ARCHITECTURE CIVIL ENGINEERING ENVIRONMENT
The Silesian University of Technology
No. 4/2022

doi: 10.2478/ACEE-2022-0039

ANALYSIS AND DEFINITION OF RESTORATION STRATEGIES WITH H-BIM APPLICATIONS. THE CASE STUDY OF VITTORIO GIORGINI'S "CASA ESAGONO" IN BARATTI, ITALY

Denise ULIVIERI [a*], Stefania LANDI [b*], Cristina PARDINI [c], Marco Giorgio BEVILACQUA [d], Massimiliano MARTINO [e], Marco DEL FRANCIA [f]

[a] Prof. University of Pisa, DESTeC (Department of Energy, Systems, Territory and Construction Engineering), Largo Lucio Lazzarino, 1, 56122 Pisa, Italy, ORCID 0000-0001-6173-927X
*E-mail address: *denise.ulivieri@unipi.it*

[b] Eng. PhD; University of Pisa, DESTeC, Largo Lucio Lazzarino, 1, 56122 Pisa, Italy, ORCID 0000-0002-3822-4451
*E-mail address: *stefania.landi@ing.unipi.it*

[c] Eng.; University of Pisa, DESTeC, Largo Lucio Lazzarino, 1, 56122 Pisa, Italy

[d] Prof; University of Pisa, DESTeC, Largo Lucio Lazzarino, 1, 56122 Pisa, Italy, ORCID 0000-0002-6063-0333

[e] Arch.; University of Pisa, DESTeC, Largo Lucio Lazzarino, 1, 56122 Pisa, Italy

[f] Arch.; B.A.Co (Baratti Architettura e Arte Contemporanea) Association, Via X Settembre, 15, 57025 Piombino, Italy

Received: 17.02.2022; Revised: 14.06.2022; Accepted: 29.11.2022

Abstract

This contribution is focused on the "Casa Esagono" realized in 1957 by Vittorio Giorgini in Baratti (LI), Italy. The research objective is to lay the foundations for a restoration plan of this experimental wooden architecture, which is now in precarious conditions due to its location near the sea, and whose constructive features, has always raised great questions about the technical feasibility of a full restoration. The paper describes the workflow for the implementation of the H-BIM model, aimed to organise all the data deriving from the historical and on-site research, and the restoration programme. The historical analysis about the house and the architect was the basis for the geometric survey and the analysis of building materials. All building components were subjected to visual analysis aimed to identify deterioration forms. The proposed conservation approach aims to maintain as much of the original elements as possible, while increasing their durability. H-BIM revealed to be the ideal tool to manage the entire restoration process, whose ultimate goal is to celebrate Giorgini's work, to exploit the potential of the house as a cultural attraction.

Keywords: **Casa Esagono; Conservation; H-Bim; Modern Architecture; Vittorio Giorgini; Wooden architecture.**

1. INTRODUCTION

This paper presents a research study on the "Casa Esagono", realized in 1957 in Baratti (LI, Italy) by Vittorio Giorgini, aimed to lay the foundations for a restoration plan of this experimental wooden architecture, which is now in precarious conditions due to its location near the sea. The study was developed under a research agreement between DESTEC University of Pisa and the Municipality of Piombino, with the collaboration of B.A.Co. The historical analysis focused on the house and the figure of the non-conformist architect. On this basis, the geometric survey was developed for a representation in scale 1:25 plus architectural details. The building components were subjected to visual analysis, aimed to identify materials and types of deterioration. A conservation approach was finally proposed with the aim to maintain as much of the original elements, while increasing their durability in the coastal environment. The contribution will describe the workflow for the implementation of the H-BIM model, conceived for organising all the data deriving from the historical and onsite research, and the restoration programme. The acronym H-BIM (Historic Building Information Modelling) is a recently created term to identify the application of BIM modelling, widely used for designing new buildings, to any project or intervention concerning the architectural heritage [1, 2, 3]. The development of a parametric model, created using a BIM software, allows different types of data to be associated with the modelled elements. This step is called "computerisation" of the model. By using H-BIM, it is possible manage and organise effectively all the needed information relating to the entire life of a historic building, which must necessarily be considered to define the restoration project, as well as during the restoration works. In this way, all the expert professionals involved in the restoration process can easily access the data and constantly update any information, a characteristic which turns to be particularly useful for the ongoing monitoring of the site conditions and for developing and managing a preventive maintenance plan. The methodology to develop an H-BIM model, also applied to the case study, includes the following phases: the documentary research aimed at obtaining information about the project, such as history and construction aspects; the geometric survey, the analysis of materials and current conditions; and, finally, the BIM modelling through dedicated software with subsequent computerisation and management of the model.

2. THE ARCHITECT, THE PROJECT AND THE HISTORY OF CASA ESAGONO

The multi-faceted architect Vittorio Giorgini has dedicated his life to the experimental investigation of forms linked to nature. His studies "were focused on building techniques capable of producing housing solutions that were efficient, functional, suited to the needs of everyday life and economically viable" [4]. Giorgini coined the term "Spatiology" to define his studies, meaning "the study of space naturally with the basis of that morphology which was taught by nature and which could not be accepted by the culture of the time" [5]. The account of his passionate research will flow into the book "Spatiology. The morphology of the natural sciences in architecture and design" [6].

In 1957, he graduated in Architecture in Florence, where he carried out professional and teaching activities. At that time, the Florentine cultural environment was lively but stiffened by the academic architectural language. So, during the late 1960s, Giorgini left Italy for the United States, where he became a lecturer at the Pratt Institute in New York. However, it was in the Gulf of Baratti, a marvellous stretch of Tuscan coastline, that Giorgini produced the two significant works, Casa Esagono (1957) and Casa Saldarini (1962), which best express his research. Despite the coldness reserved for him by his contemporaries, his entire life's work is now subjected to a renewed interest, and the two houses are placed under a magnifying glass.

Figure 1.
(left) The model of Casa Esagono and (center and right) the house under construction [source: B.A.Co Vittorio Giorgini Archive]

Giorgini is familiar with the MERO component created by engineer Max Mengeringhausen, and with the connecting joints designed by Konrad Wachsmann for the US Air Force. He ponders the hexagonal model of Buckminster Fuller's Dymaxion House of 1929 and is aware of the design path of some of the most innovative architects, engineers and artists of the time, such as Frank Lloyd Wright and Le Corbusier. The prefabricated modular elements of the Casa Esagono arrive on-site ready for installation (Fig. 1).

Giorgini meticulously studies the individual prefabricated elements, the system of joints, the hinges connecting the pillars to the plinth, systematically conceiving the entire structure, and getting even to design the individual interior furnishings. Casa Esagono is the forerunner of the large-scale design phase, coinciding with the US period, in which Giorgini worked diligently on conventional systems [1]. The layout is a weave of hexagonal modules, reminiscent of a molecular structure or a beehive, in which six of them are arranged around the central one, connected by skilful joints. The central module serves for several functions: as an entrance, as an internal balcony overlooking the stairs, and as a hallway-distributor for the various rooms [7]. A few steps from the Casa Esagono, Giorgini built the Saldarini House, later called the Whale house because of its zoomorphic appearance, where he applied the study of morphology in the natural sciences to architectural design. The two houses form an organic part of the landscape. Both are suspended from the ground, which is barely furrowed by light supports, as a sign of deep respect for the mother earth on which they are built.

Giorgini sold Casa Esagono in 1969, the year he decided to move to America. Over time the house underwent a series of vicissitudes. The furnishings were lost during the 1980s when the ownership passed to the Municipality of Piombino, which handed it over for management ten years later. During this period, the structure underwent a series of heavy modifications. These included the application over all the façades of a plywood cladding nailed directly to the original light-coloured wood panelling and the subsequent application of a dark-coloured impregnating agent. In addition, metal props were inserted to support the floor without any plausible reason. In 2004, the corrugated steel roofing was repaired because of its serious state of corrosion, copper flashings were installed on the pillars and some repair works were carried out on the deteriorated steel components exposed outdoor.

It is only in recent years that the Esagono has found a new life. In 2013, the Municipality of Piombino handed over the building to the B.A.Co Baratti Architettura e Arte Contemporanea association, which is also the custodian of Vittorio Giorgini's archives, and takes care of the house and uses it as a venue for exhibitions and cultural events. The latest interventions on Casa Esagono date back to 2019 with the replacement of the metal props of the attic and the local repair of the roof damaged by the wind. Following further wind damage, the roof underwent a more extensive repair work in 2021, with the complete replacement of the roof covering.

3. GEOMETRICAL SURVEY AND ANALYSIS OF THE STRUCTURAL CONCEPT

A detailed geometric survey of the house was carried out verifying, by direct measurements, the dimensions of the whole house and of each of its components on the base of the drawings of the executive project stored in the Vittorio Giorgini Archive. An extensive photographic survey was also carried out. The results were several survey drawings (plans, elevations, sections, details) in scale from 1:25 to 1:10, including exploded axonometric views to better understand nodes and connections between each structural component.

The foundation consists of six reinforced concrete hexagonal-shaped plinths, each placed on a concrete slab. A special steel joint connects each plinth to a mushroom pillar, composed by four L-shaped wooden elements radially disposed. The joint is composed by three elements welded together: a hexagonal base, a sphere, and a cruciform element where the lower extreme of the four L-shaped elements converge (Fig. 2).

The first-floor slab is composed by seven hexagonal modules. Each module consists of a wooden structure composed of main beams, secondary beams and edge beams connected by steel joints, and a deck of nailed wooden staves arranged following a concentric hexagonal pattern. Each module has the same scaffolding, except for the central one, where the helicoidal stair is placed. The access to the main floor is through a trapdoor in the floor slab. The hip roof structure is made by a complex system of trusses arranged radially around a central hexagonal drum. Simple wooden planks and corrugated metal sheets complete the roof structure. The windows of the house, with single sash opening and sliding shutters, are located in the special box-shaped structures pro-

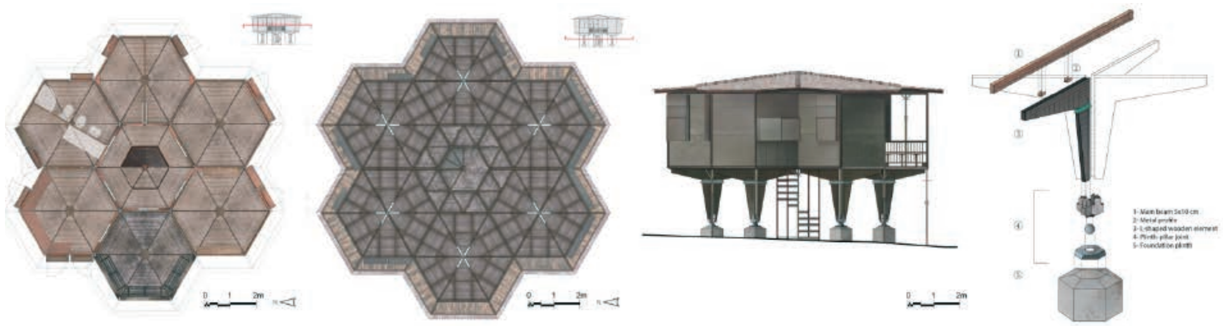


Figure 2.
Plan and structure of the first floor, West elevation (original scale 1:25) and Axonometric view of the pillar (original scale 1:10). [source: survey and graphic elaboration by C. Pardini]

jecting outwards the external perimeter. Further box-shaped structures are used as storing spaces.

The ceilings of each module are made of wooden staves arranged similarly to the floor following a concentric pattern, except for the central hexagon which has main and secondary beams arranged orthogonally surmounted by wooden planks (Fig. 2).

4. ANALYSIS OF CURRENT CONDITIONS AND APPROACH TO THE PROJECT

The cladding intervention in the 1990s, beyond making the house look very differently than in the historical photos, makes it impossible to verify the state of conservation of the perimeter walls, which should be assessed after the removal of the plywood panels. From what could be observed, the two main problems with the house structure are the loosening of several joints at the main floor slab perimeter, where some past temporary repairs are visible, and the advanced state of corrosion of the stairs structure and the floor slabs bolted joints, due to the exposure to the coastal environment. The joints between the plinth and the pillar, instead, are in good condition thanks to the protective paint layers applied. As for the interior, Casa Esagono is almost bare of most of its original furnishings. The interior cladding shows chromatic alteration, stains and deformations of varying degrees caused by humidity, which in some cases have led to cracks. The ceilings show dark stains due to water infiltration. The floorings, near some of the structural joints, shows deformations and rotting due to incoming moisture caused by the same loosening of the joints. Over the years, some degraded parts have been replaced, in particular, wall panels, some doors and windows (Fig. 3).

Diagnostic investigations will clearly be required to understand the condition of the concealed parts.

Based on the analyses carried out on Casa Esagono and based on the state of the art [8], which included an in-depth examination of restoration works carried out on 20th century wooden architectures, a targeted conservation approach was defined, based on maintaining the largest percentage of original elements in place through their restoration, while increasing their durability in view of the aggressive coastal environment. This approach involves the treatment of each element through customized and pre-tested restoration techniques, so as to intervene consciously and in proportion to the actual state of conservation of each part. Only in the most serious cases of deterioration the removal and replacement are accepted, replicating the elements in terms of materials, form and finish. The restoration process, therefore, involve both on-site and in-lab operations, where the elements previously catalogued will be transported.

5. IMPLEMENTATION OF THE H-BIM MODEL

After the realization of the 2D survey drawings and the visual analysis of current conditions, an Excel file was created for each of the building components (foundation, load-bearing structure, vertical connections etc.) reporting the following information: the type of element, the materials, the list of maintenance or recovery operations carried out over the years (if any), the list of degradation phenomena with description and indication of the operations necessary for recovery (Fig. 4).

Then, the 2D survey drawings were imported as an external file in DWG format, into Graphisoft ArchiCAD24, providing the basis for the 3D model-

Figure 3.
Loosening of slab joint, stair's structure corrosion, flooring and wall cladding deformations [source: photo by S. Landi]

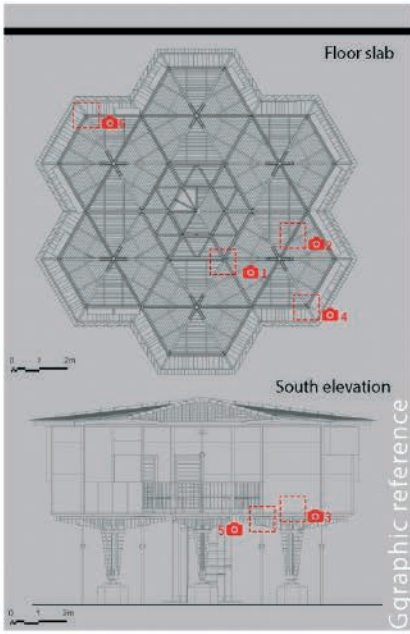
ling of the building. The main tool used for the creation of the 3D elements was Morph tool of the Design menu and all the related tools. Each element was modeled as an individual element or as an Object (union of several Morph elements); this choice was considered on the basis of the recovery interventions foreseen for each element. The necessity of a partial disassembly of the structure, consequent to the defined intervention strategy, and therefore the need to perform a preliminary cataloguing and numbering of the components, finds in H-BIM an ideal support for the management of this phase [9]. In this way, each real component of Casa Esagono structure have a virtual correspondent in the 3D model, thanks to which it is possible to describe its current conditions and all the necessary conservation interventions. For cataloguing the house components, a method has been proposed that indicates, for each element, the coordinates of the position. The same morphology of the house, indeed, suggests the possibility of cataloguing the elements referring to the hexagonal modules of which they are part, numbered clockwise and assigning "0" to the central hexagon. Based on this macroscopic subdivision, it has been possible to assign an Identification code to all the elements (Fig. 5).

Therefore, the identification code of each element generated by default was modified accordingly under ID Properties. At the end of the modelling and cataloguing phase, we proceeded with the "computerization" of the elements. Graphisoft ArchiCAD24 allows to assign some predefined information in the ID and Properties list. However, the software also offers the possibility of modifying or adding new properties that can be assigned through by Properties Manager of the Options menu. Referring to the case study, to optimize the management of recovery interventions, new groups and properties have been created concerning the current state of conservation of the elements and the necessary recovery interventions. In the Existing State group, the properties created are related to Materials and Deterioration Types.

In the Conservation Intervention group, the properties created are related to the intervention necessary to carry out the restoration of the element and are subdivided according to the material (Wooden elements, Metallic elements, and Reinforced concrete elements) [10]. Once the necessary information has been assigned to the elements, it is possible to create specific Schedules by Settings Option in Document field. By querying the model, it is possible to extrapolate from the Schedules all the information associated with the elements with the possibility of modifying and/or updating them. In this way, it will be possible to create targeted lists according to the needs, such as filter and quantify all the elements that require a particular intervention.

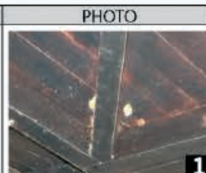
Finally, we would like to emphasize one of the advantages offered by the H-BIM methodology: the interoperability, that defines the ability of a system or an IT product to cooperate by exchanging information with other systems or products in a more reliable and resource-optimized way. The model can exchange information on the Graphisoft ArchiCAD file with other software improving data management. With Export Property Values from Schedules (File menu, Interoperability subgroup Element Properties), it is possible to make the information in the Interactive Board to interact with an Excel spreadsheet [11], which allows for optimal data management in a more efficient way than the Schedules offered by Graphisoft Archicad. A further advantage is the possibility of managing the IFC (Industry Foundation Class) data of the model. The IFC is the international standard for exporting and sharing information contained in BIM models with different software, allowing the possibility of querying the elements by quickly selecting only those of interest thanks to an intuitive graphical interface [12].

Floor slab



ELEMENT	TYPOLOGY	MATERIALS	
Slab	The slab of the structure is composed of seven modular units made integral with each other through metal joints. Each module of the slab is made with a composite beam structure. The beam system is subdivided into main and secondary beams. the main beams are connected to the underlying columns by means of metal brackets. this load-bearing structure is completed with a single plank of flooring.	Main beams	pine wood
		Secondary beams	pine wood
		Splices metallic	iron

PAST INTERVENTIONS			
Period	90's	2019	 Archive of the Office of Public Works of the Municipality of Piombino.
Institution	Office of Public Works of the Municipality of Piombino	Office of Public Works of the Municipality of Piombino	
Intervention	- The exterior surfaces of the attic are treated with a waterproofing paint; - Metal props are installed at the floor nodes for safety.	Substitution of props	

DETERIORATION TYPE	PHOTO	DESCRIPTION AND CAUSES
Surface Deposit	 1	Surface deposition affects all foundation plinths as a result of exposure to weather and biological agents.
Corrosion	 2	Corrosion affects the metal joints of floor beams. The phenomenon extends to most of these elements and is caused by direct exposure to atmospheric agents and the action of salt.
Cracking	 3	This phenomenon is caused by the mechanical pressure exerted by the installation of the metal bracket.
Inproper interventions	 4	Inappropriate local repair work.
Disconnection	 5	Disconnections of main slab beam joints affecting multiple nodes in the structure.
Provisional structures	 6	Installation of metal props at the main nodes of the slab.

	INTERVENTIONS	DESCRIPTION
1	Floor slab discharge	Disassembly of the slab, after unloading the same from the structure of the roof of the walls and partitions in the case where: - The endoscopy showed that the underlying pillar is seriously damaged and therefore it is necessary to dismantle it completely; - Whether the slabs and particularly the edge beams of that hexagon show signs of sagging and loosening of joints.
2	Restoration operations in laboratory	Transport to laboratory for restoration of recoverable damaged elements. - Cleaning of surfaces from surface deposits; - Mechanical removal by sanding the surface of the coating. - Replacement of non-recoverable elements with new elements of the same shape or size. - Surface preparation for protective treatments; - Application of UV and salt protection for external wooden elements.
3	Metal parts recovery operations	- Removal of all metal elements seriously corroded (i.e. of which the reduction of section compromises the structural resistance) and replacement with new elements equal in shape and size - Restoration of all elements that are not severely corroded (i.e. whose section reduction does not compromise structural strength) by removing the rust layer and applying protective paint that is resistant in or near the marine environment.
4	Reassembly	Reassembly of the floor structure.

Figure 4.
Example of Excel sheet for the floor slab [source: elaboration by Cristina Pardini]

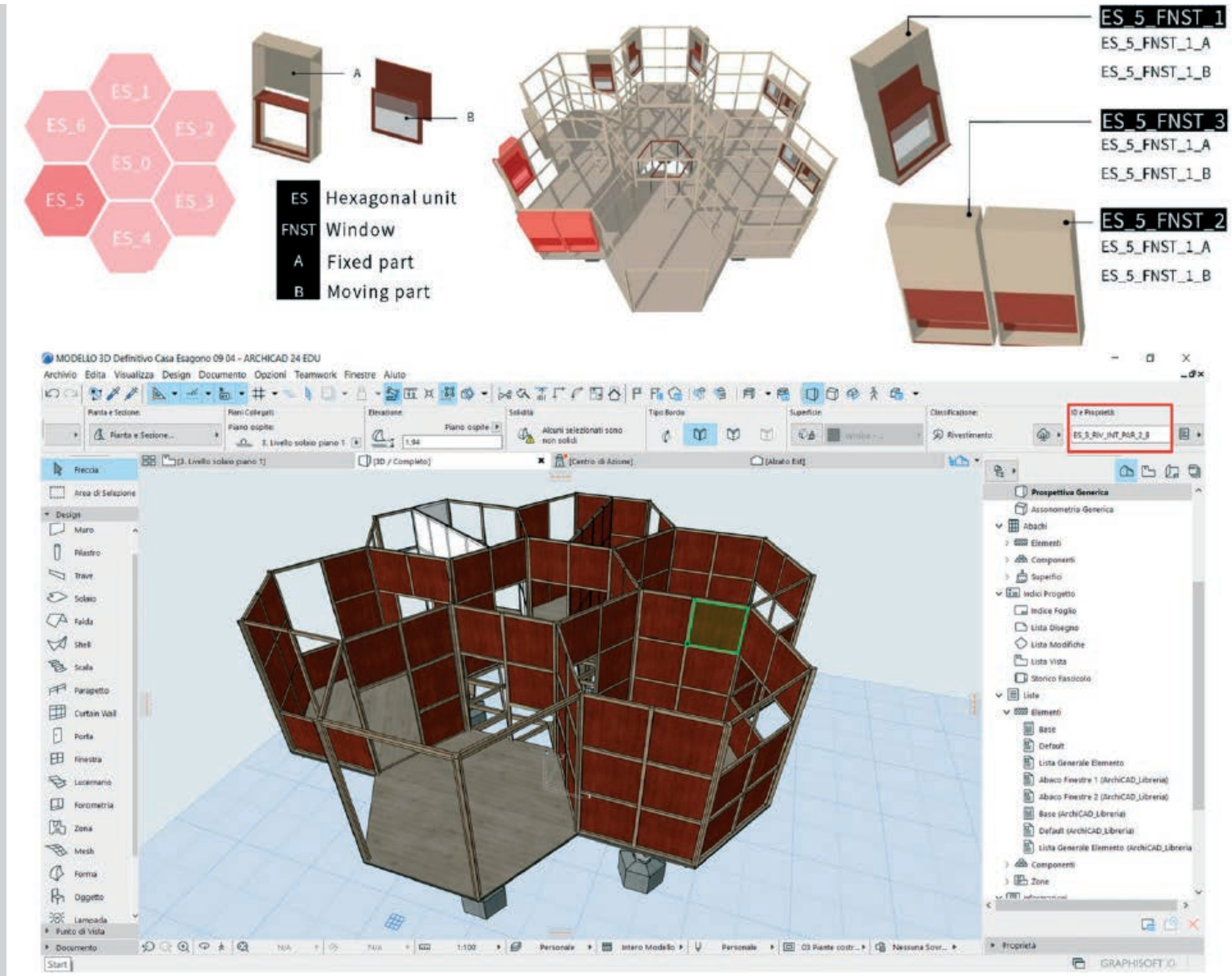


Figure 5.
H-Bim model views and extracts [source: elaboration by C. Pardini]

6. CONCLUSIONS

The research study presented intends to demonstrate the possibility of carrying out the restoration of this architectural masterwork that, due to its constructive features, has always raised great questions about the technical feasibility of such an intervention.

At the same time, this work contributes in an original and innovative way in the broader field of H-BIM research from a methodological perspective, by emphasising the need of developing case-specific workflows and H-BIM models depending on the features of the case study, as well as in the field of built heritage conservation, by identifying and addressing the highly specific challenges that the case study, as a 20th century heritage building, arises.

Thanks to the support of the H-BIM model, it is possible to realize a sensitive and sustainable restoration of Casa Esagono. The final result will be the creation of a virtual archive of the building complete and updatable thanks to which, it will be possible to filter and extrapolate in a targeted manner the necessary data for the estimation of costs or raw materials to be used in the conservation works, allowing to save both materials and financial resources.

The use of a H-BIM model, therefore, revealed to be the ideal tool to manage the entire restoration process, whose ultimate goals are to exploit the potential of the house as a cultural attraction, capable of attracting visitors far outside the local context, and to celebrate and preserve Vittorio Giorgini's work.

ACKNOWLEDGEMENTS

The study was developed under a research agreement between DESTEC University of Pisa and the Municipality of Piombino, with the collaboration of B.A.Co.

REFERENCES

[1] Adami, A., et al. 2018. HBIM for Planned Conservation: A New Approach to Information Management. Proceedings of the 23rd International Conference on Cultural Heritage and New Technologies 2018. CHNT 23, 2018 (Vienna 2019), Museen der Stadt Wien – Stadtarchäolog.

[2] López, F.J., et al. (2018) A Review of Heritage Building Information Modeling (H-BIM). *Multimodal Technologies and Interaction, 2*(2), 21.

[3] Pocobelli, D. P., et al. (2018) BIM for heritage science: a review. *Heritage Science*, 6, 30.

[4] Ulivieri, D., Giorgetti, L., Tognetti, B. (2020). Vittorio Giorgini Spatiology–Morphology Architect. *Nexus Network Journal*, 22, 191–210.

[5] Giorgini, V. (2006). Storia di uno stronzo. Audio tape, unpublished biography.

[6] Giorgini, V. (1995). Spatiology. The morphology of the natural sciences in architecture and design, Bergamo: L'Arca Edizioni.

[7] Del Francia, M. (ed.), (2000). Vittorio Giorgini. La natura come modello (Vittorio Giorgini. Nature as a model). Firenze: Angelo Pontecorboli.

[8] ICOMOS-ISC20C (2017). Madrid-New Delhi Document – Approaches to the Conservation of Twentieth-Century Cultural Heritage.

[9] Murphy, M., McGovern, E., Pavia, S. (2009). Historic building information modelling (H-BIM). ISPRS Annals of the Photogrammetry, *Remote Sensing and Spatial Information Sciences, 27*(4), 311–327.

[10] Oreni, D., Brumana, R., Georgopoulos, A., Cuca, B. (2013). HBIM for conservation and management of built heritage: Towards a library of vaults and wooden bean floors. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, II*(5/W1), 49–54.

[11] Bacci, G., et al. (2019). HBIM methodologies for the architectural restoration. The case of the ex-church of San Quirico all'Olivo in Lucca, Tuscany. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII*(2/W11), 121–126.

[12] Pardini, C. (2021). Casa Esagono di Vittorio Giorgini a Baratti (LI): analisi dello stato di conservazione e definizione di strategie per il restauro con applicativi H-BIM (Vittorio Giorgini's Casa Esagono in Baratti (LI): analysis of the state of conservation and definition of conservation strategies with H-BIM applications) (Master thesis, University of Pisa). Italy, Pisa.