H-BIM Modelling for Enhancing Modernism Architectural Archives. Reliability of Reconstructive Modelling for "on Paper" Architecture

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Abstract.
In recent years a culture of conservation has been developed also regarding Modernism archives, that come to us with their often considerable amount of materials. Valorization, interpretation, fruition and sharing of knowledge address the works of many international scholars. In particular, using the continuous innovations of digital modelling tools, a field of this research is developing reconstruction and new interpretations of masters' unbuilt or demolished projects. Contemporarily to the rising of H-BIM for modelling architectural heritage, some experiments aimed to represent on paper architectures are exploiting BIM potentialities. Moreover, some recent researches links H-BIM modelling with displaying of uncertainties of digital reconstructions.
The present research constitutes a step of experience aimed at the generalisation of a methodology for the visualization of the level of reliability of digital reconstruction of architectures starting from archival documentary heritage. The peculiarity of the case study, an architecture now documented on paper but which has completed its cycle of existence through construction and subsequent demolishment, and that of the archival fond, which has come down to us in fragmentary form, make it an interesting example because of the complexity of the issues it poses.

Keywords: Modernism Archives, Reconstructive Modelling, H-BIM, Reconstruction Reliability, Aldo Morbelli, On-Paper Architecture.

1 Introduction

The architectural archives are unique and significant sources for the scientific research aimed to understanding Architecture in all its aspects connected with multiple disciplines (history of architecture, conservation, design theory, history of representation).

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In particular, using the continuous innovations of digital modelling tools, a field of this research is developing reconstruction and new interpretations of masters' unbuilt or demolished projects.

At the end of 20th century, some scholars mainly used CAD, 3D computer graphics, and motion graphics in the process of reconstructive modelling and animation [1] [2].

In more recent years, simultaneously with the rising of H-BIM for modelling architectural heritage, some experiments aimed to represent unbuilt, no longer existing, and partially built architectures are exploiting BIM potentialities.

Moreover, some recent researches link H-BIM modelling with displaying of uncertainties. The present proposal aims to apply BIM modelling to the digital reconstruction of unbuilt and demolished architecture, referring to the documental heritage at the Archives at the Biblioteca Centrale di Architettura "Roberto Gabetti", Politecnico di Torino. In particular, these archives kept the works of Carlo Mollino (1905-1973), subject of previous studies related to H-BIM reconstructive modelling [3] [4] and Aldo Morbelli (1903-1963) that will be deepened in this paper. The reconstructive 3D models already realized are collected in a web-site today in construction.

For this reason, the establishment of a methodological framework for these kinds of 3D models, is needed.

Reconstructive digital modelling using archival sources starts from graphical analysis, that is a real survey work implying: the hypotheses of reconstruction of sketches and drawings sequence, the check of the consistency between the scale drawings, and the proposals of integration of the missing data. After doing this, each project has to be decomposed e.g. identifying its levels, its technological elements, its functions.

Agreeing the statements of the Charter of London (2009) [5], in this kind of digital reconstructions the knowledge they represent should distinguish between evidence and hypothesis, and between different levels of probability.

The buildings analyzed are digitally modelled by Revit® and some features and potentialities of BIM tools are evaluated, also comparing with the previous experiments.

In particular, in this phase of the research, we are exploring the potentiality of BIM aimed to evidencing the reliability of reconstructive modelling based on different documentary sources.

For this reason, the case study in progress, i.e. Casa Treves-Sacerdote by Morbelli built in Turin from 1947 and demolished in 1964, can flank the already made reconstructions, assuming with them the role as a prototype for the creation of future reconstructive models.

2 Background and State of Art

As anticipated, digital reconstruction based on archival sources is a matter that requires a high level of interpretation [6].

The results of graphical analysis could be collected in a digital model, and the practice of decomposition is crucial, addressing the successive choice of modelling strategies. Graphical analysis and digital modelling offer new life to objects that become explorable, sectionable and decomposable, and allow the scholars to propose new interpretations of the architects' work, also in relation with the historical context and physical environment, in which they had to be built.

Being in the case of hypothetical reconstruction of a cultural heritage, it should be clear the extent and nature of any factual uncertainty [5]. Moreover, "documentation of the evaluative, analytical, deductive, interpretative and creative decision made in the course of computer-based visualisation should be disseminated in such a way that the relationship between research sources, implicit knowledge, explicit reasoning, and visualisation-based outcomes can be understood" [5]. The Charter of London is a general reference for computer-based visualizations of cultural heritage [7]. In particular, the Charter underlines two core concepts for digital reconstruction: the intellectual transparency, intended as the "provision of information, presented in any medium or format, to allow users to understand the nature and scope of 'knowledge claim' made by a computer-based visualisation outcome" [5], and Paradata as "information about human processes of understanding and interpretation of data objects" [5].

Sharing the basilar concepts of the Charter, the Principles of Seville (2012) [8] are devoted to the specific field of virtual archaeology. The scope of interest of the Principles is conceptually quite similar to that of digital reconstruction from archival documents. Indeed, as Brusaporci observed, the "principle of transparency has been widely developed in the archaeological field, where the digital reconstruction of artifacts (in their ancient configuration) is largely based on indirect information, comparative analysis, interpretative hypothesis" [9].

The Principles state that "all computer-based visualization must be essentially transparent, i.e. testable by other researchers or professionals, since the validity, and therefore the scope, of the conclusions produced by such visualization will depend largely on the ability of others to confirm or refute the results obtained" [8].

About these two main references and the related notions of transparency, reliability, paradata, and metadata see the in-depth writings of Brusaporci (2017) [9], and Maiezza (2019) [10].

Ippolito (2015) deals with the issue of transparency and reliability of 'Archeological Architecture''s digital reconstructions. The work presents two case studies on Etruscan and Roman heritage and develops "intensive survey conceived as a structured system capable of organizing diverse information like texts, images, 2D and 3D models as well as of representation conceived as an instrument for describing, popularizing and communicating information related to cultural heritage" [11]. The scholar underlines the value of exchanging objective data open to further interpretations, between the interdisciplinary group that works on this kind of heritage. Moreover, the research on one side defines criteria for cataloguing the objects related to the properties of archaeological objects, on the other identifies three typologies of elements aimed to the scientific nature and reliability of the knowledge process. They are distinguished as: certain, extractable, and deduced. This classification, and the specifications given by the author, was very interesting for the construction of our research's methodological framework.

In regard to BIM modelling for representing transparency and reliability of digital reconstructions some researches should be remembered.

In particular, BIM was mainly applied for creating 3D semantic models of the architectural projects from Renaissance treatises, and modelling partially existing buildings (integrating survey of the rests and documentary sources). These case studies, characterized by the need of integration of different sources, highlight the issue of transparency and reliability of the process and results of reconstruction.

In the following, will be developed the reference to several case studies that faced this issue.

The research of Apollonio, Gaiani, Sun [12] was based on Palladio's treatise, exploiting BIM potentialities in regard to the semantic construction of the digital model, the object-based parametric modelling, the multiple data enrichment to the geometric model, and the displaying of uncertainties. This last issue was faced aiming to allow transparency of information to users, and to demonstrate the solutions chosen for representing uncertainties and lacks. The scholars defined eight levels of progressive uncertainty for reconstruction process. The progression goes from the reconstruction based original designs to the reconstructive conjectures failing references. The uncertainty display used the density slicing color code.

This research refers to sources comparable to those of our case study, but the decomposition criteria are based on the architectural orders that rule Renaissance architecture.

Another research on this line, carried out by the same Apollonio with Giovannini [13], deepened the issues of validation of 3D modelling reconstruction process, exchange and reuse of information, and collaboration between experts. It concerned the digital reconstruction of Porta Aurea in Ravenna documented by fragment and ruins, and different iconographic and textual documents. In this case was proposed a gradient color scale for visualizing the uncertainty in a progression that goes from reconstruction based on laser scanning survey of archaeological fragments to reconstruction failing references.

Few years later, Bianchini and Nicastro [14] defined a new parameter in the process of integration of BIM with survey, communication and management of built Cultural Heritage. This parameter is the Level of Reliability (LOR), intended to measuring and explaining the consistency and transparency of digital objects, resulting from critical analysis and interpretation of Cultural Heritage. The methodology has been applied to two architectural complexes inside Sapienza Main Campus in Rome. The coding of LOR has to consider both the geometric reliability of digital objects and their ontological correspondence to the real buildings they intend to describe.

Despite the difference between the last case study, and that we are carrying out, the interest of this research is in the possibility of generalization of the method, applicable to very different case study in the field of Cultural Heritage.

Finally, our research group has faced the issue of reliability of digital reconstruction from archival sources in a previous work [4] (Fig. 1). The case study was the unbuilt project for the "Teatro Comunale" in Cagliari, designed by Carlo Mollino between 1964 and 1965. The building has been digitally modelled and the potentialities of BIM aimed to evidencing the reliability of reconstructive modelling based on different documentary sources have been evaluated (Fig. 2), also in light of the aim to create a collection of reconstructive models, to be shared on-line.

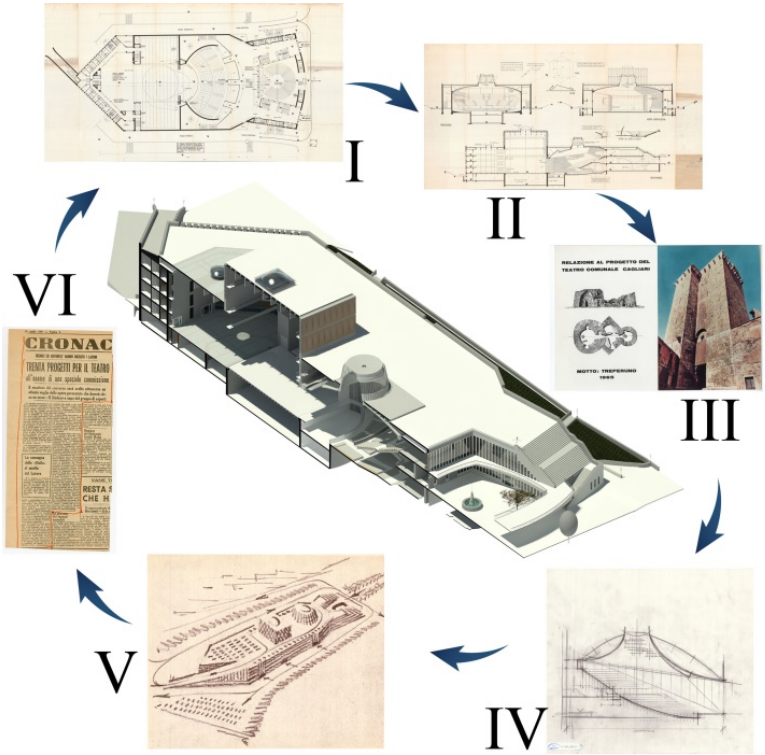

Fig. 1. Level of analysis of archival sources of the project for the "Teatro Comunale" in Cagliari. (Source: Spallone, Capaldi 2019).

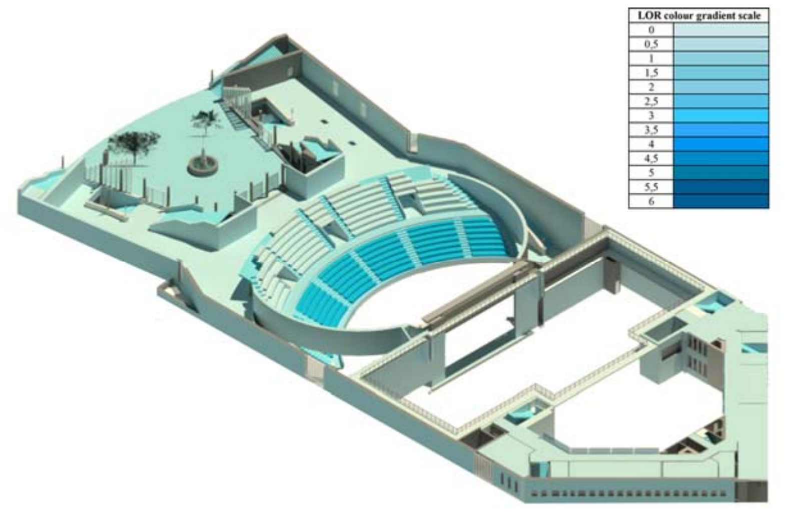

Fig. 2. Level of reliability of digital reconstruction of the project for the "Teatro Comunale" in Cagliari. (Source: Spallone, Capaldi 2019).

3 Methodology

The Charter of London states that "it may not always be possible to determine, *a priori*, the most appropriate method, the choice of computer-based visualisation method (e.g. more or less photo-realistic, impressionistic or schematic; representation of hypotheses or of the available evidence; dynamic or static) or the decision to develop a new method, should be based on an evaluation of the likely success of each approach in addressing each aim" [5].

The Charter's indications would seem to allow a relativization of the digital reconstruction method. In the current phase of research, it is believed, however, that it is useful to identify a "common denominator" able to build a unifying framework, at least to describe case collections characterized by elements of homogeneity (cultural, temporal, geographical, typological...).

The two main archival fonds of architects of Modernism, those of Carlo Mollino and Aldo Morbelli (Figg. 3-4), owned by the Central Library of Architecture "Roberto Gabetti", at Politecnico di Torino, offer interesting case studies on which to experiment such methodologies.

The first fond come to us almost complete, since Mollino's collaborators, at his death in 1973, brought the materials preserved in the professional studio (which concerned the projects of Carlo Mollino and his father Eugenio) to the Architecture Faculty offices. The second fond arrived, incomplete, at the Central Library of Architecture, donated by the heirs in 2017.

Restricting the analysis to documents related to architectural projects, we can list over 130 projects, only twenty of which were built by Mollino, while as far as Aldo Morbelli's work is concerned, since the archive is currently being inventoried, we can speak of a comparable total number of projects, with the difference that most of them have been realized.

From the very beginning, in the same years, Mollino and Morbelli seemed to compete and, in some cases, share private clients in Piedmont - families of the intelligentsia and families of the emerging industry - as well as public commissions, obtained through competitions.

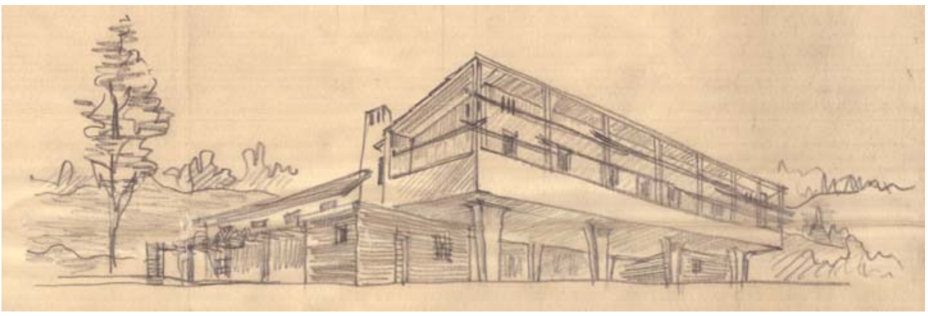

Fig. 3. Perspective view of Cascina Treves-Sacerdote (Archivi della Biblioteca Centrale di Architettura "Roberto Gabetti", Politecnico di Torino, in the following BCA. Fondo Aldo Morbelli).

The architectural typologies on which they work are also the same: from houses in mountain and rural areas, to luxury condominiums and economic-popular buildings, to office and entertainment buildings.

As part of the two architects' wide-ranging activity, Drawing expresses the right balance between intuition, formal invention and technical solution to the projectual problem [15].

Mollino's projects had many variations: together with descriptive materials and photographs, dozens and dozens of sketches, overall drawings and executive details characterize them, regardless of their aim to be built. They are traced "elaborating and re-elaborating on the same sheet of paper at the same time sketches, construction details, iconographic models, distribution solutions" [16].

Morbelli's drawings, sometimes flanked by short texts, correspondence and photographs, document the architect's graphic skill: he moves from technical to expressive drawing, through overall and interior perspectives, the latter enriched by furnishings, frills and figures.

Among Mollino's projects, about twelve were previously digitally re-constructed, choosing different software and modelling strategies in response to the different features of the specific project analyzed. Today, the digital reconstruction of Morbelli's buildings has involved a couple of projects. The comparison between the fonds of the two masters can encourage generalizations useful to form a common work base.

Therefore, the present experiments are developed in the field of digital reconstructions of architectures whose main research source is the twentieth century documentary heritage of analogical nature. These sources can be classified as graphic, iconographic and textual documentation. The field of investigation is so limited that they can be defined as cases linked to the life cycle of the building, between conception and construction, with an increasing degree of complexity. With a warning: according to the objectives of the reconstruction, reference models will have to be defined, which can, for example, reveal the relationship between the final drawings and construction, or compare alternative project hypotheses, or clarify sequences in the shape variations of the design of the building. Therefore, for all reconstructive models, it is crucial to define which phase to refer to in function of the heuristic meanings and cognitive values that are most important for the current research. At the two ends of the classification, we can place the ideal buildings and the existing ones, between these, the unrealised buildings, and the constructed and demolished buildings. As observed in the above mentioned previous research [4], by addressing the issue of digital reconstruction of designs, and in particular of unrealised ones, it is needed to pay attention to the role of the “re-constructor”, or rather, the “re-creator”, who analyzes, integrates, interprets and realizes a real re-project of the building.

The criteria he assumes for de-composition and re-composition are answered appropriately by BIM tools. Moreover, the operator’s working process includes rethinking, discoveries and hypotheses of alternative solutions to which BIM guarantees a good level of interactivity and, above all, the possibility of considering the time dimension in the evolution of the project.

The possibility offered by BIM to manage in a single model the life cycle of a building, from the different hypotheses, to the design phases, to the variants, to the construction, to the transformations, to the demolition, can favour the realization of models starting from the archival heritage. This does not exempt scholars from a careful choice of what should be the reference model of the modelling process. It can be identified in the hypothesis or in the project phase for which a more complete and coherent documentary basis is available, to be compared, however, with the meaning and value of the design also in relation to the master's poetics.

The available information, depending on the development phase of the projects, above described, will lead to highlight and compare different models.

As far as still existing buildings are concerned, the design model may have an important element of comparison in the survey model (which is another kind of documentation of the object). The design model, including the ideation phases up to the final and constructive ones, can be integrated with the transformations over time and possibly enriched, once its coherence has been ascertained, with diagnostic surveys aimed at reading stratigraphies and materials, and with as-built survey data.

As far as ideal buildings are concerned, in many cases, the design model and the ideation phases will be characterised by a degree of detail that does not include the executive requirements. Therefore, as for the two following cases, its value will consist of the spatial exploration of the building and its inclusion in the environmental context, if documented.

With regard to buildings that have not been constructed, the model of design and ideation phases will have a degree of definition that depends on the causes and conditions for which the projectual process has been interrupted. For example, if it is a submission for a competition, the level of definition is stated by the requirements of the call for proposals, and if the relationship with the client is broken, the definition phase cannot be defined in advance.

Finally, with regard to the buildings constructed and demolished, the model of the design and of the conceptual phases, up to the final and the constructive phases, can be compared and, if necessary, integrated with the model of the built artefact, documented by any iconographic sources that may be available after the construction, such as, for example: surveys for transformation projects, site photographs, drawings and photographs for publications, video footage...

From the previous analysis emerges the importance of the recognition of the project phases sequence, with the aim of creating not a model for each hypothesis, but a philological narration of the milestones of each project.

Given these taxonomies, the concept of transparency takes on different declinations on a case-by-case basis, in particular when we don't have a physical reference. As Brusaporci recommended, transparency and paradata (intrinsic and extrinsic) are strictly linked and the last have to be recorded into the database of the interpretative reconstructive model [9].

In the follow-up of the previous research mentioned above [4] the philological approach proposes the classification of archival documents inspired by the level of project's graphic development (from ideation sketches to final and constructive drawings), the sequence of the design process (from plans to elevations and sections), the other iconographic materials (photographs, physical models, videos…), the documental sources (correspondence, technical documents, competition notices…), and the published book or journals articles about the project, if any.

These sources (eventually grouped) have to be referred to different levels of analysis. In our intention, each level adds a quantity of information that, joined with the previous, increase the level of reliability or compliance of the reconstruction with the original design. The interpretative job, present in the entire reconstructive work, reaches its acme when inconsistencies and lacks are philologically solved by comparison with other projects of the same master or other projects belonging to the same cultural milieu.

The approach based on levels of analysis is applied in the classification and linking of archival sources and is used as an application in BIM environment. In this last, it has to be add with a second type of levels: the different floors of the building used to assign a specific position of plans, sections, and elevations in a three-dimensional space comparable with the reality. Using this method, at each floor and part of the software space corresponds the sum of the reliability of the levels of analysis found from archival documents.

Due to the classification exposed it is possible to define the level of compliance between the model created and the documents and data analysed. Defining keywords of the elements used to specify a project and applying them to the object of the research, it is possible to determine a class of correspondence that can be applied in the construction of the model to find a total class of reliability of the reconstruction made and of the parts analysed.

Fig. 4. Vintage photograph of Cascina Treves-Sacerdote (Archivi BCA. Fondo Aldo Morbelli).

4 Case study

Aldo Morbelli (1903-1963), born in Orsara Bormida in Piedmont, is an Italian architect who established his atelier in Turin in the 1930s. Morbelli worked for over thirty years producing about one hundred architectural projects, mainly for single-family houses and holiday homes in the countryside, by the sea and in the mountains, social housing for INA-CASA, entertainment buildings, and corporate representative offices. Architectural projects were often completed with studies of the interior fittings, right up to the design of the furnishings, some of which have gone into production and gave him wide fame. The reconstruction of the Teatro Regio in Turin was the most important task, obtained in 1937 thanks to the victory of a competition. It was drafted in numerous variants with his colleague Robaldo Morozzo della Rocca, but it was never completed and, on his death, passed to Carlo Mollino.

Morbelli's drawings testify to the architect's extraordinary graphic ability to control space and architecture. He uses different tools to draw: the greasy pencil, the felt-tip, and the Indian ink to draw sinuous, baroque lines, sometimes completed with watercolour and tempera (Fig. 5).

Morbelli's work has been little studied in recent years, although some of his projects were published in magazines such as Casabella, Atti e Rassegna Tecnica, L'architettura: cronache e storia, and a monographic issue of L'architettura Italiana was dedicated to his houses.

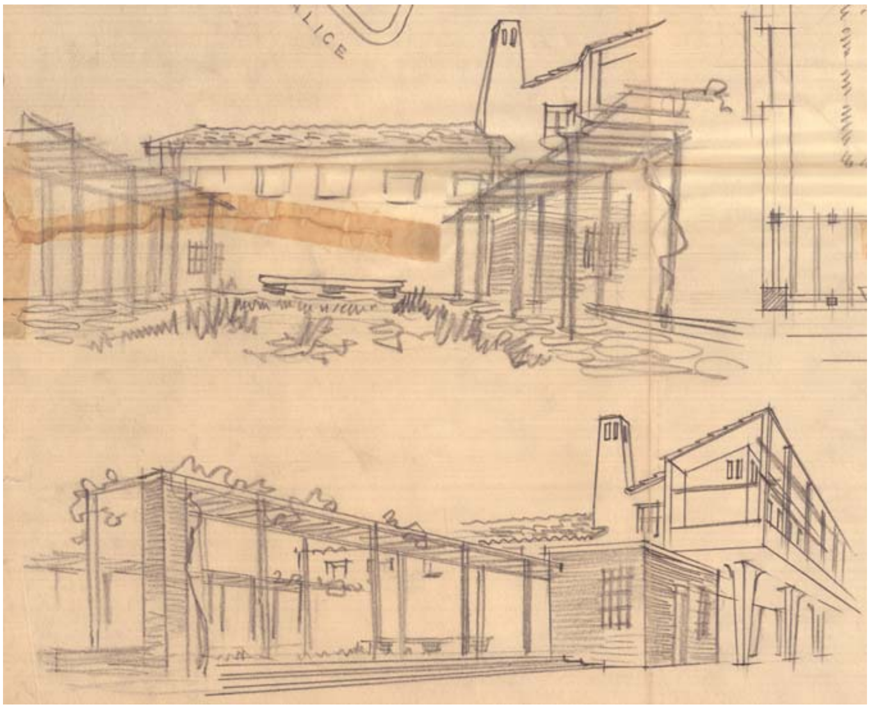

Fig. 5. Perspective view of Cascina Treves-Sacerdote (Archivi BCA. Fondo Aldo Morbelli).

A brilliant violinist, a passion he cultivated in parallel with architecture and illustration, Morbelli frequented Turin's cultural milieu: the philosopher Norberto Bobbio, the sculptor Mario Giansone and the painter Enrico Paulucci.

The theme of the country house characterized Aldo Morbelli's activity since his first professional assignments in the 1930s in the Monferrato area, in the province of Alessandria. It is a theme that he interpreted through a series of references to mediterranean architecture, making use of elementary forms, relationships of masses and voids, and insertions of curvilinear elements in constant dialogue with the external environment. He combined these features with the use of traditional materials and the inclusion of classical elements.

The Cascina Treves-Sacerdote, also called Cascina Ada, was located not far from the elegant Turin area of Borgo Crimea. Between 1947 and 1949, Morbelli designed the Cascina as a real farmhouse, equipped with barn, fruit storage room, and stable. Signs of modernity were introduced by the large dark wood balcony and the central portico supported by square-section tapered pillars finished by plaster, and plastically joined to the ceiling of the portico. The building had a U-shaped plan very articulated on the three facades. The sudden demolition, in 1964, was due to an allotment for new buildings.

The archival documentation includes eighteen plates, drawn in pencil and ink on tracing paper and heliocopies, photographs of a physical model, which has been lost, and construction-site photographs. In particular, the final drawings represent the building through a 1:1500 scale roof plan, plans, elevations and sections in scale 1:50 (Fig. 6), and construction details and finishes in scale 1:10 (Fig. 7). A series of perspective views complete the technical drawings.

The case study, beyond the general interest in digital reconstruction aimed at preserving the memory of an interesting master in the Turin architectural milieu of the mid-twentieth century, represents an object of particular complexity for testing the reliability [17] of reconstructions of architecture on paper, given that its life cycle went beyond that of construction, but was finally demolished.

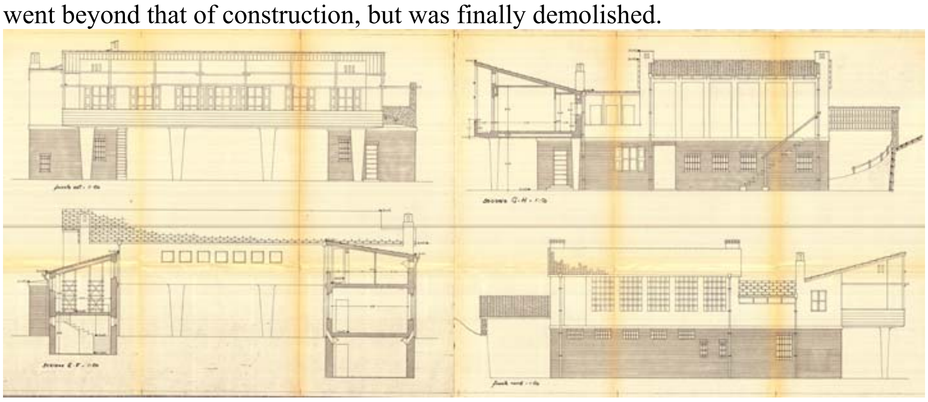

Fig. 6. Elevations and sections of Cascina Treves-Sacerdote. Original scale 1:50. (Archivi BCA. Fondo Aldo Morbelli).

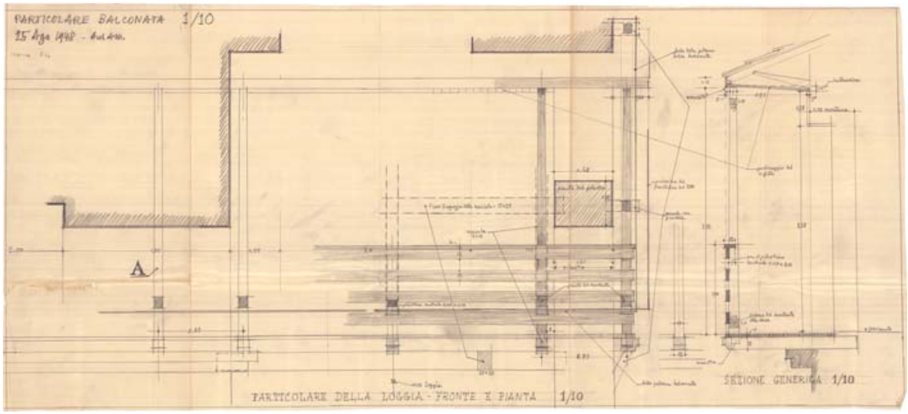

Fig. 7. Detail of the railing of Cascina Treves-Sacerdote. Original scale 1:10. (Archivi BCA. Fondo Aldo Morbelli).

5 Workflow

As mentioned above, Cascina Treves-Sacerdote has completed a life cycle from conception, to construction, to demolition. Working on a digital reconstruction using the designer's autograph drawings means referring to a phase prior to construction which, in this case, is well documented at a scale of 1:50, with some details at a scale of 1:10. These drawings, all dated 1948, therefore refer to the so-called executive phase of the project. On the other hand, site photographs refer to the phase immediately following and can be evidence of the so-called variants in progress, but also clarify elements and details not completely outlined in the drawings. For this reason, it was decided to build the digital model at the final moment of its existence on paper, taking into account that previous and subsequent phases can be easily implemented in the BIM model.

Reconstructive digital modelling from archive sources starts from a deep graphic analysis of the data, a real survey work applied to the whole complex of drawings and design documents.

This method of analysis involves the search for traces on paper, the verification of the sequence of drawings, the comparison of the data at different scales, the correspondence between the drawing and the dimensions, the analysis of the variants of the project or the elements, and the dating of each document.

Fig. 8. Archival drawings and BIM modelling of Cascina Treves-Sacerdote. (Archivi BCA. Fondo Aldo Morbelli, BIM Modelling: F. Natta).

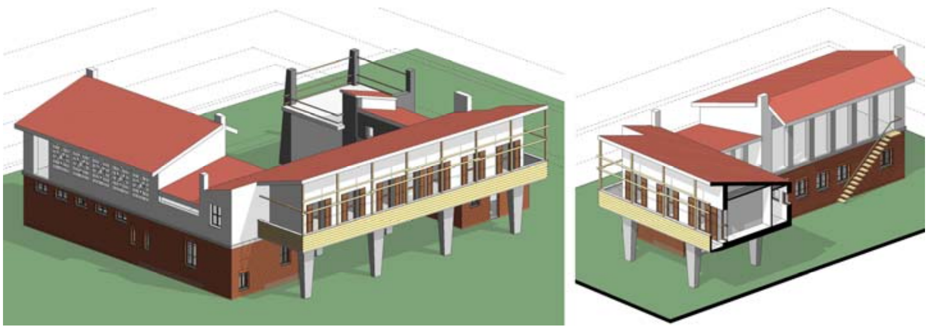

Fig. 9. Reconstructive BIM model of Cascina Treves-Sacerdote. (BIM Modelling: F. Natta).

The digitized part of Aldo Morbelli's fond allows us a general reading of the preserved documents on which to make the first considerations. The integration between drawings and photographs allows us to evaluate the relationship between the design and the building, comparing the abstraction of the idea with the material execution.

Fig. 10. Comparison of archival photos and clay render of the reconstructive model. (Photos: Archivi BCA. Fondo Aldo Morbelli, BIM Modelling: F. Natta).

The 1:50 scale plates have been analysed, selected and assumed as final drawings, referring to dating and content. The possibility of analysing elements by comparison of drawings and photographs, even partially, can provide information that enriches the interpretation of the elements, but also refute their conformation, position or existence in the built reality. Moreover, the variants during the construction works, if partially documented, complicate the interpretative work of digital reconstruction. Referring to the London Charter, the digital reconstruction of this project intends to visualize the quality of the data, distinguishing between those documented and those resulting from interpretation, also evaluating the different levels of reliability.

For the digital reconstruction it was decided to operate within BIM software, a tool for creating 'intelligent' 3D models that provides in-depth information on the digital construction phases of the building (Figg. 8, 9, 10, 11, 12).

In this phase of the research we aim to evaluate the reliability of the data in its geometric features. The tools offered within the BIM software are therefore bound to this level of evaluation: in fact, in the archive documents there is no information on the stratigraphy of the construction elements. For this reason, in analogy with what frequently happens in the analysis of the historical heritage, the elements are modelled only through the thickness and/or geometric shape.

Fig. 11. Comparison of archival photos and clay render of the reconstructive model. (Photos: Archivi BCA. Fondo Aldo Morbelli, BIM Modelling: F. Natta).

Fig. 12. Details of the colombarius, reconstruction from the design drawing and the photos of realized building. (BIM Modelling: F. Natta).

Among the software that use these processes, (in this case Autodesk's Revit® 2021 software), updates are possible during the operational phases of the work: adding information to components, modifying construction hypotheses while maintaining the same envelope, allowing the temporal dimension to be considered in the evolution of the project.
The approach to the digital realization of an architecture on paper follows a philological criterion. Through research, examination and interpretation of texts, documents, drawings (and in this case also photographs) the data are processed into a three-dimensional model.

The first phase of the study concerns the cataloguing and classification of archival documents necessary for research. The identification of the documents must therefore be carried out through the design process, in order to have a complete vision of the entire work, also starting from the first ideas often outlined through alternating sketches and drawings.

Within the selected documents, therefore, the elements necessary for the re-drawing in BIM environment, divided into seven levels of analysis, are listed:

1. plans (starting from the basement floors to the roof);
2. elevations and sections;
3. details (construction and architectural details);
4. dimensions (written measurements);
5. texts (notes about geometrical features of the building);
6. functions (possibility of unique identification of the element);
7. photos (in the construction phase and as-built).

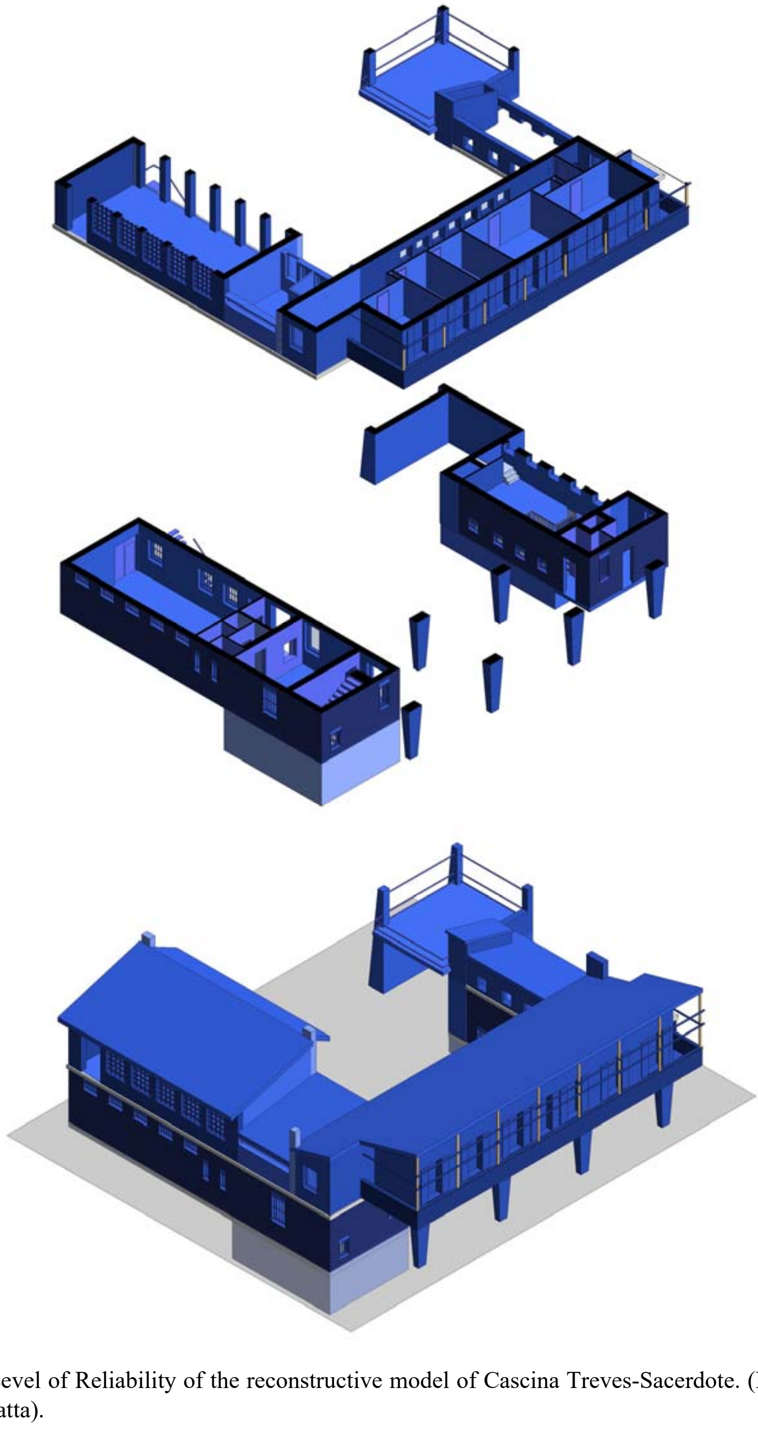

Fig. 13. Level of Reliability of the reconstructive model of Cascina Treves-Sacerdote. (Modelling: F. Natta).

As can be seen, the archival materials are sequenced according to the design workflow, starting with the plan, elevation, section and detail drawings and ending with the annotations, divided into dimensions, texts, and the functions, understood as the possibility of uniquely identifying the element through drawings. As seen above, the photographs, belonging to a later phase, must be considered with particular caution.

At this stage, the analysis documents the reliability of the reconstruction only on a quantitative level, recording the different information from the sources and giving them equal weight. However, we are aware that different weights could more effectively convey the quality of each data.

Each level provides a quantity of information which, together with the others, increases the level of reliability (LOR) of the modelled element.

The first two levels define the model in its three-dimensional representation. Each element represented in the plans is compared with its elevations and sections, if existing, otherwise it is subject to philological data integration.

The third level makes it possible to increase the degree of knowledge of the selected element (stairs, railings, interior doors and windows) through technical details of the design at a scale of 1:10.

Table 1. . Level of Reliability (LOR) Table with gradient colors and LOR values.

LOR - Colour gradient scale
0
0,5
1
1,5
2
2,5
3
3,5
4
4,5
5
5,5
6
6,5
7

LOR - Architectural elements									
CODE	FLOOR PLANS	Plans	Elevation and Sections	Details	Dimensions	Texts	Functions	Photos	Class results
	Basement level (-2,60 m.)								2,5
b	Wall (Foundation)	0	1	0	0,5	0	1	0	2,5
d	Wall (Interior)	0	0,5	0	0,5	0	1	0	2
f	Floor (Interior)	0	1	0	1	0	1	0	3
g	Stair	0,5	0	0	0,5	0	0,5	0	1,5
h	Window (Exterior)	0	0,5	0	0,5	0	0,5	0	1,5
m	Door (Interior)	0	1	0	1	0	1	0	3
	Semi-basement level (-1,20 m.)								4
b	Wall (Foundation)	1	1	0	1	0	1	0	4
d	Wall (Interior)	1	1	0	0,5	0	1	0	3,5
f	Floor (Interior)	1	1	0	1	0	1	0	4
g	Stair	1	1	0	1	0	1	0	4
h	Window (Exterior)	1	1	0	1	0	1	0	4
	Ground level (+0,00 m.)								3,5
a	Column	1	1	0	1	0	1	1	5
c	Wall (Exterior)	1	1	0	0,5	0	1	1	4,5
d	Wall (Interior)	1	1	0	0,5	0	1	0	3,5
e	Floor (Exterior)	0,5	0,5	0	0	0	0,5	0	1,5
f	Floor (Interior)	1	1	0	1	0	1	0	4
g	Stair	1	0	0	1	0	1	0,5	3,5
h	Window (Exterior)	1	1	0	0,5	0	1	1	4,5
i	Window (Interior)	1	0	0	1	0	0,5	0	2,5
l	Door (Exterior)	1	1	0	0,5	0	1	0	3,5
m	Door (Interior)	1	0,5	0,5	0,5	0	1	0	3,5
	Mezzanine level (+1,60 m.)								3,5
c	Wall (Exterior)	1	1	0	1	0	1	1	5
d	Wall (Interior)	1	0	0	0,5	0	0,5	0	2
f	Floor (Interior)	1	1	0	1	0	1	0	4
g	Stair	1	0	0	0,5	0	0,5	0	2
h	Window (Exterior)	1	1	0	1	0	1	1	5
	First floor level (+3,62 m.)								4
c	Wall (Exterior)	1	1	0,5	1	0	1	1	5,5
d	Wall (Interior)	1	1	0	1	0	1	0	4
e	Floor (Exterior)	1	1	0	1	0	1	0	4
f	Floor (Interior)	1	1	0	1	0	1	0	4
g	Stair	1	0,5	0	1	0	1	0	3,5
h	Window (Exterior)	1	1	0,5	1	0	1	1	5,5
i	Window (Interior)	1	1	0	1	0	1	0	4
l	Door (Exterior)	1	0,5	0	0,5	0	1	0	3
m	Door (Interior)	1	0,5	0	0,5	0	1	0	3
n	Railing	0	0,5	0,5	0,5	0,5	1	0,5	3,5
	Raised first floor level (+3,95 m.)								5
c	Wall (Exterior)	1	1	0	1	0	1	1	5
d	Wall (Interior)	1	1	0	1	0	1	0	4
e	Floor (Exterior)	1	1	0	1	0	1	1	5
f	Floor (Interior)	1	1	0	1	0	1	0	4
h	Window (Exterior)	1	1	0	1	0	1	1	5
m	Door (Interior)	1	1	1	1	0	1	0	5
n	Railing	1	1	1	1	0	1	1	6
	Roof level								4
o	Roof	0	1	0,5	0,5	0,5	1	1	4,5
p	Gutter	0	1	0	1	0	1	1	4
q	Chimney	0	1	0	0,5	0	0,5	1	3
	LOR - Architectural elements - Final Result								4

The next three levels (dimensions, text, functions) serve to confirm, correct or integrate what is represented. It should be noted, however, that the dimensions, which have a prescriptive value in the construction phase, are sometimes inconsistent in the drawings analysed.

The last level (photos) offers, due to the peculiarity of the case study, a term of continuous critical comparison with the archive drawings, as mentioned above.

For each floor of the building the geometrical/architectural elements are identified, catalogued and evaluated according to the objects offered by Revit® (Wall, Door, Floor...). Floor by floor each of these elements has been given a value.

The data related to each architectural element provided by the archive documents have been defined in a class of three values from 0 to 1:

- certain data (1): the element is defined through the considered level of analysis;
- incomplete data (0.5): the element is partially documented but in any case deductible in its shape and size;

- missing/incorrect data (0): the element is not documented or errors and inconsistencies are detected and needs for philological integration.

By entering this data into the reconstructive model it is possible to obtain the Level of Reliability (LOR) value of each element and the average reliability value for each identified or overall level of the whole project (Fig. 13, Table 1).

6 Results and Open Issues

The digital reconstruction of the Cascina Treves-Sacerdote project, in addition to the creation of an implementable three-dimensional model, allows us to analyse a series of data according to the information collected and subsequently processed.

The LOR table organized according to a division by floors allows to evaluate the quantity and quality of information for each level of the building. In case of lack of data, it is therefore possible to identify those areas in which to concentrate the search for new information to improve the quality of the reconstruction.

The matrix defined in a scale of 15 possible LOR values (from 0 to 7 inclusive of medium values) allows the assignment in scale of colours, from the lightest (less reliable) to the darkest (more reliable), to the elements of the three-dimensional model giving an overall view of the data quality.

The overall result of the work reaches an average value of LOR = 4 in the above-ground floor. The result is considered positive within the research while recognising the lack of information for the interiors and for the under-ground floor (LOR = 2,5).

At this stage, the overall average value may appear insignificant in itself if it is not accompanied by the reliability levels of the reconstruction of each individual element and in each of the floors of the building, based on the documentary data. On the other hand, the methodology developed will prove very useful when new data can be integrated into the life moment of the building reconstructed in this work.

Moreover, in the field of digital reconstruction from archival sources it is noted that, since the case study belongs to an incomplete fond, other information could have enriched the project, especially with regard to the technical texts and the detail drawings.

Future developments in the work will be able to draw on other projects belonging to the architect's archival heritage for comparison in order to formulate philologically coherent hypotheses with respect to stratigraphy and materials.

7 Conclusion

The present research constitutes a step of experience aimed at the generalisation of a methodology for the BIM modelling and visualization of the level of reliability of digital reconstruction of architectures starting from archival documentary heritage. The peculiarity of the case study, an architecture now documented on paper but which has completed its cycle of existence through construction and subsequent demolishment, and those of the archival fond, which has come down to us in fragmentary form, make it an interesting example because of the complexity of the issues it poses.

In the specific case study, other archival sources, such as the documents deposited at the Archivio Edilizio del Comune di Torino for the building permit that freeze the moment just before the construction, may contribute to represent one of the phases of the building's life. The possibility offered by BIM to integrate in a model the different design phases, together with the visualization of the LOR, would further increase the degree of complexity faced by the case study. Moreover, other tests on case studies with different characteristics will consolidate the methodology tested so far.

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