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BIM-GIS INTEGRATION AN INNOVATIVE TOOL TO ENHANCE URBAN HERITAGE MANAGEMENT IN THE DIGITAL ERA

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BIM-GIS INTEGRATION AN INNOVATIVE TOOL TO ENHANCE URBAN HERITAGE MANAGEMENT IN THE DIGITAL ERA

Abstract

Due to the great loss of the cities' ancient monuments and urban heritage resulting from either natural disasters or irresponsible human actions, it has become very urgent to find an innovative tool for restoring and conserving historical buildings in a smart and sustainable way. Furthermore, this tool can help in decision making regarding the selection of appropriate materials and intervention works. Such objectives have been realized through innovative integration of BIM & GIS to enhance urban heritage management. BIM data has been imported into the GIS environment to be visualized in 3D and analyse different scenarios for buildings' sustainable development. Data has been obtained by using Laser Scan, Photogrammetry and Surveys to help in the preservation of historical buildings and to provide useful insights into the management of these monuments. This paper discusses the development of the BIM and GIS integration which will contribute to obtain digital models for urban heritage cities and significantly to support the decision-making process in addition to developing urban planning processes for cities. Moreover, these models will form the base for the creation of digital twins that will later constitute a new form for heritage smart city. In this research paper, a new approach based on integrating BIM and GIS is used to create an opensource model using BIM 3D data (IFC) and 3D cadastral information (City GML) formats, and taking a small region in Beirut, Armenia Street at Rmeil and Medawar zones that were affected by the 2020'S POB blocks Rmeil (695,698,722) and Medawar (479, 479) as a case study. This paper also demonstrates the critical significance of civil society involvement, the multiple social and economic advantages, and enhancement of urban historical values. It is a more sustainable and equitable approach to urban heritage management, which benefits the stakeholders, the government, decision makers, urban planners, and the local community. The result of this study is a digital model that preserves the features of 3D BIM models.

Keywords

Geographic Information Systems (GIS), Building Information Model (BIM), Urban Heritage, UAV, TLS, 2020'S POB

1. INTRODUCTION

Paul Goldberger (2003) states that preservation "uses the past not to make us nostalgic, but to make us feel that we live in a better present … broadly defined by its connections to other eras... Successful preservation makes time a continuum, not a series of disjointed, disconnected eras." In his quote, Goldberger proves that heritage conservation enables the appreciation of the richness and diversity of different eras while integrating them into a cohesive narrative. In this day and age, urbanization is expanding globally, which has made Urban Heritage Management (UHM) crucial to balance between heritage and development. UHM involves the preservation and promotion of natural, cultural, and historical sites in urban areas. It involves assessing, protecting, restoring, and managing heritage sites in cities while ensuring their sustainability and promoting their value to the public. It also encompasses planning and developing strategies that can help in the incorporation of cultural heritage into urban development projects.

This approach is advantageous on multiple levels. Firstly, it helps to showcase the unique cultural identity, spirit, and history of a city because the urban heritage sites represent the physical manifestation of the city's history and offer a sense of continuity with the past. Secondly, it stimulates tourism, economic growth, and social cohesion through attracting tourists and visitors who are interested in experiencing the heritage and culture of a city, which rouses the local economy and creates jobs in tourism and hospitality industries. Thirdly, it promotes sustainable development in urban areas as it fosters a sense of community pride and attachment to the place, which consequently encourages investment in local infrastructure and service provision.

In order to balance between conservation and development, Architecture, Engineering and Construction (AEC) institutions are trying to find proper ways and new methodologies that help in this issue. Petti, Trillo and Makore (2020) consider that 'identifying the roles of the various stakeholders' and 'integration of Geographic Information Systems (GIS) and Building Information Modeling (BIM)' are key procedures to achieve this balance.

BIM and GIS are two AEC programs that serve different purposes and belong to different areas. Developed in the 1960s, GIS is an effective instrument used to archive and manage geospatial data (Longley, 2005), while BIM, developed in the 1980s, is a software program that provides a proficient 3D model-based system for building management (Volk et al., 2014). GIS is widely utilized for the improvement of urban structures and infrastructures' safety and efficiency on one hand, and for the analysis of the environmental data and natural risks on the other. BIM is utilized in the design and documentation of new buildings and infrastructures (Saccucci and Pelliccio, 2018).

However, and due to the current high demand, integrating BIM and GIS has become essential for the development of a smart sustainable world. Ding et al. (2017) contend that this can be made possible through data integration, quantitative analysis, application of technologies, and urban management. A certain level of interoperability between BIM and GIS can make them work perfectly in tandem. This process involves extracting and transforming geometric and semantic information of the BIM model into the GIS project. In this regard, Wook Kang et al. (2015) find that a successful compatibility between GIS and BIM affects the life cycle of the structure under study.

This issue cannot be tackled only scientifically based on historical and building materials data since they are not standardized for all assets and it is a complex and time-consuming task. At this level, an ICT (Information and Communication Technology) platform, open and accessible to everyone including the local residents, becomes necessary to collect information about the current state of the designated building. The result is a Historic Building Information Modeling (HBIM) which greatly depends on the experts' experience and data accessibility (Georgopoulos, 2017).

Moreover, tools like digital photogrammetry combined with laser scanning are used in order to achieve the geometric documentation of any historic building. Laser scanning can provide highly accurate models of heritage sites and artifacts, which can then be used for documentation, analysis, and virtual restoration. Photogrammetry, on the other hand, can produce high-quality 3D models from photographs, often using drones or other aerial platforms to capture images from unique perspectives. Both techniques can be used to create detailed and accurate representations of cultural heritage sites and artifacts, which can help to preserve these cultural resources for future generations.

The point clouds and 3D models resulting from this operation can not only serve as blueprints for Finite Element Model (FEM) but also assist in the decision-making process, for immediate rehabilitation interventions (Asteris & Plevris, 2015).

In a nutshell, extending a structure lifetime and preserving built cultural heritages for future generations require integration of data within 2D GIS thematic maps in addition to development of a 3D HBIM (Tsilimantou et al., 2020).

Heritage preservation is a worldwide concern, and Lebanon is no exception. Lebanon has a rich and diversified cultural legacy as a result of its historical occupation by numerous foreign rulers who left their mark and traces on its geography. However, the difficulty of preserving Lebanese heritage has been exacerbated by a variety of reasons. Disasters, military conflicts, and rapid unmanaged growth in and around historic cities, in addition to the underlying problem of development represented in the construction of new urban forms, have harmed this precious heritage (Kelly & Biradavolu, 2019). And most recently, the Beirut blast that happened on August 4, 2020, had a significant impact on the city's urban heritage. Many historic buildings and landmarks were damaged or destroyed, including the Mar Mikhael district. Moreover, the Mar Mikhael area has seen a revival in recent years as a hub for arts, culture, and nightlife, therefore this research pitches into preserving its buildings and heritage while keeping up with the times of development. In this work, an approach vis-à-vis the preservation of a building through GIS and BIM platform is presented, taking into account its historical, architectural, surveying and building materials data. Integration of data within 2D GIS thematic maps, and development of a 3D Historic Building Information Modeling (HBIM) are performed to achieve this purpose. As a result, all of the previously described data are amalgamated within both information systems, and significant information on the preservation state of a historic structure is exported.

The whole world is experiencing deterioration of urban heritage due to uncontrolled growth, natural disasters, and neglect. Against this problem, the AEC world depended on modern geosciences and spatial technologies as vital elements to assess and protect historical-cultural assets. Lebanon, in its turn, has always struggled to preserve its heritage because it has been affected by civil war and a multitude of crises which the last was the 2020 Port of Beirut blast (as shown in fig.1 below). The Hypothesis this paper studies is that a centralized open-source model combining BIM and GIS can enhance UHM by engaging stakeholders, optimizing planning, and fostering sustainable urban heritage development.

This research paper aims to transition from 2D GIS to 3D spatial data, particularly in the context of (HBIM). It also aims to introduce an innovative approach that involves developing a conceptual opensource model of urban heritage buildings affected by natural or man-made hazards, utilizing BIM-GIS systems.

The primary objectives are fourfold: first, to explore the benefits of preserving impacted historic assets within their communities through technology-based urban policies; second, to redefine urban heritage management by leveraging technology to address issues faced by historic buildings, thereby enhancing the quality of life and resilience of cities from a historical perspective; third, to create an open-source model of disaster-affected urban heritage buildings by integrating BIM-GIS systems, aligning with sustainability goals; and finally, to engage residents in transparent and effective historic management, contributing to the enhancement of urban heritage values. This approach seeks to foster a sustainable, resilient, and culturally enriched urban environment.

The research methods involve shifting from 2D to 3D spatial data for (HBIM). Data capture and digitization are used to create interactive historic BIM models. An interoperable BIM-GIS platform is employed for low-cost, user-accessible intelligent modeling. The research has broad applications in global urban heritage management, adaptable to various contexts, including Lebanon.

Put succinctly, the overall purpose is to extend the life of the monuments and protect built cultural heritage assets for future generations. To demonstrate the proposed methodology in terms of multidisciplinary, interoperability, and sustainability, Rmeil (695,698,722) and Medawar (479, 479) historical buildings in Armenia Street, Beirut were chosen as case studies. Implementation of this methodology integrates information derived from the structures' building materials, damage and restoration history.

2. HISTORICAL BACKGROUND

It is crucial to redraft the conservation practices of Beirut historical buildings to address the current political, cultural, and economic situations in a better way and to consider the different stakeholders' attitudes regarding modernity, national identity, and authenticity (Saliba, 2013).

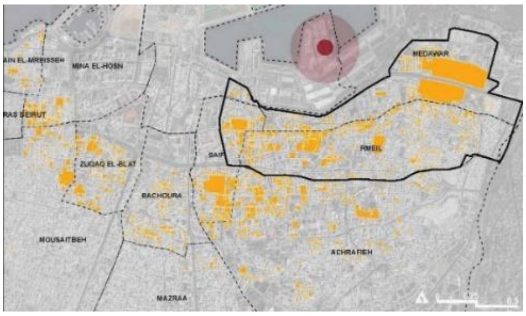


Fig.1: Beirut Heritage Buildings
Source: OEA

Fig.2: Damaged Historical Buildings
Source: OEA

Lebanon is a country with rich cultural heritage. Therefore, it has taken many steps and issued many laws to preserve its historical buildings. For instance, the Construction Law No.646/2004 regulates the issuance of building permits in Lebanon; the National Heritage Law No. 166/1933 is responsible for protecting historic buildings and sites; and the Antiquities Law No. 166/1933 is responsible for protecting archaeological sites and artifacts. The last two laws are the most important laws that protect Lebanon's cultural heritage. Moreover, and in order to promote the importance of preserving cultural heritage, UN-Habitat held a five-day training session for local volunteers, which was followed by the development of an awareness booklet including basic instructions on how to protect historical buildings. However, the owners of these historical properties still feel that they are left alone, without any financial or moral support from the government to preserve them. Therefore, they are waiting for the new rent law in order to sell them for demolition and redevelopment, which will have a great impact on protecting heritage. To prevent this, there was a law (No. 194) issued in October 2020 that enacted a two-year ban on property transfer in the affected areas, and the Beirut Heritage Initiative has published a restoration manual targeting buildings of the later Ottoman period, and will publish another one for buildings of the twentieth century. At this point, it is needed to provide property owners with the needed funds and to create a historic-building inventory to identify significant elements and develop protective policies to safeguard the historic building stock (World Monuments Fund, 2022).

Another point to highlight within this context is that the surge in housing supply development in Mar Mikhael puts this area's identity and cultural value under real danger, a danger that affects not only the material value but also the social heritage, culture, and collective memory. Recently, the Beirut blast has intensified the danger and put most of the area's buildings at risk (OEA, 2020) (as shown in fig. 2). This high damage adds to the reasons that push owners to sell their properties and reap the benefits of development. Against this tragic truth, serious work should be done to avoid a drastic change in the area's identity through stabilizing, repairing and reconstructing the residential buildings at risk of collapse (especially historic assets); reviewing construction permits; executing a more transparent process of registration; protecting the area's identity and its current inhabitants through property and zoning regulations, and building incentives; and defining Mar Mikhael as a protected zone for its unique human scale and built form. All of this should be done via a transparent platform to ensure an honest recovery process and avoid drastic irreversible changes.

Applying HUL in Beirut faces many challenges. For instance, it lacks benchmarking and national heritage asset databases, efficacy of public administration and agencies, and effective heritage preservation laws. For buildings *Rmeil (695,698,722) and Medawar (479, 479)*, and the alike neighborhood, the difficulty is that the owners need to be substantially involved in the safeguarding of urban heritage, in addition to the funding issues and lack of coordination among stakeholders.

Against this background, the technique of BIM and GIS integration that this research showcases presents an excellent solution to provide immediate structural strengthening rather than isolation or evacuation, to develop a new governance model to manage Beirut's heritage, and to revitalize existing natural patches in Armenia Street specifically (as shown in fig. 3&4 below). Despite the growing threats, national experts and international institutions have become more interested and focused on safeguarding Beirut cultural heritage, mainly after the 2020 blast. So, establishing an effective urban conservation strategy that adopts HUL, based on conducting natural, cultural, social, and architectural surveys and area mapping to identify the important assets and values on one hand and the problems facing their conservation on the other, becomes a great solution as it involves prioritizing conservation through a decision-making process, participatory planning and stakeholders' discussions.

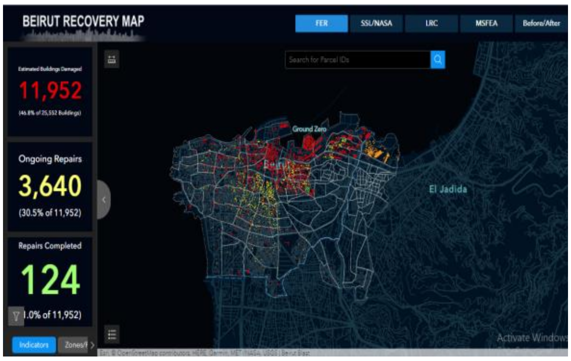


Fig.3: Map of Beirut's renovated buildings after 2020's port Beirut blast. https://beirutrecovery.org

Fig.4: Map of the Armenia Street heritage buildings renovated after 2020's port Beirut blast. https://beirutrecovery.org

3. METHODOLOGY

To gain information about the state of preservation of the historic structures and ensure that all relevant information is obtained, effective documentation processes are crucial for assessing historical structure preservation. Cultural heritage documentation adheres to specific guidelines and protocols tailored to building types and investigative purposes (inspection, diagnosis, intervention studies, monitoring, and assessment). Various data, such as georeferenced 3D point clouds, image-based materials, architectural archives, historical records, building phase documentation, and past interventions, must be included for comprehensive historic building documentation.

In this section, the methodology for the BIM-GIS integration through an online platform is defined. The aim is to visualize and represent 3D aspects of the urban heritage buildings affected by the Port of Beirut's (POB) 2020 data at both individual historic building and city block levels.

The first step involved collecting data from various stakeholders, including the DGA, Beirut municipality, and building owners. Some of this data was provided in the form of old hard copies. In addition, a geometric survey was conducted for two specific historical buildings. The subsequent steps included creating 2D architectural drawings, generating a 3D physical model using BIM software such as Revit Architecture and SketchUp, with a focus on achieving LOD3 for the highest level of detail. The next step involved producing a 3D legal and physical model compliant with the IFC standard. Subsequently, the 2D and 3D GIS data was integrated with the 3D physical and legal models. Furthermore, a 3D block model was created using ArcGIS Pro 3.0. Lastly, an integrated BIM-GIS platform, specifically ArcGIS Online, was developed to facilitate sharing BIM models as a Web Scene using ARCGIS Pro 3.0 online.

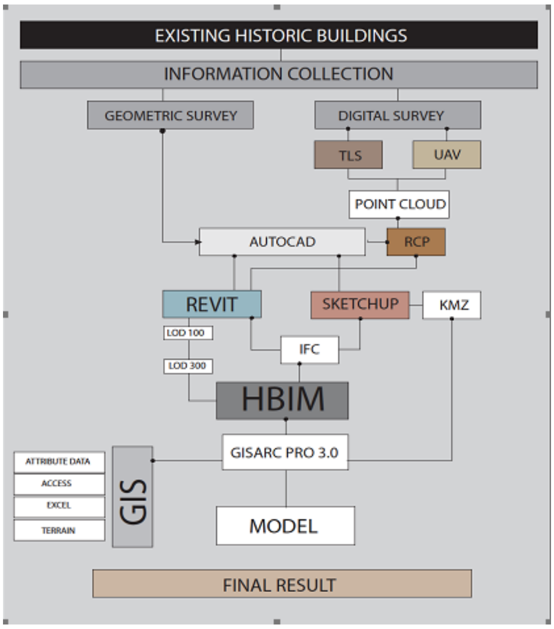


Fig.5. BIM-GIS integration methodology
Source: the author.

3.1 Methods and Tools

In this section, a comprehensive explanation of the five steps followed for constructing the platform is provided.

Step 1: Study area, software and data collection

Over the last three years, after the POB's 2020, some surveys and several experimental tests have been conducted in various areas of the Armenia Street in Mar Mikhael (as shown in fig. 6) including *Rmeil 695 and 698*. The digital measurements TLS done on August 10, 2020 by the (X,Y,Z) Lebanon via Revit 2019, were represented as BIM model LOD 100. After the POB 2020, a photogrammetry (UAV) was done for 27 buildings in Armenia Street in Mar Mikhael by the Directorate General of Antiquities (DGA). Many photos were captured and combined to point clouds only, without any following process to BIM models. Therefore, later in January 2023, the author redeveloped this work to BIM model LOD 300 by adding all the necessary data to be used in the BIM-GIS integration model. All data were collected from the DGA, Beirut Municipality, and the concerned NGO's; and the software programs used for BIM were *Revit 2019*, *Revit 2023* and *Sketchup*; and for GIS was *GISArc pro 3.0*. The latter was chosen primarily due to its capability to read Revit files directly.

To ensure the BIM model's correct positioning, a local scene was created with the coordinate reference system. The BIM model was successfully integrated, including the physical building elements, into the GIS environment while maintaining the model's geometry and semantic data. Moreover, the GIS environment provided a better representation of 2D land parcels compared to the challenges faced with managing them in the Issue for Construction (IFC) legal model.

Fig.6: Point cloud top view & perspective (UAV- TLS) Armenia Street after the POB's 2020
Source: (X,Y,Z) Lebanon.

Step 2: Creation of the 2D drawings in AutoCAD

Initially, the geometric hand survey for the *Rmeil 698*, Medawar 479 was done in 2D architectural (plans, elevations, sections, details). Then, this geometric hand survey was developed into 2D AutoCAD drawings (as shown in figures 7 & 8).

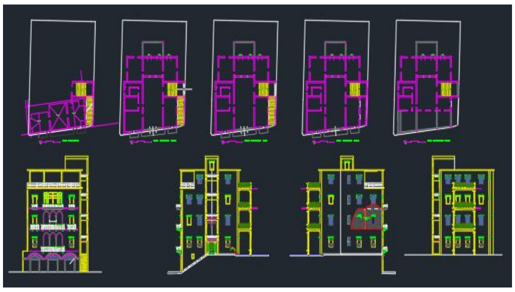


Fig.7: Creating the 2D Architectural Drawings blocks 698 Rmeil -Armenia Street from the survey.

Source: Result of processing in AUTOCAD software,the author.

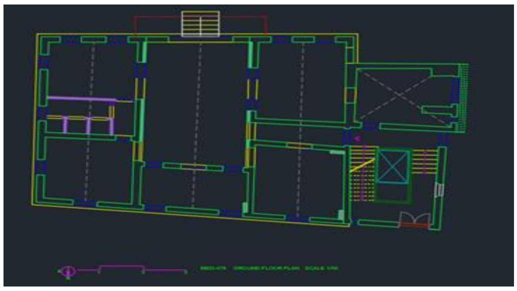


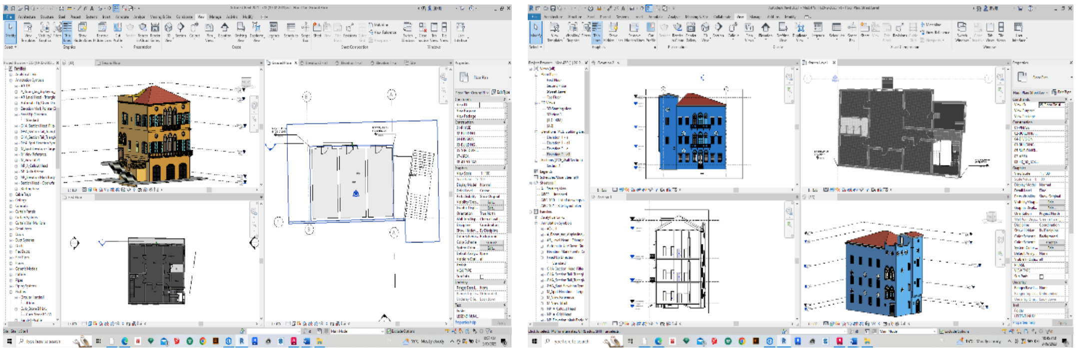
Fig.8: Creating the 2D Architectural Drawings blocks 479 Medawar -Armenia Street from the survey.

Source: Result of processing in AUTOCAD software, the author.

Step 3: BIM models

This stage involved creating BIM physical models for the Mar Mikhael-Armenia Street case study using Revit and SketchUp in order to compare their potential and capabilities as IFC. The models were constructed and developed in LOD 300, encompassing detailed elements like floors, walls, doors, windows, structural elements, columns, slabs, and spaces for 3D representation. The geometry was defined through 2D plans, elevations and sections, while semantic architectural elements and information enriched the 3D objects, including materials, textures, colors, and other properties.

Just for illustration, BIM modeling was applied on two other blocks in the same area block Medawar 479 and block Rmeil 722 (as shown in figures 9 & 10).



Figs. 9 & 10. BIM Revit model for the blocks722 Rmeil &479 Medawar, LOD3.
Source: Result of processing in Revit software, the author.

Step 4: Construction of the 3D physical model using Sketchup

The Rmeil *698* building file was developed by the author in SketchUp, and later exported as IFC file to compare it with the Revit files in the BIM-GIS integration (as shown in figures 11 & 12).

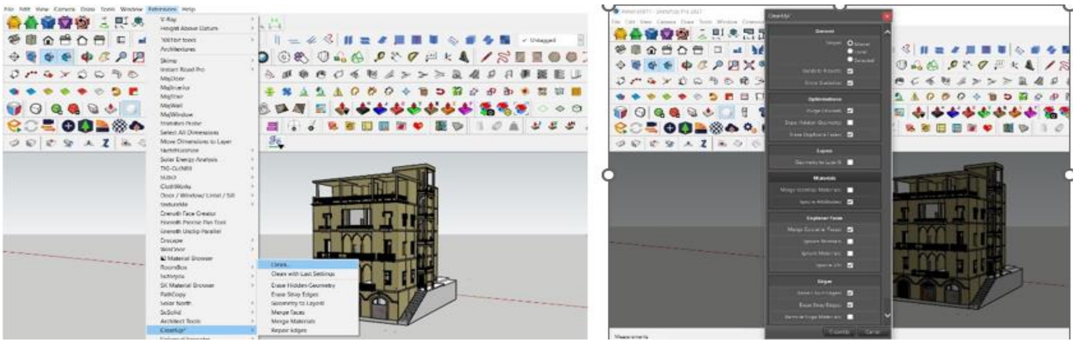


Fig.11: SketchUp 3D model for Rmeil 698
Source: Result of processing in SketchUp software, the author.

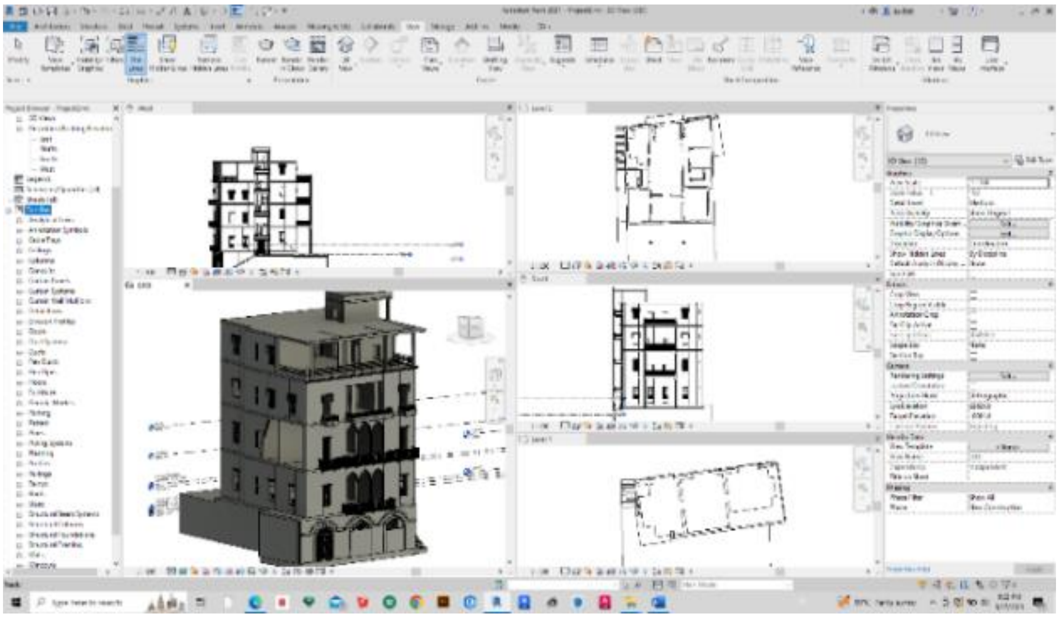


Fig.12: Rmeil 698 BIM IFC model to ArcGIS Pro3.0.
Source: Result of SketchUp to IFC software, the author.

Step 5: 3D BIM modeling to GIS

Data was processed from a 3D survey and multidisciplinary documentation to generate compatible spatial information for mapping building materials. By using 2D and 3D GIS operations within a GIS platform, the team created thematic maps through geoprocessing analysis of pertinent data. Historical building materials were also mapped using AutoCAD, Revit, SketchUp, and Arcpro3.0, employing topology building and geoprocessing analysis, which resulted in the production of detailed thematic maps. Ultimately, the aim was to use GIS technology to create detailed maps and analysis of historical building materials and damage especially after the blast.

4. CASE STUDY

In this study, a new 3D modelling approach is applied. Initially, the building's CAD footprint was created using coordinates from the survey plan and a 'survey point' from Revit for georeferencing. The survey point is a known real-world location in each project. Next, 3D objects were generated based on the georeferenced CAD layout, and 2D architectural blueprints were imported into Revit. Precision was ensured by aligning these objects with the correct floor.

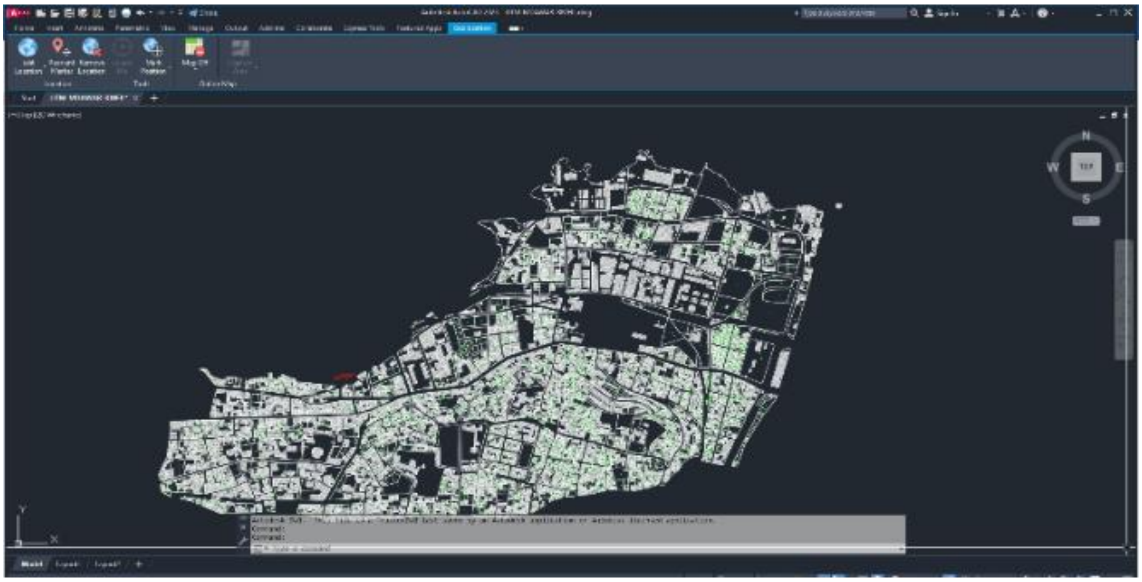


Fig.13: AutoCAD georeferenced Mar Mikhael base map
Source: the author.

The *Rmeil 695* heritage building was severely damaged by the POB's explosion, in terms of structure, decay on the facades, roof, openings, even the red tiles of the staircase roof were displaced. It is a typical early 20th-century Beiruti house, a hybrid building, belonging to the early modern heritage, with a three-arched facade, wooden balcony with Carrara marble slab balconies supported by wrought iron balustrades.

Figs. 14 a & b. 3D original photos for the block (695) Rmeil after the 2020' POB.
Source: the author.

https://digitalcommons.bau.edu.lb/apj/vol30/iss1/3
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This model involves both UAV and TLS scan to HBIM of the historic building *Rmeil 695* cleaning up the resulting point cloud, creating a mesh, importing it into BIM software, adding additional information such as walls, windows, and doors to create a complete and accurate BIM model, and finally adding metadata to provide additional information about the building. This results in a highly detailed and accurate digital representation of the building that can serve a wide range of purposes.

To integrate geometric products into both GIS and HBIM, it is necessary to achieve two objectives while surveying the building in question: first, to obtain a 3D point cloud with a high degree of accuracy; and second, to acquire the maximum data to build LOD 300.

To achieve these objectives, a survey was conducted using TLS to capture images of the building's exterior and rooms with noteworthy artistic elements. To establish a control network, GNSS and GPS surveys were used to obtain UTM coordinates and georeferenced point clouds. The necessary control points for image orientation and registration of laser scanner clouds were also measured.

After that, the point cloud was modeled Revit to BIM platform to facilitate subsequent storage and sustainable tasks using HBIM. This is done to establish a reliable methodology that considers heritage characteristics for future building management.

4.1 UAV Photogrammetry and Processing

After capturing and aligning 280 images of elevations for the (695) block Rmeil using Reality Capture software following the POB 2020, the dataset was split into two blocks for processing. The software allows processing in different formats, including Point cloud (. E57, las, .ply), Mesh (.obj, .fbx), Orthomosaic (.tiff + .tfw for geo-referencing), and Point cloud (XYZ as a text file for civil 3D or Microstation) (as shown in fig. 15 below), The final exported formats from the software are E.57, rcp, and .obj (as mesh).

Fig 15. 3D of the pointcloud model for the (695) block Rmeil
Source: photos from DGA, developed by the author.

4.2 TLS Survey for the Block Rmeil 695

Fig.16 a, b, c & d: TLS survey process for HBIM of the block Rmeil 695
Source: Jawad Chamoun, Ralph Khoury.

The FARO Focus S 150 Plus Laser Scanner was utilized to scan both the interior and exterior areas of a building with remarkable precision. The scanner can capture an impressive number of points per second (ranging from 976,000 to 2 million) within a maximum range of 150 meters. It boasts high accuracy, ensuring distance precision down to 3 mm and noise reduction to less than 2 mm. The scanning settings were configured at 4 mm intervals for every 10 meters of distance. The acquired data underwent thorough filtering to eliminate unwanted noise and redundant points. Georeferencing was achieved by using four common points from photogrammetry and GPS. The control points, both inside and outside the building, were accurately measured to meet the required 1/50 scale. To scan the exterior walls and most interior rooms, a terrestrial time-of-flight laser scanner was employed, offering an average accuracy of ± 7-9 mm. The registration process made use of target-to-target and cloud-to-cloud methods, and GNSS NR2 Altus GPS was used for geo-referencing the field survey measurements.

The acquired TLS Faro Scene data was processed using the FARO SCENE application, and registration for all setups was conducted through the FAROSCENE Software using the .fls extension. The resulting data was exported in different formats, including pointcloud (.E57), Recap (.RCP or .RCS), .dxf, or .las. The TLS point cloud underwent processing using Reality Capture Point Cloud (. E57) software to generate a mesh. The mesh was then exported to Autodesk's Recap viewer to produce a Recap file. This Recap file was subsequently incorporated into AutoCAD, REVIT, or other IFC software (Bently, Sketchup, etc.). Finally, a Revit file was created by manually tracing over the mesh to develop a detailed LOD 300 BIM model (as shown in figures 18 a &b).

Fig.17 a, b &c: 3D Views of the point cloud model from (TLS) for Rmeil 695 after renovation.
Source: the author, Jawad Chamoun & Ralph Khoury.

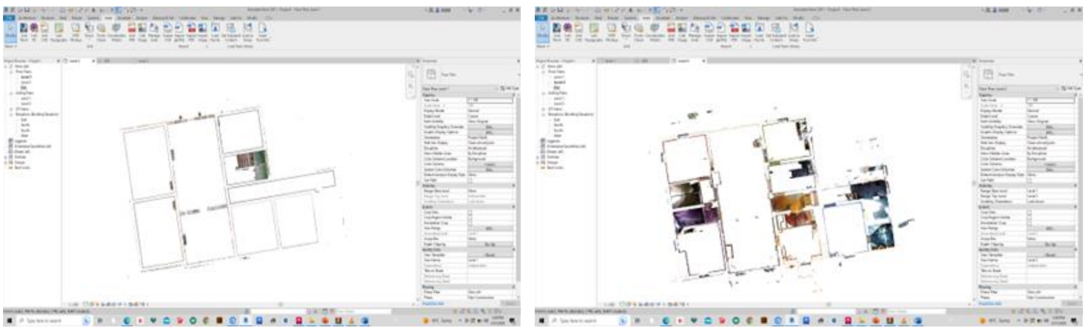


Fig.18: (a). Tracing the point cloud from. rcp and (b) Revit to BIM (LOD 300) for Rmeil 695
Source: the author.

4.3 Comparing Different Sources of Point Clouds

Two distinct sources of point clouds generated from UAV photogrammetry in the aftermath of the POB’s 2020 blast were available: one from DGA pictures and the other from TLS data. The aim was to emphasize the contrast between the building’s condition before and after renovation, presenting a novel documentation approach.

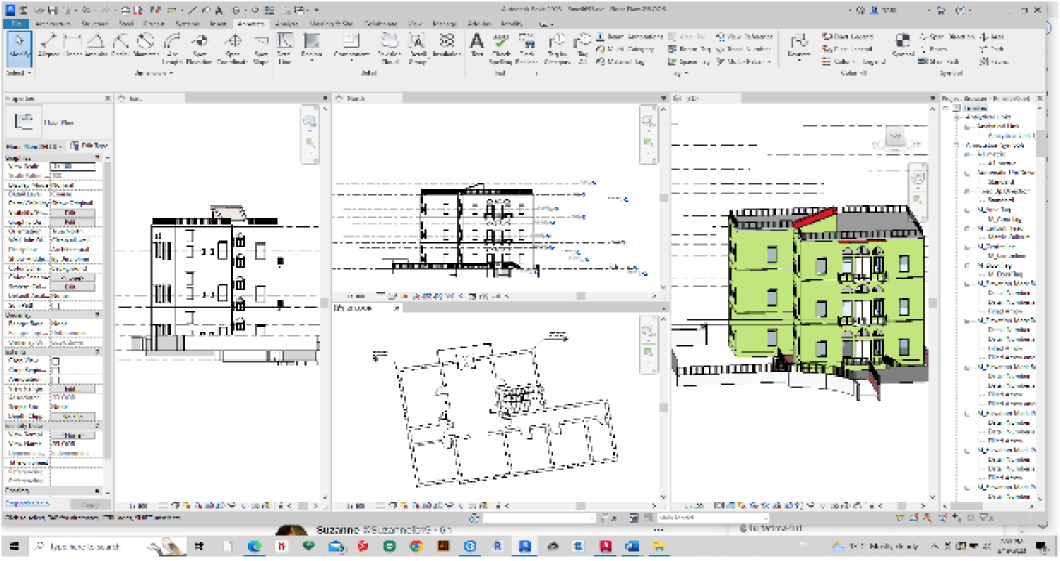


Fig.19: BIM -Revit model LOD300 Rmeil 695.
Source: Result of processing in Revit software, the author.

4.4 Integration of Photogrammetry & TLS to BIM Technical Process

This technical process explores the integration of two powerful technologies, photogrammetry and TLS (Terrestrial Laser Scanning), to enhance Building Information Modeling (BIM) workflows. The process involves transforming high-resolution aerial photos captured by photogrammetry UAVs into 3D models using Agisoft Metashape Professional software. Additionally, TLS data is also incorporated to further enrich the BIM process.

4.5 Geo-Referencing the BIM Models in ARCGIS

Geo-referencing BIM models in GIS requires aligning the models with specific geographic coordinate systems, such as Cartesian, polar, or spherical. To achieve this integration, BIM models like Revit and SketchUp need to be associated with their exact location (X, Y, Z positions) and orientation using commonly used coordinate systems like USGS, UTM, and oblique stereographic ‘Lebanon’ with datum WGS1984 UTM zone 36N (as shown in fig.13).

The geo-referenced location should include the project’s base point and survey points projected to the Lebanon grid UTM or WGS1984 system. The site outlines of the BIM models must align with True North or real-world orientation for accuracy. Elevation levels should be set up using CLARK EGN 1880 to Lebanon grid, with unique survey points in each BIM model serving as reference points in the spatial and physical world.

Two different methods can be employed to prepare the BIM model Geo-reference of structures from both Revit and SketchUp programs to import it into GIS Arcpro3.0.

4.6 Geo-Referencing the Model in BIM (Revit or IFC File)

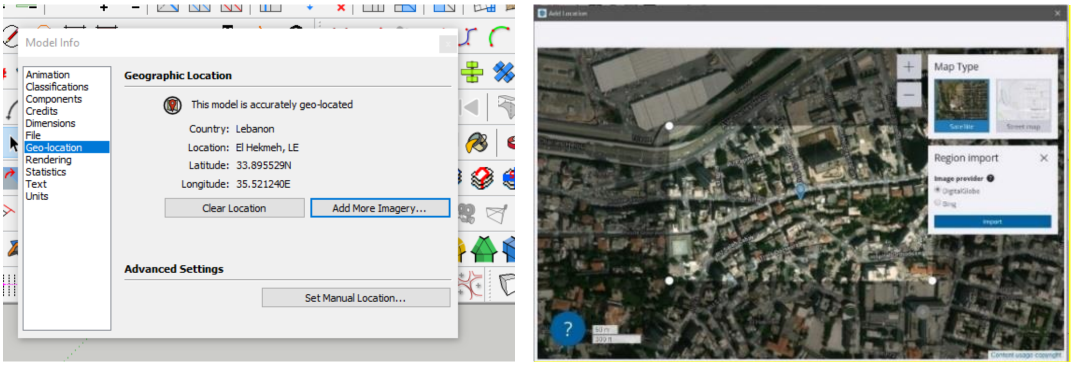
The BIM Model projection in Revit software is a tool used to establish a coordinate system for a file, ensuring accurate location data. If the file already has a known geospatial coordinate system, it should be assigned accordingly. If not, a suitable coordinate system should be selected to match the data’s location and units. If the file is correctly drawn with the defined coordinate system, geo-referencing is not required.

To verify and specify the BIM file’s coordinate system, access the Validate Position tab in the BIM file properties, accessible from the context menu in the Catalog pane. If the data does not appear in the desired position after setting the coordinate system, the geo-referencing process can be pursued. This involves using the Geo-reference tool (GIS Arcpro3.0) found in the Geo-reference tab under the building tab in the BIM Data tab.

Geo-referencing applies to a single feature layer but affects all feature layers within the file workspace or CAD dataset. For optimal results, it's advisable to add specific information like floors or the exterior shell rather than the entire file, which speeds up the process. After completing the geo-referencing, the entire file can be added, and the changes will apply to all feature layers in the CAD or BIM file. Enabling snapping while using Move and Rotate tools enhances the accuracy of positioning during geoprocessing.

4.7 Starting an ArcGIS Model

In the process of creating an ArcGIS Pro 3.0 model, the following steps are involved: First, a new project is created, followed by the addition of data to the project. Next, a map is generated, and customization is applied to the map. Additionally, when georeferencing and locating BIM Autodesk Revit files within ArcGIS Pro 3.0, the following steps are undertaken: The introduction of a new projection, specifically the Lebanon UTM projection, is performed. Geolocation transformation for Lebanon is executed, and the coordinate system for the BIM models is identified to ensure accurate integration with the geographic information system.



Figs.20 &21: Geo-reference the BIM model in ArcPro3.0
Source: the author

4.8 Preparing Data (Access, Excel) to be Exported to GIS ArcPro3.0-ArcPro 3.03 Patch (3.0.4)

Export table from Excel to ArcGIS Pro3.0 to create a view project then connect to a folder and change the symbology of the heritage buildings.

4.9 Geo-reference the SketchUp pro model (historic building Rmeil 698)

Import the SketchUp model (Historic building Rmeil 698) as IFC in ArcGIS Pro3.0.

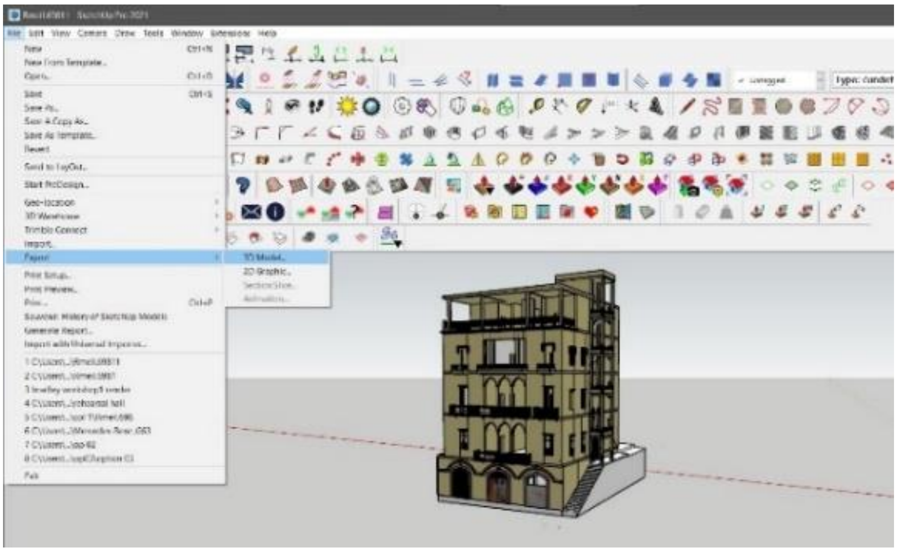


Fig.22: First draft process for the (Historic building Rmeil 698) SketchUp model inserted in ArcGIS Pro3.0.
Source: the author.

4.10 Geo-reference the BIM (Revit- IFC) Data in GIS Arcpro 3.0

This method explains that Revit, IFC, or 3D CAD files can be georeferenced in an ArcGIS Pro3.0 scene using the tools found on the Geo-reference tab. To georeference BIM data from Revit in GIS using ArcGIS Pro 3.0. First, import your BIM data in IFC format into ArcGIS Pro. Then, use the "Locate" tool to identify reference points in both your BIM and GIS data. After that, employ the "Move to Display" tool to align the BIM data with the existing GIS layers, ensuring the correct spatial reference. Next, use the "Move" tool to fine-tune the placement of your BIM data (as shown in fig. 23,24 below). Additionally, the "Elevate to Ground" tool allows you to ensure that the BIM elements align with the terrain's surface. You can also utilize the "Rotate" tool if the BIM data needs orientation adjustments. Save your georeferenced data and use the "Close Georeference" tool to finalize the process, allows to save the present condition of the offset transformation to the correctly called world file (.wld3). ensuring that your BIM data is accurately integrated into your GIS project, making it suitable for spatial analysis and decision-making in a geospatial context.

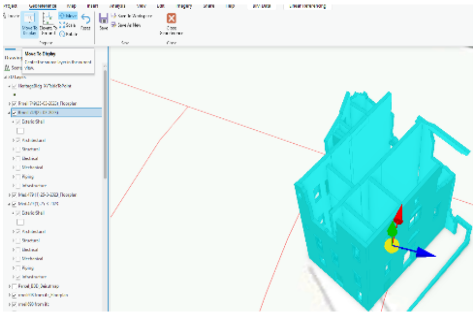


Fig.23: the georeference “Move to Display” tool of Bim models in ArcGIS Pro3.0.
Source: the author.

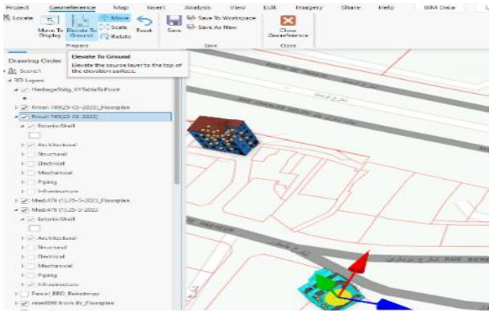


Fig.24: the georeference “Elevate To Ground” tool of Bim models in ArcGIS Pro3.0.
Source: the author.

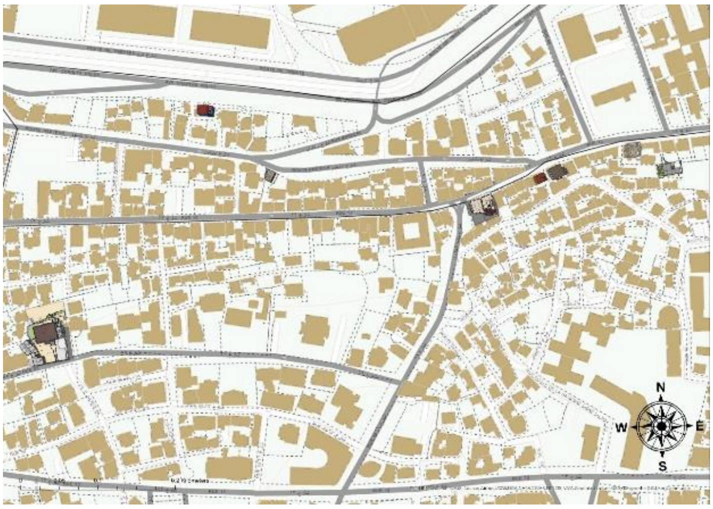


Fig.25: the thematic map from Arc pro3.0 of Bim models in ArcGIS Pro3.0.
Source: Result of processing in BIM-ArcGIS Pro v.3.0 integration, the author.

4.11 Creation of the BIM-GIS integration online Platform: Share the BIM Models to ARCGIS Pro 3.0 online as Web Scene

The final step of the process involves integration of data from BIM and GIS to manage 3D land administration data. Tools such as ‘Create Building Scene Layer Package’ and ‘Create 3D Object Scene Layer Package’ are used to convert the integrated GIS data into 3D scenes (as shown in fig. 26(a)&(b)).

To publish a scene created in ArcGIS Pro 3.0, you can share it as a web scene in your active portal. Web scenes enable users to analyze and visualize geographic data in a 3D display, A link for the web scene will be sent (https://arcg.is/0P1vCP).

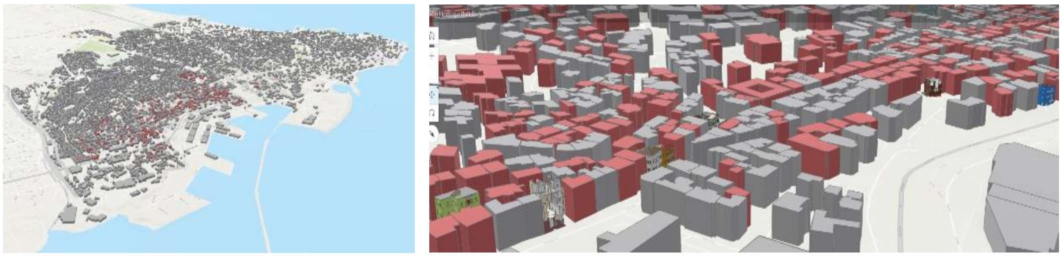


Fig.26 (a) & (b): the final Integrated BIM - ArcGIS Pro v.3.0 model .
Source: the author.

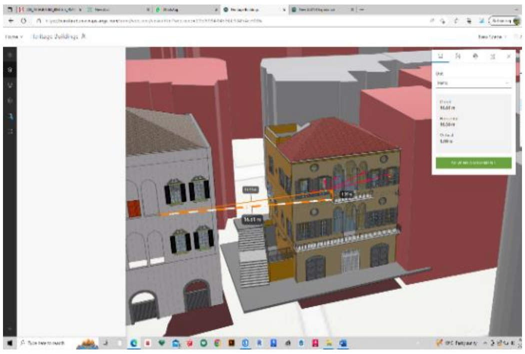


Fig.27: the user's interface of the integration of BIM-GIS Platform after the measurement tool being done.
Source: the author.

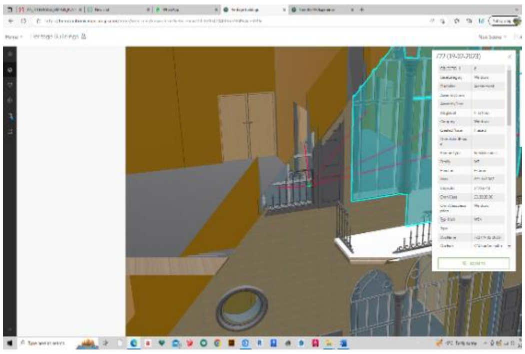


Fig.28: the user's interface of the integration of BIM-GIS Platform after the measurement tool being done.
Source: the author.

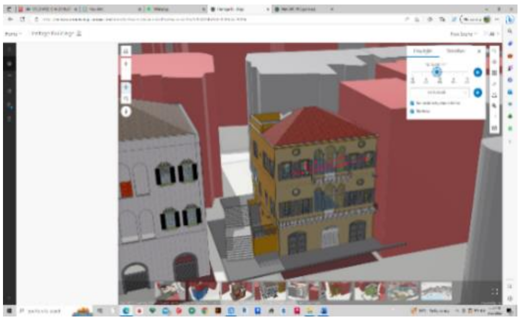


Fig.29: the user's interface of the integration of BIM-GIS Platform after the day light being changed.
Source: the author.

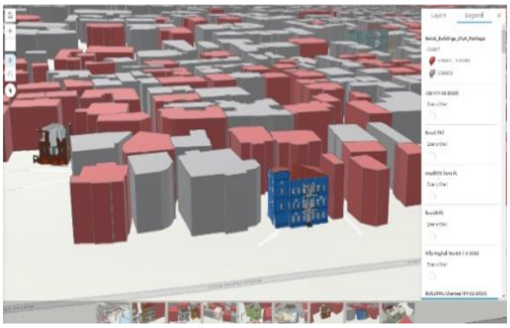


Fig.30: the user's interface of the integration of BIM-GIS Platform after an object being selected.
Source: the author.

Through ESRI's website, ArcGIS pro3.0 offers a diverse range of widgets for managing and analyzing 2D and 3D web maps. Hereafter are four selected widgets:

1. Intro to SceneLayer: This tool retrieves 3D Web Scenes from ArcGIS Online using their ID and creates layers. The layer names can be modified in ArcGIS Online and toggled on/off in the user interface.
2. Measurement in 3D: Users can measure length, area, and perimeter using this tool (as shown in figures 27&28).
3. BuildingSceneLayer with Slice widget: Users can create vertical and horizontal slices to reveal hidden elements in buildings. During this process, users can selectively exclude certain layers.

4. The User's interface of the integration of BIM-GIS Platform after the day light being changed tool (as shown in fig. 29).

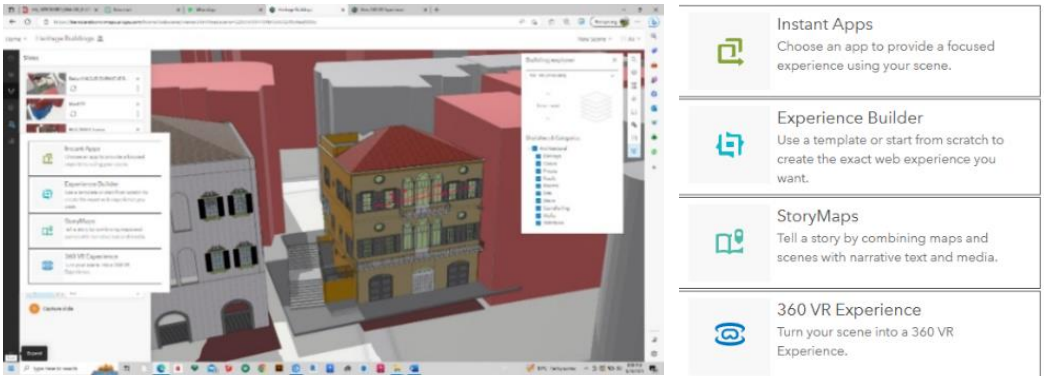


Fig.31: (a) the user's interface of the integration of BIM-GIS Platform and (b) after creation App selected.
Source: the author.

5. CONCLUSIONS

There is a growing awareness in the whole world, including Lebanon, of the need to preserve every country's historical and cultural legacy. The conservation of urban heritage in cities like Beirut is incredibly important for several reasons. ArcGIS as integrated digital environments is used in order to assess the structure and work on sustainable preservation of two historic buildings in Mar Mikhael area, Armenia Street in Beirut. The data derived from work of laser scan, photogrammetry and surveys have provided the information regarding the current state of buildings and led to the generation of a model that gives the user enhanced management over the display of individual buildings, help in the creation of thematic maps, assistance in the analysis of historical building materials and damage especially after the POB 2020's blast, and eventually assistance in the decision-making regarding the selection of the appropriate restoration materials and intervention works.

Moreover, the interoperability of these two information systems generated data that were incorporated within an HBIM. ArcGIS Pro 3.0 helped in creating, managing, analyzing, and sharing spatial data, mainly spatial relationships between different features such as buildings, streets, and parks. It provided advanced tools for mapping, visualization, and data analysis, and supported a wide range of data formats and sources. ArcGIS Pro 3.0 includes BIM data support, which enables users to import BIM data into the GIS environment and visualize it in 3D, but it does not have full BIM functionality. It helps in creating, managing, and sharing buildings' models with rich geometric and semantic information. Its main function is to support the creation of building models using industry-standard BIM software such as Autodesk Revit, and to provide tools for managing BIM data and integrating it with GIS data. It also includes advanced BIM functionality such as clash detection, construction sequencing, and cost estimation. The creation of detailed 3D models of buildings and urban spaces were used to visualize and analyze different scenarios for buildings' sustainable development.

BIM-ArcGIS v Pro 3.0 offers essential features utilized to leverage urban heritage management and sustainability. The resulting model provides numerous benefits:

- Enhanced accuracy and detail: Integrating a comprehensive HBIM model with GIS data offers a precise representation of the heritage site, aiding in identifying conservation problems and devising effective solutions.
- Improved planning and decision-making: Stakeholders can visualize site conditions and make informed decisions regarding conservation efforts through the model's assistance.
- Streamlined collaboration: The integration of BIM and GIS provides a unified model for planning and decision-making, enabling seamless communication and cooperation among stakeholders.

- Efficient maintenance and monitoring: Utilizing the model allows for effective site maintenance and monitoring, promptly addressing any identified issues or changes.

Besides, the opensource platform has significant potential in promoting urban heritage values. It can raise awareness and understanding of local heritage, leading to improved conservation efforts. Engaging the community fosters better communication and coordination among stakeholders, such as Beirut Municipality and DGA. Furthermore, it boosts tourism, contributing to economic benefits for the community, particularly after the challenges of 2020'S POB.

Further research should prioritize developing methods to share and integrate GIS-BIM and city-scale data to address the mentioned challenges. Additionally, enriching the platform with data from other city elements can improve infrastructure and facility management. Developing algorithms for automated processes would enhance interoperability, save time, and promote citizen engagement in smart cities.

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