Enhancing Transparency and Reliability in HBIM: the Case Study of the Former *IX Maggio* Colony

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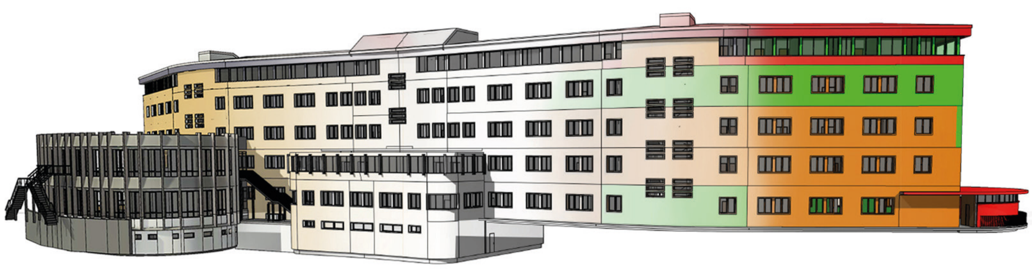
Abstract

The contribution falls within the field of architectural heritage documentation through BIM information modeling, focusing on the themes of transparency and reliability in digital representation.
By developing the case study of the former *IX Maggio* Colony for the children of the People of the Sea, designed by Ettore Rossi (1937), an operational workflow was tested to organize and manage information in a 'transparent' and 'reliable' manner. In particular, both the sources that supported the modelling and the assessment of its reliability were included in the model. Reliability, depending on the different levels of model development (low, medium, high), was introduced through specially created parameters and conditional properties applied to the filters for its visualization in a color scale. The parameterization and the information base of the BIM have therefore been exploited to obtain a digital archive, structured and 'reliable', which can be offered as a useful tool for the knowledge and documentation of the building, but also as a reliable basis for future restoration activities.

Keywords
HBIM, reliability, transparency, former IX *Maggio* Colony.



HBIM model of the former for the *IX Maggio* Colony and visualization of its reliability (elaboration by authors).

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Introduction

This study examines the use of BIM (Building Information Modeling) for architectural heritage documentation. The knowledge and proper organization of available information are fundamental requirements for any activity concerning an architectural asset [Bruno, Roncella 2018, pp. 171-178].
BIM, as a structured information system, naturally lends itself to this purpose. The ability to manage diverse information about the architectural asset within a single interoperable environment and to visualize it easily through a graphical interface has made HBIM (Historic Building Information Modeling) a key reference in the field [Ávila *et al.* 2024, p 1191].
However, applying a methodology originally designed for new constructions to historical buildings presents significant challenges, as these structures do not conform to the standardization and typification principles of BIM ensuring that the information content of the model meets the requirements defined during the preliminary assessment of the building's characteristics and objectives [Brusaporci, Maiezza, Tata 2018, pp. 179-184].
Often, the available information is insufficient to reach the desired Level of Development (LOD) or Level of Information Need (LoIN), according to new regulatory guidelines. Additionally, inconsistency in informational attributes of different components often arise, with some components being less developed due to a lack of data.
In some cases, the need for a highly detailed building description, requiring a higher LOD, leads to assumptions that are only partially supported by historical sources. This increases the interpretative nature of the model, sometimes filling gaps with speculative reconstructions due to missing data.
This raises crucial issues regarding transparency and reliability in modeling: declaring the sources used and explicitly stating their level of interpretation is a fundamental requirement to ensure the scientific validity of the digital representation [The London Charter 2009; Principles of Sevilla 2017; Bentkowska-Kafel, Denard, Baker 2012].
This study addresses these challenges by experimenting with an operational workflow for the documentation of architectural heritage in a BIM environment, through the development of a case study of the Ex Coloniy for the Children of the People of the Sea *IX Maggio* building.

The *IX Maggio* Colony: architecture and history

The Colony *IX Maggio,* built in the Roio district in 1937 by Ettore Rossi (1894-1968), is part of the broader architectural experimentation in Italy during the 1930s and 1940s, particularly in response to the government's social policies [Pagano 1937, pp. 24-27].
Rossi, known for developing the concept of the 'modern hospital', introduced the monobloc typology, a model already widespread in the United States at the beginning of the 20th

Fig. 1. Main view of the former colony *IX Maggio*: point cloud and two-dimensional representation (elaboration by the authors).

century. Designed in 1934 and completed in 1937, the Roio colony represents an evolution of Rossi's previous hospital designs, including those in Viterbo (1933-1934), Bolzano (1934), and Modena (1933-1934) [Pandolfi, 2013; Sfamurri, 2006, pp. 204-207].
The building follows a 4.5 × 5 m geometric module and features three entrance and stairway systems, with the central one equipped with an elevator. It is structured across four main levels, plus a semi-basement and a rooftop terrace. The semi-basement housed service areas, while the ground floor contained dining halls and classrooms. The upper three floors accommodated dormitories, covering a total area of 1,600 square meters. Equipped with kitchens, a laundry facility, a heating plant, storage rooms, hot water and refrigeration systems, as well as its own power generation and lighting system, the colony was considered an extremely modern facility for its time.
Externally, the complex included a small square with a podium, lawns for outdoor activities, and sports fields. The design followed rationalist principles, with solar orientation playing a crucial role in the architectural layout. From a figurative point of view, Rossi gave the building a curved form, similar to the 1933-1934 design proposed for the *Palazzo del Littorio*, alongside Ridolfi, Cafiero, and La Padula [Zammerini 2002, pp. 1-93]. This approach created a large open space in front of the building, suitable for accommodating crowds during public gatherings.
Between 1946 and 1954, the building served as a shelter for refugees from Istria and Dalmatia. From 1968 to 1977, it underwent complete renovation to accommodate its new function as the Faculty of Engineering. Designed by Leonardo Del Bufalo (1914-1984), this intervention significantly altered both its functional layout and architectural appearance.
From a functional standpoint, the internal layout was entirely reconfigured. The central section was allocated to faculty governance and department offices, while the lateral wings were reorganized for educational activities. To increase classroom capacity, the architect made a decision that, while significantly expanding usable space, also resulted in the most severe alteration to the original structure, both qualitatively and quantitatively: the loggia on the top floor was completely demolished to make way for an additional floor. A new steel and glass structure with a low-pitched roof, supported by steel trusses, was built over the former terrace. Additionally, the semicircular open loggias on the ground floor were enclosed with walls and windows.
To create the Faculty Council Hall, another elevation was added at the rear central section of the building, originally just two stories high. This new structure, also made of steel, extended the building towards the north.

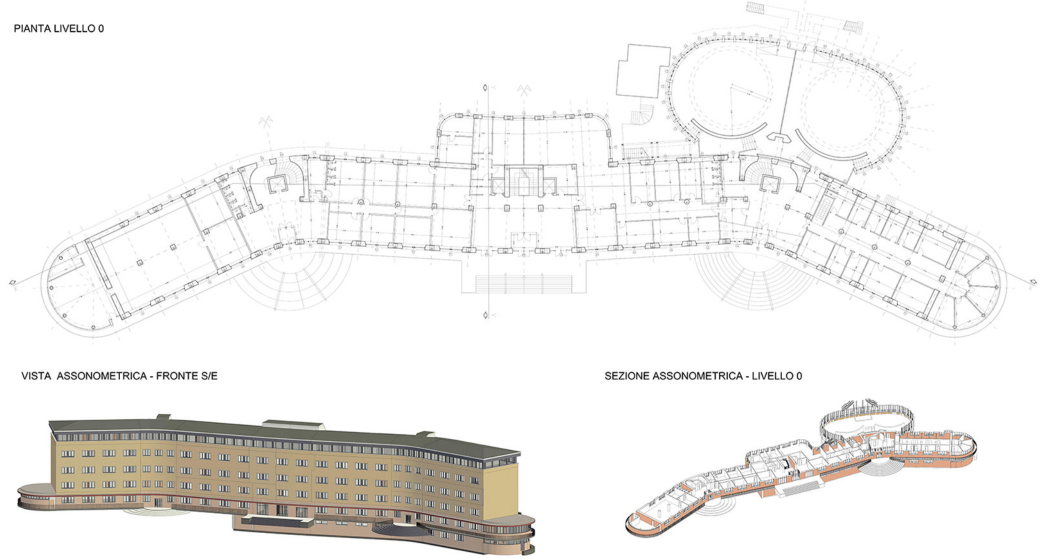

Fig. 2. Ground floor plan, model view, axonometric section (elaboration by the authors).

Between 1975 and 1977, Leonardo Del Bufalo also designed a new three-story extension at the back of the building. Constructed in reinforced concrete with exposed perimeter ribs, it housed four classrooms and additional service areas.
Subsequent modifications included the complete replacement of the original iron-framed external windows with aluminum ones, whose much thicker profiles significantly altered the appearance of the building's translucent elements. Furthermore, to improve accessibility to the lateral classroom wings, elevators were installed in the two stairwells, completely transforming their spatial configuration.
Severely damaged by the 2009 earthquake, the building remains abandoned to this day.

Survey and knowledge

The building underwent a comprehensive survey campaign integrating (TLS) Terrestrial Laser Scanning, aerial photogrammetry via drone (UAV), and direct measurement methods.
Laser scanning was used to capture the building's façades and entrances. Specifically, a phase-shift scanner (*Faro Focus S70*) equipped with an integrated HDR camera was employed. This device features a 360° horizontal and 300° vertical field of view.
A total of 46 scans were conducted, including three interior scans to fix the position of the stairwells. The instrument resolution -defined by the density of horizontal and vertical points on a spherical surface with an adjustable radius- was set to 1/4, meaning a point spacing of 6.1 mm at 10 meters from the scanner. The scan quality, which refers to the number of measurements taken to verify each point, was set to 2x for increased accuracy.
The individual scans were processed and registered using *Scene 2018.0.0.648* software through automated alignment procedures. These relied either on the placement of spherical targets (0.0695 m radius) visible in consecutive scans -particularly useful for aligning interior and exterior point clouds- or on automatic recognition of matching point constellations across multiple scans.
The resulting point cloud was then enriched with data from drone photogrammetry, which was essential for capturing the roof and other hard-to-reach areas that could not be surveyed using traditional methods.

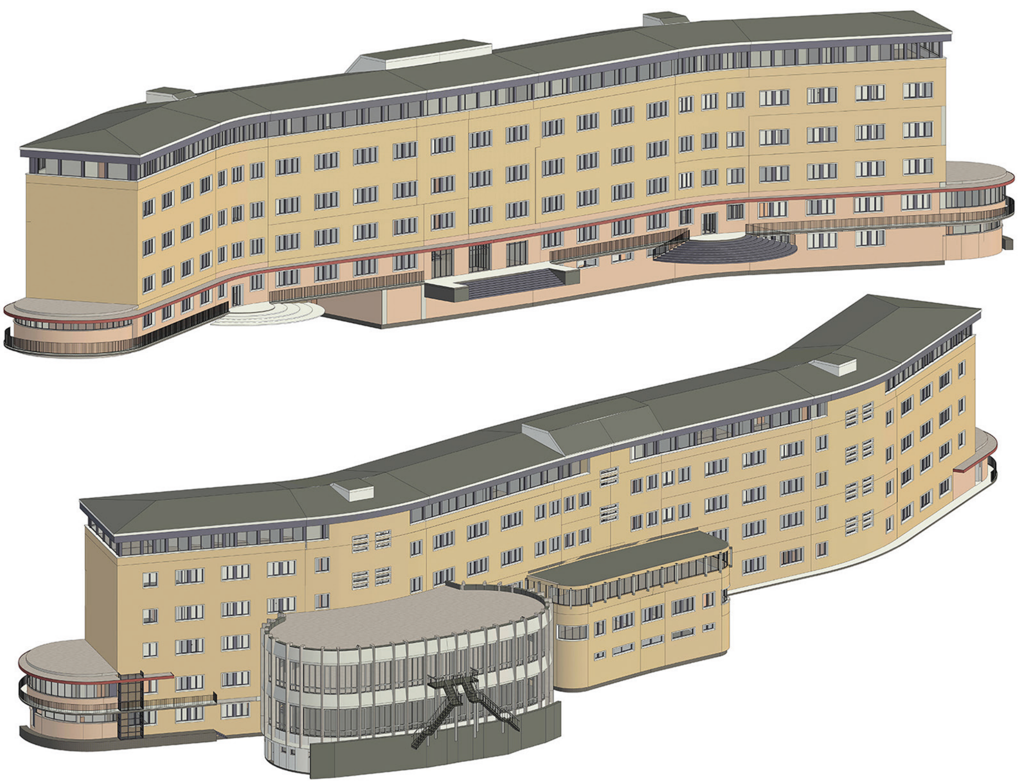

Fig. 3. Axonometric views of the HBIM model (elaboration by the authors).

For the photogrammetric survey, a *DJI Mini 2 ultra-light* drone was used, collecting 118 images at a 4000 × 2250 px resolution. These images were processed with *Agisoft Metashape*, generating: a 'Sparse Cloud' (consisting only of corresponding points between images) with 86,413 points and a 'Dense Cloud' (a densified version of the Sparse Cloud with an increased number of points) with 23,496,384 points, which, after cleaning and filtering unnecessary points, was reduced to 11,510,822 points.
Where the point cloud presented shadowed areas –caused by internal geometries, external obstructions, or missing acquisition stations– these gaps were supplemented with data from direct survey methods.
The final point cloud, combined with direct survey data, provided the basis for geometric and dimensional analysis and subsequent graphical representation of the building. Horizontal and vertical section planes were extracted from significant areas to generate slices of the point cloud. These served as the foundation for producing a 2D restitution model, later developed into an HBIM model.
Additionally, archival and documentary research was crucial in retrieving information not directly measurable –such as construction techniques– which are essential for the accurate information modeling of architectural heritage. The available documentation primarily included diagnostic surveys and previous project drawings, particularly those related to the expansion carried out by Del Bufalo.

HBIM model

The goal of the HBIM modeling of the former *Colonia* was to create a digital archive of the building, useful for its documentation and, in the future, for its restoration. Therefore, a high 'Level of Information' (LOD or LOIN, according to the latest regulations) was pursued, corresponding to an updated 'As-Built' model.
Based on a critical analysis of the available data, the information modeling was developed within *Autodesk Revit 2024*. After setting up a grid and level system to serve as a reference both horizontally and vertically, the modeling process focused on system families representing the building's vertical and horizontal enclosures. Loadable families, particularly windows and doors, were modeled and parameterized based on both geometric and material attributes.
However, despite the intended characteristics of the model, which required a detailed description of the building in all its aspects, both geometric and non-geometric, it was necessary to work with the available information, which was not always exhaustive and, most importantly, varied in completeness depending on the architectural components.
A key aspect addressed during the modeling of the former *Colonia* was the reliability of the model [Bianchini, Nicastro 2018, pp. 208-225], defined through the Level of Quality (LoQi), which measures the reliability of the HBIM model's information attributes [Maiezza 2019, pp. 461-466; Maiezza, Tata 2021, pp. 15.1-15.10]. A Global Parameter was created to establish three different Levels of Information (LoI) within the model: low, medium, and high.

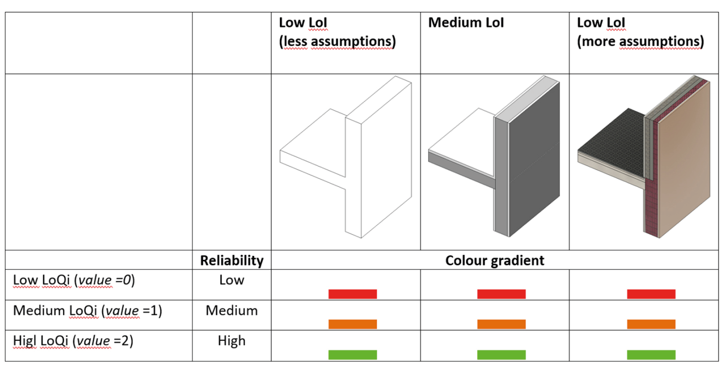

Fig. 4. Color gradient diagram as a function of model reliability in the three possible 'Levels of Information' (LoI) (elaboration by the authors).

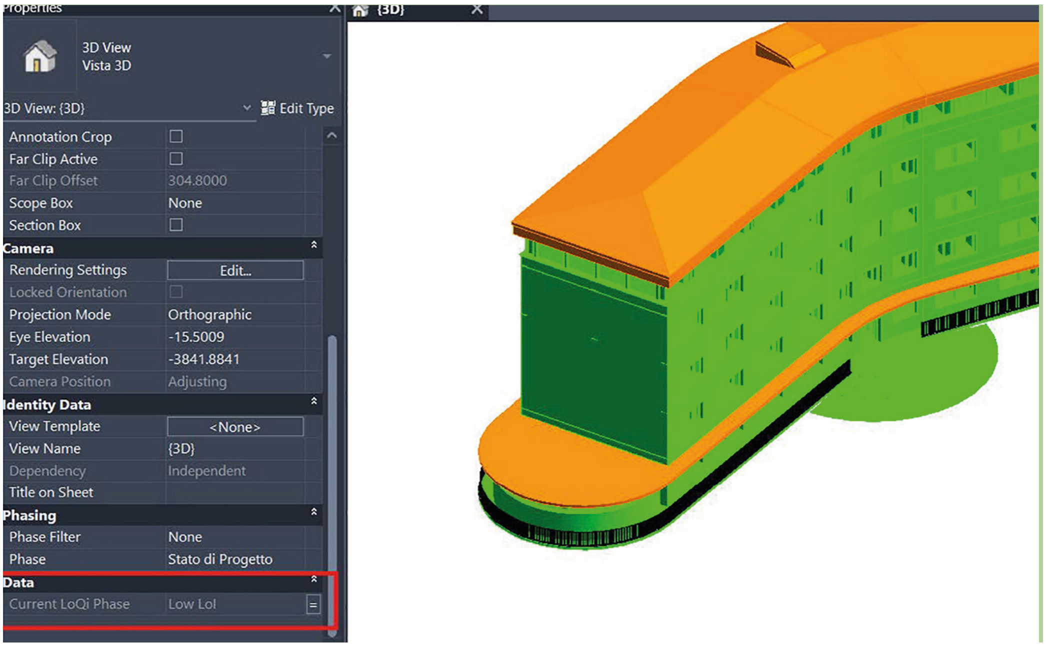

Fig. 5. 'LoI Global Parameter' setup: the parameter text value corresponding to a specific 'LoI' Phase (elaboration by the authors).

The low LoI refers only to the dimensional attributes of architectural elements (e.g., wall or floor thickness). Therefore, the LoQi reliability parameter values do not consider layers or material composition. Three reliability levels were defined, ranging from 0 (lowest reliability) to 2 (highest reliability), visually represented by a color gradient:

- Level 0 - Red: Insufficient geometric information is available for the element; modeling information is assumed based on comparisons with similar/adjacent elements and visual inspection (Parameter Value = 0).
- Level 1 - Orange: Main dimensional information is partially known and investigated (e.g., walls with only one face available for dimensional survey, partially accessible elements) (Parameter Value = 1).
- Level 2 - Green: Main dimensional features are known and accurately represented (Parameter Value = 2).

In the Medium LoI, only the construction typology of the element is considered (e.g., brick masonry, stone masonry, reinforced concrete slab, or steel beam and brick vault slab), with a qualitative rather than detailed stratification:

- Level 0 - Red: Only partial geometrical data can be assumed, unavailability to directly access inner layers of the element (Parameter Value = 0).
- Level - Orange: known geometric data, inner layers typology is assumed from adjacent and or similar elements or partially available from survey (Parameter Value = 1).
- Level 2-Green: Geometrical and main dimensional features of the element are available; construction typology is exposed or known by direct survey or tests (Parameter Value=2).

To achieve a high LoI, additional assumptions may be required, as the available information remains the same as in the previous 'LoI' levels. The high LoI involves investigating and critically assessing the layers of the architectural element, meaning that geometrical data, knowledge of layer thickness, and material composition contribute to the LoQi reliability parameter values.

The three possible reliability levels for the high LoI phase are:

- Level 0 - Red: geometrical and layers information about the element is assumed by historical and/or limited survey information with low grade of reliability (e.g. elements with only partial or insufficient source information, elements with only geometrical data available from survey, elements only partially or entirely unavailable to direct survey).
- Level 1- Orange: known geometric data, layers composition information about the element is partially available from survey and/or from direct resemblance and adjacence to

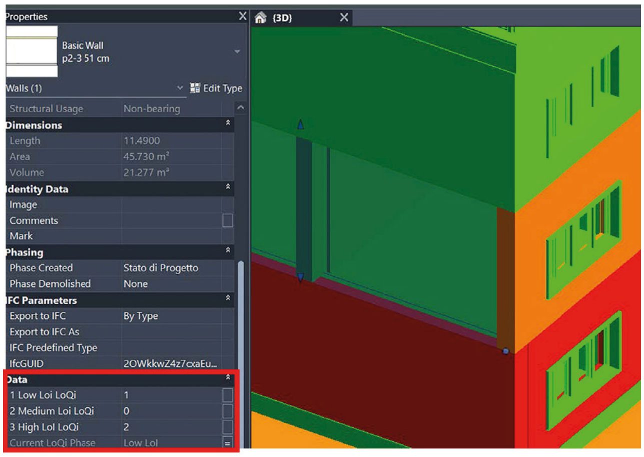

Fig. 6. LoQi instance parameters values: different LoQi element displayed at a given LoI phase, going from 0 (lowest LoQi for a given LoI level) to 2 (maximum LoQi) (elaboration by the authors).

evaluated Level 2 elements of the same category (e.g. portion of walls and floors geometrically similar and adjacent to a Level 2 element and critically assumed to be built at the same time span and with same construction technique of the corresponding similar tested elements)

- Level 2 - Green: geometrical and layers composition information about the element is directly available from source (e.g. direct wall core drilling test, core access of the element available due to partial wall collapse etc.)

From an operational perspective, three instance parameters (Low LoI LoQi, Medium LoI LoQi, High LoI LoQi) were created, each allowing for the assignment of a value ranging from 0 to 2 (0 - Low reliability, 1 - Medium reliability, 2 - High reliability). A 'Global Parameter' ('Current LoQi Phase') was then introduced to indicate the current LoI Phase (Low, Medium, or High).

By using conditional properties between LoI and LoQi along with a color filter that combines the various possible LoQi and LoI combinations, the model visually displays elements in the corresponding reliability levels. Thus, the model will show elements as Green (High LoQi), Orange (Medium LoQi), and Red (High LoQi) in any given LoI phase by adding the conditional property between the LoI and LoQi and colour filter combining the various possible LoQi and LoI combinations.

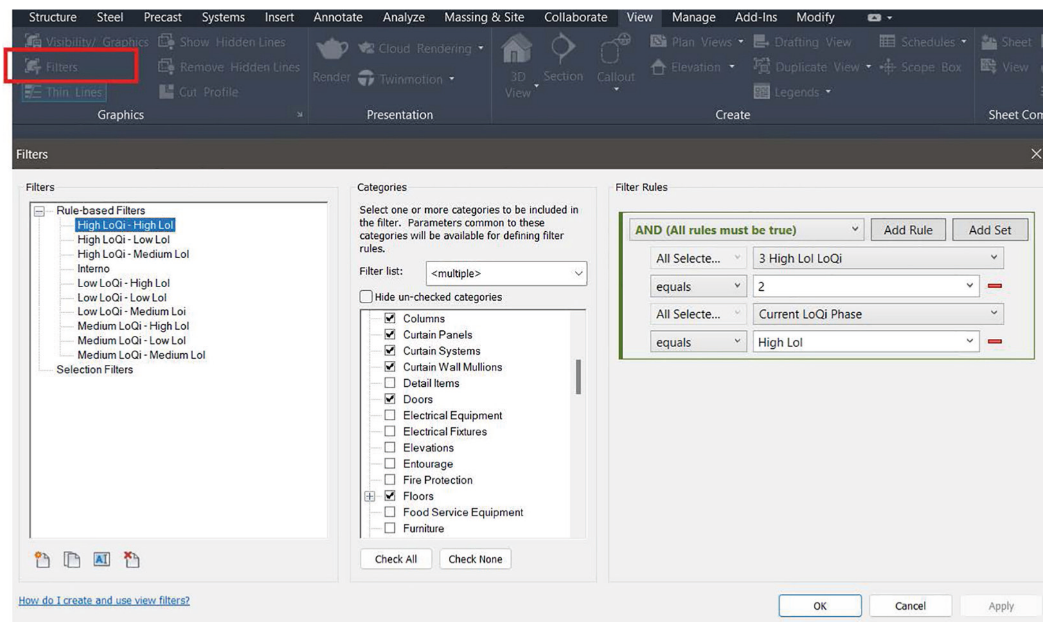

Fig. 7. Rule-based conditional filters between LoQi and LoI parameters: if the considered LoI phase corresponds to the Global Parameter (Project LoI Phase) and the LoQi value of the element equals the specific value of the rule, the element will be colour filtered correctly as per Visibility Overrides (Figure 8) (elaboration by the authors).

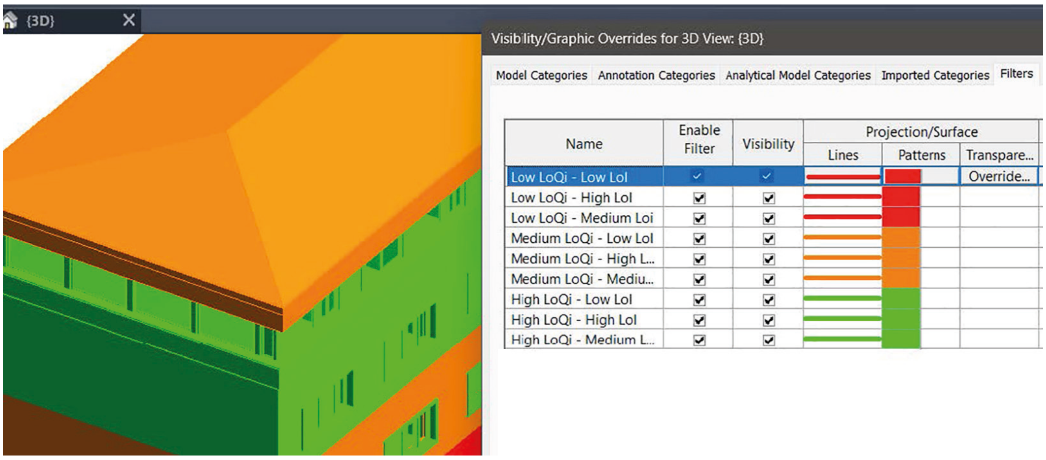

Fig. 8. Visibility/graphics overrides applied according to conditional rules: overrides are in green for High LoQi, orange for Medium LoQi and red for low LoQi for the considered LoI level (elaboration by the authors).

Once compared, toggling the LoI Phase Global parameter allows to easily compare different LoI Phases for the same view.
Regarding transparency, additional instance parameters have been created to display the sources (.img, .txt, .url) that contributed to the LoQi parameter evaluation across different LoI phases.

Conclusions

The study and HBIM modeling of the former *IX Maggio* Colony for the Children of the People of the Sea have highlighted both the potential and the challenges of HBIM.
On one hand, its potential lies in aspects that have attracted the interest of those working with architectural heritage: the ability to store and manage data within a single structured and shared environment, accessible to all stakeholders, easily updatable, and integrable.
On the other hand, the issues of transparency and reliability in HBIM modeling remain critical challenges in architectural heritage documentation, where the limitations of available information become even more pronounced [Brusaporci 2017, pp. 66-93]. The available information, often scarce and incomplete, forms the foundation for the informational development of the model which may not always reach the desired level of development in accordance with the project's goals and the characteristics of the studied element.
The necessity of making assumptions during modeling underscores the importance of always declaring the sources used and the corresponding level of interpretation. In this regard, BIM provides an opportunity to supplement the model with metadata and paradata, enhancing clarity and accountability [Murphy *et al.* 2025].

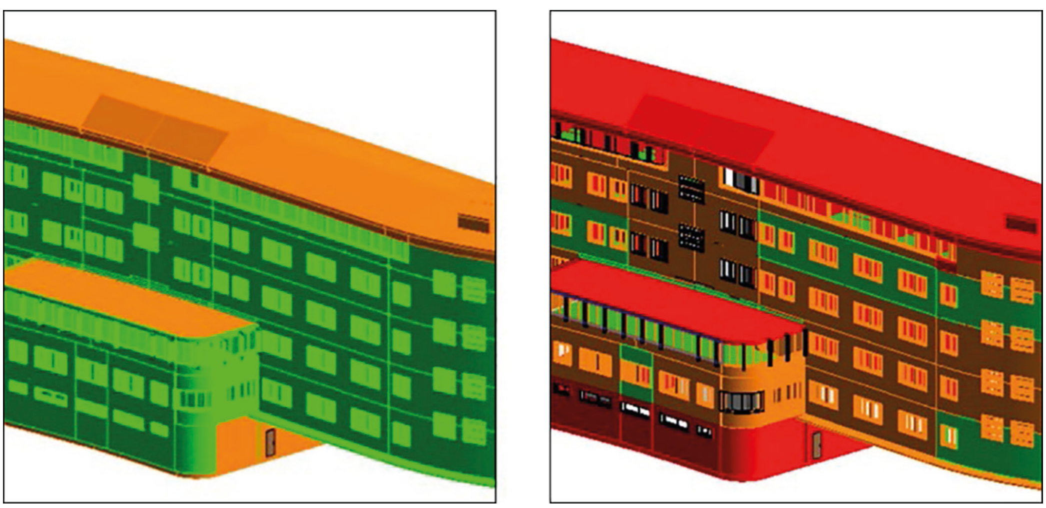

Fig. 9. Similar views with different LoI settings: low LoI on the left, high LoI on the right (elaboration by the authors).

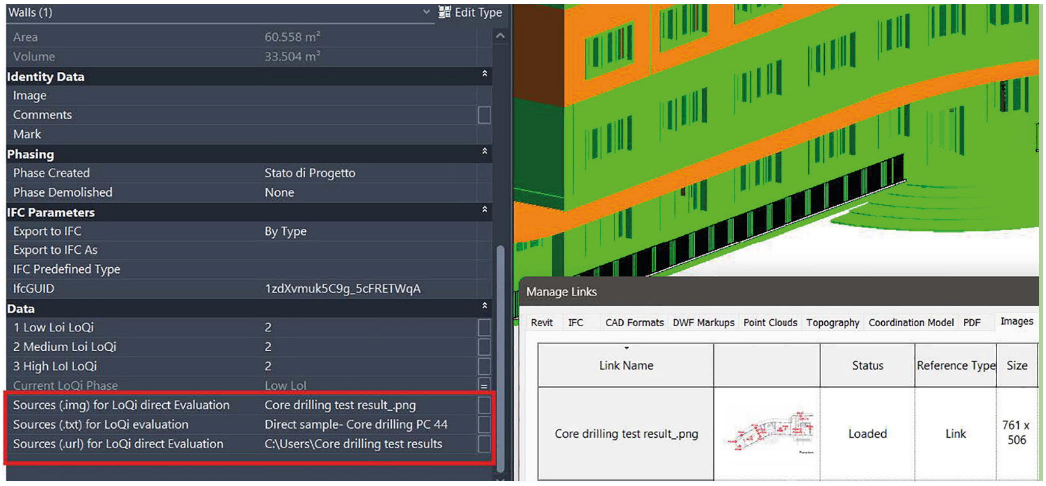

Fig. 10. Sources instance parameters and links: an example of a selected element that has a direct source link to a core drilling test result and drilling sample location map is shown (elaboration by authors).

In the proposed case study, reliability statements regarding the model's representation, corresponding to different levels of model development, have been incorporated using custom parameters and conditional properties applied to visualization filters.
More specifically, the 'Current LoQi Phase' global parameter enables the visualization of model reliability through a color gradient, corresponding to different Levels of Information (LoI): Low LoI (only dimensional attributes), Medium LoI (construction typology of elements), and High LoI (detailed description of components).
For each element, reliability is specified at the three different levels of development through the assignment of three instance parameters (Low LoI LoQi, Medium LoI LoQi, High LoI LoQi).
This approach allows for the simultaneous visualization of the model's varying reliability levels, depending on the considered LoI (Level of Information).
Finally, the available sources that supported the modeling process have been incorporated into the model through dedicated parameters.
The parametrization and informative basis of BIM were thus utilized to ensure source transparency and to declare the reliability of the interpretative model of the case study.
Thanks to the organization of information within a digital archive that is both structured and 'reliable,' the HBIM model of the former Colony serves as a valuable tool for knowledge and documentation, providing a solid foundation for future restoration activities of the building [1].

Notes

[1] This work has been carried out in the framework of the project PRIN 2022 (D. D. n.104 of February 2, 2022) "GUIDANCE - GUidelines for H-BIM Documentation, mAnagemeNt and Conservation of built heritage assEts", funded by the European Union - Next Generation EU."

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