. Economic Benefits

Early error detection through the integration of 5D BIM facilitates the reduction of construction delays, generating significant financial benefits, such as economic savings (197.6%) in specialized consulting services [14, 15, 20]. The integration of 4D and 5D dimensions provides a highly accurate metric for synchronizing costs and schedules, unlike traditional tools such as MS Project or static spreadsheets. This integration allows for an immediate comparison between planned and actual expenses [16], shifting project control from a reactive, after-the-fact review to a proactive, dynamic, and real-time process [17].

This transition minimizes financial discrepancies and improves budget accuracy by identifying specific activities that generate cost overruns [17, 18, 48]. From an interoperability perspective, a relevant research gap persists; for example, in highway design, the limitations of the IFC standard continue to hinder fluid semantic exchange [19]. There is evidence of consensus among researchers that the use of 5D BIM is essential for sound financial oversight [5, 14, 16], and its true value lies in how it integrates cost data throughout the project lifecycle, enabling stakeholders to make faster, data-driven decisions [20].

Significant obstacles to the implementation of BIM 5D have been identified. Technical capacity alone is not sufficient; a solid legal foundation is required. From this perspective, while BIM 5D could, in theory, resolve contractual disputes, its practical utility depends on its formal incorporation into national legal frameworks [5].

The fragmentation of financial metrics observed in Europe and Asia presents another challenge. The variety of measurement standards complicates the possibility of direct comparisons of cost overruns between regions [16]. Adopting standardized indicators such as the Cost Performance Index (CPI) and Earned Value (EV) for project baseline management allows for monitoring and controlling schedules and costs from an objective and shared perspective [11, 16, 20].

A significant discrepancy is evident between 5D BIM theory (focused on 3D/4D cost integration) and its current application in infrastructure projects. Publications on the real-world implementation of this approach remain surprisingly scarce [14, 15], despite the growing literature on models and simulations. The combination of technical complexity, lack of specialized training, and rigid organizational cultures contributes to this discrepancy and encourages a focus on tracking real-world cases and comparing the results of 5D BIM with traditional workflows [14].

Although the 4D and 5D dimensions conceptually align time and cost management, standardized Key Performance Indicators (KPIs) for comparing results across different sectors or countries are still lacking [14, 15]. The development of global and standardized metrics promotes a transparent and international evaluation of 5D-BIM efficiency [16].

4.2. Benefits of Programming and Planning

Good project management practices depend on proper planning to meet deadlines without compromising quality. Building Information Modeling (BIM) has redefined this process by centralizing documentation and optimizing coordination among various stakeholders [5, 14]. The use of a structured information flow, driven by BIM and integrated with Earned Value Management (EVM), provides a robust framework for project monitoring. This integration is not just a theoretical goal, but a practical method for maintaining tight control over construction progress [21, 22].

Relevant research, ranging from schedule optimization to the integration of 4D/5D BIM with emerging technologies such as digital twins, Geographic Information Systems (GIS), Microsimulation, and Advanced Data Management, has the primary objective of optimizing time and costs through more detailed planning [10, 23, 24]. Integrated 4D simulation with traffic analysis allows for the evaluation of the impact of schedules on urban mobility, establishing itself as a tool to support project management [12, 13]. Other studies highlight the incorporation of data management in BIM environments during the execution phase, demonstrating that the implementation of real-time inspections with 4D BIM allows for the detection of up to 90% of design conflicts, significantly reducing project duration and associated costs [12]. Similarly, the combined application of EVM and 5D BIM provides integrated control of the physical and financial progress of construction projects [21, 22].

There is evidence of an evolution towards predictive and efficient management models in the integration of 4D (time) and 5D (cost) BIM in infrastructure projects [1, 8, 9]. Most studies highlight that these dimensions improve schedule control, enable predictive simulations, and contribute to greater efficiency in cost management [16]. Quality monitoring through real-time tracking and more effective project data management are facilitated by this integration [21, 25, 22]. However, the main obstacles to its widespread adoption are the lack of clear data management standards, as well as the high costs associated with software investment and training [12, 13].

In this context, it is recommended that the application of methodological frameworks such as Virtual Design and Construction (VDC) and the Industry Foundation Classes–Information Project Model (IFC-IPM) be expanded to other infrastructure sectors, and that research be conducted to evaluate the implementation of BIM in relation to sustainability [23]. Similarly, strengthening the participation of stakeholders involved in operation and maintenance (O&M) from the early design phases facilitates the generation of unified and consistent data throughout the project lifecycle [22].

4.3. Technical and Quality Benefits

It is evident that optimizing data volume and analysis time significantly increases productivity, particularly when quantifying how defects impact infrastructure. Reducing the transition period from CAD to BIM protocols has been shown to optimize labor output [1, 8, 26, 27], extending efficiency gains to the workforce. Beyond new builds, the synergy between BIM and GIS facilitates faster, more precise remodeling processes [28]. There is a broad consensus that BIM not only cuts construction costs but also refines maintenance management and strengthens stakeholder coordination. Most notably, some studies report a transformative reduction in total project costs (ranging from 65% to 70%) alongside a drastic decrease in the volume of required technical drawings [29, 30, 31].

On the other hand, the integration of BIM-GIS and BIM-LCA (Life Cycle Assessment) allows for a better understanding of the infrastructure within its urban environment [9, 10, 28]. In other cases, it enables the automation of road calculations, allowing for optimal quality assessment [9, 32, 33]. Furthermore, BIM allows for visualization, simulation, and early warning in tunnel construction [34]. One study analyzed mentions as a future proposal the integration of BIM with computational design methods for infrastructure modeling under the "as-built" BIM model, reducing time and errors during the design process [35].

4.4. Sustainability and Risk Management Benefits

Beyond operational efficiency, recent research underscores a growing pivot toward sustainability and proactive risk management. For instance, the convergence of BIM and GIS is now recognized as a strategic driver for meeting Sustainable Development Goals [36-39]. Central to this shift is the role of BIM in developing "Digital Twins," which serve as high-fidelity replicas for continuous monitoring. By providing real-time, weekly, and project-level feedback, these digital models significantly curb material waste [6, 40] and enhance the precision of feasibility studies throughout various development phases [7, 41].

On the other hand, BIM models strengthen risk management in underground works, anticipating potential infrastructure damage and optimizing mitigation measures [7]. However, a gap remains in the standardized measurement of environmental and safety impacts. Most articles formulate hypotheses or conceptual examples without comparative studies that confirm the sustainable benefits, so without these assessments, timely risk assessments during construction, emergency situations, and reducing energy consumption cannot be achieved [42-44], as these authors agree.

4.5. Benefits in Innovation and Trends

In the Advanced Technologies subcategory, there are studies related to the application of digital twins, machine learning, and Structural Health Monitoring (SHM) as tools that strengthen predictive and preventive management. These technologies allow for simulating infrastructure behavior, detecting failures before they occur, optimizing maintenance, reducing risks, and improving operational efficiency [2, 4, 45-48]. The fact that most studies are conducted in controlled experimental environments creates a need to validate the benefits in real-world projects.

Regarding the subcategory "Digitalization and Efficiency in Construction," it is evident that the integration of advanced tools (such as Scan-to-BIM, augmented reality, and BIM-GIS) is redefining on-site coordination. Process automation combined with these cutting-edge technologies reduces errors while optimizing the interaction between project deadlines and budget constraints [3, 49-53]. In a collaborative data environment, these innovations facilitate precise control of physical and financial milestones, which strengthens traceability and transparency throughout the entire construction lifecycle, transitioning from fragmented traditional methods to a unified digital workflow.

5. Conclusion

The implementation of 5D BIM contributes to better financial planning and cost control, reducing cost overruns and project delays, and strengthening governance and transparency in resource allocation. However, high initial implementation costs and a lack of standardized frameworks limit its adoption.

The 4D dimension allows for the simulation of construction processes, facilitating better coordination, more efficient scheduling, and effective risk anticipation. It also demonstrates greater control over project deadlines and overall performance, but its effectiveness depends heavily on software interoperability and the availability of adequate technical training.

Integrated BIM models, combined with complementary tools such as Geographic Information Systems (GIS) and Life Cycle Assessment (LCA), improve design accuracy, reduce errors, and optimize overall construction quality. However, the lack of unified standards limits the replicability of these results in different contexts.

The implementation of 4D/5D BIM supports lifecycle assessments, waste reduction strategies, and effective risk management through simulation and predictive monitoring. The need to develop standardized metrics capable of objectively measuring these benefits is a critical factor in this implementation.

The evolution of BIM toward a smarter digital ecosystem is evident, where information plays a central role in supporting technical, economic, and environmental decision-making.

6. Research Gaps, Future Directions, and SDG Contributions

There is a clear concentration of studies in geographically developed contexts, particularly in China, Europe, Asia, and Germany, which limits the extrapolation of results to emerging realities such as Latin America. Likewise, few studies address the integration of 4D and 5D BIM with emerging technologies such as artificial intelligence, digital twins, and predictive analytics in infrastructure projects. Most studies focus on developing qualitative benefits, neglecting quantitative metrics that would allow for an accurate assessment of the impact of 4D and 5D BIM on relevant aspects such as environmental sustainability, emissions reduction, and resource efficiency. Furthermore, deficiencies are identified in the standardization of formats, the interoperability of platforms, and the systematic measurement of social and environmental impacts, fundamental aspects to broaden the scope and legitimacy of the benefits attributed to BIM 4D/5D.

Regarding future lines of research, the need to develop research that explores the following is highlighted:

(i) Creating econometric models that relate the adoption of BIM to the financial performance of projects in emerging contexts,
(ii) Investigating the integration of 4D BIM with predictive and real time management tools,
(iii) Exploring the interoperability between BIM and complementary platforms (Geographic Information System, Life Cycle Assessment, Finite Element Analysis) in order to improve design accuracy and early error detection,
(iv) Creating sustainability metrics applied to 4D/5D BIM that allow measuring environmental, social, and energy impacts, and
(v) Developing and validating integrated BIM–Digital Twin–Machine Learning models that allow monitoring and predicting the performance of infrastructures in real time.

From a perspective related to the Sustainable Development Goals (SDGs) of the 2023 Agenda for Sustainable Development, this study presents the following contributions:

- Theoretical contribution: strengthens research and innovation in resilient infrastructure technologies (SDG 9), provides theoretical foundations for sustainable urban and public works planning (SDG 11), and promotes international academic cooperation and knowledge networks on BIM (SDG 17).

- Practical contribution: fosters productivity and economic efficiency in the construction industry (SDG 8), drives technological transformation and innovation in infrastructure (SDG 12), promotes the responsible use of materials and energy through efficient construction (SDG 13), and reduces emissions and environmental footprint by optimizing schedules and resources (SDG 13).
- Social contribution: supports technical education and digital skills training (SDG 4), reduces the technological gap between developed and developing countries (SDG 10), promotes safe and resilient cities through efficient infrastructure (SDG 11), and fosters transparent and accountable institutions in public project management (SDG 12).

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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