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THE DIGITAL DOCUMENTATION OF HERITAGE BUILDINGS USING HISTORIC BUILDING INFORMATION MODELLING (HBIM) TOOLS

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Abstract

Conventional documentation methods remain widely used in heritage conservation practice; however, these approaches often yield fragmented records, inefficiencies, and limited accessibility, which may hinder long-term conservation efforts. In response to these limitations, digital documentation has emerged as a critical alternative, particularly through the application of Historic Building Information Modelling (HBIM). HBIM enables the systematic recording, analysis, and management of heritage building data while supporting data security, governance, and the long-term integrity of information. This study explores the application of HBIM as a digital documentation and archival tool for heritage buildings in Negeri Sembilan, Malaysia, addressing practical challenges associated with data acquisition, modelling accuracy, and contextual adaptation within conventional conservation practice. The primary objectives of the study are to document selected heritage buildings through measured surveys and to generate accurate two-dimensional (2D) and three-dimensional (3D) digital models as a comprehensive conservation record. The research adopts on-site observation and building measurement combined with 3D simulation techniques to produce structured digital documentation. The resulting HBIM models provide an integrated platform for recording architectural elements, monitoring building conditions, and facilitating future rehabilitation and refurbishment works. By promoting digital-based documentation practices, this study supports sustainable conservation approaches aligned with green technology principles and contributes to Sustainable Development Goal 11 (Sustainable Cities and Communities). Overall, the findings demonstrate that HBIM offers a reliable and effective framework for enhancing the long-term preservation and management of heritage buildings in Malaysia.

Keywords: Heritage building, Digital documentation, Historic Building Information Modelling (HBIM) tools

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INTRODUCTION

Due to their historical, architectural, and cultural importance, the management and preservation of cultural assets, particularly heritage structures, has become increasingly critical in the digital era. Nevertheless, these structures face obstacles such as documentation deficiencies, degradation, and the necessity of sustainable management strategies. Heritage Building Information Modelling (HBIM) has emerged as a potent instrument for addressing these challenges, and Building Information Modelling (BIM) has been implemented in a variety of historical contexts.

HBIM tools suit sustainable heritage restoration initiatives, as they facilitate the storage, utilization, and domain knowledge of large amounts of data throughout the lifespan of a building. HBIM incorporates a variety of data sources, including architectural drawings, laser scans, and historical records, in order to generate a comprehensive and precise model of heritage buildings (Karasaka & Ulutas, 2023). Nevertheless, the construction sector's adoption of HBIM has remained sluggish due to the need for industry collaboration and the acquisition of new skills (Ali et al., 2018; Khalil et al., 2021). The ecological footprint of buildings can be reduced, and economic growth and environmental protection can be promoted through the use of green technology, which employs environmentally favorable practices and materials (Ali et al., 2018; Salam, 2020; Baik, 2024).

The application of Historic Building Information Modelling (HBIM) has been widely explored in international heritage conservation practices, demonstrating its potential as a comprehensive digital documentation and management tool. Studies from Europe, East Asia, and the Middle East provide valuable insights into how HBIM can be adapted to different cultural, climatic, and regulatory contexts, offering relevant lessons for implementation in Malaysia. At the international policy level, organizations such as UNESCO advocate for the use of digital technologies in heritage documentation to enhance risk preparedness, monitoring, and sustainable management. HBIM is increasingly recognized as a tool that supports these objectives by enabling accurate digital archiving and informed decision-making throughout the building lifecycle.

A comprehensive approach to heritage management which promotes sustainability while preserving cultural and historical significance can be achieved by integrating HBIM, digital documentation, and green technology. By combining these innovative technologies and practices, the construction sector can modernize its approach to heritage preservation and environmental sustainability. This integration will allow for more efficient planning, maintenance, and restoration of historic buildings, while also reducing the overall carbon footprint of construction projects. Ultimately, the adoption of HBIM,

digital documentation, and green technology in the construction industry can lead to a more sustainable future for both our cultural heritage and the environment.

LITERATURE REVIEW

Digital Documentation

There are three (3) key factors defined as a BIM, which are processes, technologies, and behaviors. Technologies in BIM are the tools or software used in the process. Cultural heritage projects worldwide are increasingly being undertaken due to their growing importance in socio-economic development. The need for reliable digital 3D models as digital documentation for remote planning and management is increasing. Many software tools are available for modelling and documenting monuments.

Digital documentation in Building Information Modelling (BIM) is considered the most effective solution, provided proper methodologies, tools, and functions are available. Various modelling tools, such as ArchiCAD, Bentley Architecture, Revit Architecture, Tekla, and others, have been effectively deployed in practice to meet this demand (Rocha et al., 2020). BIM for heritage buildings is developed through designing parametric objects and selecting compatible technologies to create a rich information model. BIM tools can provide a comprehensive data set for building restoration, allowing users to model the three-dimensional compounds of a building and link various information to it (Trillo et al., 2015; Salleh et al., 2022; Robador et al., 2023).

Heritage Building Information Modeling (HBIM)

Heritage Building Information Modelling (HBIM) is a subset of Building Information Modelling (BIM) that employs modern digital technology for the protection and management of historical structures. HBIM, which amalgamates conventional architectural methods with contemporary technologies, facilitates the development of a three-dimensional model of heritage structures. These models would integrate data on architectural, structural, and historical features to promote a comprehensive approach to heritage conservation (Karasaka & Ulutas, 2023). Sophisticated technologies typically linked to the documentation of the aforementioned data include 3D scanning, photogrammetry, and GIS. Moreover, cutting-edge technology such as 3D laser scanning, photogrammetry, and unmanned aerial vehicles (UAVs) is employed to obtain high-resolution photographs of a structure's geometry and condition. This data is utilized in the modeling step to generate a detailed 3D model, which is subsequently employed for analysis and simulation to evaluate structural integrity, thermal performance, and environmental consequences (Mohammed and Ahmed, 2020).

HBIM facilitates conservation and management initiatives by allowing for meticulous planning and implementation of restoration projects. By

incorporating accurate and detailed digital representations of historic structures, preservationists and conservationists can make informed decisions about the best methods for restoring and maintaining these important buildings (Salam, 2020; Baik, 2024). The use of HBIM helps to ensure that restoration projects are carried out with precision, taking into account the unique characteristics and needs of each structure. The primary goal of using HBIM in conservation efforts is to preserve historic buildings for future generations to enjoy and appreciate.

Heritage conservation HBIM is shifting from simple 3D models to advanced digital as highlighted by Yang and Koehl (2022), using high-resolution structural analysis than traditional methods. For our documentation of heritage buildings in Negeri Sembilan, adopting these global workflows is essential to bridge the gap between physical geometry and historical data. Ultimately, aligning digital tools with the National Heritage Act 2005 ensures that local preservation meets international technical rigour and SDG 11 goals (Mohamad & Hassan, 2025).

RESEARCH METHODOLOGY

This research employs a case study method to examine specific experiences and specifications, particularly when several components and connections are implicated. This approach facilitates the creation of an extensive model that delineates real behavioural patterns via observation (Fidel, 1984), and enables the researcher to attain a clearer understanding of particular issues and offers diverse perspectives. The chosen case study is Masjid Lama Kampung Pelangai, situated in Kuala Pilah, Negeri Sembilan, a heritage mosque renowned for its historical and cultural importance. This mosque was chosen as the case study because the mosque is 100 years old and abandoned, as shown in Figure 1.

The construction of newer, larger, and more modern masjid in nearby areas has resulted in a functional redundancy of the old timber masjid. As congregational needs have evolved, especially due to rising populations in urban centres, focus has often shifted toward concrete buildings with modern amenities, leading to the neglect of traditional structures. Another contributing factor is a lack of awareness and recognition of the cultural and architectural value of such heritage buildings. The investigation of Masjid Lama Kampung Pelangai aims to investigate how to execute the digital documentation, and evaluate the integration with Heritage Building Information Modelling (HBIM). The research aims to utilize current technology, including drone piloting and 3D simulation, to meticulously document the mosque's architectural features and formulate effective conservation measures which honor its historical and cultural importance.



Figure 1: The actual condition of Masjid Lama Kampung Pelangai, Kuala Pilah.

Sources: Author, 2024

On-site observations were initially conducted to assess the current physical condition and architectural characteristics of the case study mosque. The building exhibits distinctive features of traditional Malay architecture, including a multi-tiered pitched roof, intricate timber carvings, and an elevated structural form designed to mitigate flooding. These elements were systematically recorded to ensure accuracy in the digital documentation process.

Comprehensive measured surveys were undertaken during the site visit, including triangulation measurements, vertical and horizontal elevations, floor slab thickness, roof geometry, and ground-level discrepancies. Manual measurement tools were complemented by visual inspection to capture construction details and material conditions. Site observation remains a critical method for heritage documentation, as it provides primary data reflecting the authentic physical environment and attributes of the structure (Robert, 2011; Baik et al., 2021).

Collaboration with INTI International University was used to capture aerial perspectives and intricate designs using drones for the creation of realistic 3D virtual models. All data were recorded digitally, with 2D working drawings generated using Autodesk AutoCAD and 3D models produced with Autodesk Revit. To enhance the accuracy and completeness of the documentation, Unmanned Aerial Vehicle (UAV) technology was employed to capture aerial imagery and detailed visual data of inaccessible architectural components. The UAV data collection was conducted in collaboration with INTI International University using a DJI Mavic 3 Thermal drone. The drone was operated at controlled flight altitudes ranging between approximately 20 m and 40 m, ensuring comprehensive coverage of roof structures, façade details, and overall building geometry while maintaining image stability and safety compliance.

The UAV was equipped with high-resolution optical sensors, enabling the capture of detailed photographs suitable for photogrammetric reference and 3D modelling. Multiple overlapping images were obtained to improve spatial accuracy and reduce data gaps, particularly for complex roof forms and

decorative elements. The use of UAVs significantly enhanced data precision and minimized physical intrusion, which is essential when documenting heritage structures.

All collected data were recorded and archived in digital formats. Two-dimensional (2D) working drawings, including plans, elevations, and sections, were generated using Autodesk AutoCAD based on measured survey data and site observations. Subsequently, three-dimensional (3D) models were developed using Autodesk Revit to construct an HBIM-based digital representation of the mosque. The HBIM model integrates geometric information with descriptive attributes, allowing architectural elements to be systematically categorized and documented. This digital workflow supports further analysis, condition monitoring, and future conservation planning. By combining on-site observation, UAV-assisted documentation, and 3D simulation software, the methodology ensures the production of accurate, reliable, and comprehensive digital records that can support rehabilitation, refurbishment, and long-term heritage management.

ANALYSIS AND DISCUSSION

Phase 1: The application of Drones for capturing data.

In the initial phase of the assessment, unmanned aerial vehicles (UAVs), commonly known as drones, were employed to capture high-resolution visual data of Masjid Lama Kampong Pelangai. This technology facilitated a comprehensive aerial survey of the building, enabling access to hard-to-reach areas such as the roof structure, upper timber framework, and deteriorated external facades without compromising the fragile condition of the site. The drone imagery provided detailed photographic documentation and orthomosaic maps that were instrumental in identifying signs of physical degradation, including roof deformation, missing shingles, biological growth, and structural displacements. The use of drones enhanced safety and efficiency during the data collection process and ensured minimal physical interference with the heritage fabric. This method proved especially valuable in establishing an accurate visual baseline for further structural analysis and conservation planning in subsequent phases.

Phase 2: The exploration of HBIM tools to create 2D and 3D Modelling.

The data were generated in AutoCAD for 2D drawings, as shown in Figure 2, 3 and 4, then transferred to Autodesk Revit for 3D Modelling and Rendering, as shown in Figure 5. The collected data, thoroughly clarified, encompasses the decoration and authenticity of the structure and ensures precision in the elements obtained. Presented herein are images of the 3D simulation of HBIM for Masjid Lama Kampong Pelangai. This digital documentation method will enhance the

green technology initiative as the sector transitions to more sustainable practices. Digital documentation will enable construction firms to minimize paper waste, enhance communication, and increase productivity during the construction process. The transition to sustainability in construction will yield environmental benefits, cost reductions, and enhanced competitiveness within the industry. All players in the building industry must adopt sustainable practices and collaborate towards an environmentally friendly future.

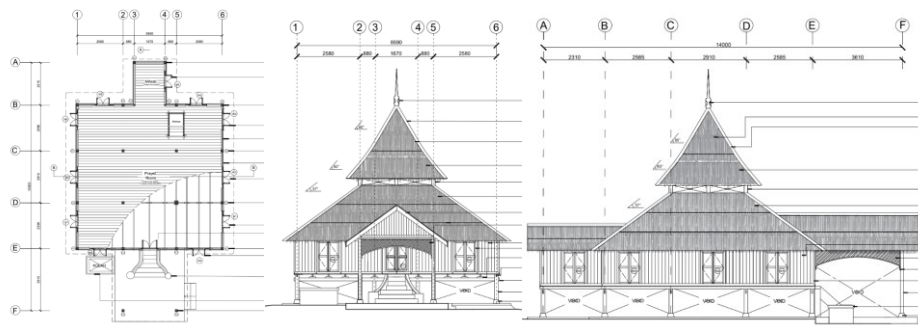


Figure 2: 2D drawings of HBIM Tools
Sources: USIM, 2023

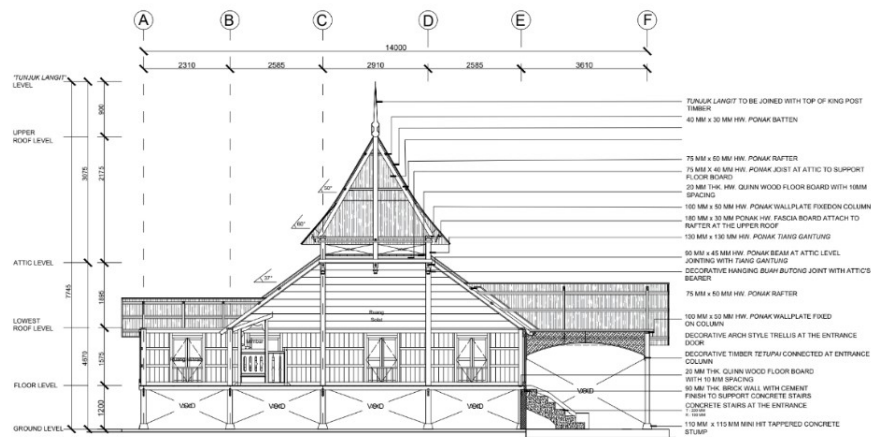


Figure 3: The section cut to show internal details of Masjid Lama Kampung pelangai.
Sources: USIM, 2023

The implementation of digital documentation will facilitate the tracking and monitoring of materials and resources, enabling construction organizations to make better informed decisions regarding their supply chain and waste management. This proactive strategy for sustainability will not only diminish the

industry's carbon impact but also address the increasing demand for eco-friendly structures. A construction company might utilize Building Information Modelling (BIM) software and digital archive using website for better documentation. Digital simulation can be used to pinpoint opportunities for material reuse or recycling, resulting in cost reductions and ecological advantages during the construction process.

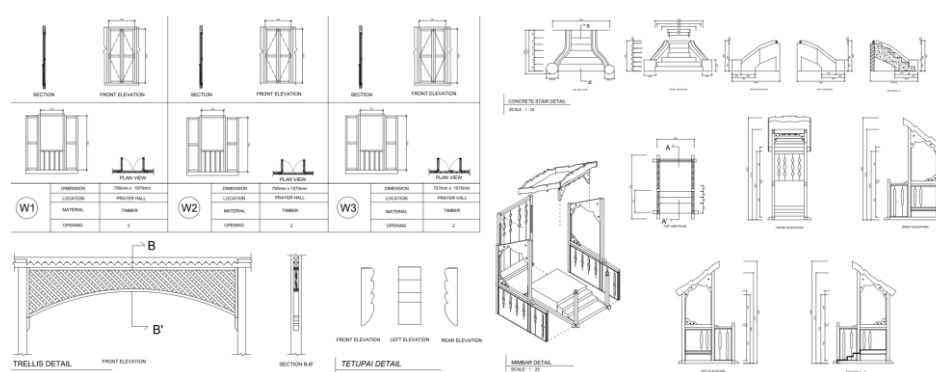


Figure 4: The details of structural components.

Sources: USIM, 2023

Phase 3: Digital Archiving

In Phase 3, digital archiving was conducted to preserve and systematize the data collected from both field assessments and drone surveys, demonstrating a vital component of the conservation process. Utilizing photogrammetry, 3D modeling, and Building Information Modeling (BIM) techniques, the architectural elements of Masjid Lama Kampung Pelangai were digitally reconstructed to create a comprehensive and accurate visual archive. This process enabled the documentation of structural details, material conditions, and spatial configurations in their current state, ensuring that even if further deterioration does occur, an exact digital record is retained. The archive provides a reference point for future restoration efforts; supports academic research and heritage education; and facilitates virtual access to the site for broader public engagement. By integrating digital archiving into the conservation workflow, the project aligns with modern heritage management practices, ensuring both the physical and informational preservation of the mosque for future generations.

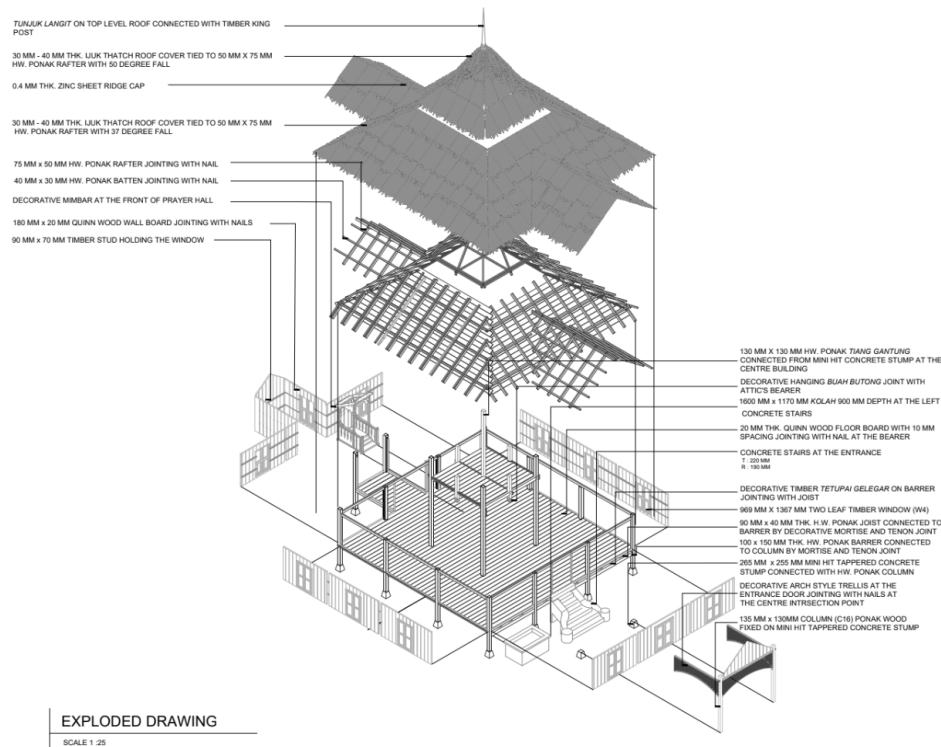


Figure 5: 3D Exploded and simulation using HBIM Tools.
Sources: USIM, 2023

The findings indicate that the application of Historic Building Information Modelling (HBIM) offers significant advantages over conventional documentation methods in terms of accuracy, efficiency, and long-term data management. Unlike traditional manual drawings and fragmented archival records, HBIM integrates geometric, visual, and descriptive information within a single digital platform, reducing data redundancy and minimizing the risk of information loss. Additionally, HBIM improves time efficiency by streamlining the workflow from site measurement to digital modelling, while facilitating interdisciplinary collaboration among conservators, architects, and authorities through shared and easily accessible datasets.

CONCLUSION

This study examines the extent of practitioner engagement with digital documentation in heritage conservation practice. The findings indicate that most practitioners continue to rely on conventional methods for storing and managing

conservation information, while the adoption of digital documentation is largely limited to certified conservators. Among those who employ digital approaches, 3D laser scanning is the most commonly used tool; however, its application remains partial, with digital outputs often supplementing rather than replacing traditional records. As a result, conservation documentation practices remain fragmented, with parallel use of digital and manual methods.

This continued reliance on traditional documentation can be attributed to several factors, including limited access to advanced digital equipment, insufficient technical training, and the absence of standardized digital documentation guidelines within the Malaysian conservation sector. In addition, some practitioners demonstrate a preference for established, hands-on documentation practices, which are perceived as more familiar and reliable. These findings highlight the need for greater institutional support, targeted capacity-building initiatives, and clearer regulatory frameworks to encourage wider and more effective adoption of digital documentation tools. Strengthening practitioner engagement with HBIM and related technologies would enhance data accuracy, improve long-term information management, and support more sustainable heritage conservation practices in Malaysia.

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