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BIM for maintenance and public management of buildings in Brazil: systematic literature review

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BIM para manutenção e gestão pública de edificações no Brasil: revisão sistemática da literatura

RESUMO

Objetivo – O objetivo deste artigo foi analisar o impacto do *Building Information Modeling* (BIM) na operação e manutenção de edifícios públicos no Brasil, mapeando avanços e desafios na implementação por órgãos públicos a partir de uma Revisão Sistemática da Literatura (RSL).
Metodologia - Utilizando o protocolo *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA), foram revisados artigos das bases de dados Scielo, Semantic Scholar e Periódicos Capes, definindo critérios de elegibilidade e, por fim, selecionando 14 estudos entre 2018 e 2024 que abordam a aplicação do BIM para manutenção de edificações públicas.
Originalidade/relevância - Este é o primeiro estudo a realizar uma revisão sistemática sobre a aplicação do BIM na operação e manutenção de edificações públicas no Brasil, preenchendo uma lacuna teórica significativa. A originalidade da pesquisa reside na identificação dos desafios e oportunidades dessa tecnologia no contexto institucional, destacando sua relevância acadêmica para o avanço da gestão pública eficiente e sustentável.
Resultados - A pesquisa revelou uma adoção ainda inicial e heterogênea do BIM nas instituições públicas brasileiras, com barreiras significativas relacionadas à falta de capacitação técnica e interoperabilidade de software, especialmente na fase avançada de manutenção dos edifícios. Enquanto a Estratégia BIM BR oferece uma estrutura para impulsionar essa tecnologia, o cenário atual exige maior investimento em infraestrutura e desenvolvimento de metodologias específicas para o setor público.
Contribuições teóricas/metodológicas - O estudo avança ao integrar a metodologia BIM na gestão pública de edificações no Brasil, propondo uma abordagem sistemática para análise de maturidade, desafios e oportunidades de implementação tecnológica em órgãos públicos.
Contribuições sociais e ambientais – Destaca-se as contribuições sociais e ambientais do BIM em edificações públicas, como a transparência na gestão, capacitação de profissionais, redução de resíduos, eficiência no uso de recursos e preservação do patrimônio público, promovendo sustentabilidade e otimização no ciclo de vida das construções.

PALAVRAS-CHAVE: Gestão de Manutenção Pública. Building Information Modeling. Infraestrutura de Edificações Públicas. Interoperabilidade BIM.

BIM for maintenance and public management of buildings in Brazil: systematic literature review

ABSTRACT

Objective – The objective of this article was to analyze the impact of Building Information Modeling (BIM) on the operation and maintenance of public buildings in Brazil, mapping advances and challenges in the implementation by public agencies based on a Systematic Literature Review (SLR).
Methodology - Using the PRISMA protocol, articles from the Scielo, Semantic Scholar and Periódicos Capes databases were reviewed, defining eligibility criteria and, finally, selecting 14 studies between 2018 and 2024 that address the application of BIM for the maintenance of public buildings.
Originality/relevance - This is the first study to carry out a systematic review on the application of BIM in the operation and maintenance of public buildings in Brazil, filling a significant theoretical gap. The originality of the research lies in the identification of the challenges and opportunities of this technology in the institutional context, highlighting its academic relevance for the advancement of efficient and sustainable public management.
Results - The research revealed a still initial and heterogeneous adoption of BIM in Brazilian public institutions, with significant barriers related to the lack of technical training and software interoperability, especially in the advanced maintenance phase. While the BIM BR Strategy offers a framework to drive this technology, the current scenario requires greater investment in infrastructure and development of specific methodologies for the public sector.
Theoretical/Methodological Contributions – The study advances by integrating the BIM methodology into public building management in Brazil, proposing a systematic approach for analyzing maturity, challenges and opportunities for technological implementation in public bodies.
Social and environmental contributions - The study highlights the social and environmental contributions of BIM in public buildings, such as transparency in management, training of professionals, reduction of waste, efficiency in the use of resources and preservation of public assets, promoting sustainability and optimization in the life cycle of buildings.

KEYWORDS: Public Maintenance Management. Building Information Modeling. Public Building Infrastructure. BIM Interoperability.

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BIM para mantenimiento y gestión pública de edificios en Brasil: revisión sistemática de la literatura

RESUMEN

Objetivo – El objetivo de este artículo fue analizar el impacto del Building Information Modeling (BIM) en la operación y mantenimiento de edificios públicos en Brasil, mapeando los avances y desafíos en la implementación por parte de los organismos públicos con base en una Revisión Sistemática de la Literatura (RSL).
Metodología - Utilizando el protocolo PRISMA, se revisaron artículos de las bases de datos Scielo, Semantic Scholar y Periódicos Capes, definiendo criterios de elegibilidad y, finalmente, seleccionando 14 estudios entre 2018 y 2024 que abordan la aplicación de BIM para el mantenimiento de edificios públicos.
Originalidad/relevancia - Este es el primer estudio que realiza una revisión sistemática sobre la aplicación de BIM en la operación y mantenimiento de edificios públicos en Brasil, llenando un vacío teórico importante. La originalidad de la investigación radica en identificar los desafíos y oportunidades de esta tecnología en el contexto institucional, destacando su relevancia académica para el avance de una gestión pública eficiente y sostenible.
Resultados - La investigación reveló una adopción temprana y heterogénea de BIM en las instituciones públicas brasileñas, con importantes barreras relacionadas con la falta de capacitación técnica e interoperabilidad del software, especialmente en la fase avanzada del mantenimiento de los edificios. Si bien la Estrategia BIM BR ofrece un marco para impulsar esta tecnología, el escenario actual requiere mayor inversión en infraestructura y desarrollo de metodologías específicas para el sector público.
Contribuciones teórico/metodológicas - El estudio avanza integrando la metodología BIM en la gestión pública de edificios en Brasil, proponiendo un enfoque sistemático para analizar la madurez, los desafíos y las oportunidades de implementación tecnológica en los organismos públicos.
Contribuciones sociales y ambientales - El estudio destaca las contribuciones sociales y ambientales del BIM en la edificación pública, como la transparencia en la gestión, la formación profesional, la reducción de residuos, la eficiencia en el uso de los recursos y la preservación de los bienes públicos, promoviendo la sostenibilidad y la optimización del ciclo. vida de los edificios.

PALABRAS CLAVE: Gestión de Mantenimiento Público. Modelado de información de construcción. Infraestructura de edificación pública. Interoperabilidad BIM.

GRAPHICAL ABSTRACT

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1 INTRODUCTION

Building Information Modeling (BIM) is a very effective methodology for developing, managing, and operating buildings. It consists of constructing the building in a virtual environment, allowing the extraction of information that allows problems to be detected and solutions to be proposed before construction (Brito, 2019), renovation, or maintenance, avoiding unnecessary expenses and compatibility errors. To achieve this, it is necessary to model in a virtual environment all the information relevant to the intended objective, with the items identified and quantified for budgeting, with the various disciplines compatible and interoperable, and with the information necessary for managing building maintenance (Amorim, 2023). However, in most public works, the use of BIM for management and maintenance is conditioned on projects developed or executed with this technology, which makes its dissemination difficult (Duque *et al.*, 2023).

Thus, the use of BIM in the management and maintenance of buildings proves to be an effective approach, especially due to its ability to document the useful life of the construction, minimizing rework. Considering that the public sector is largely responsible for public buildings from planning to maintenance, the adoption of BIM could bring significant benefits, allowing the development of more efficient strategies in the application of public resources for the management of these properties (Amorim, 2023). Despite the advantages mentioned, in Brazil, the use of information modeling (BIM) for the development, management and operation of buildings is still little explored. The most commonly used model is the two-dimensional drawing, with the most diverse disciplines developing their projects individually and linearly (Fernandes; Scheer; Miceli Junior, 2020).

In order to increase productivity and reduce construction costs over time in the Brazilian construction industry, the Decree that established the Strategic Committee for the implementation of Building Information Modeling in Brazil was published on June 5, 2017. In May 2018, Decree No. 9,377 promulgated the National BIM Dissemination Strategy. This decree has undergone reformulations, but the objective of disseminating BIM throughout the country remains the same. On January 22, 2024, Decree No. 11,888 (Brazil, 2024) was published, updating the BIM implementation strategies in the country. The BIM BR Strategy promotes BIM implementation in stages, divided into 3 phases, the first being project development, the second being budgeting and construction management, and the third being operation and maintenance. The phases were scheduled to be implemented in 2021 (Phase 1), 2024 (Phase 2), and 2028 (Phase 3). In the public sphere, Law No. 14,133/2021, which regulates public tenders and contracts, promotes the gradual adoption of BIM in tenders for engineering and architectural works and services, aiming to encourage the adoption of BIM by Brazilian public departments, as presented in Article 19, paragraph 3 (Brasil, 2021).

In addition to the dimension of legislation to enhance the adoption of the BIM methodology, it is worth mentioning the research by Bonfante, Palmisano and Godoy (2024) regarding research on BIM teaching and learning carried out in the period from 2013 to 2020, originating from Higher Education Institutions in the country, in which it was possible to identify only 14 master's dissertations and 5 doctoral theses, a fact that indicates little academic production on the subject, which negatively impacts the process of qualification and training of

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professionals who will work with this methodology.

Despite these regulations, there is a discrepancy in BIM maturity among the most diverse Brazilian public agencies. Although there are public agencies that are references in the use of the methodology, such as the Brazilian Army, the Navy, the National Department of Transport Infrastructure (DNIT), the Government of Santa Catarina and the Government of Paraná, in others, the use of BIM is shallow or non-existent. In this scenario, it is necessary to identify the level of BIM maturity in Brazilian public agencies in order to understand the challenges faced so that solutions can be proposed in public institutions.

Succar (2008) states that there are several possibilities for classifying the BIM maturity level of a construction sector (Architecture, Engineering, Construction and Operations - AECO), dividing it into stages that must be implemented in stages. Following the same reasoning, the Phases proposed by the BIM BR Strategy aim to gradually implement BIM in the public sector (design, construction, operation and maintenance), since the development of the project occurs through the continuous integration of information in the BIM model.

Therefore, why has there not been a gradual and homogeneous implementation in public institutions in Brazil? Why are there public agencies so advanced in the use of BIM, with teams and methodological processes for interoperational development of projects and maintenance of buildings, while there are still others using BIM as a three-dimensional architectural design? To answer these questions, a systematic review of articles that mention the use of BIM as an operation and maintenance tool in public agencies was carried out, in which few articles were found, and of these, few related BIM maturity to operation and maintenance.

2 METHODOLOGY

Aiming to update the theme of BIM implementation in Brazilian public institutions, regarding the operation and maintenance phase of public buildings, a systematic review of the literature was carried out using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart (Galvão; Pansani; Harrad, 2015). Thus, articles were selected using objective criteria allowing the reproduction of this research.

Since this is specific research on the Brazilian scenario, a computational search was carried out in databases that contain national research and that have comprehensive data coverage. The Scielo, Semantics Scholar and Capes Periodicals databases were used. Since this is a subject related to a recent technology that is constantly evolving, the search was limited to articles published between 2018 and 2024. The research was carried out in 4 stages, the first being the identification of the articles, the second the screening of the articles based on content delimitations with a focus on the problem presented, the third stage aimed to review the resulting articles and the fourth stage the analysis of the articles was carried out and the result presented.

2.1 Article Identification

The research aims to understand the evolution of the study of BIM methodology in the operation and maintenance phases of Brazilian public buildings. To this end, within the central theme, the keyword “Building Information Modeling” was used, which corresponds to the full

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term, and the keyword “BIM” which corresponds to the acronym that is widely used. These terms were used in all databases used. It is worth noting that the keyword “Building Information Modeling” in several cases appears spelled as “Building Information Modelling”, however, this did not interfere in the results obtained due to the fact that a check was carried out for the use of both terms in the searches performed.

A priori, we tried to use the central keywords together with the keyword’s “public”, “public” and “maintenance”. As each database has its own methodology for searching for scientific works, different results occurred between them in the search with all the terms already mentioned, which culminated in different terms for each database according to Table 1.

Table 1 – Relationship between the Databases used and the search terms employed.

Database	Search terms used
Scielo	(ab:(BIM OR “Building Information Modeling”))
Semantics Scholar	((“Building Information Modeling” OR BIM) AND (público OR pública) AND manutenção))
Periódicos Capes	((“Building Information Modeling” OR BIM) AND (público OR pública))

Source: Prepared by the authors.

Using the Semantic Scholar portal, it was possible to find articles with all the keywords cited. For the Periódicos Capes portal, the term “maintenance” was eliminated so that the search would return results. Finally, the search on the Scielo portal did not obtain results using all the keywords and the result was maintained with the removal of the term “maintenance”. Only when the terms “public” and “publica” were eliminated was the search successful. Based on the sum of the articles found, the next screening stage was followed, according to Figure 1. Thus, in the identification stage, 543 articles published since 2018 were obtained for analysis.

Figure 1 – PRISMA Flowchart.

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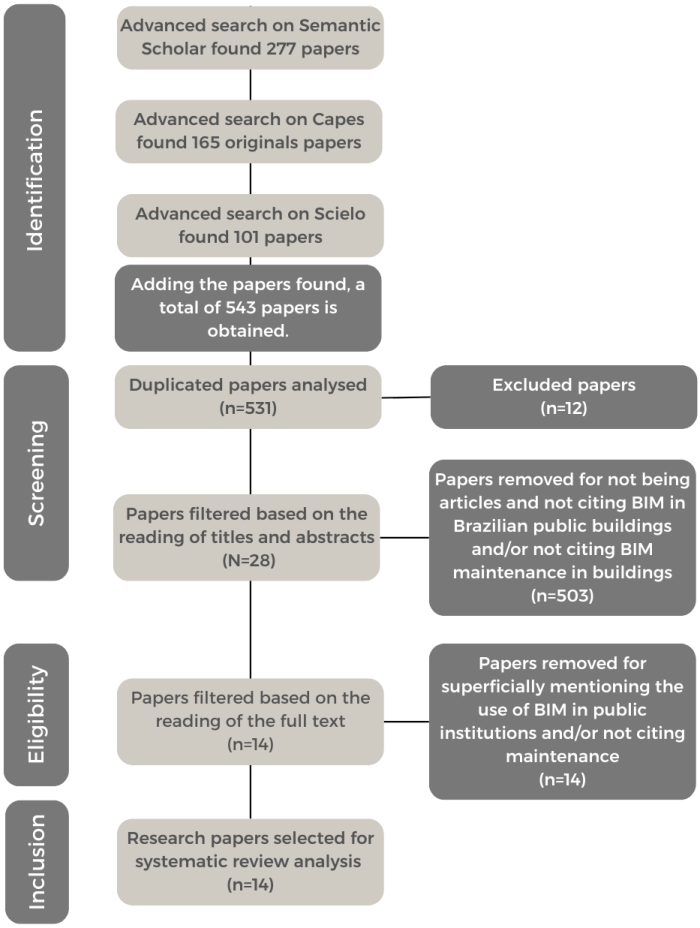

Source: Prepared by the authors.

2.2 Screening and Selection Criteria

After selection in each portal, a data cross-referencing was carried out between the 543 articles and those that were repeated were eliminated, resulting in 531 articles, which were analyzed by reading the titles and abstracts, eliminating those that did not address BIM in public institutions and/or BIM maintenance in buildings, those of foreign origin and those that were not published in scientific journals, resulting in 28 articles.

2.3 Eligibility Assessment of Full-Text Articles

The resulting texts, 28 articles, were read in full, and the presence of the use of the BIM methodology for the maintenance of public buildings was analyzed. Since the BIM dissemination decree is relatively recent, enacted in 2018 and reformulated in 2024, there is still no significant adoption of the BIM methodology in public agencies. Those that have already adopted it, as observed in the articles read, are still in the early stages of implementation, with BIM maintenance still far from the reality of Brazilian public agencies. Therefore, the articles that contained the overview of the BIM methodology in public agencies in the country were selected in order to observe its evolution and acceptance. Among the 28 articles read, following these criteria, 14 articles were selected and will be discussed below.

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3 RESULTS AND DISCUSSIONS

3.1 BIM BR Strategy and BIM Maturity Level

The selected articles address the use of the BIM methodology in various segments of Brazilian public bodies, showing the problems and needs of public civil construction and how BIM contributes or could contribute to mitigating these problems. For the analysis of the articles, it is understood that it is of vital importance to cite Decree No. 11,888, of January 22, 2024, which establishes the National Strategy for the Dissemination of Building Information Modeling in Brazil - BIM BR Strategy and establishes the Building Information Modeling Strategy Steering Committee and the influence of this decree on BIM implementations in the public sector in Brazil (BRASIL, 2024).

Given the importance of the BIM Strategy for promoting BIM in the Brazilian public sector, it is necessary to assess the level of maturity of BIM use in the country to verify how the technology is advancing and determine whether the BIM Strategy is being successful, in addition to identifying deficiencies and outlining solutions to achieve the proposed objective. In this sense, the selected articles were analyzed to identify the level of BIM maturity and whether they correspond to the current Phase 2. Of the 14 articles selected and classified, seven discuss Phase 1 (50%), two discuss Phase 2 (14%), and five discuss Phase 3 (36%).

3.1.1 Phase 1 – BIM Planning and Design

Of the selected articles classified in Phase 1, they generally discuss the introductory view of BIM, presenting the advantages of BIM in relation to the use of the Computer-Aided Design (CAD) project system, in an attempt to encourage the use of the methodology. They point out the low adoption of BIM by the public sector (and by the private AECO sector as well), the constant reluctance to adopt new technologies, the lack of technological structure to introduce BIM and mainly the lack of training of professionals in the civil construction industry. These articles mention the advantages of error prevention through BIM modeling and the interoperability and compatibility of projects between different disciplines, as well as the reduction of construction costs through more complete projects and consequently more accurate budgeting.

When analyzing public works, the cost and monitoring of public spending is extremely important for the country's growth and development. In this sense, Marini *et al*. (2022) advocate the use of BIM to develop more complete projects that allow the extraction of quantitative data and more appropriate budgeting, which will, in turn, allow better planning and monitoring of public works.

Barros and Luna (2024), when analyzing the implementation of a city hall in Ceará, discuss the difficulties in increasing the complexity of BIM use due to the lack of training of employees, thus preventing Phase 2 of planning and budgeting of the projects developed from being reached. Citing the same difficulty, Barros and Melo (2020) state that due to the lack of qualified professionals, there is a great difficulty in interoperability between the different BIM software for exchanging information between the different disciplines. Software problems are also mentioned in the article by Santos and Piacente (2021), in which budgeting requires the use

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of different software and that compatibility between them still requires studies and more efficient techniques. In a comparison between BIM implementation in Brazil and the United Kingdom, Santos *et al*. (2021) conclude that the low adoption of BIM by Brazilian public bodies is due to the low training of public servants and the lack of qualified professionals to efficiently implement BIM in Brazil. Thus, the reality of BIM maturity in the public sector does not match what is proposed by the BIM BR Strategy.

Quintas (2020) provides an introductory and positive view of the use of BIM in the budgeting of public works, perhaps because he does not provide a case study on the subject, he does not present any disadvantages. Sodré (2021), along the same lines, discusses the importance of the BIM BR Strategy for accessibility to the BIM methodology in Brazil, citing the actions aimed at this promotion, such as the establishment of the BIM BR Forum, agreements and partnerships with the Brazilian Association of Technical Standards and courses available and taught free of charge.

3.1.2 Phase 2 – Construction Execution: Budgets, Construction Management and Post-Execution Modeling

Among the selected articles, it is clear that a large part of public agencies still lack the use of BIM technology; the articles already mentioned are still in the early stages or are still experimenting with the technology. However, in Brazil, some departments that are references in the use of BIM have demonstrated preparation and an implementation strategy and continue to encourage others and create reference material. This is the case of the Brazilian Army, the State of Paraná and Santa Catarina, the Foundation for the Development of Education (FDE) of the State of São Paulo and the Oswaldo Cruz Foundation (FIOCRUZ). In these cases, there was experimentation and development of BIM techniques and technologies that were appropriate to the demands of each of these agencies.

The articles that present greater BIM maturity are essentially case studies in which experiments took place and a result was achieved. Andrade, Biotto and Serra (2021), as an example of an article classified as Phase 2, carried out a case study of BIM budgeting of public works using the National System of Civil Construction Cost and Index Research Table (SINAPI), presenting the difficulties and solutions to the problems encountered, presenting the software used and the interoperability between them.

Coelho Filho and Jacinto (2020) cite the same problem in their case study on the automation of budgets for public works bidding. In their experiments, they consider that it is necessary to use plugins (programs, tools or extensions that are incorporated into a main program and add more functions or resources) and mention two of them: OrçaFascio and OrçaBIM; for correct budgeting and that the use of these plugins requires accurate details of the construction elements that will be planned and budgeted. For this, a fully integrated data environment is necessary.

BIM modeling of projects for budgeting and subsequent execution must be carried out with elements that are faithful to those that will be executed and therefore requires the use of plugins or additional software that will overcome the deficiencies of the BIM software used as a basis. These difficulties require methodological knowledge of BIM modeling, compatibility and interoperability between disciplines, operation of different software, in addition to

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understanding the construction systems that will be used. In this sense, BIM maturity is intrinsically connected with the structuring of the BIM team and with the infrastructure of the public agency.

3.1.3 Phase 3 – BIM Operation and Maintenance

In order to enable BIM operation and maintenance of buildings, it is necessary to have knowledge of the entire construction process of the building, from the design process to the current state of conservation of the building, the building's occupation routine and the frequency of maintenance performed. In terms of BIM methodology, it is of fundamental importance to maintain an interoperable database operated by professionals trained to update and read information. This point is considered by the BIM BR Strategy as Phase 3, to be implemented in 2028, precisely because of its level of complexity, and for which it will require the necessary training of the team that will work with BIM.

Pereira and Correia (2019) present the results of a study that addresses the BIM implementation process in the management of the FIOCRUZ agency. The article presents the timeline of BIM implementation, the training of professionals, improvements in infrastructure, the creation of internal protocols through trial and error experiments, the interoperational difficulties encountered, the solutions adopted and the current challenges. It demonstrates a BIM maturity above the Brazilian average, serving as an example to be followed by other autarchies.

Santos, Costa and Ferreira (2021), realizing this difficulty in BIM interoperability, study and develop a BIM modeling methodology for buildings that allows for estimated budgeting and control of construction execution (Phase 2) and that will be used as a database for scheduling and monitoring the building throughout its life cycle. They mention, in agreement with the other articles, that the technical knowledge of the BIM professionals involved, the use of different software and the demand for technological infrastructure are the main challenges for good BIM management.

It is important to note that, due to the diverse functionalities of the different Brazilian public bodies, it is certain that the operation and maintenance of this database will be carried out according to the specific needs of each one, requiring strategies, protocols and training inherent to these particularities. In this sense, Miceli Jr., Pellanda and Reisc (2019) address the need for safeguarding BIM data by the Brazilian Army, which has already cataloged a large part of its collection in BIM. Because this database is accessed by several professionals and because the content of the data is of national security importance, it is important to develop ways to safeguard the data.

Oliveira *et al*. (2020) argue that maintaining a database of a building enables sustainable planning throughout its life cycle. They carried out a study to quantify materials and their waste using the BIM methodology and identified the difficulty of BIM software in quantifying volume and classifying materials in accordance with Resolution No. 307 of July 5, 2002 of the National Environmental Council (CONAMA, 2002), which establishes guidelines, criteria and procedures for the management of construction waste. The different purposes of operation and maintenance of buildings generate BIM functionalities that current software does

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not meet in its base programs, requiring the development of plugins and/or additional software to meet these demands.

Another issue encountered at this stage concerns the BIM modeling of existing buildings. There are several public buildings that were planned and built using other methodologies, whether in 2D CAD or even in technical drawings drawn by hand, which need to be re-cataloged in their current state and modeled in BIM so that BIM operation and maintenance are possible. This is the case of historic buildings, such as the one mentioned by Vanini *et al*. (2023), in which the construction techniques and details executed are so particular that they need to be cataloged for later modeling in BIM. To graphically survey this very specific data, the authors study photogrammetry and laser scanning techniques to develop a 3D point cloud mesh that is converted into 3D modeling allowing the development of a digital twin. The development of the digital twin allows the understanding of the historical evolution of the building and the planning of maintenance that is extremely important for the conservation of Brazilian Historical Heritage.

It is noted that the greatest difficulty in the BIM operation and maintenance phase refers to the need for a BIM model, analogous to the existing building, with the information necessary for planning the building's useful life. Due to the particularities of this information, the most widely used BIM software is not sufficient for the complete cataloging of the digital twin, thus requiring the use of additional protocols that still require studies and development. This challenge will require the Brazilian Government to invest in infrastructure, training of professionals and in BIM research focused on the Brazilian civil construction industry.

3.2 BIM Challenges

As a recent technology, the implementation of the BIM methodology in the Brazilian public sector entails several challenges that are inherent to the infrastructure of each agency, its function and objective. Therefore, the selected articles present, each in its own way, BIM challenges that have been overcome or are yet to be overcome, which should serve as practical examples. The BIM challenges and the results of each article are presented in Table 2.

Table 2 – Main results and challenges of implementing BIM in public bodies in the selected articles

References	BIM challenges	Main Results
Marini *et al.* (2022)	Lack of qualified professionals and reluctance to adopt new technologies.	It does not bring practical results, it only aims to promote the BIM methodology.
Barros and Luna (2024)	Lack of qualified professionals and reluctance to adopt new technologies.	It shows that the city halls studied only use Phase 1 BIM, lacking professional training and infrastructure for better development.
Santos *et al.* (2021)	Little adherence in public bodies, dissonance between the BIM BR strategy and the level of knowledge of professionals.	It shows that the evolution of maturity proposed by the BIM BR Strategy does not match the reality of a large part of the Brazilian public authorities.

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Barros and Melo (2020)	Low adherence in public bodies, lack of qualified professionals, difficulty in interoperability.	Proposes the use of IFC (Industry Foundation Classes) models for interoperability between different BIM software.
Santos and Piacente (2021)	Limitation of BIM Software for quantification and budgeting.	Proposes BIM software modeling based on the use of budgeting software.
Quintas (2020)	Infrastructure, lack of qualified professionals and reluctance to adopt new technologies.	It does not bring practical results, it only aims to promote the BIM methodology.
Sodré (2021)	-	It does not bring practical results, it only aims to promote the BIM methodology.
Andrade, Biotto and Serra (2021)	Limitation of the software used to generate quantities compatible with the SINAPI table.	Proposes BIM software modeling based on the use of budgeting software.
Coelho Filho and Jacinto (2020)	Limitation of BIM software for modeling parameterized elements that will be quantified and budgeted according to the SINAPI Table.	Suggests integrating the budgeting process with BIM modeling for effective quantification and budgeting according to the SINAPI Table. Suggests the use of OrçaFascio and OrçaBIM Plugins.
Pereira and Correia (2019)	Difficulty in interoperability, definition of internal procedural protocols, more time spent on design, technical complexity, discontinuity of actions (public administration), internal resistance to change.	It demonstrates that BIM implementation at FIOCRUZ was carried out through phased planning, professional training and investment in infrastructure. The BIM methodology used has been improved according to the challenges encountered at each stage.
Miceli Jr., Pellanda and Reisc (2019)	Lack of qualified professionals and minimum infrastructure for effective secure interoperability of BIM data.	Suggests improving BIM methodology in all phases for data security.
Oliveira *et al.* (2020)	Limitation of the software used in quantifying material according to the volume and classes of solid waste.	It suggests BIM modeling of materials according to the class of solid waste in accordance with Conama Resolution, requiring the development of specific software.
Santos, Costa and Ferreira (2021);	Infrastructure, lack of qualified professionals and limited interoperability between software and disciplines at high levels of BIM.	It proposes a BIM interoperability methodology through a database that must be fed and reviewed periodically by the team in common agreement.
Vanini *et al.* (2023)	Graphic survey of the structure of an existing building.	Use of Photogrammetry and 3D laser scanning to develop digital twins that will be used for the operation and maintenance of historic buildings.

Source: Prepared by the authors.

In the articles categorized as Phase 1, which have not yet been implemented or are still in an early stage, the challenges are common to all; the lack of professional training and the lack of adequate infrastructure are seen as barriers to the acceptance of BIM technology in the Brazilian public sector. This is the time when it is necessary to invest in software and equipment, as well as plan the implementation following the guidelines of the BIM BR Strategy. The BIM focus is on the design of new works, with an emphasis on architecture and planning aimed at the possibility of budgeting for base projects.

As for the articles classified as Phase 2, with the beginning of interoperability, the biggest challenge is the limitation of the software used to model the various disciplines and their integration, making it necessary to use different software and methods of interaction and information exchange between them. In the public sphere, budgeting is an important issue, which affects the public treasury, leading to difficulties in modeling according to what will be

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budgeted. Therefore, the BIM method used is already more mature so that the project and budget are more faithful to the real expenses.

Finally, the most mature articles, classified as Phase 3, with the BIM method consolidated, already in the operation and maintenance phase, present case studies in which the challenges are specific and particular to each infrastructure team. In these cases, the solutions adopted are specific and required a collective effort to improve the methodology used, through trial and error, which can serve as a basis for other sectors of public administration.

4 CONCLUSIONS

The BIM challenges faced by the Brazilian public sector are directly linked to the level of maturity of the institutions and the suitability of the methodologies adopted to the specific needs of each agency. Information interoperability, an essential characteristic of BIM, demands strategic planning and customized solutions that consider institutional peculiarities and their objectives.

Uneven implementation reflects structural and cultural barriers, such as the lack of technological infrastructure, lack of technical training and resistance to the adoption of new technologies. Although the BIM BR Strategy established a timetable for gradual dissemination, Brazilian public agencies have not kept up with this pace, resulting in isolated and heterogeneous advances.

The delay in implementing the BIM BR Strategy can be attributed to the lack of integration between the proposed actions and the actual capabilities of public agencies. The lack of an in-depth initial diagnosis of the level of technological and managerial readiness of institutions compromised the uniform adoption of BIM. In addition, the administrative discontinuity, typical of many public departments, and the low incentive for innovation made it difficult to consolidate consistent practices. This scenario indicates the need for greater coordination between government, academia and the private sector to correct deviations and align the schedule with institutional realities.

Overcoming these challenges requires a paradigm shift in public policies and institutional management, prioritizing the creation of collaborative and interdisciplinary environments. Investing in the training of qualified teams and the development of standardized national protocols can facilitate interoperability and broader adoption of BIM. In addition, the exchange of experiences and the replication of successful initiatives, such as those observed in reference agencies, are fundamental strategies for disseminating good practices and reducing existing disparities.

Thus, the discrepancy in the use of BIM between different institutions is mainly due to the quality of investment in infrastructure and training. The use of multiple software programs, which is often necessary, increases costs and requires trained teams to optimize resources. Well-structured planning, focused on local demands, is necessary to promote the effective adoption of BIM and achieve more efficient and sustainable public management.

Although making up for lost time does not eliminate the impacts of the initial delay, the adoption of coordinated actions can significantly accelerate BIM maturity in Brazil. The most

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important thing is that the public sector treats BIM not only as an obligation, but as a strategic tool for public management, maximizing resources and minimizing costs.

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DECLARAÇÃO DE CONFLITOS DE INTERESSE

Nós, Tatiane Cristine Silva Kono Oliveira, Angelo Palmisano e Fábio Friol Guedes de Paiva, declaramos que o manuscrito intitulado " **BIM para manutenção e gestão pública de edificações no Brasil: revisão sistemática da literatura**":

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