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HBIM AS A TOOL FOR HERITAGE PRESENTATION OF SANTA MARIA IN TRASTEVERE

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Abstract

3D laser scanning and Building Information Modeling (BIM) provides benefits such as optimizing the BIM process, increasing accuracy, and coordinating with multiple information in the same place. Applying BIM to document the Church of Santa Maria in Trastevere resulted in a comprehensive 3D model of the church documenting its history and architecture. BIM enables multidisciplinary model checking, automatic review of designs, and three-dimensional simulation. Parametric modeling establishes best practices and enables automatic updates. As well as playing a crucial role in achieving the management and development of cultural heritage, providing a comprehensive view of buildings based on three-dimensional models with "smart objects" that contain information about themselves and their relationships to other objects.

Keywords

HBIM, 3D Modeling, Survey, Architectural Heritage, Roman Church

1. *The digitization of cultural heritage and the informative model approach*

Currently, the technologies for the digitization of Cultural Heritage have been quickly developing, allowing the usage of new tools and assets for capturing a large amount of data. Furthermore, an interesting result is the possibility of building 3D models capable of rendering physical objects through dynamic systems. These systems can control, manage, and communicate an accurate replica in 3D space with a large amount of heterogeneous data (geometric, chromatic, textual, iconographic, cartographic) to open enormous perspectives for knowledge and sharing data of cultural heritage (Petti, Trillo & Makore, 2020).

In this rapid transformation, BIM and HBIM play a crucial role in achieving the development and management of Cultural Heritage.

Since introducing the term BIM (Building Information Modeling) to the construction industry, it has gone from being a field of application of a few enlightened early users to being the focus of AEC (Architecture, Engineering, Construction) technology that encompasses aspects from design to construction, to the management of a building. In 1974, Professor Charles M. Eastman first described, in a publication related to research developed at Carnegie-Mellon University in Pittsburgh, USA, entitled an outline of the building description system, a virtual building model capable of containing geometric information (Eastman et al., 1974). Thus began the development of BIM, concurrently with the development of software tools that enabled the effective creation of three-dimensional models increasingly linked to the needs of building production.

Over the past hundred years, buildings have become increasingly characterized by building systems and levels of integrated design unthinkable until the previous century. Data and communications networks, air-conditioning systems, security systems, technological solutions for upgrading building envelopes, and seismic retrofitting and improvement are just some of the specificities envisaged in architectural design. Multiple pieces of information, in the form of documents, reports, and spreadsheets, are associated with each aspect in addition to the graphic drawings. Architects, engineers, builders, and contractors have had to adapt to the changes by finding ways to coordinate, manage and maintain the different systems. These increases in specialization, scale, and complexity have led to increases in both the time and costs associated with the building lifecycle and the data and information to be managed (Bianchini, Attenni & Griffo, 2020). Keeping up with this trend, which is still growing today, has made it necessary to find a way to effectively coordinate the different aspects and communicate a large amount of information to all those involved in the building production process.

Most architecture, engineering, and construction companies have gradually abandoned drawing-based CAD technology in favor of BIM solutions, created to provide a comprehensive view of the building based on three-dimensional models. These models are composed of so-called "smart objects" that contain information about themselves and their relationships to other objects within the same model and can build or modify to allow the system propagation of changes to the entire model from which views and schedules can, in addition, to extract.

These problems alter when the inherent properties of the present items under examination change. The difficulty of identifying the geometry of some elements, the difficulty of transferring into BIM systems, the variable effects that the passage of time and weathering can have on surfaces, or the deformations of structural elements cause these aspects to clash with the difficulty of restoring the peculiarities and details that make historic building elements unique. Moreover, this process enables completely new capabilities as a multidisciplinary model checking for conflicts before construction or automatic review of a design to satisfy the building codes, bringing greater efficiency than 2D design.

Whereas it was subordinate to the representation of the abstract form through plans, elevations, and sections, BIM enables three-dimensional simulation of the building and its components. Such simulation is not limited to showing how different techniques and construction systems can be assembled in the project but can predict collisions and interferences, analyze environmental variables, and calculate the quantities of materials used in real time instead of through manually drafted metric calculations (Bruno & De Fino, 2021). In addition, the possibility of integrating aspects related to architecture, structure, and mechanics into a single three-dimensional model, and tying related documents to each of them, allows the final product to be considered more than just a digital substitute for the real object.

From the point of view of setting up the model and its constituent elements, parametric modeling allows objects to be represented not by fixed geometries and properties but by parameters and rules that determine both morphometric aspects and properties and characteristics of a different nature. Parameters and rules can define a single object and the relationships between other objects allowing them to function independently and concerning the context in which they are placed. The ability to support automatic updates constitutes state-of-the-art parametric modeling. Not only using it to create complex shapes but also; to establish best practices that a model must adhere to and to create custom object libraries.6 The need to work on the built heritage is felt in the Italian context, therefore, also determined from a normative point of view. The normative reference, consisting of UNI 11337 Construction and civil engineering works - digital management of information processes in 2017.

The standard is made with the ambitious goal applied to different types of products, whether buildings or infrastructure, and to any process of conception, production, and operation, both in the field of new construction and in the field of redevelopment and preservation of the built heritage. It defines the concepts underlying BIM (information, information content, information models, digital object, a library of digital elements); classifies information models concerning the states of processing, approval, and verification; enucleates the phases of the construction information process, going into detail about the objectives of each of them; and delves into the level of detail of the digital objects whose aggregation contributes to the construction of the model. Another essential normative reference is ISO 19650-1 of 2018, which classifies digital objects regarding the phases' objectives and the model's uses.

The standard introduced an additional element in the definition of the level of detail: the previous Level of Development (LOD, Level Development) is replaced by the Level of Information Need (LOIN, Level of Information), which in turn is divided according to the type of requirements, into geometric (LOG, Level of Geometry), and non-geometric (LOI, Level of Information).

Although the regulatory environment is constantly evolving, UNI 11337 of 2017 already proposed a difference in the definition of the level of development of objects (LOD) that makeup models expressed through a reference scale. It ranges from LOD A, in which the object is defined symbolically, to LOD G, in which the object is defined as "updated," meaning by this term "updated virtualization of the state of affairs in which the maintenance and repair work already carried out is indicated"[1], making explicit in LOD F and LOD G the levels of development for restoration. It is no coincidence that such an expansion of the standard arose precisely in the Italian context, which is characterized by the presence of numerous buildings and structures of historical and cultural interest and in which most of the activities are more concerned with the restoration and conservation of architectural heritage than with new construction.

Precisely, the need to work on the built heritage opens several issues that BIM alone cannot exhaust; therefore, defining other rules that will govern the complexity of artifacts.

2. *Critical issues of HBIM*

From a strictly theoretical point of view, the HBIM approach does not differ much from the BIM approach: even architecture that has already been built can be analyzed by breaking down and reading its constituent components with which different types of information can be associated. The model is not only prepared to be the digital substitute for the real object but also achieves the ambitious goal of configuring itself as a database: not only can digital objects be enriched through parameters and annotations, but historical, graphic (images, 2D models) or textual documentation is also associated with them.

This possibility, which is also valid in BIM processes, becomes crucial when working in the field of cultural heritage, both concerning knowledge of the object of study and model setting. In-built heritage knowledge processes, it becomes essential to associate not only graphical or textual information with the model. But also, data from integrated survey operations. In the study of existing buildings, it is necessary to monitor the state of conservation and identify problems to plan different types of intervention. However, for such processes to be more effective than those conducted through traditional modelers, a few issues must be resolved from a more strictly operational point of view.

Designing interventions on existing architectural artifacts of cultural interest implies managing heterogeneous data, information, and models, clashing with the lack of complete interoperability between dedicated systems and software; mastering the geometric constructions underlying the construction of the elements of built architecture, which are not always recognizable and regular; defining the artifacts at a semantic as well as geometric level, both individually and in the relationship with other components, which, for historical architecture, is not always possible to know.

These premises make it possible to understand that in modeling digital objects of existing architectural artifacts, the virtuous mechanisms envisaged by the adoption of BIM come into crisis. Existing buildings can be broken down into simple elements, and as much as survey operations can demonstrate the regularity of specific geometric configurations and the repetition of certain components, parametric and informational modeling of existing architecture is far more complex. It is valid with references to the geometric translation of the actual continuum and to the qualitative and semantic description.

These obstacles alter when the inherent properties of the present elements under research change. The difficulty of identifying the geometry of some artifacts, the difficulty of transferring into BIM systems, and the variable effects that the passage of time and weathering can have on surfaces or the deformations of structural elements, all of which collide with the difficulty of restoring the peculiarities and details that distinguish historic building elements. Geometrical simplification is often favored partly because of the incomplete elasticity of modelers who propose digital libraries of objects that predictably fail to express the holistic character of architectural heritage, especially when it is layered or deteriorated. The debate around these issues pushes beyond the limits of the technical approach that characterizes BIM, encroaching on the humanistic one. The reasons found in the evidence link most HBIM processes to have careful control of technical performance to a lack of consistency in the reading of the object. The presence of the term heritage prompts consideration of the semantics of the built environment, understood as the interpretation and synthesis of the elements of architecture and the compositional rules underlying its design and implementation.

Without neglect or underestimation of the technical aspects, integration of these aspects with the conceptual framework derived from different architectural surveys. Including constructive, structural, historical insight, and compositional analysis. Now closely linked to integrated technologies for the massive acquisition of range-based and image-based points (3d laser scanner and digital photogrammetry).

Currently, surveying is the basis of the geometric and information level for building models of the built heritage, extending its importance to the field of HBIM as well. Finding the correct way to relate to the survey data within HBIM processes is why they are not straightforward. Defining a methodology for moving from a numerical model of an architectural artifact to a parametric information model is still a field of experimentation (Bianchini, Attenni & Griffo, 2022t involves, in essence, conducting reverse engineering operations from the point cloud, the segmentation of which is the step in identifying surface boundaries and facilitating the modeling process. Within BIM authoring software, this activity identifies the modeling curves and surfaces directly on the point cloud, sometimes manually or using plug-ins and algorithms.

Such applications show a big step towards automating the point-cloud modeling process. However, the processes in place have some limitations mainly because, at present, reading and interpreting the qualitative data of a space or object are everyday tasks for the architect but very difficult for computers. In addition, software algorithms and plug-ins are easily applicable for automatic segmentation and modeling of plane surfaces or primitive geometries but generate erroneous or inaccurate results when trying to represent complex and irregular geometries of historic buildings (Lopez et al., 2018).

3. *Objective of research*

This experimentation in the field of HBIM focuses on the Basilica of Santa Maria in Trastevere in Rome (Italy) (Fig. 1).

Roman basilicas are undoubtedly amongst the most prestigious due to the importance of their foundation, their architectural types, and the role they play as part of Italian cultural heritage. However, there was no updated documentation about its current state. This lack of data provided fertile ground for a survey covering the entire surface of the basilica and for the HBIM.

HBIM allows us to associate a geometric model, built based on survey data, with historical information and data relating to previous studies, exploiting the advantages of modelling and digitization processes. The goal was to ensure consistency in manufacturing materials and processing which could lead to benefits such as lower costs, faster operations, and easy repairs and replacements. However, the building with the geometrical model is related to standardizing architectural components and geometrical features (Attenni, 2019), yet not adequate for existing buildings and historical artifacts. The aim should be to choose an appropriate HBIM structure and procedure for documenting the authenticity and unique characteristics of the elements (Andriasyan et al., 2020; Yang et al., 2020).

Previous attempts to standardize the process by creating a 3D model of an existing building or historical monument have demonstrated some limitations of the BIM process applied to complex and stratified architectural heritage. For example, a study published in the Journal of Cultural Heritage in 2018, titled "Challenges in modelling historic structures with BIM," discussed the difficulties of capturing the complex geometries and irregular shapes of historical buildings using BIM. The study also noted the challenges of integrating data from multiple sources and the lack of standardization in the terminology to describe historical buildings (Matracchi et al., 2021).

Another study published in the Journal of Building Engineering in 2019, titled "BIM for the documentation of historic buildings: Current limitations and future challenges," discussed the challenges of creating accurate 3D models of historical buildings due to the lack of accurate historical data and the use of non-standardized materials and construction techniques. The study also highlighted the limitations of BIM for capturing the cultural and historical significance of historical buildings (De Giorgi et al., 2021). As standardization lacks documentation of the authenticity and uniqueness of each element, the HBIM technology is efficient in accurately expressing other types of information, such as metrics, geometry, morphology, materials, and colour, which allows for further analytics and improvements to the building, as well as

Fig. 1: The Basilica of Santa Maria in Trastevere, Rome

documentation of its history for future reference and archiving (Barontini et al., 2022).

With the parametric modelling of each architectural element, HBIM technology offers a higher percentage of accuracy to enable documentation, addition, or subtraction of artifacts due to decay or restoration works while preserving their uniqueness and authenticity. The purpose is to develop a consolidated procedure that acknowledges the phases of Survey, Analytical, Consideration, and advanced stages of structures optimizing the workflow using HBIM technology (Oostwegel et al., 2022).

Using HBIM technology to create a reliable archive, each element must be documented or modelled with a high level of reliability while understanding that geometric simplification is unavoidable. The 3D models should allow for systematic readings of all the metrical, structural, and material features that distinguish the various portions of the structure, as well as the collection and storage of relevant contributions to define the architecture. In addition, the archive should be easily accessible to researchers, architects, conservators, students, and the public to be open and unified while respecting the structure. The correlation of information on cultural heritage assets is critical to represent their value. Since there is no existing library or archive that gathers all this information with these specifications, there is a need to create one. The focus should be on creating a consolidated procedure for documenting existing buildings using HBIM technology to generate a presentable, manageable, integrated, updated, and published archive among researchers.

4. *Historical notes about Santa Maria in Trastevere*

The Basilica of Santa Maria in Trastevere is one of the oldest churches in Rome, Italy. It is in the Trastevere district, on the west bank of the Tiber River (Christian, 1993). The church is dedicated to the Virgin Mary and has a long and rich history of over 1700 years. According to legend, it was founded in the 3rd century by Pope Callixtus I. The story goes that a noblewoman named Cecilia, a devout Christian lived in the Trastevere district and converted her husband and his family to Christianity. She also used her wealth to help the poor and needy in the area. After her death, a church was built where she had lived and dedicated to her and the Virgin Mary. However, there is little historical evidence to support this legend, and the actual origins of the church are unclear. The first recorded mention of the church dates to the 4th century, in a list of churches in Rome compiled by Pope Damasus I. The Basilica has undergone many changes and renovations throughout its history (Bruzelius, 1983). As a result, the church's architecture is a mix of different styles, ranging from early Christian to medieval and Baroque (Fig. 2, Fig. 3).

The original church, which was built in the 4th century, was a simple basilica with a rectangular floor plan and a wooden roof. This early church had a nave with two side aisles and an apse, which was decorated with a mosaic depicting the Virgin Mary and a child. Over the centuries, the church was expanded and renovated several times. One of the most significant renovations took place in the

Fig. 2: Interior of the Basilica of Santa Maria in Trastevere

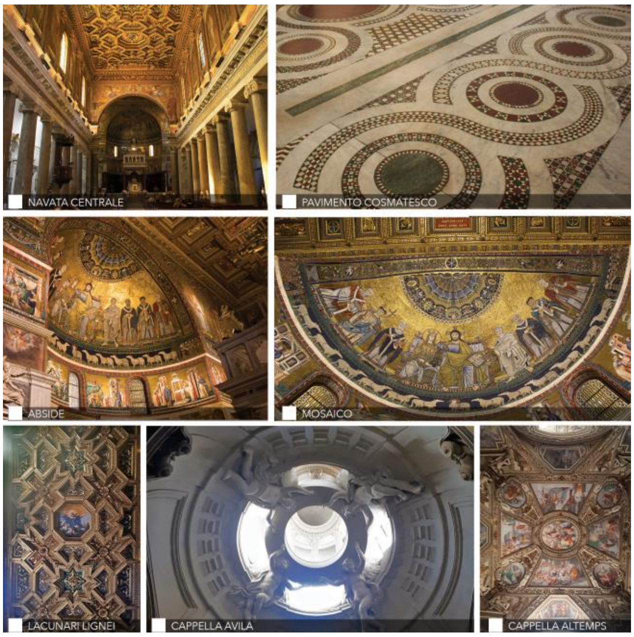


Fig. 3: Details of the interior of the Basilica of Santa Maria in Trastevere

12th century, during the pontificate of Pope Innocent II. The church was enlarged, and a new bell tower was constructed. The interior was also decorated with mosaics, frescoes, and marble decorations. The most notable addition was the mosaic in the apse, which was created by Pietro Cavallini, one of the most important artists of the medieval period.

In the 13th century, the church was further expanded, and a new nave was added. The old nave was transformed into the left transept, and the new nave was built on the right side of the church. The two naves are separated by massive columns with capitals decorated with animal and plant motifs. The floor is covered with medieval Cosmatesque marble inlays, which create a stunning geometric pattern.

During the 17th century, the church was renovated once again, and the facade was completely rebuilt in the Baroque style. The facade features a central portico with four columns, surmounted by a triangular pediment with the coat of arms of Pope Urban VIII. The facade is adorned with statues of the twelve apostles, and the two bell towers on either side were also rebuilt. The interior of the church is richly decorated with art from various periods. The apse mosaic, which dates to the 12th century, is one of the most important works of art in the church. It depicts the Virgin Mary with the infant Jesus, surrounded by angels and saints. The nave is adorned with frescoes, paintings, and sculptures from the Baroque period, including works by artists such as Pietro da Cortona, Domenico Guidi, and Carlo Maratta. The architectural orders in the central nave of Santa Maria in Trastevere not only showcase the beauty of ancient Roman architecture but also reflect the evolution of architectural styles over time. The use of salvaged columns from ancient buildings during construction was a common practice during the Middle Ages to allow builders to incorporate the grandeur of the architectural past into their contemporary structures. The columns in the central nave of Santa Maria in Trastevere (Fig.4) are decorative and serve a functional purpose. They support the weight of the structure to distribute the load evenly. The varying heights and widths of the columns add to the visual interest of the space, while the different types of capitals demonstrate the versatility of classical architectural styles. Consist of Ionic, Corinthian, and composite styles with interpretations of each style. The columns are symmetrical, with 11 on each side of the nave. Each column is unique and features a different type of marble, including red, green, and white varieties (Fig. 5, Fig. 6). The historical orders in the central nave of Santa Maria in Trastevere are a testament to the church's rich history and the skill of the artisans who created it. They serve as a reminder of the ancient past of Rome and the city's enduring artistic and cultural legacy.

Overall, the Basilica of Santa Maria in Trastevere is a fascinating example of the evolution of church architecture in Rome. Its combination of early Christian, medieval, and Baroque elements make it a unique and beautiful place of worship and a popular tourist attraction (Bony, 1979; Kinney, 1986).

Fig. 4: The main nave of Santa Maria in Trastevere

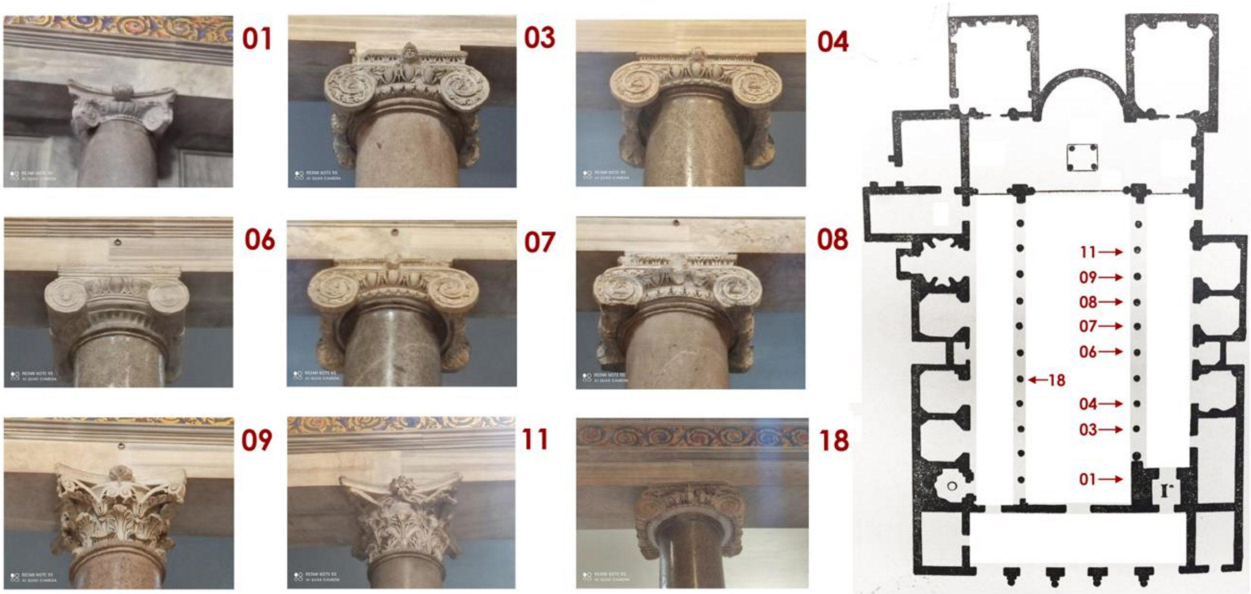


Fig. 5: Classification of the capitals of the architectural order of the main nave

5. *Methodology*

Applying BIM to document Santa Maria in Trastevere Church involved several steps. Firstly, data is captured using photogrammetry and laser scanning surveys to understand the design building and identify areas needing restoration or preservation. The primary objective was to understand and document the spatial and architectural configuration of Santa Maria in Trastevere.

Performed by merging mass acquisition methods (3D laser scansion and Structure from Motion processes) with a topographical survey (Fig.7). The main objective of topographic acquisition was to establish a system of local coordinates; targets were positioned all around

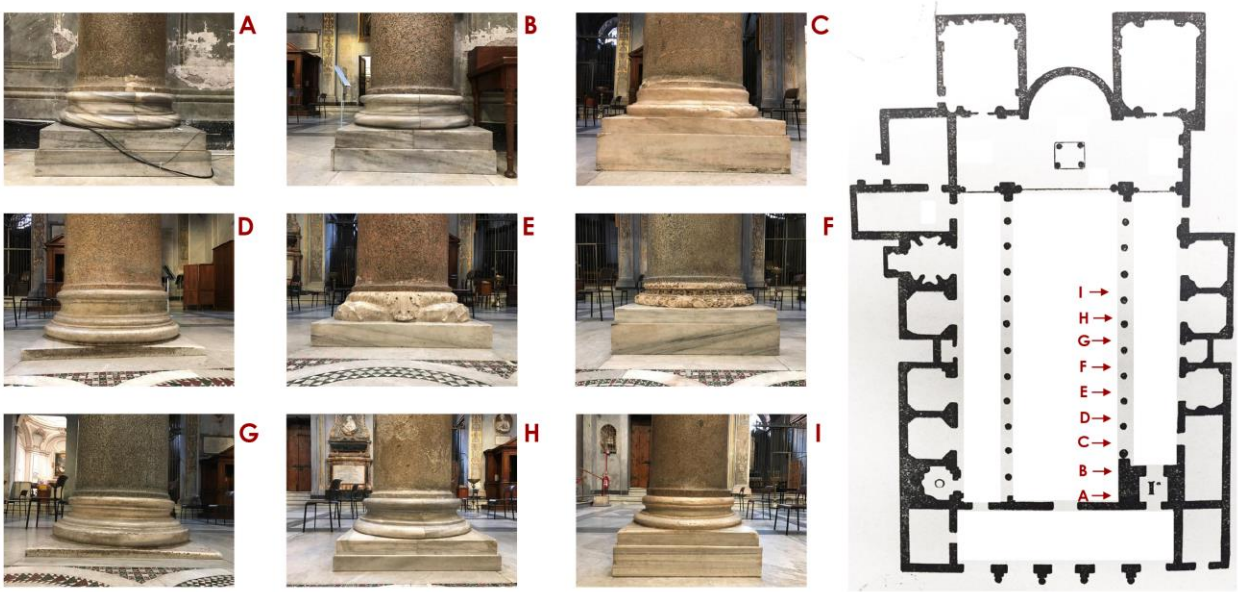


Fig. 6: Classification of the bases of the architectural order of the main nave

Fig. 7: Images of a numerical model of the Basilica of Santa Maria in Trastevere

the surveyed area as well as in certain characteristic points of the façades of the buildings in the square, on the exterior of the basilica, and several important points in the interior. Materialisation of the targets inside the areas to be surveyed, and the choice of the characteristic points (identified directly on the surfaces), allowed us to recognise them in the photographs used during the photogrammetric process and in the numerical model, thereby facilitating the next phase involving the construction of the 2D and 3D models. This kind of structured topographical reference made it possible to orient and align data from different but typologically homogeneous sources (the points clouds) using a grid of known points as reference.

The numerical model obtained from the alignment of the scansions made it possible to record the architectural spatial configuration and check its metric and geometric features (Mesrop et al., 2020). Nevertheless, this model does not accurately reflect the state of preservation of the surfaces and their treatment. Therefore, delegating the chromatic interpretation and material values using appropriately rectified digital images derived from Structure from Motion processes (Fig.8). Colour was checked bearing in mind the state of the context around the basilica

Fig. 8: Orthoimages of the main facade

Fig. 9: HBIM of Santa Maria in Trastevere

and adopting a different approach for the exterior and interior. Photographing the façade was inevitably linked to an assessment of natural lighting; we had to privilege homogeneous lighting in order to minimise contrast and be able to select fixed parameters for the whole photographic set. The images were taken with an overcast sky; this provided diffuse lighting and the required homogeneity thanks to soft shadows that tended to remain the same throughout the campaign. Instead, the shots taken inside the basilica were set up so as to create as much homogeneous lighting as possible; we identified and compensated for the shadow cones by inserting additional light sources. Construction of the models also included using a colour checker during the acquisition phase in order to correctly balance the whites in the images and, during processing, select the right colour temperature, thereby improving accurate restitution of the scene. This approach allowed us to create a single three-dimensional, integrated digital model enhancing the way we could dynamically and interactively examine several features.

The second step is to use the point cloud as a starting point in the HBIM system, as it is the gateway to having details within reach while being able to observe, measure, and understand from multiple perspectives that cannot be obtained with any other techniques (Rubens et al., 2023). The next step is to start the 3D modelling procedure (Fig.9, Fig.10) (Nagy & Ashraf, 2021; Galera-Rodríguez et al., 2022).

The third stage involves determining the domains of the modelled elements and deciding which knowledge is essential to present. Each will have a set of properties, attributes, and relationships to link between the structure of semantics and network of elements in the BIM environment (Murphy, McGovern & Pavia, 2009).

By collecting and cataloguing this information, the availability and accessibility of all necessary knowledge to be improved, making it easier to explain and observe interventions or investigations documented for further progress toward creating a comprehensive and informative archive (Kamaruzaman & Solihin, 2019).

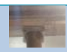
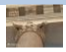
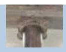
As a result creating a comprehensive 3D model of the church to form a BIM with LOD of 300 or Italian standards LOD C, which incorporated pertinent details about the church's design, materials, and construction history utilizing the BIM model to document the church's history, encompassing its original design, any alterations or renovations made over time, and any significant events associated with the building, this documentation was crucial in comprehending the church's architectural significance and devising restoration plans; moreover, generating visualizations, renderings, and animations using the BIM model to illustrate the evolution of the church and how it was built (Gargaro et al., 2018). These visuals served as engaging and informative presentations on the church's history and architecture, with the focal point of the documentation being the ventral nave of Santa

Maria in Trastevere. The modelling process is divided into four segments, external structure, internal structure, the focal study area, and automizing the placement of the detailed models (Godinho et al., 2020). First comes the external structure: the exterior walls, roofs, gallery, and porch modelled with a lower LOD of 200 consisting of only the generic shapes and openings, using simple extrusions to replace some of the statuses in the gallery, columns in the atrium, and the niches on the external walls. Subsequently, the Interior Structure consists of two subsegments (Santagati et al., 2021). The walls were carefully modelled using the linked point cloud to replicate their specific thickness, curvature, edge, and cornice. Utilizing the model-in-place wall feature was to preserve all these characteristics and lock them in their specified levels to maintain their correct heights. Successively the floors, ceilings, and roofs were modelled using generic family types. Later their layering was later adjusted by the documented details of each element. The roofs of the altar, the transept, and the tower were not visible in the point cloud. Therefore, to ensure accuracy, historical documents of precedent surveys were used. Openings were meticulously modelled considering the cornices around them in the point cloud and previous documented surveys. Secondly, the domes and vaults were modelled to replicate their unique non-uniform shapes using modelling mass in place, combined with reference lines and planes to indicate each shift or alteration in their forms. All essential information, such as level, dimensions, materials, and specific parameters related to each element type, position, and historical data, were added as parameters to each family type. (Tab. 1 and Tab. 2). Additionally Adding the mutual parameters for all the elements to the project parameters and filling them with historical data.

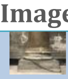
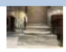
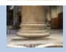
The third segment was the focal point which needed particular attention to precisely model the architectural details of the central nave and use the template of Revit generic family for capitals, columns, and bases individually. The point cloud data was exported as an FBX file containing each element as a mesh in separate file and inserted into the Revit family file to enhance the accuracy of each element's modelling. For the bases, a generic extrusion combined with revolving around the axis, utilizing the mesh to form each scotia, torus, and plinth. Regarding the columns, the revolve extrusion or blend between two shapes modelling methods were used accordingly to each specific case, as each column differed from the other in thickness and shape, with variations in thickness, positioning of the column and some inconsistencies of the column forms (Fig.11).

The most intricate elements were the capitals, which possessed numerous unique characteristics requiring meticulous preservation to ensure accurate documentation. Employing multiple modelling techniques to achieve this objective. Fourthly, the bases, columns, and capitals are placed in a Revit adaptive generic model template, using the adaptive point component feature to streamline the placement of each element on top of one another and within the church's floor plan. This process enhanced the accuracy and efficiency of the placement of the elements, which automatically clicked into position when clicked on the element below it or the floor plan.

Tab. 1: Table of examples of the parameters inserted in the Capitals family.

Mark	Height	Type	Position	Material	Image
SMT00C13A	0.224	Ionic	Second to the right	Granite	
SMT00C14A	0.573	Corinthian	Third to the right	Granite	
SMT00C15A	0.482	Ionic	Fourth to the right	Granite	

Tab. 2: Table of examples of the parameters inserted in the Bases family.

Mark	Height	Width	Length	Type	Position	Material	Image
SMT00B01A	0.633	0.614	1.214	Attic	First to the left	Granite	
SMT00B02A	0.628	1.32	1.3	Attic	Second to the left	Granite	
SMT00B03A	0.571	1.32	1.37	Corinthian	Third to the left	Granite	

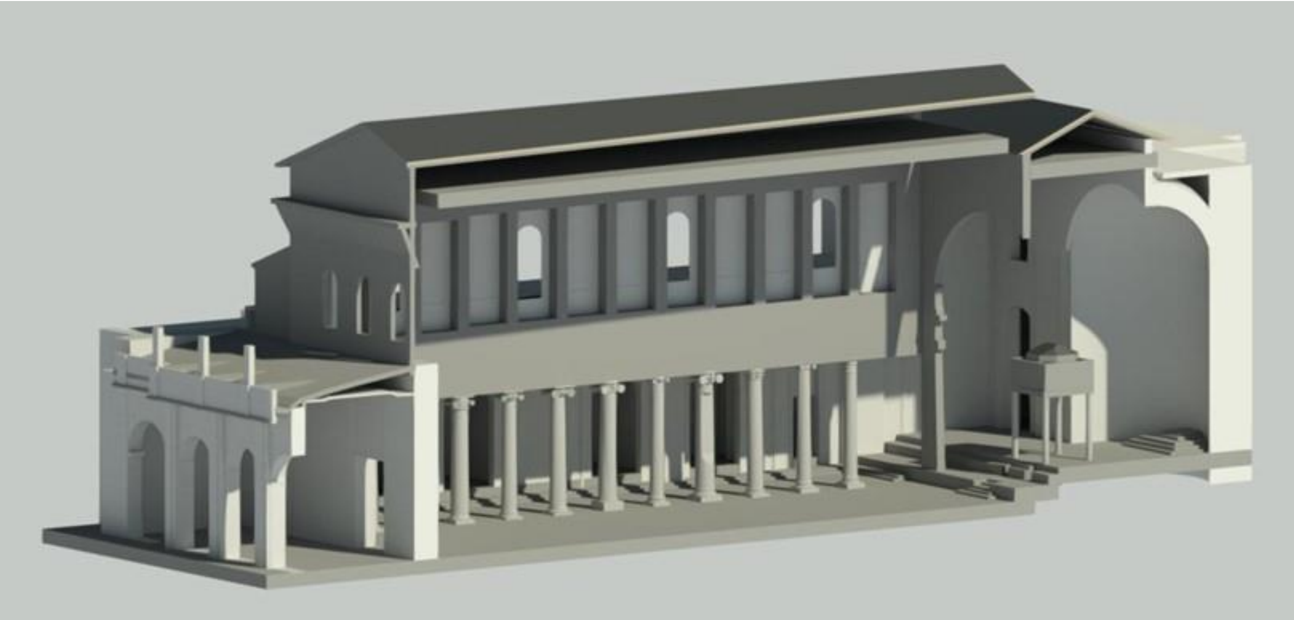


Fig. 10: HBIM, section vertical through the main nave

Adding Customized parameters to each element to accommodate the type of information required to support it, including dimensions, materials, photos from the survey, historical documentation, historical data regarding each element or a specific part of the element, placement date, restoration date, URL links to online references or articles related to each element, and a unique code name assigned to each element (Fig.12).

Fig. 11: Point cloud inside the family around the model with the adaptive point component and example of one modelled architectural order

Fig. 12: Example of modelled capitals

6. *Obtained results*

This innovative modelling approach has significantly increased the accuracy and intricacy of each element, surpassing the limitations of traditional 2D or 3D modelling techniques (Fig.13). By employing an automated process, all the elements were meticulously crafted to showcase their unique characteristics and historical significance, resulting in a comprehensive BIM model that captures all the pertinent information about the church. The resulting model is a digital representation of Santa Maria in Trastevere Church, including all relevant

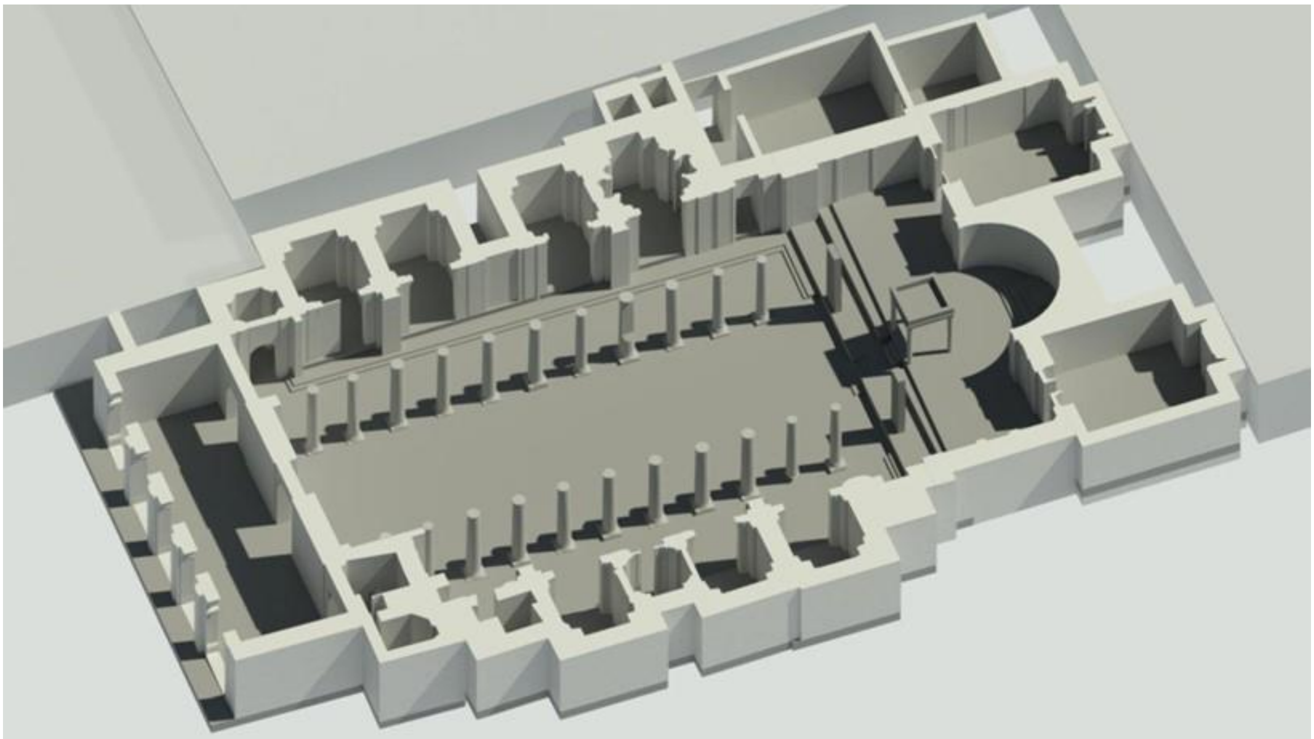


Fig. 13: 2.5D plan of the model

historical and current data, derived from the survey elaboration.

This level of detail makes the model ideal for archiving, facilitating future operations, and providing an easily accessible resource for researchers and conservators. This impressive outcome demonstrates that Historic Building Information Modelling (HBIM) is a powerful tool for accurately documenting and presenting historical architecture. Furthermore, it has the potential to support ongoing preservation efforts, thus ensuring that this beautiful and historically significant structures can be appreciated and admired for generations to come.

7. Conclusion

In the final analysis, the BIM application of technology has significantly enhanced the documentation and conservation of historic architecture, as exemplified by the Santa Maria in Trastevere Church project architects and engineers with sophisticated BIM technology can generate highly detailed 3D models of historical structures, incorporating pertinent data regarding their design, materials, and construction chronology. This cutting-edge technology permits ongoing preservation endeavours by creating a digital record of a building's framework and substances, thereby allowing for the tracking of changes over time and the identification of areas in need of repair or restoration. Moreover, utilizing visualizations, renderings, and animations created digital building record of framework and substances, allowing it to track changes over time and identify areas needing repair or restoration. Moreover, utilizing visualizations, renderings, and animations created from BIM models enables the creation of captivating and informative presentations regarding the history of the structure and architecture. In the end, BIM represents a valuable instrument for safeguarding our cultural heritage and ensuring that historical architecture is valued and comprehended by future generations. HBIM responds to the current need to protect the architectural heritage pursued not only in the research field. The United Nations with "Take Action for the Sustainable Development Goals" (https://www.un.org/sustainabledevelopment/sustainable-development-goals/) also pursue the same goal, reinforces the fact that digital technologies play a significant role on a global level (Martins et al., 2020).

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