KELEBIHAN APLIKASI IMBASAN-KE-BIM DALAM PENDOKUMENTASIAN ASET WARISAN BUDAYA DI MALAYSIA

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Abstrak


Kata Kunci: Keaslian, Warisan Budaya, Pendokumentasian, Imbasan-ke-BIM, Pengimbas Laser Terrestrial 3D

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THE ADVANTAGES OF SCAN-TO-BIM IN DOCUMENTING CULTURAL HERITAGE ASSETS IN MALAYSIA

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Abstract

Cultural heritage conservation is a complex process requiring innovative methods and techniques to facilitate its restoration, management and valorization. Accurate documentation of heritage assets is crucial in ensuring that any changes, repair, addition or demolition of parts of the assets are properly recorded to maintain the authenticity of the assets. The aim of this study is to establish the advantages of scan-to-BIM application in documenting cultural heritage assets in Malaysia as a critical procedure in the steps to conserve the asset. The methodology adopted in this study is mixed mode. Primary data is acquired from the use of 3D laser scanner (3DTLS) at reconnaissance stage on Gedung Raja Abdullah building, Klang, Selangor, Malaysia. This study analyses the Scan-to-BIM advantages in order to ascertain the best practice method in documenting historical buildings and managing cultural heritage assets. The output from this study demonstrates the versatility of data collected through Scan-to-BIM that allows them to be manipulated into different forms, which subsequently can be used for various purposes.

Keywords: Authenticity, Cultural Heritage, Documentation, Scan-to-BIM, 3D Terrestrial Laser Scanner
1.0 Introduction

The practice of heritage building conservation requires careful attention from building owners, and the involvement of expertise from a various professionals such as town planners, conservation architects, building surveyors, landscape architects, quantity surveyors, specialize engineers, building contractors, archaeologist, art historians and antiquities. All this expertise demands a high degree of corporation, teamwork, experience, communication and knowledge of building materials and construction especially when dealing with historic buildings because repair and conservation work is an expensive item to historic buildings. The correct diagnosis of building defects associated with the correct remedial action and the obligations to conservation principles is the only economic basis for successful conservation.

However, there are many conservation consultants that are faced with difficulties in performing conservation for historic buildings. The complexity of historic constructions, with irregular geometry, non-uniform materials, variable morphology, modifications and damages, pose numerous challenges in the digital modeling and simulation of structural performances under different types of actions. On a typical construction project, a lot of information is produced. Over its life span, a built heritage suffers from human made damage and natural disaster. In the event that a particular building no longer exists, the accessible data source is limited to the archived materials (such as historical documents, bibliographic references, photographs, drawings, etc.) and remaining damaged sites (ruins and partly existing structures). The trouble is that information is often unstructured, poorly coordinated and difficult to find.

It is difficult to verify the data accuracy of historic buildings documented using the traditional method of measuring using a tape measure or manually drawn plans on paper. In addition, due to the many changes made in the field during construction stage, design drawings usually have numerous inaccuracies. There are occasions whereby clients increase and decrease budgets and scope during construction while the contractors have to respond to existing conditions and any uncoordinated issues in drawings. Therefore, some contractors try to be smart by adjusting the drawings themselves. As a result, inaccuracy between the drawings and the built construction occurs unrecorded.

1.1 BIM and H-BIM in Built Heritage Conservation

The introduction of Building Information Modelling (BIM) in conservation of built heritage ideally will help solve many issues arising in the miss-match of information and uncoordinated repair works. BIM is a system that allows architects, engineers and contractors to more efficiently design, build, and operate buildings and infrastructure by using digital information throughout construction life-cycle. BIM which is also defined as a process related to the creation and use of digital models for design, construction and operations of projects has changed the paradigm of construction industry not only from technological aspects (software and design tools), but also in the approach; bringing the conservation methods to become closer to the concept of standardization.
Designers will create digital 3D models that include all data with physical and functional characteristics using BIM. In a building survey to acquire as-built data, BIM data are not only geometrical, but also targeted on the accurate data of the cultural heritage condition. This survey process increasingly becoming essential as it tackles the most critical issue in the field of conservation and refurbishment, which is the data reliability and outcomes of input data (Ciribini et al., 2015). Even though latest developments in BIM have introduced progressive simulation capabilities, the characterization complexity of historic buildings is still a challenging task for the lack of reliable processes for structural replication. Therefore, Historical Building Information Modelling (H-BIM) was introduced to the built heritage field to overcome the problems.

H-BIM is created as a new system of modelling historic structures. H-BIM enable users to understand, document, advertise, and virtually reconstruct the built heritage. This system requires that data from the old building is collected using 3D terrestrial laser scanning with digital cameras (Murphy et al., 2013). H-BIM is generally based on Scan-to-BIM process that allows generation of 3D model from point cloud. Parametric tools can reduce human involvement in 3D modeling process; the goal is to develop a pipeline that allows this process to become increasingly automatic.

1.2 Research Objectives

This study presents the process of Scan-to-BIM from the Gedung Raja Abdullah project to show the advantages in digital heritage documentation. The purpose of Scan-to-BIM application in documenting cultural heritage assets in Malaysia is to provide an accurate and reliable data pool of the building, which can be subsequently used by various stakeholders involved in the conservation process. Moreover, in the field of the architectural heritage it is essential to realize the importance of a preserved information model, used as common database for all the players involved, owners, designers, contractors and facility managers.

The main aim of this study is to demonstrate how adopting Scan-to-BIM as a methodology in documenting cultural heritage assets in Malaysia can bring various benefits to the industry players. The output from this research will demonstrate the versatility of data collected through Scan-to-BIM method that allows them to be manipulated into different forms, which subsequently can be used for various purposes. In this study, the data collected from this method are used to produce accurate as-built drawings and modeling, incorporated into a video animation and finally converted into physical 3D model through three dimensional printing.

2.0 Methodology

Based on the various approaches currently practiced for conservation pipeline, the study adopts the H-BIM methodology and embarks on Scan-to-BIM of heritage building using 3D laser scanning as indicate in Figures 1 and 2. The selected case study is Gedung Raja Abdullah in Klang, which is being conserved under the purview of Perbadanan Adat Istiadat dan Warisan Melayu Selangor (PADAT). Primary data is
acquired through visual analysis, 3D laser scanning and semi-structured interview from experts conducting Scan-to-BIM procedures.

**Figure 1:** Research Methodology
2.1 Photo Documentation

Any conservation work will start with reconnaissance survey that involves visual appraisal of the heritage asset. A photo documentation of building defects was done at the Gedung Raja Abdullah. For this method a digital camera and drone was used to take photo of this building. Digital cameras illustrated in Figure 3 is used to take detail image of building defects. The method of tagging the damages was carried out to mark the damages at Gedung Raja Abdullah (GRA) for reference to conservation work (see Figure 5). Meanwhile, drone was used to record the overall envelope of the project or building in order for a conservator ascertains the unreachable defect or problems around the building as illustrated in Figure 6.
**Figure 3:** Digital Single-Lens Reflex (DSLR) - Nikon N7000

**Figure 4:** Drone DJI Mavic Pro

**Figure 5:** A3/PL/01: Wood Rot (One of Tagged Photo Taken from GRA)
(Source: Researcher, 2018)

**Figure 6:** Gedung Raja Abdullah Top View Taken from Drone (Source: GHC, 2018)
2.2 3D Terrestrial Laser Scanning Method (3DTLS)

3D laser scanning technologies (3DTLS) are adopted for their ability to accelerate the spatial data collection of existing buildings or complex surfaces, as well as for the accuracy and precision of the acquired data as illustrated in Figures 7 and 8. Laser scanners are subdivided into two specific areas, aerial and terrestrial. Each one has a range and precision that is suitable for the use to which it will be destined.

**Table 1: 3D Laser Scanner Details**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Laser Scanner – Faro Focus3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance accuracy</td>
<td>up to ±2mm</td>
</tr>
<tr>
<td>Range</td>
<td>from 0.6m up to 120m</td>
</tr>
<tr>
<td>Measurement rate</td>
<td>up to 976,000 points/sec</td>
</tr>
</tbody>
</table>

**Figure 7:** Laser Scanner – Faro Focus3D  
**Figure 8:** Illustration of Laser Scanner Process
3DTLS works via a laser beam as illustrated in Figure 9, travels towards the area being scanned and back, measuring angles and distances with accuracies from millimeters to centimeters (Figure 9a). In this context, 3DTLS obtains a precise and detailed geometric reproduction of three-dimensional objects in a short time, in the form of millions of points (a cloud of points), with geometric coordinates (X,Y,Z) (Figure 9b), in a digital environment, with both metric and radiometric information.

**Figure 9:** (a) Laser Scanning Process to Create a Point Cloud; (b) Geo-referenced Point Cloud, (X, Y, Z)

In addition, three different types stand out among the 3DTLS systems: triangulation, phase difference, and Time of Flight (TOF). Each of these 3DTLS systems are capable of producing point clouds of the objects; however, the accuracy and the density of the obtained point clouds will vary depending on the selected scanner type, as well as the number of scans made (Figure 10).

**Figure 10:** Systems and Accuracy of the Terrestrial Laser Scanning (TLS)
This method is to capture current conditions with fast, straightforward and correct measurements of complex objects and buildings. The instrument accurately captures thousands of data point clouds per second as indicated in Figure 11. This process allows a single team to collect and easily share all measurements, from the floor to ceiling. This point cloud of data is a 3d representation of the building facility as illustrated in Figure 12.

![Figure 11: Setup the Equipment for the 3D Scanning Process](image1)

![Figure 12: Position of the Scanner and Three Spheres Measured in One Space](image2)

2.3 Point Clouds

The captured and processed point clouds describe, in detail, the surface of the scanned elements. Unfortunately, these point clouds do not contain additional information about the objects whose geometry they represent. Therefore, to obtain geometrical, topological, and semantic attributes, it is necessary to produce 3D geometric models or parametric objects. This 3D modeling can be described as a reverse engineering process. The segmentation and recognition of point clouds currently represent the fundamental steps for identifying the correct surfaces and facilitating the tracing or the modeling of parametric objects. These steps can be carried out semi-automatically or fully automatically through the advances added to BIM platforms, as well as the new algorithms of object recognition and point cloud segmentation as illustrated in Figures 13, 14 and 15.
Figure 13: GRA Point Cloud in Faro SCENE Software

Figure 14: The Complete Point Cloud can be visualised after All of the Scans have been Registered together using the Targets that were Placed in the Field

Figure 15: GRA Point Cloud in Recap Autodesk Software

2.4 Main Software Used in Scan-to-BIM

The details on the findings related to Scan-to-BIM indicated in steps 1-6 as well as illustrated in Figures 16, 17 and 18.

a Faro SCENE: is an important tool for 3D laser scanning that can help to process and manage scan data more efficiently. This software is for registration, navigating through the point cloud data in Faro SCENE, noise identification and removal, and validating the overall registration of the point cloud data set. It also goes into visualizing point clouds, point cloud
exporting options and applications, integration options in Faro SCENE, using third-party data, and more. The overall

b  ReCap Autodesk: this software is a simple-to-use package that allows to directly open point cloud files and, with the help of a few customizable import settings, filter unnecessary data and work with the files in a more manageable size. Moreover, since the points are generated using a native Autodesk product, the points can be extracted or imported into all other Autodesk products. ReCap point file can be used to clean up a scan of an existing building, then import it into Revit to begin an accurate 3D BIM design where it can be certain there are no conflicts with existing elements.

c  ArchiCAD (Graphisoft): This is a BIM platform, so it allows users to work with objects and model them with parametric data. In addition, the use of the open-source scripting language Geometric Description Language (GDL) allows for the creation of any type of object and the storage of these objects in the program’s internal libraries, thus permitting them to be reused or modified in the future. This platform can import and export DWG, DXF, and SketchUp files; it also provides interoperability with other BIM platforms through the use of IFC. ArchiCAD is considered to be a commercial BIM platform, due to its legal use.

d  Revit Autodesk: This is an efficient BIM platform to accurately model regular and irregular surfaces, as well as geometric anomalies of the different elements. This software has a changing parametric behavior that helps to quickly construct and change elements into a 3D model. Moreover, this platform generates construction documents with a high level of quality and flexibility. The Revit platform provides interoperability between different software applications through the use of IFC files (BuildingSMART, 2016). In addition, it is able to link DWG, DGN, Dxf, Sat, and SKP files, and it is also a useful tool to open and manipulate point clouds that are stored in .txt, RCP, or .rcs files. Moreover, the Revit platform allows for users to add new functions or add-ins from the application programming interface (API), programming languages that could be used to create add-ins written in C++, C# and Python (Learn about Revit. Autodesk Revit is considered to be a commercial BIM platform, due to its legal use. Moreover, it offers a free student version for three years.

e  Autodesk Navisworks Freedom: This software is a free viewer for NWD and DWF file formats. The use of Navisworks Freedom extends the whole-project view to all stakeholders, helping to improve the collaboration and communication. With such software it is possible to create multi-disciplinary models in a wide range of applications, including information from BIM, digital prototypes and process plant design. All of these can be combined into a single integrated project model and published into the NWD format. The published file provides access to: object properties, model hierarchy and embedded review data, including animations, viewpoints and comments.

f  Adobe Premiere Pro: Premiere Pro can be used for all common video editing tasks necessary for producing broadcast quality, high-definition video. It can
be used to import video, audio and graphics, and is used to create new, edited versions of video which can be exported to the medium and format necessary for distribution.

Figure 16: Scan-to-BIM Output

Figure 17: Point Clouds Data Process
2.5 3D Visualization of Gedung Raja Abdullah

The process of 3D visualization of the Gedung Raja Abdullah produces various outputs as indicated in Figures 19, 20 and 21. First, a digital 3D modelling of the building is done in a 3D modelling software, Revit. Secondly, the model will be animated (as illustrated in Figures 22, 23 and 24) and given a contextual environment in NavisWork. Thirdly, the 3D modelling is then printed with 3D printer in order to give a physical or tangible appreciation of the building indicated in Figures 25, 26, 27, 28 and 29.
**Figure 20:** Gedung Raja Abdulah’s elevations produced from Revit

**Figure 21:** 3D perspective produced using Revit

**Figure 22:** Animation Process in NavisWork to Show Structure of GRA Using the 3D Model from Revit.

**Figure 23:** Animation Process in NavisWork to Show the Architectural Elements of GRA Using the 3D Model from Revit.
Figure 24: Export the Naviswork File in Adobe Premiere Pro for Video editing

Figure 25: Cross-section Model Which Can Display the Interior of The Building  
Figure 26: 3D Printing Process

Figure 27: The Print Products Before Assemblage into a Complete 3D Model  
Figure 28: GRA Building Parts Prepared Before Assemblage into a Complete 3D Model
3.0 Discussion and Conclusions

BIM technologies allow for the documentation, generation, importation, or manipulation of three-dimensional models using such parametric information as specifications and technical drawings (2D), geometric properties in a collaborative model (3D), constructive temporary programming (four-dimensional(4D)), the definition of amounts and costs (five-dimensional (5D)), sustainability of the project (six-dimensional (6D)), and maintenance and life cycle management (seven-dimensional (7D)).

Scan-to-BIM is a process that allows generation of 3D model from point cloud by capturing existing conditions with high resolution. Among the benefits of employing scan-to-BIM to heritage buildings are that existing condition of the buildings are captured with high resolution, giving an accurate as-built representation and data. This data provide information to verify and audit errors with 2D as-built documentation thereby reducing client risks for renovation or rehabilitation projects.

The as-built 3D model as indicated in Figure 30 can be revisited and analysed without having to be physically present at the site thereby reducing need for recurrent physical site visits and inspection. Assessing structural integrity of assets can also be performed by experts without the risk of on-site safety issues. BIM allows better monitoring and recording construction progress and facilitates in better information management projects. On top of that data pertaining to cultural heritage assets are now digitally documented, thereby providing digital records that are auditable.
According to Logothetis et al. (2015), BIM technologies allow for the documentation, generation, importation, or manipulation of three-dimensional models using such parametric information as specifications and technical drawings (2D), geometric properties in a collaborative model (3D), constructive temporary programming (four-dimensional (4D)), the definition of amounts and costs (five-dimensional (5D)), sustainability of the project (six-dimensional (6D)), and maintenance and life cycle management (seven-dimensional (7D)) (Figure 31). This acquired information is stored in the BIM database and will allow for the creation of a virtual parametric model that can simulate the characteristics and conditions of each element as if they were real.

Figure 30: The Scan-to-BIM Benefits to the Client

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In order for BIM to be a collaborative tool, the level of development (LOD) of the project must be represented, so as to determine the degree of certainty, precision, and richness of the information contained in the modeled element and to estimate the specific use for which this information is destined. The LOD scale includes element’s geometry and attached information referred as Level of Detail (LoD) and Level of Information (LoI) (Figure 32).

Figure 32: The LOD Scale Includes Element’s Geometry and Attached Information Referred as Level of Detail (LoD) and Level of Information (LoI)

In order for BIM to effectively work in Malaysian conservation of built heritage, all key players need to collaborate in order to provide accurate data that is auditable. BIM can serve as multidisciplinary collaborative work platform, where modifications, management, or communications are shared in real time among the participants involved. This characteristic will allow for the useful data to be recovered at any time,
avoiding time wasting and reducing the possibility of errors. The collaborative work is made possible due to the interoperability of BIM platforms, which is achieved by the development of an open and standardized data structure (standard: ISO 16739), called Industry Foundation Classes (IFC). IFC facilitates and guarantees the transfer of relevant data between the different BIM authoring software applications.

At present, there are practically lack of laborers and technical experts in conservation methods and techniques, let alone in BIM consultancies. This is a major problem because almost all conservation projects involve both repair and maintenance stages requiring an understanding of and analysis of building defect diagnoses from all parties involved. Conservation needs a proper management of resources and a systematic procedure on conservation works. The activities in conservation works should therefore be handled with great sensitivity and skills in order to preserve the rare qualities of the buildings materials, architecture and craftsmanship. Having confidence in BIM (or H-BIM) as a methodology to properly manage cultural heritage assets may be the first start in ensuring the sustainability of conservation practice for built heritage in Malaysia.

4.0 Acknowledgments

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5.0 References


