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Application of BIM for project management of multifamily residential buildings: a case study

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Abstract: Building Information Modeling (BIM) is a worldwide concept for project management based on three-dimensional modeling using software compatible with this technology. These smart models work with a large amount of data, which brings projects closer to reality. The collaboration feature between designers has an important impact on production, facilitates coherence between designs from different disciplines,and minimizes incompatibilities.The last one is the main object of the case study carried out in this work, that aimed to develop the modeling and compatibility of the architectural, structural, and hydro sanitary designs of a multi-family residential building. The modeling and compatibility development process was carried out using the BIM software Autodesk® Revit and Autodesk® Navisworks, while the whole project was developed by the construction company essentially on a two-dimensional platform. The results found through this research, about 892 interferences between these three designs, shows how traditional processes are error-prone and may be improved.

Key words: BIM; project compatibility; productive processes

1 Introduction

BIM (Building Information Modeling) is a technology that emerged as a new approach to modernizing the project design system. Among other features, its purpose is to reduce errors and costs, as well as to enable greater integration among designers (EASTMAN et al., 2014).

Programs such as Autodesk® Revit or Graphisoft® ArchiCAD are the most widely used BIM software in the world today and have revolutionized the way projects are produced and presented. These software programs can perfectly reproduce a realistic three-dimensional model of a construction project with all its elements, allowing for the prediction of all construction phases and the correction of potential errors that would otherwise only be discovered during execution (MELO, 2014). Smith (2014) studies the application of BIM methodology as a project management tool and states that, when applied, it enables integration among the projects and professionals involved. Once data is shared, the processes for making changes to the project become automated. In this way, common errors in the design phase are minimized or completely eliminated (DE PAULA et al., 2017).

Incompatibilities between designs encountered on-site during construction can create various obstacles in a project's schedule. Among these, the most notable are delays in planning, material waste due to rework, and the need for design revisions. These revisions generate a large volume of versions and lead to errors in the execution routine (EASTMAN et al., 2014).

The use of automated software based on three-dimensional modeling, such as Autodesk® Revit and Autodesk® Navisworks, is more efficient in detecting these incompatibilities. These tools are capable of generating comprehensive reports of all interferences found for correction as early as the design phase. As a result, there is a considerable reduction in errors and costs that would be generated by the losses and rework resulting from these incompatibilities.

Thus, the objective of this article is to evaluate the use of BIM methodology in detecting incompatibilities between designs for a multifamily residential building.

2 Methodology

The research methodology is based on a case study and aimed to demonstrate the process of modeling and reconciling a development using the BIM methodology. The modeling was developed from the architectural, structural, and plumbing and sanitation construction drawings provided by the construction company.

The study was limited to the examination and analysis of the use of BIM software in the three-dimensional modeling of elements, with a focus on detecting design incompatibilities. The article was divided into five stages, as described in Figure 1.

First, the 3D models were developed separately, based on the 2D CAD working drawings. Next, the designs were imported into BIM management software to generate clash reports. Finally, the results were analyzed and the errors identified.

The project, referred to in this article as Building A, is a development by a local construction company, located in the city of Maceió. The architectural design, with a perspective view of the facade shown in Figure 2, consists of 16 stories, including 1 basement level, 1 pilotis level, 1 parking level, 12 standard stories with 4 apartments each, and 1 penthouse level with 2 units. It has a land area of 2,634.70 m² and a total floor area of 12,174.00 m².

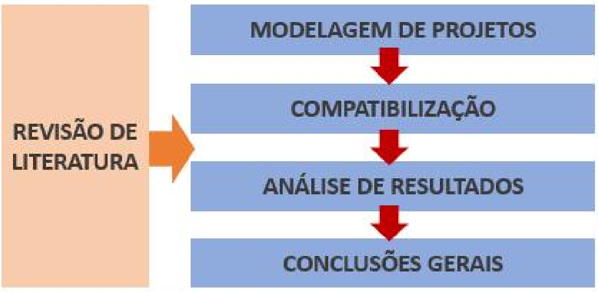


Figure 1. Research outline. Source: the authors (2020)

Figure 2. Perspective view of Building A's facade. Source: official website of the construction company under study (2019)

The design process for this project followed the traditional workflow adopted by the construction company, meaning it was coordinated by the engineer responsible for executing the work. He oversees everything from planning, design, and contracting to the final finishing touches.

The integration of the designs developed in Autodesk® AutoCAD took place through in-person meetings between the architecture and structural engineering teams, which continued until the detailed drawings for both disciplines were approved. According to the engineer in charge, the architectural designs were developed in parallel with the structural designs; that is, the routing of the piping was determined even before the final placement of the columns and beams was defined.

For this study, Autodesk® Revit 2018 BIM software was chosen to create the three-dimensional models. Different templates were used for each discipline to model the projects. For the architectural design, the native Autodesk® Revit architecture template was used. For the plumbing and sanitation design, a template available on the website of a manufacturer of PVC pipes and fittings was used; this template features various product families and allows for the automatic creation of piping systems. The structural design was provided by the designer with the advantage of having already been created in TQS, software with BIM integration. For integration with Revit, it was necessary to use a plugin available on the program's own website. During the compatibility phase, the integrated model was imported into Autodesk® Navisworks Manager 2018 to detect clashes between the analyzed designs. In addition to these two programs, the traditional Autodesk® AutoCAD was used as a reference for 3D modeling, based on the construction drawings developed by the companies.

3 Results and discussion

3.1 Architectural project modeling

The architectural design modeling process began with the architectural template, creating reference levels for the project's floors, with approximately 3 meters between each level. The information was collected from the AutoCAD construction drawings and replicated in Revit. The three-dimensional architectural model can be seen in Figure 3:

Figure 3. Three-dimensional architectural model. Source: the authors (2020)

3.2 Structural design modeling

The structural design was developed in TQS software, which allows the model to be exported to a Revit-compatible format via a plugin.

It took four export attempts to successfully open the file. The errors from the first attempts were only resolved when some inclined elements present in the original design were removed during export. Additionally, the file could only be imported into Revit by simplifying the slabs: the slabs (ribbed in the original design) in the model were defined as solid.

3.3 Modeling of the plumbing and sanitation project

Modeling of the plumbing and sanitation system began using a template available on the website of a plumbing and fittings company. This was the discipline that presented the most difficulties during development. Although pipe connections were made automatically, certain parameters, such as heights and slopes, had to be defined for the feature to function properly. Sometimes, performing the procedure using only the two-dimensional plan is not sufficient, making it necessary to work with cross-sections and 3D visualization to observe the behavior of the connection.

The connection automatically included by the program is not always the one defined in the design, making it necessary to replace it manually. Furthermore, in several cases, it was necessary to move some pipes that had already been inserted to ensure there was sufficient space for the connection. This caused some pipes to deviate from the layout designed in the original AutoCAD. The three-dimensional plumbing model can be seen in Figure 4:

Figure 4. Three-dimensional plumbing model. Source: the authors (2020)

3.4 Coordination

For coordination purposes, the Revit projects were exported to a Navisworks-compatible file. Before using the "Clash Detective" tool to detect clashes, it was necessary to configure the sets (element selection sets). The criteria for choosing the sets were based on the elements used in the tests, such as columns and beams versus the plumbing system. Once these sets were created, it was possible to generate as many combinations as necessary to analyze clashes between the generated sets.

Since the floor types are identical, only the elements of a given type were included in the definition of the sets—a change made to one floor can be automatically corrected in the others.

In addition to the "Clash Detective" tool, visual compatibility checks were performed during the modeling process. Some clashes became visible in the 3D model and could have been corrected immediately. In this study, however, such adjustments were not made, as the intention was to identify incompatibilities in designs created using 2D CAD tools.

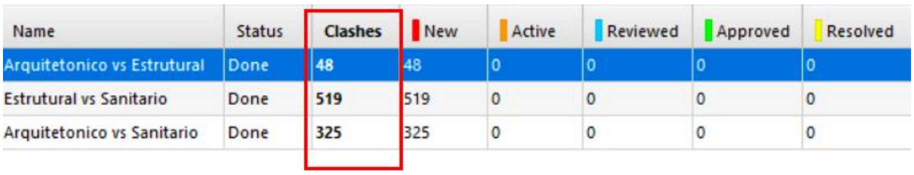
The elements analyzed in each incompatibility test were performed according to the matrix defined by Costa (2013), shown in Table 1. Coordination of elements:

Table 1. Coordination of elements. Source: adapted from COSTA (2013)

Coordinated Disciplines	Structural	Hydrosanitary
Coordinated Elements	Beams Columns Slabs	Pipes Connections
Coordinated disciplines	Structural	Architectural
Coordinated Elements	Beams Columns	Windows Doors
Coordinated disciplines	Architectural	Hydrosanitary
Coordinated Elements	Ceilings Windows Doors	Pipes Fittings

As mentioned earlier, the subject of the study is a multi-story building, where conflicts would recur in the typical floors; therefore, only one of them was included in the test to facilitate the visualization of the results.

The result of the coordination results is shown in Figure 5:



Name	Status	Clashes	New	Active	Reviewed	Approved	Resolved
Arquitetonico vs Estrutural	Done	**48**	48	0	0	0	0
Estrutural vs Sanitario	Done	**519**	519	0	0	0	0
Arquitetonico vs Sanitario	Done	**325**	325	0	0	0	0

Figure 5. Coordination results. Source: the authors (2020)

3.5 Incompatibilities between architectural and structural designs

Initially, the ceilings were included in the analysis, and 48 conflicts were detected; however, upon visual inspection of the results, it was observed that most of the conflicts were caused by the modeling itself. Notably, a conflict was found between a beam with a height greater than the distance from the slab to the ceiling in the common hallway of the standard floor plans, resulting in an exposed beam.

After removing the ceilings from the study, 11 conflicts were detected. Among the most serious are the interferences between facade frames and columns, shown in Figure 6. Additionally, the conflict between the position of the door and two columns in the Playroom.

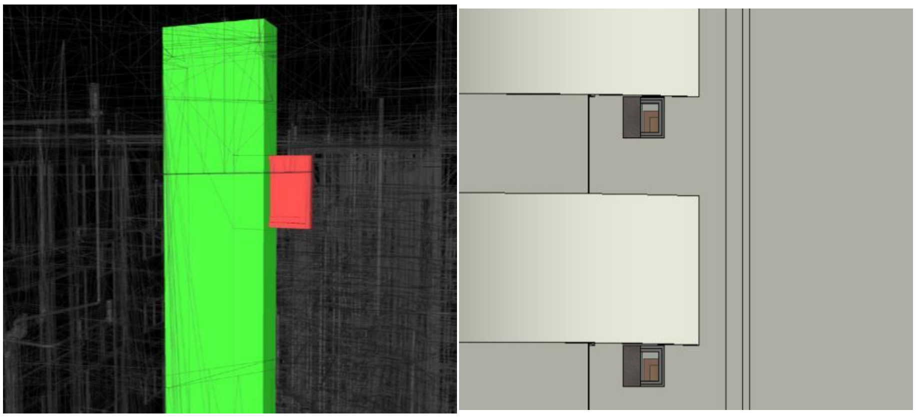


Figure 6. Interferences between facade frames and columns. Source: the authors (2020)

The number of incompatibilities found in this test, although significant, can be considered small. This can be explained by the fact that these were the only disciplines that underwent a reconciliation process during meetings.

3.6 Incompatibilities between architectural and plumbing designs

Since the utility systems model contained numerous connections that appeared as individual elements during the coordination process, a high number of interferences was expected. In fact, in this second test, 519 interferences were found. Upon analyzing the design through 3D modeling, the design solution adopted by the utility designer was deemed technically unfeasible. The routing chosen for the piping required a greater ceiling height than initially planned to ensure sufficient space for the connections. On the other hand, no incompatibilities were found between utility systems and window and door frames.

3.7 Incompatibilities between structural and plumbing designs

The result of this test generated 325 conflicts, and it was observed that the structural model did not include any horizontal holes for the passage of installations. In some cases, such as the drains in the technical slabs, the hole intersected a facade column, as can be seen in Figure 7.

Interferences were also found between horizontal pipes and beams for which no holes had been provided. For these situations, it was necessary to send the location and dimension information of the drilling to the engineer.

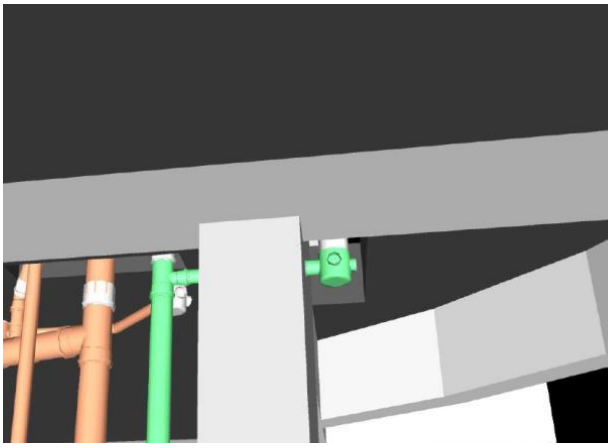


Figure 7. Interference between a facade column and a stormwater pipe. Source: the authors (2020)

4 Final considerations

Considering the results presented, it can be stated that the initial objective of the article was met and the use of the technology can be considered effective in reducing interferences. Several clashes, which had not been detected by the designers, even after coordination meetings, were found through Navisworks' automatic detection. Thus, the benefits of adopting the BIM methodology in the design phase are confirmed.

One of the factors influencing the development of the three-dimensional model is the level of experience with the software. This can make the project take longer to develop compared to traditional, two-dimensional tools. However, after a period of adaptation and training on the platform, the benefits may be more attractive.

Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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