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# Restoration Site sheet GIS: Use of Digital Tools for Collecting Data on Heritage Site intervention

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***Abstract***

*This contribution aims to illustrate the author's research work within the research group HBIMSIG-Turismo at the Universitat Politècnica de València. The research between Rome and Valencia connects two investigative realities in different fields and locations through an exchange and collaboration. The investigation intends to define a digital methodology for recovering the knowledge emerging from restoration site interventions on "widespread" cultural heritage.*

*Conservation interventions represent fundamental moments in the history of buildings as they allow for a direct understanding of the material reality of the asset. Therefore, preserving the memory of these interventions is crucial to ensuring thorough and updated knowledge of the heritage and for the virtuous management of future interventions on the asset.*

*The illustrated case study is situated in the historic centre of the city of Rome, in the ancient Rione Parione. The protection of widespread private heritage is extremely complex in this tourist area. The interventions subject to archiving involve the external surfaces of two buildings that are part of a vast and varied heritage within the multi-layered historic city.*

*The authors have defined an operational tab called the Restoration Site sheet to collect and share information related to these interventions. This digital database guides the user in filling it out. Sharing the research group's experience regarding the tourist management of the public space adjacent to the Cathedral of Valencia has enabled the integration of the digital Restoration Site sheet within a georeferenced GIS model.*

*This work illustrates the methodology used to integrate geometric-spatial data into a semantic model (database) designed to meet a specific need: preserving the memory of conservation site interventions on cultural heritage.*

***Keywords:*** *Cultural heritage, Informative system, GIS, Semantic model, Conservative site, Widespread heritage.*

## 1. Introduction: The Context of the Research

The intervention site in historical architecture is defined as a place of knowledge in two aspects. On the one hand, all direct action on the heritage building allows one to closely understand the object, acquiring new information about its constituent materials, construction technology, and transformations. On the other hand, the site of intervention is a “place of culture”, as it represents human action in history, reflecting the sensitivity of an era in its complex relationship with the ancient. The restoration project is both a new work, with equal dignity to the work being intervened upon, and a critical act of interpretation of the heritage. According to Carbonara (2011), restoration's architectural and linguistic choices must be guided by sensitivity and a critical method, allowing the project to adapt to the needs of the architecture and the site.

This demonstrates that the intervention represents a phase in the life of the building and, as such, must be documented. Indeed, a gap in knowledge concerning the history of the building can easily lead to decision-making errors during the operational phase, potentially negatively impacting the conservation of the asset and its parts. As testified by several authors, the knowledge of previous restorations, especially regarding the interventions on architectural heritage in the last century, is crucial for the project and the correct interpretation of conservation issues (Bartolomucci, 2023). It is often the case that preliminary investigations cannot be carried out during the project definition phase. This makes it very challenging for operators to develop a quality project without scientific data to support the formulated hypotheses. Access to the knowledge gained from past intervention sites would enable the production of a more informed and scientifically grounded project.

### 1.1. Computerised Documentation of Cultural Heritage in GIS: state of the art

Documentation of heritage buildings has a crucial role in safeguarding and preserving the cultural and material value of the building for the next generation. This operation is central to protecting heritage within the current Italian regulations, specifically under the Italian Code of Cultural Heritage (Art. 17 - Legislative Decree 42/2004). Like most areas of human activity, the humanities disciplines related to heritage conservation have also been influenced by the digital revolution that began in the 1980s. The first area to be reformed was the graphic representation of built structures, transitioning from manual drawing to CAD (Computer-Aided Design) software. In 2000, there was a shift from 2D digital representation to 3D modelling with the advent of BIM (Building Information Modelling) methodology (Khalil et al., 2020).

The progress of these tools is continually evolving and now also encompasses the cataloguing of cultural heritage. This has led to the emergence of new research fields investigating the application and use of ICT (Information and Communications Technology) and digital technologies in cultural heritage, and numerous policy documents identify them as a solution or catalyst for making heritage a Common Good (European Heritage Alliance, 2020).

In Italy, several research examples have been aimed at cataloguing heritage through digital tools. An early experience involved the computerised documentation for the architectural conservation of the surface conditions of the Chiostro di St. Chiara in Naples and the Mura Serviane in Rome. These experiments from the late 1980s used a precursor to GIS, associating information on materials and surface degradation with a simplified graphic representation of the elements (Ferragni et al., 1987). The first large-scale GIS experiment materialised in the Information System, known as the Risk Map of Cultural Heritage, developed by the Italian Istituto Centrale del Restauro in 1997 under the guidance of Giovanni Urbani. This was the first attempt to georeference the Italian Cultural Heritage Catalogue archive, simultaneously analysing the potential risks to which individual assets are exposed in their respective territories (Bartolomucci, 2008). During that period, individual experiments were also developed to gather information useful for the conservation of specific assets; notable GIS experiments include the "medical record" of St. Maria di Collemaggio in L’Aquila (Bartolomucci, 2004) and the information system for the documentation of the restoration of the stone surfaces of the Torre of Pisa, named AKIRA GIS Server (Capponi et al., 2001). The GIS experience for the Torre of Pisa later evolved in 2007 into the Information System for the Documentation of Restoration Sites (SICAR).

Concurrently with these GIS experiments, the BIM methodology also emerged as a potential response to historic heritage documentation needs. Building Information Modeling (BIM) offers a collaborative working methodology that, supported by digital technologies, generates more efficient methods for the design, execution, and maintenance of buildings (HM Government, 2015).

### 1.2. The Restoration Site sheet tool

Given the testimonial value of interventions, there arises a need to develop a tool for collecting and preserving information related to the construction site.

This involves primarily three categories of information:

- Indirect knowledge, that is, the preliminary research[1] and the consequent planned intervention;
- The history of the restoration site, which includes all the transformation carried out and the work of each day on the site;
- Direct knowledge gained from the site through close interaction with the object of intervention.

The research develops from these premises within the PhD program in Architectural Restoration at the Sapienza University of Rome[2], and it is enriched through the exchange with the HBIMSIGTUR research group at the Universitat Politècnica de València. This study aims to create and test a methodology for collecting data related to intervention sites on cultural heritage and to enhance their potential through digitalisation and collaborative software.

The *Restoration Site Sheet* database has been developed and divided into sections where information can be collected and catalogued to meet this need. This includes data related to preliminary research and the building's history, integrated with findings that emerged during the intervention. These pieces of information can be extracted from the database and graphically placed in a summary sheet.

The database was developed within a Microsoft Excel spreadsheet. This intuitive and widely used software is open source and compatible with other spreadsheet programs.

The database structure (Figure 1) adheres to the cataloguing standards of the Italian Central Institute for Catalog and Documentation[3]. The fields to be filled are divided into paragraphs and subparagraphs and possess the same properties as the cataloguing sheets for cultural assets developed by the Italian Ministry of Culture.

All information can be entered into the respective fields, most of which have guided completion through defined vocabularies. The definition of closed vocabularies is an important tool to collect homogeneous and high-quality data (Acierno, 2023).

[1] For public interventions on heritage in Italy, it is mandatory to draft a technical report containing information collected by specialized personnel during a preliminary survey (DM 154/2017). For interventions on private heritage, a request for authorization from the protection authorities is required, which includes the preliminary study carried out to develop the project (art. 31 D.lgs 42/2004).

[2] These topics are part of a PhD thesis in the Department of History, Drawing, and Restoration of Architecture at Sapienza University of Rome, XXXVIII cycle, under the supervision of Professor Simona Salvo (PNRRN research grant, ex m.d 351/22 or m.d 352/22). The application to the case study presented in this article was made possible thanks to the collaboration with an Italian restoration company and the Universitat Politècnica de València, in which the implementation and the application to the case study are being developed thanks to the research group HBIMSIG-Turismo (Dra. María José Viñals, Dra. Concepción López González, Dr. Jorge García Valldecabres, Pablo Ariel Escudero, Renan Cornelio Vieira de Souza Rolim and Patricio Rodrigo Orozco Carpio).

[3] The Central Institute for Cataloging and Documentation (ICCD) is affiliated with the Italian Ministry of Culture. It has scientific and administrative autonomy and is now part of the Central Institute for the Digitization of Cultural Heritage - Digital Library.

The cataloguing of data on interventions within a Knowledge Organization System (KOS), such as the *Restoration Site sheet,* can be instrumental in defining a quality project. Sharing all this information, gathering it in a single container, allows the operator to systematise the project hypotheses with the reality of the conservation site, calibrating the intervention. Furthermore, it is a strategic tool for planning future interventions on heritage and managing the asset.

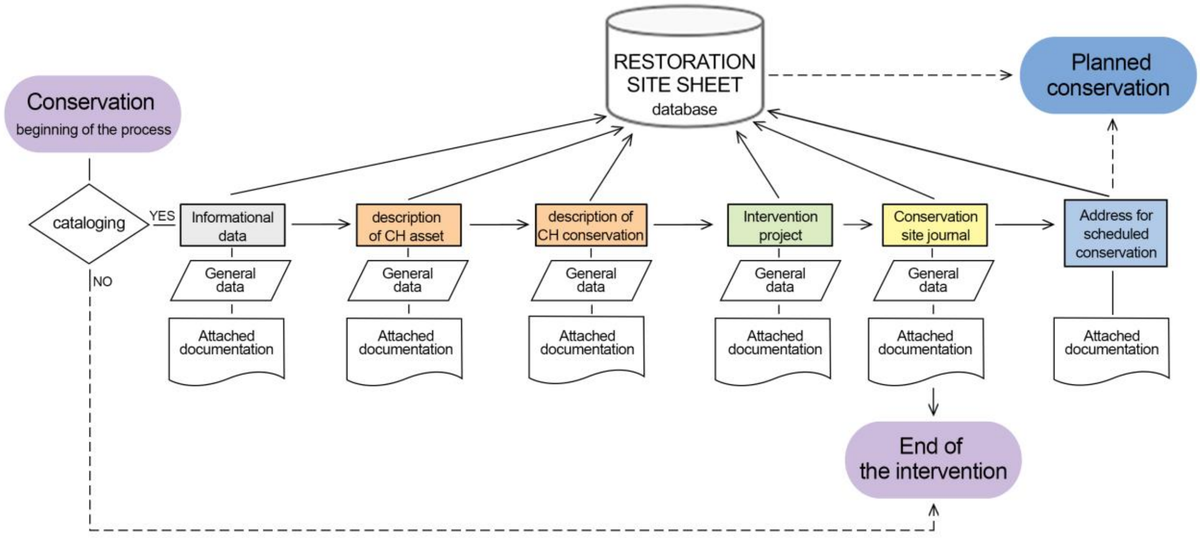


**Figure 1.** The structure of the Restoration Site Sheet database. Source: Author's elaboration.

### 1.3. The advantages of implementing the Restoration Site Sheet with a collaborative methodology

Historical architecture cannot be considered a single entity but the result of transformations and stratifications over time. These complex buildings require optimal interdisciplinary coordination among all the figures involved in the conservation and heritage management process. This peculiarity of intervention on built heritage increases the complexity of the intervention and suggests the use of a holistic and collaborative methodology.

BIM tools link information coherently and easily to a graphical representation known as a parametric model. Additionally, when adapted to collaborative platforms, BIM tools aid in developing interdisciplinary activities (Building Smart Spain, 2018). It is an architectural project management methodology that allows for the simultaneous and integrated intervention of various professionals in a single space: the digital model of the building. The application of BIM to cultural heritage is referred to as Heritage Building Information Modeling (HBIM). Given the potential of the described tool, an effort was made to integrate the methodology with the sheet's developed instrument.

## 2. Objective of the research

The ongoing research at the Department of Architectural Graphic Expression at the Universitat Politècnica de València aims to develop a collaborative methodology for the expeditious collection of data related to conservation and restoration sites, integrating the *Restoration Site sheet* database into a more complex process.

Furthermore, it was crucial to understand the best way to utilise the data collected during the 3D surveys by the research team or by a company. The objective was to develop a three-dimensional model from the available point clouds of the buildings, using the spreadsheet as an external database.

Generally, we refer to HBIM when we think about collaborative, informative systems for heritage. It is important to emphasise that it is not merely a digital tool or software but a methodology for managing data related to the conservation project. According to the Bew-Richards model (Figure 2) concerning the maturity levels, it is necessary to reach Level 2 to achieve a "collaborative" tool. In this case, work is carried out in a common data environment with two different databases: the BIM model, a database of geometric information and data, and another database with extended data (Excel, Access, etc.) outside the BIM model. In collaborative BIM models, information from both databases is connected by plug-ins (García-Valldecabres et al., 2020). For this initial phase of the research, it has been decided to develop a 3D model at this collaborative level of maturity, starting from the point cloud we have and using the *Restoration Site sheet* as the external database.

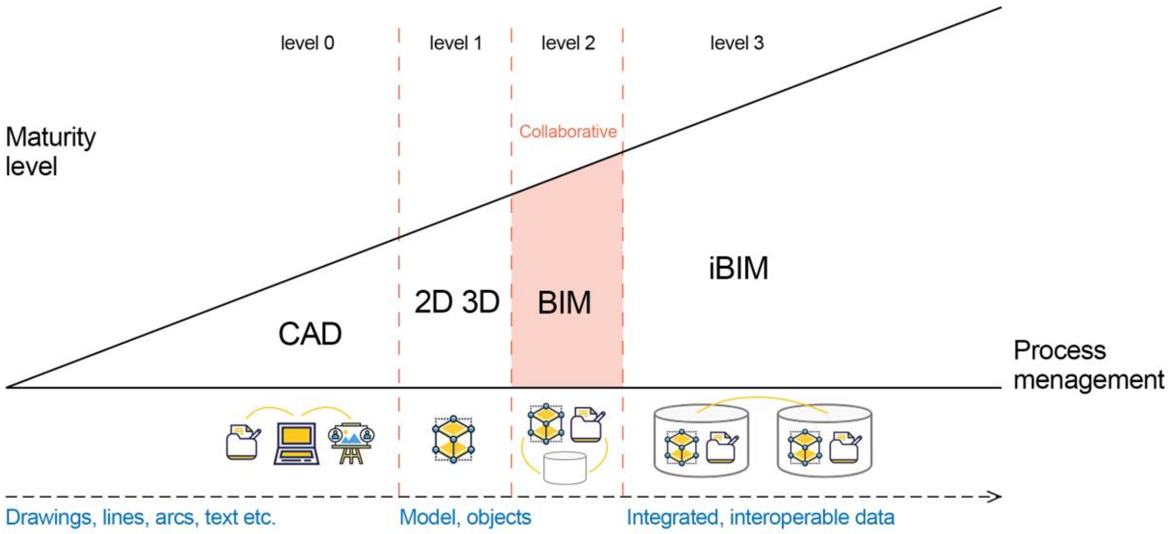


**Figure 2.** Level of maturity according to the Bew-Richards model. Source: Author's elaboration.

## 3. Methodology and Application

In the analysed case, the external database has already been defined by developing the *Restoration Site sheet*. Therefore, it was necessary to create the second database, the digital model[4] of the buildings. This process began with the data provided by the company, which included laser scanner surveys of the buildings to be intervened upon. Among these surveys, a model representing five buildings undergoing conservation of their external facades was chosen for development.

It should be noted that the company's current standard process greatly limits the potential of the captured point clouds. The survey technicians generally use point clouds to obtain orthophotos of the building facades. These images, extrapolated from the point cloud, are then used to create a 2D survey using Autodesk AutoCAD® software. To understand the methodology for developing the 3D model in depth, it is necessary to introduce the analysed case study.

### 3.1. The application: company's Conservation Sites in Rione VI Parione in Rome

The survey of the company's conservation sites in January 2023 highlighted 65 ongoing or scheduled sites involving restoring the external surfaces of private buildings. Among these buildings, 13 were declared by the Italian Ministry of Culture as architectures of National Cultural Interest. More than half of the sites are located in the historic centre of Rome, with seven buildings specifically situated in the ancient Rione Parione (Figure 3). The case study selection focused on 5 of these sites in the district, for which a unified 3D laser scanner survey had been conducted by the company.

[4] The methodology described below was developed by the research group HMIBSIG-Turismo (Universitat Politècnica de València).

### *3.1.1. The Reasons for the Case Study Selection*

The reasons for this choice are also linked to the exceptional richness of the area in terms of historic architectural surfaces. The name Rione Parione is believed to derive from the word "*paries*", meaning large wall or rampart. During the Roman era, it was home to the Stadium and Theater of Domiziano and the Theater and Curia of Pompeo (Pericoli Ridolfini, 1973). It maintained a cultural significance for centuries, characterised by the presence of theatres, bookstores, printing houses, shops, and hotels where wealthy travellers and diplomats stayed. In the 15th and 16th centuries, many of Rome’s most notable families resided in their palaces, including the Orsini, Borgia, Sforza, Nardini, and Massimo families. Among these splendid residences, the Massimo family’s palace on the current Corso Vittorio, Palazzo Massimo alle Colonne, stands out. It was designed in the early 16th century by the architect Baldassarre Peruzzi (1481-1536).


**Figure 3.** Localisation of the case study sites. On the top left is Rome's city centre, and on the Rione VI Parione. Top right, the Rione VI Parione. Bottom left is the point cloud captured in the 3d survey. Bottom right is the localisation of the buildings on the point cloud. Source: Author’s elaboration.

At the same time, in Rome, especially in the Ponte and Parione districts, there was a trend to beautify building facades using graffiti and monochromatic chiaroscuro techniques. Of these interventions, carried out by the greatest artists of the time, only a few traces remain today, on the verge of disappearing. Therefore, the investigation is set in a context of fragile yet highly valuable cultural preservation, aiming to test how a tool like this can contribute to conserving these valuable external surfaces.

Another factor in the selection was the proximity of the sites and the presence of a single-point cloud for the area. This proximity simplifies data collection on site and allows for developing a single model to compile information from multiple sites, creating a georeferenced territorial information system, albeit on a small scale.

 

Compiling this data in a single model also allows these architectures to be seen not as isolated points but within a complex context with strong historical and artistic connections. This context includes the public road represented in the model, serving as a place of daily exchange and visual enjoyment of these architectures.

Finally, the surveyed sites in the point cloud are at different stages of progress; some have been completed, and others are about to begin. This allows testing the flexibility of the *Restoration Site sheet* database to collect data a priori and during the intervention, as initially planned, and *a posteriori* as a final repository for all the company's construction sites.

### 3.2. GIS or HBIM? How to obtain an expeditious and collaborative model

The described case study presents certain specificities, as it involves private interventions for conserving external surfaces in culturally significant buildings within an extremely value-rich and fragile urban context. Therefore, the developed methodology had to meet the needs for cost-effectiveness and speed of interventions. Additionally, it was necessary to use the data collected through the company's surveys to develop digital models of the buildings.

Thus, it was considered appropriate to develop an expedited modelling methodology that utilised the point clouds directly to develop a mesh model where the information from the survey forms could be collected. At the same time, the developed mesh retained the "raw" data from the surveys, which could be analysed in the future for subsequent interventions on the building. The developed workflow aims to be economical and quick to be applicable by companies operating in the field of historic building conservation. Moreover, as previously described, the analysed interventions concerned the external surfaces of the buildings, which is why developing a parametric three-dimensional model by modelling the individual elements could be extremely complex and unsuitable for the extent of the interventions planned on the historic surfaces. For the reasons described, it was decided to abandon the idea of developing an HBIM model and instead use a three-dimensional collaborative model obtained from the point cloud, which will then be linked to a semantic model in GIS.

It is essential to define the characteristics of the informative model to be developed based on the peculiarities of the building and the type of intervention it is subjected to. The choice of methodology should start from these premises, leading to the decision of which software to use based on the expected level of maturity.

### 3.3. Tools and Method

The first step was to verify the accuracy of the surveys conducted to understand the quality of the available data. For the 3D laser scanner survey, the FARO® CAM2 FocusS 70 by CAM2® (the Italian subsidiary of the FARO® group) was used. The manufacturer reported in the technical datasheet that the measurement noise was 0.3 mm at 10 m for 90% (white) and 0.4 mm at 10 m for 10% (dark grey). The same data were 0.3 mm at 25 m for 90% (white) and 0.5 mm at 25 m for 10% (dark grey). It was verified that the average registration error of the nine scanning stations was less than 6 mm for the overlap parameter.

The point cloud of the construction sites located in the Parione area was aligned and registered using FARO® SCENE version 2022.1 software. The registered point cloud was imported in .E57 format into Autodesk® Recap 2023 version 23.0 to begin the point noise clean-up process. Subsequently, it was decided to use the open-source software Cloud Compare version 2.13 alpha to eliminate redundancy defects and irrelevant elements reported in the 3D survey (Figure 4), which were not pertinent to the research.

The same software was used to classify the cloud into facades and pavement and then to segment the facades according to the building's limits. After that, the segmented point clouds were exported to Meshlab 2022.02 to generate the respective textured meshes (Figure 5). The resulting meshes were exported as .obj files to introduce them in a GIS, in this case, ArcGIS pro 3.2.2 (Figure 6).

In ArcGIS, it was possible to link the semantic information to its corresponding element; for this, the sheet was formatted in Excel and then inserted as a data table in the GIS (Figure 7-8). This will allow the information to be visualised through pop-ups.

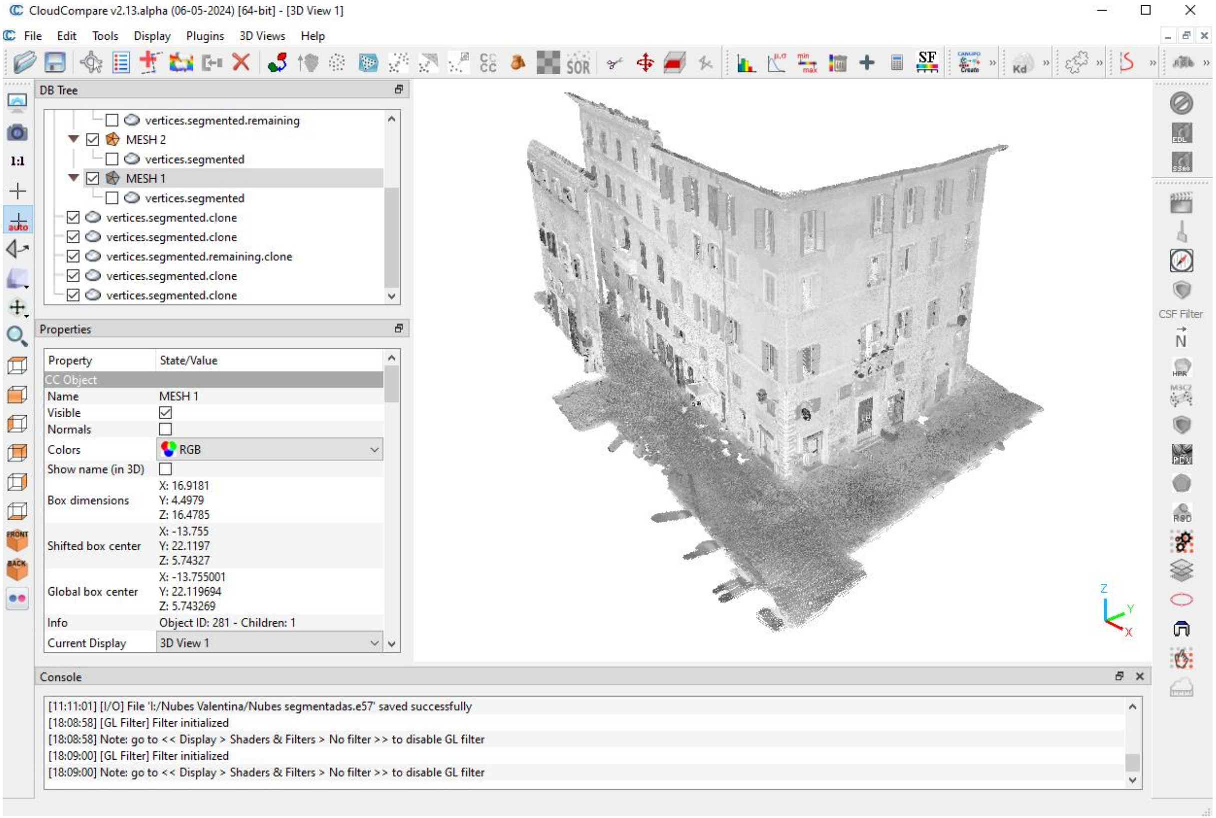


**Figure 4.** Point cloud in Cloud Compare after the noise clean-up process. Source: Author's elaboration.

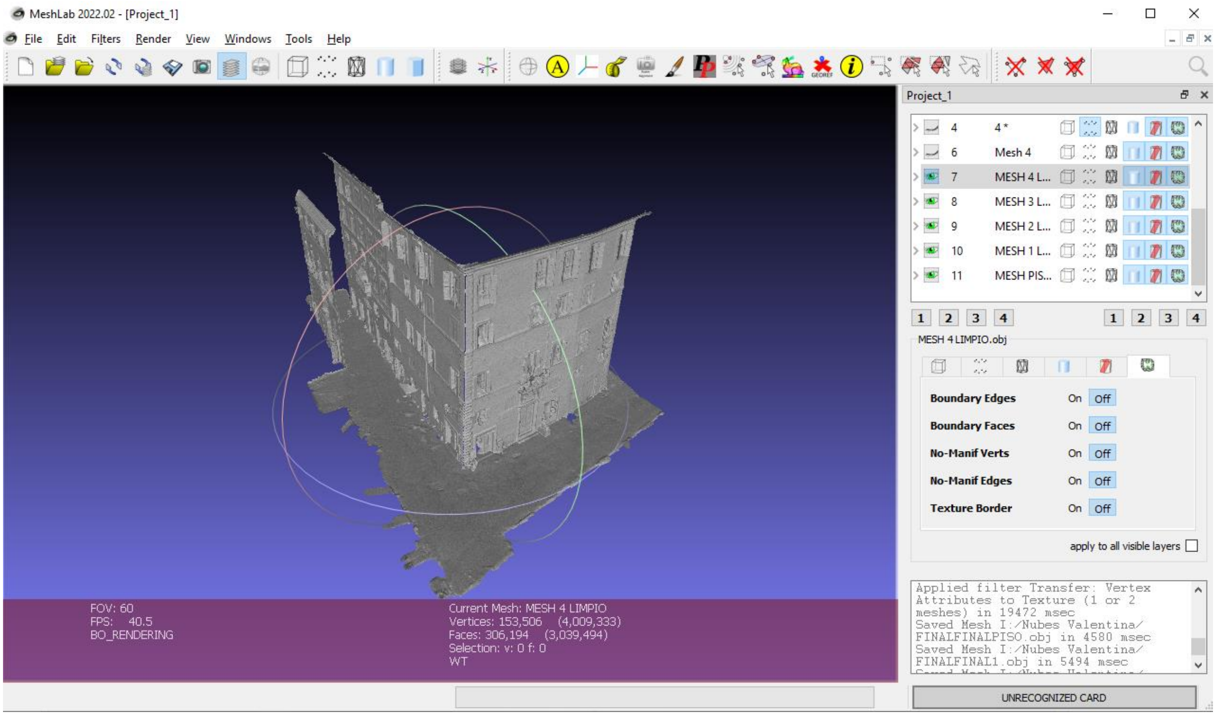


**Figure 5.** Digital model in MeshLab. Source: Author's elaboration.

## 4. Results

A model was obtained in ArcGIS where the facades are visualised as segmented 3D mesh elements containing the information from the sheets. This information can be easily visualised and modified interoperably as required.

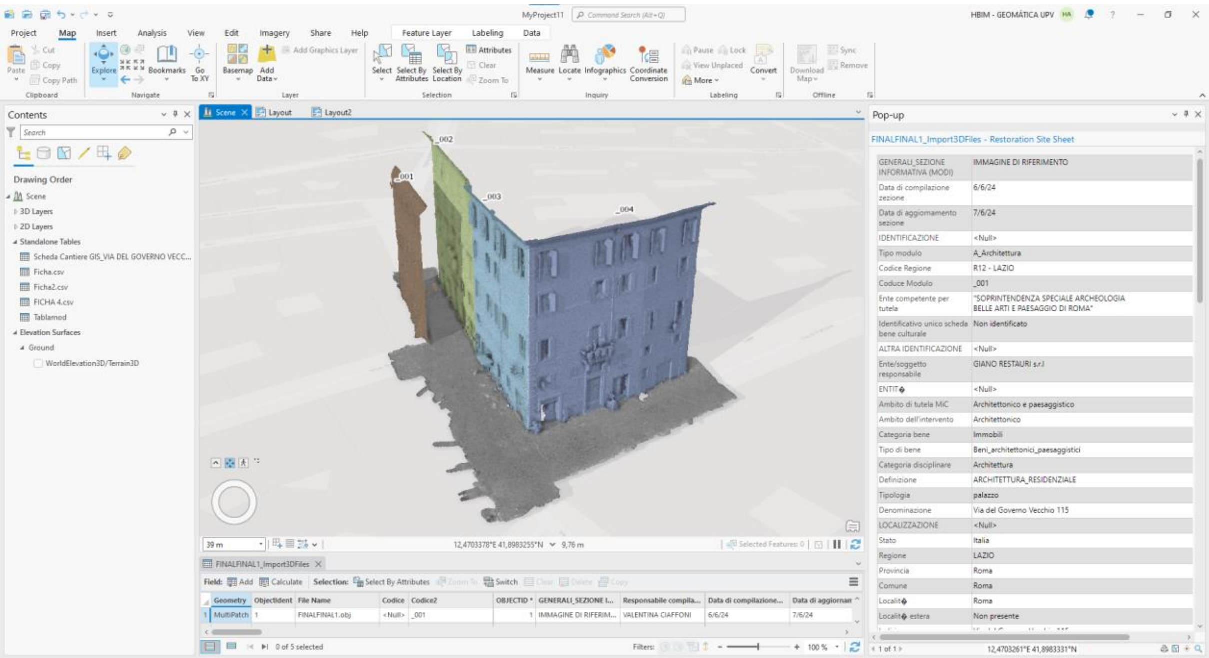

**Figure 6.** Visualisation of the collaborative model in ArcGIS. The Restoration Site Sheet is linked to the collaborative model on the right side. Source: Author's elaboration.


**Figure 7.** The collaborative model in ArcGIS. Source: Author's elaboration.

## 5. Conclusions

The application to the case study has demonstrated the validity of the developed methodology. The model allows for the collection and visualisation of documentation as planned in the preliminary phase. The modelling method has several advantages: it is quick, cost-effective, and easy to visualise. These elements are fundamental to making the workflow applicable to heritage conservation sites. Furthermore, this methodology enables the use of data collected by private companies during surveys, ensuring the cost-effectiveness of the operation.

The research also highlighted that collecting coloured point clouds could be an improvement, as it preserves the chromatic data of the buildings, which is significant for the conservation of historic building surfaces. Additionally, the potential integration of this methodology with photogrammetry is noted, as it allows for preserving the "image" and the state of surface degradation over time. Moreover, a photogrammetric survey enables the comparison of the pre-intervention and post-intervention states to evaluate the conservation, which, being strongly linked to a certain historical period, must be open to discussion. It is essential to geolocate the intervention sites to place the information within the specific context of interest. This way, the developed information model can be associated with other territorial geographic systems to control and manage heritage interventions.

Additionally, it would be beneficial to test the use of the methodology during the ongoing work to verify the actual collaborative nature of the tool; in this initial test, the building model was used only as a repository without real-time data exchange. One of the current limitations of using point clouds is the software constraints, as these files are extremely large and not usable by all users on any device. Using a mesh, as in this case, partially resolves the problem. Still, it is important to continue working in this direction to make these systems suitable for the needs of sector operators. Furthermore, the choice to use ArcGIS software imposes a limitation. The program offers a good level of visualisation and the ability to share it online, which is better than other attempts in this experiment. Nonetheless, it would be preferable to use open-source software. In conclusion, the research has shown that the development of such a digital information model is a project in itself, whose objectives and characteristics must be defined in advance based on the type of intervention to be carried out and, above all, the intrinsic characteristics of the building to be conserved.


**Figure 8.** The collaborative model in ArcGIS with the segmented facades. Source: Author's elaboration.

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