

Geomatic data turned into BIM for the preservation of a multicultural building

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Abstract: Disseminating detailed and accessible information about the built heritage is fundamental to help understand the value and meaning of that heritage to society. To this end, the use of historic BIM (HBIM) is an emerging technology that enables engineers and relevant practitioners to understand, document and virtually reconstruct the heritage monument. This paper explores the effectiveness of the implementation of BIM with a practical application of the Sarlidje Palace Hotel, a listed building constructed circa 1909 on the island of Lesbos, Greece. Detailed geometric documentation using surveying and laser scanning was performed to obtain the essential spatial information. The 3D model was created within the Building Information Model (BIM) using collected data and existing CAD plans. The great complexity of the building required the creation of several new families besides the existing BIM Families. The BIM also allowed the modelling of the pathology of the building, which enables further understanding of the construction and provides a guide for interventions.

Key-Words: Building information Modelling (BIM), Building Pathology, Data collection, Engineering, Surveying, Terrestrial Laser Scanning, Preservation,

1 Introduction

Building Information Modeling (BIM) has proved a revolutionary technology in the last decade giving the opportunity to the construction industry to move to the digital era. The main advantages of BIM can be seen in the automation capabilities for integrated communication, data exchange and sharing within a virtual 3D environment, and effectiveness for the management of assets. The designed virtual models are directly linked with databases of geometric and non-geometric information, thus achieving the most effective management in the buildings' life cycle, from the design phase, construction, management, maintenance to its demolition. As expected, there was an early interest in extending the applications of BIM to existing buildings such as in the infrastructure sector (InfraBIM) [15, 16, 22] where the BIM helps decision makers in managing more efficiently the inventories.

Acknowledging the numerous applications and possibilities of BIM technology, it was soon considered to apply BIM on buildings of historic value [17]. Heritage or Historic Building Information Modeling (HBIM) is an approach whereby three-dimensional models and databases of historic buildings are integrated to an informative, interdisciplinary, shared and constantly evolving model. The information about historic buildings and archaeological sites can be of various forms and is usually represented as a collection of individual documents, reports, drawings, computer-aided design of 2D files or 3D models and various datasets provided by different professionals using different tools and standards [11]. In addition, information about a historic asset can be disseminated across various locations and formats whilst the quality of individual pieces of information may be unknown and inconsistent.

To-date, HBIM represents the most effective of the management systems being experimented so far

for historic constructions and monuments. It has the capability to incorporate both qualitative and quantitative information about a historic asset as well as intangible characteristics, such as heritage values and significance in a structured and consistent way, allowing easy information extraction and the production of deliverables [4].

Approaches using HBIM have been reported on specific examples of heritage buildings [9, 12, 14]. For example, the Historic England society leads conservation work of the country's heritage buildings such as the Imperial War Museum and Woodseat Hall in UK by adopting this approach [2]. A favorable application of HBIM refers to religious buildings [e.g. 6, 21]. An increasing awareness to preserve Ottoman's empire architectural heritage using HBIM is also noted [e.g.1, 3]. Public buildings of historic and industrial interest have been modelled in BIMs as good examples for managing public assets [11].

The implementation of HBIM has a number of challenges about the development of the 3D model. A critical aspect is that of the collection and processing of existing, not newly designed information. Specifically, the reliability of historical building documentation, information interpretation and intervention procedures, quality control, data protection and renewal are some of the issues someone must deal using existing data of a historic asset. Additional challenges are present in the processing of historic buildings, few to mention such as irregular geometry, non-homogeneous materials, variable morphology, not documented changes, damage and various stages of construction [15]. Recent literature also emphasises the barriers in using digital documentation due to high cost, awareness and competence [16]. Relevant literature on HBIM is addressing several issues such as the input data quality and quantity [8, 11]. An important issue in HBIM is with the type of data stored within the system and there is a lot of discussion on the ways that each data type should be stored [19, 20]. Besides the geometrical content, the type of data texture is also of importance. Texture can represent information such as age, material etc but does not necessarily need to be 'realistic' because it can be created from other data, for example infrared images [15]. Texture can be provided by the BIM software or created on a customized way based on the images of the object. This however, leads to the problem of storing additional data (e.g. visual, pictures, thermal pictures, scans of plans, historical information). Various ways have been proposed with the most prominent being the combination of HBIM with GIS [23]. Of course, still remains the amount of time

the project takes. This can only be improved by the creation of more versatile libraries of new elements or by algorithms of proper conversion of mesh models and point clouds to 3D shapes [5, 13].

Finally, the interpretation of heritage building data over time is an important issue in HBIM as it provides a framework for the results and visualization of time changes in physical and social environments. In [4, 7] it is emphasised that the existing state of a historic building is being used as a starting point and goes into the reverse engineering methodology in order to find the structure of the building and the changes over time.

In light of the above, this paper presents a practical example of developing a full HBIM for the purpose of the interpretation of heritage building data over time. The historic site selected for this work is a listed building constructed in the early 1900s at the island of Lesbos, Greece. The Sarlidje Palace Hotel was chosen due to its distinct, unique history and the different architectonic influences shown in the structure. This study's specific aims are:

- a) Development of a detailed 3D model of the Sarlidje Palace Hotel using laser scanning and geodetic techniques for the geometric documentation
- b) Assessment of the capabilities of HBIM tools for the type of monument and the purpose of documentation.
- c) Creation of an HBIM model of the Sarlidje Palace Hotel which will be available to local authorities, relevant scientists and stakeholders.

The paper is structured in 5 sections. Section 2 provides a brief description of the site and the data collection while in section 3 the development of the BIM model is discussed. Section 4 gives the results along with quality information and discussion of the results. The paper is summarized in section 5 with concluding remarks.

2 Description of the site

The case study of this project takes place in Thermi, a small town of Lesbos, located on the east coast of the island. The wider region is named after the hot springs that well up over the centuries according to the Turkish name Sarlıça (Sarlidje). The Ottoman conquest of Lesbos took place in September 1462 which created new socio-economic and residential data. Whilst the first two centuries were marked by the recession of fierce upheavals, signs of recovery appeared after the middle of the 18th century.

At that period, the general economic and social growth of the island created special conditions for development including a road network and demand for bathing and accommodation facilities in the hot spring's vicinity. Hotel Sarlidje Palace was built in 1909 under the guidance and design of French architects (Fig.1). The high level of service resulted in attracting people from Lesvos, the Asia Minor coast, the capital and all the big cities of the empire, creating a popular landmark for that period and thus improving the view of the coast. After the nation's liberation, the Sarlidje Palace which was owned by the Ottoman community of Thermi until then, came to the Greek State. It continued to glory and despite world war events, the visitors' turnout was constant.



Figure 1: The newly built hotel as shown in carte postale of the era.

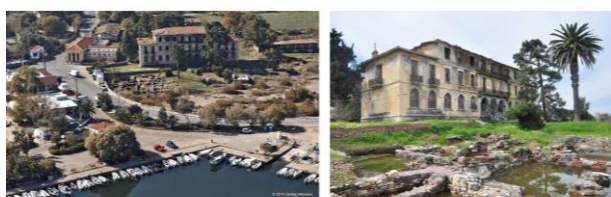


Figure 2: Views of the current state of the building and archaeological findings in the surrounding area.

Hotel Sarlidje Palace is placed into an area of about 23.5 acres with the main façade being northeast oriented. The main building was listed for preservation in 1987. It presents three main historical and construction phases including extension of its original volume, which altered the original form of the building. The first phase suggests initial construction of the hotel (1909) until the first expansion in 1925 (expanding both sides of the first floor). The 2nd intervention (expansion) took place in 1936 with the addition of two wings to

the opposite sides of the ground floor and the first floor. In 1933 archives of the building presents this as three-storey, while after the last expansion in 1936 the building was given its final dimensions (29.30m x 10.60m). During 1952-1965, the third intervention took place expanding the second floor as well as performing some indoor renovations, forming the building with the same general dimensions as to-date [24].

In its current state, the hotel forms a symmetrical three-storey building (Figure 2), presenting on the ground floor the common rooms (hall, living and dining room), while the bedrooms are placed on the first and second floors. The morphology of the views can be described as “Eclecticism” with oriental elements, for example, morphological references like the arches especially on the front view, which represent the Ottoman years when the hotel was first built (1909).

3 Development of HBIM

As there are no clear rules on the set-up of an HBIM, this is based mainly on practice. The HBIM platform has a set of different types of objects information pre-determined but also new properties that can easily be added to the specific project needs authenticity. The information is structured and object-oriented, linked directly to the building element to which it is logically referenced. For this project, it was decided to create an HBIM database that includes both geometric and non-geometric information. The geometric information is indicative of building elements, frescos or other decoration. Non-geometric data refers to data on building phases, material, colour, model, era etc. of the above categories, as well as information on intangible cultural heritage. The 3D model was developed using laser scanning data and geodetic techniques. Then, 3D objects of different elements were edited through graphics and used to create the database.

3.1 Data collection

The hotel has been abandoned since 1982 and due to lack of maintenance, parts of the structure are inaccessible or other parts of the first floor have collapsed. For this reason, only sections of the east (frontal view) and south (side) view of the exterior of the building were documented as well as the connecting parts to the interior (Fig.3).

The data collection was performed with the time of flight (TOF) terrestrial laser scanner Leica BLK360 and lasted about six hours. The quoted by the manufacturer measurement accuracy of the

instrument is 4-7mm (for a range of up to 10m and 20m respectively). The scanning speed is 360,000pts/sec and gives a complete scanning and image capture (panoramic and thermal) in less than 3min. A total of 14 scans (360°) were taken covering the exterior and interior of the building under study (Fig.4). In addition, self-adhesive (0.10x0.10)m targets were used to create tie points for the scan registration and georeferencing of the collected scans. Also, total station surveying was used (Leica Total Station-TS02) for the georeference of the final point cloud and controlling its external precision. The registration of all scans was performed in Cyclone software (Leica Geosystems) and alignment was achieved with RMS of 8mm. Due to the large volume of data, segmentation of the clouds was carried out for better and faster processing. Figure 5 shows views of the final registered point cloud which was used in the HBIM. Finally, it was necessary to export the point cloud file to an acceptable format via Autodesk ReCap software for later importing and edit into Revit software.



Figure 3: Views from parts of the building that were scanned and the use of targets for the data capture.

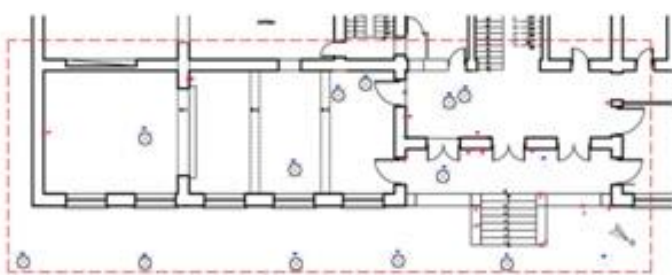


Figure 4: Location of scanner set ups (blue) and mounted targets (red) in the study area of the building.

3.2 BIM on surveying the existing condition of the monument

For the work carried out in this project, the proprietary software Autodesk Revit was chosen due to educational license accessibility, graphic versatility and general use in our geographical area.

In general, any other BIM application would have successfully supported this methodological process of translating the method into its specific tools. The collected point clouds were proceeded into forming a total geometric documentation on the existing condition of the building using means of BIM re-construction. The methodology involved two approaches. In the first approach, models were generated from the 3D laser scanner point clouds as discussed in section 4.1. In the second, BIM modelling is performed from existing information data of the building (i.e. complete CAD plans, facades and sections) [24]. In both cases, and despite the different format and data types, when imported in the BIM software they were used as background for direct design. The two approaches are discussed further in the following sections.



Figure 5: Views from the final registered point cloud that was used in the HBIM.

3.2.1 BIM modelling using laser scanner data

The registered point cloud product of the process described in section 4.1, containing all the geometric data of the existing structure in its current form, is imported in a project created in Revit. The import is based on the coordinates which allow aligning together every point cloud included thereafter. In this approach, it is vital to determine the levels of the modelled building. In the BIM structure, elements such as walls, windows, doors, stairs or roof must be tied to specific levels. The basic structure was modelled using Families, i.e. ready-made elements. Special feature elements of

the monument, such as decorative columns, sculptures over the columns, recesses or protrusions in the walls had to be modelled with the use of so-called Local models.

Another important step is to set the reference height at a certain level and the created Families are modelled based on the cloud information (e.g. point cloud section refers to wall thickness). The modeling process traces over the point cloud to snap the Family-elements on the right position (Figure 6). In this case, segments of the point cloud are inserted consecutively and oriented using their coordinates.

After determining the levels of the modelled building and tying the objects to their levels, the walls, windows, doors, roof and stairs were modelled with the use of created Families. Since the building is old, it was not possible to use ready-made elements in every case. Thus, for each case a corresponding Family or Type is created, as well as the stratification of materials leading to a more parametric way of modeling.

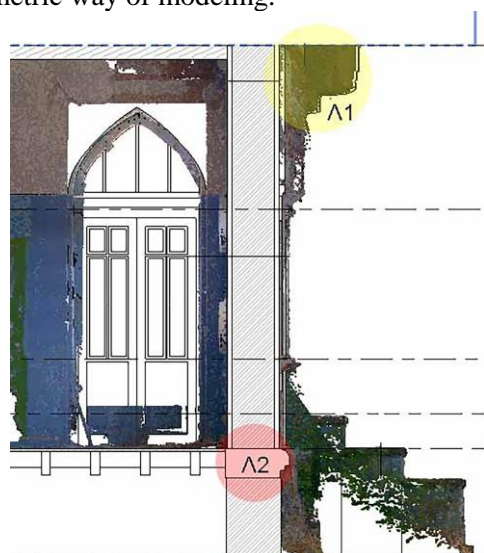


Figure 6: View of remodelled BIM model along the point cloud data information.

In some cases, such as the floors, it was not possible from the cloud to distinguish the trace of the upper surface of the floor. Therefore, effort was made to find certain cross-sections or longitudinal sections of the relevant point cloud where the Family of the desired floor was positioned on that level. It was noticed though, due to the laser scanner data noise, that was not impossible to capture the colour details and texture of the floor. This occurred at the entrance hall where mosaic flooring with decorative colour variations could not be fully observed due to abandoned heavy objects causing obstruction to the laser beam. In this case, it was essential to seek information from relevant existing literature

and previously made measurements [24] by different recording methods in order to describe the missing information such as texture, patterns and colour of the mosaic floor in a realistic mode and to present the final products in a complete way. Clearly, missing information is a common problem in the field of knowledge of historic heritage architecture. Thus, information can be found either in existing literature concerning the same or similar type structures or previously measured data. However, the latter implies the coexistence, without any link, of various models with different levels of accuracy or containers of different plots of information.

In a similar way as above, the reconstruction of the ceilings was made in the software. Based on the ceiling height, from measurements on the point cloud, the relative Family type with the stratification of materials was positioned on the specific level.

Besides the basic reconstructed elements (walls, floors, ceilings), greater complexity present particular morphological and architectural features of the building which cannot be represented by the existing Revit Families. In such cases, greater attention is required to make good use of the data transformed from the laser scanner to the HBIM model.

A brief description of the modeling methodology followed for complex elements, is given below:

- i. The decorative brick trim and drawn mortar which traverses the front façade, is modeled after sketching the desired profile and sweeping it through a path across the side of the building.
- ii. The main entrance staircase made of stone is created by setting up an entire new Family with the desired dimensions for the height and width measured directly on the point cloud.
- iii. The balcony railing of the entrance terrace (constructed by stone columns and filled with clay masonry) is a complex structure that cannot be described by ready-made elements of the software. Thus, it was modelled from individual Families (column, nested Family-complex of bricks) (Figure 7).
- iv. The arches of the main façade are depicted as a wall set exactly as the Family type created for the external masonry on which some voids were drawn and placed.
- v. The three baluster types holding the balcony of the first floor were created entirely as new 'Structural Framing Families', parameterized and saved to be inserted in the project as many times as needed.
- vi. Decorative brick trims around the openings (windows/doors) were modeled as 'In Place

Families' tracing over the captured and projected point cloud

- vii. Wooden framing (doors and windows with the characteristic arches on top) on various dimensions consisting of wooden railing and glass were based on existing options of the Family Library of the software, and were processed for attributing them to the project,
- viii. The colouring of the walls (both internally and externally of the building) was created using the tools of 'Split Face and Paint'. Figure 8 depicts a view of the final 3D model from the central entrance having each element painted based on the original intense colours of the building (Figure 8).

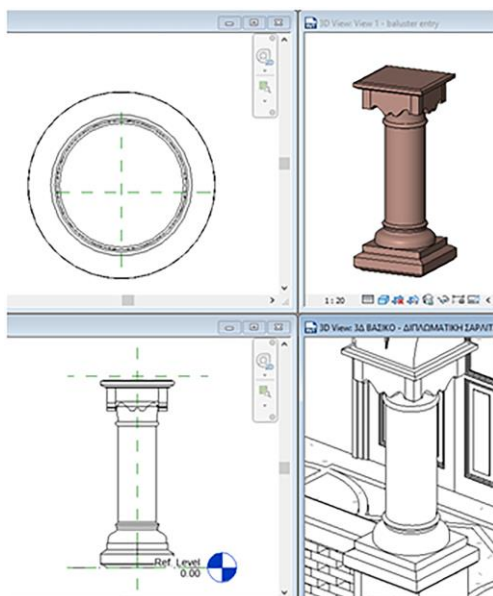


Figure 7: Views from Revit to create a column in a Family (type column).

Using the above procedure, the final model was created and various 2D products could be exported automatically. These include plans, facades and sections where for the final editing the user may need to add only few details. An example is given in Figure 8 where the particular morphological elements that were created in separate Families and introduced into a common model are evident. In addition, thematic maps can be produced and refer to the presentation of the existing condition, the pathology of the site, the construction, and the used materials.



Figure 8: View of the final BIM model.

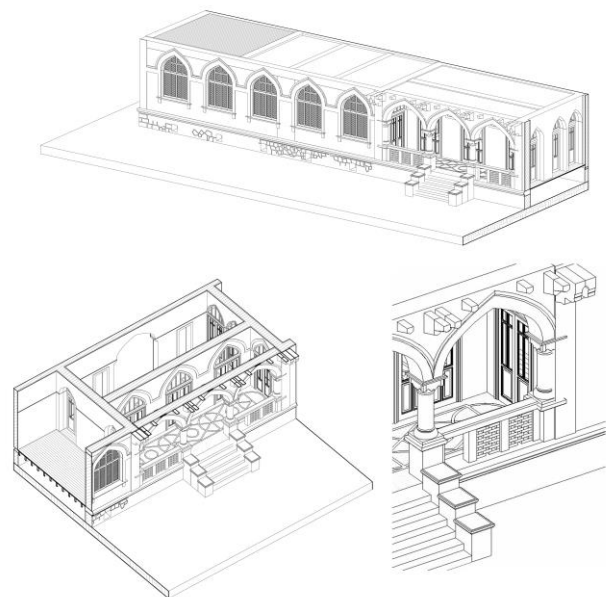


Figure 8: Views of the model in the BIM.

All these products can aid to the study on the maintenance and reconstruction of the monument by relevant engineers. By setting a parameter (for example, Existing Condition) to every element of the model, any kind of information recorded can be traced by the user in the form of tables and drawings. In this way, it is possible to create a digital database that would potentially cover the building's evolution over time up to the present condition and serve as a tool for future interventions or additions and monitoring.

3.2.2 BIM modelling from CAD data

In the second modeling stage, the construction building phases were documented using existing CAD drawings based on the work by [24]. The advantage of HBIM through the software is to track the evolution of a building. Specifically, for the Sarlidje Hotel, five distinct construction phases can

be chronological categorized as: Structural Phase A (1909), Structural Phase B (1925), Structural Phase C (1936), Structural Phase D (1952-1965), and finally, Phase E which refers to the existing state from 1965 up to-date [24]. In the final phase there has been no addition to the structure of the building. Two options are given for introducing the design background. The first refers to importing the CAD files directly in the BIM software and the second, linking a CAD file to the software, which makes it possible to automatically update the model after modifying the 2D drawing in AutoCAD environment. In this work, the first option was followed.

In addition, the plans are introduced sequentially, per phase and per level, thus completing the height of the building over time. The plans were designed in an arbitrary system and there is no automatic recognition and orientation process in the software. Therefore, a number of common points per level are 'locked' in the project because they serve as tie points. With this process, geo-referencing is achieved of all plans into a common system.

The digital reconstruction of the model based on the plans, was implemented with the same software tools discussed in 3.2.1. The model at every stage compared and checked with the dimensions and levels of corresponding plans in CAD. With an effort to reduce the time process, details of the drawing data during the transfer to the software are removed, because the final product is intended to be used as an auxiliary tool for presenting the hotel's phases and ontologies throughout the lifecycle. Figure 10 shows views from the final product attributing the five distinct construction phases.

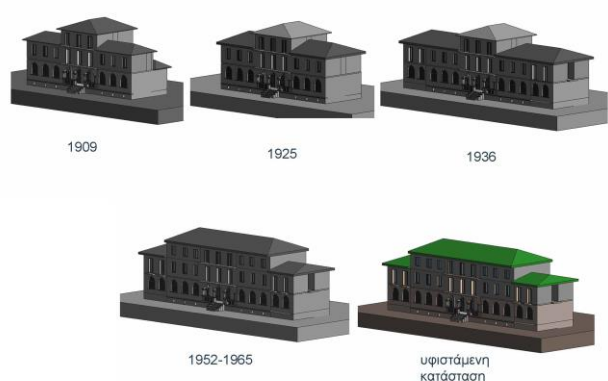


Figure 10: Construction phases of Sarlidje Palace showing the building's life cycle.

4 Products of the developed HBIM

4.1 Architectural plans and pathology

An essential aspect of the BIM is the production of outputs not only in the form of drawings (outlines, plans, sections etc.) where the geometry is the main concern, but also outputs of descriptive nature such as pathology recording drawings (Figure 11). In the example shown in Figure 11, qualitative description of the condition of the structure is provided within the BIM. In the modelling stage of the BIM each structure element contains a parameter for the preservation stage as evaluated on site and inserted to the model by the engineer (dark green for good condition, light green for moderate condition and red for bad condition). Such parameters can be used for other qualitative information, such as the construction phases of the building, notes on the pathology of the elements on floor plans or views and restoration suggestions etc. This information can be finally plotted into plans or schedules in the form of tables and may serve as semantic parameters [18].

In that sense, the implementation of surface information management allows graphic and quantitative control of relevant data in the field of preventive conservation, providing consultation on the HBIM model in the form of tables of numerical data. These tables can in turn be filtered according to parameters related to chronological phases (dates of specific interventions, drafting reports on damages status, etc.) or to specific areas of the model based on identification or membership attributes.

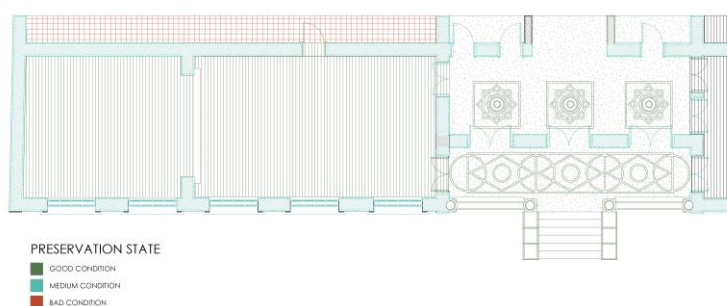


Figure 11: Example of descriptive plan for the condition of the building. Qualitative description of the condition of the structure is provided within the BIM model finally plotted into plans or schedules in the form of tables that may serve as semantic parameters.

This information is mapped by the laser scanner data which allow to record deviations and the engineer can refer to this information at any time. In the example of the ceiling shown in Figure 12, the deviations from the current state (measured point

clouds) and the created digital model can be clearly seen specifically where the roof is bending. It is emphasized that the rendering of the pathology shows the existing distortion of the examined area with the given detail and the accuracy of the initial data. In the modeling phase though, which is mainly used for the presentation of the architectural form of the structure, there is usually smoothing and filtering of data that depends on the type of monument and the purpose of the project. In any case, the data and their products within the software are available to the user at any time. They form a database from which qualitative and quantitative conclusions can be drawn. By introducing parameters to create an annotation field of individual architectural or historical elements, recording pathology etc., text information can be used in any type of the products (Figure 13).



Figure 12: Deviations of the ceiling from the current state (measured point clouds) and the created digital model.

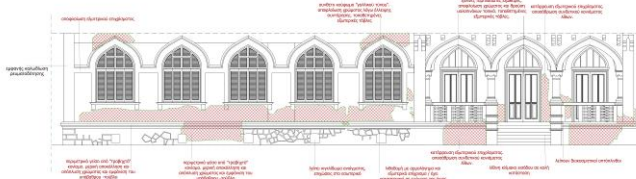


Figure 13: Front view of the building from the 3D model and the facade with annotations on the pathology.

Sample views from the final models of the BIM documentation of the building are given in Figure 14 (cross sections and longitudinal sections of the building). These are 2D and 3D plans as well as thematic drawings using the capabilities of the BIM software. Of course, the final products are available for further processing and modification as the need arises each time. It is noted that the drawings were based on the geometric information derived from

the 3D scanning and were enriched with locally based observation and comparison with existing architectural plans.



Figure 14: Cross sections and longitudinal sections of the building.

Finally, as the BIM is a design tool and mainly used for new construction, it is possible to interfere within the project by adding new elements to the existing structure and virtually add or remove parts. The ability to create a new construction phase is performed by collecting all new elements, separating them and simultaneously displaying them in harmony with the existing part as a whole (Figure 15). An architectural proposal for the restoration and re-use of Sarlidje Palace, along with the exploitation of the surrounding area with the addition of a new hotel unit is shown in Figure 15. The creation of the proposed architectural representation is a product of BIM Design [24].



Figure 15: Proposed architectural development using BIM.

4.2 Discussion

The use of BIM software in management of cultural heritage monuments has many benefits especially when combined with highly accurate collected data. With reference to the data type, it is necessary to choose a spatial rather point-

wise technique for HBIM. Among the available techniques, laser scanning seems an obvious solution with many advantages, but the main interest is the general methodology of transformation of the data captured in an HBIM model with a very specific objective.

With reference to the modelling of the data within the BIM, it is important to consider that the model should not only be the reflection of the current physical reality (material and documentary) of a historic structure. It must also contain all those elements that are hidden or lost today (historic data, documentary findings etc.) because they provide essential information for further analysis of the models. Regarding the modeling process, efforts should be made to apply a method that guarantees the least possible deviation between the real structure and the HBIM model. This objective implies supporting the process in reverse engineering tools that allow generating surfaces of any nature adapted to the irregular geometry of the structure.

There are however, limitations in the modelling of historic buildings as this type of software was developed for modern design and new construction. The complex geometry of these monuments by their nature requires a high level of familiarity with the modelling tools of BIM. BIM enables different design methodologies from standard practices by customizing ready-made Family objects or creating new Families. It can also perform the modelling with In Place elements by using background geometric information from point clouds or CAD format. The geometric model it can be further enriched with qualitative information. In some cases of modelling with repeatedly used basic elements (e.g. window frames, decorative elements) it was found that is better to model these from the measurements derived from the point cloud, creating corresponding Families.

The purpose of the study, the documentation, the outputs and the processing within BIM software must be clarified from the beginning. Currently, the usual form of presenting the existing state of a construction is in 2D drawings (plans, sections etc) and thematic maps which provide the information as a common vocabulary between engineers. When using 3D tools in a BIM environment, the digitization of the particular morphology of a monument is a matter of concern due to the architectural elements that often differ from modern standard elements. Also, when the structure presents deformations caused by deterioration from age or even complete abandonment, as discussed in

this case study, BIM can be a useful tool in documenting its pathology and understanding the construction as it presents the use of parameters in every element modelled.

BIM as a rendering tool relies on 3D design and automatic updating of all views (floor plans, sections, views, 3D model). In this project, the methodology involved firstly, the approximation of the existing state of the building by remodelling it with the software building blocks and by following closely the point cloud information. In this way the 3D model was created and all possible 2D renders of it, reproducing the structural system, and then adding details visible to the final output scale (1:50). Subsequently, the points that are highly distorted and therefore divergent between clouds and pattern, such as parts of the ceilings, wooden beams, breakage and flushing of stone parts, etc., are marked locally only in 2D drawings without affecting the rest of the model. Finally, the engineer can at any time refer to the point cloud inserted in the project as a means of comparing the ideal - correct state of 3D reconstruction with respect to the cloud and measure the divergence.

For the generation of the HBIM model described in this work, a specific commercial BIM software was used. The successful translation of the initial theoretical model into the object structure of a BIM application is based on the categorization of objects and their visualization. These aspects are developed in all BIM software due to the very nature of this technology. Although there are variations in the implementation of such aspects in different software, it can be said that the proposed methodology is transferable to any commercial BIM package.

5 Conclusions

This work has led to the development of a pipeline capable of supporting the implementation of HBIM for a specific project in the process of knowledge and management of information for conservation actions. Thus, the contribution to the existing knowledge is not only in the heritage use of the BIM but in the approach. The use of BIM in architectural heritage has been placed not only in the partial scope of the accurate graphic survey but also in its role as a wealth management tool accessible from the various disciplines involved.

The model was developed using a combination of laser scanner and geodetic data along with architectural survey information. The final model arises, consequently, from interpretation of the

metric data based on historic and architectural knowledge of the element studied. The translation of the acquired raw data into 3D graphic entities that contain and generate geometric and qualitative information, was based on a conceptual approach that evolved also from previous work due to the high levels of complexity of the building.

With particular reference to the current state of the Sarlidje Palace Hotel, it was shown that the building has most damages concentrated on the top floor. These damages are responsible for the destruction for part of the roof which puts the building in poor condition. The methodology used in this project can serve as a basis for the modelling of the building as a whole and the derived products provide information for decision making on the required interventions.

Finally, the general methodological approach in this work on the application of BIM in heritage architecture includes not only conservation information but also actions that encompass the concept of future development. This refers, in general, to knowledge, management and intervention in historic buildings through the visualization of proposed models as was shown in this work, allowing interaction with the model without specialized training in BIM methodology. This link is considered key in the conception of the HBIM model as an essential tool in the maintenance and management of updated information on the object of study. The model itself is capable of generating information that channels new knowledge about the complex transformation processes that characterize historical architecture.

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