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BUILDING INFORMATION MODELING (BIM) AND PROJECT MANAGEMENT: DIGITAL TWINS THAT ALLOW THE COSTS OPTIMIZATION BASED ON THE SIMULATION OF COMPUTATIONAL MODELS

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BUILDING INFORMATION MODELING (BIM) AND PROJECT MANAGEMENT: DIGITAL TWINS THAT ALLOW THE COSTS OPTIMIZATION BASED ON THE SIMULATION OF COMPUTATIONAL MODELS

Abstract: This technical report discusses the significance of using building information modelling (BIM) in project management as a tool to enhance cost reduction based on the simulation of computational models. The **methodology** employed was the case study of a software solution that makes its product libraries available in BIM format, intended for the simulation of computational models of a multinational company. Data were collected through document analysis and interviews with specialists from the Siemens company. The **conclusion** of the data analysis of this study resulted in a better understanding of the issues that the simulation of computational models idealised by BIM methodology and their data proposes to solve. The findings show that the simulation of computational models contributes to decision-making in civil construction, whether in the design of new buildings or modernization processes. The **contribution** of this work is strengthened by presenting a benefits proposal for the use of computational modelling in the context of civil construction using good design practises.

Keywords: Project Management. BIM. Building Information Modelling. Project Optimization.

1 Introduction

The objective of this technical report is to discuss the importance of using computer model simulation in the development and management of projects using building information modelling (BIM). As a study objective, a solution of software libraries from Siemens, a German multinational company, was analysed to understand how the simulation of computational models on BIM can contribute to decision making to reduce costs in civil construction, considering both contexts of projects in new constructions and modernization processes – BIM simulations even allow the simulation of the later operation of the building, the idea here is to ensure that if construction costs can be reduced in one way, these decisions also positively impact the reduction of operating costs, through the right decisions taken with the computer simulation process. According to Valezi, Abreu-Tardeli, and Nascimento (2018), the importance of technical-scientific reports is given, since they document the results obtained from the activities and/or experiences carried out, as well as allowing to discuss the results in technical activity. In the same direction, the work of Biancolino, Kniess, Maccari and Rabechini Jr (2012), highlights the importance of the technical contribution of a work carried out with professional application and made with the rigor of scientific research.

The reported case presents the benefits of applying simulation of computational models in the development and management of projects using BIM software libraries. In this case, to achieve the cost reduction idealized by the software libraries of the Siemens company, it was identified that the application of BIM supports decision-making throughout the life cycle of a building project. In this sense, it is possible to virtually build a building, and only after the virtual model meets all technical requirements, is it released to be physically constructed – this allows the building to support the needs of changes that occur throughout its useful life. The study by Asdrubali, Baggio, Prada and Grazieschi (2020), recommends that the useful life of a building is approximately 50 years – this will need regular modernizations.

This technical report uses the qualitative approach with the application of the case study methodology to analyse the benefits of the use of computational modelling simulation to develop building projects and to propose the benefits using the best practices of projects in the context of civil construction. On the other hand, the methodological procedure consisted in documentary analysis and interviews with Siemen's specialists.

Following in the next sections of this technical report: theoretical framework, methodology, context of the technical report and problem situation, obtained results and analysis, conclusion and final considerations, references, and appendix.

2 Theoretical Framework

This chapter introduces the theory that underlies the topic studied. This is organized into three parts, to meet the general objective. The first part proposes a reflection on BIM and its value proposition. The second part introduces BIM as a tool in project management. The last part investigates the benefits of using the BIM methodology in construction projects.

2.1 The building information modelling (BIM) and its value proposition

With the advancement of technology in the digital world, digitization offers a new path in terms of how commercial buildings can be planned, built, operated, and managed (Siemens Switzerland Ltd, 2018). According to Cozmiuc and Petrisor (2018), the digital transformation, developed in a disruptive way in Industry 4.0, contemplates the fusion of virtualization with integration at different levels. Motivated by the opportunities that the virtualization process offers, a new option for high-performance building projects is born, which contemplates the minimization of risks and the maximization of profits throughout its life cycle – to make this possible, the conceptions of digitized projects include both the 3D design of the building structure, as well as the electric and electronic systems that will be shipped and simulated, as well as all the attributes that are related to each other, in other words, semantically (Mayer, et al., 2014) (Siemens Switzerland Ltd, 2018). In this context, it is possible to develop projects that in addition to being efficient, safe, and comfortable, meet the highest technical levels of use and operation requirements, also known in the market as human-centred (Siemens Switzerland Ltd, 2018).

To carry out simulations of computational models, BIM objects and their data are made available through devices libraries. Between structural and systemic libraries, the building's structural libraries include items such as separation of environments, stairs, doors, and windows, and the libraries of electronic systems devices, offer items that allow predictively simulating, operating, and knowing technical details of a building even before its construction, and, ultimately, create its digital twin (Siemens Switzerland Ltd, 2018). Nationally, the Brazilian government, through Decree 9.983 / 2019, presents its national strategy for the dissemination of BIM in Brazil and potentially attracts investments in the sector (BRASIL, 2019). In the author's view, an important measure for the development of the economy of this sector in the country.

The BIM is a powerful work methodology, internationally regulated by ISO 19650 that uses digital representation libraries that facilitate the design, construction, and process operation to form a basis for the decision process (ISO 19650-1, 2018). According to the German Federal Ministry of Transport and Digital Infrastructure, BIM is a methodology based on cooperation that makes use of digital structural models of buildings that deal with relevant data of the useful lifecycle of buildings that even allows the transparent communication of information for future processing – its methodological premises assure a significant increase in productivity in the design, construction and operation of buildings process as well as in infrastructure facilities (Whitlock, Abanda, Manjia , Pettang, & Nkeng, 2021).

It should be emphasized that the use of BIM in building projects generates a high potential for optimization in each phase of the building's lifecycle. In the design phase, data provides support for gathering essential and up-to-date data on technical requirements and avoids extra work or rework. In the construction phase, the data provide support for accurate documentation, minimizing the risk of delays and budgeting. In the operation phase, the data provide support for relevant operational documentation, which directly impacts maintenance and more profitable management throughout the building's life cycle.

Figure 1 presents a real application, developed with BIM objects and their data libraries – Figure 1a, 1b, and 1c, presents the fields of BIM use for design, construction and operation phases, and Figure 1d, presents an example of device data BIM provided by Siemens Building Products.

Figure 1 – Example of BIM application and device library.

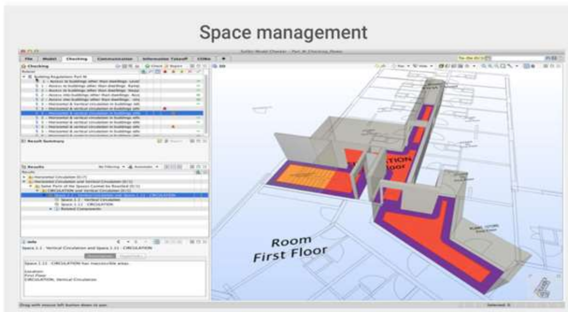


Figure 1a – BIM use in design phase.

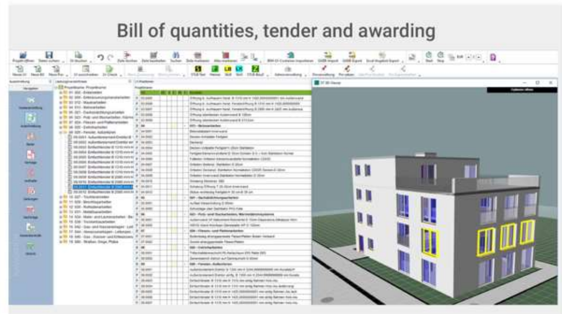


Figure 1c – BIM use in operation phase.

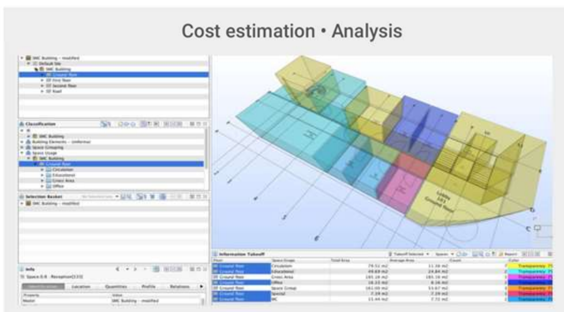


Figure 1b – BIM use in construction phase.

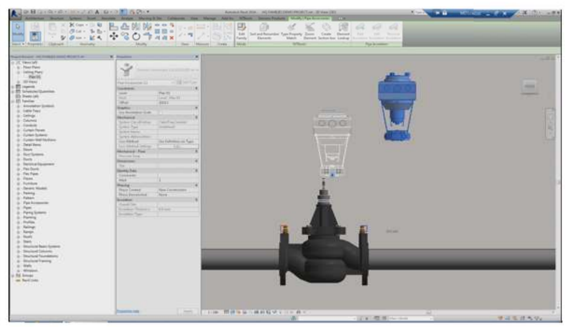


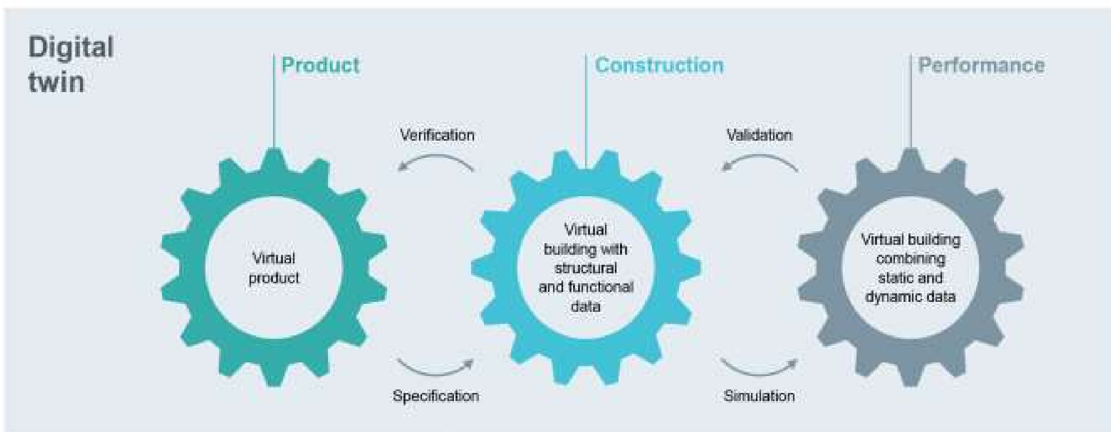
Figure 1d – Example of a BIM device by Siemens.

Source: Figures 1a, 1b and 1c provided by DEUBIM / EDUBIM, and Figure 1d provided by Siemens.

The term digital twin is widely used in conjunction with projects that use the BIM methodology – In itself, the term contemplates the fusion of knowledge between the areas of Internet of Things, big data, and cloud computing for applications that allow the physical (real) to interact with the virtual (simulated) building spaces (Nie, Xu, Cheng, & Yu, 2019).

A digital twin of a building allows performing a digital simulation of its physical equivalent twin. The computational model simulation process gathers dynamic and static data from various data sources, that includes a 3D model, providing relevant data output so that decision making is effective – for example, it is possible to simulate the effects of lighting, thermal load, and air quality conditions inside a building's office complexes, such as temperature, humidity, and CO_2 for decision making in the context of thermal and energy efficiency (Siemens Switzerland Ltd, 2018). In this context, there is a direct correlation between the real world to be built and the simulated virtual world. The computer model simulation process provides a real-time understanding of the performance that a building can have, starting at its launch, and extended throughout its life cycle, thus resulting in an intelligent, economical, and sustainable building (Siemens Switzerland Ltd, 2018). In this sense, several studies have been conducted to understand possible biases that may exist between the real twin and the simulated virtual twin (Gichane, et al., 2020). According to Siemens Switzerland Ltd (2018), a project of a building that will have the simulation of its digital twin must have the following structures: 1 – Digital twin of the devices in a building; 2 – Digital twin of the structural components of a building, this means incorporating static data such as floor plans, location of assets, etc.; 3 – Digital twin of dynamic data, such as performance data, time-series data. In this sense, for complete digitization, market simulation software and systems must consider these three frameworks, in other words, each framework applies one of the three digital twins that together serve the entire digitization ecosystem. Figure 2 exemplifies these three structures.

Figure 2 – Digital twin defined.



Source: As extracted from the literature from (Siemens Switzerland Ltd, 2018, p. 6).

The next topic introduces BIM conceptualization from the perspective of project management – in contexts of management and its benefits.

2.2 The building information modelling (BIM) as tool in project management

Applying the BIM methodology is not only a software tool that can be innovative, but its use can significantly change the way a project will be acquired, built, managed, and operated. Arguably, the benefits of applying the BIM methodology do not apply directly to project managers – the benefits are measured by the effective contribution to the success of the project, delivered by the project managers. The findings of Xiao and Noble (2014), summarize important and in-depth points of this discussion, as shown in Table 1.

Table 1 – Potential Benefits of BIM to Project Management.

Potential BIM Benefits to Project Management	Rationale
Project programme and budget control	A BIM model can instantly update both the programme and budget when modifications are made to the design.
Design team collaboration	A BIM model can enable the impact of changes to be fully analysed and thus the scope can be monitored to enable the PM to liaise easily with the design team and clients.
Subcontractor control	Increased knowledge on clash detection changes, information requests etc. results in sub-contractor work becoming more predictable.
Request for Information (RFI) and change orders	The increased certainty brought about by BIM should result in a marked reduction in the number of changes and RFI's.
Progress monitoring	By utilising BIM, the PM has more tools available to understand and report on progress.
Client understanding	The client can understand a virtual model far easier than a 2D drawing, thus increasing understanding and satisfaction about the end product.
Project closure	BIM captures O&M information which can be used throughout the life of the building. This also saves significantly on administration costs as well as on-going management.
Mandatory BIM and growth	As clients increasingly request BIM, the PM firm can become skilled and grow faster than competitors.

Source: As extracted from the literature from (Xiao & Noble, 2014, pp. 694-695).

The Project Manager is a key player in delivering successful projects – within the context of success, BIM can support, in addition to the traditional delivery of results, more effective delivery of value in projects (Xiao & Noble, 2014). In this context, these findings are fully aligned with the PMBOK, which determines that the project manager is responsible for achieving the project objectives, through the successful delivery of the project, this includes the integration of processes and knowledge management described in the team management item (PMI, 2017). On the other hand, keeping the attention on PMBOK, it is important to highlight that chapter 12 recognizes the BIM methodology as an advance in tools that support the idea of significant time, money, and schedule savings in the projects that use it (PMI, 2017). In the same direction, the roles and responsibilities of project managers must be clearly defined – the use of BIM will become increasingly attractive, precisely because it is based on delivering value, however, it should be noted that the project managers will always be the protagonist and the tools and methodologies are nothing more than improving the processes in projects (RICS, 2017). According to Fadey (2017), an important factor to potentialize the benefits that the BIM methodology can provide in project management may be in the contracting model adopted for the delivery of the building project.

2.3 The benefits of building information modelling (BIM) in cost optimization in projects

According to the report data published by Dodge Data and Analytics (2013), projects using BIM are impacted by five benefits: Fewer RFIs during construction, reduced material waste, shortened schedule, lower final construction cost and fewer safety incidents. In a survey carried out by owners in the US and UK, developed by McGrow Hill Construction (2014), the owners were asked to describe the benefits they saw in the application of BIM methodology in their companies, the results can be seen in Figure 3.

Figure 3 – The owners' perspectives on the benefits of BIM.

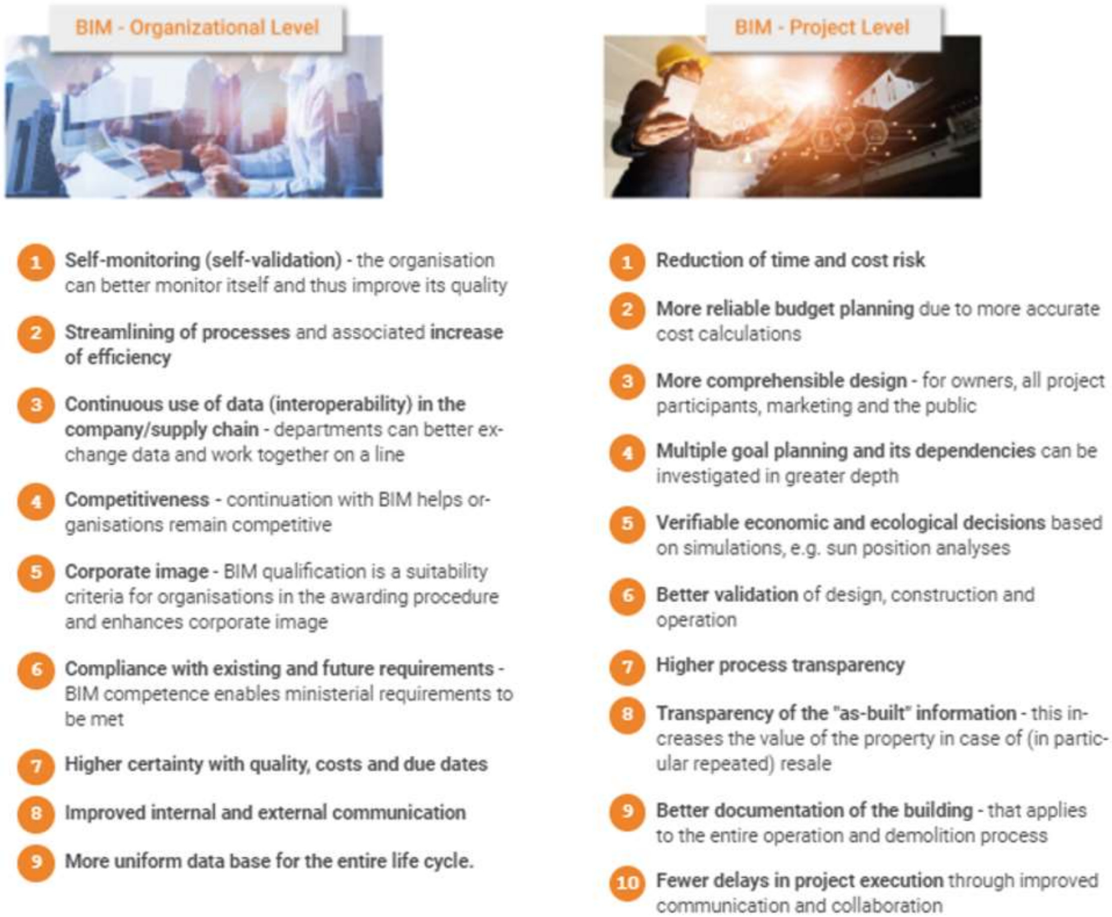
Ranking	US	UK
1	Better Team Coordination/ Collaboration	Better Team Coordination/ Collaboration (tie)
2	Use for Facility Maintenance and Operations/ Long-Term Management	Better Accuracy/ Fewer Errors/ Better Quality (tie)
3	Helps With Visualization/ Understanding Concepts & Scope	More Efficient Design/ Build Process/ Standardized (tie)
4	Better Accuracy/ Fewer Errors/ Better Quality	Cost Savings
5	Cost Savings	Helps With Visualization/ Understanding Concepts & Scope

Source: As extracted from the literature from (McGrow Hill Construction, 2014, p. 34).

The BIM methodology is at the centre of innovation, regardless of government or private contexts, which has strategic benefits from cost, quality, and policy goals (EUBIM, 2016).

According to the DEUBIM / EDUBIM., there are 19 reasons to implement the BIM methodology, with benefits that permeate both the organization and the projects. Figure 4 shows the benefits.

Figure 4 – The benefits of implement BIM methodology according to DEUBIM / EDUBIM.



Source: Image courtesy by DEUBIM / EDUBIM.

Addressing a triad of design – construction – operation, a computer model simulation significantly contributes to consistent cost and time reduction. In the design phase, BIM technology makes it possible to compare the technical contributions provided by the project participants. Empirical findings show that the use of BIM technology increases the quality of the project, brings precision to the cost estimating, and provides support for the control of changes, and rework reduction (Yaru, 2021). In the sequence of the triad: design - construction - operation, it is important to mention the importance of the construction element, in this sense, it is worth resuming some important concepts evangelized by BIM. According to the glossary of the German company EDUBIM (2021), a simulation dimension can be up to six-dimensional, which are: 2D - floor plans, two-dimensional, with x,y coordinates; 3D – graphical description, three-dimensional, with x,y,z coordinates; 4D – four-dimensional, refers to the connection between 3D and time components, which allows simulating models in time; 5D –

five-dimensional, refers to the connection between 4D and costs, which allows for the inclusion of cost estimates; 6D – six-dimensional, refers to sustainability and facility management, which allows monitoring the life cycle of a conceptual model of a building. In the construction phase, BIM ensures cost savings by significantly increasing the accuracy of the modelling – using 4D (time), 5D (cost) and 6D (as-built) simulations not only to calculate costs and times but also to compare them with the actual construction progress (Smith, 2014) (Lee, et al., 2021). To finish the triad, the operational costs phase gains notoriety if integrated with the technical requirements in the design process. That is, the main idea is to ensure maintenance histories linked to the components. In this regard, the findings of Yin, Liu, Yuan, Wang, and Al-Hussein, (2020), demonstrate that performing facility management allows maintenance and management personnel to obtain complete information in real-time before making any management decisions.

Holistically, the BIM methodology facilitates the communication between the project team members, which allows increasing the communication process, a key factor in the creation of digital twins, annoying double work due to miscommunication or outdated data is avoided – processing and storage the project data from a single location and serving the entire project team (Kocakaya, Namlı, & Işıkdağ, 2019). The findings of Olugboyega and Windapo (2020) assure that the use of BIM makes consistent both the mixed and structured communication. People also are at the centre of the BIM methodology, data from this research show the importance of the role of the project manager and the involvement of the multidisciplinary team members responsible for the success of the projects. The findings of Kouch, Illikainen, and Perälä (2018), define that there are five factors of challenges and issues in the use of BIM methodology, these factors can be described in five main fields, such as people, technology, process, organization, and policy. On the other hand, the research of Amuda-Yusuf (2018) presents a model that organizes 28 critical success factors into just five groups of factors, which are: 1 – the commitment of stakeholders and knowledge of BIM; 2 – the potential to adopt technology; 3 – organizational support; 4 – collaborative synergy among professionals and; 5 – cultural orientation. Different studies that moving in the same direction.

Finally, at the end of this chapter, it is important to show some numbers that translate into figures the time and cost savings capacity that the BIM methodology can offer. Previously, a traditionally study from Stanford University Gao and Fischer (2008) reported the following savings data after analysing 32 cases of projects: up to 40% decrease in non-budgeted change-orders, up to 7% shortened project timeline, up to 9% lower operational costs and up to 3.5%

higher occupancy rate. The next section introduces the methodological procedure that contemplates the field research. Other studies and technical reports from specialist companies on the matter have also published complementary and consolidating data, such as data reported by the Boston Consulting Group by the study of Gerbert, Castagnino, Rothballer, Renz, and Filitz (2016) that informs for the Vertical Construction segment, which it supplies two categories of data: 1 – cost reduction: which is expected to reduce design, engineering and construction costs of up to 15% - for complex buildings, such as hospitals, a reduction of up to 25% is expected, and for the operation, numbers of up to 23% are expected; 2 – time reduction: Construction phase with faster deliveries with estimation up to 30% of the time. According to EUBIM (2021), the adoption of BIM delivers up to 10% of savings to the construction and up to 20% of capital project expenditure. In a recent study, the finds of the research of Duarte, Zemero, de Souza, Tostes, and Bezerra (2021), analysed how BIM could improve energy efficiency in an educational building. Through the BIM simulations, it was possible to achieve the energy reductions nearby 8%...12% for the lighting system and nearby 7%...9% for the ventilation system.

The next section introduces the methodological procedure that contemplates the field research.

3 Methodology of technical production

Qualitative research (QR) entails delving deeper into a topic to comprehend it – QR is a multifaceted method that includes interview, observation, textual analysis, and field research (Tracy, 2020). In the QR methodology, inductive or deductive approaches can be used. The inductive approach is one of reasoning – a straightforward approach to creating understanding that works from the bottom up, or from small to large. In contrast, the deductive approach begins with external theories and works its way through assumptions and criteria to frame the study's meanings. Either of the two approaches allows us to examine the phenomenon under investigation so that it can be described from the researcher's perspective, specifically for that context, using specific criteria (Tracy, 2020).

The importance of using structured questionnaires from the fact that they allow for the collection of data in a structured, organised, and planned manner, and they are recommended when comparing databases (Tracy, 2020).

As the objective of this technical report is to verify how the simulation of computational models that make use of BIM can support the optimization of costs in projects, the qualitative method with a deductive approach was used, and an interview guided by a structured questionnaire was defied for being the most suitable to achieve the objective of this study. The field interview included steps for planning, data collection and data analysis steps. In the planning phase, the questions were developed based on the theoretical framework. During the collection phase, interviews were conducted, and a questionnaire was completed. Finally, in the analysis phase, the answers were analysed so that they could be compared to the theory presented in the theoretical framework.

4 Context of the technical report and problem situation

The production of this technical report took place in a German multinational company that was founded in 1847 in Germany and has been present in Brazil since 1867 (Siemens, 2012). With nearly 1600 employees in Brazil, it has its headquarters in São Paulo – SP, and operates in the sector of various industries. Siemens also manufactures products for the building applications and provides libraries of its products designed in CAD and BIM for use by all project stakeholders, which includes project-offices, technical consultants, architects' offices, and construction companies. These libraries include features such as: 1 – open BIM, download IFC files; 2 – 2D & 3D, download DXF and RFA files; 3 – Draw into REVIT, using REVIT kernel; 4 – Symbol view at LOD100, display as 2D symbols When creating 2D plans in REVIT; 5 – Industry classifications, data sets include ETIM, IFC, OmniClass and UniClass classifications.

The solution of libraries developed in BIM by the German manufacturer aims to provide precise technical information about products that can be used in combination with other software platforms which can generate the simulation of computational models, including the cost reductions analysis in the phases of the design, construction, and operation.

According to RICS (2017), the application of BIM in project management has relevant benefits for project managers as it centralizes, organises, documents, and distributes all project information – its methodological design also integrates people, projects, and organizations.

5 Obtained results and analysis

From the empirical intervention, two interviews were conducted with two Siemens specialists – one specialist works at Siemens Switzerland and the other specialist works in Siemens Brazil. The Swiss specialist is a senior manager who helps Siemens to develop and execute the regulatory initiatives and industry relations strategies for the buildings divisions. He previously held the role of head of innovation and championed innovation across other Siemens divisions – he also is a key liaison point to buildingSMART International. The Brazilian specialist is a product portfolio manager with nearly twenty years of experience in building divisions. Both specialists are basic training engineers.

The obtained results through the interviews are presented in accordance with Table 2.

Table 2 – Summary of the results of interviews with experts.

Analysis Category	Summary of the results of interviews with experts
Benefits of using BIM in design and construction projects in operation of buildings and infrastructure	Improved space management, streamlined maintenance, energy efficiency, renovations and economical retrofits, life-cycle management enhancement, information transparency for the project manager in all project phases, easy team-member communication, centralised project information in a single location, costs reduction in each phase, faster deliveries, and the possibility of optimizing the dimensioning of project teams
Experience regarding the return on investment (ROI) with the use of BIM in buildings and infrastructure projects from design to demolition	Adopting BIM processes is becoming increasingly popular at all stages of the building's lifecycle – that is, from design to construction (20%) and through operations and maintenance (80%). Consequently, the role of ROI in technology-decision making is shifting
Factors related to the project can restrict the use of BIM in construction projects	The evidence shows that in Europe the use of BIM is more consolidated when compared to data from Brazil. It is possible that the lack of knowledge of project stakeholders is the biggest factor. On the customer side, many have no idea what BIM is. On the project side, many designers, engineers, architects, and project managers do not know the methodology or have very basic information, insufficient for decision making
Factors related to the company / organisation can restrict the use of BIM in construction projects	The lack of experience leads to a lack of transparency of the benefits resulting from the use of the BIM methodology. Another important factor is the high cost of simulation software licenses and the costs of personnel technical training for project teams

Source: Elaborated by the author – extracted from the interviews content.

By creating a parallel between the aspects presented in the theoretical framework with the results obtained through the interviews and summarized in Table 2, it is possible to re-present them in Table 3, however, by reorganizing the data so that they maintain the benefits as a focal point. the adoption of the BIM methodology in projects.

Table 3 – Summary of the benefits reported in theoretical framework.

Benefits reported in theoretical framework	**Main authors**	**Was this benefit identified in the interviews?**
Customers understand (concepts and scope)	(Xiao & Noble, 2014) (McGrow Hill Construction, 2014) DEUBIM / EDUBIM	Yes
Project success and/ or better validation	(Xiao & Noble, 2014) DEUBIM / EDUBIM	No
Better team collaboration and communication preventing the rework	(Xiao & Noble, 2014) (McGrow Hill Construction, 2014) (Kocakaya, Namlı, & Işıkdağ, 2019) (Olugboyega & Windapo, 2020) (Yaru, 2021)	Yes
Accurate documentation	DEUBIM / EDUBIM	Yes
Lower final construction cost (costs savings) / budget planning	(Gao & Fischer, 2008) (Dodge Data & Analytics, 2013) (Xiao & Noble, 2014) (McGrow Hill Construction, 2014) (Gerbert, Castagnino, Rothballer, Renz, & Filitz, 2016) (EDUBIM, 2021) DEUBIM / EDUBIM	Yes
Reduction of time and cost risk	(Gao & Fischer, 2008) (Gerbert, Castagnino, Rothballer, Renz, & Filitz, 2016) DEUBIM / EDUBIM	Yes
Subcontractor control	(Xiao & Noble, 2014)	No
RFI and change orders	(Dodge Data & Analytics, 2013) (Xiao & Noble, 2014)	Yes
Shortened schedule with fewer delays in project execution	(Dodge Data & Analytics, 2013) DEUBIM / EDUBIM	Yes
Reduced material waste	(Dodge Data & Analytics, 2013)	No
Fewer safety incidents	(Dodge Data & Analytics, 2013)	No
Facility management, operation, and maintenance	(Gao & Fischer, 2008) (McGrow Hill Construction, 2014) (Gerbert, Castagnino, Rothballer, Renz, & Filitz, 2016) (Yin, Liu, Yuan, Wang, & Al-Hussein, 2020)	Yes
Ecological decisions	DEUBIM / EDUBIM	No
Process transparency	DEUBIM / EDUBIM	Yes
Energy efficiency	(Duarte, Zemero, de Souza, Tostes, & Bezerra, 2021)	No
Project closure	(Xiao & Noble, 2014)	Yes

Source: Elaborated by the author.

The benefits of applying the BIM methodology are not directly applicable to the project managers, however can be measured by the effective contribution of project managers to the success of the projects (Xiao & Noble, 2014), and always will be the protagonist that ensures the project success (RICS, 2017).

The following section presents the conclusion and final considerations of this study.

6 Conclusion and final considerations

The importance of implementing the BIM method from the perspective of project management was explored in this technical report. BIM has a wide range of applications, which supports the development of other research, whether in the technical field for project development or in terms of customer understanding and project effectiveness – it is possible that the civil construction is still fragmented, preventing it from being used more effectively (Borrmann, König, Koch, & Beetz, 2018).

This technical report demonstrates the significance of presenting the benefits of using the BIM methodology from a different perspective than the technical characteristics of its application; in other words, the emphasis was not on evaluating the effect of BIM on the development of more efficient projects, but on the emphasis of application within the area of project management. As previously stated, the benefits of BIM are not directly related to the project manager but have a direct impact on project success when correctly applied by the protagonist project manager – in this context, traditional processes must be adequate in terms of planning and execution phases, to reach the project's effectiveness. (Tulke & Schumann, 2018).

The literature reviewed in this research addresses several perspectives of authors on the benefits of using BIM for the simulation of computational models aimed at cost optimization and project management support. In accordance with the proposed objective, a technology manufacturer was consulted, and two experts contributed with their practical views that could be compared with the theory recorded in the theoretical framework, resulting in the documentation of a collaborative finds between academia and corporation. This work contributes to practical terms, and it is worth noting that BIM simulation and standardization is a current theme and matter of several research, including new areas, such as the case of energy efficiency (Treeck, Wimmer, & Maile, 2018).

If the number of respondents was increased, the results could be larger, richer, and thus more comprehensive. It is recommended that future research investigate the relationship of project success with the use of BIM, as it is possible that the more complex the project, more benefits it is possible to achieve.

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Appendix

Appendix A – Research questionnaire

This questionary was sent by email to the research respondents.

1. Please, how many years of experience do you have with BIM? (please, consider the total experience of Siemens and other companies you worked for)

2. Based on your experience and vision, list the benefits of using BIM in design and construction projects and more important for Siemens in operation of buildings and infrastructure.

3. Based on your experience and vision, could you report your experience regarding the return on investment (ROI) with the use of BIM in buildings and infrastructure projects from design to demolition?

4. Based on your experience and vision, what factors <u>related to the project</u> can restrict the use of BIM in construction projects?

5. Based on your experience and vision, what factors <u>related to the company / organisation</u> can restrict the use of BIM in construction projects?