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Historical Architecture and BIM Modelling: Between Representation of Reality and Conceptual Abstraction

Silvia Cutarelli[1*]

[1] Department of History, Representation and Restoration of Architecture, Faculty of Architecture, Sapienza University of Rome, piazza Borghese 9, 00186 Rome, Italy
[*] Corresponding author, e-mail: silvia.cutarelli@uniroma1.it

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Abstract
The essay aims to explore the applications of BIM to design regarding historic buildings, which will become mandatory in Italy from 2025 for public works above €1 million. Despite the advantages in coordinated data management and information sharing among the actors involved in contracts, problems related to the geometric representation and semantic definition of the virtual entities that populate the models have been recognized by the scientific community. Critical issues that have emerged from the study of significant experiences can be traced back to the difficulty of adapting tools designed for the projects of new buildings to the characteristics of the cultural heritage. In particular, the complexity of proposing congruent categorisations and parameterisations seems related to only partial correspondence between historical building components, IFC classes and BIM software categories. These limitations often lead to the identification of contingent solutions and expedients, which solve only the problems of geometric representation. In contrast, the ability to adequately share information stored in databases, interoperable through the IFC format, is conveyed by an appropriate semantic description. Formal representation in the BIM environment effectively refers to standardized industrial production, reproducibility of building elements and, more generally, to the goals of globalisation. Thus, the proposed reflections aim to encourage a conscious use of these tools and to outline implementation perspectives useful to bring the digital environment closer to the concrete reality of historical architecture, unique and irreproducible in origin and transformation, often realized through artisanal processes and anchored to specific contexts in multiple aspects.
Keywords
historical architecture, BIM modelling, geometric and semantic representation, systems for digital information management, taxonomy of historical building elements

1 Introduction

The extension of Building Information Modelling (BIM) into historic architecture has recently been encouraged in Italy by laws passed regarding public works: Ministerial Decree no. 560 of 1 December 2017 established modalities, timing, and economic thresholds for the gradual introduction of these systems, while Legislative Decree no. 36 of 31 March 2023 indicated that digital information management tools will become mandatory for public contracts exceeding one million euro from 2025[1].

These criteria refer only to the value of the works, and concern both new constructions and work undertaken on existing building (with the exception of ordinary and extraordinary maintenance). The regulation also provides that the data processed in the information models, specified according to the requirements and definition levels of a specification attached to the tender documents, must be usable through interoperable platforms and non-proprietary open formats, in order to protect competition between economic operators in the sector and at the same time favour the sharing of information between entities and professionals involved in the contracts[2]. This clarification explicitly distinguishes the contents of BIM models from the tools used to generate them, and thus leads to the verification of the possibility of representing built reality through digital systems. Despite the advantages this creates in terms

1 Art. 6, Ministerial Decree 560/2017 and Art. 43, Legislative Decree 36/2023.

2 Art. 43 and Annex I.9, Legislative Decree 36/2023.

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of coordinated data management, interoperability, and the integration of discrete disciplinary competences, problems have emerged in the representation of the built environment that relate to the geometric and semantic definitions of, and taxonomies for, historical building elements through Industry Foundation Classes (IFC) standards (BuildingSMART International, 2024) and the most prevalent architectural software.

The critical issues detected by the scientific community in the modelling of heterogeneous architecture in terms of geographic area and timescale are generally attributable to the difficulty of adapting tools designed primarily for new constructions, to the characteristics of cultural heritage, which in Italy is often characterised by buildings that have been stratified over centuries. Compared to the process followed in the design field ('as-designed', 'as-built', 'as-maintained'), the restitution of existing buildings is based on a different approach, established by the preliminary acquisition of historical construction information, and by surveys conducted through integrated techniques, that aimed to obtain a cloud of sufficiently precise datapoints; the partial knowledge of architectural entities and the purposes of the models guide the identification of building components and the corresponding digital taxonomic families, three-dimensional representation of the building by authoring software, and the implementation of data in order to obtain different types of output (Scianna et al., 2020). The exportation of proprietary files into an open format, however, is not a neutral operation, but implies an automatic or manual translation of native software categories and subcategories: for example entities modelled with Revit (Autodesk, 2024) in the *Basic Wall* family and translated to *IfcWall* classes when exported retain all the information assigned to them; on the other hand, instances of the *Generic Models* category, attributed by an operator to the same class, do not carry the IFC properties that refer to walls.

The procedures for deconstructing the building and correlating its physical and virtual elements therefore need attention, since the solutions and adaptations that are required to render the characteristics of the historic building in a digital format condition both the semantic aspects and the operations managed through the classification of families, i.e., the setting up of views, schedules and counts, the integration of parameters, and the interchange of data.

2 Geometrical modelling

The potential of an information system designed to model an industrial building process is to some extent inhibited in the geometric representation of historical architecture: the selection of tools aimed at managing the uniform arrangement and serial repetition of components, or verifying axiality and alignments – such as the *Grid* and *Beam System* families, type parameters, and equidistance constraints – is reserved for buildings that have compositional, structural and material homogeneity.

The need to build customised families, either generated from scratch or reworked from existing ones, leads one to consider parameterising the geometric configuration. In the 'system families', the available options are bound to the software settings: the tapering of wall cross-sections, for example, is managed in Revit through instance parameters relative to interior and exterior angles; the planimetric variation of the wall's thickness must instead be resolved through targeted solutions, such as 'in-place' models, despite the fact that it is quite common to find inclined layouts in structures affected by the rectification of roads, regularisation of rooms, reconnection of heterogeneous pre-existences, and realisation of elevations.

The geometric parameterisation of 'loadable families' offers higher margins of flexibility and allows for different instances from a single type, pre-empting the possibility of adapting such prototypes to further projects, and organising libraries that refer to specific historical or geographical contexts; this possibility is dependent on the level of detail (LoD) of the representation and the reiteration of similar components (Fai and Rafeiro, 2014), characterised by a figurative code that is obvious in direct survey and sometimes made explicit in the historical treatises. Building on these assumptions, the modelling of parametric families primarily referred to architectural orders (Daniels and Georgopoulos, 2023; Murphy et al., 2013; Potestà, 2021); basic forms and compositional rules are translated into the digital domain by means of special programming languages, such as the Geometric Description Language integrated in Archicad (Graphisoft, 2024), or through the definition of geometric primitives, reference planes and parameters useful for modulating dimensions and proportions (Fig. 1).

By contrast, the versatility of elements outside a formally codified canon implies obvious approximations, in which the 'digital twin' is replaced by a simplified substitute. In this process, the typological reading of historical building components appears useful when selecting criteria based on consolidated investigative paths and in guiding the identification of schematic forms of reference.

Similar in-depth investigations, initiated in the context of research relating to the historical town centres of

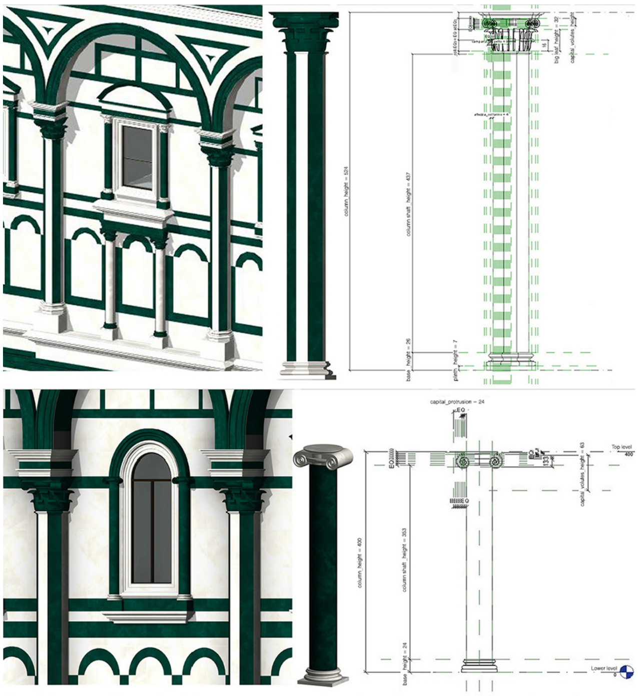

Fig. 1 The Baptistery of San Giovanni, Florence: parametric modelling of composite pillars and ionic half-columns (reworking from Potestà, 2021)

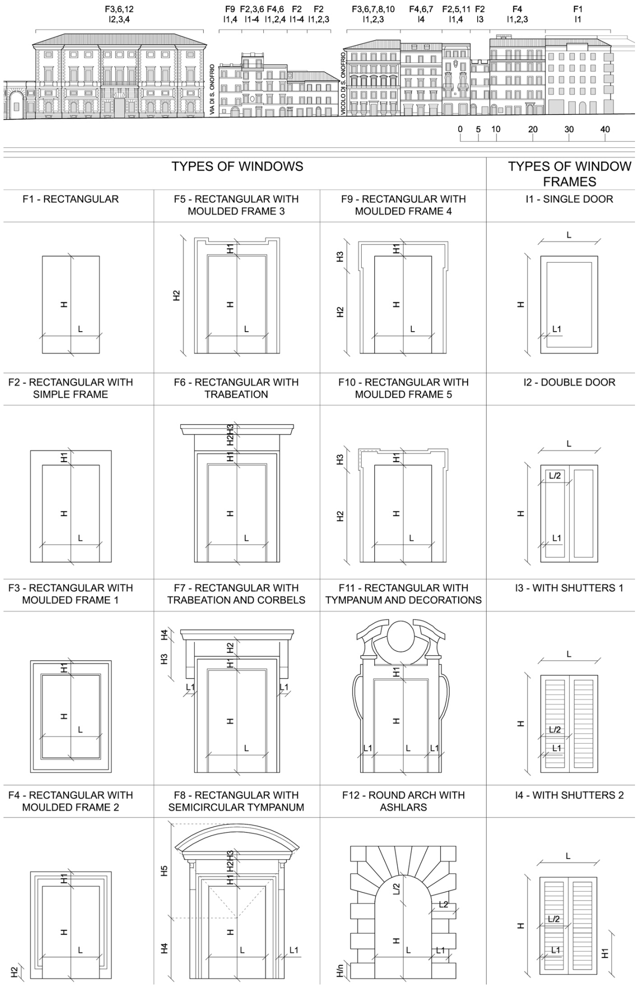

Fig. 2 Via della Lungara, Rome: typological classification of windows and fixtures before the modelling of loadable families (Cutarelli, 2023)

central Italy that were damaged in the 2016 earthquake (Zampilli and Brunori, 2021:pp. 225–237), as well as the Lungara area in Rome[3], require the expansion of surveys from an architectural scale to an urban one in order to determine suitable applications, and to organise appropriate classifications (Cutarelli, 2023) (Fig. 2).

On the other hand, the representation of construction details, figurative details and irregular components that are derived from extensions, adaptations, collapses, or demolitions, is outside the scope of such procedures and presents differing degrees of complexity; ever-more refined modelling approaches adapt in relation to specific problems, but are not always effective from the point of view of interoperability, since exports and imports in IFC format often lead to loss of information. A benchmarking activities conducted in the 2018 Italian Society of Photogrammetry and Topography (SIFET) resulted in emblematic conclusions in this respect: different groups of participants modelled the remains of the Penna kiln in Scicli, Sicily, in a BIM environment, reproducing the jagged ridges of the walls by means of in-place modelling or by the subtraction of solids from parallelepiped shapes (Scianna et al, 2018); the latter solution led to a number of critical issues in the exchange of data between different types of software, as the texture of the faces and negative instances were not preserved (Fig. 3).

A reliable reproduction of complex three-dimensional forms that arise from compositional origin, transformational events, or structural instabilities, requires complex procedures; these imply the availability of point-cloud management software, and platforms exclusively oriented towards graphic representation or the use of plugins for the semi-automatic creation of parametric objects from numerical data. For example the vaults of Castel Masegra in Sondrio, Italy, were rendered by means of Non-Uniform Rational B-Splines Modelling (NURBS) curves and surfaces, built on Rhinoceros (TML Inc, 2024) and subsequently exported to Revit (Barazzetti et al., 2015);

3 The study was developed by the Unità di Roma (scientific coordinator: Prof. D. Fiorani) within the framework of the Progetto di Rilevante Interesse Nazionale (Project of Relevant National Interest, PRIN) 2017 *HPFC – Historic Preservation Foundation Classes* (principal investigator: Prof. S. Della Torre), the results of which are currently being printed in the "ArcHistoR" journal.

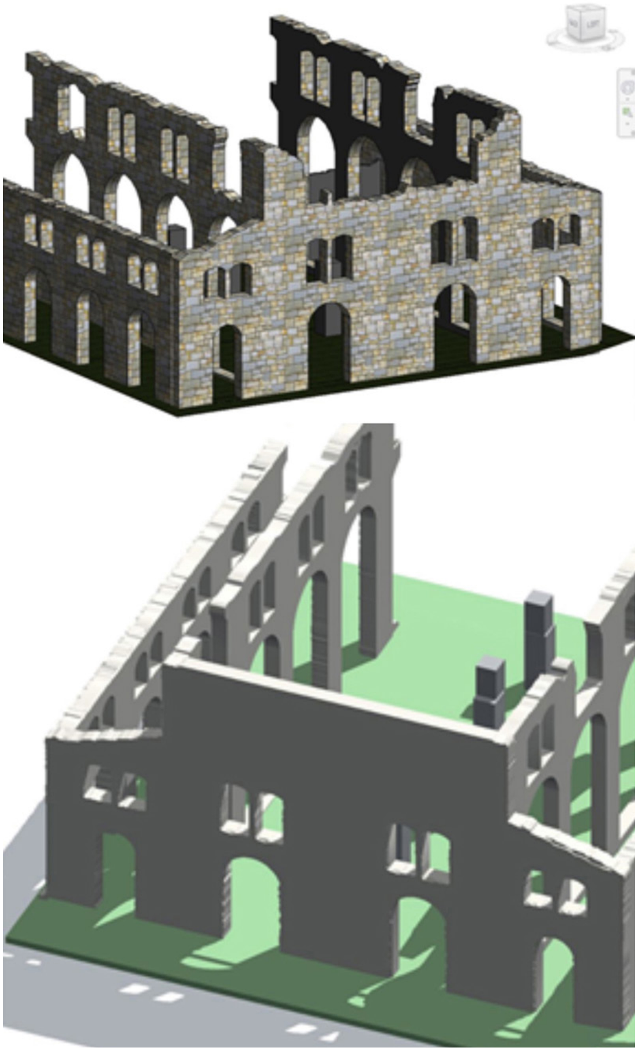

Fig. 3 Penna kiln in Scicli: interoperability issues related to modelling strategies. The project on the top, exported as IFC and opened in different software, has lost the data related to wall textures and ridge geometry, represented through the subtraction of solids (Scianna et al., 2018)

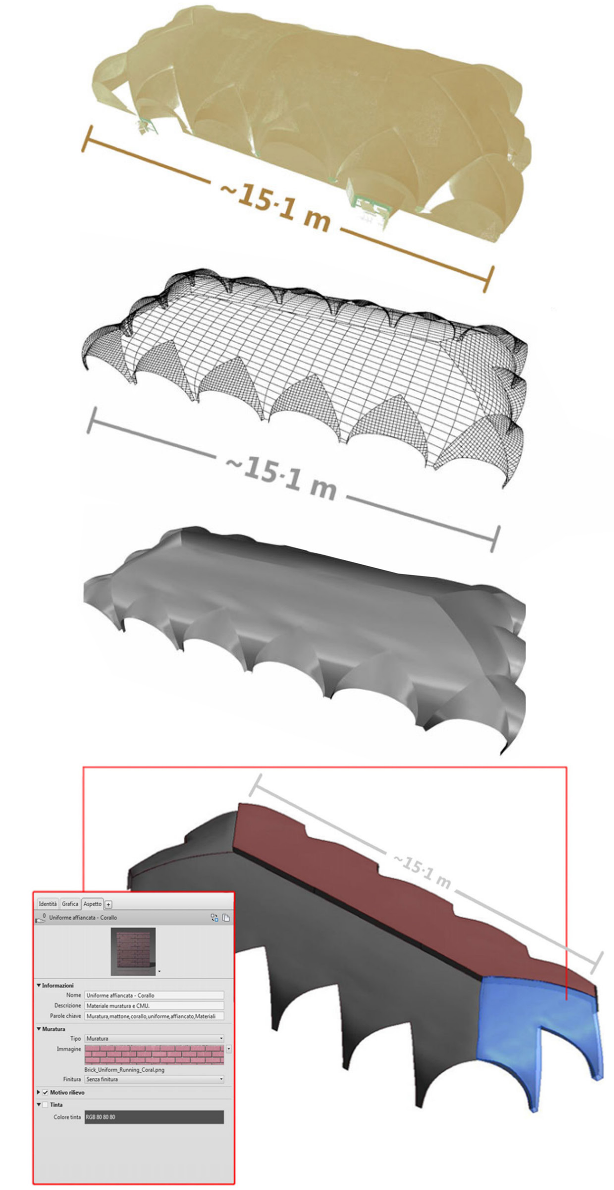

Fig. 4 Castel Masegra, Sondrio: modelling of a barrel vault with lunetts (Barazzetti et al., 2015). The properties associated in this table with the parametric object describe its identity, physical characteristics and graphic attributes (name, description, keywords, type of masonry, pattern, finish etc.)

the resulting three-dimensional volumes were generated in the BIM environment from adaptive surface-based models assigned to the *Basic Wall* family (Fig. 4).

A similar strategy was also tested when modelling the walls of the Basilica of Collemaggio in L'Aquila, which were deformed and out-of-plumb by buckling due to the 2009 earthquake (Brumana et al., 2018). On the other hand, the drum and dome of the Four Courts, Dublin, damaged during the Civil War in 1922, were represented by segmenting the point cloud, importing horizontal shear sections into Archicad, and creating meshes and three-dimensional elements using a plug-in implemented with procedural rules and calculation algorithms (Dore et al., 2015).

These restitution processes are rather onerous and sometimes incompatible with operational practice; in the professional sphere, point clouds are often used as a direct reference for tracing the geometries of elements, rectifying three-dimensional volumes, reducing the complexity of the model, and delegating the recording of accurate information to different systems. Even in geometrically reliable representations, recurring simplifications are sometimes discovered: the approximation of similar wall thicknesses by means of an average value is, for example, a common expedient, aimed at avoiding the multiplication of family types and thus induced by the very definition of the *IfcWall* class[4].

3 Semantic aspects

The semantic representation of historical building components suffers from a lack of useful information to specify their characteristics; for example the system families provided by the Autodesk Revit, such as walls, floors or roofs, are qualified by type parameters that return the stratigraphy of sections, materials, physical properties and graphic attributes, while those referring to instances define constraints, dimensions, creation and demolition phases. The integration of data related to construction, structural and chronological aspects is generally entrusted to customised properties, either set directly in the model ('project parameters'), stored in an external .txt file to be attributed to different families and projects ('shared parameters'), or configured within separate autonomous and interoperable databases, which may also be achieved through dedicated plugins[5]. Whichever solution is adopted, the implementation of properties is subordinate to its predefined data structure, managed in Revit by categories; this condition imposes somewhat rigid rules and implies the need to verify the correspondence between historical building elements and digital classes, characterised by specific definitions, properties, and relationships.

A preliminary examination (Table 1) firstly reveals the lack of representative classes and families of building components such as arches, vaults and domes; the geometric models of individual instances must therefore be traced back to alternative categories, such as *Walls* or *Floors*, from which they derive their semantic sets.

Cladding, *flooring* and *roofing* are instead described by respective types in the *IfcCovering class*, but commercial applications do not always provide equivalent families: Revit, for example, only reproduces these elements in the stratigraphy of walls, floors and roofs. On the other hand, the presence of overlapping and incomplete historical finishes, accompanied by information regarding particular workmanship or the state of conservation, requires cladding to be modelled separately from the structures that support it, setting up one or more wall families consisting only of the finishing layer. This expedient, adopted in the model related to the archaeological remains of the crypt of Saints Sergius and Bacchus in Rome (Scianna et al., 2015), partially resolves the semantic aspects.

The parameters added to the claddings – which for the Roman structures were borrowed from the archaeological form devised by Italy's Istituto Centrale per il Catalogo e la Documentazione (Central Institute for Cataloguing and Documentation, ICCD) – must however be assigned to the category *Walls*. By extending supplementary properties to all instances that can be ascribed to them, the software requires filters to be added in order to display or list information pertinent only to the cladding, while its adherence to the support is to be expressed through a proximity constraint. The lack of an autonomous family does not prevent the representation of information content in this case, but requires additional operations and settings congruent with the decomposition criteria of the architectural 'organism'.

Less straightforward is the modelling of data referring to aggregated construction units, such as wooden floors, which present heterogeneous relationships with corresponding classes and families. A double-beam floor with a deck consisting of planks, screed, and floor is rendered, for example, by two or more families of beams and a floor consisting of layers containing substrate and finishing functions. Any additional parameters can be assigned to families of homogeneous elements (Parente and Ottoni, 2023) (*Beam*, *Beam System* and *Floor*), while the properties of the entire floor are assigned to categories usually used to group instances, such as *Model Group* or *Assemblies*: the former, similar to CAD blocks, are used to manage repeated groups of objects such as furniture; the latter is instead used to identify assemblies accompanied by quantitative information, documents, and graphical filters for the display of parameters. The evident limitation of representative categories of aggregate components, and the impossibility of assigning parameters to subclasses, prevents the digital classification from being brought into line with the built reality, and the definition of the relationships that exist between the individual constituent elements. As mentioned above, the possibility of modelling additional building components such as trussed roofs using the same family implies the addition of filters necessary for ordering views, schedules and counts.

4 The definitions discussed below refer to IFC version 4.3.2.0, which is currently the most recent official publication; <https://standards.buildingsmart.org/IFC/RELEASE/IFC4_3/> [Accessed: 05 June 2024].

5 Revit's DiRoots plug-in allows, for example, the export of a Microsoft Excel file from the database, consisting of one or more worksheets referring to element categories, annotations, and schedules. The parameter values of individual instances, identified by a unique ID, can be edited and reloaded into the model, which is automatically updated.

Table 1 Summary of correlation between generic building elements of historical buildings, Revit categories and families, and IFC classes. System families are shown in pink, loadable families in green, and components with no correspondence are indicated by light blue.

Building Elements	Revit Categories and Families		IFC Classes
Foundations	Structural foundations	Isolated	IfcFooting
		Wall (foundation)	
		Slab	
Elevation structures	Walls	Basic Wall	IfcWall
		Stacked Wall	
		Curtain Wall	IfcCurtainWall
		Wall: Sweep	IfcBuildingElementProxy
	Structural Columns	Structural Column	IfcColumn
	Columns: Architectural	Rectangular Column	IfcColumn
		Circular Column	
	Arches		
Orientation structures	Floors	Floor	IfcSlab
	Structural framing	Beam	IfcBeam
	Structure Beam Systems	Beam System	IfcAssembly
	Vaults		
	Ceilings	Basic Ceiling	IfcCovering
		Compound Ceiling	
Roofs	Roofs	Basic Roof	IfcRoof
		Sloped glazing	
		Roof: Soffit	
	Structural framing	Beam	IfcBeam
		Truss	IfcBuildingElementProxy
	Domes		
Vertical connections	Stairs	Assembled Stair	IfcStair
		Cast-In-Place Stair	
		Precast Stair	
		Monolithic Landing	
		Non-Monolithic Landing	
		Stringer	
		Carriage	
	Ramps	Ramp	IfcRamp
Protection elements	Railings	Railing	IfcRailing
	Walls	Basic Wall	IfcWall
Flooring	Flooring		IfcCovering
Coverings	Coverings		IfcCovering
Roof covering	Roof covering		IfcCovering
Fixtures	Doors	Door	IfcDoor
	Windows	Window	IfcWindow

More complex is the virtual reproduction of historical masonry, which, although related to specific classes and families, does not find an appropriate formal description in the BIM environment. Indeed *IfcWall* returns two main modes of representation and distinguishes only those occurrences characterised by constant thickness, expressed through the juxtaposition of material layers. Such a limited schematization, inadequate for representing core and facing structures, has considerable repercussions for models of existing buildings, because it leads to the selection of generic wall families and the multiplication of types only on the basis of width, i.e., a marginal parameter for the typological classification of historical masonry. The amalgamation of similar wall thicknesses – which is sometimes adopted to obviate the proliferation of types, to simplify the management of instances, and to reduce representation times – decreases the geometric reliability of the model, and leads to the loss of significant data for construction analysis, structural verification, in-depth diagnostics, and design hypotheses.

The impossibility of specifying the characteristics of masonry also hinders the representation of construction stratification, which should make it both possible to identify otherwise undocumented phases of transformation, and to clarify any conservation problems. This drawback leads to the distribution of masonry being rendered by means of different devices. For example in the case of L'Aquila's Basilica of Collemaggio, the textures of the northern wall have been identified by means of distinct types of the *Basic Wall* family, characterised by a reduced thickness of approximately 1 cm (Brumana et al., 2018[6]). Such instances, accompanied by graphic fields and descriptive information, tend to reproduce the heterogeneity of the facing walls in the digital environment, but the lack of an appropriate taxonomic formalization leads instead to the configuration of two-dimensional entities, referenced in the model (Fig. 5). The generic types used to identify the stratigraphic wall units in the underground oratory of Rome's San Saba, on the other hand, have a thickness equal to that of the north wall: the outlines digitised in the CAD environment and then uploaded to Revit distinguish the exposed wall portions from those covered with plaster; the three-dimensional instances, obtained by reconfiguring the standard profiles on the basis of the imported contours, make quantitative data, construction discontinuities and material differences explicit (Fig. 6). This approach, closer to the built reality but not exactly proximate, allows the results of a surface reading to be transferred to the masonry structure; the system, however, does not allow the stratigraphic relationships between the various family types to be expressed, which had to be integrated into the project through an ontology, and added to the *Walls* category as instance parameters (Acierno, 2017; Fiorani, 2017).

The modelling of doors, windows, pilasters, and columns in a dedicated environment offers greater scope for customisation, allowing loadable families to be represented and ordered in relation to the corresponding building components.

6 The thickness was obtained by dividing the volumes and areas shown in the abacus on p. 563.

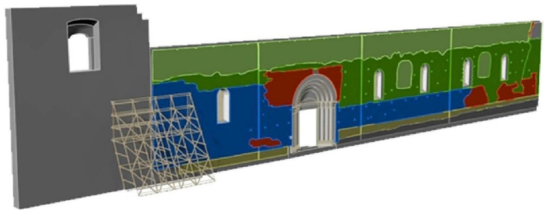

Fig. 5 Basilica di Collemaggio, L'Aquila: reconstruction in a BIM environment of the mapping of the masonry on the north wall (Brumana et al., 2018)

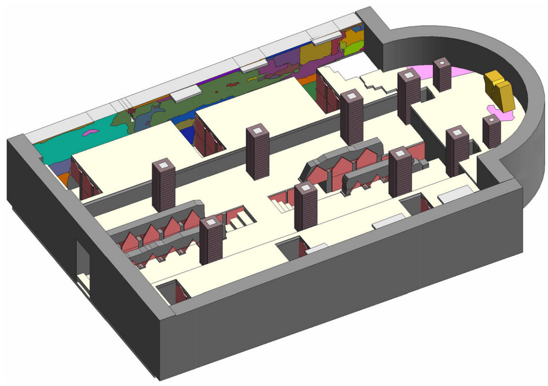

Fig. 6 Underground oratory of San Saba, Rome: modelling in the BIM environment of the stratigraphic wall units on the north wall

This limited survey reveals conceptual shortcomings and misalignments that distance digital representation from the built reality. Despite its ambition to spread globally and extend to existing architectures, the IFC format presents classifications and definitions of building elements that are not always adequate to describe cultural heritage (Diara and Rinaudo, 2020); the subclasses of *IfcBuiltElement* are also linked, at least in part, to technologies that are widespread in the United States and can be traced back to relatively recent times. The type enumeration given in *IfcMemberTypeEnum*, for example, identifies the components of discontinuous systems such as wooden roofs, curtain walls and balloon frames; the distinction between families identifying load-bearing supports and cladding elements, *Structural Column* and *Column: Architectural*, instead reflect the techniques used in late 19th-century American architecture.

On the other hand, the formal representation of techniques used in distant eras and in limited territories appears hardly compatible with the standardised approach of BIM systems. As has already been observed (Fiorani, 2017), the reuse of heterogeneous elements that have a different function from the original one – which is widespread in medieval Italian architecture – presents, for example, diametrically opposed characteristics in terms of variety and specificity of the construction actions; the *spolia*, therefore, are not adequately reproduced in this type of formal description. In the model of San Saba's subterranean oratory, for instance, the tiles adapted to divide, cover and close the tombs of the early medieval cemetery were schematized by means of autonomous instances of *Generic Models* (Fig. 7), a geometrically flexible but semantically poorly connoted loadable family.

Despite the constant updating of software and recent advances in the research sphere, ultimately systems designed for new buildings have obvious limitations in the representation of the state of conservation. At present, only one piece of software, Edificius (ACCA, 2024), includes families that refer to the phenomena of degradation and instability, subdivided into additive and subtractive; in the application for the church of San Pietro *in Vinculis* in Naples (Lanzara et al., 2021), perimeter instances from photographic images or point clouds referenced by the model are associated with graphical fields, dimensional data, and descriptive information recorded in a database, or linked to boards stored in a collaborative platform (Fig. 8).

The modelling of differing states of damage in software without dedicated categories, on the other hand, follows different strategies: degradation phenomena are added as properties that are generically referenced in the elements, or even represented graphically to delimit materials on the surfaces that compensate for the types of decay (*Split face* and *Paint*) using specific commands. However the need to visualise and compute the extent of the phenomena, add properties, define schedules and export the entities into IFC, more often leads to the use of adaptive families of *Generic Models* based on lines or surfaces (D'Agostino et al., 2023). Although more effective, this solution has a number of drawbacks connected to the use of a category designed for unspecific purposes, to the consequent attribution of any supplementary parameters also to families that are not necessarily representative of the state of conservation, to limitations on the control vertices

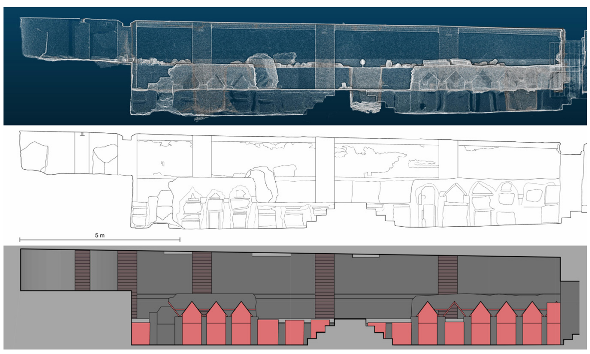

Fig. 7 Early mediaeval cemetery of the underground oratory of San Saba, Rome: longitudinal sections obtained by means of point cloud, two-dimensional elaboration carried out in Autocad and model in Revit

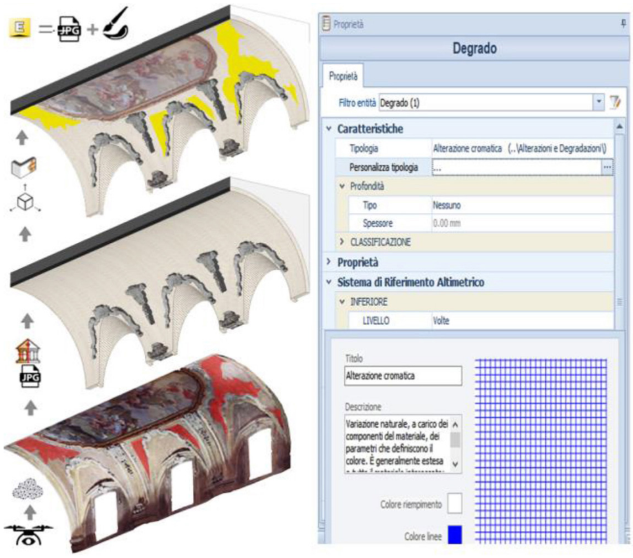

Fig. 8 Church of San Pietro *in Vinculis*, Naples: mapping of the decay on the vaults using Edificius software (Lanzara et al., 2021). The properties associated in this table with the parametric object describe type of decay, thickness, altimetry reference system, description, pattern

of instances, and to the approximations introduced in the three-dimensional restitution of structural instability. In the model used to describe Villa Medici in Poggio a Caiano, for example, the representation of cracks was generated by extruding a rectangle on the path of a spline, and then parametrising the distances between horizontal and vertical planes to delimit the path (Ferraretti et al., 2018). The critical characteristics of the procedure, made explicit by the authors, relate to the impossibility of representing the edge profiles, which provide significant information in the interpreting of the pattern of cracks. Moreover, the length of the lesions, obtained by means of Pythagoras' theorem from the distances between the planes, is only reliable for shapes that approximate the diagonal.

These approaches are centred on the need to solve application problems and are outside the scope of aspects related to data interoperability. In a research project on Villa Venier Contarini in Mira, near Venice, modelling of the state of conservation using IFC classes was initiated with the aim of planning maintenance in relation to the severity of damage[7] (Zanni et al., 2024). The standardised formal description favours the use of open systems and the interchange of information; however, the semantic definition of the selected properties, the actual congruence with the representation of damage status in historic buildings, and the calculation methods using specific values or algebraic formulas, must be considered with extreme caution. For example, the definition of *AssessmentCondition* returns the general condition

7 I am grateful to Luca Sbrogiò for an exchange of views on this experience.

of an element, estimated by means of a scale agreed between the different actors in the building process. *AssetCriticality*, *AssetFrailty* and *AssetPriority* constitute qualitative assessments, varying between *verylow* and *veryhigh* values; they are directed to consider respectively[8]: "the asset's criticality to the operation of the facility"; "the asset's frailty to breakage or deterioration"; "the operational and maintenance priority of the asset" based on the combination of criticality and fragility. *MonitoringType* describes the monitoring strategies of an asset (inspections, preventative maintenance plans, in-depth diagnostics through devices and sensors, etc.); finally, *RiskAssessmentMethodology* describes risk estimation methodology with reference to British or international standards relating to health and safety at work. These descriptions present only partial affinities with consolidated concepts in the conservation discipline, such as the vulnerability of heritage assets, the severity of decay, the urgency of intervention, and the risk of loss of cultural patrimony. Descriptions, vocabularies, and computation methods are made explicit, for example, in the compilation rules of the Carta del Rischio (Risk Map; Italian Ministry of Culture, 2024), the Italian Ministry of Culture's territorial information system which aims to estimate the risk of loss of cultural heritage and plan interventions according to a priority index[9]. The correspondence between the two conceptual systems, though, is by no means taken for granted, and a careful verification of their semantic alignment seems desirable in order to avoid simplification and misunderstanding with respect to activities oriented to the management and planned conservation of the historic built environment.

4 Conclusions

The advantages of BIM in the AEC sector, that relate to the simplification of modelling processes, the optimisation of graphic drafting and design documentation timeframes, and the reduction of costs due to modifications, variations during construction, and unforeseen site events, are less evident in the representation of historical architecture for multiple extrinsic and intrinsic reasons. Inevitable gaps in knowledge prevent a complete definition of the construction and material characteristics of building components, while the heterogeneity and complexity of the elements limits the possibility of constructing parametric families and standardising representation strategies; the constraints imposed by descriptions and classifications that are not always adequate for this field complicate modelling procedures, which are substantiated by unconventional solutions, contingent approaches, and unavoidable expedients, which sometimes only resolve geometric aspects without associating the virtual entities with an appropriate set of information. The prerogatives of interference control, error reduction and constant verification of updates also seem to be hampered by the need to entrust accurate information or additional data to numerical models, external databases, and collaborative platforms.

The difficulties of geometric and semantic representation identified by the scientific community have fuelled proposals aimed at estimating the degree of reliability of the digital models, which assess the intrinsic geometric characteristics of the artefact, the availability of data obtained from surveys, specialist investigations and documentary sources, the presence of information regarding materials, construction techniques, compositional rules and state of conservation, the results of geometric compliance checks, and the nature of any operational indications for further investigation (Bianchini and Nicastro, 2018). Codified evaluation parameters, tested in relation to the models of the Roman temple of Divus Claudius and the Institute of Botany designed in the 1930s by Giuseppe Capponi (Attenni et al., 2019), are aimed at assessing the level of depth of representation and the geometric congruence, rather than the actual ability of the system to render content relevant to the characteristics of the buildings (Fig. 9).

Building Information Modelling, on the other hand, is derived from industrial production, standardisation of elements, and technical reproducibility which, according to Walter Benjamin, cancels out the distinction between original and copy, subverting the traditional ways of enjoying artistic products (Benjamin, 2008); this technology is also one outcome of globalisation, since it aims to unify means, tools, and procedures on an international level. Historical architecture, by contrast, is distinguished by antithetical aspects; the attributes of uniqueness and unrepeatability are in fact linked to artisanal or semi-artisanal construction processes and transformations undergone over time, while the link with the historical-geographical context is expressed by materials, construction techniques and architectural language. The approaching of these two universes, one concrete and the other digital, therefore represents a complex challenge, to be tackled through appropriate implementations of commercial software and the IFC standard in particular, the need for suitable classification systems, appropriate semantic

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8 <https://standards.buildingsmart.org/IFC/RELEASE/IFC4_3/HTML/lexical/Pset_MaintenanceStrategy.htm> [Accessed 5 June 2024].

9 <http://www.cartadelrischio.beniculturali.it> [Accessed 5 June 2024]; see attached documentation in the section "Scheda Vulnerabilità – Stato di Conservazione" (in Italian).

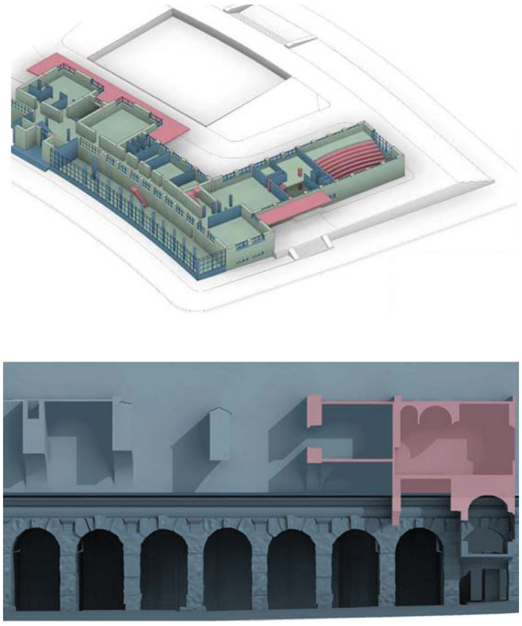

Fig. 9 Botanical institute and temple of Divus Claudius, Rome: the BIM model's levels of high, medium, and low reliability are shown in green, blue and red, respectively (Attenni et al., 2019)

definitions and further descriptive properties give rise to in-depth perspectives that must find the necessary support through methodological approaches consolidated in the disciplinary sphere of conservation.

The objective of achieving a greater adherence to built reality blatantly belies the abused definition of 'digital twin'; this expression fuels a dangerous misunderstanding, as it prefigures the possibility of obtaining the virtual equivalent of an existing building. As has already been pointed out (Parente and Ottoni, 2023), conceptual abstraction implies instead a critical selection of the data to be transposed into the model, which does not return a faithful duplicate, but a discrete representation of the built. The simplifications inherent in digital translation thus imply approximations that are only acceptable when the information collected is selected according to appropriate criteria; at the same time, it is necessary to evaluate the intrinsic coherence of the process of digital reconstruction in the choice of tools used. In this sense the loss of data that occurs in the passage from a point cloud to a parametric model represents an emblematic case, computable by means of appropriate verification of geometric correspondence. Less immediate, on the other hand, are indicators that allow one to consider possible mismatches of the information.

Following the experiments conducted so far, the decision to use this technology only on the basis of economic parameters, and to extend it to public contracts that are below the EU threshold, seems short-sighted. On a regulatory level, the constitutional principle of good performance of public administration, with its corollaries of efficiency, cost-effectiveness and effectiveness, should correct this orientation in order to avoid unreliable and excessively onerous modelling in terms of time and cost.

The conditions for preferential application of BIM software should in fact be identified and subordinated to the characteristics of the buildings to be represented (compositional regularity, seriality or repetition of components, evidence of a figurative code, limited stratifications, the absence of deformations, etc.), while retaining awareness that an immediate transposition of tools that have been designed for different purposes may not represent an appropriate choice.

The current Italian code for public contracts, on the other hand, does not explicitly oblige contracting authorities to use BIM systems, but does prescribe the application of open methods and tools for digital management of information in the construction sector.

This provision, which is somewhat generic, does not exclude the use of 3D GIS or platforms for the semantic structuring of three-dimensional representations; while waiting for BIM to allow digital representations more in keeping with the specifics of historical architecture, it therefore does not seem inappropriate also to consider the selection of alternative or complementary systems.

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