BIM-FM Methodology Applied to a University Building

1. Introduction

Technological evolution has been a determining factor for civil construction and the entire life cycle of the building, increasingly thinking about solutions that optimize both time and cost. All sectors that can gain an advantage in this optimization are explored and encouraged. This technological era brought the implementation of software that supports the monitoring of the work, as well as improving the management of the building, through electronic documentation and files to support the use, operation, and maintenance.

Building Information Modeling (BIM) is already a consolidated reality both in Brazil and Portugal and its use has grown more and more, bringing new approaches and expanding its area of operation. It becomes evident that BIM brings great advantages, especially in the exchange of information between the actors involved in the life cycle of the enterprise, generating global benefits in terms of costs and time.

For the present study, the use of BIM technology applied in building management will be addressed, that is, BIM 7D or BIM-FM (Facility Management). In this dimension, aspects related to the management of the construction life cycle are addressed, from which it is possible to control equipment warranty, determine maintenance plans, and classify spaces and elements, aiming to improve maintenance planning and actions. In this way, the BIM-FM methodology is a precious or even essential aid in the case of large buildings/installations, for efficient management of the use, operation, and maintenance phase of the building.

The main objective of this article is to present the application of the BIM-FM methodology to the management of equipment and the exterior envelope of the building/block A of the Federal Technological University of Paraná (UTFPR), Ecoville campus, with the help of shared parameters created in the Revit software and filled in following the regulations in force for each of them, in addition to files obtained through COBie (Construction Operation Building Information Exchange) spreadsheets and Maintenance Sheets prepared based, in particular, on standards and technical documents.

The Maintenance Sheets, which will contribute to the correct maintenance procedure of each relevant element of the building, will be of great value in aiding the maintenance of the building.

To achieve the proposed objective, specific objectives were stipulated such as:

- Three-dimensional modeling of the building with the help of the Revit software, as well as the detailing of the facilities, facades, and roof as an object of study;
- Deepening the level of detail in the study areas to have information in the model that will support future consultations and maintenance procedures based on current regulations and technical documents;
- Deepen non-geometric information about the building, to guarantee the detailed extraction of data through COBie spreadsheets, which can be used in maintenance management software and/or support the installation manager through files in xml format;
- Analysis of the extracted COBie sheets and study of the information obtained;
- Construction of Maintenance Sheets for facade cladding, roofing, and window frames.

2. Case study

2.1 Study building

The building of the present study is block A of UTFPR, Ecoville campus, located in Brazil in the city of Curitiba.

The building was built to meet the demand for some courses offered by UTFPR. Work began in 2002 when only half of the block was built. The works were restarted in 2006 and were completed in 2010.

The structure was made of reinforced concrete and the masonry was made of ceramic brick.
According to the architectural project, the total wall thickness of the exterior envelope is 15 cm: considering 9 cm ceramic brick, a slurry layer, which can vary from 5 mm to 7 mm, a roughcast layer to smooth the surface, between 2 cm and 2.5 cm, and a cement plaster layer of 5 mm.
The roof data, extracted from the same project, define the covering with 6 mm of fiber cement tiles, with a 10% slope, fixed to a metal structure, which is supported on a 10 cm thick reinforced concrete slab.
In all ceilings, an air layer of 70 cm was considered between the slab and the expanded polystyrene (EPS) coating. The frames are made of natural anodized aluminum with 6 mm glass.
The building consists of the ground floor, a basement, and three upper floors, as shown in Figure 1. The basement contains a storage room and a room used as an electrical and internet network cabling center. In terms of accessibility, the building contains stairs, an elevator, and emergency stairs.
On the upper floors, the main compartments are the following: laboratories, classrooms, architectural studios, professors' rooms, toilets, department heads, and coordination rooms.
In this block, there is some equipment such as an elevator, air conditioning, and wall fans in some classrooms and the service room. These were introduced in building modeling and will appear in COBie sheets.
The maintenance of the building is carried out mostly in a corrective way, being done through service requests.

Figure 1 - Rear elevation (left) and front elevation (right)
Source: [1]

2.2 Building modeling

To assist in this step, we chose to use the Revit program version 2022, available from Autodesk. As the building did not have any three-dimensional modeling, it was based on the execution project available in PDF format and with in situ verification to supply the changes that occurred over time, such as changes in layout, changes in the type of coating of the exterior wall and changes in the rear elevation, such as the absence of the platband to adjust the volume of the building.
Figure 2 shows the main and right elevations of the building modeled in Revit.

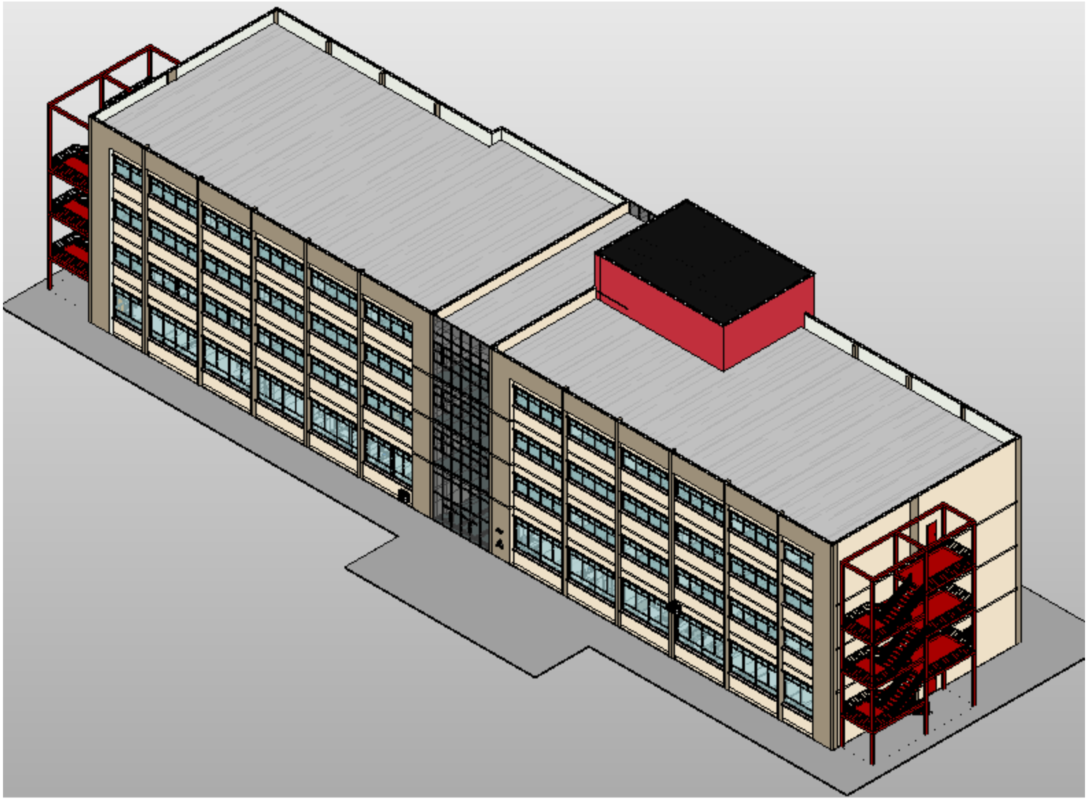

Figure 2 - Perspective of the Revit model of the building
Source: [1]

2.3 Classification systems

Classification systems reinforce the concept of interoperability, as throughout the construction process all information is organized and classified following a standardized structure. Among the various classification systems, the most used internationally are Uniformat, Masterformat, UniClass, and OmniClass. In Brazil, there is also the system proposed by NBR 15965-1 [2].
NBR 15965-1 [2] is based on an organizational scheme that presents six major classes of construction (spaces, results, processes, resources, properties/characteristics, and information) and the general relationships between them, as participants in the life cycle of an enterprise. NBR 15965-1 [2] is subdivided into seven parts, where the first part deals with terminology and structure, and the other six deal with one of the classification themes mentioned in Table 1, showing the various combinations that can be obtained within each theme. Based on this information, an example of the classification of openings, passages, and protections is presented in Table 2.

Table 1 - Class structure
Source: [2]

Group ID	Theme	Subject	Subject identifier	Classification
0	Characteristics of objects	Materials	M	0M
		Properties	P	0P
1	Processes	Phases	F	1F
		Services	S	1S
		Disciplines	D	1D
2	Resources	Functions	N	2N
		Equipment	Q	2Q
		Components	C	2C
3	Construction results	Elements	E	3E
		Construction	R	3R
4	Construction units and spaces	Units	U	4U
		Spaces	A	4A
5	Construction information	Information	I	5I

Table 2 - Proposal for classification of openings, passages, and protections
Source: [2]

Code	Term
2C.30.00	Openings, passages, and protections
2C.30.20.00	Windows
2C.30.20.11	Window components
2C.30.20.11.11	Profiles for windows
2C.30.20.11.14	Window frames and sills
2C.30.20.11.17	Venetian
2C.30.20.14	Windows by material type

Although many classification systems can be used for the use of COBie without presenting any kind of restriction, in this article OmniClass will be used. This system was chosen for standardization because it is a type of classification that allows user-oriented exploration, as it has a large set of data that can be gradually filtered according to their choices. With this, a mix of data is obtained according to the required needs. This system is like the Brazilian classification system in terms of its gradual filters. However, the Brazilian system does not have connectivity to Revit, which would make it difficult to speed up the classification of the building, since its classification is performed by consulting the reference standards.
Tables 11, 13, 21, 22, 23, and 24 of the OmniClass system were used in the model.

2.4 Shared Parameters

Since the BIM 7D dimension is the most relevant to the theme proposed in this article, it implies an increase in information aimed at preventive maintenance and project management. This dimension allows stakeholders to extract information regarding the equipment that makes up the building, and have access to maintenance specifications, manuals, warranty periods, and manufacturer information, among others, providing optimized management of the asset life cycle over time.
To improve/deepen the data entered in the model, it became necessary to create shared parameters between families in Revit (these parameters must be added in each new building case). These parameters will be fed with constructive data of the elements, as well as their maintenance data to store data relevant to maintenance (Table 3) and characteristics of each element so that it is possible through the model to obtain this information for various purposes. These parameters will also be useful as aids in filling in Maintenance Forms referring to the elements of the study.

Table 3 - Shared parameters - constructive and maintenance data
Source: adapted from [1]

Shared Parameters	
Constructive Data	Maintenance Data
Air permeability class	Inspection cycle [years]
Thermal transmission coefficient - U_w [W/m²·ºC]	Cleaning cycle [years]
RGB color - frame	Proactive maintenance cycle [years]
RGB color - glass	Date of last intervention - corrective action [dd/mm/yyyy]
Water tightness	Construction/installation date [dd/mm/yyyy]
Solar factor – *Sw* [%]	Replacement date - construction/installation + service life [dd/mm/yyyy]
Weighted sound reduction index - R_w [dB]	Supporting document
Reaction to fire (outer coating)	

2.5 Level of Development (LOD)

Ensuring that the model is filled with as much information as possible will facilitate the extraction of data for maintenance (e.g. service life), as it will be possible to have a broader view of all the characteristics of the elements, as well as the physical, thermal and geometric properties an all.

For roofs and walls, Revit calculates the Thermal Transmission Coefficient (U_w) based on the thermal characteristics of each material/layer added to the model. For this, it is necessary to insert the values referring to the Thermal Conductivity (λ) of these materials in the respective properties. The values for the air layers that make up the building elements were calculated based on NBR 15220-2 [3].

In addition to deepening the thermal characteristics of the materials, it became necessary that the layers of the elements of the exterior envelope were well defined and as close to reality as possible. Thus, the values calculated (U_w) by Revit will be more accurate for future performance comparisons.

The layers used in the composition of the masonry exterior wall as well as their thickness are shown in Figure 3.

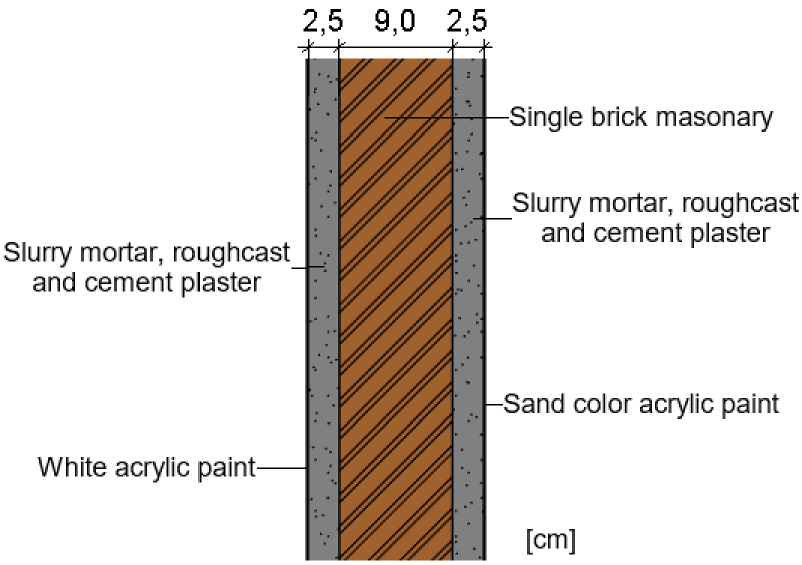

Figure 3 - Exterior wall layers
Source: [1]

2.6 Comparison with the real model

To be as faithful as possible to the geometry of the building, careful modeling was carried out, rich in details, especially in the points that will be part of the extraction of maintenance data, such as the facades and windows of the exterior envelope. The deepening of these physical characteristics will generally facilitate the interpretation of the spaces of the building.

In Figure 4, the interior corridor on the ground floor is shown, ignoring the existing lighting fixtures in the real building.

Figure 4 – Internal view of the ground floor corridor: real view (left) and Revit model (right)
Source: [1]

2.7 Construction and maintenance parameters

It is necessary to fill in these shared parameters based on standards and technical documentation, to have an adequate foundation when analyzing the data entered during decision actions in the operation and maintenance phases. These parameters were divided into two types: constructive parameters and maintenance parameters.

2.7.1 Constructive parameters

NBR 15575-1 [4] presents data at three levels for the useful life of constructive elements as shown in Table 4.

Table 4 – Levels of service life of building elements
Source: [4]

	Service life (years)		
Element	Minimum	Intermediate	Higher
Pitched roofs - roof covering	13	17	20
Façade ceramic cladding	20	25	30
Painted surfaces	8	10	12
Aluminum frame	20	25	30
False ceiling	8	10	12
Roof - waterproofing	8	10	12
Interior floor covering	13	17	20

Silva and Brito [5], based on a large set of international data, present average values for the useful life of some of the elements in Table 4, which may be comparable with the intermediate values extracted from NBR 15575-1 [4]. This comparison is presented in Table 5.

Table 5 - Comparison of the average values of the service life of building elements
Source: [4], [5]

	Service life (years)		
Element	NBR15575-1 [4]	Silva and Brito [5]	Average
Fiber cement tile	17	24	20.5
Façade ceramic cladding	25	36	30.5
Painted surfaces	10	12	11.0
Aluminum frame	25	34	29.5

Based on the comparison between the useful life of the construction elements, it can be seen that the average values presented by Silva and Brito [5] are higher than the values of the intermediate level presented by NBR 15575-1 [4]. The average of the two bibliographic references approximates the values of the higher level of the same standard (Table 4). Therefore, the parameters used to fill in the useful life of the elements in the model will be based on the values of the upper level of the Brazilian standard, since it presents data referring to other elements that will be relevant in filling the model.

2.7.2 Maintenance parameters

For maintenance data, Madureira et al. [6] present a periodicity proposal for actions regarding the maintenance of buildings, ranging from small interventions to the deadline for replacing the material/element (corresponding to the useful life). This proposal is presented in Table 6 for facade cladding and in Table 7 for doors and windows.

Table 6 – Maintenance data for façade claddings
Source: [6]

Element	Maintenance	Periodicity
Painted surfaces	Inspection	2 years
	Cleaning	When necessary
	Replacement	8 years
Façade ceramic cladding	Inspection	3 years
	Cleaning	10 years
	Treatment of surfaces	After repair work
	Minor intervention	13 years
	Replacement	26 years

Table 7 – Doors and windows maintenance material data
Source: [6]

Element	Maintenance	Periodicity
Aluminum	Cleaning	2 years
	Minor intervention	10 years
	Replacement	35 years
Glass	Cleaning	Regularly
	Replacement	When necessary
Metal accessories and seals	Minor intervention	1 year
	Replacement	When necessary

Regarding the Brazilian reality, the data consist of different standards, where the maintenance information (minor intervention and replacement) referenced by Madureira et al. [6] are like proactive maintenance and lifetime actions. This nomenclature is the same that will be used to prepare the Maintenance Sheets. From this information and with the replacement data adjusted to the higher values of Table 4, a comparative analysis was prepared to obtain the best choice for insertion in the model, which is presented in Table 8 (data related to roof elements are not presented).

Table 8 – Comparative analysis of maintenance data
Source: [1]

		Periodicity	
Element	Maintenance	Brasil (standard)	Madureira et al. [6]
Painted surfaces	Inspection	3 years (NBR 5674) [7]	2 years
	Cleaning	3 years (NBR 5674) [7]	When necessary
	Replacement	12 years (NBR 15575-1) [4]	8 years
Façade ceramic cladding	Inspection	1 year (NBR 5674) [7]	3 years
	Cleaning	3 years (NBR 5674) [7]	10 years
	Minor intervention	1 year (NBR 5674) [7]	13 years
	Replacement	30 years (NBR 15575-1) [4]	26 years
Aluminum (Windows and doors)	Cleaning	3 months (NBR 5674] [7]	2 years
	Minor intervention	1 year (NBR 5674) [7]	10 years
	Replacement	30 years (NBR 15575-1) [4]	35 years
Glass (Windows and doors)	Cleaning	Regularly (adopted)	Regularly
	Replacement	When breaks are found	When necessary

		(adopted)	
Metal accessories and seals (Windows and doors)	Minor intervention	1 year (NBR 5674) [7]	1 year
	Replacement	When performance failures are found (adopted)	When necessary

For this model, a proposal for the maintenance periodicity was elaborated from Table 8. These values are shown in Table 9. Except for the replacement data (based on the upper level of Table 4), the choice of periodicity of other maintenance actions was based on Brazilian normalization (presumably more adapted to the Brazilian climate reality) and because they have enough data for all parameters present in the model.

Table 9 – Maintenance periodicity proposal
Source: [1]

Element	Maintenance	Periodicity proposal
Painted surfaces	Inspection	3 years
	Cleaning	3 years
	Replacement	12 years
Façade ceramic cladding	Inspection	2 years
	Cleaning	5 years
	Proactive actions	7 years
	Replacement	30 years
Aluminum (Windows and doors)	Inspection	1 year
	Cleaning	1 year
	Proactive actions	1 year
	Replacement	30 years
Glass (Windows and doors)	Cleaning	Regularly
	Replacement	When breaks are detected
Metal accessories and seals (Windows and doors)	Proactive actions	1 year
	Replacement	When performance failures are found

2.8 Maintenance Sheets

The Maintenance Sheets are of paramount importance for the maintenance of the building, as they will contain information relevant to the building's operations, the measures that must be taken, their frequency, the means necessary for them to be completed, and those responsible for each one of them.
For this article, Maintenance Sheets were prepared for three types of solutions: covering the roof, covering the exterior wall with ceramic tiles (extract from the sheet in Table 10), and window frames.
These sheets, as well as other documents related to maintenance, were stored in a virtual repository, where the building manager has full access to insert, remove and modify any documents, and his team can have access to consult the information they deem relevant for each element type.

Table 10 – Maintenance Sheet - Exterior wall with ceramic tile cladding
Source: adapted from [1]

Operation	Actions	Frequency
Inspection	Inspection of infiltration signals and cracks	2 years
	Inspection of the detachment, cracking, or fracture of ceramic tiles	2 years
	Inspection of joints between ceramic tiles	1 year
	Inspection of dirt and stains on the surface of tiles and joints	1 year
Operation	Actions	Frequency
Cleaning	Washing of ceramic tiles	5 years
	Cleaning of joints	5 years

Operation	Actions	Frequency
Proactive measures	Application of water repellent and biocide products to protect the exterior walls	7 years [1]
	Fix poorly fixed tiles	When necessary
	Correct punctual failures in the joints between ceramic tiles	1 year
Operation	Actions	Frequency

Corrective measures	Replacement of cracked, fractured, or missing tiles	When necessary
	Correction of joints between tiles and fractionation/peripheral joints	When necessary
Operation	Actions	Frequency
Replacement	Total replacement of ceramic tiles	30 years [2]
	Total replacement of joints	12 years [2]
	Wall replacement	60 years [2]

Note:
[1] According to the validity of the product stipulated by the manufacturer;
[2] The NBR 15575-1: 2021 establishes that this is the minimum value for the element to fit the top level indicated by it. It is suggested that an inspection be carried out after this period and only if it is necessary to perform the total replacement of the element.

3. Conclusion

The use of BIM technology for building management is still little used in Brazil since most of the maintenance is done in a corrective way without much planning. According to the analysis of the maintenance of the building studied, it was found that a large part of its maintenance is carried out only when the failure of the equipment/element is detected, and this leads to great costs and inconvenience to the users of the building.
The purpose of this article was to address ways for the maintenance manager to manage effectively, schedule, and reduce costs and inconvenience to the maximum during this phase of the building's life cycle. Using the Revit software, it was possible to create parameters that would store the construction and maintenance data relevant to the exterior of the building, deepening the level of information of these elements that will be stored in the developed model and, when necessary, can be consulted and updated by the building managers. From the deepening of the information present in the model, it was possible to create the Maintenance Sheets that will serve to assist in the correct fulfillment of the maintenance of the elements addressed. Such files are stored in a shared repository and can also be accessed through a parameter present in the Revit model.
With the proposed method, there are great benefits that this technology brings to the sector, as the information goes beyond just a three-dimensional representation. It aggregates detailed and pertinent information that will be used by the building manager, and when fed from the design phase, it aggregates more complete information from all the actors in the construction process, reducing the search for information about the elements of the model, as it guarantees more structured and reliable, inserted by those responsible for each area of activity.

References

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