Direct imaging of polymer filaments pulled from rebounding drops

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BIM Model Reconstruction of Architectural Archives: A Case Study in Turin, Italy

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Abstract

This contribution critically reflects on research dedicated to enhancing architectural archives through BIM and disseminating them online. The case study focuses on a building designed by Felice Bardelli for the INA Casa program in postwar Turin, in an area affected by bombing during World War II. The research is based on the Betta-Bardelli archive housed at the Polytechnic University of Turin and consisting of technical drawings, structural calculations, and administrative documents. The project involves digitizing, georeferencing, and creating an information model (BIM) of the archival material to virtually restore the buildings and their historical urban contexts. This methodological approach transforms academic archives from mere repositories of documents into active, accessible, and interactive cultural infrastructures. Thus, the digital model becomes a tool for analyzing, conserving, and disseminating design heritage, fostering a new form of communication and interdisciplinary research.

1. Introduction (MV, MP, MMB)

The contribution offers some of critical reflections on a research study dedicated to the valorisation of architectural archives through BIM modeling and online dissemination.
The research addresses those issues by analyzing a case study of a building by engineer and architect Felice Bardelli (1905-1993), precisely one of the buildings designed for INA Casa programme (National Institute of Assurances for Housing) during the late 1950s and all the 1960s, in Turin, Italy. This example is of great interest since this building was designed to restore an urban area that was destroyed by Allied bombings during the Second World War. The research starts by investigating the archival materials hosted by the Department of Structural, Building, and Geotechnical Engineering (DISEG) of the Politecnico di Torino and goes through the BIM modeling of design drawings (Fig. 1 and Fig. 2).

2. Role of information modeling strategies in the revitalization of archival documents (MMB)

For the past thirty years, national institutions, particularly the Central Institute for Cataloguing and Documentation (ICCD) with its General Catalog of Cultural Heritage and the Ministry of Culture's department dedicated to archival heritage, have actively worked to define shared models for describing, creating metadata for, and ensuring the interoperability of historical and artistic heritage, both nationally and internationally.
Scholars of architectural design have been researching various topics related to architectural archives for some time now. These topics include the analysis and two-dimensional interpretation of drawings, three-dimensional reconfiguration of spaces, experimentation with graphic languages for visualization, and the immersive and interactive exploration of data and its interpretation. They have also researched techniques for presenting 2D and 3D content online.
These investigations have led to the creation of open-access digital products that aim to define an effective communication model to enhance archived data. Over the last thirty years, national institutions, particularly the Central Institute for Cataloguing and Documentation (ICCD) with its new General Catalog of Cultural Heritage and the Ministry of Culture with its department dedicated to archival heritage, have been working to define shared models for the description, metadata, and interoperability of historical and artistic heritage, both nationally and internationally.

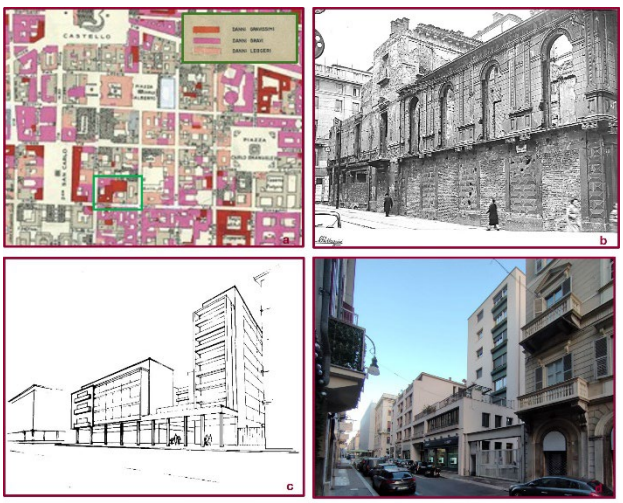

Figure 1. Case study: Bardelli’s INA Case building.

Scholars of architectural design have been researching various topics related to architectural archives, such as the analysis and two-dimensional interpretation of drawings, three-dimensional reconfiguration of spaces, experimentation with graphic languages for visualization, and the immersive and interactive exploration of data and its interpretation. They have also studied techniques for presenting 2D and 3D content online.
These investigations have led to the creation of open-access digital products that aim to define an effective communication model for enhancing archived data. In the current landscape of documentation, preservation, and archival heritage related to works of architecture and engineering, information modeling is a central tool for interpreting and enhancing documents.
These archives, which are often composed of diverse materials such as photographs, drawings, historical documents, and surveys, can become interactive, dynamic, and accessible resources through digital modeling.

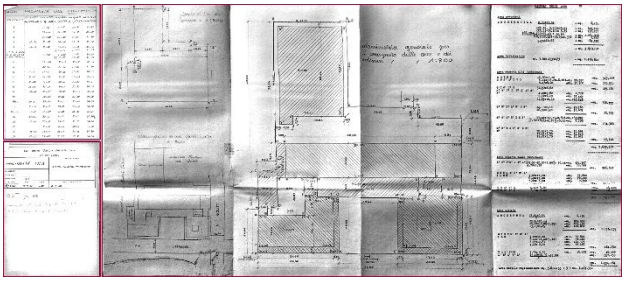

Figure 2. Examples of Betta-Bardelli’s archival sources.

Archives are in danger of remaining static entities, closed collections, even with the opportunities offered by digital consultation. The lack of interaction with the world of research often relegates them to the role of simple tools for retrieving information. On the contrary, closer dialogue with the academic and scientific community could enhance the value of the documentary heritage they hold, elevating it to a living cultural resource to be studied and shared. In this perspective, archives can become dynamic spaces at the service of research, offering essential materials for interdisciplinary analysis and projects (Palestini, 2022).

When access to an architectural asset is no longer possible due to its state of preservation at a given point in time, the digital model can serve as a substitute for the physical artifact, facilitating reading, analysis, and philological-conjectural reconstruction. In this context, universities play a strategic role in dematerializing and disseminating design knowledge by promoting advanced methodologies for integrated data management and involving complementary polytechnic knowledge.

The first strategic step is digitization: historical photographs, graphic designs, and visual or oral testimonies are collected, sorted, and transformed into a searchable database. Three-dimensional modeling techniques are then used to virtually reconstruct artifacts and urban contexts from these sources. Once the geometric model is obtained, it is integrated into information modeling environments where, according to the scale of knowledge restoration, each element of the project is described in geometric, topological, functional, and historical-chronological terms. This structure is not merely a visual representation; it is a place that can convey data and its evolution over time, processing it to transform it into information. In these cases, the concept of a Building Object Model (BOM) is essential (Donato, Bocconcino, & Giannetti, 2017): each component of the model is associated with metadata and links, enabling navigation, analysis, and comparison of successive design evolution snapshots or similar cases.

The ability to "dimmer," or adjust the intensity of the representation scale, is also fundamental. Depending on the purpose—documentation, design, structural simulation, or dissemination—it is possible to calibrate the level of detail by modulating the geometric and informational complexity of the model and associating the appropriate documentary components to trace the path of the sources and their graphic classification (Palestini, 2016). Parametric modeling allows objects to be simplified or detailed in a manner consistent with analytical or communication needs. It also allows additional explanatory data to be associated with the model, promoting greater transparency and the possibility of reusing the information base.

Interactive web platforms complete this system by offering a participatory environment where experts, students, and citizens can contribute to enriching the digital heritage. These platforms are designed to ensure interoperability, data quality, and usability according to shared standards. This approach promotes the construction of scalable, searchable, and updatable digital archives that enhance research, teaching, training, and heritage protection activities.

Adopting information modeling strategies in university archives transforms the representation of the built environment into an evolutionary, multidisciplinary process that brings together technology, history, interpretation, design, and graphic representation tools to interpret, share, and make original documents accessible too.

3. Information model and archival documentation: mediation, not replacement (MMB)

The information model serves a mediating function, rather than a replacement function of archival documentation. Integrating digital information models and archival sources is one of the most delicate and fascinating issues in design, document heritage representation, and management. Digital tools offer unparalleled potential for consulting, organizing, and analyzing collections. However, they also pose a risk of obscuring or oversimplifying the layered, expressive, and historical value of original documents due to their apparent efficiency and accessibility. When dealing with project drawings, graphic tables, sketches, and iconographic documentation in particular, it is essential to recognize that the information model can serve as an interface, but not a substitute.

In an archival context, information models are structured systems for managing and navigating data. They organize heterogeneous sets of documents, metadata, and historical and spatial references relationally. They enable faster searches, multiple classifications, and semantic and geographical interconnections between sources. However, due to their parametric and systematic nature, these tools cannot replicate or absorb the visual, material, and conceptual complexity of the original documentation.

The expressive power of a freehand drawing, the choice of paper, visible erasures, marginal annotations, and stroke details are elements not fully conveyed by the model's codified structure.

Therefore, it is necessary to avoid the misconception that digitization and the construction of information models are equivalent to an "improved" version of the source. The model is a mediation device that guides the user in consulting and understanding the material but does not fully represent it.

As Mario Carpo (2017) points out, in the digital information age, it is not the copy that is replicated, but rather the algorithm—the rule that generates the object. Applying this logic to archives, there is a risk of prioritizing the structure of the data and the information protocol over the cultural objects from which the data originates. This means neglecting the visual content and historical materiality of the sources, as well as their documentary aura.

Similarly, Massimo Scolari (2015) emphasizes the conceptual and critical autonomy of graphic representation, which cannot be reduced to illustrative support or technical byproduct.

Applying this perspective to the archival field, we understand that every historical graphic document carries a symbolic and interpretive significance that cannot be fully restored by computer reworking. Thus, the information model should be considered a guide for interrogating sources rather than their definitive synthesis or visualization.

Methodologically, this implies that any information structure designed based on archival documents — whether a database, GIS system, BIM model, or digital atlas — must maintain an explicit and continuous link with the original sources. This link should not only be established through hypertext links or digital reproductions, but also by recognizing the centrality of the source in the construction of meaning. The risk of "disanchored" consultation, in which users navigate between data and images

without accessing the original document, must be avoided by valuing documentation as a direct witness to design thinking and not just as a container of information.
In academia and research practice, this translates to a renewed focus on directly reading sources. Every information model, no matter how advanced, must be accompanied by the intentional use of tables, graphic designs, and archival materials in their original form. Only through this coexistence can the historical, technical, and expressive complexity that makes archival documents irreplaceable tools for understanding the project be preserved.
The information model should be understood as a tool for access, not a totalizing device. Its value lies in its ability to guide research, create semantic networks, and make documentary heritage more accessible. However, its use must always be subordinate to the source, which has an invaluable wealth of interpretive potential. From this perspective, the task of research is not to replace memory with information but rather to bring the two into dialogue by building tools that respect the complex and open nature of archival documents (Fig. 3).

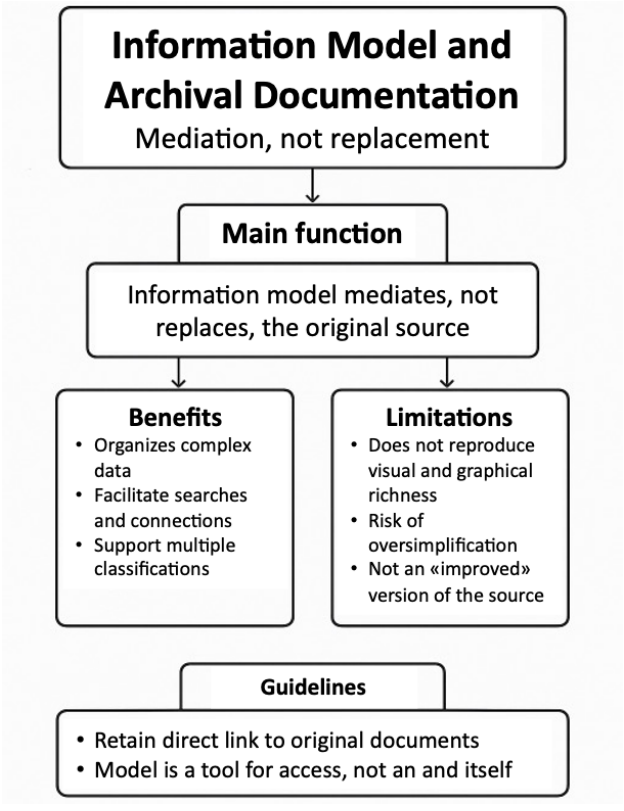

Figure 3. Issues related to the role of information model with respect archival sources

4. Architectural archives: a state of the art (MP)

Recently, architectural and project archives have become the focus of a dynamic and evolving cultural discourse, particularly within the Italian context (aaa-italia.org; Carassi 2023; Palestini 2016, 2017, 2023; Palestini, Pellegrini 2024; Zheng et al. 2023). This growing interest reflects not only a reassessment of archival practices but also a broader recognition of the epistemological and cultural value embedded in such collections (de Vietter, Sampaio 2022). Notably for this topic, many institutions of higher education – especially faculties and departments of architecture and engineering – have emerged as key custodians of these archives.
These academic environments have increasingly taken on the role of safeguarding not only their own historical legacies but also those of affiliated professionals and scholars, primarily through bequests, donations, and other forms of knowledge transfer (Barker 2016; Bettazzi 2023; Cappelletti, Morosini, Vitale 2023; Docci 2022b). This trend signals a significant transformation in the function and perception of architectural and engineering archives as academic heritage, in the sense of the Declaration of Halle (2000) and the Council of Europe on the Heritage of universities (European Council 2005).
Still, once primarily seen as repositories of institutional memory – preserving the tangible and intangible history of universities themselves – these archives are progressively being redefined as sites of collective memory and disciplinary development (Docci 2022a).
The integration of private collections into public academic holdings fosters their transition from being just personal archives to become sort of institutional ones, enhancing both their accessibility and scholarly relevance. As a result, these archives are no longer viewed as passive containers of information, but as active agents in the advancement of scientific research (Palestini 2022; Farroni 2023). Moreover, academic archives, as well as architectural archives *strictu sensu*, can now act as 'cultural infrastructures', since they can foster interdisciplinary collaboration and public engagement (Simpson, Fukuno & Minani 2019).The focus of our research is the architectural and engineering archives preserved within academic institutions.
In the international landscape, architectural archives reflect a broad and multifaceted reality. In fact, these collections encompass a wide array of institutional and professional contexts, ranging from those directly linked to architecture and engineering education (Tewes 2019; Quagliaroli & Casey 2021) to those centred on the work of prominent – as well as lesser-known – architectural practitioners (Spallone & Paluan 2016; Incerti, Mei, Castagnoli 2022; Sdegno & Riavis 2022). Among the archives embedded within academic institutions, one of the most notable examples is the Architecture Collection of the MIT Museum, which houses thousands of thesis projects and class drawings produced from the late 19th through the 20th century. These materials document the pedagogical evolution of architectural education at MIT and trace the professional trajectories of alumni and faculty, including influential firms such as Kallmann McKinnell & Wood Architects (MIT Museum). A similar architectural archive is preserved at the Borthwick Institute for Archives of the University of York (York University). In Europe, similar initiatives underscore the role of academic and cultural institutions in preserving architectural heritage. The Architekturmuseum der Technischen Universität München (TUM) stands out for its dual function as both a museum and a dedicated archive. It conserves an extensive body of drawings and physical models created by students, highlighting the continuous interplay between education and practice in architectural culture (Fig. 4).
Likewise, the Deutsches Architekturmuseum (DAM) in Frankfurt am Main maintains a museum-like structure while safeguarding over 200,000 drawings, 35,000 photographs, and approximately 1,300 architectural models. These materials document the work of internationally renowned figures such as Louis I. Kahn, Ludwig Mies van der Rohe, and Rem Koolhaas.
In the Italian context, the MAXXI Museum's Centre for Architecture Archives plays a pivotal role in preserving and promoting architectural culture. With over 60,000 drawings, 75,000 photographs, and a wealth of additional materials – including physical models and correspondence – the archive holds the legacies of seminal figures like Aldo Rossi, Paolo

Soleri, and the radical architecture group Superstudio (MAXXI) (Fig. 5).

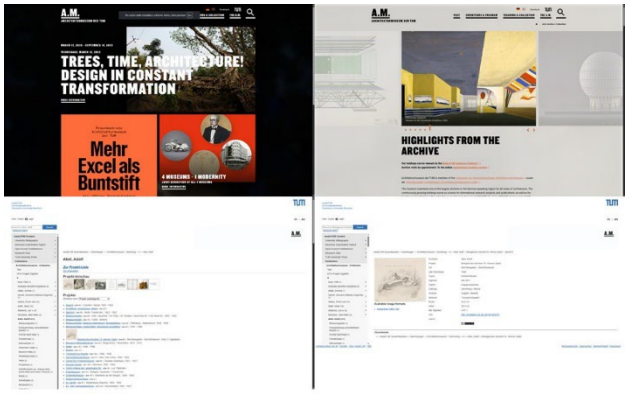

Figure 4. The TUM Architektur Museum. The institution offers an online-accessible database with many digitized materials.

These international examples collectively demonstrate that architectural archives today represent far more than mere repositories of technical drawings. As emphasized by Gay (2015), the term architectural archive encompasses a wide spectrum of visual and material artefacts generated throughout the architectural design and construction process. These include sketches, photographs, models, diagrams, written annotations, and even audiovisual recordings that capture various stages of ideation and realization (Bouzar 2023).

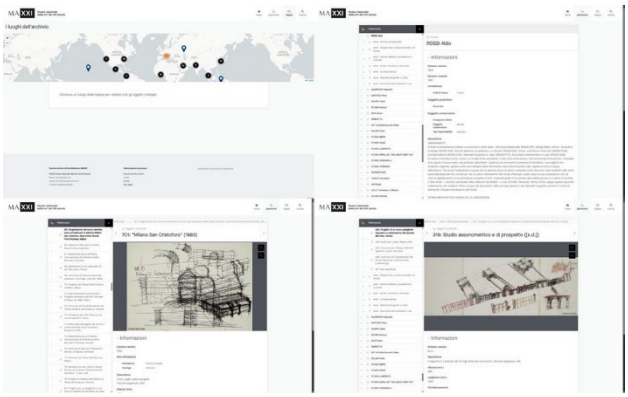

Figure 5. The MAXXI’s Centre for Architecture Archives. The institution offers an online-accessible database with many digitized materials. The navigation can be accessed both via a table of contents and via interactive maps.

A significant trend shared by many of these cases is the prominent role of universities and their affiliated schools of architecture and engineering in both hosting and curating such collections. Increasingly, these archives are being integrated into the broader framework of university museums and cultural infrastructures. This evolution reflects a broader shift in the understanding of academic heritage. Where once universities were primarily seen as guardians of their own institutional memory – both material and immaterial – they are now also being recognized as stewards of external legacies closely tied to their academic disciplines. Bequests, donations, and temporary deposits have enabled the transfer of private collections into institutional holdings, allowing them to evolve into fully recognized archival bodies (Bodrato 2023; Palestini 2019). This transformation not only enhances the research value of university archives but also reinforces their role as dynamic centres of cultural production, public history, and interdisciplinary inquiries.

5. Materials and Methods (MP)

The project aims at valorisation and dissemination of the architectural and engineering archive of the Department ISEG of the Politecnico di Torino. Specifically, it focuses on the investigation and experimentation of novel methods for processing, organizing, and communicating the information contained within the archive. The primary objective is to leverage information technology to enhance the expressive and communicative potential of such documents. This process of valorisation involves the possibility of accessing the heritage and integrating it with new knowledge (Bocconcino, Vozzola 2022). With this research we focus on the initial reconnaissance of the Betta-Bardelli architectural and engineering archive. The architect Pietro Betta (1878-1932) was a leading figure in Turin’s architectural and urban planning scene across the First World War and the subsequent first post-war period. He graduated in architecture at the Regia Scuola di Applicazione per gli Ingegneri di Torino in 1905. Alongside professional practice, Betta was a professor at the Faculty of Architecture in Turin (Chair of Urban Planning) and at the Faculty of Engineering (Chair of History of Styles). He is renowned for his comprehensive vision of the Taylorist urban model (Magnaghi, Monge, Re, 1995). His most notable projects include Casa Avezzano (1912) and the Palazzo “Ordo Restaurationis, Restauratio Ordinis” (1929), both located in Turin. Felice Bardelli (1905-1993) graduated in Civil Engineering (with a specialisation in construction) from the Regia Scuola di Applicazione per gli Ingegneri di Torino in 1927 and began his professional career in Betta’s studio, becoming one of his most important collaborators. There he formed close professional ties with the architect Domenico Morelli and collaborated with him on numerous projects (Magnaghi, Monge, Re 1995). His contributions to the design of lot F of the Ina-Casa in Turin’s Vallette district are also noteworthy. The Betta-Bardelli archive is composed by 6 numbered files related to Pietro Betta’s practice and 26 numbered files related to Felice Bardelli’s practice (Tab. 1). Each file is named with a short name and may contain materials of different projects. The materials primarily date from the 1930s through to the late 20th century and provide invaluable insights into architectural practices in Piedmont and broader Italy during that period. Each project is described by many different types of graphic sources, such as architectural technical drawings, structural mechanics calculations and representations, as well as written relations, letters and administrative duties (such as receipts of the payments of building taxes).

Pietro Betta	Felice Bardelli			
1 ARCH. BETTA	A	L	O tris	T bis
2 ARCH. BETTA	B	M	P	U
4 ARCH. BETTA	C	M bis	Q	V
5 ARCH. BETTA	D	N	Q bis	V bis
6 ARCH. BETTA	E	O	R	INA 1
7 ARCH. BETTA	F	L	S	INA 2
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Tab. 1. The Betta-Bardelli architectural and engineering archive consistency.

The first step of our project will provide a georeferenced account of the interventions promoted by the two professionals at the national level, with a particular focus on the numerous projects undertaken in the Turin city region. The most significant of these is the creation of interactive maps for the contextualization of the projects and the documents describing them. These have been digitized and presented both geographically and temporally, with the historical presentation of the documentation in a temporal sequence.

Such an analysis will allow for the examination of design consistencies in relation to the current state of the places in question, as well as the contextualization of the transformations undergone by individual buildings in relation to the social changes resulting from the evolving approach to the city’s various neighbourhoods.
Concurrently, the creation of navigable virtual environments enables users to access the archive and consult the drawings and three-dimensional reconstructions of the buildings through geometrically simplified models, which nevertheless contain a wealth of information.

6. Results and discussion: BIM for the valorization of Bardelli’s project (MV)

The proposed work was developed in several phases. The initial, preparatory and foundational phase was based on a systematic analysis of the documentary material preserved in the Betta-Bardelli collection.
The exploration of the original drawings made it possible to identify a series of relevant design themes that deserve critical analysis, including social housing (with particular reference to the INA Casa programme), public and religious buildings, with a particular focus on executive and detailed design.
The focus of the documentation is on the analysis of the different scales of representation used to develop the projects, ranging from urban scale, 1:500 – 1:1000, to detailed drawings at 1:20, 1:10 and 1:1.
The case studies identified include pilot projects, which will be used to understand how to digitise projects and create 3D models of buildings. One of the case studies identified concerns the INA Casa office building, located on the corner of Via Giolitti and Via Lagrange in Turin, which is an emblematic project within the process of urban reconstruction after the Second World War, following the damage suffered by the city during the bombings. The archival documentation relating to this project is remarkably diverse in type, including photographs of war damage, structural calculations, technical reports and detailed architectural drawings, such as that relating to the window sill of one of the types of windows found on the various façades of the building.
In order to highlight the design contribution of engineer Giuseppe Bardelli, a three-dimensional information model (BIM) was developed that relates the new volume to the pre-existing urban block affected by the war.
The model, initially developed on a 1:500 urban scale, integrates geometric data and alphanumeric information relating to historic buildings and original volumes, serving as an operational tool for both scientific research and the dissemination and enhancement of heritage (Banfi et al., 2023; Fiorillo et al., 2023; Giovannini et al., 2024).
The analysis of the design phases, set on an urban scale, highlights a significant evolution in the definition of the intervention: in an initial hypothesis, the complete demolition of the existing building was envisaged, a hypothesis subsequently superseded by a design variant that promoted the conservation of the historic buildings on Via Lagrange, reducing the overall volume and abandoning a porticoed structure in favour of a single compact architectural volume. The use of BIM modelling allowed us to create a multi-temporal model for the different phases that represented the building within the urban context (Fig. 6).

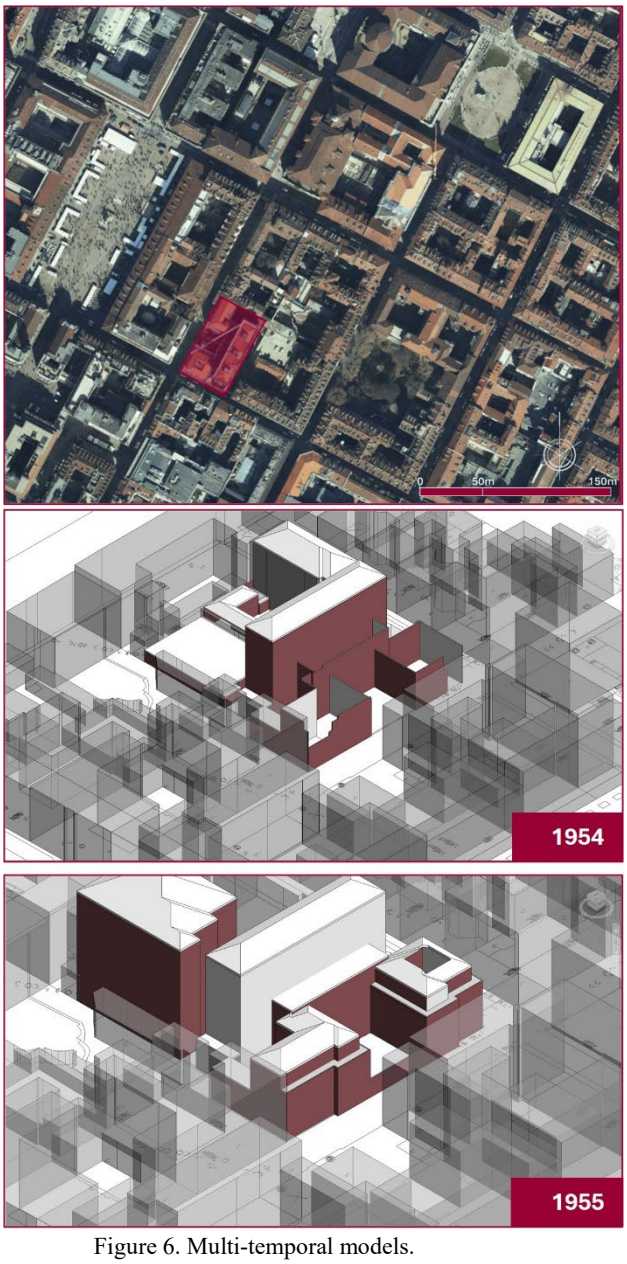

Figure 6. Multi-temporal models.

In order to correctly represent these transformations and understand the dialogue between the new and the existing, the BIM model was articulated through the reconstruction of the three main design variants, thus allowing a comparative analysis of the different solutions proposed.
This process of analysis and reconstruction made it possible to critically investigate the ways in which the project fits into the urban context, highlighting the tensions, potential and specificities of the intervention within the historic fabric. In this context, it can be said that digital tools have facilitated the sharing of material relating to the artefacts, both in their three-dimensional representation of knowledge and in the presentation of the artefact itself in its context (Pisani et al., 2023), emphasising the importance of modelling from archive

documentation to understand the link between the artefact and the urban context in which it is located (Fig. 7).

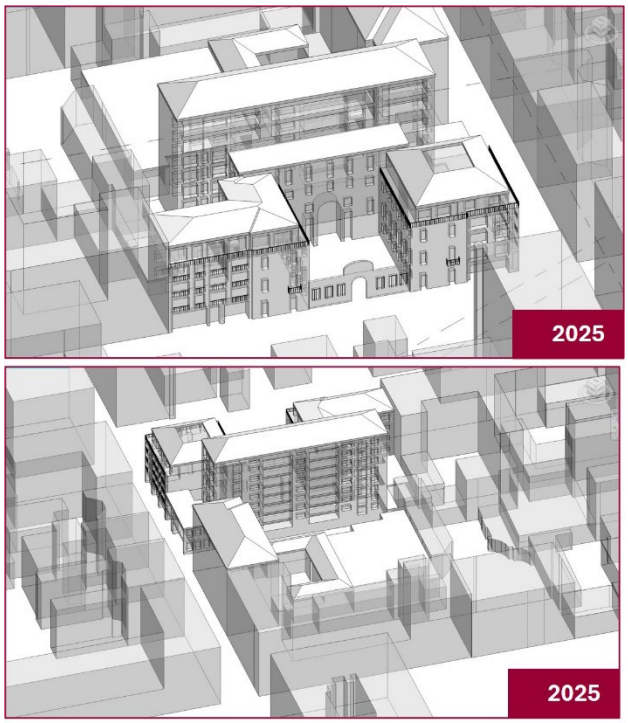

Figure 7. The model of the building today in its urban context.

The use of an H-BIM model has allowed us, and will allow us, on the one hand, to have a systematic representation of the changes to which the building has been subjected, from the preparatory design phases to those of construction. At the same time, it is possible to integrate the various data sources into a single integrated model, which can be queried and used to support knowledge of the evolution of the city's urban fabric. In this context, by linking data to specific time periods, H-BIM allows us to analyse the evolution of a structure and changes in its condition (Cheng et al., 2015).

7. Conclusions and future developments (MV, MP, MMB)

The development of the research work conducted, will allow us to represent, at different scales, from the urban scale, to the block scale, up to the building scale, the process of urban renewal that affected the block and part of the building tissue of the historic city centre, during the first post-war years.
The comparison of design solutions, made possible within the BIM environment, will prove fundamental for a deeper understanding of the management dynamics of the architectural project. Furthermore, the transition from the archival document to the informed model will support subsequent dissemination operations through model sharing and extended reality applications.

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Author Contributions Statement

Although the contribution was conceived jointly, M. M. Bocconcino is author of paragraphs 2. Role of information modeling strategies in the revitalization of archival documents and 3. Information model and archival documentation: mediation, not replacement; M. Pavignano is author of paragraphs 4. Architectural archives and 5. Materials and Methods:, M. Vozzola is author of paragraph 6. Results and discussion: BIM for the valorization of Bardelli’s project. Paragraphs 1. Introduction and 8. Conclusions and future developments were coauthored by all the Authors.

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