



KLÊNIO CARLOS DA SILVA¹, ALBA NÉLIDA DE MENDONÇA BISPO²

¹ Universidade Federal de São João Del Rei, São João Del Rei, Brazil

kleniosilva@studioideia.com

² Universidade Federal de Minas Gerais, Minas Gerais, Brazil

bispo.alba@gmail.com

ABSTRACT

This study applies Building Information Modeling - BIM and photogrammetry to documentation and asset management. The object of analysis was the Cultural Center of the Federal University of São João del Rei, called Baroness Solar, in the historical center of São João Del Rei, Brazil. It is based on three methodological steps: literature review, including Eastman (2011), Oliveira (2008), Grotelaars (2015), and Tolentino (2016); documentary research in local public institutions; facade photogrammetry and BIM modeling. The results reflect on the benefits and challenges of heritage preservation.

Keywords:

BIM, heritage buildings, Reality capture, photogrammetry from UAV, Baroness Solar.

BIM AND REALITY CAPTURE APPLIED TO HERITAGE BUILDINGS, A STUDY BASED ON BARONESS SOLAR, BRAZIL

1. BIM METHODOLOGY APPLIED TO HERITAGE BUILDINGS

Eastman et al. (2011, p.93-94) state that a reliable and updated BIM Model is one of the best ways to manage as-built constructions. This database is a useful facility management tool because of its accuracy and integration with other areas. Also, it can be used on all buildings, including heritage ones, which in most cases have a long-life cycle involving renovations, demolitions and modifications over time. According to Khaddaj and Srour (2016), the as-built BIM model can work as a database for professionals and users for maintenance and restoration, contributing to building conservation and sustainability.

According to Oliveira (2008), "one of the best practices for preserving heritage memory is the registration and documentation, which has been done throughout the history of mankind, from prehistoric paintings to sophisticated laser scanning." At this point, it is necessary to reflect on the role of documentation and the fact that it will never replace the artifact itself. This consideration is particularly relevant when it comes to heritage, in which the environment, the light, the sensations are unique; one can simulate it but never replace it. All the tools have to work to preserve and maintain the original state. The research of BIM application to heritage buildings brings a new branch named Historic Building Information Modeling (HBIM). Among these new studies and possibilities, one can notice the significant development of techniques in reality capture like photogrammetry, laser scanning, and their use for creating models based on point clouds

that work as a source for 3D modeling, visualization, measuring, material information, quantification, and many other BIM uses. There are relevant researches in Brazil about reality capture and BIM, among which it is possible to cite: the Glass House by the architect Lina Bo Bardi; Ruins of the Jesuit Missions, a historic site in the state of Rio Grande do Sul; and the photogrammetry from Unmanned Aerial Vehicles (UAV) of facades in the historical center of Salvador city in the state of Bahia. In order to contribute, this study focuses on a medium-sized city in the state of Minas Gerais, which concentrates the majority of designated heritage buildings by the National Institute of Historical and Artistic Heritage - IPHAN in Brazil.



Figure 1. Localization of Baroness Solar. Source: Silva (2017).

2. THE BUILDING: BARONESS SOLAR MINAS GERAIS, BRAZIL

Baroness Solar is a typical house from the colonial period in Brazil built in the historical center of São João Del Rei, an inner-city in the state of Minas Gerais, Brazil, and integrates the historical site listed by the IPHAN. There are some representative characteristics in constructions of that time, like stone portals, solid wood doors and windows, many adornments inside and outside. In addition, the walls combine two construction types: stone walls and adobe bricks, the roof is composed of clay tiles, and wood structure. According to documents of the Federal University of São João Del Rei (UFSJ), the three-story house was built in the beginning of the 19th century by orders of Francisco de Paula de Almeida Magalhães, a relevant person in the city by that time. Throughout its existence, the house has been a residence, shoe factory, military quarter, Italian immigrant hostel and a school (UFSJ, 2017). Nowadays, it belongs to the UFSJ and it functions as a cultural center, hosting art exhibitions from national and international artists and also as an administrative office.

3. DATA CAPTURING

In order to create a virtual building, this research used many sources such as photographs, CAD Files,

blueprints, and as a primary source, the point cloud made by photogrammetry from UAV. The study starts with the analysis of two CAD files: one provided by the UFSJ Infrastructure Department and another one by UFSJ students under the guidance of professor Luzia dos Santos Abreu. Both files offered highly detailed documentation about the building components. However, on-site verification was necessary due to the fact the research exists in two different files without any standard among them, which could lead to errors and rework.

During on-site visits, it was noticed the walls are self-supporting. They were stone masonry in exterior and adobe masonry in some internals. In some cases, the materials could be verified through observation windows, which made it possible to see the wall core. Furthermore, the photographs, annotations, and interviews during the research were crucial sources of information to model the facades and building details virtually. The next stage was the documentation by photogrammetry of the facades. Grotelaars states about the technique:

“Aerophotogrammetry, when the camera is carried by aircraft, helicopters, balloons, or unmanned aerial vehicles (UAV), with applications in areas such as agriculture, rural and urban cadastral survey, mining control activities, environmental monitoring, disaster prevention plans, and others.” Grotelaars (2015, p.69)¹

The photogrammetry was made in collaboration with the agronomist Marcos Resende and the architecture students of UFSJ. The equipment used by the team were a Total Station Topcon GTS 239W for coordinates survey, a drone Phantom 4 Advanced for the flight, and the digital camera GoPro Hero 4 for capture photos.

The first stage was an on-site observation of the building and its surroundings.

Secondly, control points were marked on the Solar’s facade to be referenced in photos; this process is not essential but highly recommended. After that,

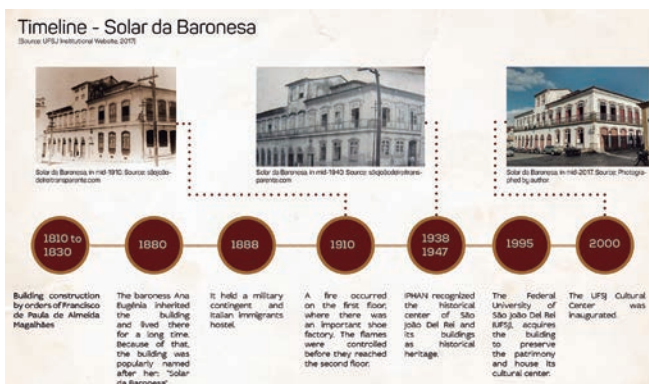


Figure 2. Timeline of Baronesa’s Solar. Source: Elaborated by the author.

the coordinates were measured with Total Station equipment, defining an origin point distant from the edification and measuring distances and angles between them. The next and final stage was the photo capture by a camera aboard an UAV.

In this regard, an automatic flight plan was made, covering all the building facades. The pictures were captured every five seconds; thus there was at least thirty percent overlapping in every pair of photos, a requisite of major manufacturers. After the first flight, it was decided that a higher one had to be done in order to increase the number of roof details captured.

4. DATA PROCESSING

The survey of facades ends with the processing of the collected data in Autodesk's software Recap Photo 2018 and Recap Pro, which are available in the educational version. The entire process of creating a point cloud took about four hours, including the upload and some configurations, such as specifying coordinates between control points and choosing a geographic coordinate system.

Results were given in two format files: one three-dimensional mesh with textures in Recap Photo which was exported in.OBJ file format, good for visualization and measures such as walls and roofs. Another one was a point cloud in Recap Pro in.RCS file format, that can be used as a source for BIM modeling and other analyses, such as constructed and projected comparisons.

One can notice the applications are not restricted to one building; they can expand to the urban scale, capturing data from a vast area. Moreover, the point cloud was optimized and refined in Recap Pro software. According to the publication English Heritage (2011, p.12), the step of refining and checking is particularly relevant to use it as a reference for modeling. Three necessary steps are: defining an origin system for the project, sectioning the model to cover only the relevant region and cleaning unnecessary points; this way we can improve the navigation and modelling

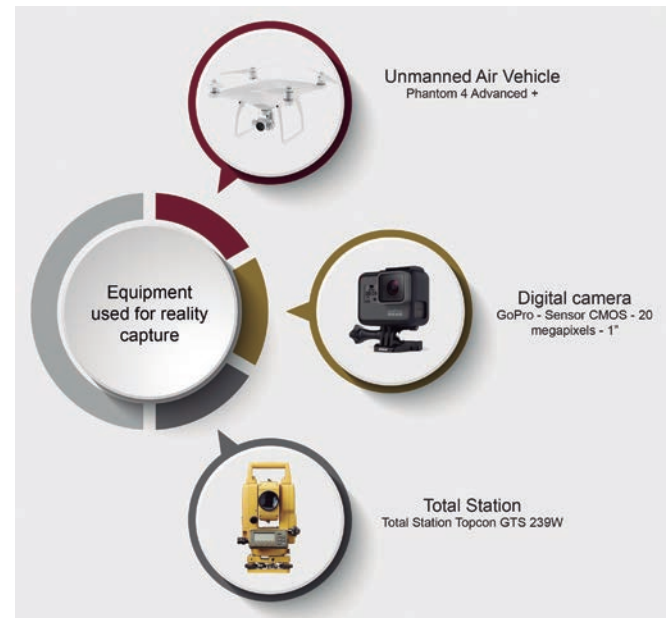


Figure 3. Localization of Baroness Solar. Source: Silva (2017).

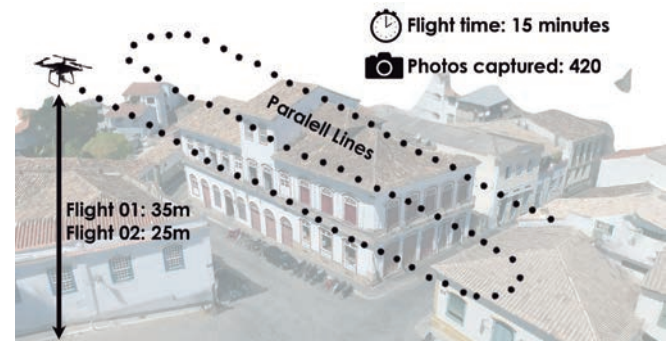


Figure 4. The UAV flight plane over Baroness Solar. Source: Silva (2017).

performance. The point cloud density achieved was in average 81 pts/m² and the measures were compared between virtual model and site building. One can notice that BIM processes with reality capturing data can increase precision and reduce work time. According to Groetelaars (2014), it is a fast process in

comparison with traditional surveys, requiring a lower number of people working on-site and consequently decreasing workplace accidents. On the other hand, considerable investment in pieces of equipment and computer software is required, which is an obstacle to popularizing the technique.

5. BIM MODELLING

The Baroness Solar BIM model was created in Revit educational version with LOD 300 and LOD 350 classification for components. It was made to study how this kind of modeling can contribute to maintaining updated building documentation and possible applications such as maintenance, design authoring and asset management of UFSJ.

At that stage it is necessary to analyze what are the BIM uses and the respective processes defined by the BIM manager. Therefore, in Baroness Solar's virtual construction, parameters such as location, date, management agent, window conservation state, or wall humidity were input into the model. Thus, the information can be exported, shown in schedules, or connected to an asset database management. In the modeling process, the first step was setting the origin point, and linking the point cloud with CAD files at the same coordinates, in order to assure a reliable positioning and subsequent stages. After this, the levels

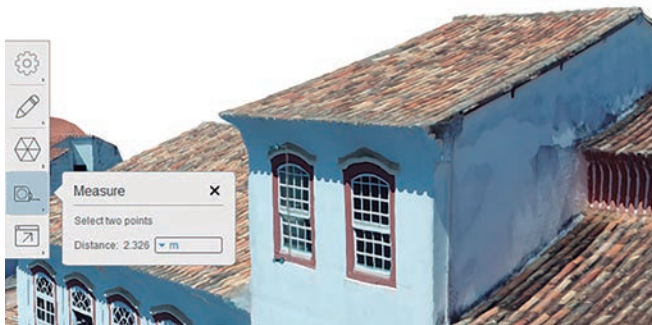


Figure 5. Measuring extraction from the mesh model of Baroness Solar. Source: Silva (2017).

were created to reference the different component heights, one for each story. The walls were the first components modeled since they are needed to host components such as windows and limit others like floors and roofs. The regular walls were created with their respective layers containing data about thickness and material, which allows an accurate quantification. However, issues with the irregular wall thickness were reported and to solve that problem, it was necessary to use a specific software technique called Model In Place, which is not useful for quantification since it does not allow layers. The doors and windows were created based on CAD files and orthoimages extracted from the point cloud. In this as-built model, there is not much variance in frame measures, so it was decided to create only material and text parameters and keep the same geometry for similar components. All of them have a parameter named "conservation state" to be filled, updated, and scheduled. After all the processes involved in the modeling, the virtual building can provide much information such as sections, floor plans, schedules, renderings, clash detections, and other uses that serve many professionals. However, it is important to mention that it is not a simple process, nor is it a fully automatized one. For a proper BIM model, it is essential to know how the data is managed accordingly to the software and how to model and to manage data.



Figure 6. Urban scale 3D mesh and photo captures location above the Baroness Solar building. Source: Silva (2017).

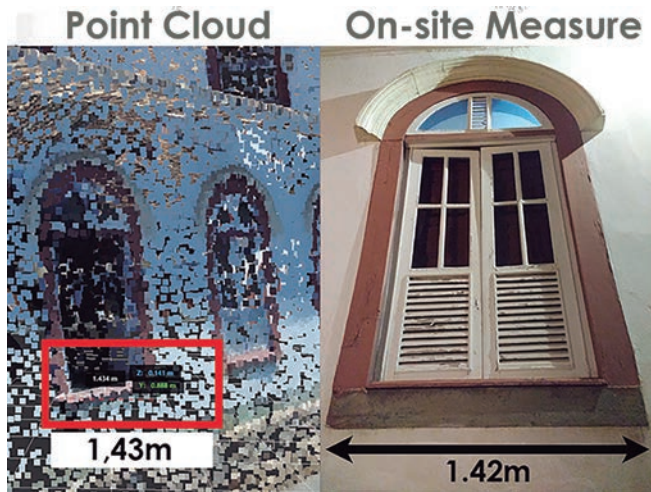


Figure 7. Comparison between the point cloud and real measures show an average accuracy between 1cm to 3cm. Source: Silva (2017).

6. RESULTS AND APPLICATIONS

The study of the whole process from data capturing to modeling and organizing it in intelligible information generated three main products: a BIM Model with updated facade documentation, a point cloud of the exterior building, and a Bachelor's dissertation. From the process of BIM modeling in order to update the documentation of Baroness Solar, one can notice that it is a relevant issue to preserve the edification and facilitate future activities of renovation and maintenance of the UFSJ cultural center. As for importance of documentation, Oliveira states that: *"Besides the documentary, symbolic, and social value of cultural building representation, it is a crucial instrument for those who have the mission to preserve a monument. Furthermore, it is the basis to develop intervention projects; the surveys made with precision permit detailed analysis of the architectural design and its transformations."* Oliveira (2008)²

The BIM model of a pre-existing edification could be created over a real and accurate point cloud given by



Figure 8. Baroness's Solar model in Revit Software. Source: Silva (2017).

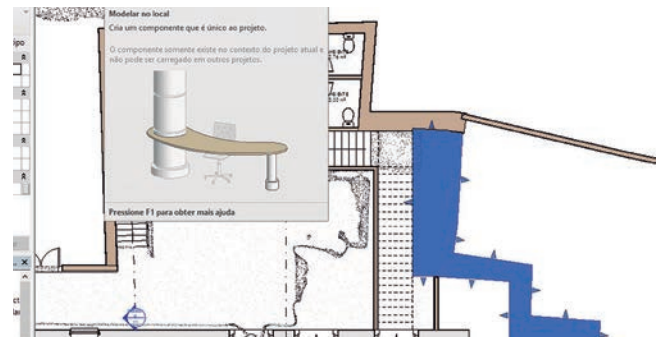


Figure 9. Irregular thickness of walls is a modeling difficulty in Revit Source: Silva (2017).

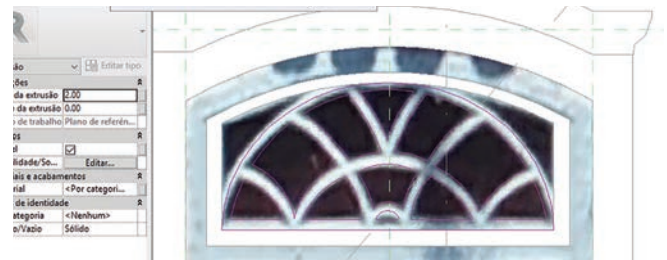


Figure 10. Orthoimages used for creating building components. Source: Silva (2017).



Figure 11. Point cloud + BIM model. Source: Silva (2017).

photogrammetry. After the modeling process, it serves for documentation, energy analysis, maintenance planning, among other needs. These simulations are particularly useful for heritage buildings because of their specific construction systems and cultural value. Furthermore, this work seeks to contribute to the inventory process of the cultural center. Since the model is a centralized database, all the information is integrated and any addition or modification shall update all sources of data simultaneously. That fact helps professionals to work over reliable documentation, doing simple tasks such as making a painting budget, or more complex ones such as retrofit projects. In the end, the Bachelors' dissertation documented the process, with the advantages and challenges of applying new technologies in heritage buildings. The survey of Baroness Solar shared results with other professionals who are also looking forward to a better application of BIM in historic edifications.

NOTE

1 Translation provided by the author: Aerofotogrametria, quando a câmera é transportada por aeronaves, balões, helicópteros ou veículos aéreos não tripulados (VANT), podendo ser aplicadas em áreas como: agricultura, levantamento cadastral urbano e rural, controle de mineração, monitoramento ambiental de cidades, prevenção de desastres naturais, etc.

2 Translation provided by the author: Mas, além do valor documental, simbólico e afetivo da representação cadastral de um edifício de interesse cultural, ela é instrumento inseparável dos que têm a difícil missão de intervir em um monumento. Além de ser a base óbvia sobre a qual vamos elaborar o nosso projeto de intervenção, os cadastros feitos com apuro e exatidão nos permitem leitura mais detalhada da evolução do organismo arquitetônico e suas transformações.

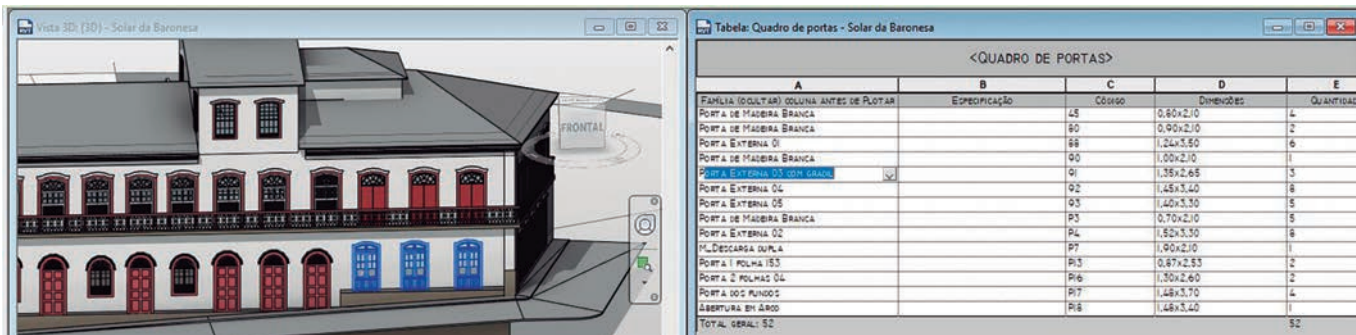


Figure 12. Model and schedules are linked when modeled in BIM software. Source: Silva (2017).

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