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# Modeling as a Critical Process of Knowledge: Survey of Buildings in a State of Ruin

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**Abstract:** HBIM modeling presupposes a series of methodological and content questions depending on the type of historic building being investigated. A particular case refers to a multitude of buildings, isolated or aggregated, that sprinkle our territory that do not stand out for their valuable architectural characteristics abandoned for different reasons and turned to ruins. This building category retains a valuable judgment when the typological constructive characteristics are recognized as explanations of "making architecture", strongly linked to a place and to a time and that are worth preserving. The study of a ruin as a building typology involves various issues starting from the survey, both in terms of structure stability and room accessibility, and in terms of survey techniques to be used to acquire geometries that have lost their original conformation. The loss and deformation of the shape are therefore the main obstacles in the reconstruction of the historical evolutionary phases, fundamental for the definition of a recovery project that respects the nature of the building, now in a state of instability. Informed digital models, soon mandatory by law in most building processes, applied to the ruins thus become not only a means of documenting, cataloging, and communicating the built heritage but, above all, a tool that serves the project.

**Keywords:** ruins; modeling; HBIM; digital survey; VPL; database

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## 1. Introduction

Our territory is littered with buildings in a state of ruin. Buildings that do not have a specific and recognizable archaeological value, that do not have a 'noble history' or a high typological dignity but which, in any case, the community recognizes as an integral part of the built heritage. If, on one hand, being in this situation is a guarantee of its permanence, on the other, it also means inevitably losing the building due to natural causes. A significant part of the building heritage in a state of ruin is the one deriving from gradual abandonment resulting from social and cultural transformations rather than natural disasters. Entire abandoned building areas can be recognized in our territory, as well as a multitude of individual buildings that, for different reasons, have become an integral part of the landscape. "In this sense, the very start of the transformation process into ruin underlies a natural event or a socio-cultural motivation that has determined its exit from the dimension of material utility and the confluence towards a spiritual utility, linked to the recovery of aesthetic value and the documented meaning of the construction material" [1] (p. 109) (Figure 1).

**Figure 1.** Some examples of isolated and aggregated buildings in a state of ruin.

Therefore, if we want to try to unhinge this short circuit between the permanence of the identity value and the need for reconversion/reuse (given the irreversibility of the sociocultural mutations that determine the status of a ruin), a starting point could be the one offered by the new knowledge modeling processes able to connect in a single model the multiple information necessary for the definition of possible recovery and requalification interventions. In this case, the point cloud is defined as a "model" not in a topological sense but in an etymological one: reference is made to a scientific field in which a model is used to simulate a phenomenon; in this case, the point cloud, albeit in a noncontinuous manner, simulates the shape of the real object. These methods of integrated information management (commonly defined as BIM) could also constitute a tool for the definition of a knowledge network in the local area (municipal, provincial, and regional) through which the map of cultural interest can be updated to encourage virtuous processes of recovery and punctual (not generalized) enhancement.

The historical period we are experiencing is witness to fervent research activity in the field of BIM applied to build heritage (the H-BIM) [2–5] (HBIM: acronym first used in 2009 (Murhpy et al., 2009)). Over the years, the field of application has extended from “historic” buildings to the entire historical building “heritage”). Studies on this topic are also encouraged by recent legal provisions that establish that use of the BIM procedure became mandatory for large public contracts starting from 1 January 2019 and for amounts of less than one million euros starting from 2025 (in Italy, the Ministerial Decree 560 of 1 December 2017 (published on the MIT website on 12 January 2018 and the Procurement Code L. no. 120 del 11 September 2020 and the next DM no. 312 del 2 August 2021). Although this procedure is fully operational, there are many doubts about its real effectiveness. The main problems are related to the use of standardized architectural elements, which are mainly used in the design of new buildings whose parametric variations generate an infinity of different elements linked, however, to the uniqueness of the formal matrix that generates them. This concept is in stark contrast to what most characterizes historical building heritage, namely the irregular and complex shapes made unique first by the craftsmanship of the process and then by the passage of time [6]. Dealing with historic buildings also raises other problems and can lead to some critical issues that the BIM processes applied to new buildings do not consider. What BIM processes certainly do not take into consideration is the knowledge phase, which instead turns out to be fundamental for any approach to a historic building and consists of the analysis of bibliographic and archival sources, of the execution of surveys, of specialist diagnostic investigations, etc., with the consequent involvement of additional professional operators and greater difficulties in implementing a fully interoperable process [7].

If all the aforementioned difficulties are assumed to be surmountable, the question that arises in this particular case, namely that of buildings in a state of ruin, is how to deal with the irregularity and uniqueness of the shape. How to deal with the diversity of the information, digital platforms, and skills involved. Is it possible—and, above all, would it make sense to do so—to deal with the absence of a shape or its distortion in a way that makes it extremely difficult, if not impossible, to recognize the shape itself? The positive answer to this last question derives from the recognition of a specific value of which the ruin is testimony, such as the use of a particular construction technique or the presence of formal and stylistic elements, and which a specific local community identifies as typical of a particular place and historical period.

In this case, a further question arises of how to best define the knowledge models of a ruin, taking into account that the difficulties on HBIM are, in this case, extremely amplified both in terms of geometric–parametric modeling and in terms of information.

First of all, we need to ask ourselves how and what to model; the surviving architectural structures to be translated into simple forms have an extremely complex nature, which, following the activation of kinematics, also significantly deviate from the geometry of the plan. However, if the issue of simplifying the form is difficult, even more controversial is the issue of modeling the difference and the total absence of some architectural components.

Regarding the field of computerization of these geometries, it must be considered that a forgotten and abandoned building, whose static nature is often extremely compromised, leaves the detector with limited possibilities for interactions, especially in terms of the internal rooms' accessibility. The direct investigations on the artifact are mostly partial and, in any case, refer to the surface aspect, since more invasive investigations would compromise even more the fragile stability of the existing structures. Consequently, as often happens in HBIM processes, the information related to the wall cores will turn out to be few and partial, thus conditioning the modeling of the masonry stratigraphy based on generic or, at times, only hypothetical information [8].

Finally, BIM is a multidimensional tool that aims to manage the construction process throughout the life cycle of the building. This occurs by associating a rich heterogeneous information apparatus to the three-dimensional elements; the variable correlation of these two aspects, geometry and information, however, determines considerable problems in the identification and evaluation of the so-called "levels" of digital data: LoD, LoG, and LoI. LoD (Level of Development) has the task of precisely defining the depth of the various information contained within the model. In an American context, the American Institute of Architects (AIA) has published a LoD framework for the AIA G202-2013 BIM Protocol, defining a scale of values ranging from 100 (conceptual model that can be associated with a preliminary phase of the project) to the 500 (“as-built” model). The Italian legislation that refers to LoD as UNI11337-4:2017 and uses a scale of values that goes from A (geometric symbolic model) to G (model updated to the current state). The information needed to define the LoD of an object is of two types: geometric (Level of Geometry) and nongeometric (Level of Information), depending on the depth of the investigation carried out on the building, and will therefore vary from one architectural component to another. Therefore, it is plausible to think that it will not be possible, for example, to identify a unique LoD value of the overall model.

## 2. Materials and Methods

For the applications foreseen in the following article, a ruin located in the municipality of San Gemini (TR, Umbrian city of Italy) in the area called “Località Valleantica” is used as an object of study. The artifact is currently in a state of ruin resulting from its loss of functionality. Over the course of a few decades, the state of neglect has led to a strong deterioration of the construction elements, with more or less extensive collapses, accentuation of the deformation states of the wall structures, and the presence of dense vegetation grown both inside the rooms and close to most of the walls. Nevertheless, from the visual analysis of the construction elements and from the study of the overall configuration of the wall core, it is clear that the building is determined by historical stratifications and by different levels of alterations. Unfortunately, in this specific case, the documentary research was unsuccessful, having only a few and non-exhaustive maps that do not clarify either the overall conformation of the building or its evolutionary history; as shown by the Gregorian cadaster, it already appears in the 1800s with the current conformation of the building envelope, a fact that does not highlight its historical origins (Figure 2).

Compared to other single buildings scattered in the vast surrounding agricultural area, it is not possible to describe the building as valuable architecture. However, a comparison between the construction elements detected and the information provided by the manual repertory of types and recurring elements in a traditional building (ordinary supplement no. 1 to the “Official Bulletin”, General Series, no. 40 of 12, August 2015 text that lists and describes the general and typological characteristics of traditional building, the recurring construction and architectural and decorative elements commonly found in some types of traditional local buildings) highlights how the building shows forms and elements typical of a local architectural tradition. This "know-how of architecture" is even more tangible thanks to the presence of manuals that try to parameterize on the paper techniques and architectural elements usual for that period. These factors increase the prestige of the product and motivate its interest as an object of experimentation in the digital BIM field.


(a) (b)

**Figure 2.** *Cont.*


**Figure 2.** (**a**) Extract from the Gregorian cadaster, 1819. (**b**) Enlarged extract of an aerial photo, scale 1:20.000, from 1940, taken from the archive of the Italian Air Force. (**c**,**d**) Photographic views of the building.

In this case, the integration of the techniques was fundamental to be able to have a point cloud that could cover most of the surfaces, since, as previously mentioned, this type of artefact presents objective accessibility and visibility difficulties; the first geometric acquisition took place using a TLS (Terrestrial Laser Scanner: acquisition with Faro C130X supplied to CRITEVAT (Engineering Research Center for the Protection and Enhancement of the Environment and Territory) of Rieti and data preprocessing using SCENE software), with a project of the location of the instrument that allowed the acquisition of the entire external perimeter and some covered areas on the ground floor; some rooms were only partially detected, because they are visible from the outside, while most of the internal ones were completely excluded due to the unsafe structures and the vegetation that prevented access (Figure 3).

To overcome these limitations, we used a photogrammetric approach through an UAV (Unmanned Aerial Vehicle: acquisition with an Anafi Parrot drone and data processing with Agisoft Metashape for photogrammetry (images 4608 × 3456 pixels) to obtain pictures in both the zenith and inclined modes, thus allowing the representation of all the inaccessible parts (Figure 4).


**Figure 3.** (**a**) Project of instrument location for massive acquisition with a laser scanner. (**b**) View of the aligned point cloud.

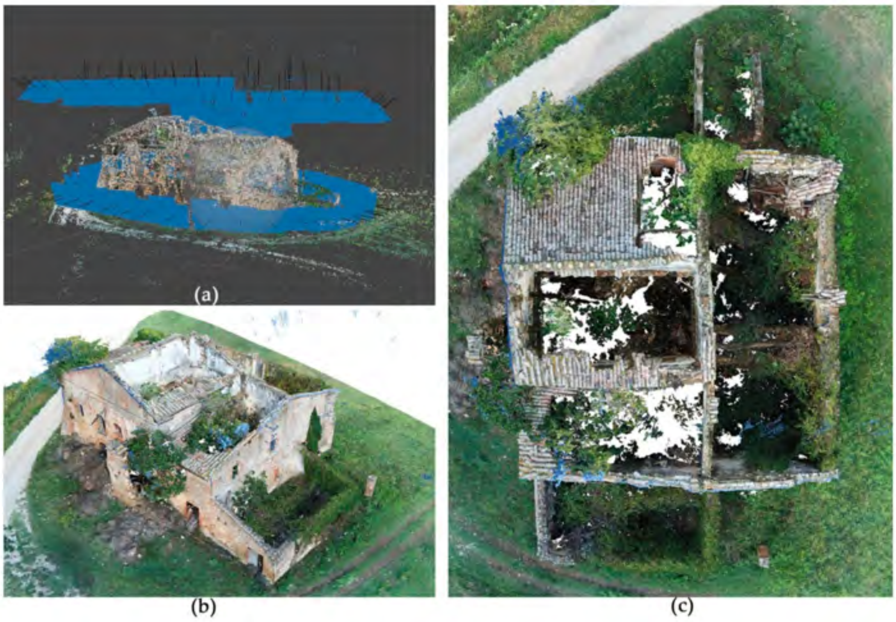



**Figure 4.** (**a**) Sparse cloud generated to allow the relative orientation of the images partly aerially and partly from the ground. (**b**) Perspective view of the dense cloud. (**c**) Top view of the roofs visible in the dense cloud.

The integration (the merging of the models took place through the use of CloudCompare software) of the numerical model from TLS with the one obtained from SAPR made it possible to obtain an overall point cloud with a very high coverage coefficient of the surveyed surfaces. It should also be remembered that, although the basic digital data always consists of the point in its Cartesian coordinates and the corresponding RGB value, the two point clouds present characteristics of inhomogeneity in their respective real resolutions (namely, in the quantity of points in the space unit) determined by the different acquisition modes; in the first case, TLS, the point resolution, is determined by the instrumental resolution setting (based on a spherical grid), by the position of the instrument with respect to the building, and by the reciprocal position between the different stations, whose position is often conditioned by environmental interference factors, as in this specific case [11]; in the second case, SAPR, the point resolution is determined by the photographic image characteristics but, above all, by the material characteristics of the detected surface whose texture may or may not facilitate the processing algorithms of the relative orientation of the different photographs and, consequently, of the dense cloud elaboration. In buildings as the one under study, the surfaces normally show such deterioration states as to facilitate the photogrammetric procedure, thus obtaining particularly effective models.

That said, the approach to modeling in a digital BIM environment of the building under study at this point could follow two distinct and opposing paths: the first involves the construction ad hoc of nonparametric families, which tend to adapt to complex and distorted shapes, quite often out of alignment, slavishly following the point cloud model. A second path, on the other hand, and the one that was actually followed in this experimentation, reserves the right to critically analyze the building, breaking it down into parts and analyzing the main construction elements in order to bring the elements themselves back into a regular configuration relative to the time phase preceding collapse and degradation present today.

The original form reconstruction passes through the study of its transformation, analyzing the point cloud not as a discontinuous model to be replicated in a continuous mathematical environment but as the last stage of a shape metamorphosis that is entirely to be reconstructed. In this sense, instead of importing the point cloud into the modelling (Autodesk Revit version 2019 software was used for modeling in a BIM environment, while Dynamo for Revit software was used for visual programming (pg. 11)) software and working towards the 3D model creation that can adapt to it, we proceeded with two-dimensional intermediate steps, the aim of which were to identify the guidelines for the model. The point cloud is sectioned with horizontal and vertical planes in order to obtain thin slices on which to establish some basic reasoning: identify the limit of the internal environments, establish the wall thicknesses, and evaluate the alignments of the latter net of deformations outside the plane (Figure 5).

It is important to highlight that only this second approach allows to define the modeling as a critical process of knowledge in which the construction of a geometric–parametric model is certainly a simplification of the actual state but is, at the same time, an anticipation of the recovery project (this aspect will be better clarified in Section 4 of the text).

After setting the guidelines for the construction of vertical and horizontals structures, we proceeded to study the architectural components related to the openings on the walls and to analyze the material aspects [12].

Regarding this last point, it is known that the point cloud is a digital model representative of the actual state not only from a geometric point of view but also from a material point of view; however, it is testimonial only to the superficial aspect and does not investigate in any way the stratigraphic composition of the elements.

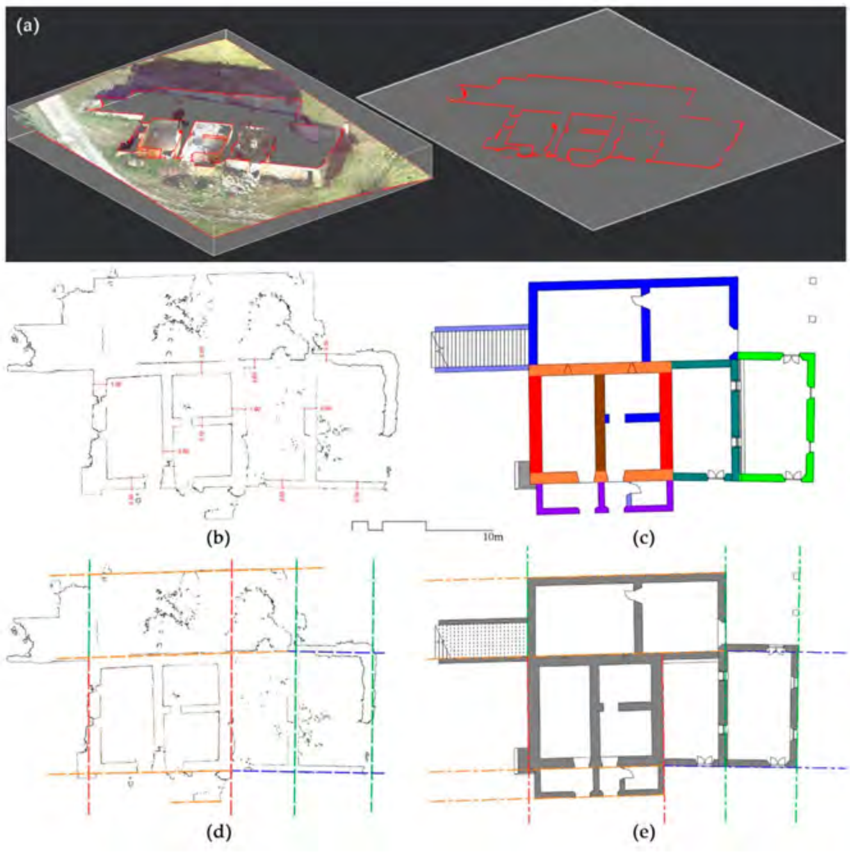



**Figure 5.** (**a**) Segmentation process of the point cloud into slices in order to extract two-dimensional information, (**b**,**d**) one of the slices on which the thicknesses and alignments were analyzed respectively; (**c**) thematic plan view of the BIM model in which a color os associated with the wall parameter "thickness" for each value derived from the survey; this process highlights the building partitions with similar characteristics. (**e**) Plain view of the BIM model in which the alignments deduced from the cloud analysis are not a parameter of the element but the guideline on which it is built.

Therefore, except for those unsafe or partially collapsed parts that expose the structure, in many cases, the wall core must be hypothesized. It will therefore be important to define, during the modeling process, the accuracy of the characteristics assigned to the various elements. Based on the visual analysis of the components, it was possible to recognize a certain value in the building, both for the construction techniques used and for the presence of elements that can be traced in an Umbrian medieval building manual. Such manuals can be considered as a collection of rules and parameters that describe the architectural component in its most general form, which, through parametric variation, tends to become more specific, adapting to the case in question. Such feedback increases the value of the artefact, which is part of the Heritage category and not only the definition of Historic. Except for some stratigraphies just mentioned in the manual, which were used in the reconstruction process to hypothesize the conformation of the missing slabs, we mostly concentrated on the modeling of the point elements by applying the parameters of lability for the dimensions, partitions, and quantity of sub-elements to the suggested geometries (Figure 6).

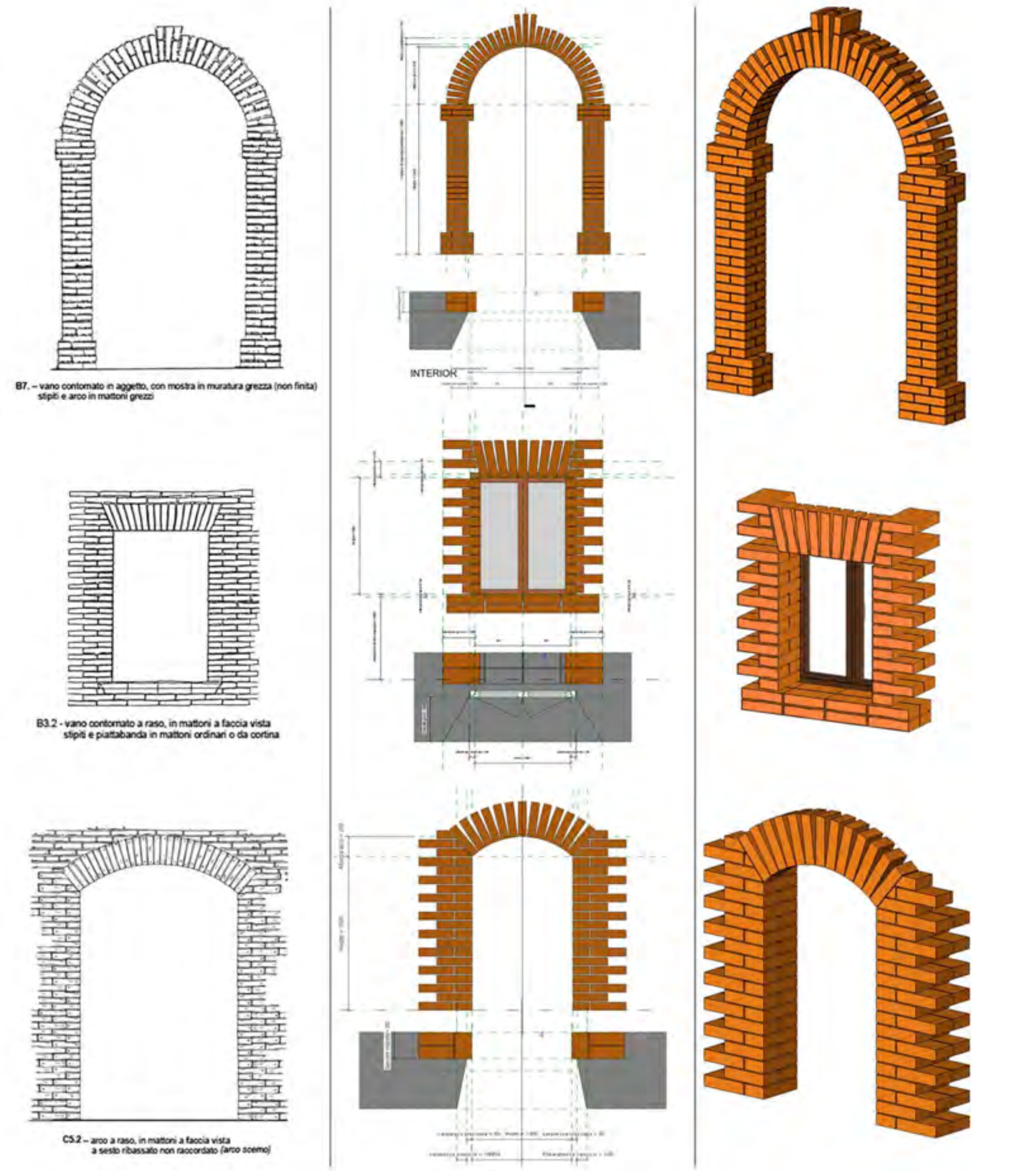



**Figure 6.** Comparison between the two-dimensional bibliographic reference, the medieval Umbrian manual repertory of the types, and recurring elements in a traditional building, and the three-dimensional parametric elements constructed based on typological recognition: (**a**) protruding compartment with unfinished masonry jambs (unfinished) and a rough brick arch, (**b**) compartment with a coplanar frame in exposed brick, with jambs and strips in the usual brick or for plugging, and a (**c**) coplanar arch in exposed brick with a lowered arch not connected.

As for the wall faces, the visual analysis of the various components led to the recognition of at least 6 wall samples documented for convenience in tabular form in electronic calculation sheets (Figure 7). This heterogeneity construction, coherently with the different thicknesses and wall alignments and with the presence of cantonals along the same facings, tends to suggest a certain stratification that took place over time. By putting the information collected into a system, it was therefore possible to structure a temporal sequence capable of describing the building evolution.

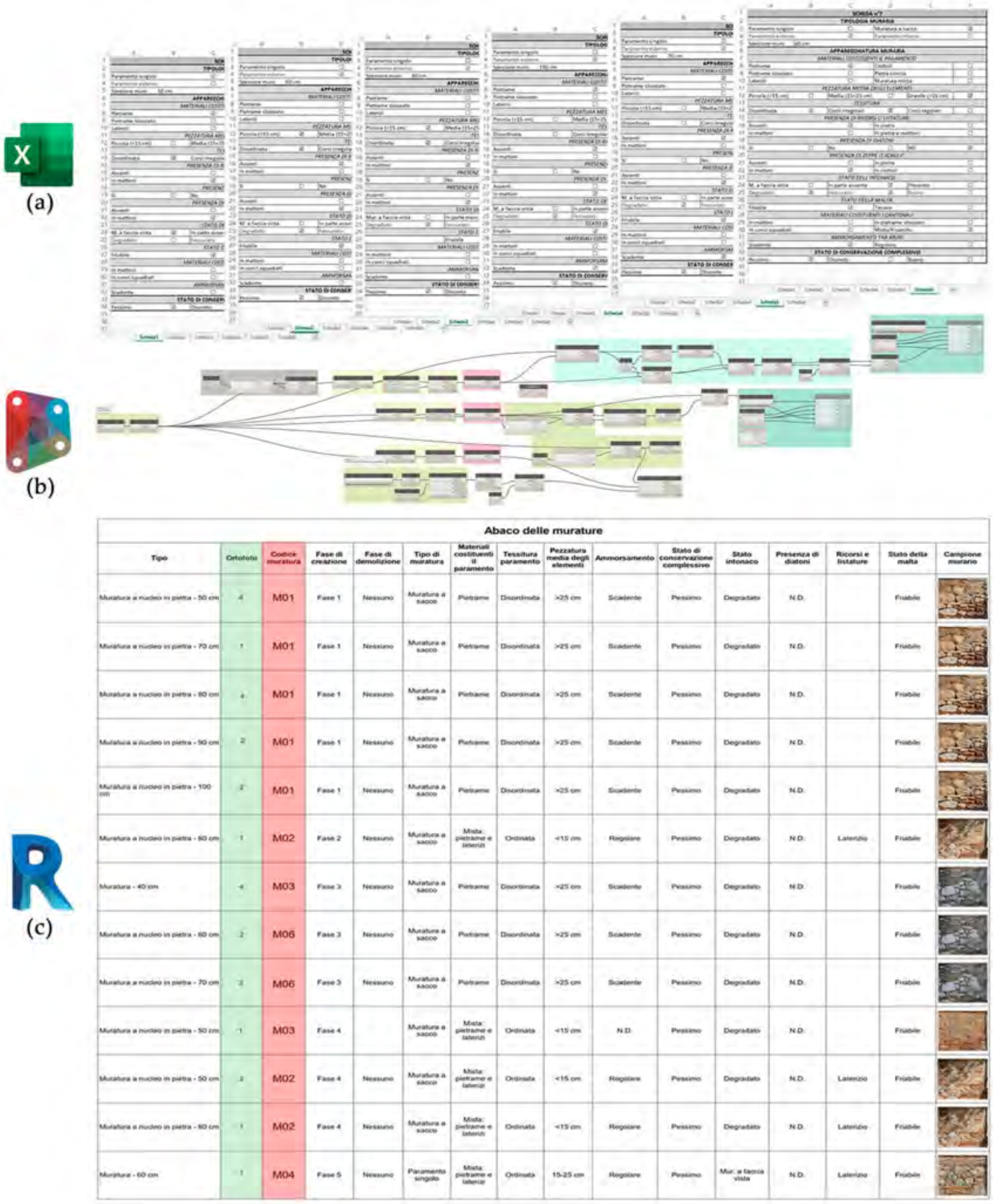
Parallel to the modeling process, an exclusively informative and nongeometric dataset was created in which textual and alphanumeric data were cataloged. This operation was carried out in order to make this information more manageable through commonly used tools and software, open to wide use, and which do not necessarily force the use of BIM modeling applications. For example, electronic spreadsheets were set up in Excel to be able to manage the data collected during the analysis of the various wall samples in tabular form and thus catalog the information in a more efficient way. The information relating to the samples was therefore linked to the various 3D components with the use of visual programming; an algorithm acts as a link between the alphanumeric information independent of the BIM environment and the models themselves. In this sense, the use of the Visual Programming Language (VPL), which allows to exploit the advantages of computer programming not through syntax but borrowed from the graphic manipulation of elements: boxes and arrows, makes everything easier, especially for those who are not insiders, not having to acquire computer programmer skills. The information dataset, or the input data, are processed by the visual algorithm and exported as output parameters of the various architectural components. Since there is a one-to-one relationship between the parties, as the parameter information changes within the BIM application, it is always possible to reverse the flow of the algorithm and thus update the textual data (Figure 7).

In this way, the visual algorithms make it possible to facilitate the management of the information load, which, due to the process of analysis and knowledge of the existing building not envisaged for new constructions, in HBIM processes, significantly exceeds what is expected in a BIM process. It is also possible to state that, in the case of damaged or deteriorated buildings, the management of the information load also assumes a predesign value, since the compilation of the intervention parameters on the building is in response to the declaration of deterioration of the same. A parameter is assigned to each element capable of describing its conservation state, a description contained in the Excel worksheet by those who are responsible for carrying out this type of analysis. In the presence of this parameter, the designer will have to suggest interventions capable of eliminating or limiting the expressed needs of the current state. The value to be attributed to these two parameters: "degradation" and "intervention" is something that goes beyond modeling in a BIM environment, which makes it agile and easy to manage by users, but at the same time, the information is connectable with its geometry, thus ensuring interoperability between professional figures and digital applications (Figure 8).

## 3. Results

Five construction phases have been identified, starting from the original nucleus with subsequent additions over time of building blocks that have changed both the overall configuration and paths and methods of use of the spaces. Thanks to the BIM tool, it was possible to leave a trace of this analysis, being able to overwrite the various configurations as a succession of hypothetical design states that followed one another in the past. The last reconstructed configuration is indeed ideal, as it is the result of hypotheses and deductions, but it is also ideal because it is integral; it does not consider either the distortion of the elements or their collapse. The transition between the last design stage and the current state of ruin collects all those events of decay, instability, and loss that characterize the building as we see it today. In this case, therefore, we have chosen to create visibility parameters that allow to view the entire configuration of the building or only the structures actually present.

The use of this parameters allows, at the same time, to add information features to the components and to query the model to obtain thematic views. For example, by assigning on/off visibility parameters, it is possible to view and distinguish real parts and hypothesized parts in the same model.




| Tipo | Ortofoto | Codice muratura | Fase di creazione | Fase di demolizione | Tipo di muratura | Materiali costituenti il paramento | Tessitura paramento | Pezzatura media degli elementi | Ammorsamento | Stato di conservazione complessivo | Stato intonaco | Presenza di diatoni | Ricorsi e listature | Stato della malta | Campione murario |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Muratura a nucleo in pietra - 50 cm | 4 | M01 | Fase 1 | Nessuno | Muratura a sacco | Pietrame | Disordinata | >25 cm | Scadente | Pessimo | Degradato | N.D. | | Friabile | |
| Muratura a nucleo in pietra - 70 cm | 1 | M01 | Fase 1 | Nessuno | Muratura a sacco | Pietrame | Disordinata | >25 cm | Scadente | Pessimo | Degradato | N.D. | | Friabile | |
| Muratura a nucleo in pietra - 80 cm | 4 | M01 | Fase 1 | Nessuno | Muratura a sacco | Pietrame | Disordinata | >25 cm | Scadente | Pessimo | Degradato | N.D. | | Friabile | |
| Muratura a nucleo in pietra - 90 cm | 2 | M01 | Fase 1 | Nessuno | Muratura a sacco | Pietrame | Disordinata | >25 cm | Scadente | Pessimo | Degradato | N.D. | | Friabile | |
| Muratura a nucleo in pietra - 100 cm | 2 | M01 | Fase 1 | Nessuno | Muratura a sacco | Pietrame | Disordinata | >25 cm | Scadente | Pessimo | Degradato | N.D. | | Friabile | |
| Muratura a nucleo in pietra - 60 cm | 1 | M02 | Fase 2 | Nessuno | Muratura a sacco | Mista: pietrame e laterizi | Ordinata | <15 cm | Regolare | Pessimo | Degradato | N.D. | Laterizio | Friabile | |
| Muratura - 40 cm | 4 | M03 | Fase 3 | Nessuno | Muratura a sacco | Pietrame | Disordinata | >25 cm | Scadente | Pessimo | Degradato | N.D. | | Friabile | |
| Muratura a nucleo in pietra - 60 cm | 2 | M06 | Fase 3 | Nessuno | Muratura a sacco | Pietrame | Disordinata | >25 cm | Scadente | Pessimo | Degradato | N.D. | | Friabile | |
| Muratura a nucleo in pietra - 70 cm | 3 | M06 | Fase 3 | Nessuno | Muratura a sacco | Pietrame | Disordinata | >25 cm | Scadente | Pessimo | Degradato | N.D. | | Friabile | |
| Muratura a nucleo in pietra - 50 cm | 1 | M03 | Fase 4 | | Muratura a sacco | Mista: pietrame e laterizi | Ordinata | <15 cm | N.D. | Pessimo | Degradato | N.D. | | Friabile | |
| Muratura a nucleo in pietra - 50 cm | 2 | M02 | Fase 4 | Nessuno | Muratura a sacco | Mista: pietrame e laterizi | Ordinata | <15 cm | Regolare | Pessimo | Degradato | N.D. | Laterizio | Friabile | |
| Muratura a nucleo in pietra - 60 cm | 1 | M02 | Fase 4 | Nessuno | Muratura a sacco | Mista: pietrame e laterizi | Ordinata | <15 cm | Regolare | Pessimo | Degradato | N.D. | Laterizio | Friabile | |
| Muratura - 60 cm | 1 | M04 | Fase 5 | Nessuno | Paramento singolo | Mista: pietrame e laterizi | Ordinata | 15-25 cm | Regolare | Pessimo | Mur. a faccia vista | N.D. | Laterizio | Friabile | |

**Figure 7.** The records relating to the wall samples, suitably cataloged within alphanumeric spreadsheets (**a**), are linked to the continuous three-dimensional model through visual programming (**b**). Within the modeler, it is possible to use the same information in table form (**c**) while maintaining the ease of modification of the original platform. The codes (red) assigned to the wall elements are visible in the relative images (green) (see Figure 10).

It is starting from the simplified model of the actual state that the HBIM process—analysis, critical interpretation, synthesis, construction, and information—is interrupted, and the classic BIM process can instead take place, which involves a whole series of design actions on the existing building aimed at a future time (Figure 9).

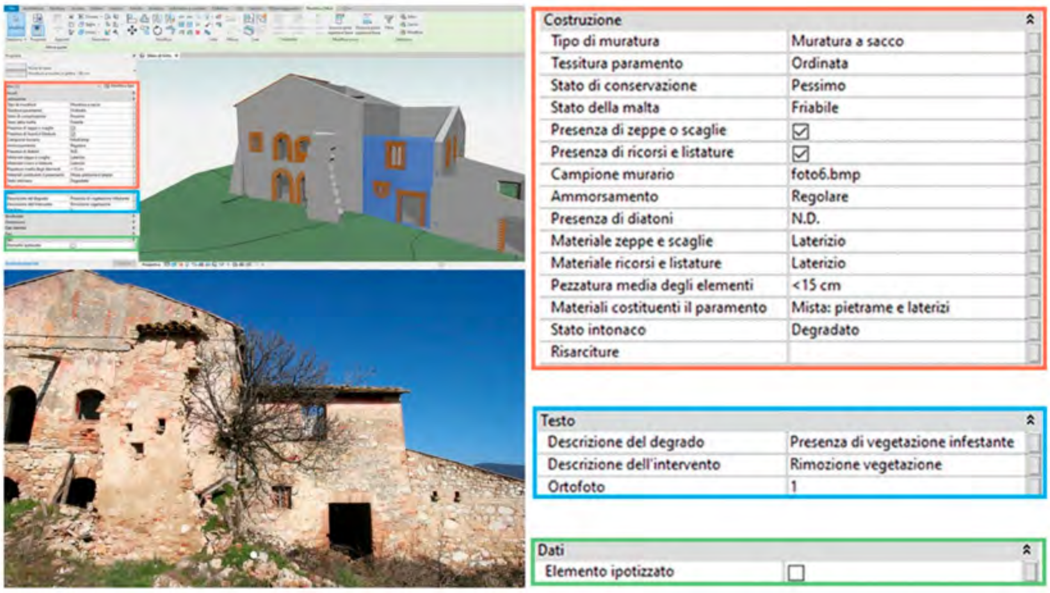



**Figure 8.** Visualization in the continuous model of a building element and its properties. Through the creation of textual parameters linked to the information with VPL, it is possible to characterize the three-dimensional elements both in terms of the actual state and with design responses to the declaration of decay. Furthermore, through on/off parameters, it is possible to declare the real or hypothetical nature of the element itself (see Figure 9).

As regards documentation and communication of the current state, it is known that BIM software manages the material aspects of the elements as constant parameters of the same (with textures) or, at most, simple stitching operations are allowed. The latter option is not to be taken into consideration for models constructed using a simplified way, as there would be no correspondence between image and surface. For buildings such as the one under study that, due to alterations over time, has different stratigraphies (sack walls, solid brick masonry, mixed stones, etc.) and different wall finishes, it seems almost impossible to manage the most superficial aspects of elements "in the manner of BIM". The modeling of the surviving plasters and the representation of the deterioration on the various elements would force the model to free itself from the optimization and simplification process described so far in favor of complicated ad hoc modeling solutions.

However, as has been said, geometries that present very complex shapes and material aspects make the photogrammetric acquisition procedure generate particularly effective numerical models; from these, it is possible to extrapolate orthophotos that, once connected to the model directly in the application or via links, can be used as a basis for thematic mappings. The image itself can become a parameter of an element, and in the same way other parameters, codes and marks can be assigned to the image. In this way, a two-way mechanism is triggered between the 3D model and 2D/1D information (graphic/alphanumeric) capable of relating geometries, images, and textual abacuses in a single database (Figure 10).

Finally, if the survey model has been used to extract selected information useful for structuring the BIM model, it is ultimately appropriate to evaluate the point cloud deviation with the continuous model. The difference between the two digital models is not only an indication of the BIM model accuracy, but it also provides food for thought in relation to the transformations that the geometries have had over time, suggesting, for example, static–structural reflections relating to kinematics that are still active (Figure 11).

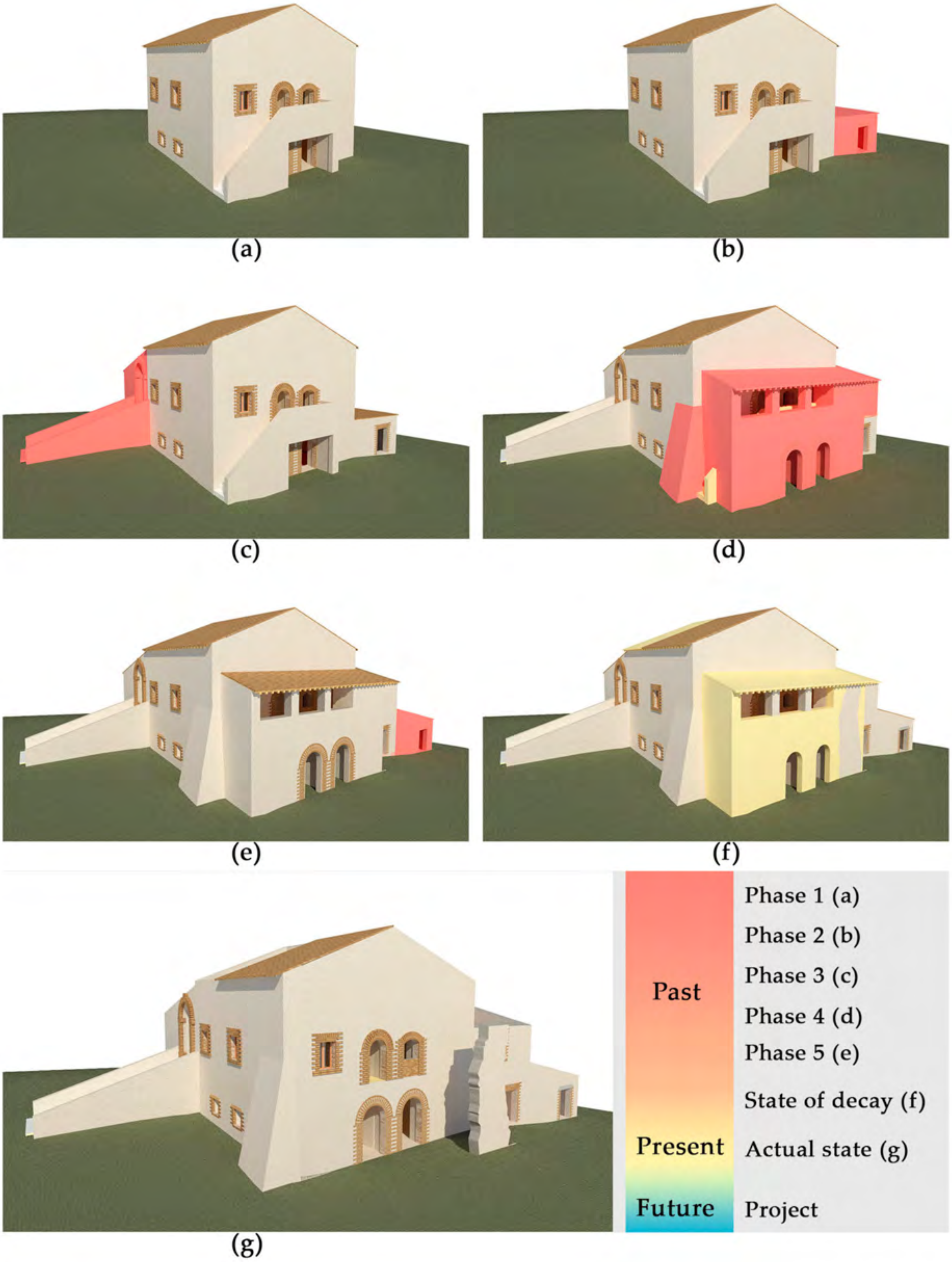



**Figure 9.** The historical evolution of the building is made explicit through the overwriting of the temporal phases of the model; each subsequent phase keeps a memory of the previous state and highlights the change. (**a**–**e**) Evolutionary phases of the building over time, and (**f**) representation of the hypothesized parts that, through on/off filter parameters, allow to visualize the actual state (**g**). (**g**) It is starting from the latter model that the designer, in a future time phase, proposes design solutions aimed at restoring the building.

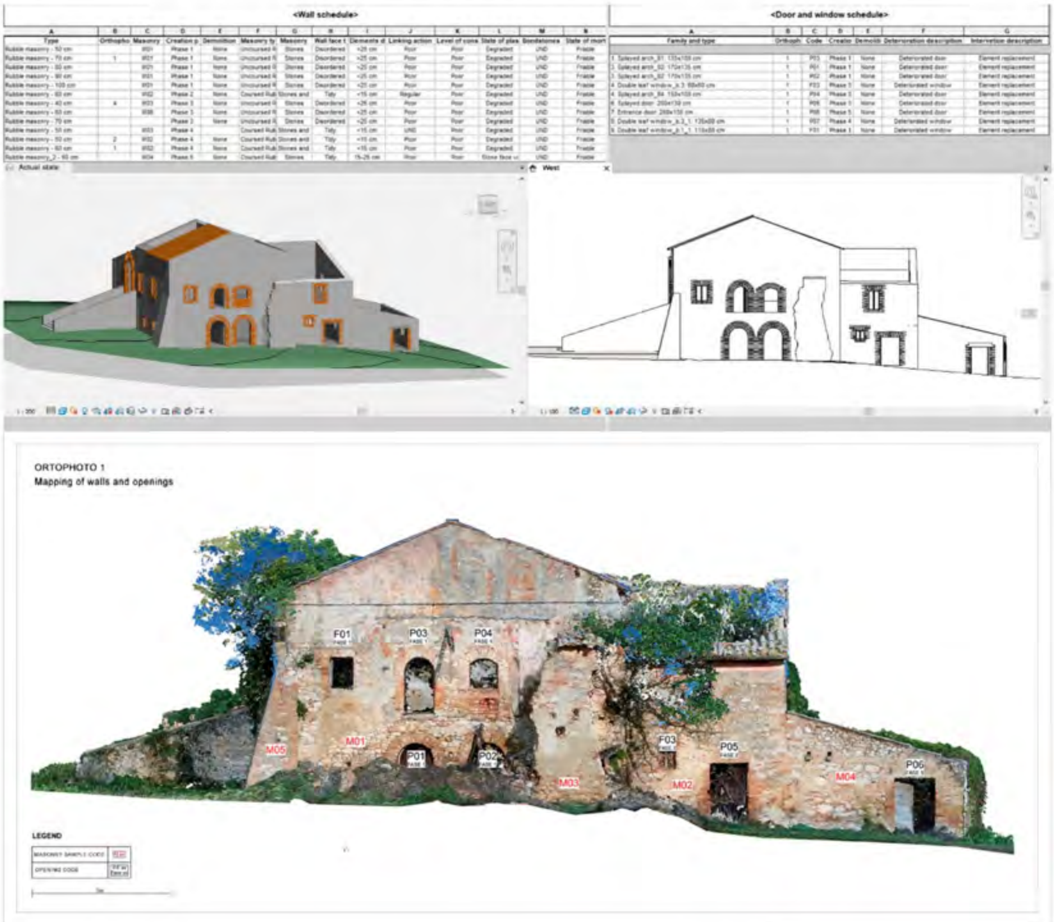



**Figure 10.** Views from BIM Revit software in which it is possible to note the interdisciplinary approach between descriptive alphanumeric data, three-dimensional geometric data in various configurations, and two-dimensional orthophotographic data. The data are interrelated, and the same information can be found in each configuration. The codes and images are one-to-one parameters (see Figure 7).

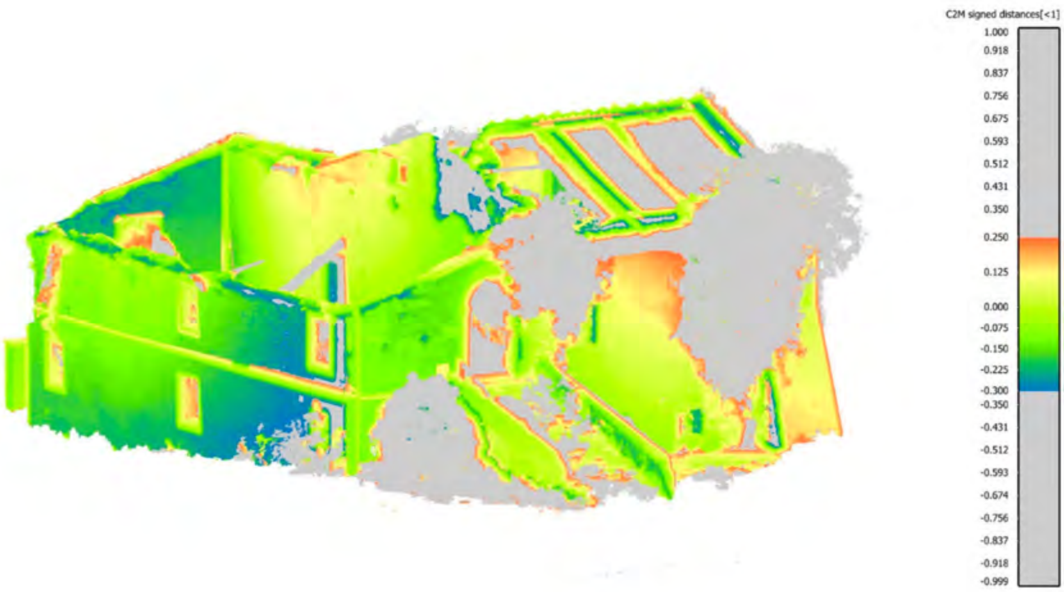



**Figure 11.** Calculation of the deviation between the ideal continuous BIM model and the numerical model obtained from the survey; values are expressed in meters.

## 4. Discussion

The application of HBIM processes on buildings that are in a particular state of ruin raises a series of questions both in terms of method and content. First of all, the usefulness of integrated digital survey methods (terrestrial laser scanner and photogrammetry) is evident when accessibility and safety are in many cases strongly conditioned.

Furthermore, since it is a historical building with typological and/or constructive characteristics to be safeguarded, the implementation of investigations on the construction elements through associations and comparisons with historical documentary sources and manuals—aspect that characterize the HBIM processes—represents another significant element, as demonstrated by the experimentation carried out on the case study. On the other hand, the major criticalities in these particular cases concern the correlations between the different representative models of the architectural object in relation to its stratifications by the addition and/or replacement of parts but, above all, in the relationship between presence and absence, between what is visible—often in precarious conditions close to collapse—and what is no longer visible. The modeling of absence therefore becomes a particular moment in the processes of knowledge of these artefacts when choices are imposed that, in the absence of documentary sources, in some cases, allow to reconstruct the form by analogy or by deduction, while, in others, they only presuppose the hypotheses. The research experimentation has focused on these last aspects with scenarios still to be investigated in part and evaluated both in terms of effectiveness and validation of the procedures. It is also considered useful for the purposes of a necessary interdisciplinary comparison to propose to the attention of the scientific community some initial critical reflections according to a consolidated experimental logic of a deductive type.

The modeling for digital BIM objects of an existing architectural artifact must necessarily deal with a process of geometric simplification of real forms. This occurs to the extent that the frenetic search for a perfect correspondence of the mathematical model to the actual state, the point cloud, does not affect the effectiveness of the modeling process itself. Too many times, it happens to see apparently identical objects modeled in the BIM environment, with the same structure, materials, and partitions, designed on the basis of the same compositional principle but afferent within the modeler to different types of objects; it is desirable not to have those few millimeters that differentiate them millimeters that are linked not to a design intention but certainly to the artisan process of laying the elements themselves. This happens because the digital acquisition techniques are now so advanced as to elaborate a practically perfect cast of the actual state and, having a huge amount of data with such a high level of detail, can make it difficult for the operator abstracting from a single detail to insert it into an overall reading of the building and, consequently, to insert it into the process of subjectivity knowledge that is typical of a critical interpretation.

Therefore, the main questions are: Does it make sense to declare that there are different types of the same element just because “the cloud states so”? Even more, does it make sense to use a parametric tool, which was created to optimize processes, to build uniqueness, even if there is none? Finally, if it is a certain fact that the measurement of the deviation is the only scientific way to declare the accuracy of a mathematical model, it is equally true that the mathematical model that comes closest to the cloud, and is therefore composed of uniqueness, is more valid than one that deviates further from it but can parametrically communicate the history and design intentions of the building?

It must be taken into account that, for a building in a state of ruin, the geometric simplification of some elements that have lost their original form due to decay or instability can be even more marked and evident than in other historic buildings, especially when dealing with the theme of absence: the reconstruction of a missing component is based on a deductive process; consequently, a simplified form is consistent with a hypothetical and ideal nature. For such buildings, simplification in the modeling process can take on an even deeper meaning; as mentioned, these are buildings of poor architectural value that do not need to be preserved in the state in which they are found; far from it. The project for the recovery of these buildings must, in any case, include actions to consolidate and restore the original static properties of the elements. Therefore, the geometric simplification in the ruin BIM model not only facilitates the construction process of the model itself but can also become a pre-project action.

Granted these geometric exceptions, the approach to modeling such a building in a parametric mathematical digital environment remains an extremely difficult fact, because the geometries are the product of the research and studies conducted. The representative model of the current state is not, as mentioned, a mere tracing of the survey model but a synthesis of events that occurred over time derived from the bibliographic study and from the critical analysis of the survey model itself.

The preliminary knowledge phase to modeling and the management of the information load is what differentiates an HBIM from a classic BIM. In general, however, it is possible to affirm that no recovery project will ever be valid if it does not base its roots on an accurate historical study, a process that usually produces a multitude of heterogeneous information (photographic, cartographic, textual, etc.). The strategy implemented by the experimentation conducted on the Vallantica ruin was intended to safeguard the nature of the information by not entrusting it exclusively to three-dimensional modeling software in order to ensure agility in the process and autonomy for professionals. This work setting, although autonomous and sectoral, has positive implications in terms of interoperability if we consider the possibility of connecting in a semiautomatically way the various information and three-dimensional databases with each other, so that a continuous supported information flow can be established by a two-way connection. A necessary condition for interoperability is that there is no loss or distortion of data along this flow.

The use of visual languages makes the whole process totally explicit, making a great contribution to the "transparency aspect" [13]. It also allows to preserve the nature of the information while maintaining the ease of management and modification within textual software by the operators, slims the process of linking the data to the model, and does not affect the main feature of instant revision of the changes of a BIM model.

## 5. Conclusions

As already anticipated in the introduction, this experimentation does not allow to draw real conclusions but allows to highlight some specificities and problems of the HBIM according to the characteristics of the case study. Among the categories that distinguish the historical building heritage, that of buildings in a state of ruin undoubtedly presents some specificities for which the BIM approach requires some methodological and operational choices. The multidisciplinary knowledge that is the basis of any project for the recovery and enhancement of a building heritage is fed into the BIM through the model sharing that is not only the geometric so-to-speak "material" visibly tangible but that is, at the same time, also abstract, immaterial, invisible, and intangible. The peculiarity of the process lies in the ability to promote real interoperability also through the implementation of sharing algorithms through the VPL and the possibility of making the invisible visible through, for example, correlation maps between models or through conversions of numerical data in suitable graphic displays. Modeling knowledge therefore means, in a typical sense of science and technology, interpreting the phenomenon (in our case, a building) by defining a logical structure of data organization, material and immaterial, capable of facilitating, and also feeding, virtuous processes of enhancement of our huge and varied cultural heritage.

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