HBIM MODELLING FOR THE ARCHITECTURAL VALORISATION VIA A MAINTENANCE DIGITAL ECO-SYSTEM

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ABSTRACT:

The present contribution falls within the framework of the actions envisaged by the "SMART Bethlehem – Sustainable Management And Renewal of Technology in the City of Bethlehem" (2022 – ongoing) research project, scientifically coordinated by the University of Pavia and co-founded by the Italian Agency for Cooperation and Development (AICS). Among the main objectives of the cooperation project is the sustainable urban and territorial development of the Bethlehem area by means of multi-scalar activities, mainly focusing on refurbishment and energy optimisation of a few relevant municipality buildings. A test case implementation of the HBIM methodology was then carried out on the Peace Center, an iconic building facing the "Manger Square" in close proximity to the "Nativity Church", aiming to validate the proposed systematisation of a scan-to-BIM approach focused on the development of an optimised data repository for the planned operation and maintenance activities. An ECO-Systemic workflow is presented, organised in five recursive steps. Starting from a SLAM-TLS integrated digital survey (3DS), the federated sub-models that comprise the overall project are geo-referenced (GEO) within a shared coordinate system (FSC) environment, thereby providing the basis for the subsequent architectural modelling of the built asset (ARC) and the associated enhancement of the level of information (LOI).

1. INTRODUCTION

The hereby proposed research activities have been carried out in the framework of the "SMART Bethlehem – Sustainable Management And Renewal of Technology in the City of Bethlehem" (2022 – ongoing) project, which stems from the positive cooperation and development experience of two projects co-founded by AICS and the municipalities of Pavia and Turin (3D Bethlehem and NUR – New Urban Resources). SMART-Bethlehem is a cooperation project co-founded by the Italian Agency for Cooperation and Development (AICS) and coordinated by the Province of Pavia with a partnership composed of the Municipality of Bethlehem, the Metropolitan City of Turin, the Italian Municipalities of Pavia, Parma, Padula and Bruino (the latter being the leader of Co.Co.Pa – Coordinamento Comuni per la Pace, Turin), ANCI Lombardia, the National Park of Cilento-Vallo di Diano-Alburni, the Joint Services Council for Tourism Development in Bethlehem Governorate, VIS – International Voluntary Service for NGO Development, the SISTERR – Pavia Territorial System for International Cooperation, the University of Pavia (scientific coordination), the Polytechnic University of Turin, the University of Bethlehem, Links Foundation, Ai Engineering S.r.l. and the Piacenti S.p.A. The project is scientifically coordinated by Professor Sandro Parrinello and the research laboratory DAda-Lab of DICAr – Department of Civil Engineering and Architecture, University of Pavia.

The main objective of the cooperation project is to foster the sustainable urban and territorial development of the Bethlehem area by planning multiscalar activities. To this end, a reduction in the power consumption of municipal buildings, the energy optimisation of public facilities, and "capacity building" activities for the municipality personnel were envisaged. This type of operation cannot disregard an in-depth analysis of the built heritage, for which an initial integrated survey action was necessary, followed by a parametric information modelling (HBIM: Historic Building Information Modelling) of the buildings to be rehabilitated. In this context, the Scan-to-HBIM modelling of the Peace Center, the case study covered in this paper, was carried out with the purpose of generating a digital ECO-System (intended as an Enriched COoperative System) that could effectively serve as the basis for future requalification activities, as well as for the designing of a centre for the cultural valorisation of the Bethlehem community.

An already comprehensive database of the Bethlehem city Center had been developed through the survey activities carried out within the framework of the "3D Bethlehem – Management and control of urban growth for the development of heritage and improvement of life in the city of Bethlehem" (2018-2021) which was coordinated by University of Pavia in collaboration with the Municipality of Pavia and financed with the contribution of AICS and many other national and international partners (Parrinello and Picchio, 2019). Therefore, in order to integrate this preexisting database, survey campaigns of the interiors of the municipal buildings were planned. In particular, for the Peace Center – facing the central square of the city (Manger square) in the immediate vicinity of the Nativity Church – acquisitions with a Mobile Laser Scanner (MLS), i.e., the handheld Leica Geosystem BLK2GO, were tested, supplemented, where necessary, with Static Terrestrial Laser Scans (TLS), employing a Faro CAM 2 S150. The point clouds obtained as output formed the geometrically accurate basis for the subsequent parametric modelling phase.

Indeed, the Scan-to-HBIM Ecosystemic approach, implemented within the Autodesk Revit environment, covered five recursive phases: starting with the 3D integrated survey (3DS) phase, followed by the georeferencing (GEO) of the federated models (FSC), to eventually set up the environment suitable for the architectural modelling of the Peace Center (ARC) in its current state of preservation (Sanseverino et al., 2022b). The last stage of

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the proposed workflow concerns the level of information enhancement (LOI), which is effectively carried out throughout the modelling process; in particular, we focused on further optimising the BIM objects by implementing advanced materials, i.e., Physically Based Materials (Mc Dermott, 2018), for extended reality application (Farella et al., 2022).

2. RECENT SOLUTIONS AND CRITICALITIES CONCERNING THE HBIM APPROACH

The methodology of Building Information Modelling (BIM) conveys a possible combination of symbolic representation and numerical modelling, responding to cognitive and descriptive needs on the design and, with certain precautions, on the built heritage. As a matter of principle, three-dimensional digital duplicates attempt to provide a faithful reproduction of the physical world but, unlike new buildings, the existing heritage requires the acquisition of additional information for a correct assessment of its state of preservation (Dell'Amico, 2022). The latter process is called Historic BIM (HBIM), which is nothing else than a reverse-engineering approach applied to existing buildings, especially those imbued with Cultural Heritage values (Murphy et al., 2013).

2.1 The Scan-to-BIM workflow

Despite the recognised advantages of using BIM in architecture and engineering, extending this procedure to the architectural heritage is neither immediate nor critical. Key issues, such as the uniqueness and irregularity of historical architecture and the great quantity of information necessary for the knowledge of architectural heritage, require appropriate reflections (Brusaporci et al., 2018). Namely, the information modelling of Cultural Heritage imposes the setting up of a reliable digital survey database (Morandotti et al., 2019); however, the efficient transformation of remote-sensing data into as-built parametric smart models is currently an unsolved challenge (Rocha et al., 2020).
First, within the framework of the so-called Scan-to-BIM approach, the survey and modelling efforts must be proportioned according to the project requirements. As the Level of Development (LOD) grows, there is a progressive increase in information and geometric content; conversely, the degree of parametrisation is progressively reduced to comply with the accurate representation of the asset state of preservation (Brusaporci et al., 2018; Lo Turco et al., 2022).
The HBIM methodology is renowned for its multiple uses, among which it is worth mentioning the as-built modelling aimed at providing a support tool for restoration and refurbishment purposes (Sun et al., 2019; Tommasi et al., 2016). Furthermore, the performance of analysis of degradation using a BIM design approach with the help of *ad hoc* parameters populated with materials, suppliers, operating and structural and energy analysis data presents a vital tool for facility management (Barba et al., 2020) and for risk management and structural health monitoring applications (Alirezaei et al., 2022; Barazzetti et al., 2016). Moreover, design optimisation, such as exhibition path and museum visiting flows estimation (Ferretti et al., 2022; Lo Turco et al., 2022), and building performance and life cycle cost assessment (Matos et al., 2020), also envisage the development of dedicated Visual Programming Language (VPL) scripts.
On the other hand, scan-to-BIM is still mainly a time and effort-consuming manual process (Rocha et al., 2020), usually employing the generation of specifically developed parametric objects (Chiabrando et al., 2017). Therefore, several experiments concerning automatic surface recognition (Romero-Jarén and Arranz, 2021; Sun et al., 2022) and NURBS modelling of historic architectural decorative apparatuses (Acosta et al., 2022; Barazzetti et al., 2015) can be found in the literature. This kind of application additionally entails a certain degree of automatisation, variously employing Artificial Intelligence (AI) algorithms for automatic segmentation and semantisation of the survey database (Teruggi et al., 2021).
Eventually, it is worth noting that during the last decade, the relevance of real-time rendering for visualisation, communication, and model validation purposes – combined with optimisation techniques (Johansson et al., 2015) and the advances in the current technology – has led to democratisation and a significant improvement in the extended reality applications (Banfi et al., 2021; Du et al., 2018). Indeed, even some of the previously mentioned research proposals also include implementing mixed reality tools (Alirezaei et al., 2022; Ferretti et al., 2022; Teruggi et al., 2021).

2.2 The SLAM survey for Cultural Heritage valorisation

In the framework of information modelling approaches, the amount of source data is as much a resource as a bottleneck. Indeed, the benefit of faster on-site data acquisition is sometimes necessary and data collection procedures are moving towards rapid 3D mapping approaches, evolving from traditional static scanning towards MMS (Mobile Mapping Systems) based on SLAM (Simultaneous Localisation And Mapping) technology implemented in portable devices. The ever-growing relevance of these solutions relies on the possibility of carrying out massive and cost-effective documentation, specifically in view of the generation of BIM-HBIM models (Sammartano et al., 2021).
Although the quality of the singular scans is notably reduced compared to the static solutions, several studies have been carried out on both outputs comparisons; the results are particularly convincing for the employment of SLAM technologies in urban representations. Notably, they allow speeding up acquisition procedures for documentation at an urban scale, making it possible to map different urban contexts, thus overcoming the difficulties linked to reduced accessibility or to magnitudes that cannot be covered within an adequate timeframe by the established 3D surveying procedures, i.e., Terrestrial Laser Scanners (TLS) (Dell'Amico, 2021). Thanks to the SLAM algorithm and the integrated IMU (Inertial Measurement Unit) sensor, both wearable (Hess and Ferreyra, 2021; Sammartano et al., 2021) and handheld (La Placa and Doria, 2022; Parrinello and La Placa, 2021) MLS solutions have proven to be suitable for the documentation and valorisation of ever-changing natural and historical environments, without needing the support of a global navigation satellite system (GNSS) (Barba et al., 2021). Furthermore, knowing that the quality of mobile acquisitions is primarily based on how data are acquired, many precautions can be implemented to maximise the results, such as previous inspection, walking slow (0.5 m/s), good coverage and high-resolution data (Guida et al., 2021).

3. THE CASE STUDY

The Peace Center (figure 1) is placed in the core of the city centre – facing the "Manger Square" and next to the " Nativity Church" – and it was built on the occasion of the new millennium to emphasise the concepts of peace, democracy, religious tolerance and diversity. During the excavations, traces of a church and floor mosaics dating back to the Crusaders, Mamluks and Ottomans were found, which led to three floors below the level of the square being set aside for a UNESCO-sponsored archaeological museum, supplemented with digital content, which unfortunately was never finished and is currently at a standstill. To the present day, although commercial activities partially occupy the building, most of the spaces on the upper floor remain neglected and used as temporary storage, resulting in slow deterioration due to infiltration. Therefore, in the framework of the actions envisaged by the SMART Bethlehem project, in terms of urban renovation and energy efficiency, a digital survey of the complex and its surroundings was carried out for the subsequent HBIM modelling.

Figure 1. Photograph of the Peace Center overlooking "Manger Square", in the Bethlehem City Centre.

4. MATERIALS AND METHODS

The methodological approach proposed in the following concerns a systematisation of the scan-to-BIM workflow, which, despite its many applications, to date has not yet encountered an effective and shared formulation, validated on a reality-based model derived primarily from a SLAM survey (figure 2). As previously mentioned, ECO-Systemic workflow developed in five recursive steps was implemented within the Autodesk Revit environment, followed five recursive steps, starting from the 3D integrated survey (I phase – 3DS), for the setting up of a georeferenced informative model ready to be integrated within the developed GIS system of the City Center developed as the main output of the 3D Bethlehem project.
The HBIM model of the Peace Center was first referenced using the EPSG:28191 – Palestine 1923/Palestine Grid coordinate system – the same adopted in the previous applications – (II phase – GEO) via a superordinate environmental model storing the shared coordinates (III Phase – FSC).

Figure 2. Photobashing of the Scan-to-HBIM modelling workflow employed for the Peace Center.

The prospicient buildings modelled for the GIS were also generated as instances in Revit using a VPL script (Sanseverino et al., 2022b). The state-of-the-art architectural BIM model of the Peace Center (Phase IV – ARC) was then developed. First, an in-depth analysis of the asset was carried out in order to break it down into its elementary components and correctly catalogue them, thereby furthering the census activities previously undertaken at the urban scale (Doria and Picchio, 2020). Next, the categorised components were modelled either as system families or as loadable parametric families designed ad hoc, occasionally employing further nested parametric elements. Finally, the Level of Information (V phase – LOI) of the modelled smart objects was further increased through the generation of advanced PBR materials in order to make the HBIM model ready for real-time rendering design (Banfi et al., 2021; Guarini and Rossi, 2022; Sanseverino et al., 2022a).

4.1 The 2022 SLAM survey

Although perceived as inaccurate for certain types of applications the SLAM technology has been considered within the scan-model workflows to reduce production time, thanks to the potentiality to cover a large acquisition area within a short amount of time (Dell'Amico, 2021). The main advantage of those instruments is the "scan-while-walking", making the survey of large areas more efficient with respect to the traditional TLS survey, in terms of timesaving. Therefore, in the last years, the availability of Mobile Mapping Systems (MMS) proved to be an interesting alternative to TLS for a large set of applications, especially if portable as handheld or backpack tools (Sammartano et al., 2021).
The survey campaign, dating back to March 2022, mainly focused on the data acquisition of the Peace Center's indoor space; particular attention was paid to the vertical connections, different types of opening elements and the various interconnected spaces located at different elevations. For this purpose, a handheld mobile laser scanner (MLS), i.e., the LEICA Geosystems BLK2GO, was employed. The MLS – specifically designed for surveying interiors with a noise value equal to +/- 3 cm and a declared indoor accuracy of +/- 10 mm – has a minimum range of 0.5 m horizontally and 0.7 m vertically and a maximum range of 25 m, a Field of View (FoV) of 360° horizontally and 270° vertically, and a Point Measurement Range of 420,000 pts/sec. The system is additionally equipped with three integrated panoramic cameras (4.8 Mpixel 300° x 135°) for the acquisition of colourimetric data, added to the metric data acquired by the laser scanner. Furthermore, the built-in camera allows the capturing of specific frames when necessary.
The scanning process can be checked via the proprietary app – the BLK2GO LIVE installed on a mobile device – and employs the innovative GrandSLAM technology, combining the LiDAR SLAM, Visual SLAM, and the IMU.

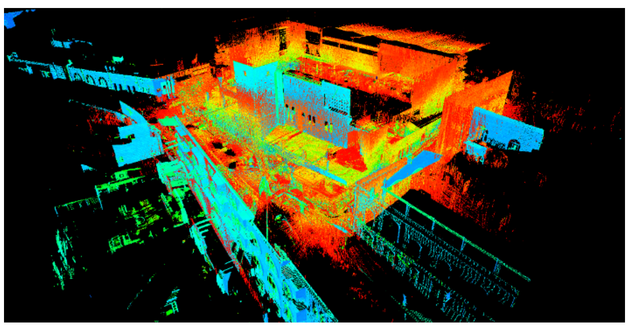

Figure 3. Overview of the registered SLAM and 2022 TLS surveys within Leica Cyclone REGISTER 360° PLUS.

To minimise internal error, the 44 scan trajectories were carried out by walking slowly and in closed loops, taking great care to get back to the starting point each time, and assuring a minimum overlap of 50% between one another. On average, the walking paths took 15-25 minutes of recording time, resulting in single scans containing 40-100 million points. Eventually, the SLAM database was registered in the Leica Geosystems Cyclone REGISTER 360° PLUS software environment obtaining a first 46 GB point cloud, exported in an E57 format, with an absolute error of 1.2 cm (figure 3).

4.2 The integrated survey database

As previously stated, an accurate three-dimensional survey (3DS) is the mandatory first step within a Scan-to-HBIM workflow in the field of Cultural Heritage so as to capture even the finest detail defining the historical asset under investigation. To this end, the 2022 SLAM database was integrated with the existing 2018 Terrestrial Laser Scanning (TLS) data (Parrinello et al., 2018) – consisting of 38 selected black-and-white scans undertaken close to the Peace Center (figure 4) – and a few additional coloured TLS scans, also acquired during the March 2022 survey campaign. Both TLS surveys employed the Faro CAM 2 S150 scanner.

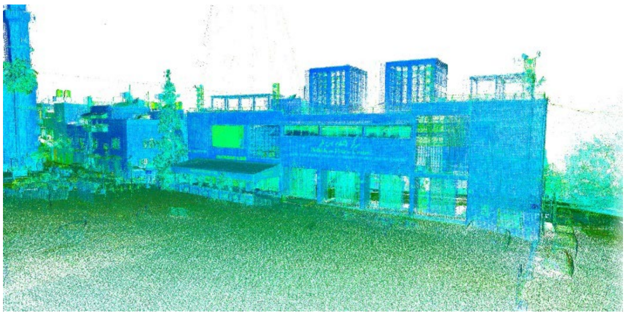

Figure 4. Overview of the 2018 TLS database.

The 2018 acquisitions, planned for the urban survey of the Bethlehem City centre, were carried out by setting a resolution corresponding to 12.3 and 15.3 mm @ 10 m and a quality of 4x, thus obtaining singular scans containing between 3.5 and 12 million points. On the other hand, the 2022 TLS acquisitions, aimed at supporting the survey of the Peace Center's exteriors, have been carried out by setting a 7.7 mm @ 10 m resolution and a 4x quality, resulting in singular scans with a maximum of 30 million points.

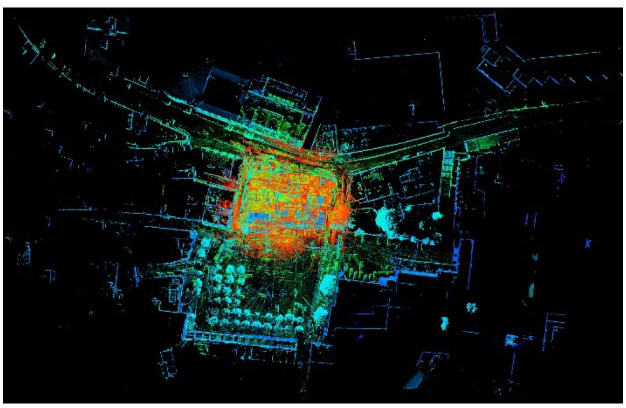

Figure 5. Plan view of the integrated 2018 and 2022 databases registered within Leica Cyclone REGISTER 360° PLUS.

The 2022 survey was registered in the Cyclone REGISTER 360° PLUS piece of software, later importing the already georeferenced 2018 database, thus referencing the updated data upon it. The final output was a 53.2 GB overall point cloud with an RMS error equal to 2.1 cm and an average error of 1.3 cm (figure 5).

For the purpose of HBIM modelling within the Autodesk Revit environment, a propaedeutic step is to import the integrated survey database within Autodesk ReCap. Here the resulting point cloud can be unified – even retaining the original spacing grid – to reduce calculation effort and then organised into sub-regions, which can likewise be switched on and off as required within Revit. Namely, we decomposed the Peace Center point cloud into six regions, while the 2018 exteriors were unified within one unique group (figure 6).

In addition to the 3D measurements, an extensive photographic database was also acquired during the 2022 survey campaign using a 77D Canon camera and a 360° Ricoh Theta camera for general documentation purposes.

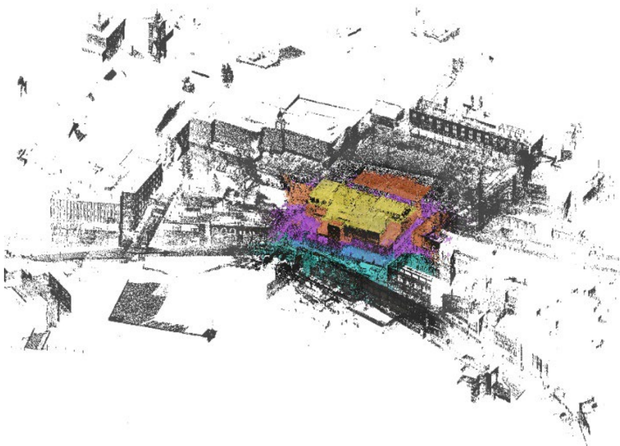

Figure 6. Oveview of the integrated 2018 and 2022 databases broken down in regions within Autodesk ReCap.

4.3 Georeferencing and federated models setting up

When working with topographic coordinates, approximation issues arise in some software not designed to manage this type of coordinates (i.e., Meshlab, Dynamo, etc.). Due to BIM software working with a cartesian coordinate system, linking a georeferenced RCP point cloud to a Revit project will automatically move closer to the new internal origin, obliterating the previous coordinate values. To address this issue, importing other types of correctly georeferenced data into the BIM environment and acquiring their projected coordinate values is recommended.

Upon setting up a superordinate Revit project for the definition of the shared reference systems, it is then advisable to link all the sub-models that comprise the entire projects (FSC phase) and proceed to assign to each of them the selected shared coordinate (GEO phase). Namely, linked CAD data in DWG or DXF format still store this information that can be "published" to the entire project. Furthermore, importing the mesh models of an urban context via *ad hoc* developed VPL scripts will retain the previously assigned coordinates, supporting the correct georeferencing of the entire Revit project.

Although the long-term aim of BIM modelling is the parameterisation and standardisation of the employed smart objects, when the subject is unique, as in the case of the complex surroundings of the Bethlehem City Centre, which is typically

different and characteristic of each historic fabric, the focus should rather be on standardising the process in order to reproduce it most authentically, for further investigation. It was then decided to directly import, as a standalone model, a selected area of the urban context in the immediate proximity of the Peace Center, derived from the mesh model produced for the setting up of the 3D GIS, i.e., one of the main outputs of the 3D Bethlehem project (Parrinello et al., 2020). The dedicated VPL script reproduces the exact features of the NURBS model, as realised in the Mc Neel Rhinoceros piece of software and exported to OBJ. It then generates in the Autodesk Revit environment an "instance" in the form of a "DirectShape" with an assigned name, material, and category, therefore providing the base for a possible enhancement of the related Level of Information through the implementation of additional parameters (figure 7).
In the present application, we opted for working with two separate sub-models – one for the architectural model of the Peace Center and the integrated point cloud to be used as a reference and one for its surroundings – so as to integrate them just when necessary and reduce the computation effort during the manual modelling phase (ARC).

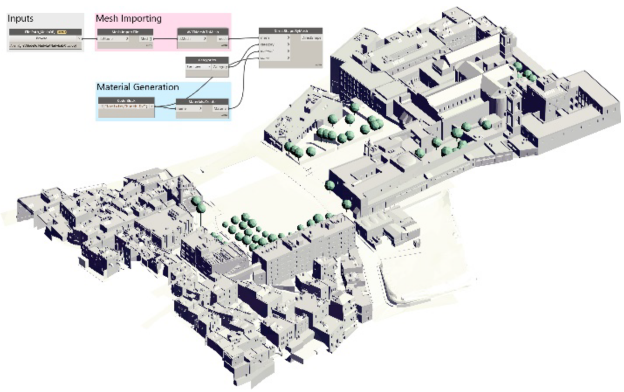

Figure 7. Mesh model of the Peace Center surroundings reproduced as a "DirectShape" in the BIM environment through *ad hoc* Visual Programming Language (VPL) scripts.

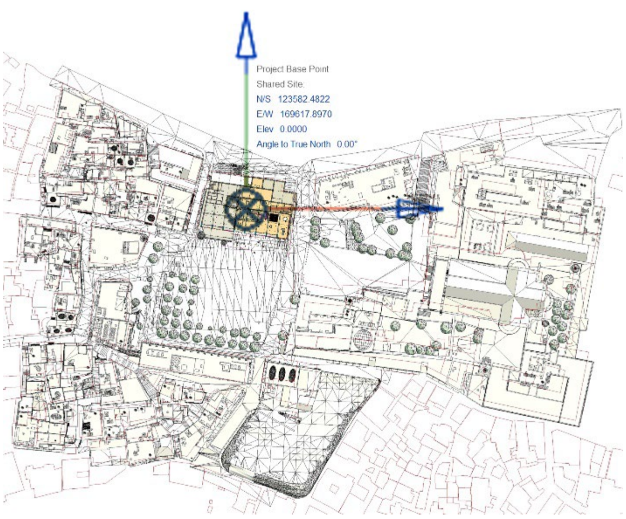

Figure 8. Overview of the georeferenced (GEO) and federated models (FSC) of the City Center and the Peace Center.

Consequently, the organisation of the shared environment within the overall RVT project was performed according to the following procedure (figure 8):

1. The superordinate model was georeferenced using the coordinates acquired from the CAD master plan derived from the 3D GIS and georeferenced in the EPSG:28191 reference system.
2. Then the RVT sub-models were linked into the shared environment using, only for the first time, the internal Project Base Points as a reference.
3. Finally, the shared coordinates were published back to the sub-models to be stored as their new internal origin.

4.4 HBIM and Level of Information modelling

When designing an information model, the objectives to be pursued are the foremost factors to bear in mind, whether these are asset management, planning rehabilitation and maintenance works, or defining a construction work schedule as well as the "Level of Development" (LOD) required to achieve the intended goals. Consistent with the established refurbishment goals, a LOD 350 – Corresponding to the Italian LOD D of "Detailed Object" (UNI Ente Italiano Normazione, 2017) – was set as a target. Consequently, a series of criteria have been implemented concerning the definition of the individual smart elements comprising the project. Namely, the suitability of fully parametric elements for their potential reuse, rather than local models without parameters, should be defined on a case-by-case basis while also specifying additional descriptors according to the required level of detail (Lo Turco et al., 2022).
Once the point cloud had been correctly inserted into the RVT project and the model georeferenced, it was possible to start the manual Scan-to-BIM modelling process (ARC phase).
First of all, a "project north" was defined; it is intended as rotation with respect to the "true north", i.e., the georeferenced one, performed just into the specific project to ease the placement of the structural elements following the x and y axes and according to a reference grid.
Following an in-depth visual analysis of the asset and its subsequent breaking down into its elemental components, the BIM modelling proceeded according to a bottom-up approach, starting from the structural elements, such as the columns, walls and floors, whose exact placement was also derived from the original blueprints of the Peace Center. In detail, the floors, walls, and various vertical connections were realised as "system families", thus duplicating the preexisting types and further detailing the novel ones according to surveyed geometries.

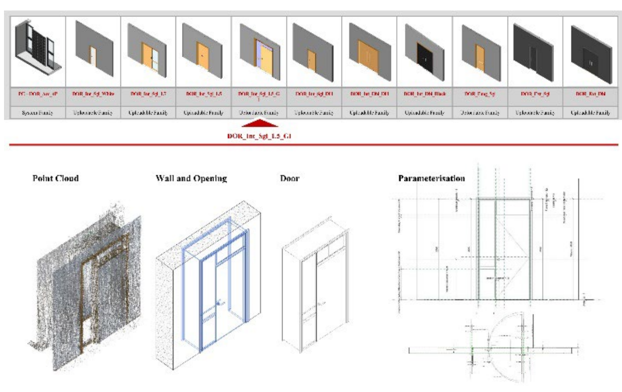

Figure 9. Schedule of the *ad hoc* parametrised doors of Peace Center (upper). Example of a loadable family (lower).

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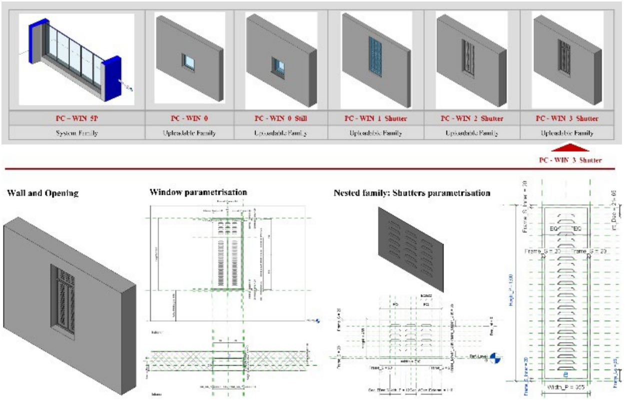

Figure 10. Schedule of the *ad hoc* parametrised windows of Peace Center (upper). Example of a loadable nested family (lower).

Figure 12. Example of the PBR material generated to reproduce the local stone layer of the asset's external walls and floors.

On the other hand, the distinctive character of the architectural asset required the development of a series of *ad hoc* parametrised elements, mainly generated from scratch as "loadable families", to fit its actual features. In detail, following the footsteps of the previous cataloguing – albeit carried out at an urban scale (Doria and Picchio, 2020) – reference schedules of the Peace Center doors (figure 9) and windows (figure 10) were developed to keep a trace of the implemented smart objects. Furthermore, for adequate parameterisation of the windows, it was necessary to further break them down into separately generated units and reassemble them into "nested families", paying attention to correctly reconnecting the respective parameters (figure 10 - lower).
HBIM model, resulting from the 3D modelling, complied with the level of complexity required by the defined LOD and presented maximum deviation from the reality-based model within 5 cm, corresponding to a Level of Accuracy (LOA) 20 (figure 11) according to the United States Institute of Building Documentation (USIBD) definition (USIBD U.S. Institute of Building Documentation, 2016).
Additionally, the finishing materials, as identified from the photographic sources, were provided (LOI phase) by generating PBR-type of material into the Revit browser and later assigning the required maps – as raster images – within each corresponding section (Sanseverino et al., 2022a).

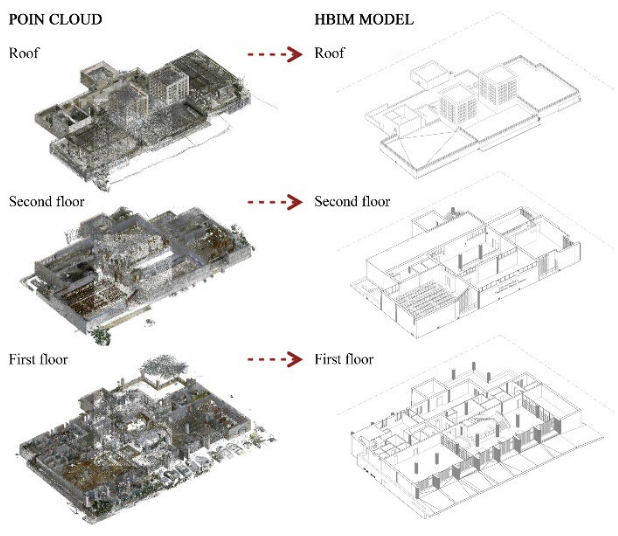

Figure 11. Visual comparison between the integrated point cloud and the HBIM model of the Peace Center.

For this purpose, both downloadable and specifically generated maps were employed (figure 12). Moreover, setting up a data repository with a user-friendly interface – such as the real-time rendering plug-in Chaos Enscape for Revit – complemented by the foreseen "capacity building" actions will allow the BIM platform to serve as an effective tool for future maintenance works (figure 13).

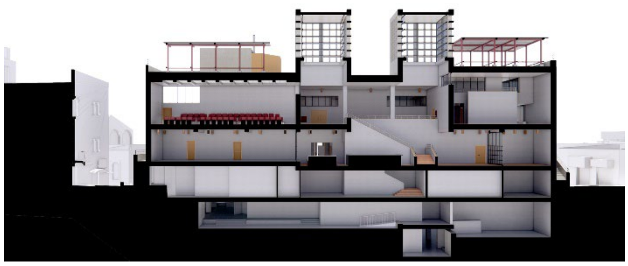

Figure 13. Longitudinal section of the texturised HBIM model integrated within the mesh model urban context.

5. CONCLUSIONS AND FUTURE DEVELOPMENTS

The aim of the proposed application herein is to validate the systematisation of acquisition and digitisation processes aimed at the development of methodological protocols for the generation of HBIM systems on historical architectures. In particular, with regard to data acquisition procedures, an integrated acquisition method that employs SLAM mobile technology and TLS laser tools was tested, with the aim of verifying on a spatially complex architecture a simplification and consequent optimisation of the Scan-to-BIM operational paradigm.
Regarding sustainability, above all in terms of time, the use of state-of-the-art mobile laser scanners (MLS) supplied by Leica Geosystems allowed a halving of work times while still guaranteeing a degree of metric reliability and data quality (La Placa and Doria, 2022) sufficient to achieve the pre-set Level of Development. It only required the integration of photographic data in the case of detailed modelling, comparable to an as-built, or for the correct decoding of material finishes.
The implementation of a scan-to-BIM process makes it possible to develop a three-dimensional simulacrum on which to implement the technical information and thus plan monitoring and maintenance actions for the building (Morandotti et al., 2019).

The HBIM model is not static, the LOD can be increased at any time, thereby delivering a model that can be modified quickly and effectively to increase productivity (Rocha et al., 2020). In addition, the results are already optimised for real-time rendering applications operating within the BIM software, so any changes applied to the geometry and/or materials will be immediately visible, while equally direct and quick access is provided to object properties (figure 14). The development of a BIM model optimised for visualisation not only helped in the modelling phase but also set the base for the development of the refurbishment project envisaged among the SMART Bethlehem goals, allowing for direct validation of the design choices. Indeed, these innovative visualisation models not only provide a scientific basis but also represent a remarkable tool for the preservation and dissemination of cultural heritage.

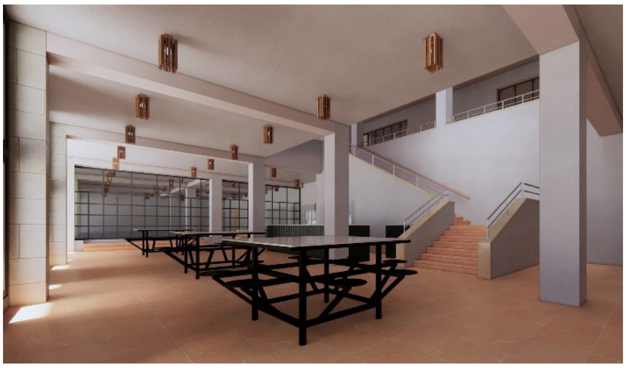

Figure 14. Rendered view of the Peace Center interiors realised by means of Chaos Enscape for Revit plug-in for the real-time rendering.

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