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HBIM for a Coordinated Renovation of Historical Assets at Risk

Cecilia Bolognesi [1], Valentina Demo [1], Mirko Bovi[1]

[1] Politecnico di Milano, ABC Department, 20131 Milano, Italy - (cecilia.bolognesi, valentina.demo, mirko .bovi)@polimi.it

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Abstract

Italy is a territory with strong needs for joint actions for maintenance interventions on historical architecture assets that are part of the Cultural Heritage. The need for digital documentation plans as conservation projects for endangered sites has a particular urgency for those assets that, divided among different owners, risk multiple interventions in an unregulated manner, with the result of waste of time and public money. The specific case deals with a project whose aim is to optimize a renovation and maintenance intervention of a farmhouse that is part of an asset with multiple public owners, which uses not only digitization and modelling techniques in scan to BIM processes but also optimizes and automatize the information exchange processes between the elements of the same asset; the aim is to improve interoperability for maintenance and restoration processes to be managed by different and not always skilled stakeholders. The proposed workflow propose a method that can also be exported in large assets optimizing processes. The case study used deals with one of the several neoclassical farmhouses spread throughout the large, monumental park of the Reggia di Monza in Lombardy, Italy, Cascina Mulini Asciutti. The farmhouses are currently owned by a consortium participated by several public entities and present numerous grades of degradation and the necessity of important maintenance interventions.

1. Introduction

1.1 General framework

By 2030, the member states of the European community have committed themselves to digitising all monuments and cultural heritage sites considered to be at risk (Alsadik, 2022) as well as those suffering from overtourism (Beckele et al.,2018), in the hope of protecting them from the damage that may result. This European recommendation (EU Commission Recommendation, 2021) has therefore created a broad digitisation movement, which places a lot of hope and opportunities in 3D modelling. The scenarios that open are complex and now more than ever it is necessary to guarantee the cultural heritage sector the possibility of optimal management (Scianna, 2020) not only of individual monuments but also of large assets.

Just as for new constructions in fact, use of BIM is strategic for the management, planning and organisation of the renovation projects.

Due to its greater complexity the restoration site can obtain undoubted advantages from the BIM methodology for the organisation of work; it allows saving of time, errors or better management of variants, implementing greater attention to costs and offering greater guarantees on the quality of work. The H-BIM model when updated becomes the information container for building maintenance (Bacci, 2019), offering opportunities for monitoring over time preservation, maintenance interventions and building management. However, in case of large assets, the methodology requires a prior management of greater complexity (Diara, 2021): issues of interoperability between different models arise due to the distributed creation over time, to problems related to the parameterisation and sharing of objects identified only within specific models, and challenges related to the automaticity of processes for updating and computation of work. To face the challenges of Cultural Heritage building maintenance, public authorities should be able to provide themselves with the best tools for planned maintenance inside an advanced BIM methodology (Brusaporci, 2018; Tasselli, 2017); this methodology makes modelling only the basis of a more complex process where the research question remains: how can informed digital models of our historical buildings offer concerted solutions for conservation and renovation processes of our Cultural Heritage exportable to complex assets avoiding fragmented and dispersed tailor-made solution. If we assume the theme of detailed 3D modelling at the building scale (Lo Turco, 2017), considering scan to BIM workflows as part of a normal process the problem is shifted later in the path. So, while we face the rapidly growing of digitized heritage, informed models, produced by professionals, researchers, owners, it is still not evident how can the chaotic number of models accelerate processes in terms of saving time, conservation, maintenance, renovation, in the case of large assets also.

1.2 Relevance

The presented case (Figure 1) is relevant for several reasons: the digitized management of the built heritage is assuming a central role in the debate on the future of cultural heritage but also in the construction industry, for obvious reasons related to the opportunities it offers in the construction market due its extension, its age, its state of conservation, and its criticality in relation to the economic development of a country.

Figure 1. The case study. Cascina Mulini Asciutti, Parco di Monza. Point cloud overlapped by BIM model.

It is very common to be in the presence of public heritage shared among different territorial entities, which immediately translates into different approaches to the management and conservation of artifacts, even with the possibility of serious negligence. For this reason, the theme of transparent sharing of data generated by different models among various operators is of great relevance, so much so that it is also present in many of the project call of the European Community as seen in recent

Horizons too. We can consider as an attempt to harmonize different digital environments European Cooperative Cloud for Cultural Heritage (Brunet, 2022), a shared platform designed to provide cultural heritage professionals and researchers with access to data, scientific resources, training, and advanced digital tools tailored to their needs. This open source platform, developed by ECHOES (European Cloud for Heritage OpEn Science), aims to bring fragmented communities in the field of cultural heritage into a new community around the Digital Commons, to build a practical infrastructure that can help the work of Cultural Heritage professionals supporting multiple media, services for data management, visualization, analysis, enrichment, preservation, and encoding data. The most advanced technologies from generative AI to machine learning are implemented in part of the system.
However, the generation of the digital model offers opportunities to develop relationships between itself and the tools of the profession, even with project management tools such as a WBS; these tools do not need to be experienced in artificial intelligence processes but can well exploit the potential of the model and a chain of tools very attractive and linked together by simple scripts.
In the presented case, the use of the digital model, inserted in an interoperable context, facilitates all process phases towards the maintenance and enhancement of the artifact.

2. The asset and the process

2.1 The mills and the farmhouses

The Monza Park (Rephisti, 1989) , located in Lombardy, is one of the largest enclosed parks in Europe, covering approximately 730 hectares. The construction work for the park, which began in 1805, involved an already inhabited and structured area, characterized by villas, farmhouses, and mills. In the 17th century, the first noble residences began to appear. In 1777, the architect Giuseppe Piermarini started the construction of the palace and gardens of the country residence of Archduke Ferdinand of Austria, marking an important testimony of the new landscape taste in Italy, characterized by English gardens. Eugenio Beauharnais, with the support of his stepfather Napoleon, conceived the idea of extending the gardens of the Royal Villa towards the North, commissioning Luigi Canonica to draft a first plan for the Park. The project included interventions on existing buildings, the continuation of agricultural activities, and the regulation of the natural landscape. In 1807, the perimeter wall, 10 miles long and about 3 meters high, designed by Carlo Fossati, took shape to delimit and protect the complex. The fundamental element for the Monza Park is represented by the water resource, mainly the Lambro River.

Figure 2. The Lambro River in Carta della Barca, 1616.

From the cartographic documents of the early 1600s (Figure 2), related to the representation of the course of the Lambro River, a rich network of springs and irrigation ditches emerges, used to irrigate the fields and feed the numerous mills in the area.

From the map drawn by engineer Barca in 1615, which documents the ancient origins of the complex, three mills appear: The Dry Mills (Figure 3) , The Mills of San Giorgio, and the Cantone Mill. The Dry Mills complex, designed by engineer Tazzini, is intended for grinding cereals and wheat. It is located along a ditch fed by the river thanks to a sluice positioned further north.

Figure 3. The Mulini Asciutti building.

The current building, dating back to the early 1930s, consists of two bodies connected by a large central arch and two barns on the sides, following a composition of simple, symmetrical, and functional volumes. The exterior, made of brick and adorned with limestone cornices and string courses, covers the two parallel bodies connected by a five-arched portico. On the ground floor, there are the grinding rooms connected to the six mill wheels, and on the upper floor, the millers' residences. The large stables with barn and granary, separate from the mill, have symmetrical shapes with refined elements such as the false triangular pediment, light stone keystones, and the eaves cornice. North of the ditch, beyond a wooden bridge, there is a small bakery building (Figure 4) .

Figure 4. Point cloud from digital survey of the whole complex.

The three mills are a minor part of the Park's architectural presences: there are 26 farmsteads (Figure 5) spread over its 700 hectares, with limited variety of styles from neoclassical to gothic; it is since 1919 following the assassination of King Umberto the First and the subsequent abandonment by the Savoy family of the entire complex that the management of the Park has been entrusted to a consortium formed by four different entities including the municipality of Monza and Milan. But even though the rules governing the management of the Park and the shared properties have been reformulated several times, the fragmented decision-making has helped neither the preservation nor the rehabilitation of these monuments that dot the green spaces united by the same stylistic issues showing degradation and lack of re-functionalization.

Figure 5. Four of the Cascine in Monza Park: Cascina Mirabellino, Mirabello, Cattabrega, Costa Bassa

2.2 The workflow from the survey to the digital model

The survey of the Dry Mills was carried out with a time-of-flight laser scanner, RTC 360, an time of flight laser scan that can acquire two million points per second. Therefore, 35 set up were made aligned in situ within the proprietary Cyclon Field software. The software allows visual alignment by overlapping each individual scan or by common points between two consecutive ones, thus allowing for a cloud with 60 percent overlap and an average error of 0.003 m. The site survey phase was carried out by one operator and lasted about 5 hours, producing a single point cloud.

The first phase of digital modelling involves importing the point cloud into Revit software, using the indexed point cloud file formats .rcp or .rcs generated through the use of "Autodesk ReCap." The placement of the point cloud—whose origin was previously defined during the point cloud processing phase—is done using the "origin to internal origin" method, to align the project origin in Revit with the origin of the point cloud.

Within the Revit file, the cloud is re-modelled starting with the insertion of grids and levels, which are developed like all families within a tolerance of 3 cm.

To carry out the modelling as accurately as possible, it is essential to understand the building's history to grasp its functions over time and the various architectural components associated with them.

This involves important work in cataloguing both general geometries and more detailed objects that will be modelled using the software. An initial classification of all the elements to be modelled in the software is possible and fundamental for the subsequent phases, using system families, loadable families, and in-place families.

System families are used to model walls, roofs, and floors; loadable families are used for windows, doors, beams, and detailed façade elements such as arches, cornices, and string courses. In the model, families will be named as follows: Modeled ElementName_Building_Type.

The last category includes all those elements so specific and unique to the project that their creation—and thus customization—through loadable families would be inefficient. These are the in-place families. In-place families are saved within the project, and any changes to their values will affect only the selected family.

In line with the established preliminary organization, the modelling of the case study was carried out for each building individually: the main body of the Cascina, which represents the primary building of the complex; the barns, divided into South Barn and North Barn; and finally, the Oven.

The first loadable Families used to complete the structural part of the farmhouse building were those of the beams and trusses supported by 'the analysis of photographs, historical drawings of the building and the point cloud Within the families it was possible to define the materials that make up the different parts modelled thanks to the parameter "Material".

The classification of elements is the key aspect of the entire process described here. The classification and modelling of arches, for example, is formulated in this case but must also be adaptable to other farmhouses in the Park, as they are characteristic components that repeat in various forms in different buildings; these are full arches or lowered arches. Additionally, being an element of connection and stylistic coherence between the different buildings in the Park, the modelling phase is also fundamental. Currently, the modelling software does not have a specific family for the modelling of arches (Figure 6) but offers several possibilities in this regard: local families can be used (in this case not recommended as they are elements that often repeat on the facade), generic models, or other types of wall-based families (Ori, 2021). The chosen approach involves using the same family template used for the creation of windows, the "Metric Window," as it presents the wall as a host, i.e., an object on which the family can then be positioned, and the presence of a void that can be modified with the tools present in the family editor (Murphy, 2021).

Famiglia	Tipo	Livello	Numero
Arco_Cascina Ingresso	Arco_430 cm	Cascina_LAV_Piano Primo	1
Arco_Cascina Parete Ovest	Arco_214 cm	Cascina_LAV_Piano terra	6
Arco_Cascina abbaini	Arco_300 cm	Cascina_LAV_Sottotetto	2
Arco_Cascina – ribassato tipo 1	Arco_280 cm	Cascina_LAV_Piano terra	3
Arco_Cascina – ribassato tipo 2	Arco_285 cm	Cascina_LAV_Piano terra	1
Arco_Cascina – ribassato tipo 3	Arco_300 cm	Cascina_LAV_Piano terra	4

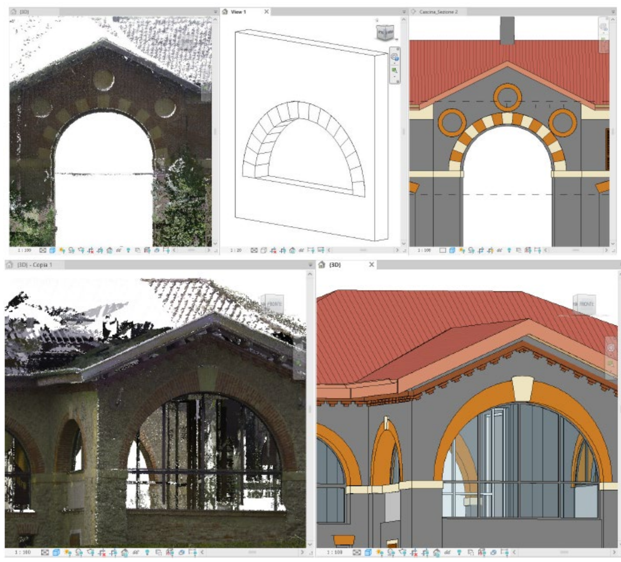

Figure 6: classification of arches as local family and modelling.

For the naming of these families, it was crucial to highlight the field named "Arch" to be able to subsequently define a different WBS parameter from that of the actual windows.

At the end of the modelling process there were few elements of Local Families, mostly linked to the modelling of the vault in the centre of the farmhouse porch, a single element that did not reflect regular geometric parameters which was resolved with a complex path extrusion.

2.3 From the model to the WBS

Once the modelling phase was completed, schedules were created; they are fundamental tools for various project verification functions. Specifically, the function of the schedules was to support the verification of the values of the parameters of the objects inserted in the model. By inserting specific objects into the tables, we can easily check their properties listed in the property columns, and if necessary, modify any parameter directly from the schedule, automatically updating the project. These schedules were subsequently used to monitor the WBS (Work Breakdown Structure) parameters that will be integrated into the model.

The WBS (Work Breakdown Structure) can be classified as a project management tool within the model of the analysed case study; it uses a "Top Down" approach, breaking down the project into smaller and more manageable components following a hierarchical structure that corresponds to the different levels of the WBS. This breakdown facilitates the planning, management, and control of the activities necessary to complete the project. The main function of the WBS is to divide the work into its parts, organized according to hierarchical sections. This approach allows for a clear and detailed view of the various phases of the project, ensuring that each activity is identified, assigned, and monitored precisely until the necessary resources for each phase of the project are identified. Depending on the number of levels chosen, the WBS can reach a very detailed classification. The choice of the number of levels depends on the complexity of the project and specific needs. In this case, the WBS was composed following the logic dictated by the definition of an estimated metric computation. For this case of Mulini Asciutti, the structure of the WBS levels takes as reference the UNI 8290 standard, which offers a structure to classify in detail the technological units and technical components that make up the building system. These functional levels were then integrated with spatial WBS levels to obtain a more complete view of the project. The WBS was therefore structured according to a predetermined logic, dictated by the definition of an estimated metric computation, which will lead to the attribution of an identification code to each element of the model. Subsequently in the computation, for each processing, the same specific WBS codes will be associated to identify the objects on which that processing will be carried out. The WBS scheme of Mulini Sciutti is divided into five different levels where the first three are spatial levels, while the remaining two are functional levels:

- Level 1: Buildings in the Monza Park
- Level 2: Buildings within the project area
- Level 3: Altimetric levels
- Level 4: Category
- Level 5: Type

The first level of WBS (WBS_1) includes a cataloging of all the buildings present in the Monza Park; in the specific case of Mulini Asciutti, the assigned code is 15. Consequently, all elements modelled in Revit for this case study will have the WBS_1 code 15, as they are integral parts of the project.

From an analysis of the common elements among the various farmhouses in the Park, the presence of some recurring and distinctive elements that characterize the rustic architecture of the Mulini Asciutti and other farmhouses has emerged, clearly differentiating it from the noble architecture of the Park's villas. Among these are the arches, both round and segmental, frequently recurring elements in the buildings that demonstrate attention to detail, as well as the artisanal quality of the construction, typical of the historic rural structures present, which significantly contribute to creating a sense of unity and continuity among the constructions. But also colums, pillars, some windows, gables

2.4 The script, a bridge from WBS to renovation phase

Once the WBS levels have been defined and the parameters created in Revit, it is necessary to assign the identifying WBS codes to each object that composes the digital model.In terms of big buildings and assets, this can be an issue. To do this, two different tools will be used: the first is Dynamo, with which scripts will be created to allow the automatic compilation of WBS parameters in Revit; the second is represented by schedules as a verification and possible modification of the codes to be entered.

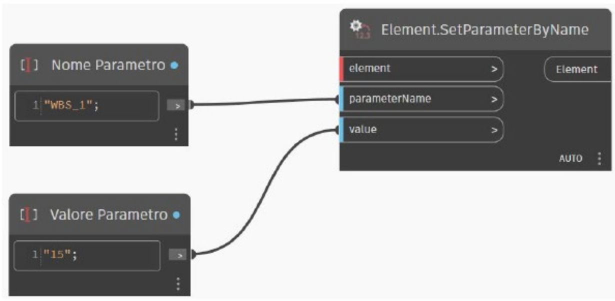

Figure 7: script with entry of parameter name and value.

To insert the parameter values of the five WBS levels and the total WBS within the model, it is necessary to create scripts suitable for the automatic compilation of these fields. Dynamo scripts were developed to fill in the WBS parameters inside the model, to automatically associate WBS parameters to objects. In Dynamo, the same steps that would otherwise be done manually will be recreated. The common procedure involves selecting the object, viewing the parameter to be modified, and associating the parameter value through typing. This procedure will be executed in Dynamo through scripts. Once the node and function in Dynamo that allows defining the value of a parameter are identified, texts will be automatically associated and connected as input. At this point, it is necessary to define the elements that will be identified with the value just given to WBS_1 (Figure 7). All modelled elements will have the same WBS_1 code as they are part of the project area which, as explained earlier, is related to the entire park with the first level of WBS. By running the script, the parameters in Revit will be automatically filled in, and in the Watch panel, all the elements recognized in the view and assigned the defined WBS_1 value will be displayed.

If a warning appears indicating that some of the recognized elements do not have the WBS_1 parameter, it means a lack of association between the WBS parameters, and all the categories present in the model. In this case a further check will then be made through the schedules.

Figure 8: Left-WB4-Classification of objects according to category, right-WB5- Classification of objects according to type.

For each WBS parameter to be inserted, specific nodes were used for the selection of elements of each of the four buildings in the complex; for example, in WBS 3, the codes are assigned based on the level to which the elements are associated. The model includes four ground floors, four first floors, and four attic floors; therefore, four different scripts were created for code 01 of WBS_3, and the same number for the other codes, for a total of 12 scripts for the complete compilation of WBS_3.

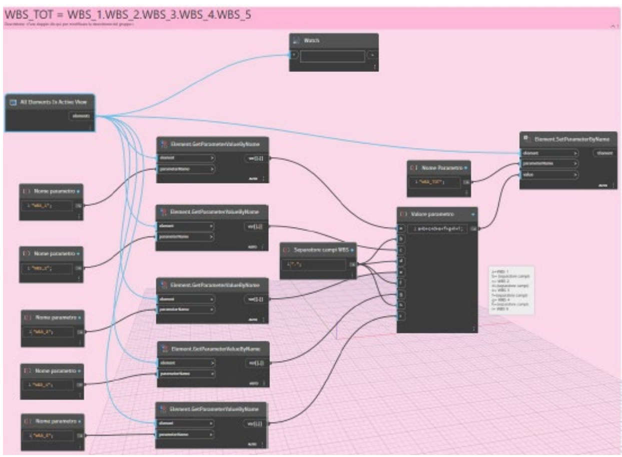

Figure 9. General script for compiling the WBS_TOT parameter.

Once all the scripts necessary for the compilation of the parameters of the first four levels of WBS have been defined (Figure 8) , it is necessary to create a final script for the automatic compilation of WBS_TOT. With this parameter, each element will be coded by concatenating the codes of the five levels of WBS according to this organization: WBS_1.WBS_2.WBS_3.WBS_4.WBS_5 (Figure 9).

2.5 From IFC to estimated calculation of intervention

To export the model from Revit in IFC format it is necessary to create a 3D view where all the objects that need to be exported are visible. In this case, since the model will be used for the compilation of the works in a detailed metric computation, it is necessary to have all the objects in the model visible. Specifically, the computation will be drafted only on the main building of Cascina.

When prepared the 3D view with the objects we want to export and the mapped category with the classes is set as the 'phase to be exported' in the 'as-built' state.

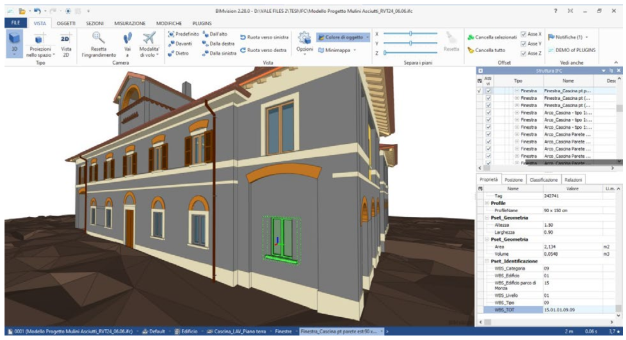

Figure 10. IFC model with object properties panel within BimVision software

To configure this type of export, Revit offers several options available in the 'Property Sets' panel. In this case, two Property Sets were created: one for identification, which identifies the object through the WBS codes, and one for geometry, which identifies the dimensions and quantities. These data will be used subsequently for the computation, in which the WBS will be associated with the computation item and, through the association of the object including the dimensions, the latter will consequently be linked to the item and automatically filled.

Currently, one of the most common procedures for Revit users is to export schedules containing quantities of materials and work and then import them into the spreadsheets of various computation programs used. This method presents some issues since manual data entry can lead to a series of errors caused by oversights or misunderstandings during transcription. Within Dynamo, scripts have been created to enable the automatic compilation of WBS parameters in Revit. By connecting the IFC model with WBS parameters automatically associated through Dynamo scripts it is possible to directly associate work items with objects modelled in Revit. Dynamo scripts customized allow the automatic association of WBS parameters to the objects. This methodology significantly reduces the risk of errors and allows for automatic updates to the metric computation based on changes made to the digital model.

For the computation of the works that, after the general WBS codifications, can be extended to all the architectures of the Park, the specific software PriMus-IFC was used, which allows importing IFC (Figure 10) files directly into the program. For the case study of Mulini Asciutti, the reference price list chosen was that of the Lombardy region for 2023 (LisLombardia_OOPP_2023), available online for free and loaded directly into the Primus file. Since it is a building of historical significance, coherent works for possible restoration interventions were hypothesized and included in the computation, thus allowing the association of the elements on which they will be executed. An automatic element selection mode is used, both for similar and customized entities, by defining the chosen filter as that of WBS-TOT. In this way, the program will recognize all the elements of the model having that specific parameter and will select them automatically. Thanks to this customized automatic selection (Figure 11), any update of the IFC file that involves modifications to the elements will be automatically reflected in the computation. In this way, the program will recognize all the elements of the model having that specific parameter and will select them automatically.

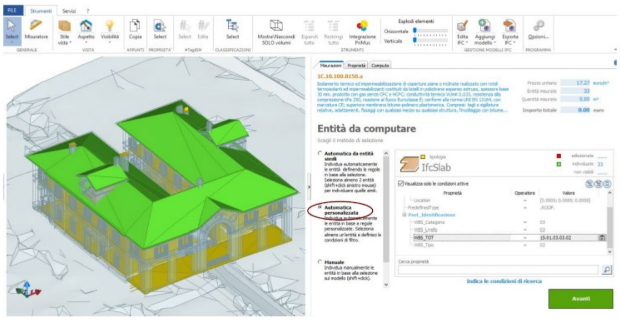

Figure 11. Example of automatic roof selection.

Thanks to this customized automatic selection, any update of the IFC file that involves modifications to the elements will be automatically reflected in the computation.

3. Conclusion

Digitization pushes us towards the efficiency of processes through methods that improve the transparency of flows and the correctness of collaborations. The presence of platforms that facilitate interoperability allows collaboration among sector professionals, guiding towards a unification of languages and procedures. In this specific case study, the proposed HBIM workflow demonstrates the effectiveness of a sharable automatized workflow for renovation processes of cultural assets: here we developed an automated accounting process for maintenance work on an asset, using a single building as a test reference. The automation of the process facilitate administrative checks, professional precise works among architects and builders. This is possible thanks to optimization of information exchange processes through BIM models, interoperability and automation; this approach can be applied as a method for different assets to various buildings, enhancing maintenance and restoration efforts. The case study highlights the potential for broader application.
Regarding the future developments of the HBIM project for the coordinated renovation of historical assets at risk, there are several promising directions:
-the adoption of open-source parametric tools and interoperable standards could be further developed to improve data management and facilitate optimized workflows among different teams.
-the automation of the compilation of WBS parameters using parametric software to schedule intervention phases could be extended to other historical buildings, to other complex enhancing the efficiency and accuracy of maintenance and restoration interventions.
-the use of platforms like the European Cooperative Cloud for Cultural Heritage could be expanded to include more professionals and researchers, keeping professional tools as a key to harmonize and connects intervention promoting shared digital community for cultural heritage preservation.
-integration with emerging digital technologies, such as artificial intelligence and augmented reality, could offer new opportunities to improve the documentation, management, and preservation of historical assets or to automatize more processes like the one here described.

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