A Scan-to-HBIM Workflow to Trace the Level of Modelling Accuracy. The Case of Palazzo Carignano in Turin

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Abstract

Baroque architecture presents considerable morphological complexities relating to structural systems, distributive characteristics, and decorative elements. Palazzo Carignano in Turin, designed by Guarino Guarini from 1679, is a quintessential example of the period. The need to comply with public works regulations, monitor the state of conservation, and document the building required to plan new integrated digital surveys and create HBIM models. The workflow developed combines integrated digital surveying methodology with HBIM modeling process, dedicated to both the structural and architectural systems, as well as the decorative elements. The Level of Accuracy (LOA), a control parameter for surveying and modeling, is central to connecting the two phases of the process and represents one of the main challenges of the research.

1. Introduction

Baroque architecture presents considerable morphological complexities relating to structural systems, distributive characteristics, and decorative elements. Palazzo Carignano in Turin, designed by Guarino Guarini from 1679, is a quintessential example of the period.

The need to comply with public works regulations, monitor the state of conservation, and document the building required to plan new integrated digital surveys and create HBIM models.

The work outlined in this proposal is rooted in a broader project focusing on the physical and cognitive accessibility of the palace, which the Residenze Reali Sabaude – Museo di Palazzo Carignano commissioned and funded as part of the PNRR (National Recovery and Resilience Plan).

The workflow developed combines integrated digital surveying methodology with HBIM modeling process (Nieto et al., 2022), dedicated to both the structural and architectural systems, as well as the decorative elements. The Level of Accuracy (LOA), a control parameter for surveying and modeling, is central to connecting the two phases of the process and represents one of the main challenges of the research.

2. Methodological framework and pipeline

The section of Palazzo Carignano, built at the end of the 17th century, has a U-shaped layout, with a façade facing the square that is approximately 80 meters long and side wings facing the lateral streets, which are approximately 42 meters long. The depth of the wing is approximately 24 meters, the height of the building at its roof ridge is approximately 30 meters, and that of the central body is approximately 40 meters. The primary construction material is brick, used in standard blocks (approximately 23.5 x 11 x 5.5 cm) and in special pieces, both for the load-bearing structure, vertical partitions, and vaults, as well as for most of the ornamental system. The palace stands out in the panorama of Baroque civil architecture for its use of visible brickwork on all exterior surfaces (Fig. 1). The building was designed and constructed using measurements based on the local metric system of the time, which was divided into *trabucchi, piedi liprandi*, and *once*. One *trabucco* (approx. 3.0825 m) contains six *piedi liprandi*, one *piede liprando* (approx. 0.5137 m) contains 12 *once* (one *oncia* approx. 0.0428). Knowledge of the unit of measurement used is fundamental in constructing the digital model, which is set according to the International System of Units (SI), to recognize the modularity and proportions present in the building in question.

In the current research, integrated digital surveying and HBIM modelling covered the entire 17th-century building's external facades and roof, the ceremonial route rooms, the museum spaces of the Mezzogiorno and Mezzanotte apartments, located at the ground floor, and the upper lantern. The acquisition project was planned by integrating various surveying methods,

Figure 1. Palazzo Carignano in Turin by Guarino Guarini. Photo: F. Natta.

including 3D laser scanning, terrestrial and aerial photogrammetry, and topographic survey, the latter of which was used to verify the survey's accuracy.
The HBIM modelling project was divided into two phases: the first refers to the Scan-to-BIM process, which aims to create an architectural information model. The second involves enriching the HBIM model with the stylistic and ornamental elements that characterize the building, also made in a BIM environment.
The aim of generating a tool for geometric and informative knowledge and documentation, to be used in maintenance, restoration, and monitoring operations, informed the methodologies for organizing and creating the model.
The connection between the two macro-activities, surveying and modeling, revealed a significant link in the concept of LOA, as expressed in USIBD Document C120TM (Version 3.0, 2019). The level of accuracy of the survey data has been validated by the control network, which has verified the overall accuracy of the system and validated the data acquisition process. In light of the concept of LOA, when designing the modeling workflow for a historic building based on digital surveying, it is essential to set limits on the deviation of the model from the survey data. Furthermore, it is necessary to recognize that the LOA obtained through data acquisition (Measured Accuracy) may differ from the LOA of the HBIM model (Represented Accuracy).
Several studies face the issue of LOA applications in the Scan-to-BIM processes.
Graham et al. (2018) listed existing standards and guidelines concerning BIM modelling. They introduced a new benchmark specific to existing and heritage buildings developed by Carleton Immersive Media Studio (CIMS), which sharply linked the Level of Development (LOD) and LOA.
Radanovic et al. (2020) reviewed existing heritage building modelling approaches, both parametric and reality-based, with a focus on the geometric accuracy and semantic richness of the generated models. They propose a platform that combines parametric and reality-based modelling approaches, aiming to simplify the Scan-to-BIM process, which has been recognised as a bottleneck in heritage BIM. As it will be seen, the current proposal follows a different path, but the comparison could be interesting.
Esfahani et al. (2021) provided insight into the dimensional certainty of BIMs generated by Scan-to-BIM and established a series of modeling scenarios, including manual and semi-automated approaches. This reference could open a new way for developing the present work.
As mentioned above, the complexity of the building contrasts with its apparent symmetry, and the irregularities, evident in the ground plans (Spallone et al., 2025), are further obscured by the curvilinear facades facing the square and courtyard. The rich decorative apparatus also tends to conceal significant differences in the heights of the openings on the same floor, as on one of the facades, where they are about 30 centimeters higher than the others. The windows and doors, which are handcrafted and have been partially replaced over the centuries, are equally varied. A detailed study has led to the classification of approximately twenty different types of windows and doors, for which specific abaci have been created, as will be seen.
The decision to model vast majority of the decorative elements, as moldings, cornices, capitals, pediments, and friezes in a BIM environment led, on the one hand, to a significant simplification and, on the other hand, made it possible to use lighter models without the risk of incompatibility issues due to the importation of meshes from other software. Only the vaults, the staircases' moldings, and the Ionic capitals were created by geometric modeling software.
The choice of the LOA20 for the architectural model, which will be discussed further below, is somewhat restrictive given the building's complexity. However, this constraint has enabled the discovery and highlighting of alignments, deviations, and indentations in both horizontal and vertical sections within the HBIM model. These observations have made it possible to highlight, for example, how the tapering of the walls in the vertical sections was resolved at the cornices, using the modularity of the brick blocks. In addition to these undoubted advantages for scholars, the adherence and, conversely, the maximum deviations declared by the point cloud facilitate the work of the various operators involved in the conservation, restoration, and management of the asset, allowing them to have a stable model whose reliability is declared, which can record geometric changes over time and collect information relating to knowledge analyses and interventions carried out. In many cases, this can avoid the need to refer back to the point cloud, the result of the acquisition, i.e., raw material, to deduce metric and geometric data, and offers the advantage of having useful information for new interventions that can be continuously implemented.
In fact, despite the undeniable limitations imposed by the BIM process in geometric modeling of Built Heritage (BH), the informative potential it offers is considerable in the Operation and Maintenance (O&M) lifecycle phase and Facilities Management (FM) scope, which represent the main objectives in preserving the asset. In this sense, the statement by Lovell et al. (2023) is exciting, as it suggests that the only standard definition applicable to HBIM is the recent definition of the Level of Information Need (LOIN). As is well known, LOIN includes the level of model detail (LOD) and the level of associated information (LOI), positing that in some instances, a low level of model detail can be mitigated by a high level of associated information.

3. Digital survey methodology and results

The main problems encountered in surveying Palazzo Carignano included large-scale variations between the building and the ornamental and sculptural details, interference from tourists, areas characterised by optically uncooperative materials, and the need to control overall accuracy. Therefore, from a methodological point of view, three surveying methods were integrated: topographic, range-based, and photogrammetric. The construction of a topographic network and the acquisition of GCPs distributed on the floor and main vertical surfaces served a dual purpose: on the one hand, to provide orientation data for range-based and image-based data; on the other, to verify the survey's accuracy through residual analysis. Range-based 3D acquisition was used extensively to survey all building surfaces, except the roof. Finally, photogrammetric acquisition from the ground and by drone was used to acquire the missing roof data and internal façades, generating high-resolution ortho-images. In addition, an experiment was conducted in some specific rooms with optically uncooperative surfaces to provide a basis for comparison with the range-based data.
The support and control survey was conducted by creating a 3D topographic network, consisting of a closed loop along the main staircase of the building and three open branches towards the square, the internal courtyard and the Mezzogiorno apartment. The Zoom 35 Pro (Geomax) total station was used, and the measurements were processed, resulting in a loop closure error of less than 3 mm in both planimetry and elevation. Using the total station in reflectorless mode, 61 GCPs were surveyed, corresponding to architectural details distributed at different elevations, both inside and outside the building. Finally, the reference system located at the S1 station was rotated and translated with respect to a new vertex coinciding with a recognisable point on the main façade of the building, with the

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X-axis aligned with the façade. This step was necessary to simplify subsequent data visualisation and to identify a point recognisable within the range-based data (Fig. 2).

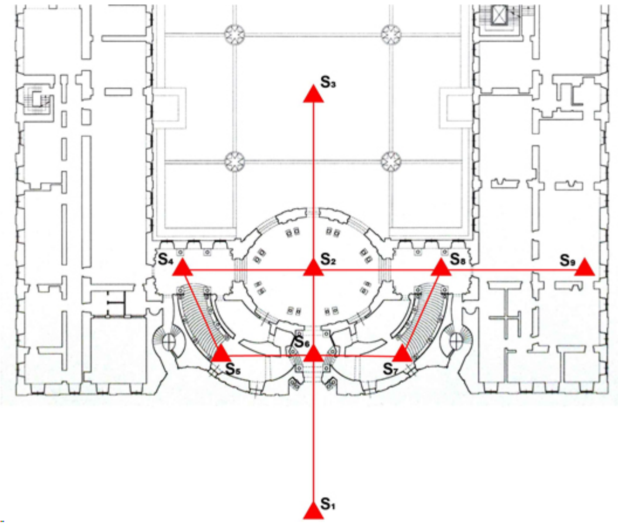

Figure 2. 3D topographic network. Editing: M. Russo.

The range-based acquisition phase was carried out using the RTC360 3D laser scanner (Leica), chosen for its precision, portability, real-time coverage control enabled by the VIS system, and optimal performance on optically uncooperative surfaces. A total of 199 colour scans were acquired, with resolutions ranging from 3 mm@10 m to 6 mm@10 m, depending on the geometric complexity of the scene and the working distance. During the acquisition phase, tourists' interference certainly affected data quality, leading to the propagation of shadow areas and the need for outlier removal. The 3D laser scanner data was managed in the SW Register (Leica), filtering and refining scan orientation and verifying the quality of the connections. Once the entire scan system had been oriented, it was rotated and translated with respect to the topographic reference system and imported into ReCap (Autodesk) in native resolution. Within the programme, an additional 58 GCPs coordinates were extracted to supplement the topographic ones for the three rooms of the Mezzogiorno apartments, to support the processing of photogrammetric data. The range-based point cloud was finally sub-sampled with steps of 5 mm, 1 cm, and 2 cm to facilitate integration with the Autodesk Revit BIM software (Fig. 3).

Figure 3. Range-based point cloud. Processing: M. Russo.

The photogrammetric acquisition by drone was performed using a DJI Mavic mini 2 drone equipped with an FC7303 camera (4000 x 3000 pixels, 4.49 focal length, 1.62-micron pixel size). The first nadir-axis flight with manual control and 60-80% overlap between horizontal and vertical strips captured all portions of the roof at a distance of 10 metres from the roof, achieving an average GSD of 10 mm with 437 photographs. The second flight was dedicated to covering the interior façades at an average distance of 5 metres, achieving a GSD of 7 mm for 427 photographs. The ground-based photogrammetric acquisition process was also initiated on an experimental basis in the three rooms with gilding and mirrors in the Mezzogiorno apartments, to determine the best product between range-based and image-based methods (Fig. 4).

Figure 4. Photogrammetric acquisition inside the Mezzogiorno apartments. Processing: M. Russo.

The photographic campaign was conducted using a Sony Alpha 7 Mark IV (61 MP, 35.9×23.9 mm) and a telescopic pole, reproducing a 60-80% coverage between horizontal and vertical lines and inserting inclined axis shots to stiffen the photogrammetric block. Acquisition was planned at a distance of 1.5 metres, obtaining a GSD of 0.4 mm.
Each wall was treated separately, acquiring between 80 and 160 images per wall. All photogrammetric blocks were oriented following the topographic/range-based GPCs in Metashape (Agisoft), yielding average residuals of 0.019 m for external drone images and 0.005 m for internal ground images. At the end of this process, a dense point cloud was constructed and imported into Recap (Autodesk) software to integrate the range-based cloud, keeping the levels separate for better management. At the same time, ortho-images of the building's internal and external façades and the roof were extracted (Fig. 5).

Figure 5. Orthophoto of the courtyard facade. Processing: M. Russo.

The final stage of the survey consisted of an accuracy check of the overall point cloud produced. To this end, 25 topographic CPs were identified and compared with homologous range-based ones, yielding an average residual of 16 mm. This value demonstrates the overall level of accuracy achieved by the survey, consistent with the traceability of the overall process, while ensuring good initial reliability for the interpretative 3D modelling phase (Fig. 6).

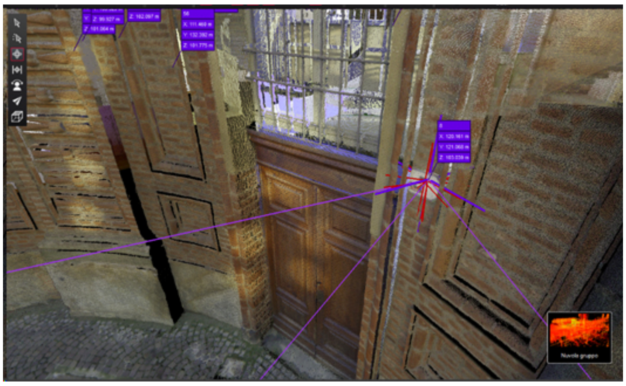

Figure 6. Accuracy check. Editing: M. Russo.

4. Preliminary analyses of Palazzo Carignano architectural layout and features

As highlighted in the section describing the working methodology, the building has a high level of irregularity, which is also reflected in the layout of the façades: although they are featured by an organisation that qualitatively aims to restore symmetry and rhythmic modularity to the elements that constitute their framework, they are affected by numerous irregularities, which are always masked and attenuated by the decorative apparatus.

In this context, characterised by a great variability of elements, with consequent difficulties in their standardisation, it was essential for the subsequent modelling phases to carry out an accurate study of the features that hierarchically mark and subdivide the individual façades (baseboards, string courses and moldings, engaged piers and decorated bands) and the openings (doors, french windows, windows, oculi, ...) and the decorative elements associated with them.

In this phase, we analyzed a combination of digital laser scanner surveys and orthophotos of the façades derived from digital photogrammetry.

The first phase of the analysis focused on classifying openings by size and, in accordance with the chosen LOA, identifying the horizontal planes that define the positions of the string courses and window sill bands, and the vertical planes that define the axes of the overlapping openings.

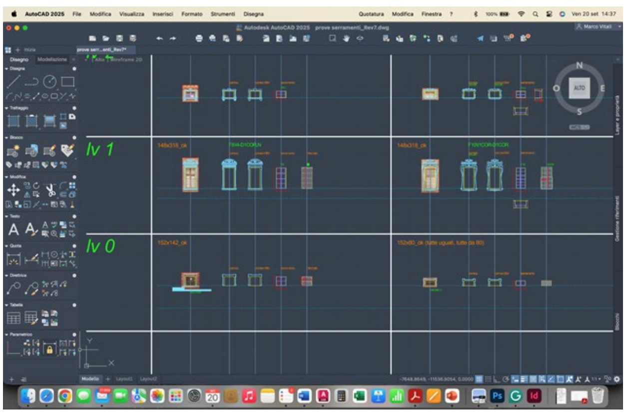

Figure 7. Preliminary geometric and morphological analysis of windows, doors, and frames. Drawing: R. Spallone.

The analysis made it possible to standardise, where possible, and position the elements characterising the individual façades in space, ensuring a modelling phase that would allow the geometries of the objects to be regularised and the qualitatively recurring elements to be organised into homogeneous classes. Regarding the geometry of the openings, including ironworks (grilles), over twenty different types were identified and classified. A typological table was created using two-dimensional drawings generated with Autodesk AutoCAD 2025 software, which is adaptable to the various sizes of the openings (Fig. 7).

The openings were also accompanied by decorative elements, featuring different frames for each level of the building. At the same level, they differ further, with variations between the external façades facing the street and the internal courtyard. On the main floor, the openings facing the courtyard exhibit further diversification in the decoration of the north wing compared to those on the other façades.

In all cases where the decorative elements were found to be related to architectural orders and moldings, the elements created were compared with Guarino Guarini's treatise, *Architettura civile* (1737), in order to create the geometric constructions of the elements in accordance with the instructions in the text. Moldings, string courses, corbels, capitals, engaged piers, etc., were detailed and then simplified accordingly. This simplification was carefully studied to maintain the recognizability of the ornamentation on the one hand and to ensure that the HBIM modelling phase was not overly complex on the other. In this regard, the HBIM modelling techniques used to restore the ornamental elements consist of parallel extrusion (in the case of continuous elements, such as cornices or decorative bands) or perpendicular to the façade surfaces (in the case of point elements) (Fig. 8).

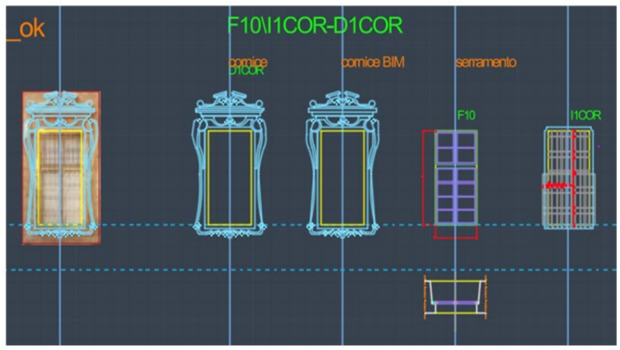

Figure 8. Detail of the preliminary geometric and morphological analysis of the frames and simplification aimed at BIM modelling. Drawing: M. Vitali.

The aim of restoring the decorative system is to recall the stylistic features of Baroque architecture developed by Guarini, including the vibrations of the surfaces that characterise its aesthetic qualities.

5. H-BIM settings

The primary objective of the Palazzo Carignano Asset Information Model (AIM) was to maintain an accurate record of the building and its decorative elements. The BIM model uses are digital visualisation and two-dimensional view extraction. Potential future BIM uses could include the implementation of data, after knowledge operations, and professional interventions or conservation activities planning.

The production of the informative model has been fulfilled using Autodesk Revit (2025 version) and without any information requirements provided by the appointing party (EN ISO 19650-1:2018). Chosen BIM authoring software allows for modeling the reality either using parametric elements or importing complex geometries from other software.

Following model uses and goals and due to asset dimensions, it has been decided not to produce federated models. A unique model contains all the disciplines (architectural and structural) and the entire building (all the storeys, main elements and decorative apparatus).

The definition of LOIN has represented an important milestone to be achieved before Scan-to-BIM process. EN ISO 7817-1 was the standard followed to define how to represent object geometries and which information to associate with them. For all the objects (any part of the perceivable or conceivable world) (EN ISO 7817-1:2024), geometrical and alphanumeric information was set to define the modelling workflow and property sets to be applied to elements. Documentation, the third concept which describes LOIN, was not essential for fulfilling model goals and current BIM uses. According to the standard, to specify geometrical information of an object, five independent aspects should be defined: detail, dimensionality, location, appearance, and parametric behaviour. Dimensionality and location were equal for every object. These were modelled in 3D and located in a relative coordinate system. Appearance was symbolic for many objects; they were represented by a diffuse generic colour. Windows, doors, and curtain walls had a more realistic appearance. A transparent material was applied to the glass panels, while a generic wood material was used for the frames. This material was also used for beams and trusses. Detail and parametric behaviour were considered crucial for respecting LOA20 as a fundamental principle of this research. Different detail levels were associated with objects, and this choice has had consequences on the way the objects were modelled. Only volumes were modelled for walls, floors, ceilings, vaults, and roofs. For doors and windows, the number and dimensions of panels, frames, and battens were modelled to precisely define all different opening types. Molding, cornice, pediment, and frieze geometries were simplified to strike a compromise between the representation style and the effort required for the modeling process. Ionic capitals are the most complex 3D geometries within the model, being highly detailed and closely resembling real shapes.

During the modeling process, the priority was to create as many parametric or constructive geometries as possible. Depending on BIM authoring software, as said, just three object categories were not modelled using these criteria: vaults, staircases' moldings, and column Ionic capitals. Due to the geometry complexity and the inadequacy of Revit tools, these objects have been modelled in other software. Then, they have been imported inside the model. They are classified as explicit geometries which cannot be modified by parameters. Objects belonging to categories inside BIM authoring software were modeled as parametric geometries (walls, floors, roofs, doors, windows, stairs, railings, beams, trusses). Constructive geometry process was finally used for representing decorative apparatus. Moldings, cornices, capitals, pediments, columns and friezes were generated by geometric primitives extruded, swept or revolved to create solids.

To define alphanumerical information, information content and identification have been specified. Two property sets were exported to collect information about survey analysis and opening types. A property was set for walls, floors, doors and windows to define if they were modelled using 2024 survey data or different sources. For floors a Boolean property was also set to specified if walking surfaces have been surveyed or not, the same as the interior side of walls and windows. With these properties, supposed geometry dimensions have been distinguished from certain ones. Properties for door and windows, finally, were able to specify all type objects composing an opening. An opening could be composed by up to three horizontal portions. Each portion could be a door or a window which are defined by different types of panels, frame and battens. The property set collects all these data.

Identification is deeply linked to codification system adopted. Family and type names were set to identify elements depending on their main function, location and peculiar features. As starting point to define rules for naming elements, standards provided by Agenzia del Demanio were used. Agenzia del Demanio has defined a precise workflow for receiving information concerning its works and goods during an appointment. In "BIM method statement" document, codification system is explained. Rules, contractions and name structure have been adopted to follow this well know codification system, and some adjustments have been made for the specific case study.

Elements are named with three fields separated by an underscore, while a field can be composed of multiple values separated by a minus. The first field is about element function: MUR for walls, CRN for cornices, VOL for vaults, DCR-FIN for window decorative apparatus and may others. The second filed indicates element location, and it is composed by the combination of these acronyms: INT and EST for internal or external walls; an acronym for levels; STR or COR to indicate if elements are located along the street or inside the court; CER, MZN, MZG for locating elements in the ceremonial route rooms or in Mezzanotte and Mezzogiorno apartments. The final field is optional, and it can be composed by multiple values detailing element characteristics. For Revit system families, element dimension is indicated (wall and floor thickness). Different objects with the same function and located in the same place are distinguished by a progressive letter or a short description in pascal case. For example, DCR_POR-P00_STR_CER-PiramideQuattroLati and DCR_POR-P00_STR_CER-Parastina indicate two decorations located at level 00, close to the main door of the palace (ceremonial route, street side), but composed by different geometries.

6. HBIM modelling strategies and As-Built reliability

The transition from the unstructured data of the point cloud to the semantic structure of the BIM represents one of the most critical phases in the digital reconstruction of Built Heritage. This process is not merely a geometric translation but constitutes an epistemological act of interpretation, where the surveyor must synthesize the complexity of the as-built reality into parametric elements. As highlighted in the literature (Banfi et al., 2017), the management of generative processes for complex historical buildings requires a paradigm shift from standard modeling workflows to adaptive strategies capable of preserving the uniqueness of the architectural morphology.

As seen above, the Scan-to-BIM workflow was driven by the specific objective of achieving a Level of Accuracy (LOA) 20, as defined by international specifications USIBD 2019. This target dictated the modelling tolerance and the strategy for simplifying the Baroque geometries without compromising the architectural legibility. Revit, integrated with Rhinoceros, only in the case of the above-mentioned complex decoration surfaces, ensures an interoperable workflow essential for the preservation of geometric information.

Below, the operational strategies employed for the primary architectural elements, along with an analysis of the deviations encountered, are outlined.

The modelling of the façades presented significant challenges due to the geometric complexity of Guarini's building. The approach involved the creation of specific parametric families to manage the extreme variability in wall thicknesses documented by the survey data. For the external envelope, "Basic Wall" families were generated with variable thicknesses.

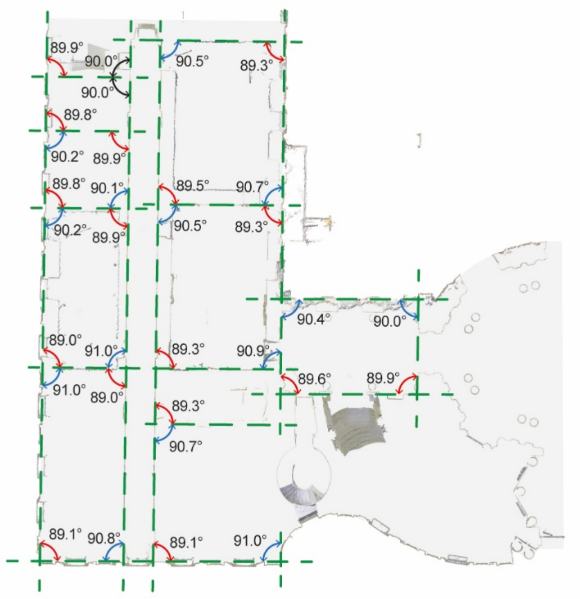

Figure 9. Overlapping of wall alignments with the point cloud and check of the out-of-square. Editing: F. Natta.

Similarly, internal partition walls required a wide range of dimensions. A distinct case was represented by the walls' connection between the original 17th-century block and the 19th-century expansion; here, massive masonry sections of 160 cm and 225 cm were modelled to represent the transition between the two construction phases. The geometric definition of these walls followed a rigorous methodology to respect the imposed LOA limits. For rectilinear segments, the positioning was constrained by alignment lines previously traced on the point cloud slices (Fig. 9).

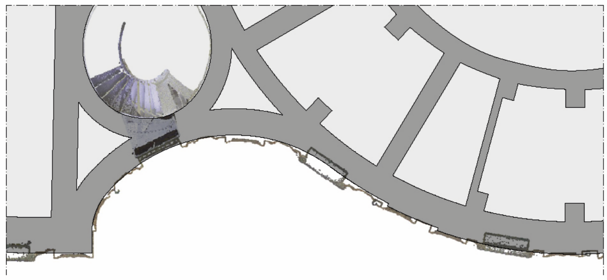

Figure 10. Detail of the curved façade modelling showing the overlapping walls strategy to handle the stepped masonry. Processing: F. Natta.

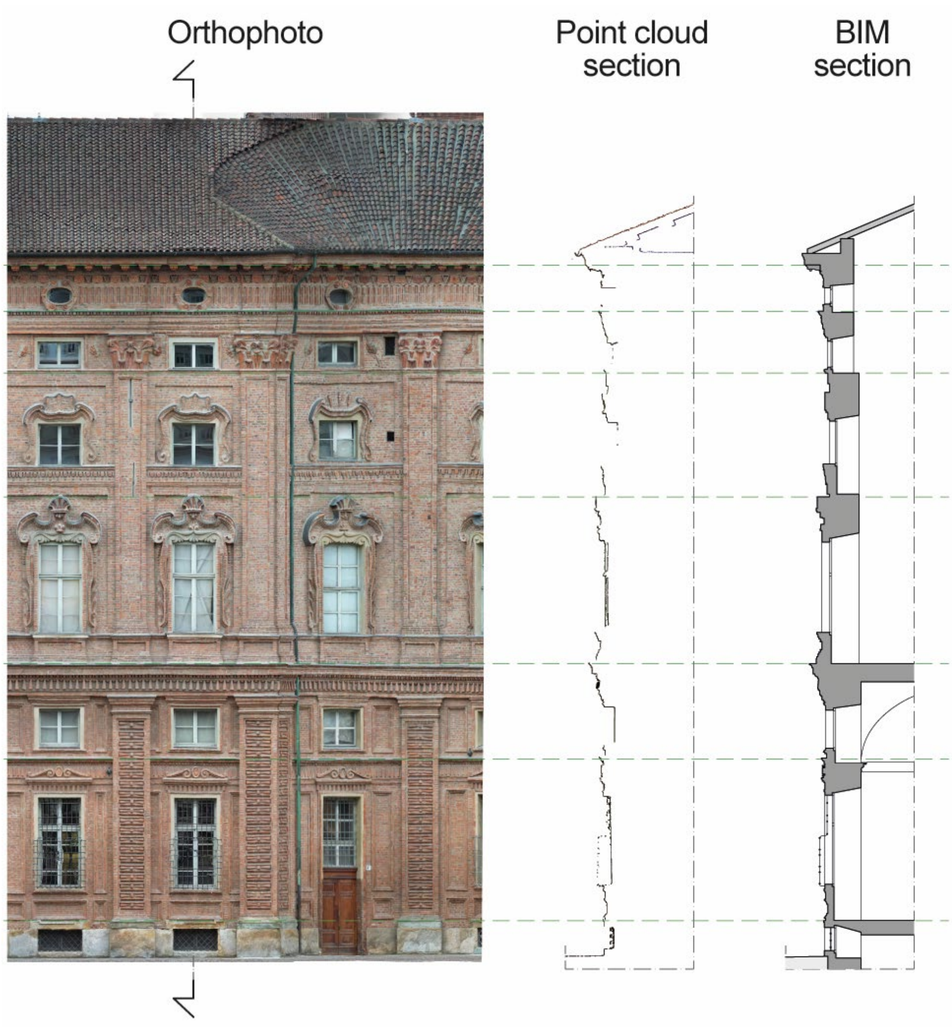

Figure 11. Correspondences between the point cloud and HBIM model sections, and the orthophoto to identify the walls tapering at different levels. Processing: F. Natta

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However, the curvilinear façade required a more complex interpretative process. The reconstruction of the curves aimed to minimize the number of generating centers to maintain parametric manageability. Crucially, the detailed analysis of the point cloud revealed a discrepancy between the apparent continuity of the façade and the actual masonry layout. It was observed that the architectural orders masked a discontinuous trend in the curtain wall.

The masonry actually present wall recesses, with setbacks of approximately 10 cm (reasonably corresponding to a brick module) occurring at two specific areas towards the center of the façade.

Furthermore, to manage the varying curvature radii of the plan, the wall modelling utilized a system of overlapping wall instances, allowing for tangent control and correct join geometry behavior (Fig. 10). This operation of tracing and reconstructing the curves was reiterated for each level of the building. Early investigations had already highlighted that the masonry, especially in the curved façade, exhibited significant variations in section and position relative to the lower levels (Fig. 11).

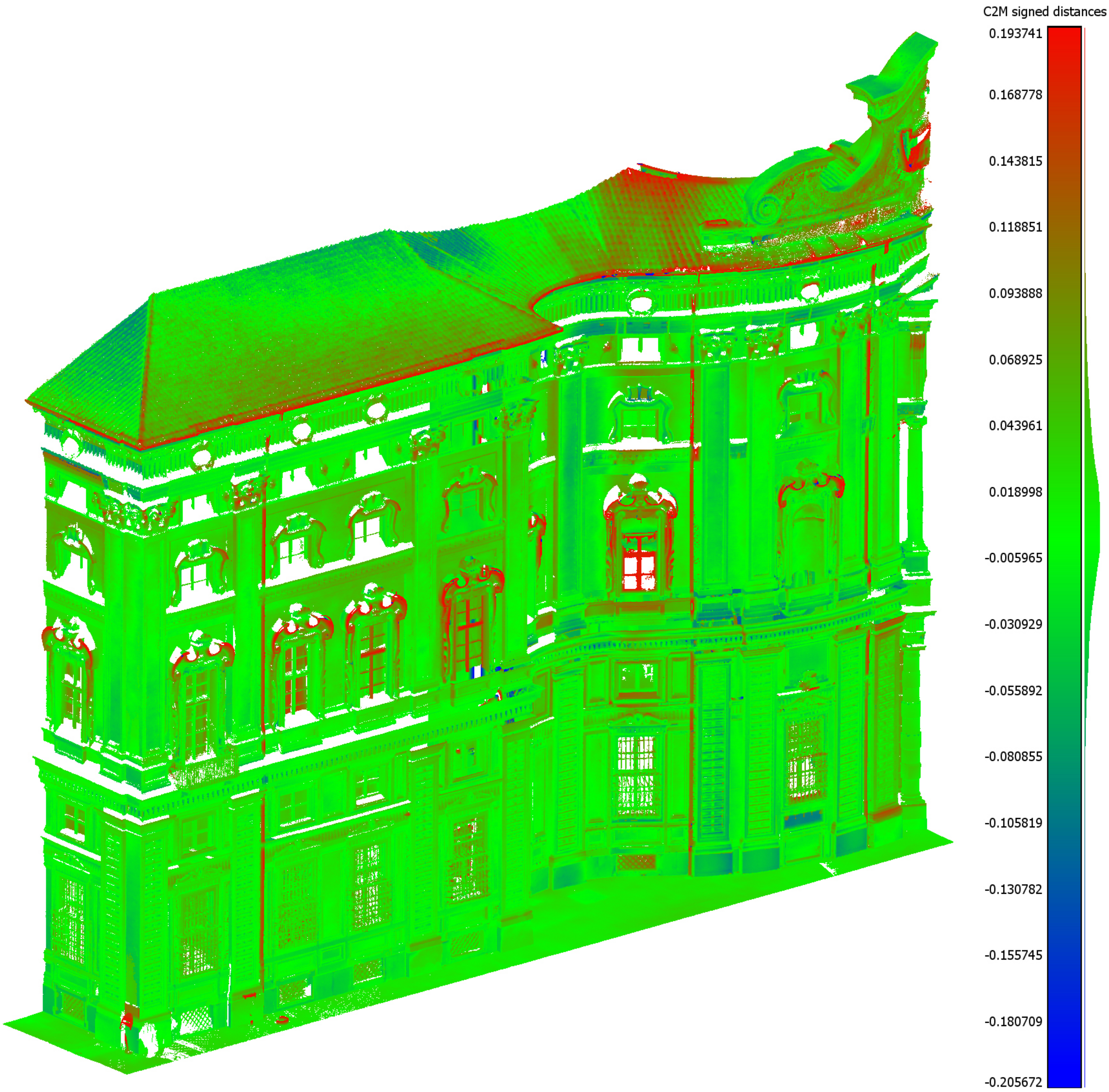

Figure 12. Overlapping of the HBIM model with the TLS point cloud. It should be noted that the LOA values of the architectural model are within the defined range, and that those that exceed it affect only the decorative elements. Processing: F. Natta.

The management of horizontal structures (floors and roofs) required a hybrid modelling approach, differentiating between elements with predictable geometries and those requiring free-form surface modelling. The floor slabs were categorized based on the availability of survey data. For external paving, "Floor" families were managed through "Shape Editing" (point manipulation) in Revit, adapting the slab geometry to the varying elevations of the paving captured by the laser scanner. For internal spaces, the approach varied depending on whether vaulted systems were present. The standard BIM tools proved insufficient for complex vaults. In these instances, the geometry was modelled in Rhinoceros, using the position of the previously created BIM walls as a reference. These surfaces were then imported into the BIM environment as "Generic Models", ensuring correct visualization and volumetric consistency. The roofing system, particularly the connection between the curved façade and the lantern, represented one of the most geometrically complex areas.

To adhere to the LOA requirements while managing the double curvature and irregular pitches, the "Roof by Face" tool was employed. The underlying geometry was generated as a "Mass" family, derived from a surface imported from Rhinoceros. This workflow enabled more accurate control over the complex intersections and the morphology of the Palazzo Carignano's covering. In the context of HBIM, the model's reliability must be declared a fundamental prerequisite. As discussed by Brusaporci et al. (2023), the As-Built model cannot be considered a simple representation of reality, but rather a reliable synthesis that must be validated quantitatively. To assess the geometric coherence of the modelled elements against the survey data, a Cloud-to-Mesh (C2M) distance analysis was performed. This validation utilized the final BIM model, including all modelled components. It is crucial to note that attempting to validate parts of models often leads to "invalid for analysis" results, as many elements are geometrically dependent on the host architecture. The model was exported to CloudCompare to calculate the signed distance field between the dense point cloud and the mesh generated from the BIM objects. The resulting color map provides an immediate assessment of the deviation (Fig. 12).

The analysis demonstrates that the modelling approach adopted – specifically, the discretization of curved walls and the adaptive management of floors – yielded excellent Scan-to-BIM reliability. The deviation values are largely contained within the tolerances established for LOA20. It must be acknowledged that the C2M comparison includes decorative elements present in the point cloud but simplified in the architectural BIM model, as discussed above. Consequently, some red areas in the deviation map do not indicate a geometric error in the structural modelling but rather a deliberate Level of Geometry (LOG) simplification inherent to the project goals. Filtering out these decorative layers, the structural correspondence between the complex Baroque masonry and the parametric model confirms the validity of the workflow, ensuring that the digital model is a metric-reliable basis for future conservation and management activities (Bonduel et al., 2017).

7. Conclusions

The workflow developed faces two interconnected challenges: the traceability of the process, which will allow future users of digital surveys and HBIM model to work on validated and open data, and the control of distances between the survey and the model, which will provide precise data on which to carry out the design activities necessary to safeguard the asset. As highlighted by the USIBD C120TM and demonstrated by the experience carried out and described, the level of accuracy of digital surveying differs from that of the HBIM model. The model deviation from the point cloud, ranging from 1.5 to 5 cm, may appear significant. However, setting the LOA of the model a priori was an essential constraint for the modeling, which allowed us, as an added value, to discover possible construction artifices aimed at hiding irregularities and asymmetries in the plan and indentations in the masonry in section.

Acknoledgements

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