Alma Mater Studiorum – Università di Bologna

CHANCES.
PRACTICES, SPACES AND BUILDINGS IN CITIES' TRANSFORMATION.

Curator: Prof. Arch. Annalisa Trentin

International Conference, 24th October 2019

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The conference wanted to provide a deeper understanding of urban transformations' research and practices, focusing on the use, re-use, design, renovation and innovative governance and management of public spaces, urban commons and buildings.

The organizing committee believes that these thoughts will largely contribute to shape and increase sustainable design, construction and planning in constant cities' transformation.

The selected contributions were built on reflections and studies concerning current or historical approaches that are changing or drastically changed the cities we lived in.

The Conference has been organised by the PhD in Architecture and Design Cultures - Department of Architecture - University of Bologna

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TOWARD A NEW POINT OF VIEW: THE H-BIM PROCEDURE

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Abstract

Aim of the paper is to present a theoretical-methodological reflection on HBIM, pointed to propose a workflow. The BIM procedure deals with new buildings design, construction, and management, and it plays an increasingly important role in the AEC field. Consequently, national and international studies and standards grow: the English PAS 1192-2 of 2013, the American BIM Forum, the European 2014/24/EU, the Italian "Decreto BIM" 1/12/2017 n. 560, the UNI 11337:2017. However, the HBIM procedure is different from the BIM one, because the HBIM roots on a surveying inductive synthesis process, where the real elements and data have to be critically understood, semantized and modelled, and composed to synthesize the whole restitutive HBIM system. Therefore, the following issues become pivotal: how to define and apply the Levels of Development (loD), Levels of Geometry (LoG), and Levels of Information (LoI); how to describe and evaluate Transparency and Reliability; how to expand the database; how to use BIM commercial software that does not fully supports HBIM. For example, the HBIM model usually does not present a uniform LoD(s) – in particular LOI(s) – (but spotty ones) because it rises from a punctual knowledge. Moreover, the historical-critical information often does not relate to the digital representation of physical and functional characteristics of a single object. Finally, yet importantly, there is the problem of the definition of the LoG of HBIM objects – derived from point clouds –, in accordance to the specific modeling aims: in fact, in order to obtain a higher LoG, a different modeling procedure can be chosen, for example for comple geometrical shapes it can be used Nurbs modeling.

Keywords

HBIM, LoD, LoIN.

1. *Introduction*

Building information modelling is defined by the US National Institute of Building Sciences (2007) as a "digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward".

BIM is a process, born for the design of new buildings, which has taken on an increasingly important role in the management of the construction process in the architecture, engineering and construction (AEC) sector. The BIM model consists of parametric three-dimensional objects, semantically related to building components, enriched with a whole series of both qualitative and quantitative informative attributes, concerning architectural, structural, and plant engineering aspects.

The model becomes a virtual abstraction that ecnompasses a whole series of heterogeneous organized information, which allow the control over the entire construction process: from design, to construction, to maintenance and eventually disposal. The organization of this information content allows for greater efficiency, resulting from the management of a large amount of data and information (geometric, plant engineering, structural, economical...) within a single, interactive and Interoperable platform.

The use of BIM allows to achieve higher quality standards compared to the traditional design, which makes it possible to have, during the different stages of the construction process, additional benefits such as: the consistency of the information and homogeneity of data which allows for the reduction in errors (with consequent reduction of the variances during construction) and times, for the optimisation of resources and easier access to information for all involved.

This procedure is also unavoidable in the field of the built heritage because of many reasons: national and international legislation provides for the progressive introduction of BIM in the public procurement sector; BIM encourages careful control of the building process and procurement, allowing for more objective and administratively transparent procedures; BIM, as a whole, is a database specifically dedicated to buildings and can therefore facilitate the collection and management of information and its use for study and design purposes.

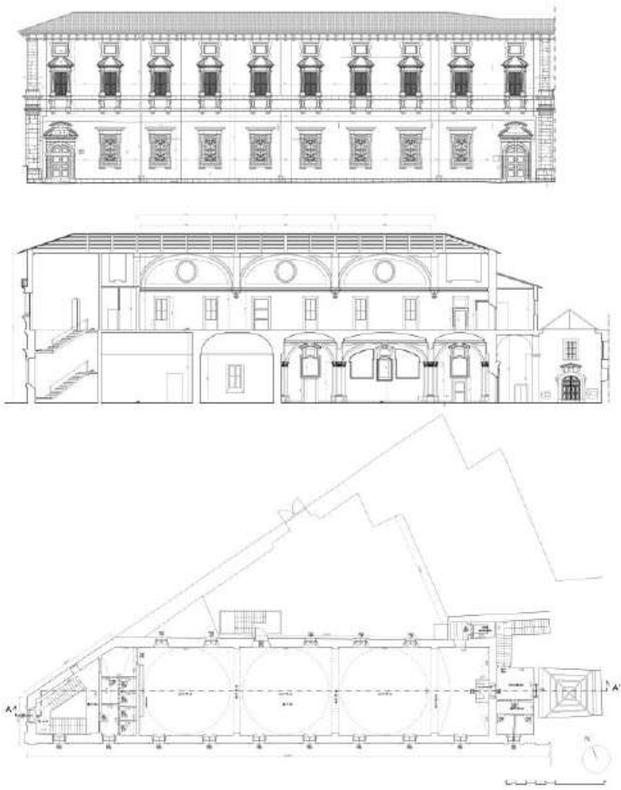

Fig. 1: Interior of convent of "San Basilio" in L'Aquila (AQ). Post sisma 2009 photography of the first floor salon.

Finally, interventions on the built heritage constitute the main economic and research commitment for the immediate future – just think of the so-called "sisma bonus", "ecobonus" Italian Government initiatives and of the legislation in support of restructuring – even in relation to the interventions on historic centers to which we are forced more and more frequently due to catastrophic natural events.

However, the HBIM procedure for historical buildings is based on a different theoretical-methodological approach compared to the well-proven BIM for new buildings, which also requires reflections on concepts of standards, on the level of developments (LoD, LoG, LoI), "reliability", "transparency", database, correlation with historical information (Brusaporci, 2017; Bianchini & Nicastro, 2018).

The aim of the paper is to highlight the different characteristics of the HBIM process as a critical process that is fundamental for an interpretive knowledge of built heritage and necessary in order to be able to develop projects of conservation, restoration, maintenance, management, enhancement (Monaco, Siconolfi, & Di Luggo, 2019).

The case study is the convent of Saint Basilio in L'Aquila (XVIII-XX Century), damaged by an earthquake in 2009 (Figure 1, 2), (CentofantI, Brusaporci, & Cerasoli, 2015).

2. *State of art*

2.1 Legislative framework

The reason for this growing interest in the BIM process is due to its undisputed potential and is evidenced by the development of several European and Italian regulations.

The United Kingdom, one of the pioneering states in this regard, was the first to set standards through a consolidated system of levels of design progress (RIBA Plan of Work) and to distinguish, for the first time, the levels of development of objects in Geometrics (Lod) and Infomative (LoI) (NBS Bim Toolkit).

It established - through the CIC BIM, BS 1192: 2007, BS 1192-4, PAS 1192-2 3, 5 and 6 protocols, and the upcoming PAS 1192-7 - standard working methods and the ex-post validation and verification procedures for the LoDs achievement required by the client in the EIR – Employer's Information Requirements – for each BIM project.

In 2014 the 2014/24/EU European Union Public Procurement Directive was published. It represents the first European Directive for the regulatory introduction of BIM for public procurement which calls on EU Member States, starting in January 2016, to "encourage, specify or impose", through dedicated legislative measures, the use of BIM as a standard of reference for all publicly funded projects and works.

Subsequently in Italy with the adoption of the "Decreto BIM" DM 1 December 2017 No. 560, the Ministry has stated the transition from a graphic sheets system to an information models system, typical of BIM. It defines also times and modalities for the introduction of electronic modeling methods and tools for construction and infrastructures. In addition, in 2017 - as an update of the UNI 11337:2009 standard, in which the concepts of BIM and digitalization of the construction sector have been setted - the UNI 11337:2017 standard was introduced and definitely approved. The latter is the first Italian technical standard on BIM; structured in ten parts some of which about to be published. It was designed to guide the digital transition, it sets the first Italian standards required for BIM projects and introduces, for the first time, BIM for restoration.

Finally, among the new BIM legislation published in December 2018, there is the international standard ISO 19650 - Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) Information management using building information modelling – of which the UNI stands as complemetary, which follows the CEN's transposition of the EN ISO 19650-1 and EN 19650-2 regulations.

The standard will consist of 5 parts of which the first two have already been published, which describe the concepts and principles for information management in a maturity stage called "Building Information Modelling (BIM) according to the ISO 19650 series". The standard applies to the entire life cycle of an asset, including strategic planning, initial design, engineering, development, preparation of documentation for assignments and construction, daily operational functioning, maintenance, renovation, repair and end of life cycle.

Fig. 2: Interior of convent of “San Basilio” in L’Aquila (AQ). Post sisma 2009 photography of the first floor salon.

One of the most significant introductions will be the proposal of the LOINs, Level of Information Need, which will replace the previous LODs - defined in Italy by UNI 11337-4:2017 - which will have to be respected by each element of the model and will be closely related to the type of use and the needs (De Gregorio, 2018; Pavan, & Mirarchi, 2019).

2.2 HBIM Procedure

The HBIM procedure is based on a different theoretical-methodological approach compared to the BIM one.

The traditional BIM procedure allows the virtual simulation - not only of geometries and spaces but also of chemical-physical properties, materials behaviors, duration... - of an entity in progress. The process starts from a project concept and develops according to successive definition steps (the Level of Development). The model is a predictive model in which, during the design process (from the project, to the construction, to maintenance and finally to the disposal) the building components that compose the digital model are enriched with information and achieve increasingly high levels of development. In this case, semantization is ex-ante (Figure 3).

The HBIM procedure, on the other hand, represents a path of critical knowledge that starts from the survey that is then subjected to a critical analysis and subsequent semantization, and finally leads to restitution through HBIM modeling. (Apollonio, Gaiani, & Zheng, 2012; Dore, & Murphy, 2015)

Therefore, in the built heritage modelling and visualization the themes of transparency and reliability are fundamental. The knowledge of the building, in fact, very often is an incomplete knowledge arising from direct and indirect non-homogeneous sources, for which, it is appropriate to declare, for each element, in addition to the type of source used for the information, the level of interpretation of that information (Brusaporci, Maiezza, & Tata, 2019a).

UNI 11337: 2017 is the first legislation to state a specific LoD for restoration. In fact, it provides for the LoD G, intended as virtualization of the update of the so-called As-Built (current status virtualization) to which corresponds, instead, the LoD F. These LoDs provide for a level of development to the highest degree of definition since this formulation derived from a simplistic transfer of the BIM procedure to the historical buildings.

In reality, however, this validity is fully theoretical since historical buildings derive from modifications and stratifications that occurred over time and that testify to the constructive cultures that have occurred over the centuries. From an information point of view, therefore, the HBIM model is based on a punctual knowledge, more or less in-depth and in most cases not exhaustive (Brusaporci, Maiezza, & Tata, 2018; Scandurra et al., 2017).

There is a difficulty in establishing an appropriate Level of Development LoD to be achieved within the model, since with historical buildings not all information is available and, while some (physical) can be investigated through diagnostics and surveys, others (e.g. historical ones) may simply be absent because they are not documented or got lost over the years. Therefore, usually LoDs are not uniform, they are spotty with different levels according to the available information for the building element.

Moreover, BIM software and platforms does not fully support the HBIM procedure. In particular, the study of a historical building for a proper understanding includes a large amount of heterogeneous data which, to be included in an HBIM model, requires an expansion of the database (Brusaporci, Maiezza, & Tata, 2019b).

Undoubtedly, to include the field of historical studies in the database can raise questions of not simple solution, that refer to the cultural dimensions of the tangible and the intangible.

A new historical information level "LoH-level of history" can be then introduced, in addition to the level of geometry LoG and the level of information LoI, in which all the information non directly related to the physicality of the individual digital element can be inserted, for whose definition could help the well-known reflection of Spagnesi (1984) on the field of the "history of architecture", understood as knowledge of "physical space built by man, that is to say of current reality" (p.7), thus the actions and transformations that have led to the current reality (historical sections), both in terms of spatial and material configuration (Figure 3, 4).

Relating to the considerations and the differences between the HBIM and the BIM procedure, a change of perspective is considered necessary, in the knowledge that the BIM procedure is not fully applicable to historical buildings and that, in order to be adapted and supported, a different methodological approach is required.

Only in this way it will be possible to define useful guidelines for the realization of an HBIM model useful for documentation, knowledge but also maintenance, management, conservation, restoration and enhancement of the architectural heritage (Di Luggo, & Scandurra, 2016; Brusaporci et al., 2019; Monaco, Siconolfi, & Di Luggo, 2019;).

3. Level of Development

The UNI 11337: 2017 standard defines the level of development (LoD) as a measure of the "nature, quantity, quality and stability of the data and information" associated with each digital element that composes the model.

The transition from one LoD to another involves an increase in both the quantity of attributes held by a BIM object and their quality, understood in the sense of granularity, reliability and data consolidation (Pavan, Mirarchi, & Giani, 2017).

Fig. 3: Render of the façade of convent of “San Basilio”.

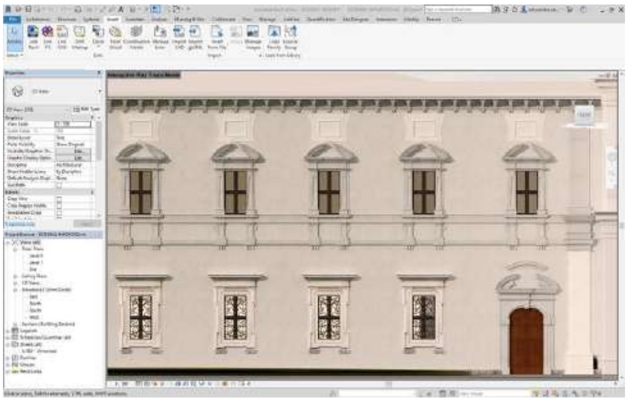

Fig. 4: Screenshot of the BIM model.

The levels of development of digital objects, although very similar to LoD USA, do not use the numerical scale in hundreds but follow an alphabetical one, which goes from the letter A (symbolic object) to the letter G (updated object). Furthermore, in the UNI it is allowed to use eventual intermediate classes of LOD, defined in the Information Specifications and identified with the lower reference letter and a whole number between 1 and 9.

According to the English system (PAS 1192-2 of 2013) and American one (BIMForum), the LoDs are defined on the basis of the levels of development of both the graphic attributes (objects level of development - geometric attributes (LoG)) and the non-graphical ones (level of object development – information attributes (LoI)).

Both LoG and LoI levels refer to aspects of the digital object representing the architectural element that, to a certain extent, can be considered quantifiable and evaluable: for example, the dimensions or the material or, again, the cost of the component. They are information regarding the physical characteristics of the architectural element, or necessary for the management of the project and the construction site.

These aspects also clearly affect the architectural components of historic buildings, but they do not exhaust the field of interest which, in the case of heritage, also includes all the historical information relating to the modifications and transformations undergone by the building and which led it to acquire the current configuration.

The UNI considers the LoD as an attribute of the single element, allowing, therefore, also LoD diversified within the overall model. However, a substantial difference should be highlighted between the BIM process and the HBIM one: if in the first, the difference between the LoDs is linked to the design phase, at the end of which there will be uniformity, the same cannot be said for the HBIM processes for the patrimony, for which, even at the conclusion of the cognitive process, it is very likely to have different LoDs due to the lack of homogeneity of the available information.

The reliability of the digital representation of an architectural asset is not unique to the entire model, which may include architectural components characterized by a profoundly inhomogeneous level of knowledge, but rather refers to the individual semantic elements.

The model’s reliability must involve both geometric and informative aspects. While, in the traditional modelling, the geometric reliability is considered as an ex-post verification of the model's accuracy in terms of deviation between point cloud and model; in the HBIM process beyond the geometric reliability, there is also the reliability delle information which, along with their transparency, is declarable a priori by the surveyor.

The informative reliability, therefore, can be defined by the modeler himself through the evaluation of the sources that can be direct or indirect.

The LoG of an architectural component, declared a priori, will influence the modeling procedure, which in the case of more complex geometric forms, may require the help of NURBS (Brumana et al., 2018). In the same way, a more advanced LoI may require a more in-depth analysis of some aspects of the architectural element such as, for example, the definition of the exact stratigraphy of a wall through diagnostics (Figure 5).

4. *Level of Geometry*

The traditional process of architectural survey is based on a succession of phases - the survey project, the taking measurements, the restitution - based on the preliminary study of the asset, in order to define the significant geometric-architectural elements, through a conceptual discretization of the physical continuum (Docci, Maestri, 2009).

Fig. 5: Photographies of the damaged vault extrados details. (Post-earthquake 2009)

Digital survey technologies have led to a partial - but above all conceptual - reversal of the process, where the scan anticipates the critical interpretative phase, delegated in post-processing (Bianchini, 2014; Gaiani, 2012). It is in this last phase, in fact, that the point cloud is critically analyzed, so as to identify the architectural components of the building and their geometric matrix.

The Level of Geometry, understood as "a constituent part of the LODs, together with the LOGs, referring to geometric attributes" (UNI 11337-4, p.3), is closely related to the survey process. In particular, the use of digital technologies means that the modeling procedures are based on the use of the generatrix and directrix obtained by sectioning the point cloud. These profiles, through operations of extrusion, revolution and subtraction, go to constitute the architectural forms of the various elements which, through a semantic modeling, are realized directly within families recognized in their architectural value.

Furthermore, the use of parameters and constraint relationships allows the parameterization of the generatrix and directrix, favoring the reuse of these architectural components for similar cases.

In this context, the computational design is particularly interesting for the parametric management of complex geometric forms through the use of generative algorithms, reducing both the difficulties and the timing of the modeling.

In this sense, the theme of geometric reliability of the model is of interest, understood as the relationship between the real object and its three-dimensional representation, i.e. as the deviation between the point cloud and the digital surface, resulting from the interpretative process operated on the basis of the survey (Figure 6).

The deviation can be evaluated on the generating elements of the architectural form, or on the entire surface, including also the interpolated part.

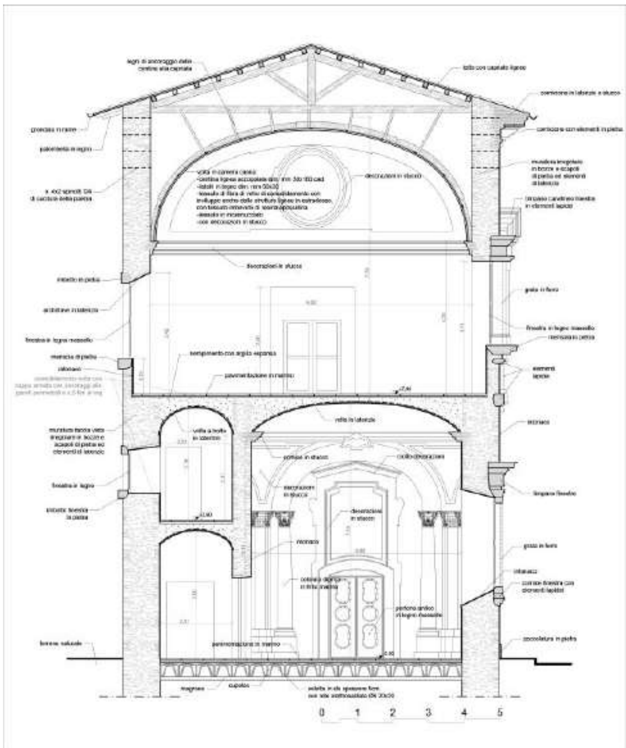

Fig. 6: Section of the construction equipment.

5. *Level of Information and Level of History*

Alongside the LoG, the Level of Development of the objects is also composed of the level of development related to information attributes (LoI), i.e. all the non-geometric attributes that characterize the representation of an architectural element.

This information includes all those aspects relating to the physicality of the component (material, mechanical properties, etc.) or that are necessary for the design and management of the construction site (costs, structural value, etc.).

These are parameters already contemplated within the BIM platforms that, developed specifically for new buildings, already include, in the database connected to the three-dimensional representation, the fields for entering the corresponding information (Figure 7).

The reliability of these contents is related to the evaluation of the sources used. The concept of Transparency is fundamental, concerning the declaration of sources and the possibility of reconstructing the critical process, operated on their basis, which led to the realization of the interpretative model (London Charther, 2009; Principles of Sevilla, 2012).

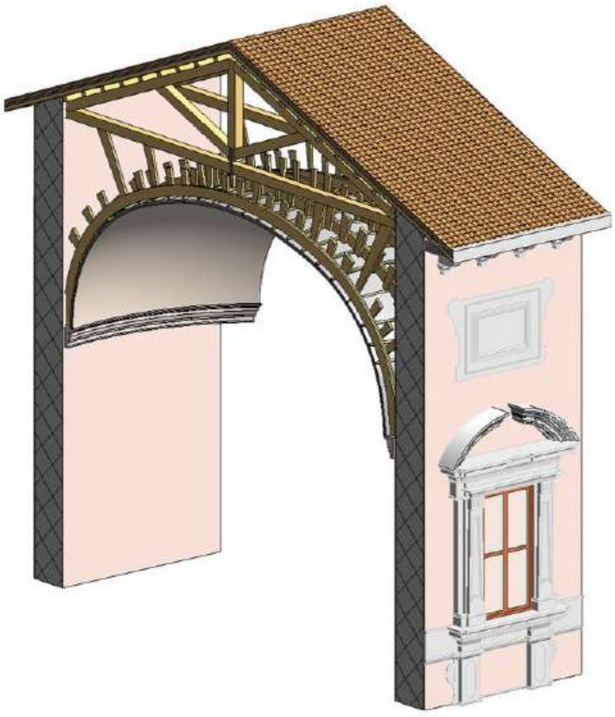

Fig. 7: Screenshot of the BIM model

The theme of transparency concerns all the contents of the model, from the geometric ones to those included within the LoI, up to those of historical nature, not contemplated in the current BIM processes (Figure 8).

Since the representation of the architectural heritage requires the management of information that are not considered in the well-established BIM procedures for the new, it is useful to introduce a new Information level, concerning historical knowledge: the Level of History (LoH).

With reference to the definitions offered by the legislation for the LoD, LoG and LoI, the LoH can be understood as *a constituent part of the LoD, together with the LoG and LoI, referred to historical information attributes*. However, the LoH differs from the LoI because it includes all those historical information relating to the tangible aspects of the architectural asset that in itself are not computable, namely all those aspects that have contributed to the formation of current configuration of the element, such as historical phases.

As this field appears to be in principle immeasurable and difficult to circumscribe, LoH is understood to be constituted primarily by archival and bibliographic references, but also by information relating to the physical transformations of the asset (historical sections). The information related to the LoH are additional to those currently manageable in a BIM environment, therefore they must be merged into an external database, an expansion of the one consisting of the same BIM model, where it is possible to archive and manage historical photos, archive documents, etc. In order to delimit the field of such information, the already cited Spagnesi dissertation on the "autonomy of the history of architecture" is assumed as a methodological reference with respect to the more general "history": "[...] the History of architecture can only be the knowledge of the physical space built by man, that is to say of the actual reality. [...] we can only analyze the occurrence of the essential reasons that produced it in a temporal succession "(Spagnesi, 1984, 7).

Also in the case of LoH it is possible to use the concept of "level", because this information can be more or less exhaustive. The historic information of the current state of the building/element can be grouped within fields such as: epochs, authors, construction site and techniques. For each field there may be more than one piece of information, it depends on the number of events that led the building to its current state, on how many of these events have been documented and if these documents are available and existing today. Three levels of LoH historical knowledge can be assumed: the high level corresponding to an exhaustive historical knowledge, the intermediate level to a partial knowledge and the low level to an absence of knowledge. These levels are related to the information of the model element; the model's reliability, instead, is related to its information content (the data, intended as documents inserted in the external database). An evaluation of the sources should be done and there can be three levels of reliability: high reliability level in the case of a modelling based on the use of direct sources; medium reliability level for the use of primary but not exhaustive sources; low reliability level for the exclusive use of indirect sources (Maiezza, 2019).

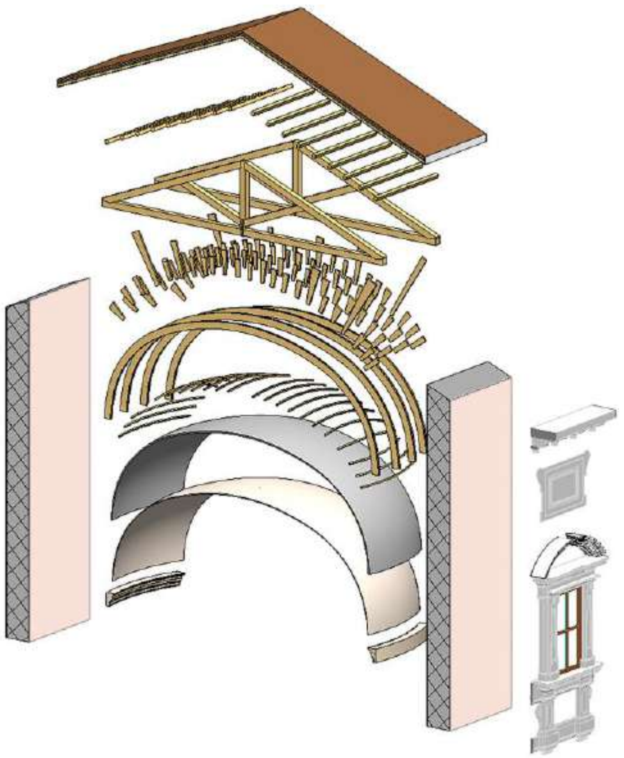

Fig. 8: Screenshot of the BIM model.

6. Conclusions: from knowledge to design

The degree of informational evolution of a digital object is defined through LoDs. Contrary to what happens in the traditional approach, in which the level of detail of object representation changes as the representation scale changes, the level of developments depends on the purposes of the model and are not related to the entire model but to the objects that make up the model.

For a more efficient use of the HBIM methodology, intended as a path to critical knowledge of the building, an expansion of the database is necessary to insert all information not strictly related to specific model elements, in particular the historical ones. For this information, it may be useful to introduce a new level of development LoH which, together with the LoGs and the LoIs, would contribute to a more accurate definition of the LoDs for the historical building.

The HBIM procedure, different from the BIM procedure, focuses on a critical surveying inductive synthesis process in which the knowledge of the asset is a punctual and spotty knowledge that doesn't stop at the mere survey and documentation of the current state, but which continues and is deepened on site during the restoration works and which can therefore be useful for monitoring and scheduled maintenance.

In this regard, the introduction, by the new ISO 19650, of LOINs could help overcome some of the limits deriving from the extension of the BIM procedure to historic buildings. In fact, especially for historical buildings, instead of trying to reach and fulfil specific classified and established LoDs for new constructions, it is possible to establish a priori, based on the model's purposes, which information is necessary - and therefore, in case of absence, investigable - and which ones are available - for example the historical ones deriving from archival and bibliographic research - and establish, a priori, the level of reliability of such information.

The concepts of transparency and reliability of the digital representation are therefore fundamental, which, like the LoINs, must be referred to the individual semantic elements. Therefore, the LoIN increasing goes in parallel with the more detailed development of the object (both from a geometrical and informative point of view) and the higher accuracy and reliability of the data.

Finally, new LoINs specified a priori depending on the needs and aims of the model, along with the issues of both model and administrative transparency become key issues when it comes to public procurement. In fact, the BIM integrated with the management of public tenders allows an optimization and a speeding up of the procedure. The realization of a single parametric model guarantees a coherence and homogeneity of the information reducing the problems deriving from their inconstistency. (Di Giuda G. M., Villa V., Loreti L., 2015). The use of the BIM methodology for the management of public tenders can benefit the entire procurement process: from the drafting of the call, to the verification and evaluation of the offers, in terms of achievable quality, time and costs reduction, competition and transparency in the assignment

(Ciribini, Bolpagni, & Oliveri, 2015; Ermolli, & De Toro,2017).

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