

# BIM-FM integrated solution resourcing to digital techniques

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## Abstract

The Facility Management has been suffering significant changes since the introduction of BIM in the AECO sector. However, there are still challenges in BIM implementation during the building use phase, such as the difficulties related to the personalization of the maintenance management information for each case, and modelling the as-built conditions. Disclosing building data to all the stakeholders involved in the building life cycle is also a challenging task. So, this paper aims to present an integrated solution for BIM-FM to categorize and prioritize maintenance management, with the resource to digital techniques. For this purpose, the methodology developed consists of 1- The recognition and preparation of the site conditions; 2- Image collection using a UAV; 3 – Image processing; 4 – Obtaining point cloud and its integration in a BIM software; 5 – 3D building modelling in Revit soft-ware, and 6 – Placement of building anomalies by means of placeholders. This work allows exploring BIM – FM representation and data integration for building condition assessment and its representation in a collaborative tool. This methodology will enhance the usability of BIM methodology in FM since it allows the data update in the model, avoids the information loss or fragmentation of the building life cycle and gives access to BIM users and non-users.

## Keywords

Facility Management, BIM, Maintenance Management, Photogrammetry, BIM-FM.

## 1. Introduction

The Architecture, Engineering, Construction and Operation (AECO) sector is facing several challenges related to the current ageing of the building stock, and the impacts of COVID-19 which required fast building adaptations [1] [2] and answers to the paradox of cost-reduction and quality increase [3]. Besides that, the AECO sector is responsible for several negative impacts on the environment, being under big pressure to contribute to carbon neutrality [4] [5] [6] [7].

Digitalization is considered by [8] as the answer to overcoming those challenges, but also, to increasing productivity, efficiency, sustainability, safety, quality levels and innovation.

Building Information Modelling (BIM) is recognized as being one of the developments that have been contributing most significantly to the digitalization of the AECO sector [8]. BIM is a collaborative methodology that has been pushing the AECO sector for the shared digital representation of the facilities, for the adequate building data sharing and storage between all the professionals involved in the building life cycle [9]. However, the difficulties related to the representation of the existing condition of buildings, the personalization of the information of maintenance management for each

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case, as well as, the access of the BIM data for all the stake-holders involved in Facility Management (FM) are still barriers to the implementation of this methodology [9].

For this purpose, an integrated solution for BIM-FM is proposed, to categorize and prioritize the maintenance management, with the resource of digital techniques. In this proposal, the photogrammetry technique is applied, to get the building point cloud and geometry, and facilitate the 3D building modelling in Revit software. Then, the building anomalies were evaluated and quantified employing the Method for Condition Assessment of Immobile Constructed Assets presented in CEN 17385:2019 [10], and represented by means of placeholders in the BIM model.

The placeholders are a family of objects, represented by a simple square geometry with parametric information about anomaly type, its severity and % of affectation of the anomaly. Besides that, the cracks were also geometrically represented in the model.

The following chapter presents the methodology developed and then described.

## **2. Methodology**

A methodology to reach an integrated solution for BIM-FM with the resource to digital techniques was developed, according to the following steps:

1. Recognition and Preparation of the site conditions.
2. Image collection using an Unmanned Aerial Vehicle (UAV) for photogrammetry purposes.
3. Image processing.
4. Obtaining point cloud and its integration in the Revit software.
5. 3D building modelling in Revit software.
6. Placement of building anomalies by means of placeholders and geometric representation of cracks.

## **3. Case study**

The methodology was developed and applied to a case study to check its future implementation. The case study is from the Geosciences Department of the University of Aveiro, in Aveiro, Portugal, authored by Architect Souto Moura. The building is composed of 4 floors. The basement is a storage room. The first and second floors are composed of classrooms and laboratories. The third floor is composed of professor offices.

The coatings are different from the traditional coatings used in the rest of the University building campus. The Northeast and southwest facades of the Geosciences Department of the University of Aveiro are composed of a concrete structures at the sight. Northwest and Southeast facades are composed of walls of concrete at sight that supports the glazed openings in all the extensions of those facades. These facades comprise a shading breezes system of pink marble supported by a metallic structure fixed to the concrete structure.

The department has a rectangular geometry with two entrances in the Northeast and Southwest facades. Figures 1 and 2 present the building under study.

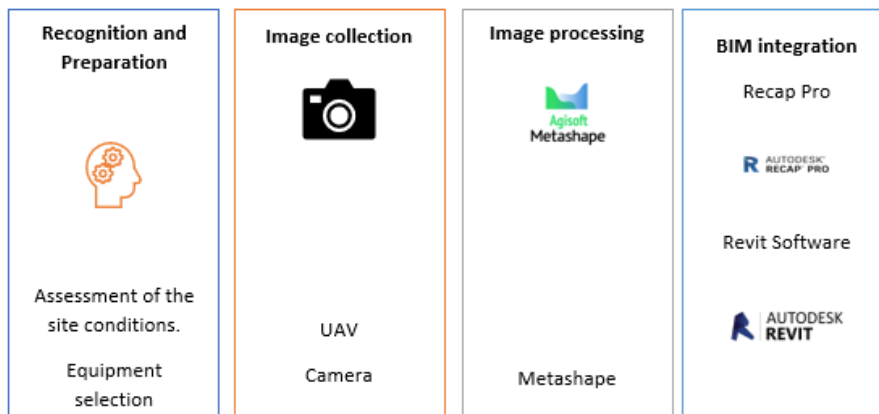


**Figure 1:** Geosciences department of Aveiro's University - South façade



**Figure 2:** Geosciences department of Aveiro's University - South façade

Afterwards, the building digitalization was the next step, which was supported by the Photogrammetry technique to obtain the building point cloud. For this process, a set of steps were considered, as presented in Figure 3.



**Figure 3:** Steps to the digital processing

### 3.1. Recognition and Preparation of the site conditions

The first step consisted of the building characterization, in which the materials were classified and the anomalies were registered. Besides that, the surrounding environment of the building was evaluated.

After the building and site conditions characterization, it was possible to verify that the building under study would have surfaces that could cause interferences in the photogrammetry technique to be applied, such as:

- clear / transparent objects (glass).
- very thin objects that contain lots of details (shadow systems that carry out some details).
- Building geometry is very regular and repetitive.

The presence of these elements with undesirable properties can cause a very sparse point cloud/lower quality of the point cloud and thus lower quality of the final model or problems with alignment. Besides that, there was no need to use targets, albeit the regular geometry and similar building pattern.

### 3.2. Image collection by means of UAV for photogrammetry purposes

The photos were shot with an UAV, a so-called drone, and a Digital Single-Lens Reflex (DSLR) camera. The specifications of these products are described in Table 1 and presented in Figure 4.

**Table 1**

Drone DJI MAVIC MINI specifications

DJI MAVI MINI	Feature
Weight	249 g
Flight Time	30-min Max.
HD Video Transmission	4 km
Vision sensor and a GPS Precise Hover	
3-Axis Gimbal	
2.7K Camera	



**Figure 4:** Drone DJI MAVIC MINI

Mavic Mini supports 12 MP aerial photos and 2.7K Quad HD videos. A 3-axis motorized gimbal provides superior camera stability and ensures clear ultra-smooth footage. The MAVIC MINI drone was used because it was the equipment available from the University, however, it is considered to be one of the best pieces of equipment for the desired purpose in terms of cost-effectiveness.

The photos were taken on a sunny day due to the availability of the drone. However, the photos were shot in the middle of the day to avoid non-desired shadows. Furthermore, the vegetation around the building caused sharp shadows on photos and thus problems with alignment and colours that do not correspond to reality.

The drone got 3 rounds to the building at different altitudes from the ground:

Height 1=4.5 meters

Height 2=14 meters

Height 3=19 meters (roof)

The camera inclination was 20 degrees down and it took photos all around the building, at least with 60% of overlap.

Since the drone could not fly next to the ground, a set of images were taken to complement and complete the model. For this purpose, a DSLR camera Sony Alpha A6100 with a lens of 16-50 mm f/3.5-5.6., was used.

### **3.3. Image processing**

After the building photos were gathered, the image processing in the software took place. The images taken were evaluated in terms of their quality and the repeated images were deleted. The following step was image processing.

The software for processing the images and creating and manipulating the point cloud was:

- Agisoft Metashape
- AutoDesk Recap PRO
- AutoDesk Revit

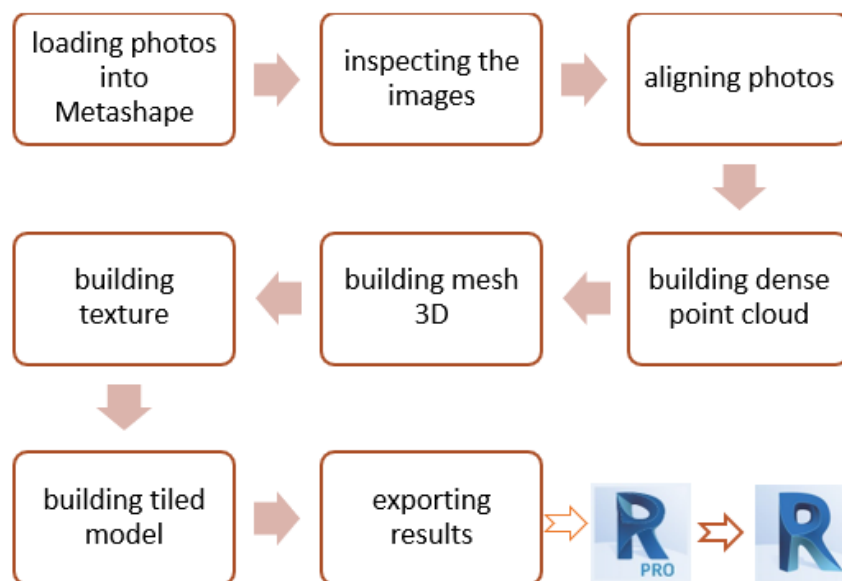
Regarding the hardware, after several attempts in other devices, a successful attempt was made by a device with the following specifications (Table 2):

**Table 2**  
Hardware features [11]

Specifications	Recommended configurations	Configurations used
Processor	Intel core i7 or AMD Ryzen 7 Processor	AMD Ryzen 9 5900X 12-core Processor 3.69 GHz
Installed RAM	32 GB	32 GB
System type		64-bit operating system x64-based processor
Graphic card	Discrete NVIDIA or AMD GPU (4+ GB VRAM)	NVIDIA RTX3070
Windows specifications	Windows 7 SP 1 or later	Windows 10 Enterprise Version 1909 TB SSD, 1TB HDD

It is recommended to make sure that the Graphics Processing Unit (GPU) device is detected by the program.

The photos were uploaded on Agisoft Metashape, which is a software that performs photogrammetric processing of digital images. In this software, the process was done according to Figure 5.



**Figure 5:** Steps of processing images in Agisoft Metashape

### 3.4. Obtaining point cloud and its integration in the Revit software

After the photos processing in Metashape according to Figure 5, it is possible to obtain the building point cloud with the geometric building information (Figures 6 and 7). The Point Cloud was exported from Metashape by the format .e57, which is not a compatible format to import to Revit. So, the file .e57 was transformed to .rpt by Autodesk Recap Pro and then imported to Autodesk Revit.

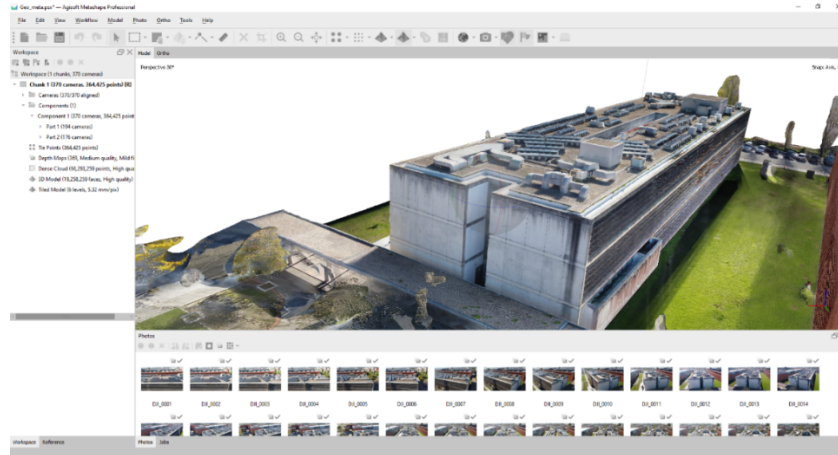


Figure 6: Point cloud in building texture – NE façade in Metashape



Figure 7: Point cloud in building texture – SE façade in Metashape

### 3.5. 3D building modelling in Revit software

After being imported to Autodesk Revit, the building geometry was modelled in overlap with the point cloud, which facilitated the modelling process, becoming a swift and prompt process (Figure 8).

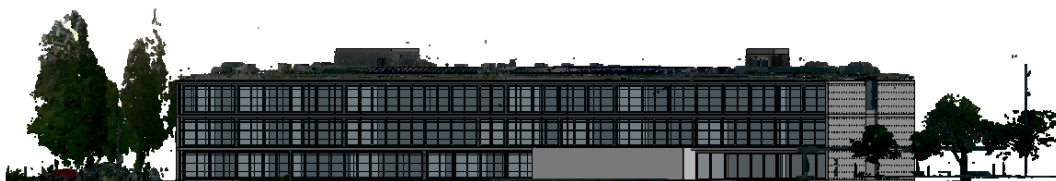
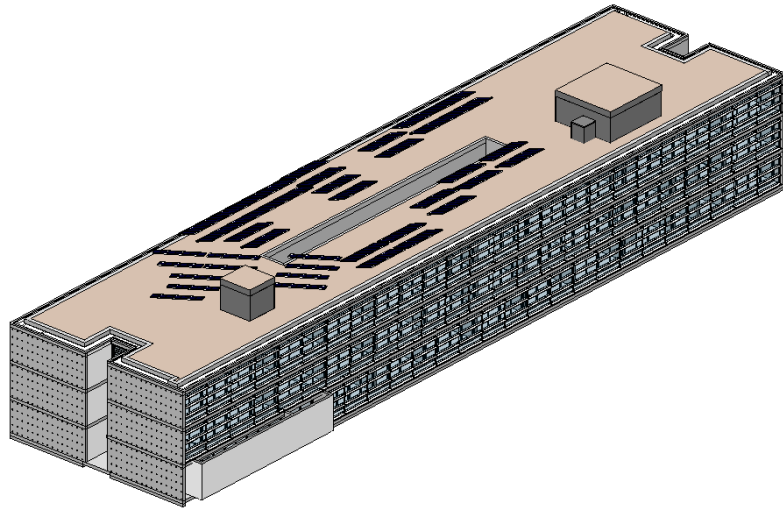


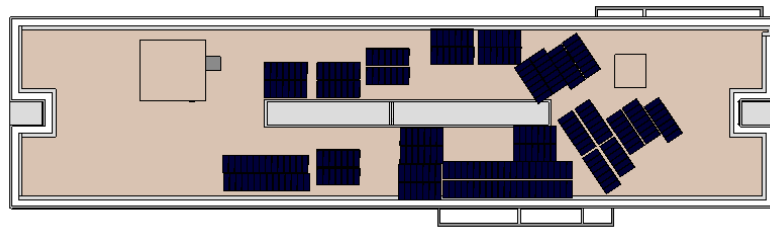
Figure 8: Steps of processing images in Agisoft Metashape

In the building modelling, the concrete facades at sight were modelled, as well as the customized glass openings. The shading breezes system and the solar panels were modelled as families of objects

to customize the dimensions, materials and respective support. Figures 9 and 10 present the building modelling.



**Figure 9:** Building Modelling in Autodesk Revit



**Figure 10:** Building Modelling in Autodesk Revit – roof plan

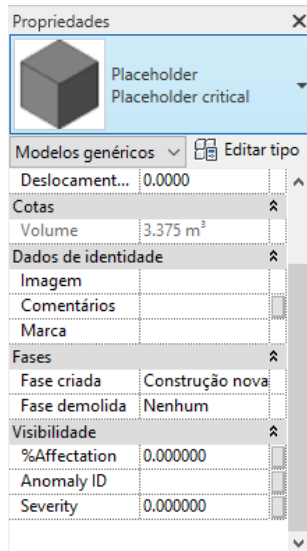
### **3.6. Placement of building anomalies by means of placeholders.**

Being the 3D building modelling in a BIM environment, more data was added to the model.

Figure 6 represents the point cloud with texture, by which is also possible to identify the place of the existing building anomalies. This representation facilitates the representation of the anomalies in the BIM model employing placeholders and crack families.

So, by the previous building inspection done, the Method for Condition Assessment of Immobile Constructed Assets presented in CEN 17385:2019 was applied. This method takes the defect severity, the level of degradation, and the extent of the defect into account, which results in the condition classes. The defect severity is related to the influence of the defect on the performance of the element. The level of degradation is related to the visible physical condition. The extent of the defect assesses the area or volume of the element that is affected. The condition class is the result of merging the severity, level of degradation and extent of defect, and represents the condition of the element.

Based on this method, a family of placeholders with parametric information about the anomaly ID, severity of the defect and the extent of the defect was developed (Figure 11).



**Figure 11:** Parametric information linked to Placeholder family

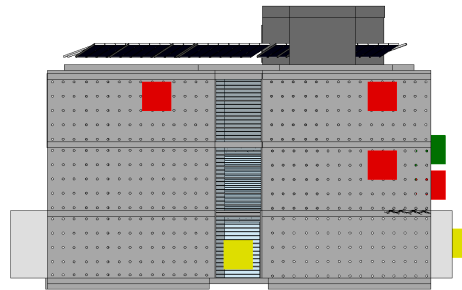
The placeholders were placed in the building model according to their condition class, the poor condition represented by red squares, the fair condition represented by the yellow square and the good condition represented by the green squares.

Figures 12 and 13 present the Northeast face of real photography and the 3D modelling with the placeholders, being the NE facade evaluated with a poor condition and represented with the red placeholders since the concrete façade has wide-spread anomalies. Besides that, cracks were also represented in the model by means of a family.

Figure 14 presents the complete building model with the placeholders translating the elements' conditions, which allows for prioritizing maintenance actions.

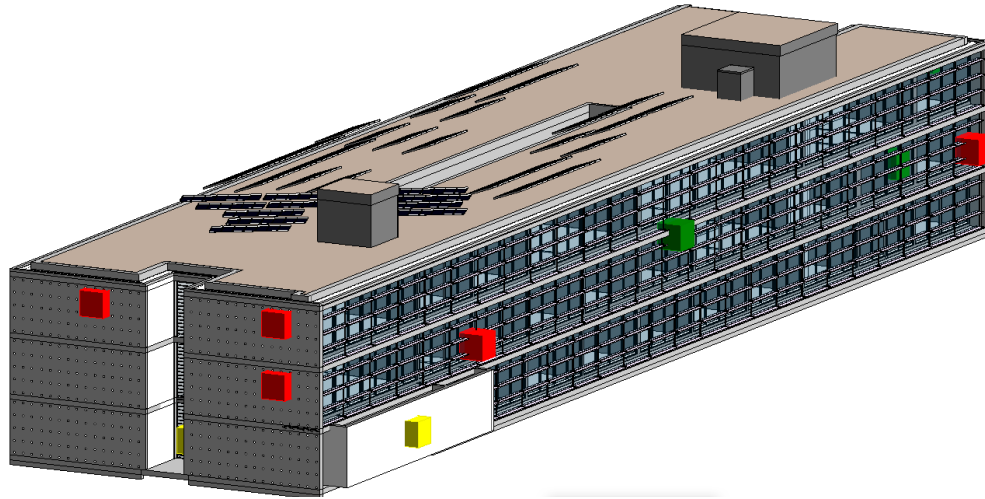


**Figure 12:** Northeast façade - photography



**Figure 13:** Northeast façade – 3D model with place-holders and cracks





**Figure 14:** Building model in Revit with placeholders and cracks

## 4. Conclusions

The operation and maintenance phase is the longest and the most expensive phase of the building life cycle, which has been adding importance to FM, especially since the digitalization of the AECO sector. BIM and other digital techniques like photogrammetry, and laser scanning, make FM gain more focus.

However, there are still some barriers to the implementation of them in FM, like the customization of maintenance management information for each case as well as the disclosure of the building life cycle information. So, this work presents a methodology that allows having a BIM-FM integrated solution for building condition assessment and its representation in a BIM environment, which is a collaborative methodology and a repository of building life cycle data. For this purpose, making use of the photogrammetry techniques, the building was modelled in Revit. And then, the placeholders and crack families were placed in the model, representing the building defects. The methodology developed, makes it possible for the systems condition assessment, its classification and representation in the 3D model, and consequently, maintenance actions prioritization and management. This methodology leverages BIM methodology in FM since it is a quick method to include building maintenance data in the model, allowing its easy update, which makes it possible to avoid the information loss or fragmentation of the building life cycle. So, this study intends to contribute to more efficient coordination of the maintenance management activities, which are under development.

As for future developments, it is expected to automatize the recognition and classification of degradation in historical buildings to finally interpolate this geometric and numerical information with a BIM methodology, obtaining a representation and quantification of the information adapted to the FM processes.

## 5. Acknowledgements

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