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Application of Building Information Modeling (BIM) in the Planning and Construction of a Building

Renata Maria Abrantes BARACHO
Architecture School, Universidade Federal de Minas Gerais
Belo Horizonte, Minas Gerais, Brasil
email: renatambaracho@gmail.com

Luiz Gustavo da Silva SANTIAGO
Engineering School, Universidade Federal de Minas Gerais
Belo Horizonte, Minas Gerais, Brasil
email: luiz.gustavo2044@gmail.com

Antonio Tagore Assumpção Mendoza e SILVA
Engineering School, Universidade Federal de Minas Gerais
Belo Horizonte, Minas Gerais, Brasil
email: antoniotagore@hotmail.com

Marcelo Franco PORTO
Engineering School, Universidade Federal de Minas Gerais
Belo Horizonte, Minas Gerais, Brasil
email: marcelofrancoporto@gmail.com

ABSTRACT

This paper aims to introduce Building Information Modeling (BIM) technology into the process of construction to achieve more efficient buildings, considering sustainability, economic improvements, reduced waste, and time optimization. The study involves the design, 3D modeling, planning, and monitoring of the work to assess the advantages and limitations of BIM through a real simulation. The methodology comprises theoretical foundations, 3D modeling, budgeting, and work monitoring. The project commenced with a 2D blueprint using Autodesk AutoCAD, followed by 3D modeling in Autodesk Revit. The resultant building, serving as an information system with a database and 3D modeling, allows for automated budgeting. The advantages of BIM encompass an interface between project and program, an interface between software, realistic renderings, precise material specifications, and family modeling. Limitations include the absence of material families, reformatting of Autodesk Revit tables when transferred to the Microsoft Excel program, generic family models with distorted renderings of reality, and heavy files. Despite these limitations, the implementation of BIM in buildings proves beneficial for projects. Collaborative work among stakeholders, optimization of project stages, and the reduction of expenses and rework can be achieved.

Keywords: Building Information Modeling – BIM; 3D Modeling; Project Management; Budget; Construction Planning; Execution of works.

1. INTRODUCTION

Building Information Modeling (BIM) can be understood as a technology, methodology or process that emerges to implement tools to assist teams involved in early visualization of construction through a project simulation. This enables the identification and prevention of errors in planning, design, construction, and operation.

This article aims to evaluate in practice the seven dimensions of BIM, with 1D and 2D dimensions representing the two-dimensional drawing in Cartesian coordinates, followed by 3D Parametric Modeling, 4D Planning, 5D Budget, 6D Sustainability, 7D Management and Maintenance.

Effectively, application of this methodology produces efficient buildings regarding sustainability standards by fostering close collaboration between the architecture-engineering-construction (AEC) sectors.

The objective here is to encourage the integration between those responsible for construction activities and other interested parties, from projects to the operation of the building, in search of economic improvements, reduction of waste generation and optimization of the construction schedule and operations.

BIM technology has been widely adopted in countries such as the United States, United Kingdom, and Norway, because, as mentioned elsewhere, the tool allows storing, managing, sharing, and exchanging project information through interoperable systems, preventing potential problems and enhancing construction performance. Thus, the application of BIM emerges as a trend to optimize management and planning stages in underdeveloped countries like Brazil. [1] “Brazil presents an advanced implementation of BIM considering the requirements of BIS - Department of Innovations and Business Skills”. However, despite advances in BIM integration in the Brazilian market, its use in public works only became mandatory in 2021.

To enrich the research and obtain a greater parameterization of materials, this study proposes a simulation of a renovation in a building in Florida (USA).

The choice is made with the consideration that it would be more viable to implement it in this building, aligning with methodologies already in place through tools that generate a closer approximation to reality.

2. CONSTRUCTION PLANNING AND CONTROL

In recent years, the construction industry has been changing processes, methods, and operations. These changes can be attributed to technological advances, consumer demands, and increased competitiveness. As a result, companies are compelled to seek methods to enhance productivity, increase profit, and reduce deadlines and inputs. To achieve expense reduction and, consequently, profit increase, companies require what are commonly referred to as management systems. In other words, these systems can be translated into planning and work control, as they are responsible for linking all stages of the process of the enterprise, from its conception to its delivery. However, given that enterprises are unique, dynamic, changeable, and interconnected, their management is increasingly complex and susceptible to error.

Thus, [2] asserts that programming and work control is not yet a process that influences and impacts the entire project. Instead, they are often perceived as components of a specific sector in a company. Unfortunately, within civil construction, these processes are still relatively ineffective, often being carried out alongside the monitoring of services by the engineer.

In this context, [3] defines planning as a process that involves thinking, controlling and correcting over time. For the author, planning is a way of guaranteeing the quality of the company's service, through monitoring and strategic resizing. The way in which those responsible for construction and project management have to provide quick and accurate answers defines the company's longevity and the ability of managers to provide such answers.

Therefore, in the constant search for effective planning and control, it is first necessary to define the project. The definition significantly impacts the productivity and performance of the production line, serving as determining factors that dictate the success of the enterprise as it reduces project uncertainties and improves the development of activities. Furthermore, [4] posits planning as a method that improves and defines decision-making based on a given service, specifying how it will be executed, the deadline, the cost, and the necessary resources.

Planning and control are invaluable for enterprises, allowing the team to map and identify service fronts in advance. This enables the identification of potential issues and facilitates proactive adaptation actions, ensuring better overall performance.

Furthermore, [3] outlines some benefits that effective planning and control can bring to work:

- Full knowledge of the work: Professionals gain comprehensive knowledge of the project, enabling them to determine the period and work front for each service precisely.
- Detection of unfavorable situations: Identification of potential unfavorable solutions and non-conformities, with professionals having the time to make decisions that impact the schedule and project flow.
- Decision agility: Effective planning provides a reliable basis for on-site decision-making.
- Relationship with the budget: Planning, linked to productivity and resource allocation databases, allows the analysis of inconsistencies and proposes improvements.
- Optimization of resource allocation: Enables the postponement of expenses, defining which service fronts can be delayed without affecting the schedule.
- Reference for monitoring: The work schedule allows professionals to compare planned activities with completed ones, facilitating the identification of services requiring preventive and/or corrective measures.
- Standardization: Through planning and control, communication between professionals improves, favoring the rationalization of processes.
- Reference for goals: Based on activity deadlines assigned by planning, goals, and bonuses can be established to enhance productivity on the site.
- Documentation and traceability: The connection between professionals and the formation of activity records establishes a historical base for the enterprise, facilitating information retrieval and issue resolution.
- Creation of historical data: Methodologies implemented in the work, through the "memory of the work," contribute to the creation of data.
- Professionalism: Effective planning demonstrates seriousness and commitment to both the work and the company, leaving a positive impression and aiding in securing new deals.

Furthermore, in pursuit of achieving such benefits within the project, it is necessary to ensure adherence to the so-called "project management triangle," which comprises three key aspects: time, quality, and cost. It is essential to recognize that any action taken to address one aspect will inevitably have repercussions on at least one of the other aspects. Therefore, in the endeavor to maintain balance within the enterprise, effective planning and control are paramount. Poorly executed planning, or even its absence altogether, can result in imbalances and subsequently lead to deficiencies in the enterprise management system. So, [3] cites some causes that lead to deficiencies in projects, namely:

- Long-standing perception of planning and control: Planning is often perceived merely as an isolated task within a technical sector of the company, lacking a solid information foundation. It is neither endorsed by the responsible authority nor implemented by the production team, thus becoming a perfunctory exercise for the department, aimed solely at impressing the customer.
- Discredit stemming from uncertainty in parameters: Due to the complexity, uniqueness, and dynamic nature of projects, coupled with a lack of control over processes and operations, uncertainty becomes an inherent factor in civil construction processes. The environment is characterized by its uniqueness, temporariness, variability, and frequent interdependencies.
- Excessive informality in planning: The absence of formalized communication between senders and receivers impedes interdepartmental communication and leads to a short-term focus that obscures the long-term vision of processes. This, in turn, results in resource allocation issues.
- The myth of the "work changer": Reflecting the perpetuation of informal practices and inefficiencies at construction sites, companies often prioritize professionals with a construction worker mentality.

These individuals tend to make quick decisions based solely on their on-site experiences and intuition, perpetuating a disconnection between professionals responsible for managing the enterprise's systems. Planning is consequently viewed as a time-wasting endeavor.

3. BUILDING INFORMATION MODELING

Building Information Modeling (BIM) can be comprehended as a technology, methodology, or process designed to assist stakeholders in planning and visualizing construction beforehand through project simulation. The primary goal is to identify and prevent issues in planning, design, construction and operation. According to [5], BIM emerged to enhance companies' decision-making capabilities by improving the analysis and qualification of information.

According to [6], BIM serves as an information system facilitating data exchange through collaboration among architecture, engineering, construction and operation. This is achieved by creating a three-dimensional, parameterized, and accurate virtual model of the project. Consequently, the methodology consists of a set of processes that, when combined, enhance communication, data production, and processing.

For [7], BIM is a series of processes enabling collaborative design, operation, and construction within an enterprise due to system interoperability. It is perceived as a process that originated from Computer-Aided Design (CAD) but surpasses two-dimensional plans, providing utility from conception to post-construction phases.

[8] recognizes that the BIM methodology is a collection of policies, processes, and technologies within a digital model. This model enables the creation, updating, and maintenance of information throughout the project life cycle. It defines the fields that constitute these sets as:

- Policies: Legislation and regulations;
- Processes: Formation, operation, use, and maintenance of structures;
- Technology: Software, hardware, and network systems;

Effectively, the methodology results in more efficient constructions that adhere to sustainability standards and foster close collaboration among Architecture, Engineering, and Construction and Operation professionals of the AEC/O industry. It promotes integrating activities among construction stakeholders, leading to economic improvements and optimized construction timelines.

BIM is a methodology that ensures project compatibility, industrialization process efficiency, and enhanced productivity on construction sites. Consequently, this technology has gained widespread adoption in countries such as the United States, the United Kingdom, and Norway.

As mentioned earlier, it serves as a tool for storing, managing, sharing, and exchanging project information through interoperable systems, thereby preventing potential problems and boosting construction performance. In the context of Brazilian projects, BIM implementation emerges as a trend to optimize management and planning stages. [1] notes that "Brazil presents an advanced implementation of BIM considering the requirements of BIS - Department of Innovations and Business Skills."

4. DEVELOPMENT

With the utilization of BIM technology and Autodesk's AutoCAD® and Revit® software, selected for their established leadership and availability of licenses through the School of Engineering at the Federal University of Minas Gerais (UFMG).

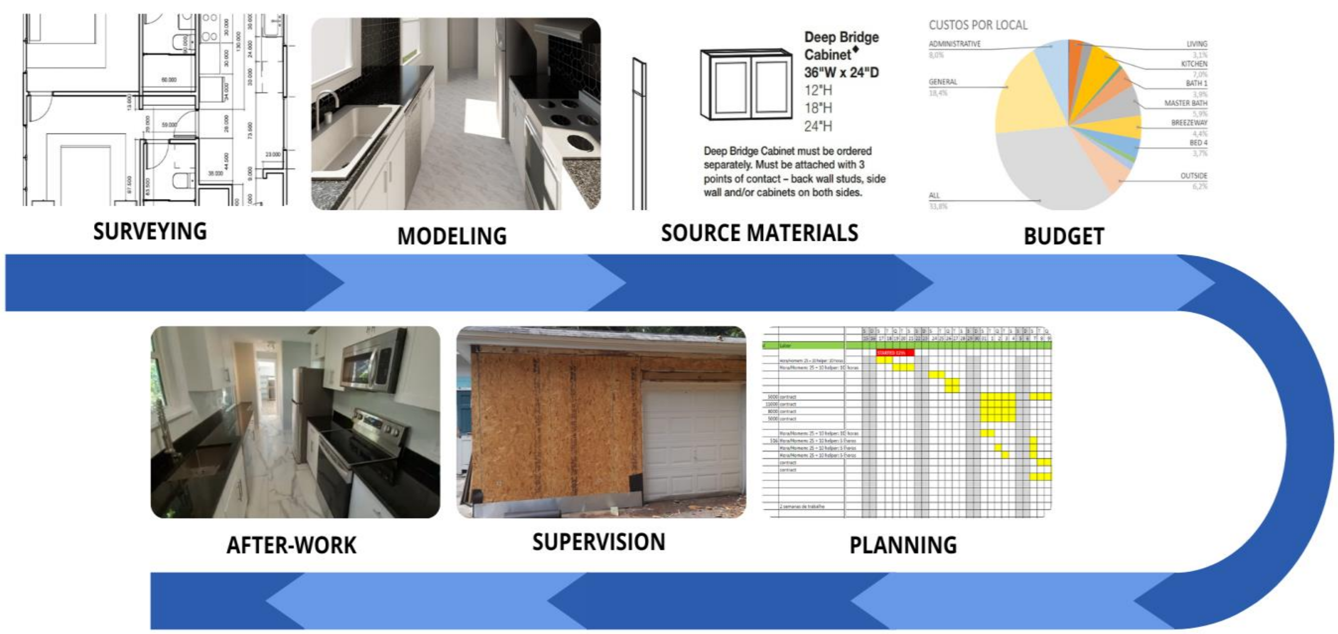

Figure 1 – Framework. Source: the author

A collaborative effort was initiated to integrate both programs for modeling purposes. AutoCAD was employed to create the initial floor plan, and Revit was subsequently utilized for 3D representation. The plan designed in AutoCAD was seamlessly imported into Revit to facilitate the 3D modeling process. Although it is feasible to complete the entire modeling process within Revit, the decision to connect both programs was made due to the novelty of BIM technology in the market, where the use of different programs remains common. This integration aimed to showcase the efficiency and practicality of BIM in the job market, enabling fruitful interaction among individuals using various software in their projects.

The comprehensive modeling encompassed material definition, finishing details, and a quantitative survey. Simultaneously, a materials study was conducted to assess suitability for repair or replacement. For replaceable fittings, a search within the modeling process was initiated to identify materials available in construction through retailers such as The Home Depot® and Lowes®, American companies serving as suppliers of materials for home and construction. Leveraging technological benefits, materials were parameterized based on families provided by manufacturers, further justifying the use of a model with U.S.-specific data.

Surveying
Surveying the site to be renovated is a fundamental step and consists of the first analysis of the environment to collect information such as the situation of the land, evaluation of the structure so that a 2D project can be created that includes the improvements.

Modeling
Once the 2D project focusing on improvements to the existing construction has been completed, the next step involves 3D modeling of the project structure. This modeling is conducted using software such as Revit and enhances the visualization of the project by producing results that closely resemble reality

Source materials
Following the completion of 3D modeling for the construction, it becomes imperative to further enhance the project by incorporating details ranging from ceramic finishings to furniture. To accomplish this, it is crucial to locate what are referred to as "families," which comprise parameterized 3D blocks provided by certain manufacturers. This stage holds significant importance, as the data contained within these blocks enables the acquisition of a more precise budget, among other advantages.

Budget
The use of data derived from modeling, together with the survey of the built area and finishing specifications, allows the costs of the work to be quantified and budgeted. This includes labor, materials, and lead time considerations.

Planning
Compiling a comprehensive schedule, incorporating insights from previous steps, and establishing links between each phase makes it easier to estimate the overall project duration.

Supervision
Vigilant monitoring of the construction process is essential to ensure compliance with the plan or to update the schedule in case of unforeseen events.

After-work
After completion of the project, it is essential to review the planned objectives about the work carried out. This ensures that the “As Built” result is aligned with the initially proposed execution.

5. RESULTS AND DISCUSSION

After conducting a comprehensive study and analyzing sketches and images, a document was generated to spatially organize the images within their respective rooms. This approach provided a clearer understanding of the layout, facilitating both 2D and 3D modeling of the residence. The process commenced with the use of AutoCAD Autodesk software, utilizing a sketch to create the floor plan, which was subsequently imported into Revit Autodesk software for 3D modeling.

The data was structured in a "digital mockup" format, forming a substantial database.

Following the modeling phase, the renovation budget proposal was finalized with the assistance of tables exported between Revit Autodesk and Microsoft® Excel. Due to limitations in some materials, approximations were made to ensure the simulation adhered to the schedule.

The three-dimensional representation enabled the creation of renderings projecting renovations for all rooms, allowing a comparison between pre-renovation, the rendering, and post-renovation. This verification demonstrated the fidelity of the simulation to the actual final state of the building, showcasing the effectiveness of the BIM methodology.

Additionally, the digital model's database facilitated the extraction of graphs and tables across various categories. This capability enabled detailed analyses of costs, timeframes, and simulations of materials, offering an efficient and realistic means to monitor project development, incorporating changes and alterations typically required in a project.

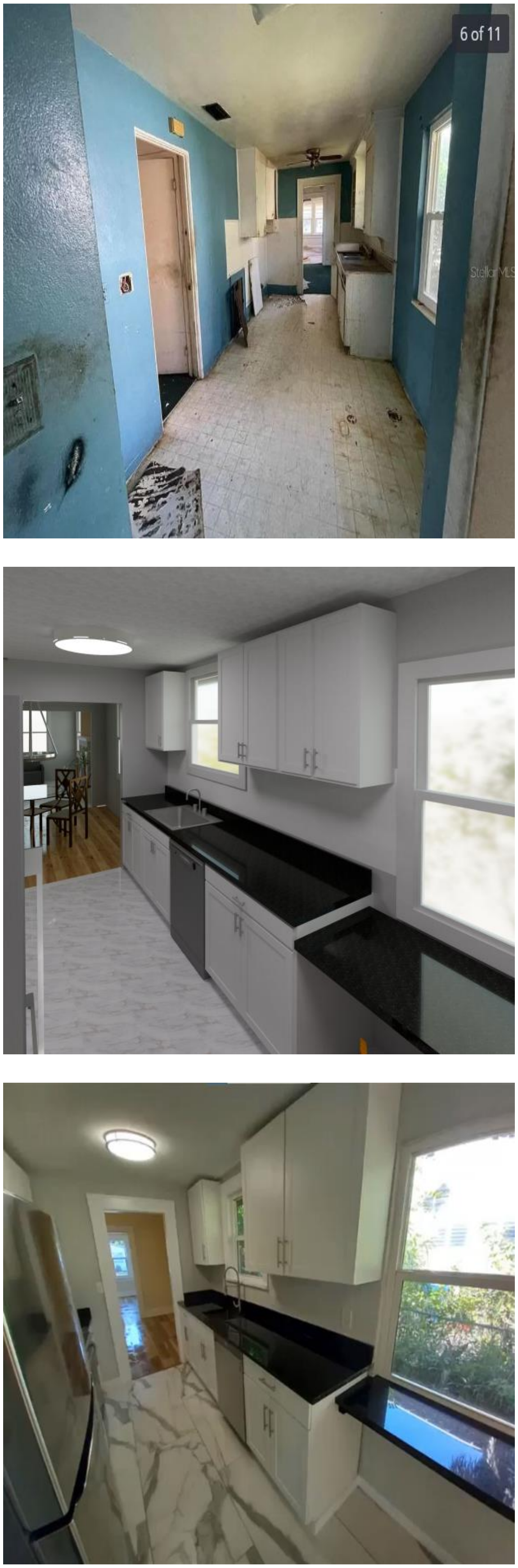

Figure 2: (a) Before work; (b) Render Revit; (c) Ready work;

Consequently, following the study, both advantages and disadvantages were identified in the course of project development. Noteworthy advantages associated with the adoption of the BIM methodology encompass: enhanced interaction between project and program; improved interoperability among software; realistic renderings; precise material specifications; and effective family modeling. On the other hand, limitations observed included: absence of certain material families; the no formatting of tables from the Revit Autodesk software to the Microsoft Excel program; distortions in reality within renderings of generic family models; and the issue of dealing with large file sizes.

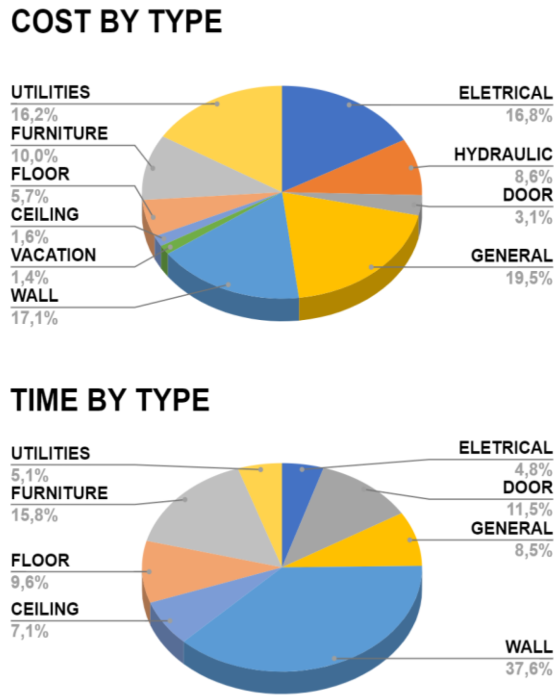

FIgure 3: (a) Cost by type (b) Time by type

In a concise summary, it was determined that despite the limitations mentioned, the incorporation of BIM technology in construction projects proves advantageous. This implementation facilitates collaborative efforts among involved parties, streamlines project stages, and consequently reduces both expenses and the likelihood of rework.

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