FROM SCAN-TO-BIM TO HERITAGE BUILDING INFORMATION MODELLING FOR AN ANCIENT ARAB-NORMAN CHURCH

M. Aricò [1], M. Lo Brutto [1,*]

[1] Department of Engineering, University of Palermo, Italy
manuela.arico@unipa.it; mauro.lobrutto@unipa.it;

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ABSTRACT:

One of the most significant issues in Cultural Heritage is the management of ancient buildings to monitor their state of conservation or to plan actions in their maintenance; this issue can be now approached thanks to the use of the Scan-to-BIM process. This method allows the creation of parametric models into a BIM environment, which are capable of enhancing the geometrical representation of building elements and integrating different types of data.

This paper shows the results of the research activities carried out by the Department of Engineering at University of Palermo (Italy) on applying the Scan-to-BIM approach to the survey and the modelling of an ancient Arab-Norman church in Palermo. This activity was motivated by a renewed interest from the local Administration towards the Arab-Norman Cultural Heritage in the city, since other more famous coeval monuments were included in the UNESCO World Heritage Sites list in 2015. The morpho-typological style of the church has been spotlighted by a high-detailed 3D laser scanner and photogrammetric survey. The aim of the modelling phase was to obtain a parametric model which was suit to render the peculiarity of this building at its best. Extensive knowledge about historical building techniques has been needed in order to model all the architectural elements. The results of this study allowed to obtain a HBIM of an Arab-Norman building and to reveal the weaknesses affecting the whole workflow; these were mainly due to the approach chosen for the modelling of the most particular architectural elements.

1. INTRODUCTION

Building Information Modelling (BIM) was originally developed for the digital representations and management of the new assets regarding the Architectural, Engineering and Construction (AEC) field; it was habitually used for the collection, maintenance and archive of information data needed to support helpful strategies for new buildings during their whole lifecycle, from design to dismantling. These data are embedded and saved in a centralised model (accessible on a collaborative platform), and they can be shared between stakeholders, manipulated, updated and extracted.

In the last years, BIM has received special attention in the Archaeological, Architectural and Cultural Heritage (CH) field. When BIM technology is applied on the 3D digitisation of ancient historical buildings, this is defined as Historical or Heritage BIM (HBIM) (Murphy et al., 2013).

HBIM is a very useful and intelligent tool in the management of CH, as it provides the documentary basis for any further analysis and development of projects about those assets for present and future maintenance, preservation and restoration purposes (Rocha et al., 2020). Historical sites are the results of alterations and refurbishments over the centuries, and their models must contain precise construction characteristics and information to be representative of such a complex reality.

The term "Scan-to-BIM" refers to the workflow which regulates the process of surveying, modelling and information managing, and allows to obtain a digital information system associated with geometric documentation, capable of transforming the raw processing of massive data acquisition into a smart model structured with semantic information (Volk et al., 2014). The workflow could be based on:

- the capture of geospatial data from digital technologies such as Terrestrial Laser Scanning (TLS) and photogrammetry;
- the creation of a point cloud from raw data;
- importing and adapting point clouds into a BIM environment for manual or semi-automatic recognition;
- the manual or semi-automated generation of parametric components with information attached;
- modelling the remaining non-standardised elements.

The Scan-to-BIM process even includes all the decisions taken on the data acquisition, the drafting actions and the modelling choices.

In the development of a Scan-to-BIM project, a great level of rigour should be imposed on every step of the workflow since the beginning. If the final representation is aimed in the knowledge of the heritage itself and its original design and functioning, this knowledge needs to be as complete as possible. Archival research about the building and investigations about traditional techniques and materials should be required prior to starting onsite surveys. These preliminary phases can be tested and verified on the data collected by TLS and photogrammetry techniques, which are broadly used in this second step. In fact, the current state of a CH building is surveyed with the highest level of accuracy in the less time-consuming and most efficient, non-invasive way. The resulting point cloud represents the acquired surface of the entire building in its as-built conditions and contains record information such as texture, colour, architectural morphology and state of conservation (Sampaio et al., 2021).

It is not advisable to construct a HBIM model without a precedent digital survey of the assets. The amount of knowledge obtainable

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[*] Corresponding author

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from the point cloud is indisputable, such a reliable basis which can be imported into the BIM platform and used for modelling, bearing in mind that the accuracy and the level of detail in the model depend from data survey (Chiabrando et al., 2017). It is therefore necessary to establish the procedures involved in the transformation of these data into a HBIM environment and to know how these processes can be optimised.

The advantage of creating parametric objects on HBIM platforms is that the resulting products are dynamic objects that can be transformed instantaneously. The aim is that both architectural and archaeological elements in the model should represent the greatest geometric similarity to real objects, with the presence of all the objects to be catalogued. Their correct collocation in the three-dimensional space and their topology are essentially for management and documentation of the historical buildings and for preservation purposes (Moyano et al., 2021).

But HBIM process presents a main weak point as well. In fact, the parametric nature of BIM clashes greatly with the precision of the as-built reality acquired by means of the point cloud. The scarce flexibility of the software tools causes loss of accuracy and details; the tolerated approximation does not allow to consider any flaws, such as items which are complex-shaped, slightly deformed or different from the ideal model due to limitation of the construction techniques used in the past or to structural failures. HBIM is thus a result of abstraction and simplification from the heritage (Bruno and Roncella, 2018), and excessive simplifications run the risk of rendering the model worthless. For establishing the maximum fidelity in the 3D reconstruction, it is necessary at all times to elaborate strategies that mediate this significant issue.

A priori choice must be made on the definition of the Level of Detail (LoD), which in HBIM is different from the LoD assigned to a new construction model. In fact, in a BIM environment, LoD is strictly related to the amount of graphical precision which should affect the entire model. Both in HBIM and BIM, LoD involves the geometrical representation only, not the semantic content of the modelled elements. It depends on the purposes and the future applications for which the model has been created (Scianna et al., 2020). In the case of a HBIM model, choosing an appropriate LoD is not easy because it refers to shaping architectural details in such a way they are not over or under modelled in comparison to the real item.

HBIM representation is a complicated, resource-intensive process and nowadays the most extensive method for segmentation and modelling is still manual. This approach is challenging and takes a long time considering that:

- complex data need to be elaborated without inaccuracies and inconsistencies and preventing accidental loss;
- the size of point cloud files is huge;
- this process cannot be made using one software alone, and interoperability between many software for different purposes is an issue which can compromise the final result;
- all of these require powerful performing machines, expert technicians and a large amount of working time.

Research is trying to move to semi-automatic and automatic methods for data processing and modelling, but these approaches are still not inclusive for all CH specialists and preparing a discretisation of reality to be fed to automatisms is neither an immediate nor an easy task itself (Croce et al., 2021).

The work focuses on the development – through an organized workflow - of an accurate, flexible and customizable HBIM system aimed to manage the integrated information data which can be obtained by the methodological application of topographical, laser scanning and photogrammetric techniques on heritage buildings. Starting from the initial point cloud, the parametric model has been developed into a BIM environment with manual procedures only and its geometrical features were associated to historical and construction data. This has been made using a database specifically created in order to store, manage and retrieve all the information about CH.

The specific workflow, based on an integrated process of survey, data acquisition, 3D modelling, database implementation and information entry, was finally tested on a historical building in Palermo (Italy), the ancient Arab-Norman church of San Giovanni Battista dei Lebbrosi (literally: St. John the Baptist's church of the Lepers). This church was the first one in Sicily to be built according to the so-called Arab-Norman style, and its typology served as a paradigm for the development of other similar coeval buildings which have recently been included in the UNESCO World Heritage Sites list and are part of the city Arab-Norman Itinerary.

2. THE CHURCH OF “SAN GIOVANNI DEI LEBBROSI”

The church of San Giovanni Battista dei Lebbrosi was erected in two distinct periods. In 1071 the Norman earls Robert and Roger I of Altavilla sieged Palermo, at that time populated by Arabs. Norman ranks were camping outside the city in a palm grove around the ruins of a Saracen castle named “Yahya” (John in Arabic), where they founded the original core of the building with few temporary structures.

After Roger I had established his kingdom in Sicily, he wanted the provisional construction to be turned into a permanent sanctuary as an ex voto for his victory. It is not known when the works ended, but the building was described as completed in a historical document dated 1085.

In 1155, at the behest of king Roger II, a leper hospital was added to the church, which was then named “of the Lepers” after this sanatorium.

In 1219 Emperor Frederick II put both buildings under the order of Teutonic Knights, who retained the properties until 1495, when the hospice was moved to the city centre.

The church is a traditional basilica with a Greek cross plan, the first one to be adopted in Palermo; the space is shaped lengthwise into three naves divided by three polygonal pillars which support four slightly irregular round arches onto internal sides.

The transept, raised from the floor by steps, runs crosswise and is set apart from the naves by three lancet arches, of which the one in the middle is the highest.

Presbytery is further divided in two small lateral wings (called *diaconicon* and *prosthesis*), and a central chancel; these spaces are respectively covered with two authentic cross vaults and a hemispherical dome supported by four lancet arches at each side of the chancel. At the corners of the square springer there are four squinches shaped as consecutive recesses, which join the dome to the walls. The transept ends in three semi-circular apses, where angular columns have their capitals decorated with Arabic inscriptions in Kufic calligraphy.

The interiors were heavily altered in the 17th century when masonry vaults were constructed above the three naves and stucco decorations were applied to the walls and concealed the lateral windows.

The drastic restoration performed by the architect Francesco Valenti between 1920 and 1934 aimed to bring the church back to its previous harsh appearance. The baroque overlaps were removed, walls were stripped, a plain wooden ceiling supported by trusses replaced the masonry vaults above the naves, floor was lowered at its original level and a new altar was built.

The exterior of the building is devoid of decorations; walls are made of small, regular sandstone ashlars (Figure 1). Windows only have lancet arched lintels and are embellished by geometrical grills added during the last restoration. The dome above the presbytery stands out for its reddish painting, chosen by Valenti who mistook red traces of pigmentation (due to crock in the plaster) for the real colour of the dome, which was white in its initial design. The main façade shows on its right side a small porch supported by a single pillar on the corner and covered with a cross vault. A bell tower and its hemispherical dome on top have been arbitrarily added by Valenti above the porch, in replacement of the original ones which were actually on the other side of the façade.

The church is now surrounded by a verdant garden, where parts of walls and fragments of paving belonging to the Saracen castle are still visible nowadays.

Figure 1. The exterior of the church.

3. DATA ACQUISITION

Data acquisition was planned since the beginning with three different methodologies:

- a TLS survey which provided scans on all the accessible areas, both internal and external;
- an Unmanned Aerial Vehicle (UAV) photogrammetric survey performed on the whole external surfaces;
- a topographic survey, which served for calculating a suitable reference system to be used during the data processing phase.

3.1 TLS survey

A preliminary TLS survey phase has been planned in order to highlight any critical aspects of the work. The acquisition planning was aimed to optimize the number and the positions of the scans to be performed, the most appropriate approach for the survey and the desired level of detail of the final point cloud; this last parameter has affected the settings for any single scan resolution and its field of view. All the assessments have been done related to the laser scanner characteristics, the architectural structure and the site conditions.

A previous site inspection revealed few issues for the data capture, such as a part of the bell tower which was closed off for safety reasons, narrow stairs, statues inside the church covering portions of walls behind; moreover, some problems could have come from the presence of groups of tourists and believers visiting the monument. A very critical aspect of the survey was the connection between the internal and external environments, made only through the entrance in the porch, which needed extra care during the survey.

Furthermore, since it was not possible to use targets, all the scans had to be planned to guarantee an adequate level of overlap for the subsequent registration phase.

The data acquisition was carried out by a phase shift laser scanner FARO Focus 3D S120. This device is characterized by a distance accuracy up to ±2 mm, a range from 0.6 m up to 120 m, a measurement speed of 976.000 points/second, a vertical and horizontal field of view of 305° and 360°.

Data acquisition was carried out to detect the whole building in its external and internal parts (Figure 2), with a total of 35 scanning locations, 16 external and 19 internal (Figure 3). The external scans were performed as followed: 5 on the apses, 4 on each side of long façades, 3 on the main façade, with a few meters distance between the scanner and the walls. Just two scans were acquired at a longer distance from the main façade (approx. 11 meters) in order to avoid an excessive laser beam inclination with respect to the frontal plane, due to the presence of the bell tower which was the highest part to be scanned.

(a) *(b)*

Figure 2. Laser scanner data acquisition: external (a) and internal survey (b).

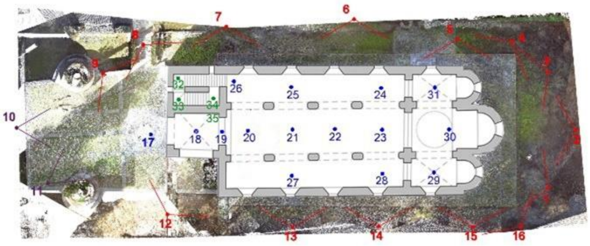


Figure 3. Scheme of scanning locations

These external scans were generally set with a 150° horizontal field of view, a 100° vertical field of view, and a scan resolution of about 6 mm at 10 m (scans in red on the scheme in figure 3), except for the two on a longer distance (scans in purple on the scheme in figure 3), which were arranged with a 60° horizontal field of view, a 100° vertical field of view and a scan resolution of 3 mm at 10 m.

The 19 internal scans were planned in order to have a complete coverage even in the most inaccessible and darkest parts; 3 scans were carried out on the porch, 9 on the naves, 3 on the transept, 4 on the stairs to the bell tower and a little storage. 15 of these scans (in blue on the scheme in figure 3) were settled with a "full-dome" field of view and a scan resolution of 6 mm at 10 m. The 4 scans on the stairs (in green on the scheme in figure 3) had the same settings but a minor scan resolution (12 mm at 10 m), due to the confined space.

3.2 UAV survey

UAV survey was carried out for acquiring all the highest external parts of the church which were difficult to be acquired with a TLS survey. A multi-rotor ultra-lightweight was used for image acquisition, which allowed flying over the study areas overcoming the restrictions imposed by UAV regulations. This methodology is widespread in the field of CH surveys; several studies have shown the usefulness of these systems in various situations (Costantino et al., 2020).

The survey was carried out by a DJI Mavic Mini, characterized by a weight of 249 g and a maximum flight duration of 30'; it is equipped with a 1/2.3" CMOS sensor of 12 MP with dimensions of 6.3 mm x 4.7 mm which produces images of 4000 pixels x 3000 pixels.

As in previous works where the UAV has been used for the 3D reconstruction of a historical building (Lo Brutto et al., 2021), different image configurations were adopted; a nadiral flight to view the roof and the domes, two circular flights with an oblique camera for the roof and the façades, and flights with a parallel view of the façades (Figure 4). One of the façades had no acquisition pictures at all because most part of it was hidden by some tall pine trees densely planted in the adjacent garden.

The image acquisition was achieved with automatic flights via the Dronelink app for flight planning; only for the flights parallel to the façades, manual controlling of the drone was necessary.

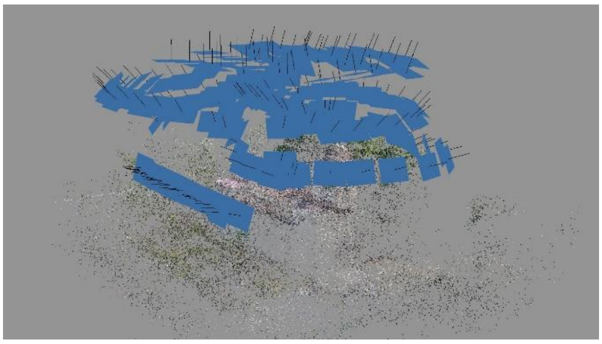


Figure 4. Scheme of UAV acquisition.

3.3 Topographic survey

A topographic survey was carried out measuring a closed traverse on the outside of the building. This was measured with a Leica TPS 1105 total station and was made of 5 points; one at each side of the church, roughly positioned in the middle of the façades (Figure 5).

Figure 5. The topographic survey.

The coordinates of those vertexes were calculated in a local reference system obtaining a root mean square (RMS) of ±4 mm for the planimetric coordinates and ±1 mm for the height component. The topographic survey was used to measure the coordinates of 43 points, uniformly distributed on façades, used for the photogrammetric survey as Ground Control Points (GCPs).

4. DATA PROCESSING

Data coming from the TLS survey were processed through Autodesk Recap software, in an automated and semi-automated way. The registration process started with the external scans; every single scan was aligned and registered according to the previous one, through the auto-register method managed by the software.

The internal scans were added once all the external scans were registered. Prior to adding the second group of scans, ReCap notified a quality report, addressing a 100% percentage of points <6mm, an average 26.1% overlap and an average 29.7% balance between scans. These parameters were calculated by ReCap during the first registration process and ensured the exact alignment of the scans.

The first two indoor scans on the porch were added to the external scan group. As realised during the site inspection, this was a critical passage. The auto-registration process was unable to match these scans with the external ones. So, in order to continue the registration process, was necessary to add some common points between scans to improve the registration step.

After these two scans were included in the registration group, all the rest of the indoor scans were imported, albeit this procedure took more time than expected. In fact, indoor scans have been acquired with a full-dome field of view, and they had an average 44 million points per scan.

The final step was adding the scans on the stairs; even for this step was necessary to process the scans in a semi-automated way due to poor scan overlapping.

After the internal scans were added and registered as well, the quality report resulted improved, with an average 34.3% overlap and an average 72.7% balance, so the alignment was successful.

Finally, all the scans were merged into a single point cloud made of about 350 million points, with a 3 mm average distance between the points. This point cloud was then stripped from unnecessary parts (vegetation, close surroundings, etc) with a manual segmentation, which reduced the point cloud to about 210 million points.

The photogrammetric processing was executed with Agisoft Metashape software according to three typical main steps: Image alignment, Optimisation and Build Dense Cloud. For the “image alignment”, the “Accuracy” parameter was set high, the key point limit of 40000 points and the tie point limit of 1000 points. The “Optimisation” was carried out setting a camera model with three radial distortion parameters and two tangential distortion parameters. 20 GCPs were used for the orientation of the image. The mean re-projection error was about 3 pixels; the RMS in object space for the GCPs was ±0.8 cm. The “Build Dense Cloud” was performed set to high “Quality”.

The two point clouds, obtained from the TLS and the UAV survey, have been then filtered and cleaned from not useful and/or wrong points, imported into CloudCompare software, aligned through a cloud-to-cloud registration procedure and finally overlapped. Visual inspection was performed thoroughly, along horizontal and vertical sections to check the cloud-to-cloud registration procedure, which was sorted out without anomalies or discrepancies.

The UAV point cloud has been furtherly cropped, in order to retain the roofing parts only, whilst the rest of it regarding the façades has been discarded. This was almost a mandatory choice; the point cloud from TLS was already dense enough and much more detailed on the external walls, whilst it was missing all the coverage, which was too high to be reached. Adding more points on the façades would have made the TLS point cloud redundant and inconsistent on those parts.

The UAV point cloud (containing now just the roof) has been finally merged to the TLS one, in order to have only one cluster. The different surveys allowed us to obtain an overall point cloud of the building from two separate perfectly superimposable point clouds.

The point cloud resulting from this merging was originally made of more than about 283 million points, and it was very difficult to handle due to its excessive resolution. Therefore, it was sub-sampled for a uniform distribution of points: the minimum distance between two points was set to 5 mm. The final point cloud for the parametric model production was reduced to about 100 million points (Figure 6) and used as the base for the parametric model.

Figure 6. The final point cloud.

5. HBIM MODELLING

The modelling phase has been approached as an organized methodology, focused on one aspect of the church at a time, in order to discretize the architectural continuum into a complex semantic abacus (Parrinello and Dell'Amico, 2020). During this decision-making and problem-solving process, many efforts have been made in terms of bringing point cloud elements back to morphologically recognisable objects to which historical and construction data have been associated. In this way, a database of the whole building would have been implicitly created, in order to have an information system based on elements that are ontologically defined not only in their dimension and functions but also in their mutual relationships, as well as in materials and intrinsic characteristics (Barrile and Fotia, 2021).

For this reason, prior to starting any modelling steps, a preliminary evaluation about the definition of an appropriate LoD must have been made in order to reproduce the church's peculiar construction details as close as possible to the original objects. LoD concept has been intended to differentiate multi-scale representations of those details from a geometrical point of view depending on data collection.

The amount of metric, materic and structural data collected during the survey has been managed into a BIM environment using Revit package by Autodesk, which rendered a parametric model capable to explore the architectural system in its entirety and the features of its single elements.

Revit was an advantageous choice because it is a hugely versatile and powerful modelling software that allows to build smart objects called families: groups of elements with a set of common properties ("parameters") and an associated graphical representation. There are three main types of families in Revit: *system, loadable* and *in-place families*. Depending on the types, their parameters can be edited only or designed on purpose to fit the new dataset. Whatever the case, elements can be always classified into the correct category so that they behave appropriately within the project.

Essential elements (walls, floors, stairs, roofs) were prioritised since they could have been shaped by the simple system families already available in the software. Secondary features such as the several types of openings and other details were modelled by in-place families, created and implemented ad-hoc, which required additional time.

The modelling phase has been preceded by a preliminary setting out of the model. The point cloud has been first converted in a .rcp file via Autodesk ReCap software; then it was imported into Revit keeping its position within the local reference system and finally locked in order to prevent accidentally moves during its modelling.

At this point, the necessary views have been set up for all the principal levels (main, bell tower, roofs and domes), in order to guarantee the correct insertion of the parametric elements.

The proper modelling phase started with the identification of the structure; walls and pillars were shaped following the outline of the point cloud in plans and sections, tracing the actual size and position of each real object, with a tolerance of approximately 1 cm.

To build the round and pointed arches in the naves and the transept, walls were then cut by a void shaped as every single arch. Real arches didn't have neither the same dimensions nor the same shape, so the point cloud has been used as a reference to outline these discrepancies from time to time when they occurred.

The ground floor was set on an arbitrary thickness of 50 cm (as there was no information about the underground structures), and modelled according to its perimeter on a plan inclined by a 2% slope toward the presbytery; the other floors on the bell tower were realized with their actual thickness.

In San Giovanni's church, the roof is supported by wooden trusses, connected via a system of primary beams and secondary rafters. Once pitches and their inclination had been set up first, trusses, beams, rafters and purlins were recreated straight away for the coverage of a single span. This supporting modular system was fortunately repeated for the whole length, so those elements have been modelled once and copied through the naves.

5.1 Modelling of architectural features

Revit has been designed for new construction, so it doesn't automatically include many architectural elements typical of CH. For this reason, there is a deficiency of libraries that meet the requirements of HBIM projects (Allegra et al, 2020); in our model various features such as steps, windows, vaults, domes, apses and doors needed to be completely modelled by creating new in-place families. This method is time-consuming, laborious and complicated, and a general understanding of what is the purpose of the family is required to approach the right solution (matching with the appropriate LoD) and to avoid unnecessary work.

In our case, this problem has been sorted out by creating in-place components through a combination of simple Boolean operations, which have been crucial in several situations recurring in the model. For example, the profile of the steps in the transept has been swept along a path on the naves.

The four lancet windows of the bell tower were modelled through Boolean operations as well; voids have been cut off from the wall in a way similar to the one adopted for modelling the arches in the naves. Then, the recessing arched lintel profiles were outlined on plan and extruded as a void along a path following the opening contour, to be subtracted from the walls (Figure 7).

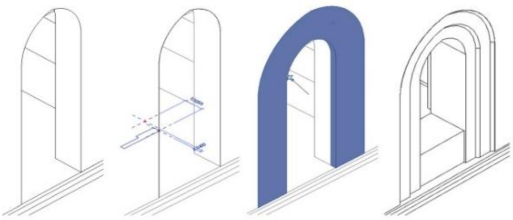


Figure 7. Modelling of bell tower windows.

An analogous approach has been adopted for the lancet arched windows on the central nave, which were however slightly different; their peculiar shape was highlighted by the point cloud, as they were shorter on the external face of the walls (due to the presence of the roof) and longer on the internal one, with a sloping face connecting the two sides. After cutting off the void from the wall, the windows sill has been lifted up (Figure 8).

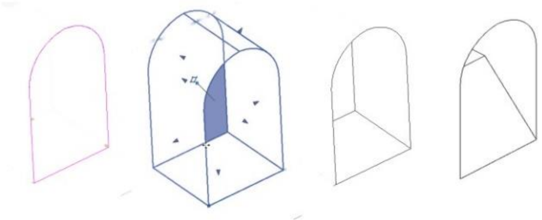
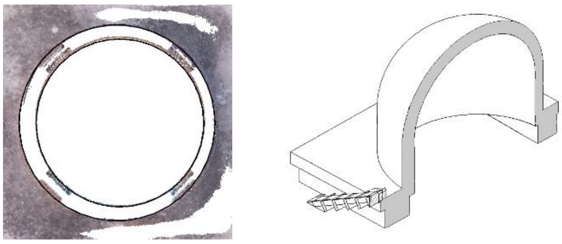


Figure 8. Modelling of windows in the central nave.

Point cloud clearly stated that the dome above the chancel didn't have a uniform wall thickness, which actually was thicker on a portion of the circular basis. In order to keep the highest fidelity to the real shape, the extrados was created with a solid in-place component of which the external profile was revolved with a 360° rotation around the z-axis; the internal profile was revolved as well but as a void to be subtracted from the solid, being aware that the two masses were not concentric to each other (Figure 9).



(a) *(b)*

Figure 9. Modelling of the main dome; view in plan (a) and in 3D section (b).

Modelling the dome on the bell tower was easier instead. In fact, this was an inaccessible area, and point cloud had very low accuracy in that part. So, the wall thickness has been considered uniform for that dome; it was simply created revolving both the external and internal profiles with a 360° rotation around the z axis (Figure 10).

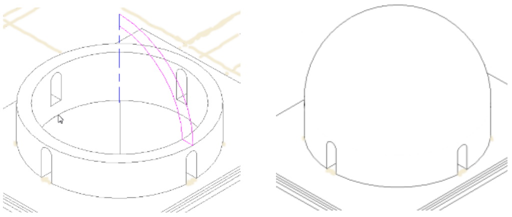


Figure 10. Modelling of the dome above the bell tower.

Boolean operations were not the only way to shape in-place components to be placed into the model; even the in-place mass tool was used for the cross vault on the porch and the three semi-circular apses. This tool is very advantageous when it comes to irregular shapes which can't be modelled with the other parametric tools in Revit, because it allows to render the parts with their actual geometry (Figure 11).

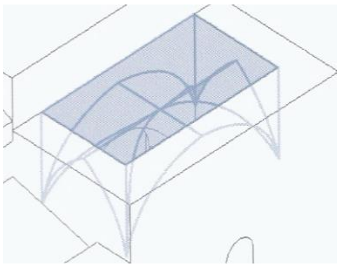


Figure 11. Modelling of cross vaults above the prosthesis.

The model was created in order to avoid conflicts and clashes between the construction elements. The interaction of floors, walls, pillars and other elements was carefully performed to ensure a perfect intersection and to reflect the original church with the highest fidelity (Figures 12 and 13). Still, some clashes were not avoidable, due to contact between contiguous parts with irregular boundaries. It's the case of the cross vault on the porch, which is constrained between four walls not perfectly orthogonal.

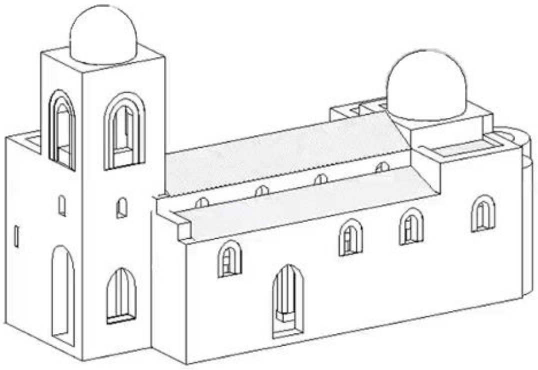


Figure 12. 3D View of the parametric model.

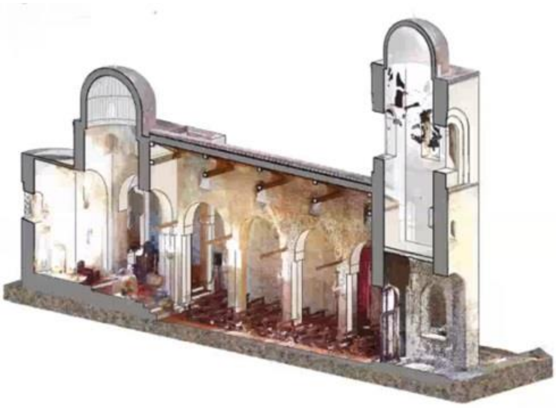


Figure 13. Axonometric sections of the parametric model with the point cloud.

6. CONCLUSIONS

The Scan-to-BIM approach is a relatively new methodology that allows raw data from TSL and photogrammetric survey acquisitions to be transformed into a smart structured model, where all the parts are associated with a digital information system. This process guarantees the undisputable advantage of managing, extracting and updating the geometric and non-geometric information of existing buildings at any time.

On the other hand, this methodology is affected by some flaws as well when applied to heritage buildings, especially for the parametric modelling phase. Heritage buildings for their nature bring at all times some critical issues; out of plumb, tapered, unaligned or not orthogonal walls, unique-shaped architectural items such as windows or arches are just few examples recurring when it comes to parametric modelling.

At now, typical BIM libraries don't include families adaptable to the peculiarity of every single historical building yet; the connection between the 3D data and the complex geometric entities is sometimes difficult to handle, due to the lack of advanced modelling tools in BIM applications. Creating and implementing ad-hoc procedures and features can overcome these issues but these are time-consuming solutions, which affect the modelling process.

The work has been organized through a controlled workflow which has led to the development and improvement of a Scan-to-BIM methodology capable of supporting the implementation of HBIM, in order to enrich the knowledge and documentation on a piece of local architectural heritage related to Arab-Norman architecture.

The church of San Giovanni dei Lebbrosi has constituted an interesting sample of study from the historical and methodological point of view. The 3D survey and the creation of the parametric model have been intended in the perspective of protecting our cultural patrimony, for shedding a light on the constructive methods of this peculiar building, and for its maintenance and eventual restoration purposes.

It must be mentioned that survey data alone didn't allow a diachronic description of the church and its building phases. So, modelling needed the support of archival documents which have been included into and actively fed the model.

The adoption of the methodological approach paid double care on minimising steps and format changes along the process in order to prevent excessive simplification and loss of information. The obtained HBIM has allowed to achieve several results, still under development. A parametric library about a local example of Arab-Norman architecture was constructed starting from a point cloud. This is very important for the city of Palermo where an Arab-Norman Itinerary has been included in the UNESCO World Heritage Sites list. Moreover, the parametric model of the church can be considered the starting point for further future investigations. The HBIM should be used to improve the knowledge about the state of sandstone masonry walls, for Finite Element Method (FEM) analysis, and for more in-depth geometric analysis of the main architectural elements. As mentioned previously about this last topic, the 3D survey and the modelling of the main dome highlighted the non-concentric construction of the dome; this feature is a new discovery which is going to be further investigated through comparison with similar local buildings.

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