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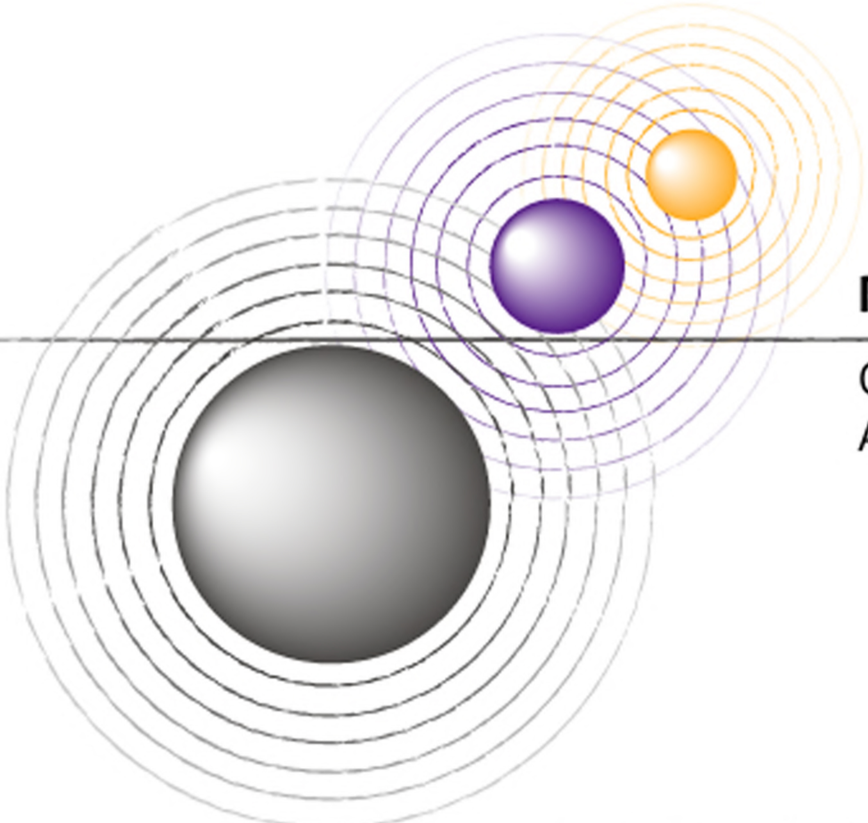
## DE LA EXPRESIÓN GRÁFICA APLICADA A LA EDIFICACIÓN



**REDRAWING THE FUTURE**

OF GRAPHIC EXPRESSION APPLIED TO BUILDING

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# THE DIGITIZATION OF INFORMATION IN HBIM PROCESSES

*EL PAPEL DE LA DIGITALIZACIÓN DE LA INFORMACIÓN EN EL PROCESO BIM*

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## 1. OBJECTIVE

In the last decade there have been numerous studies concerning the application of BIM processes (Building Information Modeling) to existing buildings, identified with the acronym HBIM (Heritage Building Information Modeling)[1]. However, despite the fervent research activity on these issues, thanks to the recent legal provisions[2], there are still strong doubts about the advantages, automatisms and expected results. The controversy arises in wanting to apply a validated methodology for designing *ex novo*, based on the use of standardized objects, cataloged within parametric libraries, to the built architectural heritage. BIM processes for the new design do not, in fact, contem-

[1] Acronym used for the first time in 2009 by Maurice Murphy (Historic Building Inofrmation Modeling. Adding intelligence to laser and image based surveys of European classical architecture). Over the years the scope of application has been extended from historic buildings to the entire historical built heritage, preferring the term "heritage" to "historic".

[2] In Italy, the Ministerial Decree 560 of 1/12/2017 establishes that the use of BIM software becomes mandatory for large public procurement works starting from January 1, 2019.

plate the uniqueness and irregularities of the historical heritage, linked both to the craftsmanship of the construction and to the deterioration caused by the passage of time. This change —from new builging to existing building— involves aspects and criticity that BIM processes do not contemplate. They consist in the preliminary phase of knowledge, analysis of historical-archival sources, which imply the participation in the process of more and more skills related to the management of cultural heritage (superintendencies, restorers, surveyors, etc). The scope of application of HBIM appears to be much broader and more heterogeneous than that of "traditional" BIM. It consequently lead to an increase in interoperability and greater difficulties inherent in modeling and computerization of the models themselves [1]. On the one hand, in fact, the result of BIM processes for new constructions is a model that contains a level of detail corresponding to an executive project, from a geometric and informative point of view, and is defined as-built BIM model. On the other hand, instead, the level of detail in HBIM processes is linked to the most complete knowledge of the information, from the geometric-constructive aspects to the historical-critical ones. However, for historical artifacts, it is not always possible to achieve a total mastery of all these aspects, such as to be able to obtain an as-built HBIM. Furthermore, "the characteristics of the architectural heritage mean that, for a complete and exhaustive documentation, a quantity of more information of an extremely heterogeneous nature is necessary, which does not always find its place in a database designed to document new buildings" [2].

The ambitious goal that HBIM processes pursue, however, is the construction of an informed model that aspires to contain the whole data and informations. This model should be just one database but heterogeneous, useful for the public administration and for the various subjects involved in the management of an architectural asset. HBIM process therefore builds the database necessary both for the documentation and monitoring of the historical building, and for the development of maintenance, restoration and recovery projects. This guarantees a better quality of interventions thanks to a multidisciplinary approach and the involvement of the various professional figures, limiting time and costs [3].

The first stage of knowledge therefore becomes fundamental for the construction of digital model consistent with the real one. If on the one hand, integrated digital survey techniques allow to capture the surfaces of an artifact with great precision and accuracy even in the presence of particularly complex shapes, on the other hand, there are still some limits for informative characterization of the shapes themselves. The gaps in the cognitive process and in the geometric definition of shapes often lead to the creation of "hybrid" models, in which some of the characteristic parameters of BIM processes are different even for some elements of the same model. It therefore happens that the Level of Details (LoD) is different from the Level of Development (LOD)[3], or the Level of Information (LOI) may not correspond to the Level of Geometry (LOG)[4] [4].

[3] The first intends to "measure" the reliability of the information characterizing a BIM model, the second defines the graphic detail of digital objects in case of visualization or representation (Rossi 2019).

[4] Modern BIM authoring software provides tools to model digital objects with different graphic detail, from a schematic display up to a high detailed one. There-fore, there it seems to be a close analogy between LOD and LoD so that we can easily conclude that simply increasing the detail of an object we can pass from one LOD to another assuming the Level of Development as equivalent to its graphic details. Reality is quite different though. While modelling a 3D component, in fact, we can define progressively different LODs affecting its Level of Development and its features but not necessarily its actual geometric detail. In this framework, LODs can differ only for the attributes of the BIM object, i.e. their Level of In-formation (LOI). On the other hand, however, any BIM object in its higher LODs must show correspondingly higher non-graphical information (the info attributes) and this evidence makes the sequence of LODs somehow independent from the Level of Detail that seems to describe only the geometric component of the modelled element. Still they do not take into account the quality of the information on which they are constructed. In any HBIM model, in fact, objects can vary a lot in term of reliability either because of the quantity of information available or of the quality of the Modeller's reading.

The main discriminating factor between the two as-built models therefore concerns the level of deep knowledge. In BIM applications, the cognitive and informative aspects follow the design levels, easily reaching the executive, defined by the architect/engineer. In HBIM applications, not only the knowledge has to be found without the certainty of reaching a good level, but above all it is characterized by heterogeneous information, filed and stored in different places, in different ways, in different platforms and different supports. For this reason, the characterization of digital models through BIM tools is currently extremely complicated.

## 2. DESIGN

In applications on architectural heritage, the preliminary phase involvesn the study and analysis of the actual state and the evolutionary history of the building. Only by comparing historical-archival sources, information resulting from the survey and diagnostic investigations, it is possible to reach a level of knowledge of the building suitable for correct hypotheses about the building, necessary for the construction of the informative model [5]. Understanding the formal, compositional, geometric and proportional aspects of the artefact, acquired through integrated digital survey activities, is fundamental in this process. Current methodologies, widely tested today, allow to reconstruct the surface of

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This is the reason why we concentrated on the coding of the Level of Reliability (LOR), an additional parameter aiming at assessing the coherence of the work-flow guiding the generation of digital objects in a HBIM model. It is actually a numeric score resulting from the balancing of several factors considered as individual items and with respect to their general role within the model. Besides, we outlined some key aspects that could influence the LOR of one single object, of a collection of objects and eventually of an entire HBIM model.

The LOR coding considers the geometric reliability of digital objects together with their ontological correspondence to the real item they represent, in form of a numeric scale spanning.

the survey object through a 3D numerical model, which integrates perfectly with the parametric one (Figure 1).

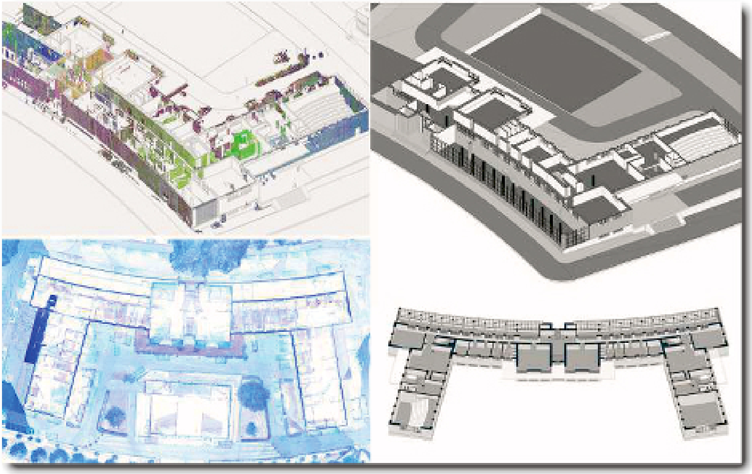

Fig. 1. Botany Institute at Sapienza Campus, integration between 3D numerical model (from 3D laser scanning) and BIM. Source: Author

This solves the problem of modeling particularly complex forms or completely artisanal and sculptural apparatuses, but the problem of informative characterization of the various elements remains. The digitization of cultural heritage is a matter of primary importance and highly topical: the acquisition of relevant digital data documents the actual state of an object at a given moment, allowing to monitor and control it over time. This is very important especially in a country like Italy which has a very high percentage of historical buildings make up the majority of the building stock. This heritage is often valuable but equally fragile, as it is inevitably subject to the passage of time but also to natural disasters. Just thinking to the earthquakes that have occurred in the last decade and that have caused serious losses in the cultural heritage of Italy central allow to understand how big the problem is.

This premise introduces the biggest obstacle that the HBIM process faces. If the acquisition of the formal aspects of a historical artifact is now easy to manage, the mastery of the material-construction aspects should include diagnostic investigations and destructive tests, rarely allowed on listed historical buildings.

The HBIM process, therefore, must necessarily provide for an alternative path of knowledge, made up of deductions and hypotheses formulated on the basis of documents that describe the building. Critical investigations that involve the study of historical, bibliographic, photographic and cartographic sources, allow to achieve the most probable reconstruction of the building's evolutionary history and a correct representation of its actual state. But the need to consult some kinds of documents clashes with the methods of conservation and dissemination of the archival heritage. In Italy, these resources are distributed among various conservation and consultation institutes, that adopt different management rules, and they are almost still linked to paper supports which are subject to deterioration and loss.

Therefore, the need for digital management of old archival data, which is felt more in this historical moment committed to having to face the pandemic[5] and the closure of many public offices, also involves HBIM processes in a certain way. It is necessary, in order to obtain a knowledge of the object of investigation as complete as possible, to transfer to the model all the information acquired through indirect investigations, considering that the classic BIM does not provide useful tools in this sense and that the heterogeneity of the information and cataloging platforms undermine the interoperability on which the whole process is based. Once the obstacle of digitizing paper information has

[5] The Italian (and world) territory has undergone numerous restrictions since March 2020 caused by the epidemic of the Covid-19 virus. To cope with the dramatic situation, many public offices have been closed, preventing the consultation of historical archives and public offices.

been overcome, they are in many cases cataloged on digital platforms, however heterogeneous and contained, depending on the type (textual, numerical, graphic, etc.), within files whose extensions do not communicate with each other (.doc,.xls.,.jpg, etc) nor, even more so, with BIM files (IFC,.rvt, etc).

The link of a specific information to the related 3D HBIM component is obviously a long and meticulous process. It is difficult also because it implies bending the rules of some applications that are created for the opposite purpose, standardization and automation, to the opposite purposes. However, the study presented aims to experiment with model characterization methodologies that aim at preserving the nature of the various information acquired during the knowledge path (direct and indirect) and at the same time ensuring the interoperability of the process.

## 3. RESULTS

The experimentation is conducted on the Institute of Botany, designed by Giuseppe Capponi within the Sapienza Campus [6,7] in Rome (1932-1935)[6]. The building today appears as a particular architectural achievement, characterized by the close dialogue between compact and symmetrical masses with transparent volumes and surfaces[7].

[6] Marcello Piacentini, who coordinated the construction of this large complex, called some young Italian architects to collaborate in the design of the buildings, thus responding to the desire of the Duce to make the new University of Rome the best expression of the Italian architectural and constructive genius of 'was a fascist.

[7] The structure is in concrete, while the facades alternate a coating of Roman travertine slabs with a curtain of brown-colored lithoceramic bricks, applied following very interesting solutions to resolve the edges through the particular arrangement of the pieces. The main value elements are the pillars between the windows arranged longitudinally, made of glass blocks, and the structure used for the towers, whose windows are hung, floor by floor, from the slabs. Other particular applications concern the acoustic plasters of pumice used for

The complex stands out from the other buildings in the university city for the coexistence of horizontal bodies and vertical elements (Figure 2), which, together with the deep ribbon windows and the transparent base of the rear façade, testify to an architectural sensitivity strongly influenced by European rationalism. The structure is made up of various emergencies that express a formal unity of the whole, mainly characterized by the presence of the two glass towers intended to house museums and herbaria, located on the main front. The building features interesting structural and architectural solutions[8], which highlight the strengths of the BIM process both with respect to modeling operations and with respect to the definition of the information content. From the compositional point of view, a stylistic and geometric matrix is highly recognizable, and the presence of recurring elements produced in series. From the point of view of the documentation, however, it is accompanied by a rich documentary apparatus concerning not only the general arrangement, but the project down to the smallest detail, from the choice of materials, to the establishment of the tender specifications, to the organization of the development of executive drawings [8].

A careful analysis of the survey data allowed to extract information on the geometric layout and the spatial articulation of the building, identifying the positions, the load-bearing elements and the relative structural axes, then the infill panels, the horizontal and vertical closures, the openings and vertical connecting elements, the external internal finishing materials, then translated into a geometric model of the current state. This model, whose accuracy is verifiable and measurable in the evaluation of the deviation with the point-like survey model,

the lining of the classrooms, the light floors of reinforced concrete on metal mesh boxes or planks, the large glass-concrete canopies.

[8] Rossi M.L, (2019). Algoritmi generativi per i modelli del patrimonio culturale. *Tesi di dottorato. Sapienza Università di Roma.*

constitutes the starting point for any maintenance and restoration projects, using a tool that, over time, becomes increasingly indispensable.

Fig. 2. Botany Institute at Sapienza Campus. Left front entrance and back, right 3D numerical model of external surfcaes and internal space (RGB reflectancy). Source: Author

At the same time, an in-depth study of the bibliographic sources has provided information on everything that is not directly detectable, or that would require destructive interventions. The development of the model, in fact, provided for the definition of the elements characterized by a high level of detail, which also includes the position of systems and ducts (made to pass inside the thickness of the walls, in such a way as to be easily accessible), paints and paintings, widely described in the archival documents. It is easy to understand how much the digitization of the documentary structure allows to know the object analyzed through the reading of the events that influenced its construction, and the need to directly connect the archive to the model. The modeling of the components, structured according to the semantic criteria that characterize BIM objects, has foreseen changes related to the customization of digital objects belonging to an artifact which, albeit simple, presents careful and appropriately designed architectural solutions for the case study examined (Figure 3, Figure 4). The cross-analysis between the survey data and the archive sources made it possible to define some parameters and starting attributes of the model (the thickness of the walls, the type of support layer, the type of external cladding in travertine slabs or lithoceramic bricks, and the type of internal plaster coating) which thus constitutes a real information database (Figure 5, Figure 6).

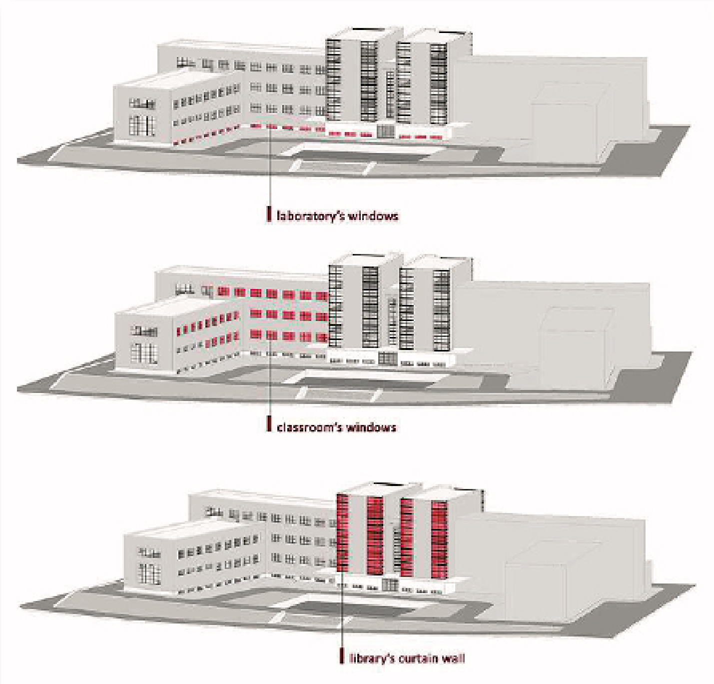


Fig. 3. Botany Institute at Sapienza Campus, HBIM. Source: Author

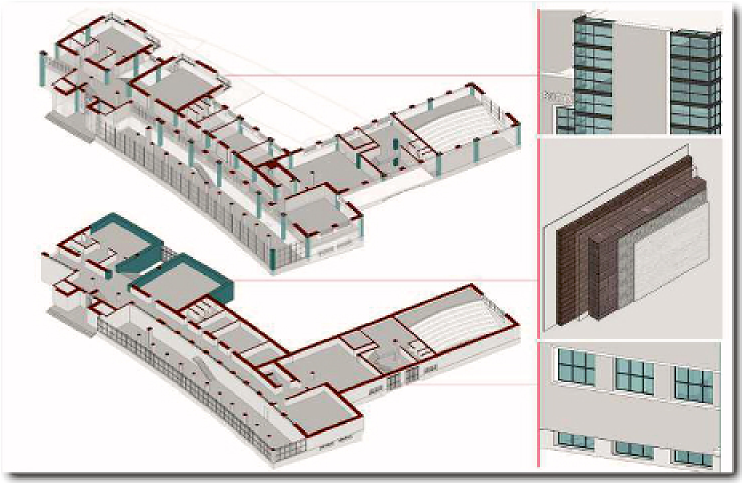

Fig. 4. Botany Institute at Sapienza Campus, HBIM. Source: Author

## 4. CONCLUSION

The process followed pursues the ambitious goal of managing the complexity of a historical architecture both at a geometric level but also at an information level. The digitization of information, however, only partially solves the problem of model characterization. In this case, the digital information is intended just as a parameter of a specific 3D element of the whole model, connected to it thanks to the possibility of using interchange formats.

In recent years, rather than pursuing the path of the interchange format, an alternative path is being drawn up, which focuses on preserving the nature of the data and the file extension in which the data itself is contained, working on "communication" between files and different platforms filtered by a sort of universal translator. The Visual Programming Language (VPL) [9] allows to take advantage of the advantages of computer programming not through syntax but borrowed from the graphic manipulation of elements, "boxes and arrows", without requiring skills in computer programming. The use of visual languages for information management would make the whole process totally explicit, making a further contribution to the transparency [10], preserving the nature of the information, streamlining the process of linking the data to the model without affecting the main characteristic of instant review of changes to a model built using HBIM processes.

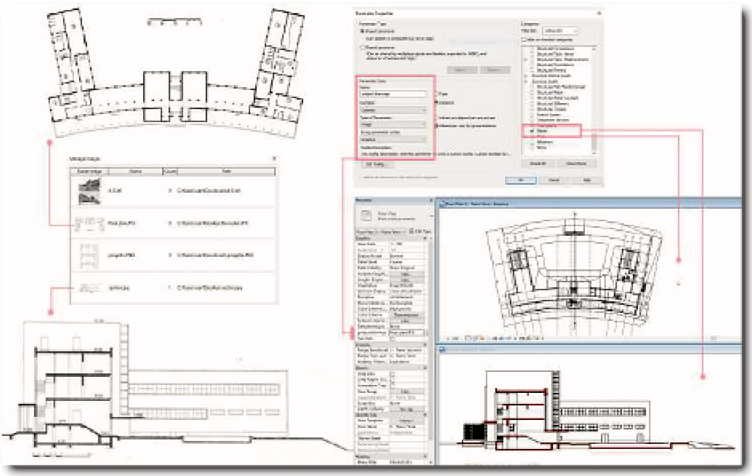

Fig. 5. Botany Institute at Sapienza Campus, HBIM. Source: Author

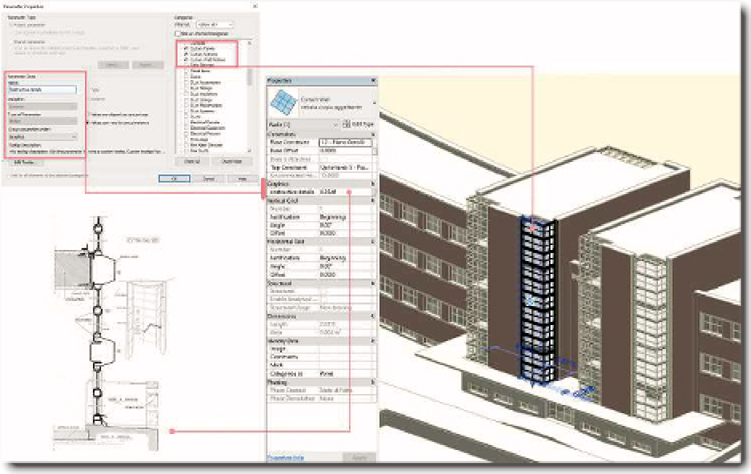

Fig. 6. Botany Institute at Sapienza Campus, HBIM. Source: Author

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