

Architectural Heritage and 3D Models

Mario Centofanti, Stefano Brusaporci and Vittorio Lucchese

Abstract Architecture represents the physical space built by man—in its immanent and tangible presence—and a spatial and temporal event. The architectural 3D digital model is the mediator between intellect and tangible reality, and it takes the form of a digital replica of the observable phenomenal reality. Thereby the model expresses—i.e. contains—the history and its passage through time; a *visual narration* that is part of the historical process and critical analysis. It's an interpretable *document*, but also a genuine critical-historical text, expressed with the figurative language of the virtual dimension. Presupposition of this methodology for historical analysis, it's a careful architectural surveying, a wise modeling project and an intelligent and critical use of the digital model.

Keywords Architecture · 3D digital models representation

1 Introduction

Information and modelling digital technologies have produced profound changes in architectural surveying and representation, accordingly to the use of 3D models.

If in the past the outcome of an architectonical representation was made by two dimensional drawings, nowadays they are integrated by 3D models.

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Architectonical heritage's 3D modelling is conceptually related to knowledge: it's required the values understanding and their appropriate documentation and representation. Digital models are architectural medium, in this way meta-models that describe the buildings, namely a complex system made by spaces, surfaces, materials, constructive technologies and degradation, with modification and stratification processes witnesses of events and cultures that have occurred over time. Therefore this kind of models are the antithesis of that digital non-places offered by video games' platforms, because they have to be representative of architectural individuals, with own characteristics, result of historical defined events, belonging to a precise context.

The chapter is divided into four sections: the second one is about the nature of the model for the historical architecture (Mario Centofanti); the third one illustrates an analysis' method, developed in the Italian experience, based on the use of interpretative models (Stefano Brusaporci); the fourth one is about a specific case study (Vittorio Lucchese).¹

2 The Role of the 3D Model in the Cognitive/Planning Process of Historical Architecture

The final product of an architectural survey is the representative model.

The meaning and essence of the changes in architectural models, in the transition from traditional surveying to surveying using 3D optical measuring techniques, above all with reference to the reciprocal interactions between subject, phenomenal reality and model, have all been amply explored.

Models can be generated by CAD software using manual modelling, or directly generated by automatic scanning, be static or dynamic, be manipulable and interactive, and demand the creation of suitable standards.

The model, in its role as mediator between the intellect and tangible reality, is the tool people use to organize their mental representations of perceptible, phenomenal reality. In the contemporary period this takes the form of a *digital replica*, with its own autonomy, and a level of verisimilitude and immersive potential that raises doubts over its being an integral substitute for reality within the cognitive process. Yet it is not possible to overcome the *otherness* between the model and the phenomenal manifestation of the real object; in a hermeneutic key, in the sense of an *isomorphic* relationship, intended not as identity but analogy [64, p. 491].

The model, in its role as a medium between the subject and the phenomenon, represents by its very nature a modification of the latter. This mutation is connected to the transit through the human mind and the patterns that significantly involve the subjective perception of the observer, and also to the reduction of the object/phenomenon represented to an entity which is in any case discretized, irrespective of the pro-

¹ The models of modern buildings presented in the paper are made by Stefano Brusaporci and Vittorio Lucchese.

grammed precision and definition. From a perceptive point of view, about the digital reproduction of the architectural reality, we recall the concepts expressed by Walter Benjamin in his classic “*The Work of Art in the Age of Mechanical Reproduction*” (1936):

the architecture as prototype of a work’s collective use through a distracted perception, that is fragmented, jerky; the substitution of the cultural value with the expositive value.

The study of architectural history focuses on the physical space constructed by man, its immanent, tangible presence and its dimension as event, as spatial and temporal happening.

The cognitive act is the experiential act. But it is the lived experience of the event as a sequence of spatial/temporal events, up to the event in the present that sums up all the previous ones. The model thus expresses — in the sense that it contains — the history and the passage of time of the situation explored from its conception, to its creation, to its transformations, up to the current period: historic/synchronic and diachronic sections, reconstructions and/or visualizations of modified situations, or intentions and prefigurations never actually implemented, or simply narrated.

If we refer to Paul Ricoeur’s reflections on the narrative dimension of architecture and the temporal dimension of architectural space [58], we can reconsider the model itself as a *visual account* of an architectural narration.

The structured, complex model, as explained thus far, figures in the process of historical/critical analysis as a ‘document’ therefore itself open to interpretation, but also a genuine *historical/critical text* expressed with the language of figuration in the virtual dimension.²

The premise of a restoration project is the necessary relationship with something pre-existing. Surveys and models therefore play a strategic role as a cognitive act—Brandi’s notion of recognition—and as a fundamental instrumental support, with regards to the *specular* relationship we expect between a descriptive/interpretative model and a planning model.

From the theoretical/methodological point of view we can draw parallels with the procedure of Reverse Modelling, in which a digital survey of surfaces and the construction of the relative digital model using polygonal or polynomial modelling represent a starting point for designing industrial products [44].

The specific nature of the architectural model however demands that we go beyond what is visible, exploring the intimate make-up of an architectural organism, namely its structural elements. The concept of duality that Brandi [9, p. 10] expressed with regards to works of art:

matter as the revelation of the image manifests the bipolar rapport between matter as appearance and matter as structure

also applies to historic architecture, where the matter/structure itself forms the architectural space. In this regard mention has been made of the notion of an *anatom-*

² “ [...] a serious graphic apparatus is first and foremost a record and at the same time a genuine historical/critical ‘text’, not expressed in the usual verbal language, but in the language of figuration.” [18, p. 472]. Also see [17, 19, 40].

ical survey, which implies the creation of a descriptive model including structural components and elements [23–25]. The latter must be explored and identified by means of the usual operations of documental analysis and non-destructive diagnosis as a precautionary measure, and then by monitoring while work in progress.

Models of this kind integrate our interpretation of geometrical and dimensional data and formal, figurative, architectural and spatial values, providing an analysis of the material and structural characteristics. To quote Vitruvius, this kind of model provides the correct premise for restoration projects that should succeed in combining the necessary *firmitas*, or solidity (reducing seismic vulnerability) with *venustas*, beauty (spatial and figurative restoration), and *utilitas*, usefulness—in terms of restoring function or repurposing. In the process of *critical restoration* the model fulfils various tasks when it comes to monitoring work in progress and any modifications to ongoing work; in terms of comparing the transformations wrought by the restoration work to the previous state of the building, and in the ongoing monitoring of the building after the restoration work for the purposes of planned maintenance.

3 From the “Graphical Analysis” to 3D Models for Architectural Analysis: The Italian Experience

In 1989 Mario Docci published a paper titled “*Disegno e rilievo: quale didattica?*” [Drawing and surveying: what didactics?], in the first issue of the journal “*Disegnare Idee Immagini—Drawing Ideas Images*”³ [31], concerning a methodology for architecture analyzing, tested by the author and his staff in the Course of Design and Surveying held at the Faculty of Architecture of the University of Rome “La Sapienza” from the academic year 1975–1976. The chapter recalls what he has already published in 1983 in the book “*Disegno e analisi architettonica*” [Drawing and architectural analysis] [33].

Aim of the chapter is presenting how drawing, in addition to be suitable for project communication, can be an instrument to study building’s characteristics. Referring to the structuralism lesson, drawing is regarded as a meta-language, that is a graphical language able to analyze another language, the architecture’s one.⁴

Although in the didactic field, it’s developed a research method for critical analysis, believing that going through the projects of great masters—modern and of the past—with drawing is a useful way to understand the architectural values.

³ The journal “Disegnare Idee Immagini—Drawing Ideas Images” is edited by the Department of Representation and Surveying (now Department of History Drawing and Restoration of Architecture) of Rome University “Sapienza”, published in Rome by Gangemi, indexed by Thomson Institute for Scientific Information (AHCI Arts and Humanities Citation Index) ISSN 1123-9247. Over the years the journal has been a constant reference for those who studies architectural analysis and representation, publishing many of the most relevant Italian essays. Except for the cited paper published in 1989, all the others issues that will be quoted from this journal are in full English text; in references there are the original Italian titles.

⁴ In general for a semiology approach to architecture:[8, 34].

In particular Docci quotes the expression “graphical analysis” from the book “*Analisi grafica dei valori architettonici*” [Graphical analysis of architectural values] of the mid-fifties (then 1960) by Vincenzo Fasolo, professor of History and Styles of Architecture since 1925; he also widely uses the instrument of drawing for reading, analyzing and comparing historic buildings in his essay “*Guida metodica per lo studio della storia dell’architettura*” [Methodological guidebook for studying the history of architecture] [36].

In the graphical analysis Docci identifies a methodology based on rigorous criteria, that allows to study proportions, volumes, forms, configurations and structures, and the relationship between all the elements that contribute to the conformation of the architectural language. In particular Docci focuses on the usefulness of schematizations, seen as a real interpretative models of architectural language [31, pp. 38–39]:

The graphic medium is used to create models for architecture, or urban space, understanding, to get a sense and analyse it as a scientist artificially reproduces a phenomenon in his laboratory. In this way drawing identifies with the model’s concept, or better with a knowledge’s graphical model. In this regard it should be noted that a model is really a model when it is composed of set of elements linked together by the same rules which govern the elements constituting the space, described by the model; therefore it couldn’t represent the building as it appears, but it establishes an analogy to point out the laws that regulate the organization of the work. Then it’s a process of reduction of the complex architectural reality, to exalt the significant characteristics, highlighting them in a schema.

On an operational level we have to do different analysis, but aware that they represent specific thematizations, and there should be a final re-composition of the results. In particular Docci suggests to conduct distributive, formal, spatial and structural analysis, of the relation between the building and its context, associated to synchronically and diachronically studies between it and others of the same architect and of other authors.

By surveying and representation digital technologies’ developing, there have been many applications related to historic buildings, especially aimed at its communication, enhancement, enjoyment and management. The debate on the relationship between new technologies and representation of architecture was, and still it is, wide-ranging [63, 65–67].

If at the beginning the studies involved on unavoidable problems of computer graphics—we remember the example of the model of the abbey of Cluny, made by IBM France in 1992—, through the years the technological progress of 3D modeling and rendering, especially real time rendering, has favored the development of virtual reality, in particular of virtual heritage that combines Information and Communication Technologies with the field of architectural heritage; moreover the technologies of augmented reality contribute to implement immersive, dynamic and interactive experiences [45]. Virtual reality allows the interacting simulation and real-time processing of all the information that is contained in the model; this aspect promotes the development and diffusion of virtual museums [59].

At the same time the graphical analysis methodology has found a way of developing in 3D modeling technologies, producing a field of study where the digital model acquires the function of “meta-model”, that is an instrument for architecture’s

critical⁵—and in particular historical-critical—analysis. Compared to traditional graphical analysis, made by two-dimensional drawing such as plants, elevations, sections, perspective and axonometric projections, 3D models allow a continuous multi-dimensional and multi-level interpretations, favoring visualizations and synthetically simulations.

Modelling and semantics problems—not more and not just issues of computer graphics—are related to the architectonic ones, so the digital model's characteristics are inseparably linked to the ones of architecture (for example if it's a ruin of classical age, a renaissance palace, a baroque church, a modern building) and to the ones of the specific and individual building under study. From this point of view the process of model's construction is particularly important, as critical synthesis and integration of architectural survey and analysis of historical documents; of particular importance it is the study of the transformation phases, of the relationships with the context, of the constructive elements. Moreover such models can be used as core aggregator and organizer of documental information, that is as framework for architectural information systems [10].

In the Italian experience numerous researches can be attribute to the area of 3D modelling for architectural analysis. According to a first classification, it's possible to distinguish between studies on historical architectures and studies on modern buildings, for which especially may be available original project; these graphical documents require a careful study, both from an historical point of view than in relation to the building.

A second classification can be made between studies on existing buildings and not more existing ones (or profoundly transformed). In the second case it is required the virtual reconstruction of missing conformations, philologically reconstructed. To this field can be attributed many of the experiences on surveying and virtual reconstruction of archaeological sites; among all we remember the researches coordinated by Francesca Fatta on the archaeological sites in Northern Africa and in Southern Italy: models are built referring to a systematic study of archaeological maps, essays on architectural and archaeological history, drawings made for excavations since the eighteenth century, artefacts in museums [37].

On 3D models for historical critical analysis, it's significant the experience coordinated by Mario Docci regarding the digital reconstruction of the Sangallo's project for the St. Peter's Basilica, based on the drawings made for Pope Paul III in 1537–1538 and on the reverse modeling of the original wooden model in 1:30 scale. Known are the criticisms advanced by Michelangelo about low lighting, excessive decorations and too many orders of columns; on the whole, he said that the project wasn't conforming to classical language. The digital model allows us to verify the values of the Sangallo's project, to study the shape of the dome, to increase proportional analysis and, last but not least, to understand the author's concept [7, 32].

⁵ The “historical-critical method” refers to a set of criteria for the historical and philological study of the architectural heritage; the building it's intended as a synthesis of modification and transformation that conduced it to the current configuration, results of architectural cultures and interventions that have taken place over time [15].

Not different experience it's the one proposed by Marco Carpicci, who presents the 3D digital reconstruction of architectures drawn by Leonardo da Vinci, considered emblematic of his thought. The study was conducted according to a philological and hermeneutic point of view, which aims to reveal Leonardo's ideas [21].

The research unit guided by Marco Gaiani presents an hypothesis of attribution to Palladio of a drawing regarding Villa Contarini a Piazzola sul Brenta (secc. XVI–XVII–XIX). Being available limited drawings, the study develops issues of model's semantization in order to built the whole model of the planned building [2].

In the chapter on the Palazzo Mattei di Giove in Rome (XVI–XVII), Livio Sacchi uses the digital model to study geometrical, proportional and constructive building's rules [61].

Mario Centofanti applies the method of 3D modeling to the study of architectural heritage, using the analysis and views made by the digital model to explore the architectural characteristics of the building of Margaret of Austria in L'Aquila (XVI–XIX centuries) [25].

On the virtual reconstruction of no more existing configurations of historical buildings, we cite the work of Stefano Brusaporci about the churches of St. Justin and St. Paul near L'Aquila (XIII–XVIII–XX centuries), churches that in 1946 have been subjected to restorations. In particular the first one was reconfigured it in a medieval way. Brusaporci virtually re-built the church as it was before according to architectural survey and archival data; the historical photographic documentation of 1946 made it possible—through techniques of digital photogrammetry, used in analogy to what happens in forensics and accident fields—to define the architectural elements now missing ([14]), (Figs. 1 and 2).

Important contributions are related to the modern architecture. The publication of 2001 titled *Architettura Disegno Modello* [Architecture Drawing Model], editors Piero Albisinni and Laura De Carlo, proposes an experience based on the use of 3D models for the graphical analysis of the works of Giovanni Michelucci, Maurizio Sacripanti and Leonardo Savioli. The study, that starts from original drawings, favours the analysis of these authors and of their works in relation to their historical context. 3D models, sectioned and/or exploded, with the analysis of selected components, promote critical representations [1].

Livio Sacchi, aiming to a close examination of the theories underlying compositional choices, presents the virtual reconstruction of some unrealized buildings—the buildings represented in *Studi per la Città Nuova* by Antonio Sant'Elia (1913–1914) and the *Danteum* by Giuseppe Terragni (1938)—as well as of a series of architectures built in the modern age, in particular the ones of the EUR district (1935–1936) in Rome [66].

Among the studies on the use of models guided by Riccardo Migliari, we remember those who have, as case studies, the *Maison Citrohan* of Le Corbusier and the *Danteum* of Giuseppe Terragni. In particular, with regard to the second one we observe the particular attention placed in setting the project, not realized, in the historical context of the city of Rome [52].

The theme of modern movement studying through digital modelling, in order to investigate and experience buildings no longer existing, it's presented by Francesco

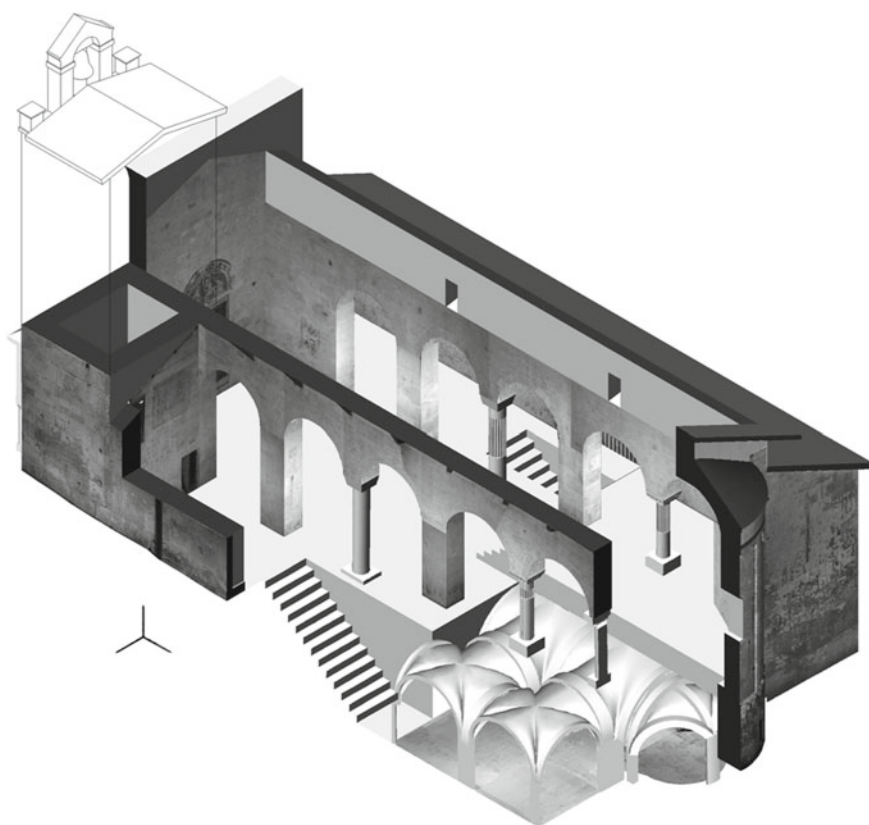


Fig. 1 Digital model of S. Justin's church. It allows to represent building's architectural characteristics

Maggio and Marcella Villa with the digital reconstruction of houses realized for the V Triennale of Milan in 1933, and then demolished [47]. Francesco Maggio also deals with the study of two existing buildings in Agrigento: the Balilla's House by Enrico del Debbio (1929) and the Post Office building by Angiolo Mazzoni (1931–1939) [46].

And similarly Stefano Brusaporci uses 3D models in his essay on modern Italian architecture [14] (Figs. 3, 4, 5, 6 and 7).

Rodolfo Maria Strollo, in a study on the complex of the observatory of Tusculum (1939), not only presents the surveying model, but uses models—derived from original drawings—to compare different planning solutions, in order to analyze for each one the figurative and material values, and at the same time to reconstruct the events that led to the final design configuration [63].

The condition of the digital model to be freely represented, interrogated and browsed, in time and space, according to broader media, semiotic and epistemological schemes, compared to traditional 2D drawings, favours the study and the



Fig. 2 3D photorealistic model of the church of S. Paul near L'Aquila (XIII–XVIII–XX centuries)

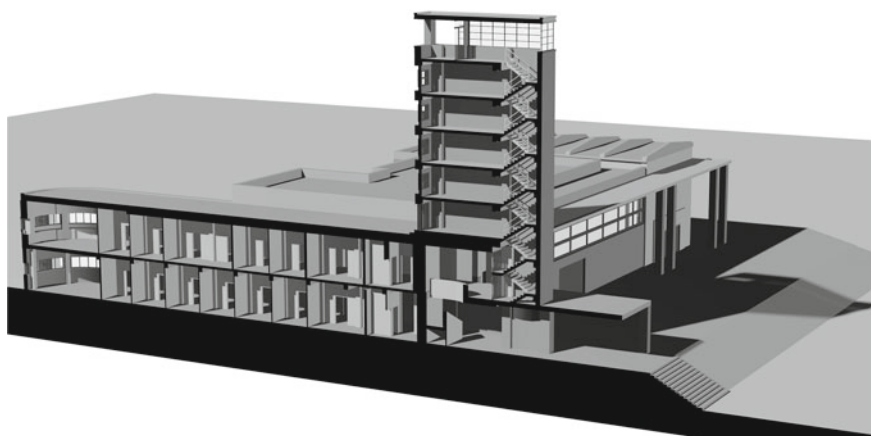


Fig. 3 Casa del Balilla in Ascoli Piceno (1933–1934). Rendering with the perspective section of the tower and office block

communication of architectural heritage's values and characteristics. With a risk of aestheticization own sake [48]—a “*Dionysian tension*” of “*absolute appear*” in the words of Purini [56, p. 95])—but with new and relevant scientific virtue.

Obviously the case studies cited are not exhaustive; they want to represent the contents of a line of research that can benefit greatly from the development of information technology but which has the presupposition of its methodological application in a

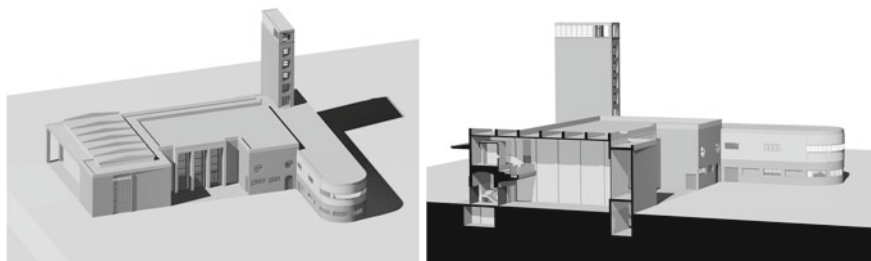


Fig. 4 Casa del Balilla in Ascoli Piceno Isometric rendering and perspective section of the cinema. You can see the office block with a tower, the hall of the gym, cinema

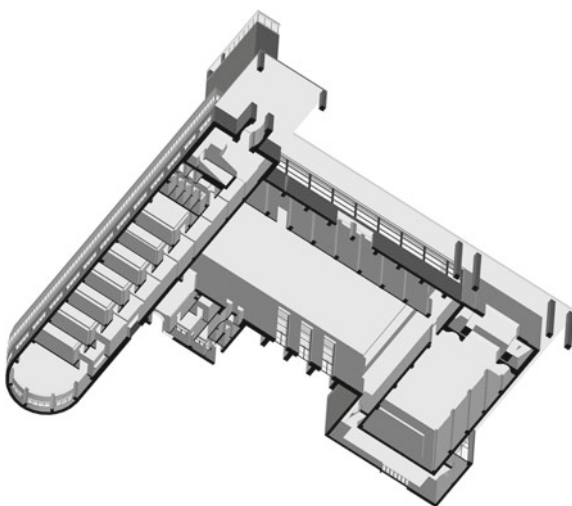


Fig. 5 Casa del Balilla in Ascoli Piceno. Render isometric split from the bottom. Although internally the buildings are connected, each has its own entrance on different elevations

depth historical analysis, in a careful architectural survey, in a wise modeling project and in an intelligent and critical use of the digital model.

4 Case Study: The “Cinema Massimo” in L’Aquila

The “Cinema Massimo” in L’Aquila, commissioned by the *Istituto Nazionale Fascista Assicurazione contro gli Infortuni sul Lavoro*, was planned by the roman architect Luigi Ciarlini between 1940 and 1941 and built between 1943 and 1947 [14]. The project is part of the renovation of the historical cities and belongs to that process of *social buildings* development, promoted by the Fascist government. In this period were built many constructions for directional activities and social services

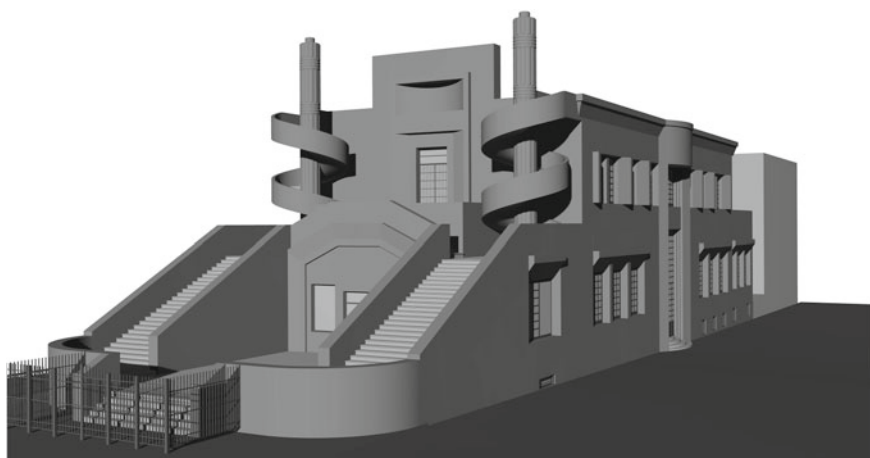


Fig. 6 Opera Nazionale Dopolavoro in Chieti (1933–1934). Rendering of the principal front, characterized by two helical stairs to reach the roof garden

such as schools, hospitals, government agencies offices, *case del Fascio*, buildings for workers' club, etc. There are "new" building typologies and among them a particular importance was given to the cinema for cultural purposes and propaganda. The renovation of L'Aquila historical city had already begun in the second half of the nineteenth century [22], focusing on the widening of Corso Federico II, the main axis of the urban plan, with the purpose, never fully completed, to build continuous porticos along the main street's sides.

The typological-distributive system of the Cinema Massimo follows from the requirements of context insertion, with the integration of the external space of the portico with the building project (Fig. 8). From the porticos, characterized by columns with entasis, you can enter in the foyer which is placed beside to the hall and interior service spaces. On the other side, the hall overlooks directly the outside through safety exits. From a constructive and formal point of view, the building is fully into the architectural and historical context of the '30s and '40s in Italy, when it began the structures building with reinforced concrete, but without the figurative value present in the European avant-garde. In fact, the Italian architecture keeps a close relationship with the formal solutions previous to the introduction of frame-systems with the presence of walls, no-loadbearing function, and of composite structures. Besides for the period are important: the search for a modern monumental style by the using of classical language without decorative elements, the admixture of elements in an eclectic style and the search on finishing materials, conditioned by the needs of autarchy. In fact in the final period of the fascist regime, the Italian state was isolated in the international context.

From a methodological point of view, the building study was deal with the elaboration of the 3D model, starting with the integrated survey (direct and photogrammetric), the analysis of the old documentation related to the project

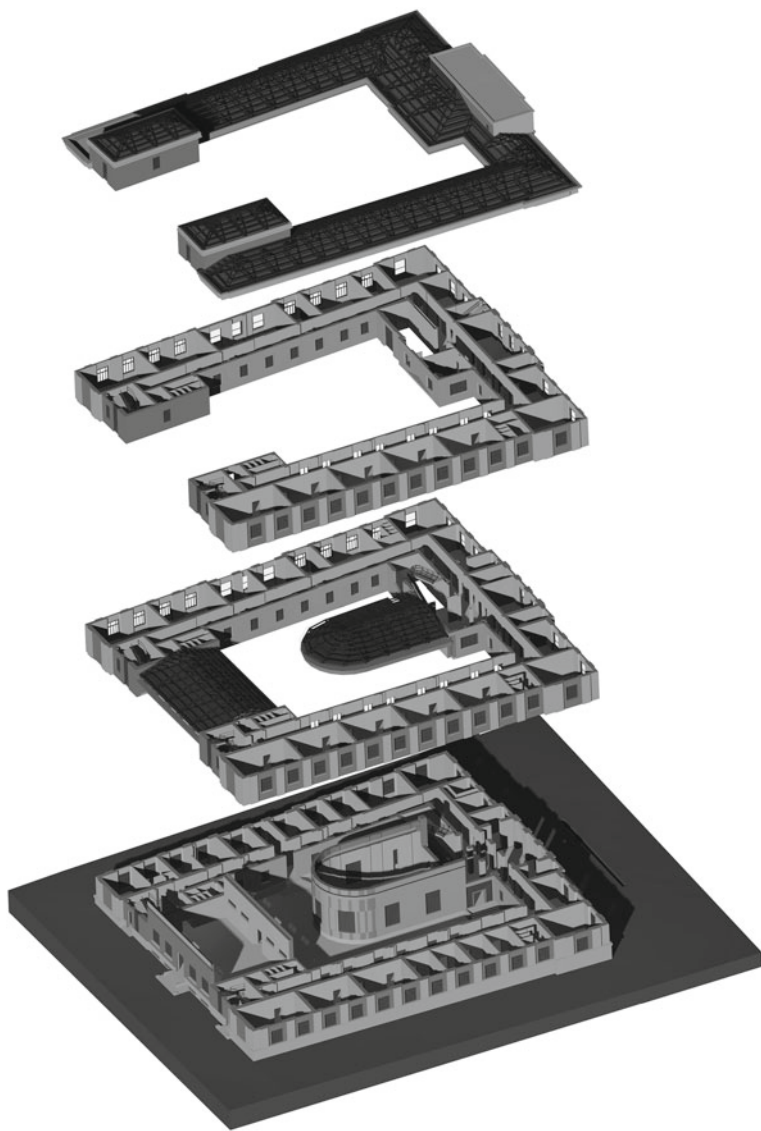


Fig. 7 School in Teramo. Isometric render split from the bottom. In correspondence with the entrance there is the Aula Magna in the courtyard; in front there is the gym that can communicate with the court or directly to the backside

(Fig. 4), a survey made in 1963 and a survey made in 2005 (Rolli G, *Rilievo e Restauro dell'edificio Cinema Massimo all'Aquila*. Dissertation, Università dell'Aquila, Facoltà di Ingegneria, Corso di Laurea in Ingegneria Edile-Architettura, a.a. 2004–2005, supervisor Prof. Mario Centofanti). In order to study the modern architecture,



Fig. 8 Cinema Massimo in L'Aquila. The principal front in an actual photo and in a project's perspective drawing

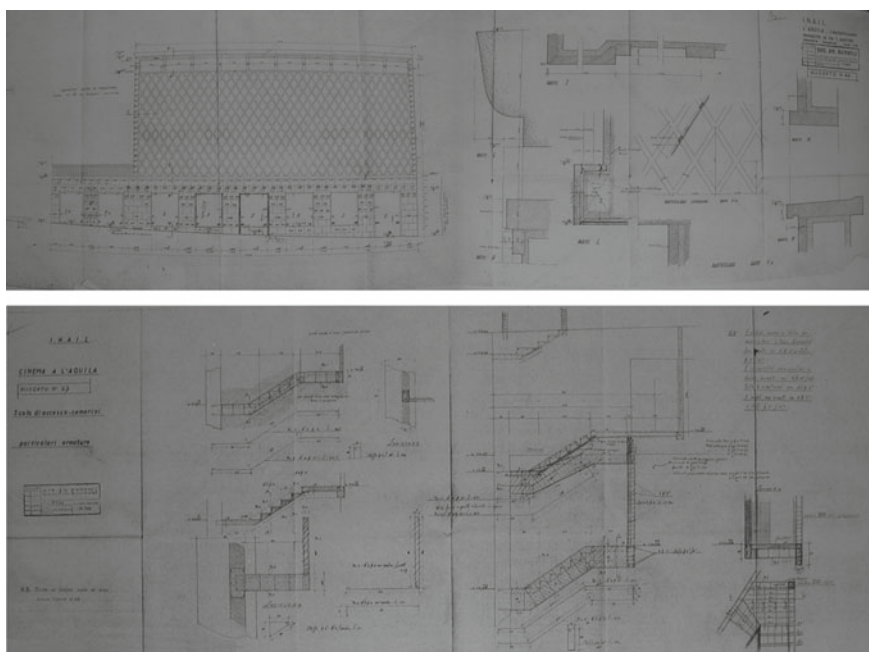


Fig. 9 Original project drawings of Cinema Massimo in L'Aquila: Carpentry and executive façade with constructive details

the analysis of project's drawings is a useful tool, also to understand construction elements not visible and not directly detectable. The available drawings about the Cinema Massimo are placed in the Historical Archive INAIL in Rome, binder "I.N.A.I.L. L'Aquila—Cinematografo"; there are plans, elevations, sections, perspective views, carpentry with details and structural calculations, some construction details until to the scale 1:2 (Fig. 9).

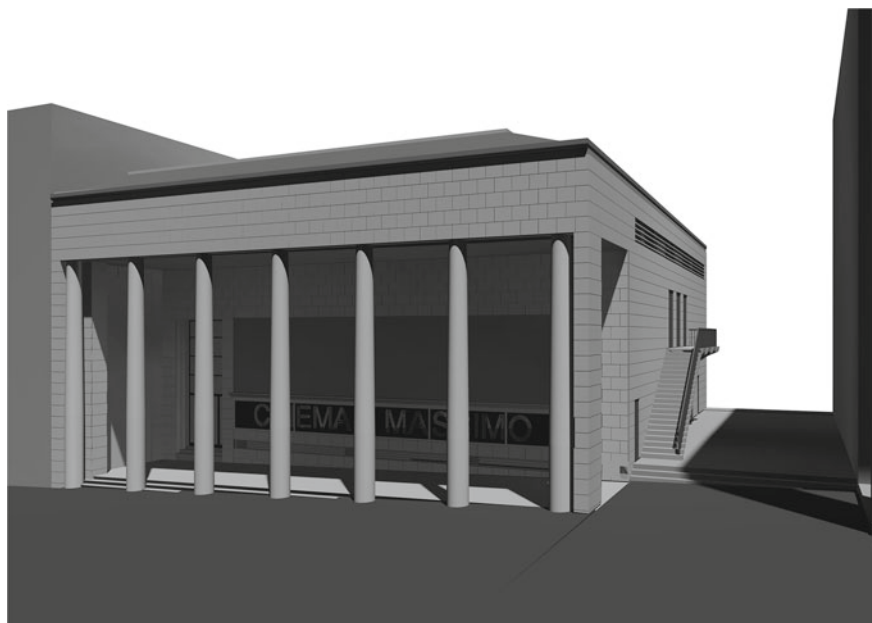


Fig. 10 3D Model of the Cinema Massimo in L'Aquila. Rendering with perspective view of the principal front.

The tridimensional model was realized with modalities and characterizations differentiated in various restitution scales, from the urban context to the architecture or decorative details.

Considering the importance of the restrictions imposed by the context to the typological planning, the model was integrated with volumetric sketches of the next buildings, in order to understand the existent spatial relations (Figs. 10 and 11).

In the building model are combined the spatial and volumetric information and the study and the representation of the constructive system. In particular, the representation ways were chosen to better understand relations between constituents. The building breaking up allows the in-depth investigation of the most innovative aspects of typological and distributive features (Figs. 12 and 13).

E.g., the perspective cross section in Fig. 12 shows the typological element that characterize the distribution system of Cinema Massimo, that is the foyer, placed beside the hall, that provides a distribution on the whole length of the hall itself, but on a single side. This distributive articulation is realized with elevations variability, which ends in helical stairs to enter in the rooms placed in the upper level, behind the hall. Skylights provide to light the foyer through curvilinear false ceiling that follows the elevations variation. Figure 13 shows the hall, that is organized in two levels, with stalls area and upper gallery, both with lateral access, covered by a false ceiling. The stage has a little space behind the screen that allows to use the hall as an auditorium or conference hall.

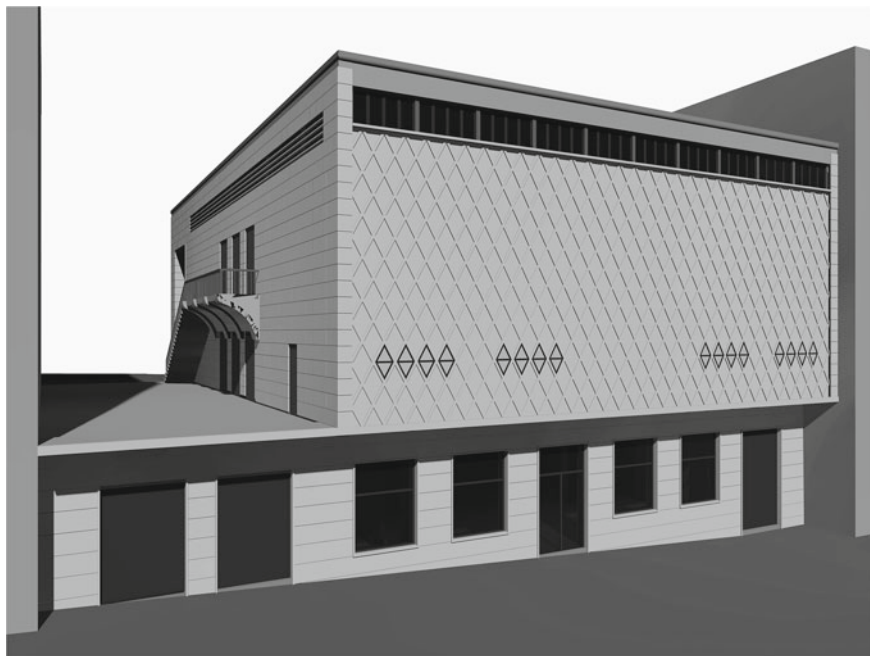


Fig. 11 Cinema Massimo in L'Aquila. Rendering with perspective view of the back front

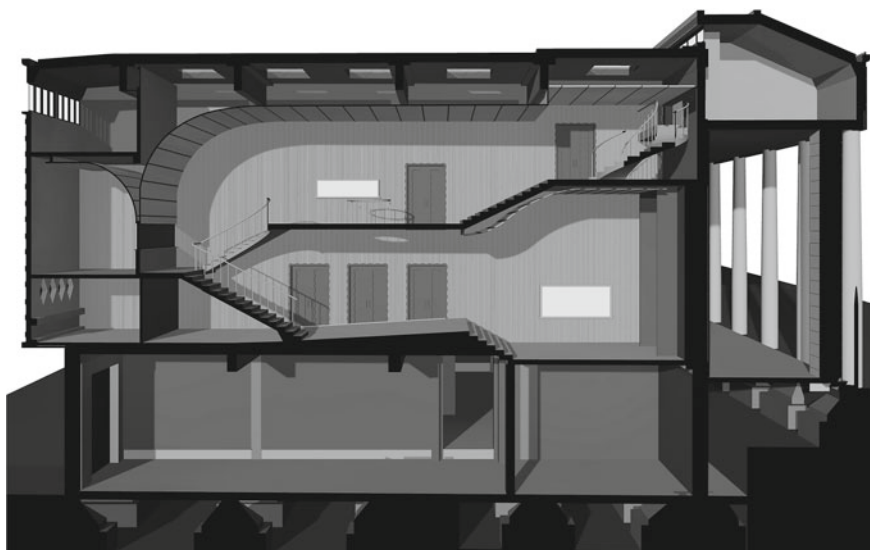


Fig. 12 Cinema Massimo in L'Aquila. Rendering with perspective section of the foyer

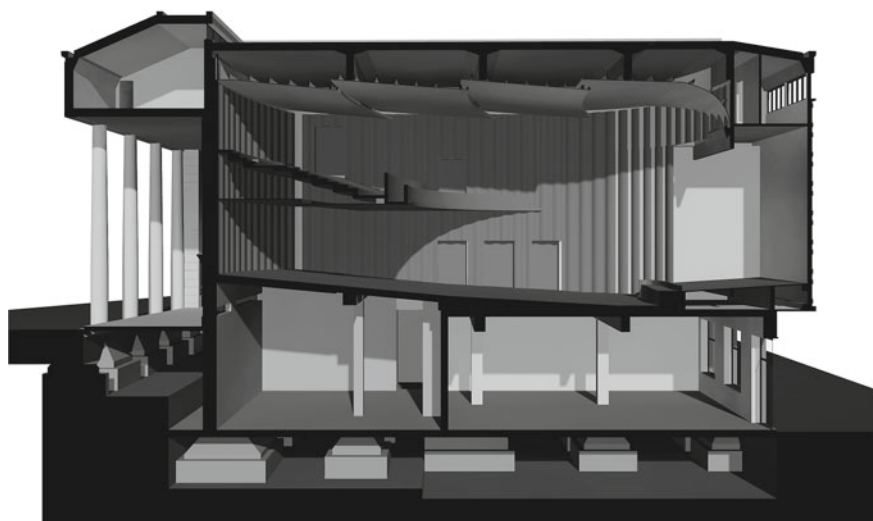


Fig. 13 Cinema Massimo in L'Aquila. Rendering with perspective section of the hall

About the model's constituent elements, these features have been differentiated according to the foundations, the reinforced concrete loadbearing frame, the floors recognizing the brick and concrete elements, the partition walls, the skylights, the false ceilings of the foyer and the hall, the fixtures, the floors, the plaster, the inner lining of the hall walls and others finishing elements, with particular highlighting on front articulation (Fig. 14). The front and the lateral side are characterized by travertine blocks, the back side by false travertine in cement mortar panels with lozenges.

The representation through components allows a suitable comprehension of the most original technological and finishing solutions, also linked to the use of new materials of the period, such as linoleum in the gallery floor, wavy plaster in the foyer walls, Murano glasses etc. These decorative elements characterize the building, so they have been in-depth studied, reducing the scale, using suitable survey methods. In particular the restitution of the bas-relief with a representation of L'Aquila city, placed on the front under the arcades, above the "Cinema Massimo" sign, has been realized with digital photogrammetry techniques, building textured meshes, starting with a point cloud and inserted in the general building model. The same technique has been experimented on the backside front of the building, characterized by the particular solution of the lozenges made of false travertine.

Fig. 14 Cinema Massimo in L'Aquila. Isometric render with detail's representation of the constructive system



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