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OVERVIEW, ADVANTAGES, AND CHALLENGES OF BIM BUDGETING PROCESSES IN THE BRAZILIAN SCENARIO

PANORAMA, VANTAGENS E DESAFIOS DA ORÇAMENTAÇÃO EM BIM NO CENÁRIO BRASILEIRO

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Abstract

This article investigates the main gains and difficulties encountered in the adoption and use of BIM (Building Information Modeling) as an assisting tool for project cost management in the Brazilian architecture and engineering offices. The study was carried out based on a systematic literature review covering the analysis of 34 articles published between 2011 and 2021. There was a growing interest in this topic, with publications in congress proceedings being more frequent than in journals. The Case Study and Design Science Research (DSR) were the most adopted research methods, and the software Revit® was the most used tool. The main gains listed for the budgeting processes of BIM projects were the automatic quantitative extraction, the better visualization provided by the virtual model, and the ease of testing constructive hypotheses. On the other hand, the most cited obstacle was the difficulty of adopting a level of detail and quality of the model suited to the budget preparation. In particular, regarding the SINAPI cost reference system, the need for adaptations was identified to better integrate this system with BIM. The main conclusion is that BIM can significantly contribute to greater assertiveness in budgeting processes if modeling guidelines are pre-established.

Keywords: systematic review of the literature, BIM, budget, Brazil.

Resumo

Este artigo se propõe a investigar os principais ganhos e dificuldades encontrados na adoção e uso do BIM (*Building Information Modeling*) como ferramenta de auxílio para o gerenciamento de custos de projetos nos escritórios brasileiros de arquitetura e engenharia. O estudo foi conduzido a partir de uma revisão sistemática da literatura, contemplando a análise de 34 artigos publicados no Brasil entre 2011 e 2021. Houve um crescimento no interesse por esse tema, tendo havido uma maior recorrência de publicações em anais de congresso do que em periódicos. O Estudo de Caso e o *Design Science Research* (DSR) foram os métodos de pesquisa mais adotados; e o software Revit®, a ferramenta mais empregada. Os principais ganhos elencados para a orçamentação em BIM foram a extração automática de quantitativos, a melhor visualização proporcionada pelo modelo virtual e a facilidade em testar hipóteses construtivas. Por outro lado, a dificuldade de definição de um nível de detalhamento e de qualidade do modelo adequados à elaboração do orçamento foi o obstáculo mais citado. No que concerne particularmente ao sistema referencial de custos SINAPI, foi identificada a necessidade de adaptações para melhor integrar este sistema com o BIM. A principal conclusão é que, caso sejam pré-estabelecidas as diretrizes de modelagens, o BIM pode contribuir significativamente para maior assertividade em processos de orçamentação.

Palavras-chave: *revisão sistemática da literatura, BIM, orçamento, Brasil.*

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Introduction

Building *Information Modeling* (BIM) "is the set of technologies and integrated processes that allow the creation, use and the updating of digital models of a building, collaboratively, to serve all the participants of the project, potentially throughout the

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life cycle of the building" (BRASIL, 2019). Succar (2013), in turn, defines BIM more broadly as a set of technologies, processes, and policies that enable multiple stakeholders to collaboratively design, build and operate a facility. Therefore, more than a graphic representation, the project modeled in BIM brings object-oriented information, which enables the management of the entire life cycle of a building.

According to the definition proposed by Succar (2013), the new scenario established for the built environment must also be combined with well-defined processes and coherent organizational policies. Aligned with this concept, the Brazilian Federal Government, as responsible for promoting the adoption of BIM in Brazil, provided for the National BIM Dissemination Strategy and established the BIM Strategy Management Committee through Decree No. 9,377 (BRASIL, 2018) and Decree No. 9,983 (BRASIL, 2019). Still, concerning governance, Federal Decree No. 10,306 (BRASIL, 2020) established the use of BIM in the direct or indirect execution of civil engineering works and engineering services carried out by agencies and entities of the Federal Public Administration.

Traditionally, the preparation of budgets in Architecture, Engineering, and Construction (AEC) projects is linked to the manual survey of quantities for each project component based on two-dimensional drawings. However, the advent of BIM caused a paradigm shift in the cost management of AEC projects, mainly due to its ease in extracting parameterized data from the virtual building model.

As for the Brazilian reality of the AEC industry, Oliveira *et al.* (2021) highlight the difficulty of comparing with the methods and software used for budgeting in BIM presented in international publications. The authors point out that, especially in the field of budgeting for public civil engineering works, in which the use of the National Research System of Civil Construction Costs and Indexes (SINAPI) is mandatory, the national reality is specific (BRASIL, 2013; 2016).

In their systematic literature review, Gruska *et al.* (2019) mapped trends and applications of BIM in the world scientific scenario regarding time and cost management in construction. They point out as a limitation that research on the planning and budgeting of civil engineering works, in the Brazilian scenario, is still incipient, highlighting the need to understand this niche for the development of research on the subject. Aligned with the suggestion of future research proposed by the authors, this article presents a Systematic Literature Review (SLR) to identify research gaps and raise advantages and challenges related to BIM project budgeting, considering the Brazilian AEC industry.

References

Cost estimation and budgeting

According to the PMBOK® Guide (PMBOK, 2008), cost is one of the knowledge areas for project management, covering processes related to planning, estimating, determining, and controlling the budget. In addition, Barbosa (2015) defines budgeting as the forecast of financial resources needed to prepare a project, which must be allocated according to the provision of services in the schedule.

As for the types of budgets, Mattos (2009) categorizes them in increasing order of reliability and accuracy as cost estimation and detailed or analytical budget. Cost estimation refers to the initial phases of the project and preliminary budget is based on the price of inputs. An analytical budget is obtained from the compositions of the unit cost of services.

Cost modeling in BIM

Lee *et al.* (2005) define BIM dimensions as an extension of the geometric and parameterized virtual model (3D BIM) to which information related to project management disciplines is added. Typically, the fourth dimension (BIM 4D) is associated with the variable time and the planning of the enterprise (FERNANDES, 2014), while BIM 5D contemplates aspects related to costs and budget (SAKAMORI, 2015). The concept of BIM multidimensionality was later expanded, adding factors related to life cycle management and building performance, such as sustainability, energy efficiency, and work safety (KAMARDEEN, 2010; OLIVEIRA; SCHEER; TAVARES, 2015).

Koutamanis (2020), however, brings the literal definition of the concept of "BIM dimensions", linking it to database theory. Although the term is used metaphorically to indicate the information processing capacities in the model, the author emphasizes that only four dimensions define an object in a symbolic representation of the construction: the three geometric dimensions and the time variable. That is, the dimensions concern the essential primary properties of each symbol in the BIM; and not what can be extracted from the model in terms of information.

Succar, Saleeb, and Sher (2016) corroborated by stating that the purpose of a given project is more critical than the amount of information added to the model. Then the concept of uses of the model has become more suitable for BIM adoption and implementation since it assesses the development needs to be demanded by each project.

The BIM Project Execution Planning Guide (MESSNER *et al*., 2022) – prepared by the Pennsylvania State University (PSU) – brings, in its version 3.0, 25 uses of the model that can be applied to BIM models to be defined according to the alignment organizational strategy. It also defined that two or three uses of the model could be related to each strategic objective intended to be achieved with the modeling. For example, if the goal is to reduce the number of contractual amendments, the uses of the model would be related to the geometric, time scheduling, and cost modeling of a construction.

Specifically, regarding modeling construction costs, Messner *et al*. (2022) describe cost estimation as one of the 25 uses proposed for the BIM model. The authors define it as a process in which BIM can be used to assist in extracting accurate quantities and budgeting, allowing to visualize the impacts that design changes throughout the project's life cycle can cause on its costs.

Regarding the benefits arising from this use of the model, the authors point out: the precise and quick quantification of modeled materials; better visualization of the constructive elements that will be estimated; exploration of different design concepts, helping decision-making and enabling faster generation of cost estimates; providing cost information throughout the project lifecycle, making change management easier; evolutionary monitoring of expenditures throughout the construction stages, when there is integration between the schedule of activities and the budget; focus on activities that add more value to the budget, such as service pricing and risk analysis, essential for detailed budgets; and ease of employing new estimators due to the highly visual process.

Among the required resources, Messner *et al*. (2022) mentioned the need for budgeting software based on the BIM model, BIM modeling software, an accurate virtual model of the building, and cost information. Concerning the necessary skills of the team, the following capabilities were listed: defining specific modeling guidelines so that the quantitative data extracted from the model is accurate, identifying quantities

compatible with the required level of estimation and manipulating the models to extract valuable amounts for budget preparation.

On the subject, Eastman *et al.* (2014) also point out that BIM supports the budgeting process with its object-oriented modeling; however, they emphasize that there are no tools that automatically generate an entire budget from a virtual model. In addition, the authors point out essential considerations related, for example, to the quantification method and measurement criteria adopted, which the estimator must define.

Method

Considering the research gap pointed out by Gruska *et al.* (2019), which highlights the need to improve studies on the applications of BIM in the Brazilian scenario for cost management, the method used to develop this study was Systematic Literature Review (SLR). As approached by Dresch, Lacerda, and Antunes Júnior (2015), it consists of a secondary study that aims to map, find, critically evaluate, and aggregate the results of primary studies in a research question.

The PICO (Population, Intervention, Comparison, and Outcomes) method (PETTICREW; ROBERTS, 2012) was used to structure the research question of this study. It consists of defining the population under investigation, the intervention that one wishes to study in this population, a factor or characteristic with which the intervention will be compared, and the results arising from this relationship.

For this research, the population was defined as budgets for building projects within the scope of the Brazilian AEC industry. For the intervention, there is the elaboration of the mentioned budget from modeling costs in BIM compared to the traditional methods of raising quantities from projects in two dimensions (2D). Finally, we seek to find the benefits and difficulties Brazilian design offices face adopting BIM technology for project budgeting. Therefore, the following question was proposed: What are the gains and challenges of using BIM for budgeting, considering the reality of Brazilian AEC design offices?

The search terms were defined and separated into two categories based on the research question: "BIM OR Building Information Modeling OR Building Information Modelling" AND "5D OR budget* OR cost OR quantit*".

Regarding the data used, that is, the sample space investigated to answer the research question, it encompasses articles indexed on the online platforms SciELO (Scientific Electronic Library Online) – for the journal *Ambiente Construído* – and Google Scholar – for the journals Gestão & Project Technology (G&TP) and PARC (Research in Architecture and Construction). Furthermore, we also considered as a source of research the proceedings available at the electronic addresses of the following congresses promoted by ANTAC (National Association of Technology in the Built Environment) due to their relevance in the Brazilian academic environment: National Meeting of Technology in the Built Environment (ENTAC) and Brazilian Symposium on Technology and Information and Communication in Construction (SBTIC), for its relevance in the national academic environment.

Next, the selection criteria were defined. As for the content analysis, inclusion and exclusion criteria were considered to select only relevant studies for the research question (Table 1). As inclusion criteria, we chose publications that: (I1) dealt with aspects related to budgeting in BIM; and (I2) included at least two of the following search terms: a term associated with BIM and another with the budgeting process. The study sample did not consider content such as monographs, dissertations, theses,

books, and guides. The period selected was from 2011 to 2021, referring to the previous eleven years, with only works available for consultation in electronic media being research instruments.

Table 1 – Filtering of journal publications

STAGE	DESCRIPTION	NUMBER OF SELECTED ARTICLES
Q:1	1st FILTERING - Application of the search *string* and selection criteria in the databases	126
Q:2	2nd FILTERING - Application of exclusion criteria (E1) and (E2)	121
Q:3	3RD FILTERING - Adherence to the topic under study confirmed in the abstract: application of inclusion criteria (I1) and exclusion criteria (E3)	24
Q:4	4TH FILTERING - Adherence to the topic under study confirmed in the full text: application of inclusion criteria (I1) and exclusion criteria (E3)	10

Source: the authors.

The inclusion criterion (I2) is justified since search engines did not index the articles taken from Brazilian conference proceedings. To this end, all documents that contained the terms "BIM OR Building Information Modeling OR Building Information Modelling" in their titles (represented by the line "Total publications" in Table 2) were initially chosen. Then, from this resulting sample, only the files that contained the terms related to the second category of the search string were selected: "5D OR budget***** OR cost OR quantit*****" (as represented in the line "Adherence to complementary search string" in Table 2), thus guaranteeing the recurrence of search terms in this class of articles.

Table 2 - Filtering of congress proceedings publications

STAGE	DESCRIPTION	NUMBER OF SELECTED ARTICLES
C:1	1st FILTERING - Application of the simple search *string* and selection criteria in the proceedings available on the ANTAC website	138
C:2	2nd FILTERING - Adherence to the complementary search *string* Inclusion criteria (I2)	102
C:3	3RD FILTERING - Adherence to the topic under study confirmed in the abstract: application of inclusion criteria (I1) and exclusion criteria (E3)	37
C:4	4TH FILTERING - Adherence to the topic under study confirmed in the full text: application of inclusion criteria (I1) and exclusion criteria (E3)	24

Source: the authors.

The following exclusion criteria were considered: (E1) publications that were not scientific articles (such as the editorials of selected journals); (E2) repeated pieces; and (E3) articles dealing with the extraction of quantities from a BIM model but which were not related to budgeting, that is, they used data collection to meet other requirements, such as energy efficiency or interference detection, for example.

A third filtering was performed for academic journals and conference papers related to adherence to the topic under study based on reading the abstract. One hundred twenty-one abstracts from journal publications and 102 from conferences were read and evaluated; 24 and 37 articles were selected under the proposed objective and meeting criteria I1 and E3, respectively.

Finally, the refinement step in selecting samples from primary studies consisted of the complete reading of all selected articles. In the analysis of these articles, their adherence to the theme object of this study was verified, with the data being archived simultaneously. At the end of this stage, 10 journal and 24 conference papers remained, as shown in Tables 1 and 2.

After completing all the filtering steps, the reading, and data collection of the 34 selected papers were finalized. The results were organized and categorized by year of publication, type of publication (journal or conference proceedings), main BIM tools used, and research methods adopted. The contributions of the analyzed studies were

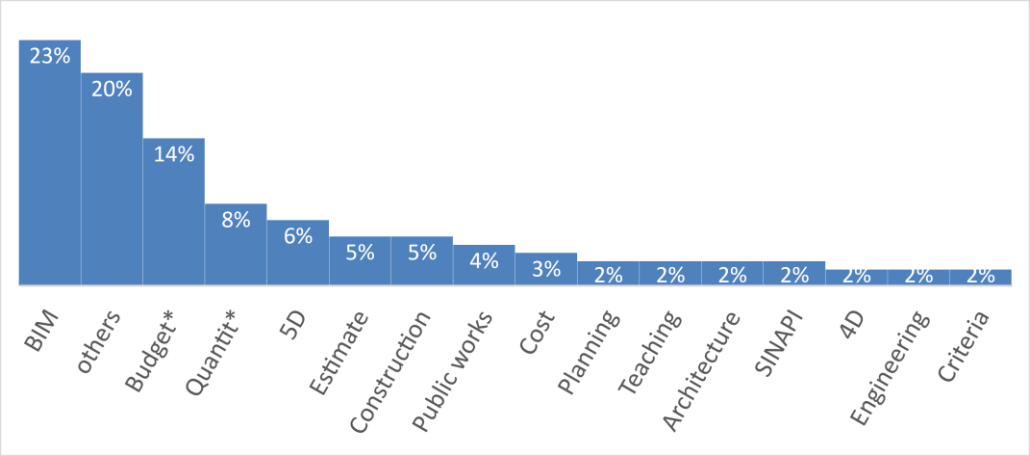
also listed, as well as the main advantages and difficulties cited for the BIM modeling of the costs of the constructions to investigate the proposed research question.

Results and discussion

The most used keywords in the analyzed articles are represented in Figure 1. Synonymous terms or acronyms, such as, for example, "BIM" or "Building Information Modeling" or "Building Information Modelling" were grouped into a single category; to refine the analysis. On the other hand, the "others" category groups keywords that had only one occurrence in the analyzed sample and, therefore, have no relevance in this investigation.

The terms "BIM" and "budget" or "budgeting" can be observed with more significant recurrence among the keywords, confirming adherence to the terms used in the search string. Terms directly related to the research question, such as "cost", "quantities", "quantitative", "estimate", and "5D BIM", were also recurrent. Comparing the number of articles that deal with cost estimation - the preliminary stage of the budget - with those that address the detailed budget, four studies dealt with the initial phase, while 20 analyzed aspects related to the project budget, pricing it based on the quantitative survey and the unitary cost compositions of the services.

Figure 1 – Occurrence of keywords in the reviewed articles

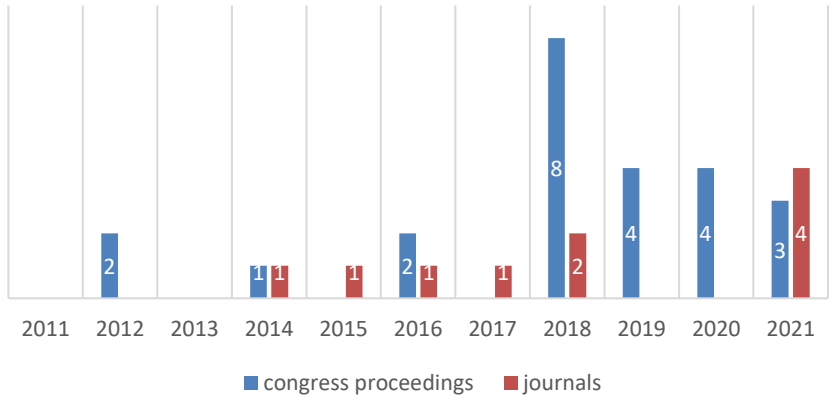


Source: the authors.

The occurrence of terms such as "planning" or "BIM 4D" is linked to 4 articles in the sample that dealt with the relationship between this subject and budgeting. It is worth noting that although the use of the term "5D" is no longer appropriate (KOUTAMANIS, 2020), it was used as a keyword in 8 articles - published in 2016 (2), 2018 (3), 2019 (2) and 2020 (1) - to refer to the universe of budgeting associated with the BIM. The terms "public works", "SINAPI", and "criteria" refer to the seven studies that investigated cost modeling in BIM focused on projects in the context of Brazilian Public Administration.

Regarding the temporal evolution of scientific production related to the topic, there was a growing trend in the number of research for publication in journals, according to Figure 2, although in 2019 and 2020, no articles were published. On the other hand, there was a more expressive number of publications for conference proceedings in 2018, totaling eight of the ten papers that made up the sample.

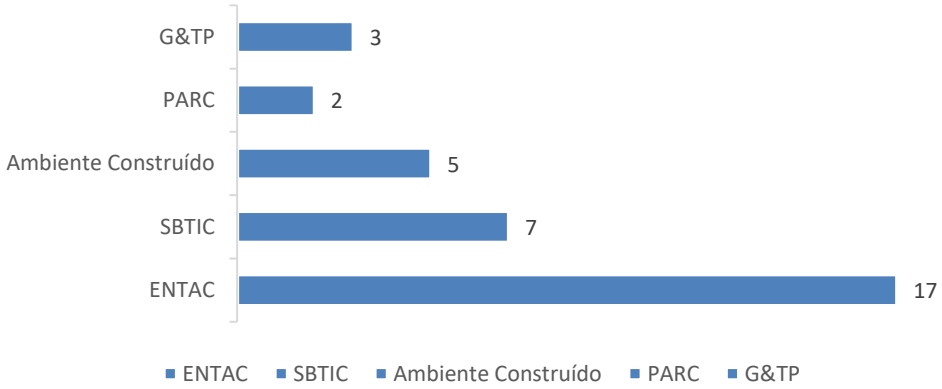
Figure 2 – Number of publications per year



Source: the authors.

Figure 3 presents the distribution of articles in the study sample in terms of publications in conferences and journals. There is a greater occurrence of conference papers.

Figure 3 - Number of publications by disclosure source



Source: the authors.

As for BIM applications to support the budgeting process, the occurrence of the three approaches mentioned by Eastman *et al.* (2014) is noticed. Table 3 summarizes the main tools cited in the analyzed articles and used for budgeting, correlated to their applications in cost modeling in BIM.

Table 3 - Main tools used for cost modeling in BIM

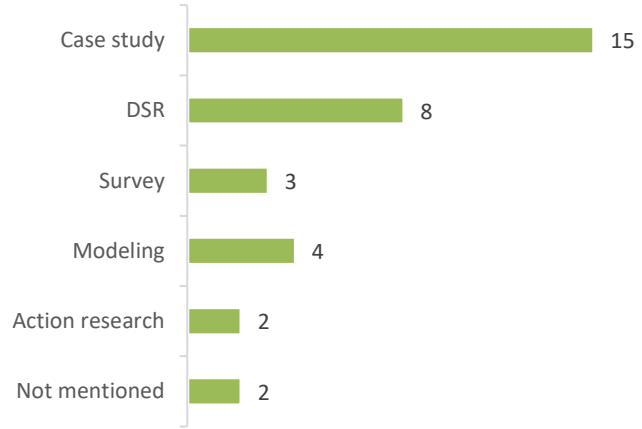
BIM APPLICATIONS TO SUPPORT THE BUDGETING PROCESS (EASTMAN *et al.*, 2014)	MAIN TOOLS
Virtual model only for quantitative export	*Autodesk Revit®, Graphisoft ArchiCad®, Autodesk* Dynamo® *and Microsoft Excel®*
Specific tool that imports data from the model and complementary manual surveys	*Autodesk Naviswork®, Autodesk* Dynamo® and *Microsoft Excel®*
Direct connection via plug-in between BIM components and the estimating software	*OrçaFascio®, with OrçaBIM® plug-in and Trimble Vico Office®*

Source: the authors.

Concerning the use of BIM software, it appears that Autodesk's Revit® was the most recurrent (63%), followed by Graphisoft's ArchiCad® (14%). Only Costa and Serra (2014) used SketchUp® to create the 3D model. Mattana and Librelotto (2018) presented the result of integrating undergraduate teaching in Architecture and Urbanism using a diversified set of software in the disciplines taught, including both Revit® and ArchiCad®.

Proceeding with the survey of the leading research methods adopted by the 34 reviewed articles (Figure 4), case study and Design Science Research (DSR) are the most used research methods. According to Dresch, Lacerda, and Antunes Júnior's (2015) definition, the "case study" consists of an exploratory, descriptive, and explanatory study and is characterized by being essentially empirical in such a way that the researchers act as observers. The DSR method, in turn, focuses on consolidating knowledge through design and developing solutions to improve existing systems, solving problems, and creating artifacts.

Figure 4 - Research methods adopted



Source: the authors.

Among the 15 articles that adopted the case study as a research method, a comparison between processes that used manual quantitative surveys and those that adopted the automatic extraction from a BIM model is frequently observed. For example, Merkel, Ioshimoto, and Souza (2018) evaluated partially using BIM modeling to quantify the door installation service. Stradiotto *et al.* (2018) investigated the need for time and cost additives, comparing projects that used BIM with traditional quantification methods, considering the universe of public works projects tendered in Santa Catarina state. Andrade, Biotto, and Serra (2021), in turn, compared the accuracy of the BIM modeling method with the traditional way of quantitative extraction, studying the need for adaptations in the model and its parameters for the adoption of SINAPI unit cost compositions, to structural masonry service.

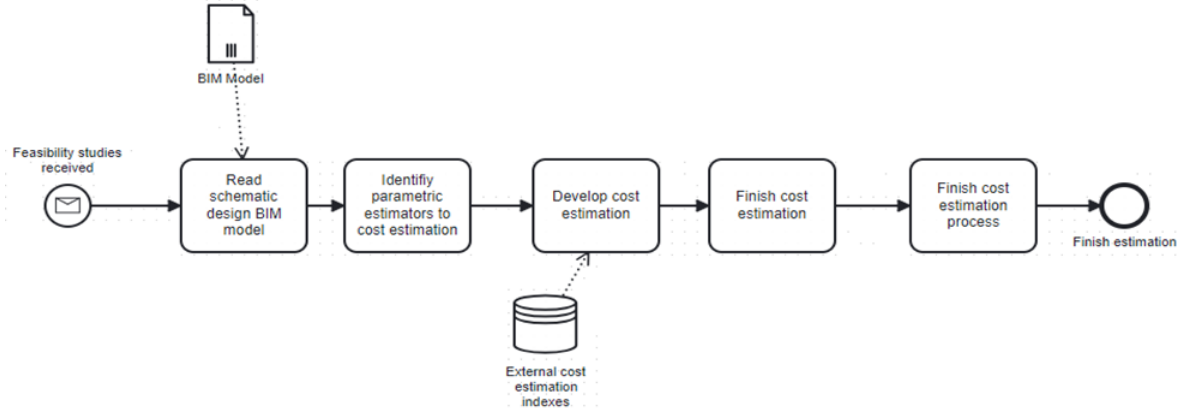
Widely used in the areas of management and engineering, DSR seeks to reduce the gap between theory and practice. Eight studies proposed artifacts as methods to solve a class of problems. For example, Santos, Costa, and Ferreira (2021) proposed a workflow for small and medium-sized companies capable of integrating BIM modeling, cost estimating, planning, and monitoring processes. Fenato *et al.* (2018), in turn, bring a method for BIM modeling of the operating budget that allows explicit calculation considerations and automates the extraction of quantities.

Both groups of articles that used a case study or DSR point to a defined sequence of tasks that involve, from the receipt of a project developed in BIM, the study and identification of services for the survey of quantities, and the subsequent survey itself. These tasks can be made through automated routines from a BIM model or manually in services that cannot be modeled (COSTA, 2015; MICELI JUNIOR; PELLANDA; REIS, 2020).

The cost estimation process is generally developed from a schematic design using parametric methodology involving reference tables and average price estimators. For

example, the average construction cost of an asset can be defined by multiplying its total area by the average cost per square meter. Figure 5 shows how to carry out this process (MICELI JUNIOR; PELLANDA; REIS, 2020).

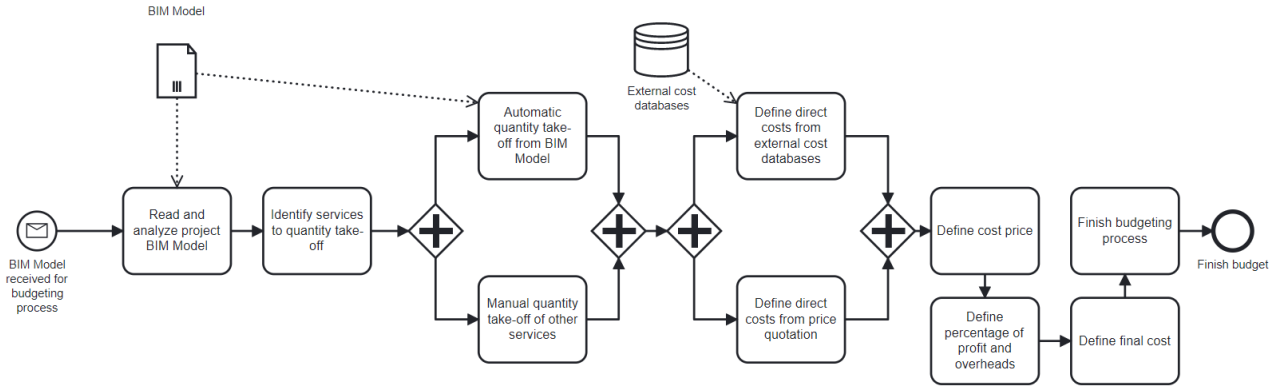
Figure 5 – Representation of a cost estimation process of a project



Source: adapted from Miceli Junior, Pellanda and Reis (2020).

On the other hand, Figure 6 shows the detailed budget process, in which direct costs are defined either by external cost databases or through quotes for inputs and services obtained from suppliers. The sum of the direct costs of each input together gives the direct cost of the construction, followed by the definition of the percentage of profits and indirect expenses and the subsequent conclusion of the detailed budget process with the final cost of the work (COSTA, 2015; SILVA; CRIPPA; SCHEER, 2019; MICELI JUNIOR; PELLANDA; REIS, 2020).

Figure 6 – Representation of a detailed budget process of a project



Source: adapted from Costa (2015) and Miceli Junior, Pellanda and Reis (2020).

The focuses of this review, the gains (Table 4) and difficulties (Table 5) in cost modeling in BIM, were addressed primarily as research results in the analyzed articles. As for the gains, compared to the benefits pointed out by the PSU in its guide (MESSNER *et al.*, 2022), it was noted that the ease of employing new estimators was not enumerated as a benefit for cost modeling in BIM in the national scenario. On the contrary, personnel training was identified as a difficulty in the Brazilian AEC industry. The other gains shown in Table 4 are in line with those raised by the PSU, indicating that, at this point, there is no differentiation for the Brazilian scenario.

Table 4 – Advantages of cost modeling in BIM

References	A1	A2	A3	A4	A5	A6	A7	A8
(MOTA; NETO BARROS 2012)		x						
(SOARES; AMORIM, 2012)	x			x				
(COSTA; SERRA, 2014)		x						
(NEIVA NETO; FARIA; BIZELLO, 2014)		x				x		
(BAGNO; ARANTES, 2016)	x		x					
(BASTO; LORDSLEEM JUNIOR, 2016)	x							x
(FENATO; SAFFARO; BARISON, 2016)	x		x					
(DANTAS FILHO.; BARROS NETO; ANGELIM, 2017)		x						
(BRITO *et al.* , 2018)	x							
(COSTA *et al.* , 2018)								x
(ELY; CARVALHO; CESAR, 2018)	x	x						
(FENATO *et al.* , 2018)	x		x			x		
(MATTANA; LIBRELOTTO, 2018)	x	x	x			x		
(MERKEL; IOSHIMOTO; SOUZA, 2018)	x							
(SENA *et al.* , 2018)				x				x
(STRADIOTTO *et al.* , 2018)							x	
(TASSARA; ARANTES, 2018)				x				
(VIANA; ARANTES, 2018)	x	x			x			
(BENAZZI JUNIOR; FREIRE, 2019)	x		x		x			
(GRUSKA *et al.* , 2019)	x	x						
(SENNA; SAUD; CASTRO, 2019)	x							
(SILVA; FERREIRA, 2019)	x							
(ANDRADE; BIOTTO; SERRA, 2020)	x	x			x	x		
(LATREILLE; SCHEER, 2020)	x	x						
(MATTANA *et al.* , 2020)	x	x					x	
(RODRIGUES *et al.* , 2020)	x		x	x	x			
(ANDRADE; BIOTTO; SERRA, 2021)	x	x			x	x		
(BEZERRA; RIBEIRO, 2021)	x	x	x	x				
(FELISBERTO *et al.* , 2021)	x			x		x		
(LATREILLE; SCHEER, 2021)			x	x	x	x		
(OLIVEIRA *et al.* , 2021)	x							
(ROMCY; SANTOS; ALMEIDA, 2021)	x				x			
(SANTOS; COSTA; FERREIRA, 2021)	x		x	x	x		x	

Note: A1 -Automatic quantitative extraction; A2 - Minimization of errors arising from manual surveys; A3 -Viewing and checking information; A4 - Decision-making assistance; A5 - Instant update of project-linked data; A6 - Traceability and identification of cost information; A7 - Ease of cost management during construction; A8 - Increased accuracy in cost estimates (early project phase). Source: the authors.

Table 5 - Challenges of cost modeling in BIM

References	C1	C2	C3	C4	C5	C6	C7	C8	C9
(MOTA; NETO BARROS, 2012)		x							
(COSTA; SERRA, 2014)	x				x				
(NEIVA NETO; FARIA; BIZELLO, 2014)	x								
(NEIVA NETO; RUSCHEL, 2015)						x			
(BAGNO; ARANTES, 2016)	x								
(BASTO; LORDSLEEM JUNIOR, 2016)		x							
(FENATO; SAFFARO; BARISON, 2016)	x		x						
(DANTAS FILHO.; BARROS NETO; ANGELIM, 2017)	x								
(BRITO ***et al.*** **,** 2018)	x								
(COSTA *et al.* , 2018)			x						
(ELY; CARVALHO; CESAR, 2018)		x							x
(FENATO ***et al.*** **,** 2018)			x						
(MATTANA; LIBRELOTTO, 2018)					x	x			
(MERKEL; IOSHIMOTO; SOUZA, 2018)	x	x			x			x	
(TASSARA; ARANTES, 2018)	x			x					
(VIANA; ARANTES, 2018)	x								
(BENAZZI JUNIOR; **FREIRE,** 2019)	x								
(GRUSKA ***et al.*** , 2019)	x			x					
(SENNA; SENNA; CASTRO, 2019)	x				x				
(SILVA; FERREIRA, 2019)			x						
(ANDRADE; BIOTTO; SERRA, 2020)			x						
(LATREILLE; SCHEER, 2020)	x	x	x						
(RODRIGUES ***et al.*** , 2020)	x	x		x					
(ANDRADE; BIOTTO; SERRA, 2021)	x		x			x			
(BEZERRA; RIBEIRO, 2021)	x	x	x	x			x		
(FELISBERTO ***et al.*** **,** 2021)	x					x			
(LATREILLE; SCHEER, 2021)	x						x		
(OLIVEIRA ***et al.*** , 2021)	x	x	x				x		
(ROMCY; SANTOS; ALMEIDA, 2021)	x								
(SANTOS; COSTA; FERREIRA, 2021)	x	x		x			x	x	

Note: C1 - Quality of information and level of detail in the model appropriate; C2 - Staff training Incompatibility of quantitative extraction with measurement criteria Interoperability related issues; C3 - Partial use of the model; C4 -Lack of information or omission of elements in the modeling; C5 - Lack of communication between professionals; C6 - Need for high financial investment; C7 - Lack of time to transition between methods. Source: the authors.

Among the advantages of using BIM to prepare budgets for constructions, compared to the traditional method of budgeting based on 2D models, the most obvious is the fact that it allows automatic extraction of quantities quickly and accurately, guaranteeing quality and the reliability of the data obtained. Also, reducing errors and omissions arising from the manual survey of quantities is often cited as a differential in applying BIM to prepare budgets.

In addition, the integration of cost information in the 3D design facilitates the visualization and checking of information, bringing them closer to the geometric characteristics of actual construction. In turn, the fact that the elements are parametrically designed in BIM facilitates the traceability and identification of cost information, bringing additional reliability and transparency to the use of public resources (FELISBERTO *et al.*, 2021).

Another benefit of using BIM is the aid to decision-making since it allows exploring different constructive scenarios to study hypotheses. The analyzed publications also list the possibility of instantly updating data linked to the project as it changes, reducing rework in case of corrections or simulations. In the public works scenario, Stradiotto *et al.* (2018) and Mattana *et al.* (2020) point to a lower need for contract changes concerning cost additives with implementing BIM projects, making cost management during construction easier.

As for greater precision in cost estimates, in the early stages of the BIM project, Basto and Lordsleem Junior (2016) show how easy it is to identify the items to which future changes in the project would bring significant changes to the final cost. FELISBERTO *et al.* (2021) deal with obtaining detailed pre-bid estimates, reducing the risk of underpricing.

On the other hand, the main difficulty mentioned for cost modeling in BIM is related to the need for the information model to be designed, developed, and prepared for data extraction to prepare the construction budget. To this end, it is essential to define, even in the initial phase of the project, standardization of modeling and classification systems of the elements that must be adopted. In this line, Tassara and Arantes (2018) reinforce the need for these guidelines to be established by managers in the early stages of the project since the lack of planning can result in difficulties in integration, collaboration, and lack of references in the standard of modeling.

The quality of the information and the detailing of the model are also determining factors for success in modeling costs in BIM (BAGNO; ARANTES, 2016; COSTA; SERRA, 2014; SENNA; SAUD; CASTRO, 2019). Silva and Ferreira (2019) warn that the Level of Development (LOD) must be compatible with the execution specifications of the services to enable the extraction of automatic quantitative, meeting the measurement criteria. Mattana and Librelotto (2018) confirm that the need for more information or omission about certain components in the modeling – such as reinforcement and the construction site – is associated with the proposed level of detail. Still, on this subject, Brito *et al.* (2018) point out the use of generative algorithms for preliminary cost estimates as an alternative, considering that, in the project's design phase, the constructive elements still need to be sufficiently detailed.

Technological restrictions inherent to BIM computational tools were verified, due to the need for more support for inserting specific budget information in the model, hindering data extraction. An example of this limitation is the lack of some classes of objects (COSTA *et al.*, 2018; FENATO *et al.*, 2018; FENATO; SAFFARO; BARISON, 2016).

Regarding the partial use of BIM, situations of use were presented in which, due to the restriction of extracting only part of the items from the budget spreadsheet automatically, it was necessary to finish the quantitative survey manually (COSTA; SERRA, 2014; MATTANA; LIBRELOTTO, 2018; MERKEL; IOSHIMOTO; SOUZA, 2018). Senna, Saud and Castro (2019) report that an obstacle was the incompatibility of some services extracted with the measurement criteria adopted by the reference tables, demanding a complementary analysis by a specialized professional. Mattana and Librelotto (2018) complement this reasoning when they address the difficulty of representing some elements in the modeling, such as, for example, the initial services of topography, drilling, projects, as well as project management.

Latreille and Scheer (2020, 2021) highlight the need for additional communication between project team members. The following were also mentioned as challenges: the need for staff training due to the shortage of skilled labor; issues related to interoperability; lack of time to make the transition between traditionally used methods and BIM technology (ELY; CARVALHO; CÉSAR, 2018) and the investment demand for the acquisition of BIM-compatible budgeting software (MERKEL; IOSHIMOTO; SOUZA, 2018).

The guidelines to help choose the type of modeling presented by Fenato *et al*. (2018), prioritizing the one that uses calculated parameters to obtain better results in automatic quantitative extraction, are among the main contributions of the analyzed studies. The authors also emphasize the need to develop classes of specific objects to improve the application of BIM to budgeting. In turn, Neiva Neto and Ruschel (2015) supply the need for object class referring to constructive projects of wooden formwork with the development of a library.

The action research carried out by Mattana and Librelotto (2018) presents various BIM tools used by management students in the Architecture and Urbanism course, focusing on construction budgeting. The authors emphasize the importance of the quantities extracted from the BIM model being aligned with the measurement criteria of the unitary compositions adopted in the budget. The collaboration between designers and the modeling quality is also essential for the success of cost modeling in BIM, evaluated by the level of detail of the information and the compatibility of the projects. Tassara and Arantes (2018) also address the importance of integration, communication, and stakeholder collaboration.

Latreille and Scheer (2020, 2021) point out the need for more standardization and subjectivity inherent in the budgeting process as a difficulty in implementing BIM in cost modeling. They also cite the ABNT NBR 15965 (ABNT, 2011) standard as a reference for BIM interoperability and collaboration processes, which proposes the development of a Construction Information Classification System suited to the reality of the national AEC industry.

Andrade, Biotto, and Serra (2020, 2021) point out that cost modeling in BIM for the budgeting process is more complex than that focused solely on extracting quantities. This conclusion is because, to incorporate this information into the model, the parameters, construction procedures, compositions, and costs of the database used as a reference must be considered.

Focused on the application of BIM in the budgeting of public works, the article by Viana and Arantes (2018) lists the major irregularities that the Federal Court of Auditors (TCU) identifies in this type of undertaking, justifying the use of BIM in its budgetary dimension, to reduce discrepancies arising from errors that are inherent in the manual survey of quantities.

Saud, Sena, and Castro (2019) developed a case study to compare the process of quantifying services in BIM with the traditional method. The authors highlighted the importance of achieving adequate Level of Detail (LoD) for the model to obtain good results. They also understand as essential of the participation of the Federal Government in encouraging the adoption of BIM in public works to catalyze the adoption of BIM in the national industry.

Silva and Ferreira (2019) expose the difficulties linked to cost modeling in BIM that meets the measurement criteria presented for the SINAPI unit cost compositions. Despite acknowledging the complexity inherent to the methodology for implementing some services, the authors guide the revision of the compositions of this database to make the budget services classification in the virtual model of the building easier.

Finally, Felisberto *et al.* (2021) propose guidelines to improve the accuracy of estimates, contemplating SINAPI and BIM, demonstrating that text parameters can be used to improve the process of estimating the elemental costs of the tree of 'SINAPI factors'.

Conclusion

Faced with the demand pointed out by Gruska *et al.* (2019), this article aimed, through conducting an RSL, to identify research gaps and raise advantages and challenges related to cost modeling in BIM, analyzing the Brazilian scientific production on the subject between 2011 and 2021 in journal articles and Congress proceedings.

It was possible to observe a growing tendency in national studies related to elaborating budgets associated with BIM models. Publications on the subject were more frequent in conference proceedings than in journals, with the case study being the most used methodological approach, followed by the DSR methodology. Autodesk Revit® software was the most used tool for modeling buildings in this context.

The most cited gain of using cost modeling in BIM was the automatic extraction of quantities, which minimizes errors arising from manual surveys. In addition, the ease of visualization of elements in the virtual model and the integration of geometry with parameters related to the budget, ensuring the traceability of information, were positive aspects highlighted in the references.

Regarding the difficulties faced, the need for the quality of information and the level of detail of the model to be adequate for extracting data for budgeting was highlighted. Specifically for the BIM budgeting of public works in Brazil, barriers were identified for choosing the compatible service among the existing variations that consider different measurement criteria and cost compositions. The importance of the Federal Government as a catalyst for the process was also highlighted, encouraging the adoption of BIM for budgeting public works.

The research gap was identified through the RSL by comparing the national reality with the benefits, skills, and needs for cost modeling in BIM, as pointed out in the PSU's BIM Project Execution Planning Guide (MESSNER et al., 2022). It was verified that only the benefit regarding the ease of using new estimators was not identified in the Brazilian context. Difficulties in training professionals were observed. Therefore, it can be understood that the Brazilian panorama still needs more research evaluating the training and implementation of BIM in public and private initiatives.

As for computational budgeting tools based on the BIM model, the required resource listed by Messner *et al*. (2022), the use of budget plug-ins associated with modeling software was often observed. No study has evaluated the compatibility of national

budgeting software, which is growing in the market, with the cost base measurement criteria available in the Brazilian AEC industry.

Another point raised in the PSU guide deals with identifying quantities compatible with the required level of estimation. It was noted that only 4 RSL articles focused on studying the preliminary costing phase, showing that the benefit of helping decision-making at the beginning of the project is still a little explored benefit.

The need for an accurate virtual model of the building and the competence required of the team to define specific modeling guidelines so that the quantitative survey is effective (both mentioned in the PSU guide) were frequently cited as difficulties to be faced. In this sense, Fenato *et al*. (2018) presented guidelines for choosing the type of modeling to obtain successful results in the extraction of quantitative data.

Concerning the ability to manipulate the models to extract quantities useful for budgeting, the researched literature raises points of incompatibility between the measurement criteria of the cost base adopted in public works (SINAPI) and the extraction of quantities from the virtual model. Also, in this sense, Latreille and Scheer (2020, 2021) point out in their suggestions for future work a way to unify the standardization of terminologies and improve cost modeling in BIM through the Brazilian standard for classification of construction information ABNT NBR 15965 (ABNT, 2011). None of the analyzed studies explored the integration between the norm and the BIM budgeting process.

Therefore, once the procedures that must be adopted are established to mitigate difficulties encountered in BIM cost modeling combined with appropriate BIM technologies and organizational policies aimed at this implementation, budgets become more assertive, confirming the significant BIM contribution to the panorama of AEC ventures.

Finally, it is worth mentioning that this review identified only part of the challenges faced in project budgeting since the sample was limited to the universe of publications of articles in the Brazilian academic context. Due to this fact, the scope of the RSL did not include BIM budgeting problems being circumvented in the daily life of the Brazilian design offices. Therefore, it is suggested that future work includes direct research with budgeting professionals from the private sector and public administration bodies to expand the mapping of barriers in the budgeting process in the Brazilian reality.

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References

ABNT. ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 15965:** Sistema de classificação da informação da construção. Parte 1: Terminologia e estrutura. Rio de Janeiro: ABNT, 2011.

ANDRADE, F. M. R.; BIOTTO, C. N.; SERRA, S. M. B. Modelagem BIM para Orçamentação com Uso do SINAPI. **Gestão & Tecnologia de Projetos**. São Carlos, v. 16, n. 2, abr./jun. 2021. DOI: https://doi.org/10.11606/gtp.v16i2.170318.

ANDRADE, F. M. R.; BIOTTO, C. N.; SERRA, S.M.B. Estudo do BIM 5D para orçamentação de um projeto público com uso do SINAPI. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 18., 2020, Porto Alegre. **Anais [...].** Porto Alegre: ANTAC, 2020. DOI: https://doi.org/10.46421/entac.v18i.1245.

BAGNO, Rodrigo; ARANTES, Eduardo. BIM no processo de orçamentação de um empreendimento residencial. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 16. 2016, São Paulo. **Anais [...].** Porto Alegre: ANTAC, 2016.

BASTO, P. E. A.; LORDSLEEM JUNIOR, A. C. O ensino de BIM em curso de graduação em engenharia civil em uma universidade dos EUA: estudo de caso. **Ambiente Construído**, Porto Alegre, v. 16, n. 4, p. 45-61, out./dez. 2016. DOI: https://doi.org/10.1590/s1678-86212016000400104.

BENAZZI JUNIOR, L. A.; FREIRE, F. Avaliação de quantitativos e planejamento de custos utilizando processo BIM. *In*: SIMPÓSIO BRASILEIRO DE TECNOLOGIA DA INFORMAÇÃO E COMUNICAÇÃO NA CONSTRUÇÃO, 2., 2019, Campinas. **Anais[...].** Porto Alegre: ANTAC, 2019. DOI: https://doi.org/10.46421/sbtic.v2i00.169.

BEZERRA, C. R. M.; RIBEIRO, S. A. Proposta de fluxo BIM otimizado para estimativa de custo e planejamento. *In*: SIMPÓSIO BRASILEIRO DE TECNOLOGIA DA INFORMAÇÃO E COMUNICAÇÃO NA CONSTRUÇÃO, 3., 2021, Uberlândia. **Anais [...].** Porto Alegre: ANTAC, 2021. p. 1-8. DOI: https://doi.org/10.46421/sbtic.v3i00.571.

BRASIL. Decreto nº 10.306, de 2 de abril de 2020. Estabelece a utilização do Building Information Modelling na execução direta ou indireta de obras e serviços de engenharia realizada pelos órgãos e pelas entidades da administração pública federal, no âmbito da Estratégia Nacional de Disseminação do Building Information Modelling - Estratégia BIM BR, instituída pelo Decreto nº 9.983, de 22 de agosto de 2019. **Diário Oficial da União**, Brasília, DF, 3 abr. 2020. p. 5. Disponível em: https://www.planalto.gov.br/ccivil_03/_ato2019-2022/2020/decreto/d10306.htm. Acesso em: 20 abr. 2023.

BRASIL. Decreto nº 7.983, de 8 de abril de 2013. Estabelece regras e critérios para elaboração do orçamento de referência de obras e serviços de engenharia, contratados e executados com recursos dos orçamentos da União, e dá outras providências. **Diário Oficial da União**, Brasília, DF, 8 de abril de 2013. Disponível em: https://www.planalto.gov.br/ccivil_03/_ato2011-2014/2013/decreto/d7983.htm. Acesso em: 20 abr. 2023.

BRASIL. Decreto nº 9.377, de 17 de maio de 2018. Institui a Estratégia Nacional de Disseminação do Building Information Modelling. **Diário Oficial da União**, Brasília, DF, 18 mai. 2018. p. 3. Disponível em: https://legislacao.presidencia.gov.br/atos/?tipo=DEC&numero=9377&ano=2018&ato=3bck3Z65UeZpWT387. Acesso em 20 abr. 2023.

BRASIL. Decreto nº 9.983, de 22 de agosto de 2019. Dispõe sobre a Estratégia Nacional de Disseminação do Building Information Modelling e institui o Comitê Gestor da Estratégia do Building Information Modelling. **Diário Oficial da União**, Brasília, DF, 23 ago. 2019. p. 2. Disponível em: https://www.planalto.gov.br/ccivil_03/_Ato2019-2022/2019/Decreto/D9983.htm#art15. Acesso em: 20 abr. 2023.

BRASIL. **Lei N° 13.303, de 30 de junho de 2016**. Dispõe sobre o estatuto jurídico da empresa pública, da sociedade de economia mista e de suas subsidiárias, no âmbito da União, dos Estados, do Distrito Federal e dos Municípios. Brasília, DF, 30 de junho de 2016. Disponível em: https://www.planalto.gov.br/ccivil_03/_ato2015-2018/2016/lei/l13303.htm. Acesso em: 20 abr. 2023.

BRITO, B. L. ARAÚJO, C. S.; FERREIRA, E. A. M.; COSTA, D. B. Estrutura lógica para programação generativa em BIM aplicada a estimativas preliminares de custo. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 17., 2018, Foz do Iguaçu. **Anais [...].** Porto Alegre: ANTAC, 2018. p. 3170-3180. Disponível em: https://eventos.antac.org.br/index.php/entac/article/view/1738. Acesso em: 20 abr. 2023.

COSTA, H. A.; FIALHO, B. C.; FRANCO, J. C.; RIBEIRO, J. TVD e BIM aplicados ao projeto de arquitetura hospitalar: experiência didática do uso de ferramentas de apoio à decisão. 2018. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 17., 2018, Foz do Iguaçu. **Anais [...].** Porto Alegre: ANTAC, 2018. Disponível em: https://eventos.antac.org.br/index.php/entac/article/view/1614. Acesso em: 17 maio. 2023.

COSTA, José Martins C. da. **Diagnóstico da Implantação do BIM em Empresas Construtoras com foco nos Processos de Planejamento, Orçamento e Controle de Obras.** 2015. 197 f. Dissertação (Mestre em Estruturas e Construção Civil) - Centro de Ciências Exatas e de Tecnologia, Universidade Federal de São Carlos, São Carlos, 2015. Disponível em: https://repositorio.ufscar.br/handle/ufscar/7179. Acesso em 20 fev. 2023.

COSTA, José Martins C.; SERRA, S. M. B. Comparação de processos de levantamento de quantitativos: tradicional e BIM. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 15., 2014, Maceió. **Anais [...].** Maceió: ENTAC, 2014.

DANTAS FILHO, J. B. P.; BARROS NETO, J. P.; ANGELIM, B. M. Mapeamento do fluxo de valor de processo de construção virtual baseado em BIM. **Ambiente Construído**, Porto Alegre, v. 17, n. 4, p. 343-358, out./dez. 2017. DOI: https://doi.org/10.1590/s1678-86212017000400201.

DRESCH, Aline; LACERDA, Daniel Pacheco; ANTUNES JÚNIOR, José Antônio Valle. Design science research. *In*: **Design science research:** a method for science and technology advanced**.** New York: Springer, 2015. p. 129-158.

EASTMAN, Charles; TEICHOLZ, Paul; SACKS Rafael; LISTON; Kathleen. **Manual de BIM:** Um guia de modelagem a informação da construção para arquitetos, engenheiros, gerentes, construtores e incorporadores**.** Porto Alegre: Bookman, 2014. 483 p.

ELY, D. M., CARVALHO, A. C. C., CÉSAR, C. G. Barreiras para a implementação do BIM na realização de orçamentos por empresas da construção. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 17., 2018, Foz do Iguaçu. **Anais [...].** Porto Alegre: ANTAC, 2018. p. 1731-1735. Disponível em: https://eventos.antac.org.br/index.php/entac/article/view/1524. Acesso em: 20 mar. 2023.

FELISBERTO, A. D.; MARCHIORI, F. F.; LOVE, P.; SIGNOR, R. BIM cost estimation guidelines for Brazilian public sector infrastructure**. PARC Pesquisa em Arquitetura e Construção**, Campinas, SP, v. 12, p. e021004, 2021. DOI: https://doi.org/10.20396/parc.v12i00.8659766.

FENATO, T. M.; SAFFARO, F. A.; BARISON, M. B.; HEINECK, L. F. M.; SCHEER, S. Método para elaboração de orçamento operacional utilizando um *software* de autoria BIM. **Ambiente Construído**, Porto Alegre, v. 18, n. 4, p. 279-299, out./dez. 2018. DOI: https://doi.org/10.1590/s1678-86212018000400305.

FENATO, Thalmus Magnoni; SAFFARO, Fernanda Aranha; BARISON, Maria Bernadete. Modelagem BIM para orçamento operacional. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 16., 2016, São Paulo. **Anais [...].** Porto Alegre: ANTAC, 2016. p. 3680-3695.

FERNANDES, C. A. P. **Interoperacionalidade em sistemas de informação.** 2014. 130 p. Dissertação (Mestre em Engenharia Civil) - Escola de Engenharia, Universidade do Minho, Azurém, Portugal. Disponível em: https://hdl.handle.net/1822/36150. Acesso em: 20 mar. 2023.

GRUSKA, C. F. G. G.; MARINHO, R. C.; VERAS, Y. M. BARROS NETO, J. P. Tendências e aplicações de BIM no orçamento e planejamento da construção civil. *In*: SIMPÓSIO BRASILEIRO DE TECNOLOGIA DA INFORMAÇÃO E COMUNICAÇÃO NA CONSTRUÇÃO, 2., 2019, Campinas. **Anais [...].** Porto Alegre: ANTAC, 2019. DOI: https://doi.org/10.46421/sbtic.v2i00.171.

KAMARDEEN, Imriyas. 8D BIM modelling tool for accident prevention through design. *In*: ANNUAL ARCOM CONFERENCE, 26., 2010. **Proceedings [...].** Leeds: Association of Researchers in Construction Management, 2010. p. 281-289.

KOUTAMANIS, Alexander. Dimensionality in BIM: Why BIM cannot have more than four dimensions? **Automation in Construction**, v. 114, p. 103153, 2020. DOI: https://doi.org/10.1016/j.autcon.2020.103153.

LATREILLE, D.; SCHEER, S. Análise de quantitativos provenientes de um modelo BIM 5D para adequação ao processo orçamentário das empresas de construção civil. **Gestão e Tecnologia de Projetos**, São Carlos, v. 16, n. 1, p.9 6-108, jan./mar. 2021. DOI: https://doi.org/10.11606/gtp.v16i1.163499.

LATREILLE, Denise; SCHEER, Sergio. Comparação de dados obtidos pelos métodos de quantificação tradicional e BIM para utilização em estimativa orçamentária do custo da construção. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 18., 2020, Porto Alegre. **Anais [...].** Porto Alegre: ANTAC, 2020. DOI: https://doi.org/10.46421/entac.v18i.1233.

LEE, A; WU, S; MARSHALL-PONTING, A. J.; AOUAD, G.; COOPER, R.; TAH, J. H. M.; ABBOTT, C.; BARRETT, P. S**. nD Modelling Roadmap:** A Vision for nD-Enabled Construction**.** Salford: University of Salford, 2005. 108 p. Disponível em: https://salford-repository.worktribe.com/preview/1495504/nD%20Modelling%20Roadmap%20-%20Developing%20a%20Vison%20of%20nD-Enabled%20Construction.pdf. Acesso em: 20 abr. 2023.

MATTOS, Aldo Dórea. **Como preparar orçamentos de obras**: dicas para orçamentistas, estudos de caso, exemplos. 2. ed. São Paulo: Pini, 2009.

MATTANA, L.; LIBRELOTTO, L. I. Estratégias para ensino de orçamentação com adoção de BIM em ambiente acadêmico. **Gestão & Tecnologia de Projetos**, São Carlos, v.1 3, n. 3, p. 97-118, dez. 2018. DOI: https://doi.org/10.11606/gtp.v13i3.139505.

MATTANA, Leticia; BEDIN, Carla; KOERICH, William Pauli; VILLELA, Mateus Coivo; PORTO, Matheus Porfírio; SOUZA, João Carlos; SPRICIGO, Danielli Godinho; FOLADOR, Beatriz. Inovações tecnológicas: da captura de dados reais até o orçamento – caso de manutenção de fachadas. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 18., 2020, Porto Alegre. **Anais [...].** Porto Alegre: ANTAC, 2020. DOI: https://doi.org/10.46421/entac.v18i.1223.

MERKEL, D. C.; IOSHIMOTO, E.; SOUZA, U. E. L. Como incentivar o uso do BIM para auxiliar a quantificação de serviços em orçamentos. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 17., 2018, Foz do Iguaçu. **Anais [...].** Porto Alegre: ANTAC, 2018. Disponível em: https://eventos.antac.org.br/index.php/entac/article/view/1733. Acesso em 20 abr. 2023.

MESSNER, J.; ANUMBA, C.; DUBLER, C.; GOODMAN, S.; KASPRZAK, C.; KREIDER, R.; LEICHT, R.; SALUJA, C.; NEVE, Z.; ZIKIC, N.; BHAWANI, S. **BIM Project Execution Planning Guide:** Version 3.0. Harrisburg: Pennsylvania State University, 2022. Disponível em: https://psu.pb.unizin.org/bimprojectexecutionplanning/. Acesso em: 4 out. 2022.

MICELI JUNIOR, G.; PELLANDA, P. C.; REIS, M. C. Management procedure for sensitive projects in the context of a BIM adoption in a public organization. *In*: CIB W78 INFORMATION TECHNOLOGY FOR CONSTRUCTION CONFERENCE (CIB W78), 37., 2020, São Paulo. **Proceedings […]**. São Paulo: CIB W78, 2020. p. 232-247. DOI: http://dx.doi.org/10.46421/2706-6568.37.2020.paper017.

MOTA, Paula Pontes; NETO BARROS, José de Paula. Processo de implantação do BIM em uma construtora de pequeno porte. *In:* ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 14., 2012, Juiz de Fora. **Anais [...].** Juiz de Fora: ENTAC, 2012. Disponível em: http://www.repositorio.ufc.br/handle/riufc/57802. Acesso em: 20 mar. 2023.

NEIVA NETO, R. S.; RUSCHEL, R. C. BIM aplicado ao projeto de fôrmas de madeira em estrutura de concreto armado. **Ambiente Construído**, Porto Alegre, v. 15, n. 4, p. 183-201, out./dez. 2015. DOI: https://doi.org/10.1590/s1678-86212015000400046.

NEIVA NETO, Romeu da Silva; FARIA, Brayer Luiz de; BIZELLO, Sérgio Adriano. Implantação de BIM em uma construtora de médio porte: caso prático, da modelagem a quantificação. **PARC Pesquisa em Arquitetura e Construção**, Campinas, v. 5, n. 1, p. 45-51, jan./jun. 2014. DOI: https://doi.org/10.20396/parc.v5i1.8634543.

OLIVEIRA, Eloise de; SCHEER, Sergio; TAVARES, Sergio Fernando. Avaliação de impactos ambientais pré-operacionais em projetos de edificações e a modelagem da informação da construção. *In*: Encontro de Tecnologia de Informação e Comunicação na Construção**,** 7.; Recife, 2025. **Anais […].** Porto Alegre: ANTAC; São Paulo: Blucher Engineering Proceedings, 2015. p. 179-191. DOI: 10.5151/engpro-tic2015-016.

OLIVEIRA, R. B.; ARAÚJO, L. G.; CARVALHO, M. T. M..; BLUMENSCHEIN, R. N. Critérios básicos de modelagem para orçamentação em BIM de um projeto arquitetônico. *In*: SIMPÓSIO BRASILEIRO DE TECNOLOGIA DA INFORMAÇÃO E COMUNICAÇÃO NA CONSTRUÇÃO, 3., 2021, Uberlândia. **Anais [...]**. Porto Alegre: ANTAC, 2021. p. 1-9. DOI: https://doi.org/10.46421/sbtic.v3i00.612.

PETTICREW, M.; ROBERTS, H. **Systematic reviews in the social sciences:** a practical guide**.** Malden: Blackwell, 2012. 335 p.

RODRIGUES, Osvaldo Sélos; DIAS, Nathalia Schimidt; SALADO, Gerusa de Cássia; KEMPTER, Eloisa Dezen. Exercícios de automação para orçamentação de obras através da ferramenta BIM. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 18., 2020, Porto Alegre. **Anais [...].** Porto Alegre: ANTAC, 2020. p. 1-9. DOI: https://doi.org/10.46421/entac.v18i.1229.

ROMCY, N. M. S.; SANTOS, V. A..; ALMEIDA, V. K. P. Proposta de disciplina de orçamentação integrada ao BIM para o curso de arquitetura e urbanismo. *In*: SIMPÓSIO BRASILEIRO DE TECNOLOGIA DA INFORMAÇÃO E COMUNICAÇÃO NA CONSTRUÇÃO, 3., 2021, Uberlândia. **Anais [...].** Porto Alegre: ANTAC, 2021. p. 1-8. DOI: https://doi.org/10.46421/sbtic.v3i00.596.

SAKAMORI, M. M. **Modelagem 5D (Bim)**: Processo de orçamentação com estudo sobre controle de custos e valor agregado para empreendimentos de construção civil**.** 2015. 118 f. Dissertação (Mestrado) - Programa de Pós-graduação em Engenharia de Construção Civil. Universidade Federal do Paraná, Curitiba, 2015. Disponível em: https://hdl.handle.net/1884/41394. Acesso em 20 mar. 2023.

SANTOS, M. C. F.; COSTA, D. B.; FERREIRA, E. A. M. Information workflow proposal for integrating cost estimating, scheduling, and monitoring with BIM in SMEs. **Ambiente Construído**, Porto Alegre, v. 21, n. 2, p. 113-129, abr./jun. 2021. DOI: https://doi.org/10.1590/s1678-86212021000200517.

SENA, T. C.; SENA, P. C. P.; PHILIPPSEN JR., L.; FABRICIO, M.; PRATSCHKE, A. Buiding information modeling (BIM) e ferramentas 4D e 5D para simulação e tomada de decisão no processo de projeto de edificações. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 17., 2018, Foz do Iguaçu. **Anais [...].** Porto Alegre: ANTAC, 2018. Disponível em: https://eventos.antac.org.br/index.php/entac/article/view/1583. Acesso em: 20 jun. 2023.

SENNA, A. C.; SAUD, D. N.; CASTRO, I. P. BIM 5D em obras públicas - BIM 5D em obras públicas - Estudo de caso comparativo entre métodos de extração de quantitativos em edificação residencial. *In*: SIMPÓSIO BRASILEIRO DE TECNOLOGIA DA INFORMAÇÃO E COMUNICAÇÃO NA CONSTRUÇÃO, 2., 2019, Campinas. **Anais [...].** Porto Alegre: ANTAC, 2019. p. 1-8. DOI: https://doi.org/10.46421/sbtic.v2i00.170.

SILVA, Paula Heloisa da; CRIPPA, Julianna; SCHEER, Sergio. BIM 4D no planejamento de obras: detalhamento, benefícios e dificuldades. **PARC Pesquisa em Arquitetura e Construção**, Campinas, SP, v. 10, p. e019010, fev. 2019. DOI: https://doi.org/10.20396/parc.v10i0.8650258.

SILVA, R. P.; FERREIRA, S. L. Análise do serviço de chapisco do SINAPI para utilização em projetos BIM. *In*: SIMPÓSIO BRASILEIRO DE TECNOLOGIA DA INFORMAÇÃO E COMUNICAÇÃO NA CONSTRUÇÃO (SBTIC), 2., 2019, Campinas. **Anais [...].** Porto Alegre: ANTAC, 2019. p. 1-5. DOI: https://doi.org/10.46421/sbtic.v2i00.168.

SOARES, Raquel Canellas; AMORIM, S. R. L. Aplicação da tecnologia BIM em estudos de viabilidade. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 14., 2012, Juiz de Fora. **Anais** [...]. Porto Alegre: ENTAC, 2012. p. 2258-2269.

STRADIOTTO, J.; KERN, A. P.; KLERING, A.; RAMÃO, A. C. L. Processo BIM em projetos de licitações de obras públicas do CRAS de Santa Catarina, Brasil. *In*: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 17., 2018, Foz do Iguaçu. **Anais[...].** Porto Alegre: ANTAC, 2018. p. 3355-3362. Disponível em: https://eventos.antac.org.br/index.php/entac/article/view/1762. Acesso em: 20 maio 2023.

SUCCAR, B. **Building Information Modelling:** conceptual constructs and performance improvement tools. 2013. 396 p. (Doctor of Philosophy) - School of Architecture and Built Environment Faculty of Engineering and Built Environment, University of Newcastle, Callaghan, 2013. Disponível em: http://hdl.handle.net/1959.13/1056167. Acesso 20 abr. 2023.

SUCCAR, Bilal; SALEEB, Noha; SHER, Willy. Model uses: foundations for a modular requirements clarification language. *In*: AUSTRALASIAN UNIVERSITIES BUILDING EDUCATION CONFERENCE, 40., 2016, Cairns. **Proceedings [...].** Canberra: Australian Buiding Codes Board, 2016. p. 45-57, 2016.

TASSARA, G., ARANTES, E. A importância da integração para a automação do BIM nas etapas de modelagem e orçamentação. In: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 17., 2018, Foz do Iguaçu.

Anais [...]. Porto Alegre: ANTAC, 2018. p. 3108-3115. Disponível em: https://eventos.antac.org.br/index.php/entac/article/view/1731. Acesso em: 20 abr. 2023.

VIANA, L. D., ARANTES, E. M. A utilização da ferramenta BIM 5D para obras públicas no Brasil. In: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 17., 2018, Foz do Iguaçu. **Anais [...].** Porto Alegre: ANTAC, 2018. p. 3087-3093.

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