

bSDD TO DOCUMENT STATE OF PRESERVATION OF ARCHITECTURAL HERITAGE IN OPEN-HBIM SYSTEMS

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ABSTRACT:

This research explores the possibility of structuring an OpenBIM process useful to work in the BIM ecosystem also for cultural heritage and historical architecture, independent of any specific software and overcoming the difficulties arising from the unique characteristics of these artefacts. The main focus of this work is the use of bSDD as a methodology to add specific information on state of preservation of surfaces and materials directly to BIM models, making it shareable and readable in any IFC viewer.

The complexity of historical architecture and the importance of information about its conservation status, puts higher requirements on the level of development of (H)BIM models and its possibility to realize a better interoperability among multiple disciplines and different software solution.

To date, there is still no single, recognised, and accepted solution that allows information on the state of preservation of historical artefacts to be documented in BIM according to shared and open workflows. In this respect, the research proposes an ordered organisation - with the use of bSDD - of all decay information present in thesauri, vocabularies, ontologies and official regulations, making it possible to use it according to a predefined process.

The testing operation used as a case study Villa Matarazzo, a historic house located in Ercolano (Naples, Italy).

1. INTRODUCTION

The implementation of openBIM standards for cultural heritage is a topic of considerable importance because the number of requests to work in BIM is constantly increasing, especially in public procurement. Public administrations that are responsible for preserving existing buildings of historical interest need to standardise databases to better manage their architectural heritage. Consequently, if documentation methods and properties are organised in an unambiguous way, interventions on existing buildings become easier to control and validate.

The application of openBIM to architectural heritage [Logothetis & Stylianidis, 2016; Diara & Rinaudo, 2018; Bosma, et al., 2016] presents known complexities because it is difficult to circumscribe geometries to a few parameters or relate knowledge to unambiguous standard concepts. Historical buildings must be the subject of systematic readings in order to identify an information system based on ontologically defined elements that can be associated with data documenting their material, historical and structural peculiarities. H-BIM therefore - or more generally E-BIM, understood as the application of BIM to existing buildings - requires the identification of procedures capable of translating the complexity of reality, without losing the specificity and uniqueness of the individual case.

An important factor in understanding existing architecture concerns the state of preservation at a given time. In fact, there is an increasing amount of research [Lanzara, et al., 2022; Tomalini A. & Giovannini, E. C., 2020] interested in studying the most effective methods to recognise, prevent and analyse pathologies that may affect building elements and building materials. The term pathology is used here to define the causes of alterations and decay of architectural surfaces.

An exact understanding of the pathological situation is indispensable in order to plan or execute project interventions aimed at safeguarding the building - or parts of it - affected by a

problem. This can be done by analysing the signs and symptoms (internal factors) caused by the pathology and monitoring the condition of all factors that can make buildings fragile (external factors).

The operational complexity associated with the process of mapping and signifying decay and alteration phenomena hinders the identification of automatic procedures capable of uniquely documenting these features in BIM systems. This is even more true about the numerous informative variables that each pathology and each symptom may have. It is therefore important to experiment with solutions that can standardise the process for documenting the state of preservation of architectural artefacts in BIM systems, in order to determine a single approach that can be shared by the various users working in the building industry.

2. OPEN BIM AND STANDARDISATION OF PROCESSES

Standard and open formats make it possible to control the correct compilation of data because they respect a predefined organisation that follows shared hierarchies and logic, without these being managed by a single provider.

For BIM, the ISO standard 16739:2013 defines that the international standard format useful to exchange information in an open way is the IFC standard (Industry Foundation Classes). It is a neutral data format designed for information exchange concerning engineering, architecture, and construction, developed by bSI - buildingSMART (International Alliance for Interoperability - IAI), an international body committed to creating and disseminating common and open data standards [www.buildingsmart.org]. In IFC, a series of entities (building elements, geometric elements, basic constructs) are related to each other and hierarchised according to an object-based logic. Thus, the type/presence of the object, the established relationship and the constitutive properties define each entity.

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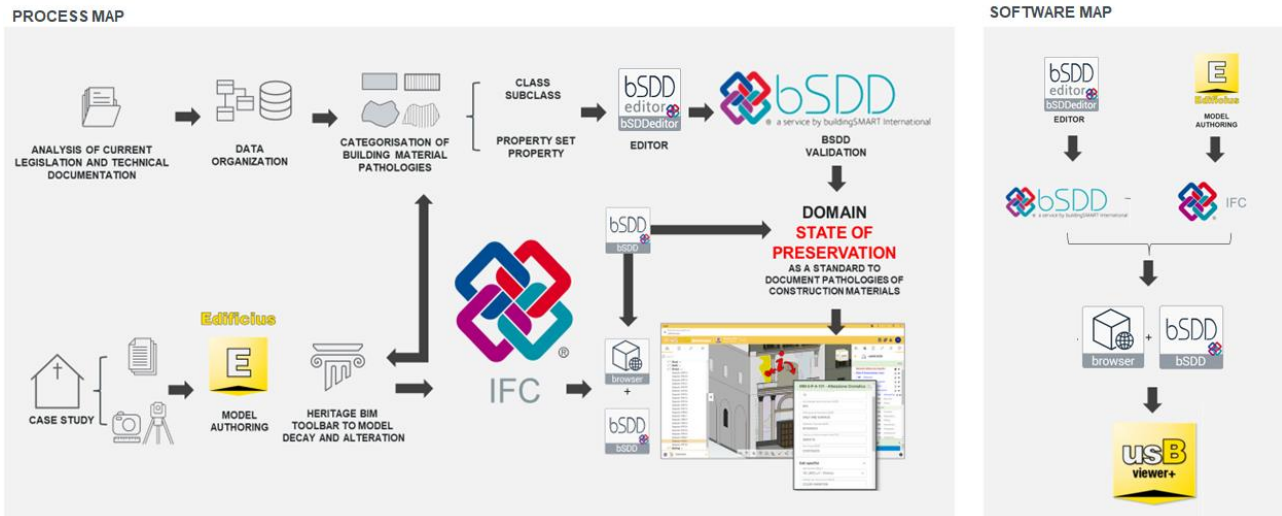


Figure 1. Process map and map of software used.

This data model, however, does not take into account all heritage needs, continually forcing operators to customise requests for information with reference to situations that are exceptions. This poses a sharing problem as customisation often depends on the subjective choices of the individual user and the platform chosen to compile the data. Therefore, a lot of information is lost or misinterpreted in the transfer phases.

In this regard, it is important to specify that the BSI standard also has a common property definition dictionary recognised as bSDD, which, in addition to national classification systems (Uniclass, Minnd, etc.) and application-specific standards (ETIM, UniversalTypes, IfcAirport, etc.), allows existing standards to be supplemented with project- or company-specific or national standards, supplementing them according to precise needs.

The bSDD is therefore a library of object concepts and attributes, related to the construction world, based on the IFD standard (ISO 12006-3), offered by bSI as an online service hosting a collection of domains, each consisting of terms, classification, material and property.

In other words, the bSDD provides the terms and their meanings, this for everything related to construction, acting as a semantic mapping tool [Majcher, 2020]. In this sense, it overcomes the obstacles of subjectivity or different world languages or software, because it recognises translations and synonyms (e.g. different words - same concept) and knows that different concepts can be expressed with the same terms (homonymy). Everything is recognised uniquely through an inseparable link between signified and signifier. Moreover, each entity has its own personal and invariable ID, which avoids the mixing of concepts: it is a GUID - Global Unique Identifier [McPartland, 2017].

Domains can be created for specific situations, can provide meaning to BIM models and can be accessed by BIM-authoring and Common Data Environment (CDE).

In particular, bSDD can create a domain ontology because it can establish multiple relationships between terms, with properties or with other standards.

ID	Nome	Proprietà
111_PSU	UST	Tecnico
111_MRF	MRF	Tecnico
111_MCC	MCC	Dati specifici
111_MCD	MCD	Dati specifici
111_EMA	EMA	Dati specifici
111_ADE	ADE	Dati specifici
111_CUS	CUS	Dati di insieme
111_EMN	EMN	Dati di insieme
111_IDR	IDR	Dati ambientali
111_CLM	CLM	Dati ambientali
111_IP	IP	Valutazione critica

- 1) Create a new bSDD document
- 2) Name the domain and add all the general data
- 3) Add a classification and all the relative information (Synonyms, country data, relations...)
- 4) Add specific properties with all the information required
- 5) Upload the json to the bSDD online service

Figure 2. Steps to create "state of preservation" domain with usBIM.bSDD tool (ACCA software).

3. bSDD FOR HBIM: TOOLS AND PROCEDURES

The management of existing structures is a topic of great importance and the subject of much research. For the most valuable architectural structures, studies aim to identify processes to guarantee safety and optimise interventions before a major damaging phenomenon occurs. The characteristics of the different studies summarise the methodologies in two possible ways, namely those that seek means to prevent damage from deteriorating and those that seek methodologies to manage the interventions to be made on already damaged artefacts.

All these processes have traditionally been carried out without the use of digital tools, or where their use is limited to single, unrelated activities. However, by encouraging collaboration between the different actors involved in a project, the digital revolution of recent years aims to identify alternative ways of working, exploiting the ways in which Building Information Modelling (BIM) can help. This is particularly in relation to the processes used in the assessment and/or management of deterioration.

Many studies propose the detection and visual identification of areas affected by decay, basing their approach on the geometries to be mapped on the architectural element in digital twins. Some find solutions for manual modelling of degraded areas and others for automated modelling with the support of point clouds or photographs [Tomalini & Giovannini, 2020; Lo Turco, et al., 2017]. In both cases, however, the work performed goes against the existing Industry Foundation Class (IFC) schema because the digital object modelled is always something generic and excluded from the entities recognised by the standard, thus remaining meaningless [Parisi, P., et al., 2019].

Other studies make available applications for scheduling maintenance interventions over time, integrating different skills [Castellano-Román & Pinto-Puerto, 2019].

As data sharing and exchange needs are expanding, data interoperability between different software tools involved cannot be limited to direct point-to-point conversions.

Common Data Environments (CDEs), structured datasets and the use of naming conventions would offer a significant advantage to asset management.

Taking advantage of new digital standards and the growing use of increasingly high-performance tools in the digitisation of the construction sector, this research proposes to define optimised procedures for the management of degradation data. The standards and characteristics recognised on a national and international scale [UNI 1182:2006; ICOMOS, 2008] have thus been identified, which it is hoped will be the subject of future in-

depth studies for the development of increasingly mature digital processes.

The main objective of this research is to structure a domain standard for documenting the state of preservation of existing artefacts. This is only possible by creating a shared language, developed with an openBIM perspective, that is useful to support AEC operators and facilitate public administrations or contractors in the validation of a BIM product with respect to the information content it must possess when it comes to projects, interventions and the management of existing manufacts [Oostwegel, et al., 2022].

This research considers bSDD to be the appropriate method for creating specific and shareable domains in openBIM and without proprietary constraints. In order to be sure to respect the standards of the shared languages throughout the process, the support of the usBIM.bSDD application, provided by the ACCA software house, was essential for structuring the DataDictionary.

3.1 Workflow

In this research, we are not trying to develop an all-encompassing standard for heritage; rather, we want to start a basis that can demonstrate that this is possible, because it is necessary. We have therefore focused on the degradation of surfaces.

The digital analysis of architectural artefacts in BIM is strongly based on semantics, which encodes the relationships between forms - and thus the digital representation of the building and its parts - and information data - mostly heterogeneous and pertaining to different sectors.

The implemented workflow takes this dual value into account in the definition of the identity characteristics of the model, focusing, in particular, on the possibility of providing a systematic application support for the unambiguous and shared documentation of information to support decision-making processes in maintenance interventions.

Specifically, the work team collected the indications and documentations of proven validity that constitute the main references in Italy on the subject. At the same time, it took on board the observations and technical suggestions of professionals and academics from the AEC world, in order to obtain the transposition into openBIM of the parameters useful for verifying the state of conservation of material surfaces according to procedures in line with professional practice.

ICOMOS-ISCS has produced an illustrated glossary on forms of alteration and, in Italy, the Nor.Ma.L. lexicon has been providing a guide to the degradation of stone materials since 1979. These guides, together with specialist manuals [Franceschi, et al., 2010;



Figure 3. Photogrammetric survey of the Villa Matarazzo in Ercolano, Naples (Italy).



Figure 4. Laser scanner and photogrammetric survey of the Villa Matarazzo in Herculaneum, Naples.

La Regina, 2009], show that a good organisation of the data may depend on a preliminary distinction of the materials that make up the architectural surfaces of historic buildings.

The work therefore distinguishes three types of materials: stone, metal and wood.

For each material, a distinction was made between alterations and decay: the former describe a change that has taken place in a material that, although modifying some of its characteristics, does not necessarily compromise its conservation (a typical example concerns the chromatic variation due to exposure to sunlight); the latter concern gradual processes that lead an architectural or structural element to lose its characteristics of form, resistance, reliability and durability, until it becomes unsuitable for the function for which it was originally intended.

For each decay and alteration, the properties and variables necessary to characterise the specific case under examination have been codified. These start with the identification of the general characteristics that contextualise the pathology (date of documentation, presence of previous interventions, nearby polluting sources, exposure to water sources, climate, etc.); they continue with the more exclusive properties in order to better circumscribe the specific case (size, colour, mechanism, typological specificity, morphology, etc.); conclude with an initial suggestion for intervention, i.e. offering operators the possibility of providing a preliminary estimate of the type of intervention that the symptomatology suggests. In the latter case, the critical historical value gradient relative to the relationship between the pathology and the evolutionary history of the artefact was taken into account, in consideration of the most conservative restoration theories.

All this constituted the "state of preservation" knowledge domain, formalizing, through usBIM.bSDD, the .json file of the related ontology consisting of Classes, Relationships, Properties, Restrictions and Instances (Figure 1).

The .json file was submitted to the bSDD service for structural checking.

In brief, the workflow performed consisted of the following phases:

- 3D graphic mapping of decay and alterations in a BIM model using ACCA's BIM Authoring software 'Edificius';
- export of the model in IFC format;

- in-depth study of existing prescriptions and indications concerning the documentation of the state of preservation of building materials;
- identification of typical materials of buildings of historical interest (stone materials, wood, metals);
- identification of pathologies divided into decay and alteration;
- identification of the properties and parameters required to define individual decay and alteration;
- systematisation of information into classes, subclasses, properties and property sets in usBIM.bSDD (Figure 2);
- export of the .json file and validation in bSDD;
- application of the 'Conservation Status' domain to the IFC model through the usBIM cloud and the specific tool usBIM.bSDD;
- verification of results with an IFC viewer.

4. CASE STUDY

The workflow was subsequently verified by applying it to the documentation of the Matarazzo villa, as a representative manufacture of the assets of historical interest to be known and safeguarded.

Villa Matarazzo is located in the city of Herculaneum and is part of the wider territorial system of the Vesuvian Villas although its construction is subsequent to that of most of the other villas of the area.

It was built in 1880 and underwent some extensions made in the early 1900s. The villa has four levels and a basement. The villa has a masonry structure and steel and brick slabs. It is located within a large park of about 5 hectares within which there are, in addition to the villa, a dependence, a farmhouse and a wide ornamental garden, which is rich in Mediterranean tree species. The park is crossed by a main axis which connects the villa with the city and is marked in the entrance area by two turrets, linguistically in agreement with the main building characterized by plaster stripped in alternating chromatic bands.

At present, the villa is in conditions of serious decay especially as regards infiltration phenomena, deterioration of the plaster, missing cornices and deteriorated and/or missing windows.

Currently the building is abandoned and is considered by the owner body which is the Campania Region to recover it in order



Figure 5. BIM model of Villa Matarazzo realised in Edificius by C. De Crescenzo as part of the her thesis in Architecture (tutor: prof. A. di Luggo, E. Buondonno; co-tutor: S. Scandurra, D. Palomba).

to allocate functions related to socio-cultural activities, at the service of tourism and the territory.

The knowledge process started with a terrestrial lidar survey integrated with an aerial digital photogrammetric survey (Figure 3; Figure 4). The lidar acquisition employed a Faro Focus 150 Plus laser scanner and a Faro s120 laser, focusing on the interior of the villa. The photogrammetric survey, on the other hand, employed a mavic 2 zoom drone, acquiring the surfaces of the villa's exterior elevations and the garden.

The point clouds obtained were georeferenced and oriented according to the same cartesian reference system, integrating the data into a single federated model.

The final survey data became the reference for BIM modelling. The software chosen for the BIM model is Edificius from the

software house ACCA. The choice of modelling software also depends on Edificius' focus on the issues related to BIM modelling of historical heritage (Figure 5).

It is important to remember that in traditional documentation processes, information on degradation pathologies is made explicit through their

representation in two-dimensional technical drawings created in a CAD environment with the support of orthographic images of the artefact under investigation. The graphic indications are also usually associated with data sheets, sometimes pre-filled, detailing the knowledge acquired through visual surveys or specific instrumental applications. The sheets make it possible to add information that the CAD drawing would not be able to make explicit, such as the type of mechanism, climatic conditions, the



Figure 6. IFC model in usBIM.browser: link to usBIM.bSDD to associate "State of Preservation" domain information with the model.

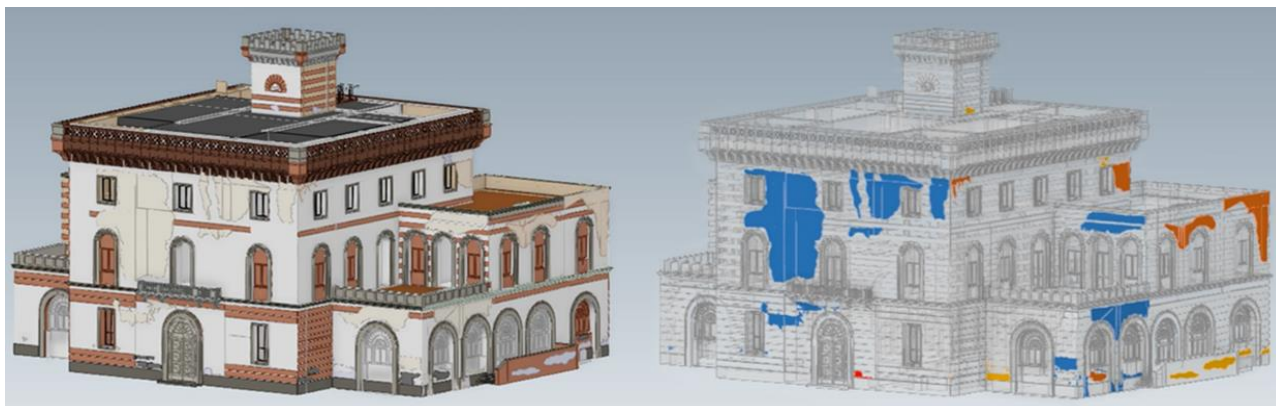


Figure 7. BIM model complete with degradation and thematic mapping with colours associated with the items in the 'State of Preservation' domain.

results of chemical analyses, data that is certainly useful, but which are totally unrelated to the representation.

Although this operative practice allows for a complete mapping of the state of conservation, knowledge of it is still linked to a few two-dimensional representations, which are not always such as to make the phenomenon understood in its entirety. In this way, in fact, the overall vision is limited to the definition of a few views, also affecting the understanding of those decay that develop on different planes.

In BIM systems, the issue of graphically documenting degradation also deserves specific attention. In fact, although there are unquestionable advantages, a rigorous and shared methodology for documenting the state of preservation has not yet been introduced.

Through a previous research carried out by the team belonging to the University of Naples Federico II in collaboration with ACCA software [Lanzara, et al., 2021], specific tools were identified to implement the BIM modelling software Edificius with specific functions for mapping alteration and decay pathologies in 3D (proxy elements) directly on the BIM model, guided by data from three-dimensional reality-based acquisitions (point clouds and orthophotos).

By overcoming the limitation of the orthophoto view, in fact, the quantification of the surface affected by a specific pathology is no longer limited to an areal zoning relative to a single point of view but, rather, is able to return the total value following the real trend of the phenomenon. The relationship established between the architectural element and the pathology, moreover, allows a greater clarification of the phenomenon with reference to the parts of the building, going beyond the mere visual representation.

Beyond Edificius (ACCA's BIM authoring software), in many BIM modelling platforms, the modelling of degradation pathologies is often only achievable through compromises, artifices and arbitrary adaptations of tools originally designed for other purposes.

In any case, even if one overcomes criticalities from a graphical point of view, there is still no homogeneity in the results in terms of information.

In Edificius, the overall point cloud was then loaded, the architectural model of the villa was created, and with the specific tool, the areas affected by alteration or decay were 'painted', redesigning them manually with the support of the three-dimensional views of the point cloud.

This step can be performed in any software, without invalidating the procedure.

The research of which this contribution is the subject was concerned with the structuring of an operational workflow aimed at identifying standard and openBIM procedures for the

informative classification of the state of preservation of artefacts, with a view to making it possible to share the information collected by the operators in a homogeneous manner, making it accessible without the risk of incurring ambiguous readings.

To this purpose, the BIM model was exported in IFC format and opened in usBIM.browser, an online service of ACCA software. usBIM.browser that allows a direct link to usBIM.bSDD. This link allows us to access bSDD and select the classification of interest: in our case, the classification of interest is a project (local) classification called "State of Preservation" (Figure 6).

In the usBIM.browser space, therefore, we see simultaneously the IFC model and the domain classes created in bSDD, with their properties and possible typologies/values.

At this time you can select IFC model entities, including proxy entities, and assign bSDD entities to them by filling in and specifying their values.

Specifically, the domain created provides for each class a set of property sets pertaining to the alteration and decay pathologies identified for each material. The property sets are divided into Environmental Data, Technical Data, Maintenance Data, Set Data, and Specific Data. Each property set connects with a set of properties and related values. For example, the property set "technical data" of the class related to "detachment" has "extent of phenomenon," "size accuracy," "spread of phenomenon," "affected material," "surface finishing technique," "morphology," etc. among the properties. Each of these properties has free values, values from predefined list, limited range of values, etc.

In usBIM.browser, each class can have its own highlight color in the model to immediately see each part that is associated with it (Figure 7).

In the case of surface condition, this also means that the color thematic visualization helps the user quickly understand the overall spread of each type of degradation present on the manifold.

All information chosen by the bSDD is automatically updated in the IFC model.

Then, saving and closing the work, the IFC model download preserves all the data input.

When we open the Matarazzo villa model in usBIM.viewer, selecting the geometric entities of interest, we find all the domain items with their values (Figure 8). In case of doubts about semantic meanings, each domain entity - and its ID - is verifiable directly in bSDD library.

All this means that all the entities necessary to document the processes of degradation of the surfaces of a historical artifact have been identified in the construction of the "state of preservation" domain and have been organized to be used by all

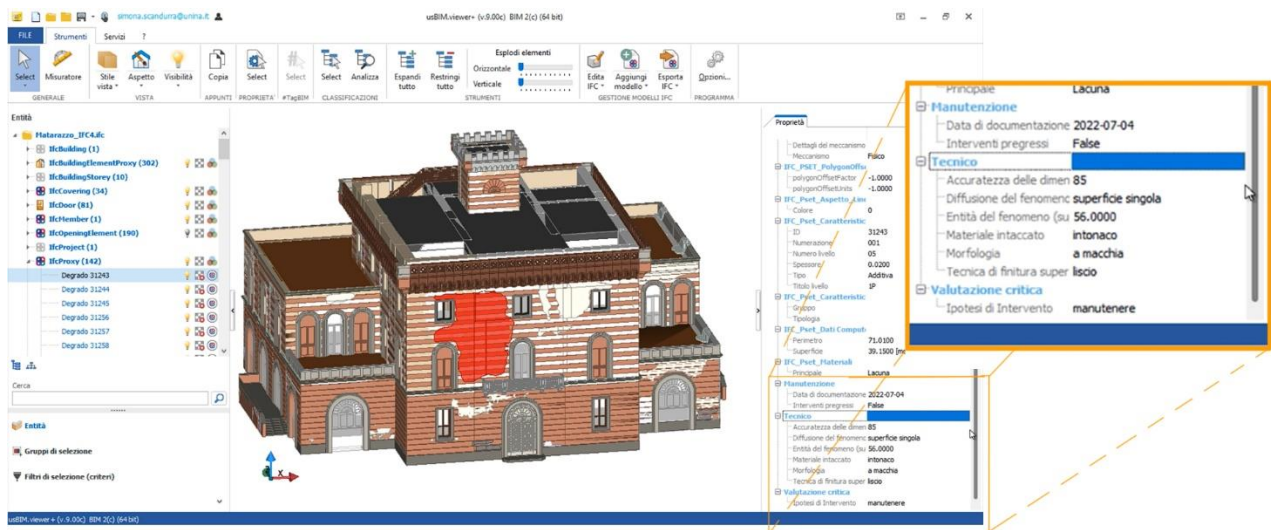


Figure 8. Locating information directly on the IFC model (usBIM.viewer - ACCA software).

according to a fixed, shared and recognizable logic. This is to ensure that:

- operators know how to organize the data collected;
- administrations/contractors know how to read the data of interest to them and how to control the data provided to them;
- the sharing of data between operators is unambiguous.

5. CONCLUSION

The workflow created for the experimentation was born in Italy out of needs strongly rooted in the national fabric, as the country is very attached to its history and the conservation of its architectural heritage. It is in fact based on the use of nomenclatures, data and definitions derived from regulations, technical recommendations and modus operandi already consolidated in Italy.

With this in mind, it was decided to define the "state of preservation" domain, codifying the various pathologies that afflict the built environment in appropriate classes, characterised by attributes that decline them in their own specificity.

By associating the information structured in this way with the elements of the IFC model (standard format for BIM), each documented pathology acquires its own meaning, increasing knowledge through the data appropriately organised in this approach.

The entire project is therefore based on openBIM standards and methodologies, using exclusively non-proprietary open formats, to guarantee an interoperable and collaborative workflow, free from technological constraints or limitations related to the use of specific software or formats, guaranteeing data quality and information consistency.

End users of the bSDD can verify the validity and conformity of the data (requested and offered), can work on their own BIM freely, implementing the necessary information and without binding other users.

Thus, a workflow is proposed within a rigorous methodology, dedicated to standardising the process of documenting data on the degradation and alterations that characterise built architectures.

The importance of the availability of a standard and the value of the cultural capital it conveys lead to an understanding of how these tools can be easily implemented also and above all in the flow of public administrations.

Moreover, information structured with precise encodings can also be interpreted by artificial intelligence, facilitating and optimising the entire control and validation process.

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