



The Importance of Using BIM in Documenting Historical Buildings in Syria after The Earthquake – Case study (Department of Immigration - Old City of Aleppo)

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Abstract

Syrian cities and historic sites have suffered severe destruction due to armed conflicts in the past decade, causing significant effects on ancient civilizations. Historic buildings are exposed to dynamic changes like environmental shifts facing challenges especially after the earthquake disaster on February 6, 2023. Many historical buildings were partially or entirely destroyed; therefore, it needs proper restoration, maintenance, and management. Many practitioners in historical building management encounter challenges during the restoration process, including inefficient project management, and project delays. These issues stem from the absence of digital documentation and the updating of information management systems. Historical buildings management still relies on traditional techniques, managing information through various coordination systems by different professionals, leading to a lack of cooperation, and interoperability. This research aims to present BIM as a supportive tool to address these issues. It explores current technologies and their roles in digitization within BIM providing a detailed Historical Building Information Modeling (HBIM) and develops a new integrated HBIM framework for the management of historical buildings in an integrated and interoperable environment that supports 3D digital documentation to maintain a heritage asset and facility management activities. The results indicate that the proposed framework is feasible and effective in achieving information integration and communication among stakeholders.

Keywords: HBIM- Historical Building Information Modeling; Heritage conservation; Restoration planning; Facility management (FM); Interoperability; Department of Immigration; Old City of Aleppo

1.0 Introduction

Architectural heritage serves as the greatest witness to the civilizations of nations and the cultures of peoples, symbolizing their development throughout history. Beyond being a social and cultural heritage that must be preserved, renovated, and inherited for future generations [1].

Reconstruction and restoration represent some of the most crucial methods for preserving heritage and history. Therefore, it is essential to establish approaches and strategies for reconstruction, restoration, as well as operation maintenance and facility management.

Many damages are caused by the lack of management practices and insufficient planning to solve resulting problems. This includes a lack of clarity in the reconstruction strategy and insufficient documentation and information provided to the project [2] These issues lead to problems such as inefficient project management, increased costs, and delays[3]. Therefore, there's an immediate need for a new approach to address these issues and Building Information Modelling (BIM) is the suitable solution [4] in this case advanced documentation method for historical buildings must be adopted to obtain a geometric model with all the information in one

database[5]. This model effectively supports the restoration process, operation, and maintenance phase (O&M) Operation & Management.

Determining the actual condition of the heritage asset through digital documentation benefits stakeholders, helping them make effective decisions throughout the life cycle of the project. The management of the 3D model, containing all the semantic information about the historical building, provides a collaborative information management platform, reducing difficulties involved in all preservation stages, including reconstruction, operation, and maintenance.[2]

Building Information Modeling (BIM) is a process that is constantly evolving in the Architecture, Engineering, and Construction (AEC) industry [6] [7]. BIM integrates the 3D model with all the semantic information throughout the life cycle of the project, where BIM digitizes, integrates, and manages all relevant information into one database based on a three-dimensional model. This can be used throughout the life cycle of the building.

The BIM model information increases with the dimensions that have been structured into seven levels and is still expanding. [8] [9]

Starting with the preliminary design stage, detailed design, construction, scheduling, and cost, all of which are integrated with the 3D model to provide information in 4D, 5D, and up to 7D models [10], within one model that plays a key role in integrated project delivery (IPD) [11] methods. Furthermore, BIM provides integration with facility management information (FM) and valuable insights for facility managers to support building management functions.

Despite the destruction caused by war and natural disasters, it creates opportunities to explore ways to develop a clear course of action and strategy for reconstruction. Given Syria's current circumstances, the development of such strategies is highly important, as they have a very profound national and symbolic dimension.

2.0 Literature Review

The documentation and registration process are the most important measures for the preservation and protection of historical buildings and historical sites [12]. In addition to learning about their history and data in detail, the documentation process serves as an identification card for the building or site, capturing its original value and condition. Currently, the preservation process must be based on a comprehensive study and understanding of the building's conditions, resulting in the determination of the plan and method of dealing with it without harming its value. Documentation is carried out during various stages of the conservation process—before, during, and after the completion of restoration work—to determine the amount and type of intervention carried out during conservation and restoration activities [13]. BIM can serve as an operational tool, facilitating collaboration among all stakeholders [14] to achieve a more innovative project. [15] The widespread adoption of BIM has experienced substantial growth over the past few decades. [16]

Historical documentation is a complex process that involves several stages, including the collection, understanding, and interpretation of historical, design, and construction information toward the end result [7]. It is also the first and most important step before conservation, maintenance, and restoration [17]

As a result, historical documentation is defined as a recording of the current status of architectural heritage and its surroundings through reports, drawings, photographs, architectural and digital construction drawings. During this process, it is essential to have a perception of the original state of the building through old photographs and drawings from architectural libraries to obtain accurate historical tracking of this heritage asset. [18]

Heritage has been divided by United Nations Educational, Scientific, and Cultural Organization (UNESCO) into a natural, cultural, and underwater heritage. It is defined as “our legacy from the past, what we live with today, and what we pass on to future generations” [19], Moreover, tangible and intangible cultural heritage are the two categories [20] that divide cultural heritage (CH). Heritage shows a nation's identity and past legacy for the future generations [1].

The importance of "BIM" lies in its capacity to integrate information and digital technology, fulfilling two crucial requirements in the field of heritage documentation. This includes the utilization of modern tools such as simulation applications, 3D printing, virtual reality, Laser Scanner, GIS, and Photogrammetry technologies in the process of archaeological documentation.

Digital documentation is particularly advantageous in cases of partial damage compared to total demolition. Existing buildings allow for the application of photogrammetric, 3D laser scanning, or other technologies.

The laser scanner employs a laser beam to focus on the target, and the reflection of the beam provides precise geometry for the historical building [21]. Equally, photogrammetry utilizes camera images to acquire as-built heritage surface information. These images are taken with a camera featuring predefined ground control points (GCPs) and are processed using the Structure from Motion (SfM) algorithm [22]. These methods yield point cloud data with millions of points and geometric coordinates, illustrating an accurate 3D representation of objects [23] and filtering of the point cloud are essential to preserve the complex geometry of the heritage building [24].

While the processed point cloud effectively captures the original complexities of historical geometries, it lacks additional information such as attributes, crucial for management activities. Therefore, the conversion of point clouds into parametric 3D geometrical models becomes necessary to incorporate additional details about geometry, material, and attributes [25] [11].

In the case of a totally demolished heritage asset, the usual practice involves relying on pre-impact information and documentation, including written descriptions, drawings, or photographs from architectural and archaeological studies. These serve as the basis for completing, rebuilding, and reconstructing heritage assets. The accuracy and detail of the information and model play a crucial role. The model may either be integrated and detailed or provide an illustrative representation of the overall external appearance of the historical building. Regardless, it becomes a significant imprint in determining and documenting the history of architectural heritage.

Historical buildings are still managed using traditional methods, lacking a unified digital database for historical data. This management involves multiple coordination systems with various stakeholders using different systems like PDF documents, Word reports, Excel spreadsheets, etc., which are often not interconnected and lack integration. Additionally, it relies on two-dimensional representation, lacking a 3D perspective, making decision-making challenging for managers. Retrieving and updating information from this type of system pose significant challenges, especially during maintenance tasks. Data exchange among stakeholders is hindered due to the lack of cooperation and a communication gap resulting from different forms. The adoption of such a traditional method leads to numerous problems during the restoration process and facility management [26].

This paper addresses the stages at which BIM can be applied in heritage building documentation processes, starting from the collection of information and architectural as-built data using modern technology compatible with BIM systems. This process leads to the creation of a Historical Building Information Model (HBIM), which can be relied upon for the development and subsequent updating of data for maintenance purposes and facility management, providing the best benefit to all stakeholders.

Historical BIM (H-BIM) is obtained through three phases:

Phase1: Data Collection Phase, often using laser scanning technology and photogrammetry to gather detailed information with high accuracy and quality, or through digital architectural as-built drawings such as CAD format.

Phase2: Data Processing, where all gathered information is processed to build a database prepared for the next stage of 3D modeling.

Phase3: Modeling Phase, which integrates all information for later use in required restoration and maintenance operations.

3.0 Historical Building Information Modeling H-BIM:

Historical Building Information Modeling (HBIM) is an advanced information management approach [27] aimed at improving the efficiency of maintenance and restoration of historical buildings. It involves

using information technology to create 3D models that contain detailed information about buildings, including their construction history, materials, and specifications.

The importance of HBIM for built cultural heritage lies in the digital representation of the physical and functional characteristics of historical buildings, considering all stages of the building's additions, modifications, restoration, and maintenance.

This technology seeks to develop a 3D digital model containing all the necessary information about a historic building, encompassing its original design, structure, and the materials and finishes used. Each part of the building is documented with high precision in the digital model, aiding in the analysis of the building's current condition and the identification of potential damage and problems.

BIM technology offers various useful applications in the maintenance and restoration of historical buildings. The efficiency and effectiveness of maintenance and restoration operations are significantly improved by the BIM process. Here are some of the main applications of historical BIM technology in the maintenance and restoration of historical buildings.

Accurate and Comprehensive Information

One of the major advantages of using specialized software for HBIM is the ability to analyze and document precise and comprehensive information about buildings. This software provides access to a vast array of accurate data regarding the building, its components, and various systems. This detailed information is crucial for making informed decisions and effectively managing historical buildings.[28]

Data Analysis and Predictions

Analyze the data associated with the buildings and predict potential implications of any possible changes. This capability enables better decision-making and efficient planning of maintenance and renovations. By understanding the potential outcomes beforehand and addressing any issues proactively, risks can be minimized.

Enhanced Collaboration and Coordination

By facilitating communication and collaboration among stakeholders involved in managing and maintaining historical buildings. In addition to allowing for easy sharing of models and data, which enhances coordination and saves time and effort. With improved collaboration, teams can work together seamlessly, ensuring a smooth workflow and efficient management of the buildings.[29]

Improved Cost Efficiency

Utilizing specialized software for HBIM can lead to improved cost efficiency in managing and maintaining historical buildings. By accurately analyzing data and predicting potential issues, planning maintenance operations more effectively. This proactive approach can help prevent costly damages and reduce overall maintenance expenses in the long run [30]

4.0 Damage Assessment to Build Cultural Heritage

The assessment of damages and condition of heritage building is based on the "European Standard for Heritage Preservation EN:16096:2012 ©. When documenting a site or part of a building, classify the particular situation and the need for intervention and resulting recommendations within the status and response categories.

The objective and motive of any survey is to assess, evaluate, and report the condition of damaged or destroyed buildings of cultural significance. Knowledge and understanding of the materiality of built cultural heritage and precise information on its current state are important, as they help specify measures necessary to preserve structures in an appropriate condition and ensure that the maintenance required to keep them at this level is well defined [7]. The recording of the fabric and condition is an indispensable basis for repair, restoration, rebuilding, or reconstruction under the aspects of monument preservation.

The assessment of damages and condition of heritage building is based on the "European Norm for the Conservation of cultural property — Condition survey and report of built cultural heritage (EN 16096:2012)" [7] When documenting an object or section of a building, the specific condition, the need for action, and the resulting recommendations are recorded in condition and urgency classes.

For each component/building element, a Condition Class (CC) shall be stated. The classification is based on an overall assessment, as shown in table 1.

Table 1: Damage Assessment with condition class

Type of damage	Code
No symptoms Apparently without perceptible change in substance	CC0
Minor symptoms Only superficially, without substantial changes (loss < 20%)	CC1
Moderate symptoms Locally limited damage / loss of surface (loss < 50%)	CC2
Major symptoms Major symptoms Serious damage, severe substantial loss / danger of collapse (loss > 50%)	CC3
Total loss Physically complete destruction of a building / of a component / element (loss > 90%)	CC4

5.0 Level of rehabilitation needed

If the identified defects are categorized as minor, moderate, or major, it is necessary to assess the extent and complexity of the intervention required for their repair. The evaluation of rehabilitation work encompasses four categories, considering the necessary actions to address the identified defects [31], as illustrated in Table 2:

Table 2: Rules for assessing the extent of the intervention

Located	Occasional defects affecting the structural element, extension does not exceed 25% of the total area.
Medium	Anomaly affecting limited areas of the structural element, extending between 26% and 50% of the total area.
Extent	Defects affecting large areas of the structural element, extending between 51% and 75% of the total area.
Total	Anomalies affecting almost all structural elements, extension exceeding 75% of the total area.

Rehabilitation requirements are categorized into three levels: minor, moderate, and severe. It is important to highlight that the outcome depends on the training and experience of the engineers throughout the process, and their judgment aligns with the criteria outlined in Table [15], as indicated in Table 3.

Table 3: Criteria for assessing the level of rehabilitation needs.

Slight rehabilitation	Coating repairs. Minor repairs to the perimeter of the building. Spatial repairs in major or minor elements.
Medium rehabilitation	Replacement of coatings. Repair and construction of new facilities. Spatial repairs, replacement or reinforcement of major or minor elements.
Severe rehabilitation	Repair, replacement or reinforcement of major or minor building elements

6.0 Research Methodology

Historical buildings need proper maintenance, which involves routine work necessary to preserve the status of heritage assets [2], such as repairs and maintenance of heritage elements like walls, columns,

fixtures, etc., and even the entire historical building. Maintenance activities enhance the performance and lifespan of historical buildings, ensuring the function of each element, preserving heritage, and making it more sustainable for the future. These maintenance activities encompass scheduled proactive maintenance and corrective maintenance. Proactive maintenance is performed at regular intervals regardless of the heritage asset's condition, involving tasks like checking the status of heritage elements. On the other hand, corrective maintenance is carried out after a failure, for example, when heritage assets requiring maintenance are severely damaged and need restoration.

The methodology for this research is based on the development of a framework to support the management of information related to historical buildings and the planning of restoration using BIM technology. The research method adopted in this study for the development and implementation of the proposed framework consists of four steps: (1) identification of problems; (2) proposing a solution; (3) framework design and development; (4) applying the proposed framework through the study case, as shown in Figure 1 (research methodology).

The success of this methodology is achieved at the following levels: (1) information source level, where BIM models can be obtained from multiple sources; (2) building and development of H-BIM model level; (3) integration level; (4) application level

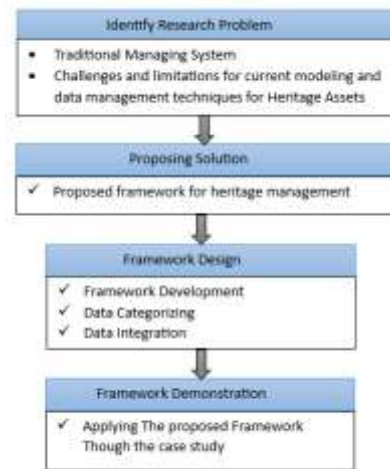


Figure 1: Research Methodology diagram

6.1. Information Source Level:

This level encompasses data from various sources to construct the BIM model in accordance with OIR (Organizational Information Requirements) and AIR (Asset Information Requirements). This information can be sourced from existing databases or may necessitate detailed surveys and research. A comprehensive understanding of a historical facility in the BIM environment requires a meticulous study of the physical form of heritage assets and additional semantic information, particularly FM data. The information necessary for managing historical buildings is categorized into geometric and non-geometric information. Geometric information relates to the complex representation of historical building components. Simultaneously, non-geometric information distinguishes the characteristics of geometric components and plays a pivotal role in heritage management, specifically for FM operations, as stakeholders are interested in these types of data during the operational stage.

The collection of geometric information can significantly impact project costs, depending on the size and complexity of the historical building. Several survey methods can be employed to obtain engineering information on historical geometric features. For simple, small, and less complex locations, CAD drawings, images, and surveys of measured buildings may suffice. For more accurate 3D data, digital (3D) scanning methods such as photographic scanning and laser scanning can be utilized. While the former is more economical and involves simpler tools and techniques, the latter requires advanced but expensive tools, techniques, and expertise.

All information required for maintenance and restoration is gathered within the heritage asset information requirements, and accurate technical information and specifications are essential for the organizational information requirements (OIR). This type of information helps stakeholders in comparing the condition of the historical building at different periods during its life cycle, enabling analysis of changes in the condition of the heritage asset.

6.2. Building and Developing of HBIM level:

At this stage, each element of a historical building is developed in the digital environment and assigned a unique identifier. The Building Information Modeling (BIM) model comprises heritage components from various disciplines, constructed in parametric models. The digital development of a heritage asset's component depends on data gathered from the information source level, which is classified as geometric, structural, and non-geometric data. These data are then included in the BIM model.

In a BIM workflow, having an extensive family library makes modeling more natural and faster [32]. Since, most of the time, these families consist of parametric elements, they can be adapted to project needs, thereby enhancing productivity [33].

However, there is a deficiency of libraries that meet the requirements of HBIM projects, resulting in the need for the complete modeling of these families. Autodesk Revit is a hugely versatile and powerful modeling tool, enabling us to create modelled families on the project itself or externally within the family editor [34].

In either case, the element can be classified into the correct category so that it behaves appropriately within the project as a family made for this purpose.

6.3. integration Level:

It consists of identification of information sources in accordance with organizational information requirements (OIR) and asset information requirements (AIR), data standards, and the integration of data into a 3D model for evaluating building performance, the integration level collects and integrates all information, documents from different sources and stakeholders into a single 3D HBIM. As a final output a complete integrated HBIM model containing geometric models, non-engineering information and associated data as shown in the figure (2).

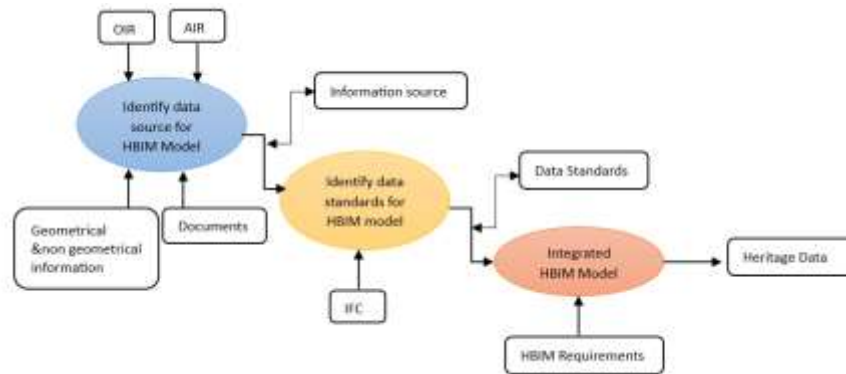


Figure 2: diagram for integration level

All integrated geometric and non-geometric data in a single database provides advantages over traditional methods for increasing efficiency with searching and conservation, data consistency and improved asset evaluation and perception.

6.4. Application level:

The application processes supported by the proposed framework are three-dimensional digital documentation containing all structural geometric and semantic information [35] about heritage building as well as operating tasks and represent a four-dimensional simulation of the scheduling process for restoration and maintenance work.

7.0 Case Study- Department of Immigration – Old City of Aleppo

7.1 Historical study and architectural description:

The building construction dates back to 1905-1907. It was established in the Ottoman style and is directly linked to the main road from the southern west side where it oversees Aleppo Citadel. In addition to its historical importance also it has a strategic location where it is close to the covered old Souq on one side and the Old City on the other.

In 1925 additional floor was added to the building where it functioned as a government building the old building has a distinctive stone façade which is rich with decorative stone architectural components, beside its distinctive staircase it has an artistic clock from the roof level.

The renovation of this building was chosen because of its historical importance and value starting from its location, which forms part of the urban fabric of the Old City of Aleppo also an important part of Aleppo Citadel.

The old city of Aleppo is registered as a (World Heritage Site) by World Heritage Center (WHC) and is therefore under the special protection of UNESCO (WHL), [8]. Due to damage to the historical buildings caused by the war, it has been registered on The World Heritage site in Danger since 2013. Therefore, the rehabilitation of this building will contribute even partially to the removal of the old city of Aleppo from this list.

7.2 Damage Assessment and classification

Based on the initial overall assessment, the building has sustained severe damage from armed attacks during the war, coupled with the recent earthquake. Consequently, the overall damages were estimated to be less than 50% of the entire building, posing a risk of total collapse, categorized with CC2 code according to the European Standards for the Conservation of Cultural Property EN: 16096:2012 ©.

As illustrated in Figures (2-3), there is partial damage on the west and south façades, along with significant damage at the main entrance. This includes a partial loss in the first-floor slab with a balcony, as well as a partial loss of the staircase figure 4 and the clock on the top roof floor.



Figure 2: west and partial collapse in south west façade- Department of Immigration



Figure 3: west façade with main entrance- Department of Immigration



Figure 4: west south façade – Department of Immigration



Figure 5: north west façade- Department of Immigration

7.3 Working mechanism for documenting:

The partially demolished archaeological building has been chosen for a thorough examination of its past documentation, relying on descriptions, photographs, and drawings. This approach is crucial because, when documenting a completely demolished heritage structure, the accuracy and credibility of previous and existing documents become paramount. This is particularly true for written descriptions and engineering drawings. Therefore, the architectural as-built drawings were obtained in the official CAD format from official entities [36].

7.4 Working Steps in Documentation with BIM Technology

- 1) Information and data were collected from drawings, charts, previous and current photographs of the entire building, as well as from old documents and architectural descriptions, incorporating all historical and semantic information obtained from official sources.
- 2) The building's current damages were assessed and classified.
- 3) The information gathered from various sources for the heritage building was analyzed and processed, preparing a database for the Historic Building Information Modeling (HBIM) model.
- 4) A digital copy of the architectural as-built drawings in CAD format, representing the building pre-destruction, served as a valuable starting point for modeling, documentation, and subsequent rebuilding.

- 5) Autodesk Revit was the primary tool used to create the heritage BIM model, incorporating all available information, including details about materials used in construction, as well as interior and exterior finishes.

7.5 HBIM Modeling

The main points of the restoration plan included minimizing changes to the original design and restoring the building to its original form before the destruction, documented in preparation for the rehabilitation phase.

All geometric and non-geometric information of the building was integrated virtually into a single model, facilitating information exchange between stakeholders [37]. Additionally, all architectural heritage elements of the building were modeled within the IFC classes, an open standard file format for BIM model representation, ensuring dynamic and seamless exchange of information.

- The building levels were specified in accordance with the surrounding streets.
- The building comprises three floors: Basement, ground, and first, along with a staircase featuring an external clock on the west façade.
- The interior and exterior stone walls, identified as structural elements, bear the entire facility.
- To represent the geometries of the heritage building, a library of parametric families was developed using Revit software. These families are based on parameters, and instances can be created with different parameter values.
- As shown in the figures below, architectural plans for the building were developed, resulting in an integrated Historical Building Information Modeling (HBIM) with all the necessary information. This model is intended for use in information management, enhancing the building's performance.

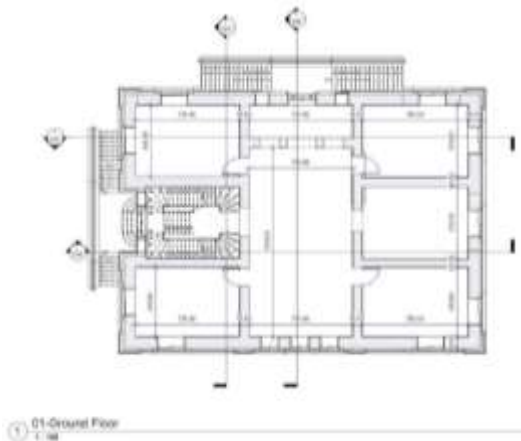


Figure 6: Ground floor plan-
Department of Immigration

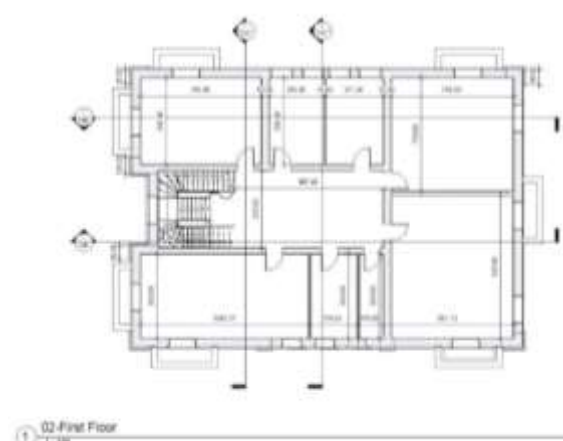


Figure 7: First floor plan-
Department of Immigration



Figure 8: west elevation-
Department of Immigration



Figure 9: North elevation-
Department of Immigration



Figure 10: East elevation-
Department of Immigration



Figure 11: South elevation-
Department of Immigration



Figure 12: Section D-D
Department of Immigration

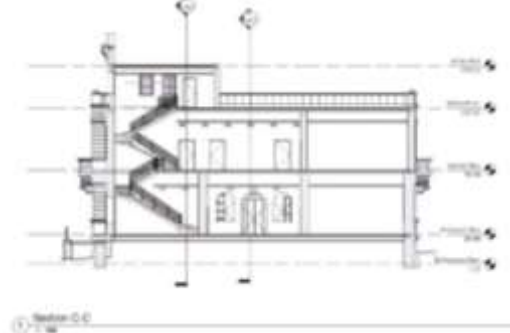


Figure 13: Section C-C-
Department of Immigration



Figure 14: current condition of the
building-
Department of Immigration



Figure 15: virtual model- demolished phase -
Department of Immigration



Figure 16: current condition of the building-
Department of Immigration



Figure 17: virtual model -demolished phase
model-
Department of Immigration



Figure 18: visualized interior post
rebuilding phase-
Department of Immigration



Figure 19: visualized interior post rebuilding
phase-
Department of Immigration

- Phases have been incorporated into the model, encompassing the damaged and collapsed sections within the building, as illustrated in the figures. By delineating construction phases in the BIM model, they were categorized into the New Construction phase, which encompasses the entire model, and the Demolished phase, incorporating the damaged or demolished parts of the building to document its current condition. Subsequently, the Reconstruction phase involves adding the missing parts from the complete model to the demolished model phase, as depicted in the figures.
- By dividing the work phases within the BIM model, Revit software has provided the capability to display both phases, as shown in figures (20-21), with contrasting colors. Additionally, we were able to calculate the bill of quantities (BOQ) for all architectural quantities related to the building restoration figure (26), as presented in figure 26. This functionality enables us to conduct structural studies and reinforcement for demolished structural elements of the building, including slabs and concrete. Moreover, it facilitates planning for MEP (Mechanical, Electrical, Plumbing) works.
- The subsequent figures illustrate the final model, offering a virtual visualization of the building post-restoration.



Figure 20: virtual model with distinguished both phases before and after reconstruction - Department of Immigration



Figure 21: virtual model with distinguished both phases- Department of Immigration



Figure 22: visualized -Virtual complete model main and north entrance- Department of Immigration



Figure 23: virtual complete model main west entrance- Department of Immigration



Figure 24: virtual complete model north entrance with east façade - Department of Immigration



Figure 25: virtual complete model east and south façade- Department of Immigration

<Wall Schedule - R>

A	B	C	D	E	F
Family and Type	Structural Material	Width	Length	Area	Volume
Basic Wall EXT 15- Railing	M Travertine(2)	17.00	1862.00	2 m ²	0.36 m ³
Basic Wall EXT 20= base corinth	M Travertine(2)	22.00	362.00	4 m ²	0.71 m ³
Basic Wall EXT 20= base corinth	M Travertine(2)	22.00	383.00	4 m ²	0.71 m ³
Basic Wall EXT 20= base corinth	M Travertine(2)	22.00	126.50	1 m ²	0.18 m ³
Basic Wall EXT 20= base corinth	M Travertine(2)	22.00	126.50	1 m ²	0.18 m ³
Basic Wall EXT 20= base corinth	M Travertine(2)	22.00	138.00	1 m ²	0.18 m ³
Basic Wall EXT 20= base corinth	M Travertine(2)	22.00	138.00	1 m ²	0.18 m ³
Basic Wall EXT 20= ea base corinth	M Travertine(1)	22.00	383.00	3 m ²	0.58 m ³
Basic Wall EXT 20= ea base corinth	M Travertine(1)	22.00	126.50	1 m ²	0.13 m ³
Basic Wall EXT 20= ea base corinth	M Travertine(1)	22.00	126.50	1 m ²	0.13 m ³
Basic Wall EXT 45 cm stone ea ea Plaster	M Travertine(2)	43.00	836.96	25 m ²	10.39 m ³
Basic Wall EXT 45 cm stone ea ea Plaster	M Travertine(2)	43.00	243.00	19 m ²	8.10 m ³
Basic Wall EXT 45 cm stone ea ea Plaster	M Travertine(2)	43.00	836.96	23 m ²	10.39 m ³
Basic Wall EXT 45 cm stone ea ea Plaster	M Travertine(2)	43.00	544.50	8 m ²	3.43 m ³
Basic Wall EXT 55 cm stone	M Travertine(2)	55.00	729.96	23 m ²	12.32 m ³
Basic Wall EXT 55 cm stone	M Travertine(2)	55.00	470.00	15 m ²	8.08 m ³
Basic Wall EXT 55 cm stone	M Travertine(2)	55.00	484.00	3 m ²	1.74 m ³
Basic Wall EXT 55 cm stone	M Travertine(2)	55.00	2325.88	3 m ²	1.07 m ³
Basic Wall EXT 55 cm stone + corner	M Travertine(2)	55.00	82.58	8 m ²	4.00 m ³
Basic Wall EXT 55 cm stone + corner	M Travertine(2)	55.00	77.58	3 m ²	1.57 m ³
Basic Wall EXT 55 cm stone + corner	M Travertine(2)	55.00	84.58	3 m ²	1.12 m ³
Basic Wall EXT 55 cm stone + corner	M Travertine(2)	55.00	82.54	8 m ²	4.00 m ³
Basic Wall EXT 65 cm stone	M Travertine(2)	65.00	548.00	8 m ²	4.00 m ³
Basic Wall EXT 65 cm stone	M Travertine(2)	65.00	518.00	18 m ²	12.29 m ³
Basic Wall EXT 65 cm stone ea corinth	M Travertine(2)	65.00	439.00	18 m ²	10.51 m ³
Basic Wall EXT 65 cm stone ea corinth	M Travertine(2)	65.00	432.00	23 m ²	15.00 m ³
Basic Wall EXT 65 cm stone ea corinth	M Travertine(2)	65.00		5 m ²	3.66 m ³
Basic Wall EXT 65 cm stone+ corner	M Travertine(2)	65.00	42.50	1 m ²	0.76 m ³
Basic Wall EXT 65 cm stone+ corner	M Travertine(2)	65.00	42.50	8 m ²	5.55 m ³
Basic Wall EXT 48 cm stone	M Travertine(1)	48.00	1919.96	15 m ²	6.90 m ³
Grand total 38					132.88 m ³

Figure 26- BOQ for stone walls

7.6 Application of the proposed Framework the Integrated Management of Historical Building Information:

The implementation of the proposed framework could serve as an effective tool for subsequent studies, and the scenario we will develop could be considered an example for other tasks. This practical case exemplifies the proposed and highly effective framework, primarily utilized by stakeholders in the maintenance and management of the building. This stands in contrast to the traditional method, where information is scattered across multiple platforms and formats. The integrated model consolidates information into a single format, providing a collaborative platform for easy access and retrieval of data. Operations are conceived and implemented with maximum efficiency and accuracy.

The methodology proposed in the theoretical study was applied to our case study to support the facility management concept and integrated information management, aligning with accurate data resulting from the modeling and data integration process. The final result is a complete Historical Building Information Model (HBIM).

For this purpose, lighting devices were distributed in the interior spaces figure (18-19) of the building, where models of lighting devices are provided as parametric families containing information such as type name, electrical information, electrical engineering data, electrical loads, dimensions and specifications, and materials, as shown in Figure 27. Several variables, presented as Shared Parameters in Figure 28, have been added to help in maintenance data management processes, scheduled in stages of work, as well as in the bill of quantities (BOQ). The added parameters as follows.

- ✓ Device installation date yy,mm,dd.
- ✓ Maintenance Workers Name responsible for Installation.
- ✓ Inspection Date yy,mm,dd.
- ✓ Unique identifier ID – Mark.
- ✓ Default operating Hours.

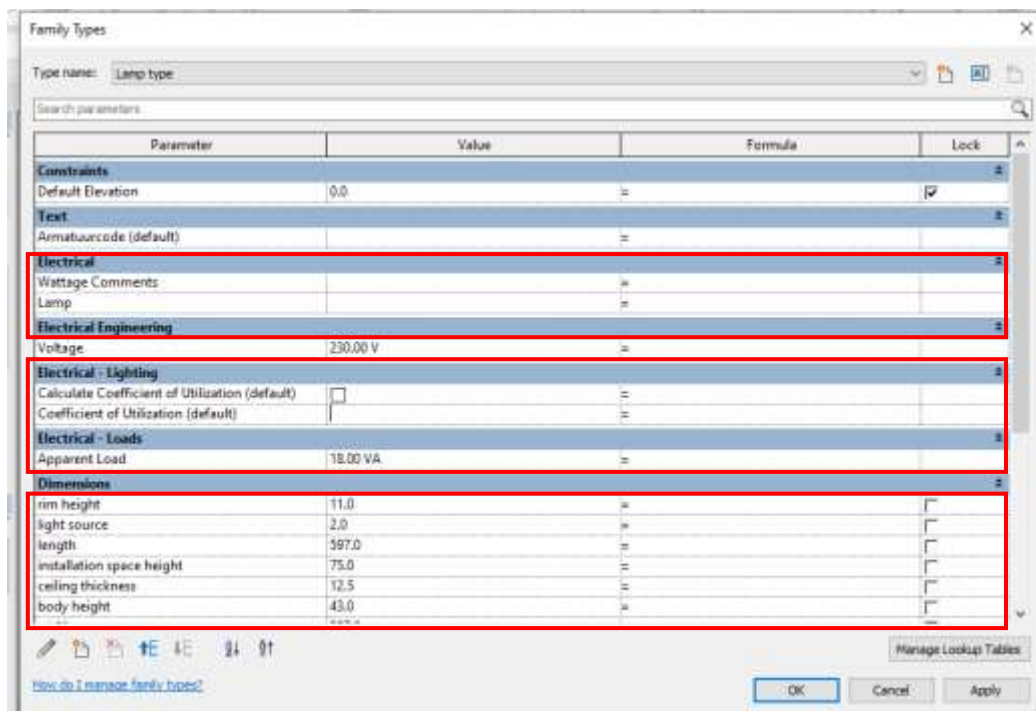


Figure 27: Lighting Device default family parameter

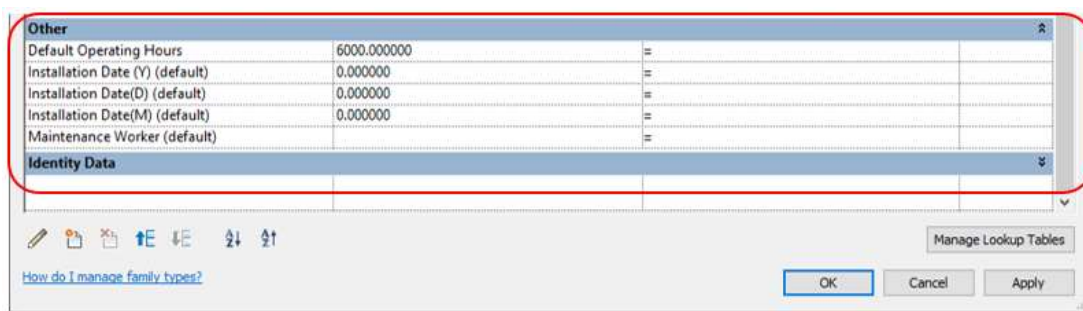


Figure 28: Lighting Device new added shared parameters for maintenance.

"The next step involved calculating quantities, as illustrated in Figure (29-30), for the lighting fixtures derived from the integrated 3D model. Parameters were added to facilitate the quantification process.

As a maintenance manager employing a proactive maintenance approach to these fixtures, figure (29-30) displays the inspection date for these devices, considering an assumed number of working days and an operating duration of 10 hours per day. The actual operating hours from the installation date of these fixtures can be calculated. Applying the principle of proactive maintenance—replacing the device when it reaches 85% of default operating hours—as a result the quantities of lighting fixtures as follows:

- ✓ The positive number indicates the number of hours by which the device has exceeded 85% of default operating hours, necessitating replacement.
- ✓ The negative result indicates the number of hours remaining for the lighting fixture to be replaced.

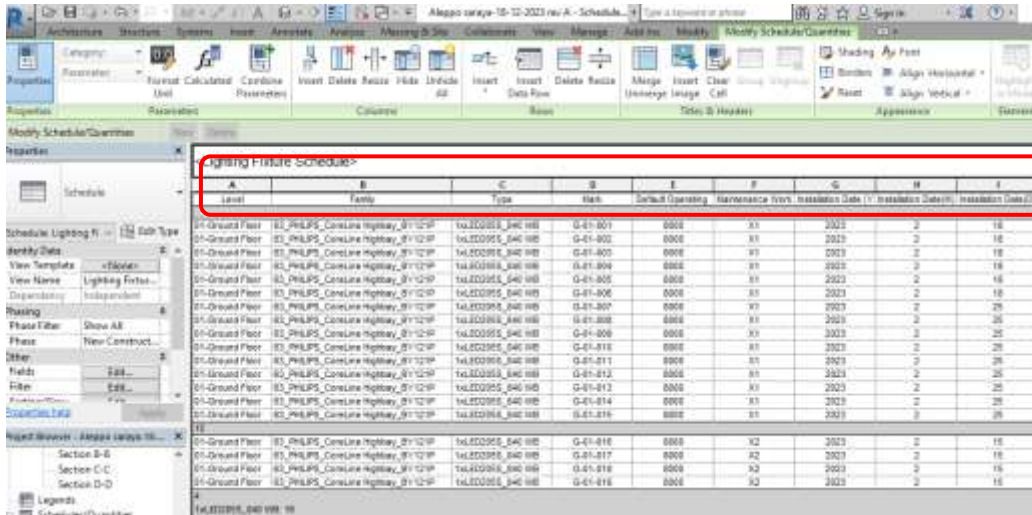


figure 29: Lighting Fixtures schedule

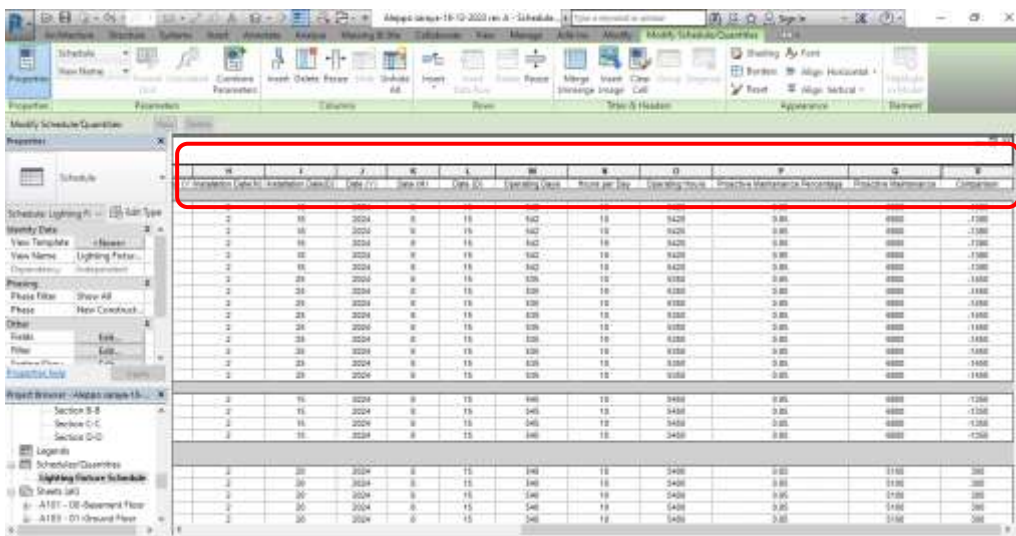


Figure 30: Lighting Fixtures schedule with final quantity

For lighting fixtures whose quantity has exceeded the default operating hours, these elements are scheduled for replacement as indicated in Table 4.

Table 4: Lighting fixtures quantity to be replaced

family	Type	Level	Maintenance worker name	Comparison result Lighting fixtures quantity
EURS_63_LF_FB_C oreLine Panel NOC RC125B NOC_PHI	Lamp type	01- Ground Floor	X1	16
EURS_63_LF_FB_C oreLine Panel NOC RC125B NOC_PHI	Lamp type	01- Ground Floor	X2	14
EURS_63_LF_FB_C oreLine Panel NOC RC125B NOC_PHI	Lamp type	01- Ground Floor	X3	22

63_PHILIPS_CoreLine Highbay_BY121P	1xLED205 S_840 WB	02-First Floor	X1	10
63_PHILIPS_CoreLine Highbay_BY121P	1xLED205 S_840 WB	02-First Floor	X2	15
63_PHILIPS_CoreLine Highbay_BY121P	1xLED205 S_840 WB	02-First Floor	X3	12
Total Quantity				89

8.0 Conclusion

Historical buildings stand as enduring assets, representing a nation's legacy, and necessitate careful preservation and management through advanced data management techniques. The utilization of Historic Building Information Modeling (HBIM) for heritage documentation offers substantial advantages across the building's life cycle. From design and construction to the operational phase, maintenance, and facility management, integrating data into HBIM enhances every aspect of the project. This improvement encompasses project output, such as the quality of drawings, project planning, and fostering effective communication and collaboration among different teams.

This paper contributes to the documentation of built cultural heritage by proposing a novel framework based on Building Information Modeling (BIM) technology, integrating information for restoration planning and facility management. The framework employs a practical map to integrate information from various stakeholders, improving communication, while simultaneously leveraging IFC open standards to enhance interoperability and information flow.

The framework is implemented in a real case study involving the Immigration Department in Aleppo. The results exhibit excellent potential for fostering integration, collaboration, and communication among stakeholders, ultimately enhancing the restoration of historical buildings and facility management processes.

The developed framework and model serve as a primary research tool for future studies, with potential expansion by integrating BIM technology to support Facility Management (FM) operations and incorporating augmented reality for restoration purposes.

9.0 Recommendations

9.1 for government institutions:

- 1) Emphasizing the significance of documenting built cultural heritage and highlighting the benefits of employing BIM technology, acknowledging its pivotal role in documentation, restoration, and reconstruction studies.
- 2) Enhancing the expertise of architects and engineers specialized in the creation of virtual models using BIM techniques. This involves providing training courses for public sector employees [38] in the modeling and architectural and historical documentation field, covering areas such as:
 - Defining 3D modeling and its applications.
 - Familiarizing workers with photogrammetric space techniques, laser scans, and their fundamental principles.
 - Training workers in the use of building information modeling techniques through hands-on experiences under the guidance of specialists in the field .
- 3) Advocating for the sustainable conservation of our heritage by transitioning heritage documents into digital formats. This transformation aims to promote public access to cultural heritage, fostering the development of digital platforms like virtual museums and cultural sites. These platforms align with the modern direction and requirements of current and future generations.

9.2 Recommendations for educational institutions

- 1) Inclusion of a more pronounced emphasis on the importance of cultural heritage, particularly architectural heritage, in educational curricula, highlighting its significance to individuals and society, along with strategies for preservation.
- 2) Integration of Historic Building Information Modeling (HBIM) concepts into architectural heritage preservation projects through collaborative efforts with archaeologists.
- 3) Organization of workshops in collaboration with governmental institutions and educational establishments to raise awareness about the significance of HBIM in historical documentation. These workshops, led by experienced specialists, should incorporate the latest advancements in heritage documentation technology, encompassing post-documentation processes.
- 4) Raising research initiatives focused on the utilization of "BIM" technology in the study and implementation of restoration, reconstruction, operation, and maintenance projects for architectural built heritage.

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