# FROM POINT CLOUD TO EXISTING BIM FOR MODELLING AND SIMULATION PURPOSES

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**ABSTRACT:**

Many BIM experts agree that employing BIM for new construction is an easy task. However, applying BIM to existing construction will be difficult but is more suitable for heritage buildings cases. These heritage buildings have unique façades and architectural vocabulary, which are of special interest. Furthermore, studying these architecture heritages require some advanced tools in order to understand and analyse their structure, components, and design. Relying only on traditional methods is not adequate, especially for architectural engineers and experts who need digital representations of architectural heritage in order to draw a complete image of any aspect of the project. Moreover, lots of these heritage architectural elements are not documented or provided in the digital architectural libraries, which in turn requires advanced and easy access methods and tools that can extract basic information professionally and explain the essence of heritage. BIM has emerged as an efficient solution that could possibly help in analysing architectural heritage through effective learning processes. Existing BIM is characterised by their ability to create and operate within a digital database of any existing by 3-D laser through scanning the building and transforming it into point-cloud as digital data, so that engineers and experts can work on existing and buildings via the BIM software. As with many heritage buildings in the world, many of the heritage buildings in the Historic district of Jeddah city, Saudi Arabia, face serious issues in terms of conservation, restoration, documentation, managing, recording, and monitoring of these valuable heritage buildings. Therefore, this paper will examine and evaluate the use of BIM in modelling and for simulation purposes, (e.g. structure and energy simulation) with regard to one of the existing heritage buildings in the Historic district of Jeddah.

## 1. INTRODUCTION

### 1.1 Historical Jeddah and the Zanal Historical House: Background

Historic Jeddah is considered as one of the most important heritage sites in the Kingdom due to its long history that dates back to more than 3000 years ago. Jeddah city is recognised as the main gateway to the most valuable cities in the Islamic world; which are Makkah Al Mukarramah and Madinah Al Munawarah. The city of Jeddah is located on the western side of the Arabian Peninsula. This area is a coastal area. As mentioned, the historic city has a long history and there are several heritage sites and buildings (around 1442 heritage buildings), which were built more than 300 to 1200 years ago (Telmesani et al., 2009). For example, Nasif Historical house, the Al Shafee mosque, Shorbatly Historical house, Bayt Baeshen, Jamjom Historical house, Zainal House and many more.

Moreover, Zainal House is located in the centre of Jeddah City, near to Allegiance Square, Al Madinah Al Munawarah Road, Al-Baghdadiyah Al-Gharbiyah. The house is considered to be the first steel and concrete building in Historic Jeddah (built in 1920), with an Italian architectural style.

Furthermore, Bayt Zainal was leased in 1949 and occupied till 1957. Since 1957, the house has been left empty. Recently, the Saudi Commission for Tourism and National Heritage (SCTH), leased the house and they are planning to reuse the building as the Headquarters of the SCTH.

In 2014, the city of Jeddah (Historic Jeddah, the Gate to Makkah) was registered in the UNESCO world heritage list (WHL). Moreover, according to UNESCO world heritage, the city contains Criteria (II), which concerns the provision of a significant "interchange of human values". Also, Criteria (IV), which refers to offering outstanding illustration of a form of "architectural buildings". Moreover, Criteria (VI), which details the presentation of an outstanding direct or tangible associated with events or living traditions.

### 1.2 Aims

This paper aims to examine and evaluate the use of BIM in modelling and for simulation purposes, (e.g. structure and energy simulation) with regard to one of the existing heritage buildings in the Historic Jeddah. Moreover, the Architectural Object Library will be used as a plug-in to speed up the process of creating the existing 3-D heritage BIM modelling. Furthermore, the existing BIM model will be based on the point cloud data generated from 3-D laser scanning and architectural photogrammetry. Byat Zanal (Zanal House) has been chosen as a case study for this examination and evaluation.

## 2. LITERATURE REVIEW

### 2.1 BIM

Building information modelling (BIM) is a creative model-based procedure that affords insight in terms supporting building and infrastructure planning, design, construction, and management (Baik, 2017). In addition to single spatial relationships, BIM goes beyond traditional CAD drawings by applying data to individual building elements (e.g. walls, windows, and chillers) and employing extensive system information and experience (system flows or building loads).

The BIM procedure requires participants from the whole project life cycle, such as the architect, engineer, contractor, owner, facility management, who can all offer input and communicate with BIM designers, and requested to implement more accurate data on energy modelling. BIM is not merely software; BIM is considered to be the process of creating and using digital models for project design, construction and operation. These models link intelligent 2-D and 3-D objects, which are used to illustrate a building's design, along with external factors, such as geographic location and local conditions, into a virtual building database that provides a single, combined source for all information related to the design of the building. The data connected to the objects includes parametrically defined graphical and non-graphical information, offering the capacity to represent geometric and functional relationships between building elements to architects, MEP engineers and contractors. This information supports a combined database, which in turn supports all of the building's project design documents and schedules (Boukara and Naamane, 2015). All graphical illustrations (plans, elevations, detail, and other design drawings), and non-graphical views, for example, design documents and schedules, automatically show any changes that are made to the building model (Saygi et al., 2013).

## 2.2 Heritage\Existing BIM

In 2009, Maurice Murphy created the term Historic Building Information Modelling (HBIM) within the Dublin Institute of Technology, according to (Murphy et al., 2009). It is designed as a multidisciplinary system that consists of smart technological tools' construction. These data technology tools, such as (3-D laser scanning and point clouds, 3-D models, digital orthophoto, monitoring data), provide presidential survey data of the historical structure that can be used in BIM digital models. This tool incorporates building content information with data from the use of survey technologies in order to create a 3-D model for the historical structure (Brusaporci et al.., 2018).

The main aim of employing Heritage BIM in Historic Jeddah was, according to (Baik, 2017, 2016; Baik et al., 2015, 2014, 2013), "to provide an interactive solution to move from the zero level of BIM (CAD and 2D drawings) to more advanced levels of BIM (level 2 and level 3)." This solution will support the preservation and data sharing for these heritage monuments with professionals, as well as the societies involved in the decision making procedure (Eastman et al., 2011; Fussel et al., 2009). Moreover, using BIM for historical monuments can offer interactive parametric objects for the architectural elements. These elements are usually mapped based on the 3-D LiDAR data, which is produced from laser scanning (Murphy et al., 2009). Existing BIM implementations can assist engineers and experts to develop their performance in terms of understanding effectively, alongside analysing and redesigning these buildings. Moreover, Using BIM for existing buildings can provide several benefits. For example, providing engineering documentation, construction techniques, knowledge of materials, the building pathologies, and damage detection on the surfaces of the buildings. Furthermore, using existing BIM can provide a wide range of materials and assembly libraries in digital format. Additionally, existing BIM can provide comprehensive information for any proposed restorations and conservations, as well as assisting in maintenance efforts and

offering virtual visits for visitors from remote locations to view the 3-D model via free viewer software (Baik, 2017).

## 3. FROM POINT CLOUD TO EBIM

The Bayt Zainal project was divided into three main phases and sub steps. The first phase started with an images survey. The second phase was using the terrestrial laser scanning to scan the building façades from outside to inside. The third phase was to analyse the parametric modelling using architectural rules to help map 3-D objects on laser scanning surveys in order to create complete 3-D BIM models of a Heritage/Existing building. In addition, architectural rules were employed to use an automatic modelling system to briefly outline the field of procedural modelling. The next step was to build a library of parametric architectural elements in (eBIM) procedure. The eBIM design framework is based on expert conservation methods that enable users to evaluate their efficiency; according to (Baik, 2017). The final step was to simulate and evaluate the building's performance.

### 3.1.1 Images survey

The field work for the Zanal house project stared with the image survey in order to provide an architecture documentation for the architecture elements of the House. The image survey task took between three to five working days. In order to capture the images of Zanal house, a professional Nikon D5100 (16 Mega Pixels) camera was used.

### 3.2 Reality Capture

### 3.2.1 Ground control points (GCPs)

The Laser scanning survey work for the Zanal house project started with finding the control points' coordinates. In this case, this refers to point number (S177), which was defined by Jeddah Municipality, and was used as reference point (Table: 1). Figure 1 shows the process of identifying the GCPs.

| Point | category | E(m) | N(m) | Height |
|-------|----------|------|------|--------|
| S177 | 2ed | 5252616.4510 | 2377712.4060 | 40.99m |

Table: 1



Figure 1: The process of identifying the GCPs.

### 3.2.2 Laser scanning survey

The second phase began with the terrestrial laser scanning (TLS) process for the Zanal house. The TLS process started with identifying the most suitable location for the laser scanning station and defining its coordinates via the Total-station based on the back-sight method (Figure 2, Figure 3). This resulted in the production of net points outside and inside the building, which provided a coordinates map for each point.
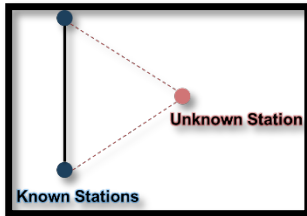


Figure 2: Back-sight method.



Figure 3: Using the Total-station on the site.

| 1 | 519241.341 | 2376326.046 |
|---|---|---|
| 2 | 519244.966 | 2376314.49 |
| 4 | 519233.5852 | 2376299.337 |
| 5 | 519230.9204 | 2376305.533 |
| 6 | 519231.4604 | 2376309.723 |
| 7 | 519232.5526 | 2376314.407 |
| 8 | 519232.7326 | 2376318.612 |
| 9 | 519233.4052 | 2376322.896 |
| 10 | 519243.9513 | 2376308.853 |
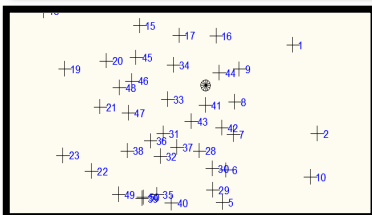


Figure 4 The coordinates map for each point.

The second step of the TLS method was to identify the most suitable spots to place the Black and White (B/W) targets (Figure 8). Furthermore, having at least three more accurate targets in common between these TLS scans is crucial.



Figure 8: Black and White (B/W) targets.



Figure 6: Utilising the (B/W) targets on the façades.

The third step of the TLS process was to scan the building façades from outside to inside. In this step, the visualisation of each scan was very important in terms of covering the whole are of the building.

Moreover, the overlapping areas between each scan was more than 50% so as to provide high registration accuracy in case the cloud-to-cloud method was used. The laser scanning resolution for each scan was .07 m with 10 m distance for inside the building and with around 70 m for outside the building. This phase took around ten working days.



Figure 7: Identifying the target.

## 3.3 Point cloud data processing

In this step, the LiDAR data was inserted into Cyclone software to register each scan with the other and to create the whole 3-D model of the building. Moreover, during this step, a number of noises were removed from the data.
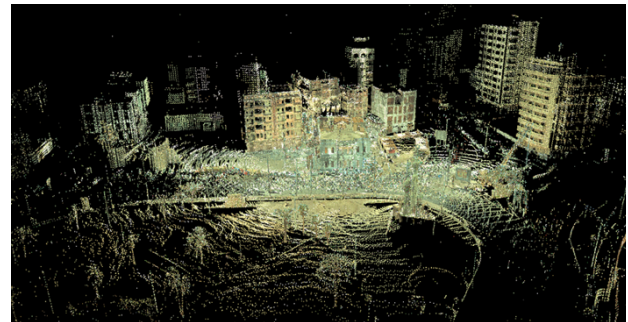


Figure 5: The 3D point cloud model of the Building.
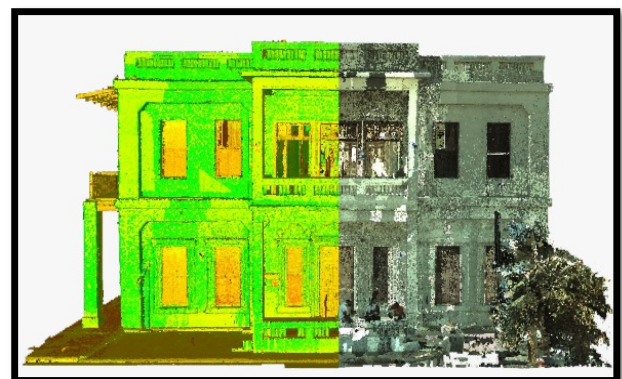


Figure 9: The 3-D point cloud model.

### 3.4 Point Clouds to eBIM Model

The TLS products were then introduced into the platform of BIM. Autodesk Revit and the eBIM procedure was applied. Moreover, the 3-D Orthographic images were inserted into their true location for façade elevations alongside plans, as well as with sections and ground points. The primary phase was the construction of walls from the plan's data. The doors, windows, columns, and all other elements of the building were illustrated. Then, the library objects were added. Library parameters were measured from the TLS data and applied into parts of the library before mapping data to the survey. This was included in the eBIM plugin in order to complete the model for the building.
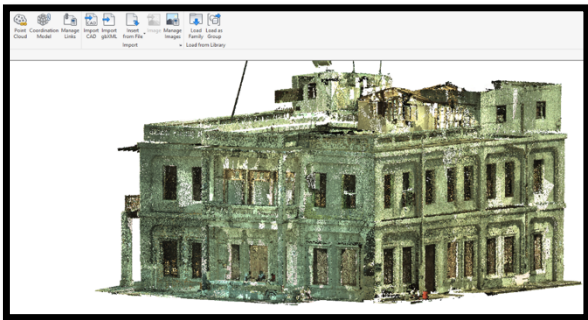


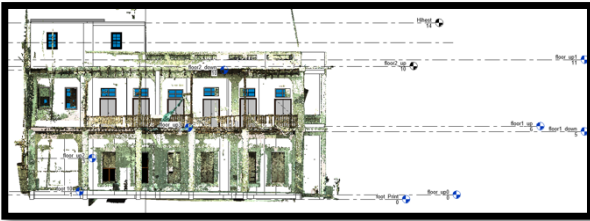Figure 11: Inserting the 3D point cloud into Autodesk Revit.



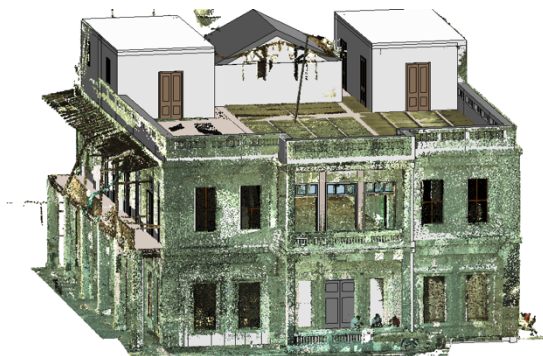Figure 13: Creating the BIM model in Autodesk Revit.



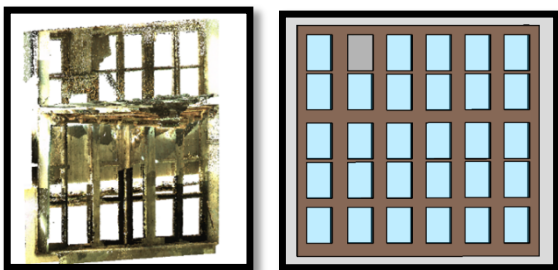Figure 14: Creating the BIM model in Autodesk Revit.



Figure 15: Creating the object library (window).



Figure 10: The 3D eBIM model of Bayt Zanal.



Figure 12: The 3D eBIM model of Bayt Zanal.

## 4. CONCLUSION

In the whole project life cycle, from design to construction and operation of new buildings, BIM is to be a standard within the AEC industry. Existing BIM is also starting to play a key role, although is not currently widely used. Due to software interoperability, a new design approach can be presented by executing the data flow. In addition, BIM can be utilised as a foundation for future processes for both structural and energy conservation and rehabilitation, but also for digitalising traditional documents. It can greatly develop the entire process by translating a multitude of traditional documents into a single, coherent federated model. The literature review and case studies have shown how the abilities of modelling and analysis from the planned workflow using Laser scanning means that eBIM can be used to create a library of parametric objects. The workflow gives new tools and methods for 3-D virtual modelling, documentation, management and analysis.

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