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Research Information System for Cultural Heritage Impact Assessment

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***Abstract* – This research aims to deepen the application of Building Information Modeling systems to the contribution of these methodologies towards supporting the knowledge of the built, the sharing of information through several stakeholders and the optimization of the restoration and conservation processes. For this purpose, the paper introduces a discussion of the state of the art on the HBIM field and the analysis of two case studies, Ponte Albanito and Castel Dragonara, both included in two regionally funded projects. The main goal of this work is the identification of the potential and limitations of the use of BIM in the archaeological field - with particular reference to the rural assets of the Apulian territory: this in order to demonstrate that it could constitute a useful preventive knowledge tool and could actively collaborate in the recovery and valorisation of the cultural heritage.**

I. INTRODUCTION

Over the course of 2022, as part of the Department of Humanities' archaeological research at the University of Foggia, a project was launched regarding knowledge of historical buildings based on a 'mindful restoration' which would be able to guarantee the protection of the architectural structure and to enhance its potential. The methodological aim of this research is that of testing H-BIM as a way of managing the various types of data gathered for input into the historical cognitive framework of architectural monuments in rural Capitanata.

The debate between archeaologists and restorers, which began in the 1980s, has acknowledged the preliminary role which archaeological analysis plays in restoration projects; however, although these analyses have become standard in the field of science, they are rarely used in the professional world. Although the Ministry for Cultural Heritage and Activities underlined, in its Guidelines for the Evaluation and Reduction of Seismic Risk for Cultural Heritage in 2010 (originally issued in 2006), how much the implementation of the 'preliminary project' of a historical building can influence the improvement of maintenance and conservation choices in restoration work (in particular chapter 4 Knowledge of the artefact § 4.1 The pathway of knowledge; § 4.1.5: Historical analyses of events and works carried out), the historical and structural understanding of the architecture is limited to a discretionary preliminary investigation at both the qualitative level and the quantitative level. This situation is exacerbated in the South of Italy where the lack of an established school of research of historical buildings has lead to the absence of a specialised class of professionals.

This research paper is part of the RISCHIA (Research Information System Cultural Heritage Impact Assessment) project, and is financed by the Puglia Region within the scope of the REFIN (Research for Innovation) and RIPARTI (research grants for the purpose of re-starting alongside businesses) notifications. The context for this investigation is rural heritage in a state of abandonment in Capitanata and the sites of farmhouses were examined. These sites, beginning with their intense agricultural exploitation in the late mediaeval period, played a role in the management and control of finances. Their distribution throughout the region with no break in continuity until the early contemporary age forms a precise model of settlement and production: the Apulian farm.

In Capitanata in particular, the Aragonese institution of the Customs for Sheep Driving (1477) and tax regulation for transhumant sheep and goat farming led to an intensification and prolonged exploitation of the farm network. Between the modern and the contemporary ages this network often developed in topographical continuity with mediaeval farms or used other pre-existing locations such as fortified sites, masserie, residential sites and abandoned rural settlements [I]. These settlements are a form of architectural heritage which is very often multilayered and large in size and generally composed of several buildings which, in northern Puglia, are predominantly in a state of abandonment. This differs from the rest of the region where, for decades, a process of conversion and development of these buildings has been in progress. There are various reasons for this difference such as the monumental character and isolated location of these buildings and, above all, the widespread lack of a political and economical vision for the development of rural heritage.

The project launched by the University of Foggia examines the 'farm system' in the belief that, despite its transformative dynamics, a long-term pattern of settlement appears, which becomes an identifying element of the rural Daunian landscape. As this is still a part of the modern-day landscape, it must be put at the centre of regional projects

which can increase knowledge of and promote new uses for it. The aim is to study multilayeredness and to highlight the potential of an approach using H-BIM to manage the archaeological and architectonic data regarding the lifetime of the building (the stratigraphy, building phases, deterioration, material technology and building techniques) and then to merge these elements into a restoration project capable of recounting the history of buildings as a means of rural regeneration [II]. The debate and experiments regarding the application of BIM to historical, architectural and archaeological buildings are vigorous and ongoing. Thus, the so-called ArchaeoBIM is being used to complement the H-BIM (Historical or Heritage BIM). With this in mind, in the area of northern Puglia, several rural architectural complexes have been selected as case studies. These are characterised by a structured historical and architectural multilayeredness extending from the mediaeval period to the contemporary age and have never been scientifically investigated. The remains of the buildings are above ground level, have not been compromised by significant restoration within the last century and are in a state of abandonment. A trial of H-BIM is proposed for the management of the exploratory framework prior to restoration, to be conducted with the involvement of the local Superintendent and professional bodies working in the field of the provision of policies for the region regarding protection and industrial and professional expertise. Among the main aims of this research, which was started a few months ago, is an evaluation of the sustainability (with regard to time and costs) of an approach using BIM. Such an approach would contain a wealth of information about materials, construction, archaeology and architecture with regard to the preservation of the building for the purpose of its restoration project. The project has so far focused on the key methods applied to the various properties. In this regard, the research has undertaken an analysis of the operational consequences (that is to say, those associated not only with the research aims but also with the eventual restoration) connected to the decision to use a Reality-Based BIM for Heritage approach rather than Historical Building Information Modelling. For each of the case studies selected, a Level of Information Need was outlined which was consistent with the historical, architectural, archaeological, gemometric and material characteristics of the structure.

II. HBIM APPLCATION TO THE FIELD OF CULTURAL HERITAGE

BIM (Building Information Modeling) was created as a modeling tool capable of connecting the geometric model and the many specialized data that contribute to the project and management of buildings (geometry, materials, systems), becoming the basis for the entire design process and subsequent building maintenance needs. The acronym of HBIM (Heritage or Historical BIM) refers to a variation in the method of modeling and parameterization of buildings in the processes of management, maintenance and enhancement of the historical architectural cultural heritage.

The term was introduced for the first time by Maurice Murphy and its meaning was clarified a few years later in his Doctoral Thesis; eventually, the definition of HBIM definitively established in a 2013 article [III].

An interesting application of BIM in the architectural field was the modeling, starting from the acquisition of the point cloud, of one of the walls of the facade of the chapter offices of the cathedral of Seville [IV]. In this case, the modeling in the BIM environment took place gradually through the analysis of the various LODs (Levels of Development) to which additional information was gradually added, such as: notes on stylistic affiliation, maintenance work, and the historical stratification of the component parts. This has made it possible to clearly represent the historical-constructive evolution of the facade, generating an in-depth tool for all the specialists involved in its restoration. On the other hand, there is a large number of studies regarding the use of BIM in the analysis of the level of conservation of buildings following calamitous events, such as earthquakes. By way of example, the study of the pre- and post-earthquake state of the church of Sant'Agata - Pieve di Sant'Agata is reported.

The use of survey technologies has helped significantly in documenting the real effects of the earthquake. By processing data it was in fact possible to determine with extreme accuracy all the changes triggered by the earthquake and how these related to the already present instability of the structure and to the relevant stratigraphic interfaces.

Moving on to the applications of the methodology in the archaeological field, new thoughts certainly arise concerning the relevance of the model to what actually exists: often, in fact, the elevation works of the excavation phases are very small, or, worse, they have become almost lost over time. In general, since the early 2000s, many applications have been developed in Italy, especially in academic environments, emphasizing the opportunities for critical analysis and reading of the archaeological evidence offered by the BIM process; this was done on the basis of models already developed in the international arena and applied both to the needs of preventive archeology and of safeguarding and enhancing the built environment [V]. For illustrative purposes one can consider the BIM model of the Solar Temple of Niuserra (2010) by the Oriental University of Naples, of the Crypt of the Church of Saints Sergius and Bacchus in Rome (2015) curated by the University of Palermo, ICAR-CNR and the Special Superintendency for Archaeological Heritage of Rome, the monastic complex of San Michele Arcangelo and the underlying catacombs of San Vittorino in L'Aquila (2015) by the Institute for Construction Technologies - CNR L'Aquila, of the Etruscan city of Marzabotto, the ancient Kainua (2016) by the Alma

Mater Studiorum of Bologna, of the Roman city of Amiternum (2018) by of the University of L'Aquila in collaboration with the Italian National Research Council Construction Technologies Institute, of the Ionic colonnade of the ancient Punic-Roman temple of Sardus Pater Babai, in the Antas valley (Fluminimaggiore, Sardinia) (2019) edited from the DICAAR of the University of Cagliari, of the Baths of Diocletian (2020) by the DICATECH Department of the Polytechnic of Bari and of the Roman Theatre of Ricina (2022) by the Department of Civil, Construction and Architecture Engineering of the Polytechnic University of Marche .

Nonetheless, the application of laser scanner and photo modeling techniques to the various phases of archaeological excavation has allowed some studies to generate information models of significant interest for archaeologists [VI] . This is the case of the research conducted on a necropolis in Numana [VII] in which, starting from planimetric views belonging to different eras and already arranged in GIS technical maps, the two-dimensional views of the subject were extracted. Graphical representations in false colors were then elaborated, according to the depth detected and transcribed for individual burials. These images, with adequate resolution, formed the content basis of a three-dimensional mesh representation of the excavation, as a form of "virtual record" of the ongoing study phase.

III. CASE STUDIES

The application of BIM to existing buildings is recent but there is a growing interest in the sector, especially regarding the potential for sharing data among the numerous professionals involved during the analysis and recovery phases of the building, with a view to effective interoperability of tools and processes [VIII].

In this regard, HBIM has, over time, established a procedure to apply the BIM approach to the reconstruction of archaeological sites [IX]. In these fields, in fact, there are such specificities as to require the creation of parameters and algorithms appropriate for the description of the components and for the documentation of information involved. These include images, reports, drawings, previous surveys, with the consequent expansion of the databases available for modeling.

Although this operational specificity of BIM may be extremely distant from the typical approaches of the archaeological process, in reality it constitutes the key to the concrete use of this methodology in an extremely complex area (that of archaeology) and is far removed from the more purely architectural field.

To achieve this objective, the approach adopted in numerous studies applied to the HBIM sector is oriented towards structuring a real design program on a scalar basis: starting from the simplified models of the objects to be analysed, i.e. purely geometric models of the objects in question , the study goes into the details of the constructive components (stratigraphies of walls, roofs, etc.) leading to the precise identification, cataloguing and filing of the historical, material, and chemical-physical characteristics of the elements constituting the decorative systems (such as bas-reliefs and pilasters, etc.), according to diversified and increasingly articulated LODs.

In this idea of HBIM, the research was based on two case studies, the so-called Castello dei Diavoli (Davil Castle) in Ponte Albanto and the Castle of Dragonara. These are two architectures with a long continuity of life from the Middle Ages up to the contemporary age. Now both are in a state of abandonment, like a large part of the rural architectural heritage of the Capitanata. This aspect, together with the need to activate restoration and requalification activities of these architectural assets, drives research towards the study of rural heritage management methodologies that enhance their intrinsic characteristics and allow a rapid and effective dissemination of the information connected to them [X].

The so-called ‘Devils’ Castle’ is situated on the northern side of the River Cervaro, at the top of the hillside where the multilayered site of Ponte Albanito lies (12km south of Foggia and 17 km east of Troia (in the province of Foggia)) in a settlement of the same name. The site of Ponte Albanito begins to be mentioned in historical records in the 11th century: the cartulary in the Chapter Archive of Troia mentions, in 1019, the presence of a farmhouse under the authority of the monastery of Saint Nicholas of Troia [XI]; the Statutum de reparatione castrorum (the inventory of fortified buildings ordered by Frederick II to be carried out by the provisores castrorum –agreed to date back to the years 1241 to 1246) mentions the Domus Pontis Albaneti among the 28 Frederician domus in Capitanata [XII]. Based on the documentary evidence, the site, possibly a farmhouse, underwent progressive depopulation between the 14th and 15th centuries. It is likely that it maintained its role as a settlement until the Modern Age, when it was chosen as one of the 23 leaseholds for the Royal Aragonese Customs. An example of the importance which the site held in the agro-pastoral system of the Customs can be seen in the building, in the 1500s, of the nearby Ponte Albanito Farmhouse. Although the multilayered site of Ponte Albanito has never been the subject of systematic investigation, the evidence demonstrates occupation of the site from the Neolithic to the Modern Period. The presence of a farmhouse, which is roughly elliptical in shape and surrounded by defensive features, can be attributed to the Mediaeval Period. These remains have so far only be seen from the air. To these can be added the imperial domus, which is traditionally known as the ‘Devils’ castle or farmhouse’. This combination (farmhouse+domus) is well known as a residential dynamic of the Frederician period. Rarely mentioned by local historians, the building has never been the subject of specific research. The surveys being carried out are demonstrating that the building, which until now had been interpreted as having a rectangular plan with

square-topped towers, in fact consists of a pseudo trapezoidal central body which lies east-west (the eastern side, at around 9 metres long, is slightly longer than the western side, which is around 10 metres long). The four corner towers are roughly the same size (around 4.5 metres by 7.5 metres) and are characterised by their rectangular design. The whole complex is built in stone on at least two levels. The interpretation of the structure's architechture, stratigraphy and materials is still in progress. Preliminary observations seem to show three building phases: the first nucleus is the pseudo-trapezoidal central structure. In a second phase this structure was enlarged symmetrically along the longer sides, thus making two avant-corps. The four towers, which serve to fortify this new build, are positioned at its four corners. The Devils' Castle's multilayeredness and ongoing contextualisation in the historical record illustrate Capitanata's extensive and widespread rural heritage. The historical value and potential for development of this are often ignored, leading to an inevitable process of deterioration and neglect.

The second case is that of Dragonara Castle. This is a complex architectural structure connected to the multilayered site of Dragonara, situated in the area of Castelnuovo della Daunia (Province of Foggia). Thanks to its geographical position, occupation from the pre-protohistoric age to the contemporary age can be seen. The present-day remains stand in the area of the city of Dragonara (1019), which is known from the interpretation of aerial photography. This formed part of a system of fortified centres founded by the Byzantines to defend against the Lombards (11th century) which is located along the northwestern frontier of the Subappenines. There have been no systematic studies regarding the development of Dragonara which, according to records, was already an episcopal see in 1045 and maintained a central role for the entire mediaeval and post-mediaeval period with regard to the historical and settlement framework of Capitanata6. The architectural complex has had no historical-reconstructive analysis and is variously interpreted by historians as a fortification of the Byzantine city or of the later Norman garrison. Other interpretations identify more phases. The most obvious modification, during a preliminary observation, is that carried out by Vincenzo di Sangro in 1709, when the structure was converted to use as a commercial farm. The building is certainly the result of a series of structural modifications. In its current state, the building consists of a rectangular plan (1,210m²) with four corner towers. On the eastern side the two towers are cylindrical, while on the western side one is square and the other is polygonal. The central section opens onto an internal courtyard paved with bricks in a herringbone pattern and around this the spaces are organised into two storeys above ground. On the ground floor there are stalls and storerooms while the upper storey is residential in nature. It is divided into large spaces which are full of light thanks to the presence of large windows. The walls show the presence of various building techniques, almost certainly due to different periods of construction and in some cases to the structural role of architectural elements. A scarp wall runs along almost the entire external perimeter where scaffolding holes and cantonali can be seen, which probably date to the first phase of construction. Of particular interest is the isolated circular tower situated around ten metres west of the building. Dating the period of foundation of this tower will be of fundamental importance. For both buildings, the research aims to describe the construction of the model in HBIM according to the following steps:

1) Acquisition of the point cloud by laser scanner survey of the building and contextual photogrammetric survey of the exteriors;

2) Geometric reconstruction of the model;

3) Analysis of the construction phases;

4) Analysis of the degradation of materials and components using non-destructive diagnostic techniques;

5) Semantic mapping of external walls.

As mentioned, the methodological objective of the research is the management of the quality of knowledge of the historic building prior to the restoration project; to this purpose, the historic farmhouse was chosen as a model and was investigated through multiple methods and approaches capable of identifying the surviving structures and reconstructing their history.

Fig. 1. Ponte Albanito site

Fig. 2. Castle of Dragonara and the circular tower

As regards the operational specifications relating to the instrumentation used and the methods of acquiring images via laser scanner, a FARO CAM 2 Scanner was used with the following settings:

- Field of view: 360° x 300°
- Scanning speed: 97Hz
- 3D Dot Accuracy: 22mm at 10m, 3.5mm at 25m
- Angular accuracy: 19”
- Measurement noise: < 0.1 mm at 10 m, 0.2 mm at 25 m
- Scan mode used: STANDARD - OFFSET at 10M = 2MM
- Number of points (Mpts) = 30.7
- Number of scans: 61

IV. RESULTS

In the modeling of these two case studies, the architectural specificities encountered, together with the different complexity of the two models, led to the identification of two different HBIM reconstruction methods. In the case of Ponte Albanito, the generation of the HBIM model had to take into consideration three important aspects:

1) the poor state of conservation of the various components has caused the loss of a large number of them over time, with the presence of many gaps in the building;

2) the widespread presence of weeds which, in fact, create numerous "visual interferences" in the survey with laser scanner techniques;

3) the great architectural specificity of the components, typical of the various construction periods of the building and of their stratification (for example, the presence of an interesting pointed arch vault in the central nucleus, probably built before the other parts and the towers).

In the architectural heritage field, in fact, BIM also deals with the interpretation of information and the assessment of semantics that allows actors to understand and manage the variety of different modelled entities and of all the related data and information.

The representation of an architectural artefact in BIM environment implies discretization of the building or, better, its decomposition in terms of its physical and constructive components. This process depends on the artefact nature, on the state of conservation of the building and, in particular, to the goal of the whole BIM process.

In fact, in the field of archaeology, the approach can be highly diversified depending on the goal: BIM could be used in order to detect what exists, sharing the information flow with the various actors involved, or to virtually reconstruct what has been lost during the time. With reference to the vast abandoned heritage that can be found in the geographical context under analysis, the Capitanata one, this research promoted the use of an approach that could bring professionals and businesses closer, in order to trigger preventive archeology procedures at the service of the future valorisation and recovery actions. In this sense, the modeling methods of the two case studies have been set according to two very different approaches: in the case of Ponte Albanito, the geometric reconstruction of the building has being carried out with the use of polygonal meshes of three different construction volumes, corresponding to the three building phases: the first is the central nucleus, the following two avant-corps and finally the block of the four towers.

This will be followed - in the next phases of the modeling - by the implementation in Revit of the information relating to the construction phases and the semantic enrichment [XIII] of the information model with the whole flow of data that can be acquired from the photo plans (such as semantic characterization of the external finishes and diagnostic results, etc.).

The modeling approach is - for this first case - closer to the world of Reality-based BIM for Heritage as it consists in the use of an automatic 3D building modeling strategy, for a more faithful and accurate representation of the elevated.

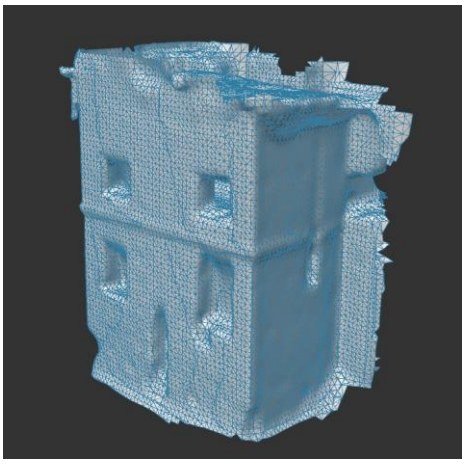

Fig. 3. Reconstruction of one of the tower of Ponte Albanito through the use of polygonal meshes

As regards, however, the case of Castel Dragonara, it was decided to resort to a first classification of the various existing spatial units according to their main function (and therefore their intended use such as, for example, the stables and warehouses lower floors, the four towers and the farmer's work and residential areas on the upper floor); this was followed by a phase of reconnection of the various spaces analyzed in relation to the various existing floor levels and the geometric specificities of the construction elements present, such as scarp walls with variable sections, arches and vaults.

The geometric reconstruction phase of all the volumes of the building is underway and was based on the use of libraries of parametric elements and components, suitably customized: from a purely geometric point of view, the use of modeling methods with extrusions, unions, revolutions has made it possible to recreate the construction elements that the software lacked, thus obtaining a realistic

representation of the existing building, to be enriched (in the future steps of the research, with all the information related to the archaeological-architectural specificities of the site, under development.

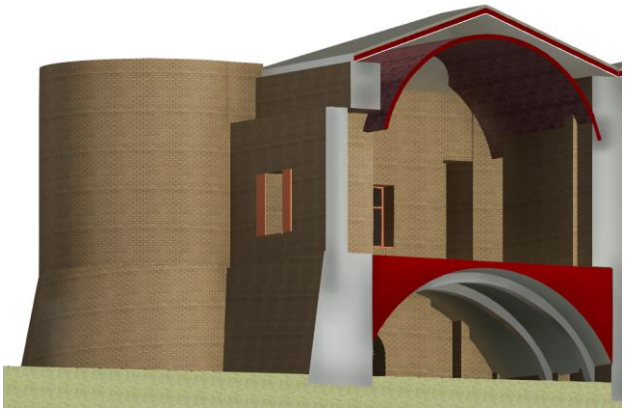

Fig. 4. Use of the "model In-place component" tool of Revit for the BIM assessment of Castle of Dragonara

V. CONCLUSIONS

This project is part of the well-structured line of research that is experimenting the BIM approach for the management, in a three-dimensional space, of an information system useful for understanding the construction process of historical architecture. So far, the investigation has focused on the survey phases and on the time/cost/benefit data collection of the various technologies to evaluate the functionality/adequacy of the techniques for the purposes of stratigraphic, material and architectural reading of the historical-constructive phases of the building. The main goal is to test a BIM workflow for the management of a geometric and information apparatus of data useful for the evolutionary understanding of the built heritage (stratigraphies, construction materials, deterioration, construction and production cycles, chemical characterization of binders) as a basis for a correct restoration project.

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