

Digital Innovation in Heritage Management: Exploring Possibilities of I-BIM and H-BIM Through Borobudur Temple and Dhanyakuria

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Abstract

Heritage buildings are vital links to our past, embodying the architectural, cultural, and historical significance of earlier eras. Their preservation has become increasingly complex due to environmental degradation, structural aging, and the evolving urban landscape. This paper investigates the application of historic building information modeling (H-BIM) as a comprehensive methodology for documenting and conserving these structures. H-BIM leverages advanced digital technologies such as photogrammetry, laser scanning, and geographic information system (GIS) mapping to produce detailed, multi-dimensional models that capture the architectural nuances of historical sites and support ongoing monitoring and management. The case study of Borobudur Temple in Indonesia illustrates the practical use of H-BIM in heritage conservation. Through the deployment of unmanned aerial vehicles (UAVs) and terrestrial photogrammetry, high-resolution 3D models were generated, revealing essential data on material composition, structural integrity, and environmental impact. This research highlights H-BIM as a digital time capsule, preserving heritage sites while accommodating contemporary needs. The paper advocates for the widespread adoption of H-BIM, emphasizing its role in enhancing accuracy, efficiency, and sustainability in heritage conservation. Recommendations include standardizing H-BIM procedures, developing user-friendly software, and incorporating advanced technologies to improve heritage site management. Ultimately, this study illustrates a case of the old town settlement (Dhanyakuria) in West Bengal and H-BIM's critical role in documenting the historical legacy for future generations.

Keywords: Historic building information modeling (H-BIM), cultural heritage preservation, digital documentation, 3D modeling.

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INTRODUCTION

Heritage is defined as something that is handed down from the past, as a tradition and result of the culture and beliefs of a generation. The historically built form that we see today is a marvel of engineering and architecture that has lost its significance, but the remarkable stones are still available to provide proof of knowledge. According to the Charter for the Conservation of Unprotected Architectural Heritage and Sites in India by the Indian National Trust for Art and Cultural Heritage (INTACH) in 2004, a heritage building is defined as any building or part of a structure that requires conservation or preservation for historical/architectural and cultural/environmental or ecological purposes. The charter defines the

responsibility of the owners of heritage buildings and buildings in heritage precincts to carry out regular repairs and maintenance [1]. On a wide scale, heritage buildings can be categorized into two categories: 'Protected' and 'Unprotected.' Sites or monuments that are under the umbrella of an authority and have gained recognition and conservation efforts are categorized under the 'Protected' category, while architectural and cultural sites that are not legally protected and are at risk of demolition or other damage are under the category of 'unprotected'. This includes living heritage and built heritage, and organizations like INTACH and the Archaeological Survey of India (ASI) have various initiatives like the Heritage at Risk Register (H@R), which maintains a ledger for the accounts of these architecturally and culturally important assets in India. However, the charter categorizes these heritage buildings according to the structure grading as Grade I, Grade II, and Grade III, respectively. Heritage Grade I includes buildings and precincts of national or historical significance that showcase outstanding architectural styles, designs, technologies, materials, and aesthetics. These structures may be linked to significant historical events, figures, movements, or institutions and are considered prime landmarks in the region. Additionally, all natural sites are categorized as Grade I. Heritage Grade II (A and B) includes buildings and precincts of regional or local significance, recognized for their special architectural or aesthetic qualities, or cultural and historical importance, although at a lesser scale than Heritage Grade I. These structures serve as local landmarks, contributing to the region's image and identity. They may be the work of master craftsmen or exemplify models of proportion and ornamentation, often designed to suit specific climatic conditions of the region. Heritage Grade III includes buildings and precincts that are significant for their contribution to the townscape, offering architectural, aesthetic, or sociological interest, although to a lesser extent than those in Heritage Grade II. These structures help define the character of their locality and may reflect the lifestyles of particular communities or regions. They may also be distinguished by their setting, special character of their façades, and uniformity in height, width, and scale [2]. These heritage buildings serve as a reference point for understanding the culture and technology of the past, making it important to preserve and conserve them properly. This makes it important to document these structures in the form of digital records that can be used as a reference to compare the structural degradation of the structure and to take adequate measures/interventions as required. With the progress of technology and advancement of software, we have the opportunity to explore the integration of BIM into heritage building mapping. As per Marko Radanović et al. [3], historic building information modeling (H-BIM) could be a methodology based on a platform that uses a layered structure, where integrated and interconnected layers can include data and models of different types, such as a polygonal textured mesh, point cloud, and parametric building information model, and help us to interpret the structural stability as well as analyze the aging of the structure.

LITERATURE REVIEW OF BIM TECHNOLOGY

BIM is a digital process used in the architecture, engineering, and construction (AEC) industry to create and manage information about a building throughout its lifecycle. BIM integrates various aspects of a construction project into a comprehensive, data-rich 3D model that includes not only the physical components of a building but also the functional and operational details. Building information modeling should be considered a process rather than a technology. It is a three-dimensional (3D) project computational representation that connects all available information to each 3D object of the model [4]. This could enhance the documentation process using conventional software such as computer-aided design (CAD), producing plan/section/elevation and details in a drawing from practical, based 3-dimensional (3D) data models.

The 1980s marked the rise of the IBM PC, Apple Macintosh, and early Internet, which contributed to the adoption of technology across industries such as AEC, aerospace, automotive, and shipbuilding. During this period, the really universal computer-aided production system (RUCAPS) software was used in the renovation of London's Heathrow Airport, making it the first CAD program to support prefabrication. Later in the decade, the building product model (BPM) emerged, covering the design, estimation, and construction phases of the building lifecycle. BPM was the first platform to manage project information from planning to completion, acting as a living archive of concepts, technologies,

and standards. However, it was limited to individual building components and lacked the collaborative features essential for the AEC industry.

In the 1990s, Autodesk's release of AutoCAD marked a turning point, particularly for architects who saw technology as a complement to their creativity. Later, the introduction of the generic building model (GBM) allowed information from current and future designs to be integrated across a project's lifecycle, fostering collaboration among stakeholders. By the close of the 20th century, BIM reached an inflection point as 3D modeling capabilities and multi-phase BIM information platforms began to merge. Since 2000, BIM has been widely adopted by architects, construction managers, and engineers. The development of professional BIM management software has accelerated with tools such as Jetstream from Navisworks, Autodesk's acquisition of Revit, and the rise of cloud computing. Building SMART International also launched the Industry Foundation Classes (IFC) format, enabling data exchange between software platforms. Governments worldwide, including the UK in 2016, have mandated BIM for public projects. BIM's development has expanded to include mobile access, virtual reality (VR), and cloud-based tools. BIM categorizes information and utility into 3D (shape), 4D (time), 5D (cost), 6D (sustainability), 7D (technical specifications and warranty), 8D (safety), and 9D (lean construction for efficiency and waste reduction), which revolutionizes building construction and management interfaces.

The approach of BIM in the industry has significantly helped improve new construction and management efficiency. On the other hand, it would significantly improve building structural monitoring and decay; incorporating this into practice would significantly impact conservation efforts. These models produced in BIM can represent a collection of data and sources of information about the building material, age of the structure, and recent development of cracks. This could be used to represent critical data, which could be crucial for heritage buildings, as models need to be updated frequently owing to discoveries or interpretations. Some of the critical data that can be tracked using BIM as a tool are geometric data, such as dimensions and volumetric data. Architectural style, which could interpret the style of architecture and extract the historic relevance of culture and practice. Material characteristics, depicting the type of material, can help recreate an equivalent material for conservation or restoration purposes. Façade degradation can help detect changes that occur over time and degrade the aesthetic purpose of the structure. Façade intervention includes the presence of historic scripts, illustrations, and frescoes, which are subjected to degradation by aging. Structural interventions encompass the degradation of structures based on building aging. Environmental change detection refers to changes in the environment that affect the structure, such as air pollution, exposure to chemicals, and natural disasters, etc. [4].

Technology and the Component

BIM technology can create a 3D virtual model of a built structure, which becomes absolutely comprehensible in all aspects and provides the possibility of important utilities during the building life cycle. BIM starts with the initial design and is used as a source of information during the construction phase. All the information is incorporated into a model and can be studied to secure valuable time and cost benefits.

The process of heritage BIM can be defined as a digital time capsule that captures the essence of a heritage structure in 3D and stores information for future use. Preserving heritage sites requires meticulous attention to detail in maintaining their historical, cultural, and architectural significance while ensuring structural integrity and safety, such as 3D, 4D, 6D, 7D, 8D, and 9D.

The methodology of Scan-to-BIM is the most convenient for mapping. Scan-to-BIM corresponds to the process of modeling a building based on its point cloud data. A point cloud is a discrete set of data points in space. The points may represent a 3D shape or object. Each point has a set of Cartesian coordinates (X, Y, Z). Points may contain data other than position, such as RGB colors, normals, timestamps, and others. Point clouds are generally produced by 3D scanners or by photogrammetry [5] software, which measures many points on the external surfaces of objects around them. The 3D footprint

is generated following a survey of the interior (and/or exterior) of the building using 3D scanning technologies. This methodology makes it possible to create or update the digital model of a building based on a footprint representative of reality with centimetric precision. This preservation information collection could depend upon the categorization of heritage buildings, such as Grade I, II, or III.

The initial documentation of a heritage building should begin with a survey using the triangulation method [3] (shown in Figure 1). This involves manually taking measurements, setting reference points (called stations), and triangulating each corner with a laser device or measuring tape. This approach helps minimize errors, as each point is determined through two measurements. With the integration of technology, BIM offers Digital Photogrammetry and Laser Scanning. Digital Photogrammetry, which includes far-range and close-range photogrammetry, can be conducted terrestrially or aerially. When combined with laser scanning, this method enables the creation of accurate three-dimensional (3D) models of buildings and landscapes. It also provides high-resolution details of the material textures and degradation.

Typically, this process involves post-processing photographs, often using a single software package. However, integrating outputs from both Digital Photogrammetry and Laser Scanning can be challenging, as proper calibration is essential to avoid error propagation. The structure from motion (SfM) methodology is also helpful, as it uses high-resolution images and camera movement to detect converging images and digitally reconstruct the 3D geometry of a structure. Terrestrial Laser Scanning (TLS) outputs are point clouds that must be processed before they can be used to build a BIM model. Processing point clouds is an essential preparatory task for creating accurate BIM models. The most common operations involved in this process include Noise Elimination. This step involved detecting and removing any scanned items that were not part of the case study, ensuring that the point cloud data were clean and relevant. Point cloud registration, this merges different point clouds of the same object, which may have been captured during different scanning sessions. The goal was to create a unified and accurate representation of the object. In the meshing step, point cloud data are used to create triangulated surfaces, which are then transformed into 3D models. As shown in Figure 2.

In the context of BIM, level of detail (LoD) and level of information (LoI) define the depth and comprehensiveness of the model. LoD refers to graphical elements, detailing textures, dimensions, and component representations, whereas LoI deals with non-graphical data, such as functionality and performance attributes. For heritage buildings, the LoD is crucial for capturing aesthetic details and tracking degradation over time. The BIM Task Group outlines the progression through BIM levels: Level 0 involves unmanaged 2D CAD, Level 1 introduces managed CAD with limited collaboration, Level 2 includes a managed 3D environment with 4D and 5D data, and Level 3 represents fully integrated BIM with collaborative data management, also known as iBIM (Figure 3) [6–9].

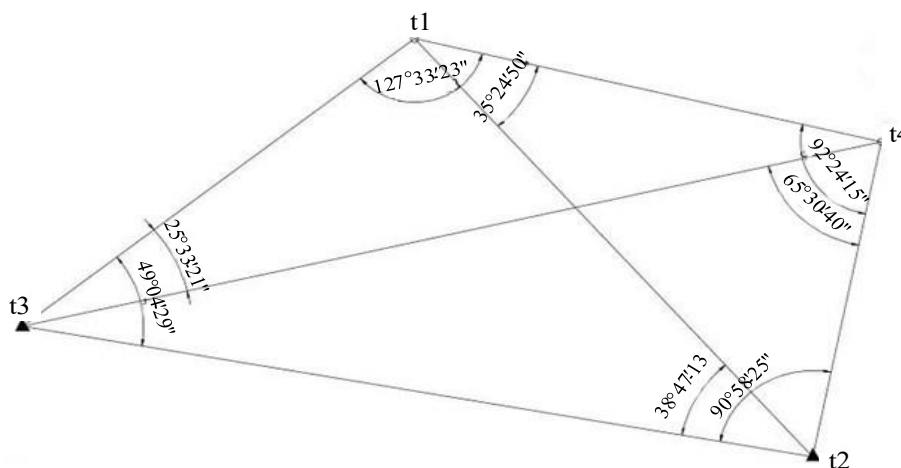


Figure 1. Triangulation method.

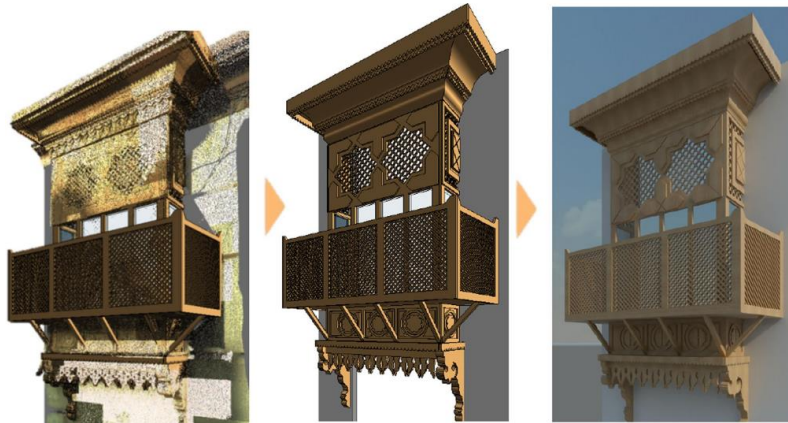


Figure 1. Process of image transformation.

INTEGRATING I-BIM WITH H-BIM

The integration of i-BIM with H-BIM offers a synergy that enhances the management and preservation of historic buildings through advanced digital tools and methodologies. i-BIM, with its emphasis on real-time collaboration, comprehensive data integration, and use of a centralized model server, facilitates seamless communication among various stakeholders, enabling them to work concurrently on different aspects of a project. This level of integration is crucial for managing complex building projects, where the coordination of multiple disciplines, such as AEC, is essential for ensuring accuracy and efficiency [10, 11]. When applied to H-BIM, which focuses on the documentation, analysis, and preservation of historical buildings, i-BIM's capabilities allow for a more sophisticated approach to the management of heritage sites. H-BIM models typically include detailed geometric representations of buildings, along with non-graphical information such as historical records, material compositions, and previous restoration efforts. By integrating these models within an i-BIM framework, stakeholders can benefit from enhanced data management, where historical information is directly linked to the physical model, thereby enabling better decision-making for conservation and restoration. Moreover, i-BIM's ability to incorporate various dimensions of data—such as 4D (time), 5D (cost), and even 6D (sustainability)—into the H-BIM environment allows for a more dynamic and predictive modeling of historic buildings. For example, project managers can simulate the impacts of different conservation methods over time, assess costs more accurately, and evaluate the sustainability of restoration materials. This integrated approach ensures the accurate preservation of historic structures and facilitates their adaptation to modern uses while maintaining their cultural and historical integrity. In summary, the integration of i-BIM with H-BIM offers a comprehensive and nuanced approach to managing historic buildings, combining advanced technological capabilities with a deep respect for heritage and conservation [11, 12].

CASE STUDY OF THE BOROBUDUR TEMPLE (INDONESIA)

The Borobudur Temple Complex is one of the greatest Buddhist monuments in the world, built in the 8th and 9th centuries AD during the reign of the Syailendra Dynasty. The monument is located in the Kedu Valley in the southern part of Central Java, Indonesia. The main temple is a stupa built in three tiers around a hill, which was a natural center: a pyramidal base with five concentric square terraces, the trunk of a cone with three circular platforms, and a monumental stupa at the top. The walls and balustrades are decorated with fine low-relief carvings, covering a total surface area of 2,520 m². Around the circular platforms are 72 openwork stupas, each containing a statue of Buddha. The Borobudur Temple Compounds consist of three monuments: the Borobudur Temple, Mendut Temple (whose depiction of Buddha is represented by a formidable monolith accompanied by two Bodhisattvas), and Pawon Temple (a smaller temple whose inner space does not reveal which deity might have been the object of worship). These three monuments represent the phases of attaining Nirvana.

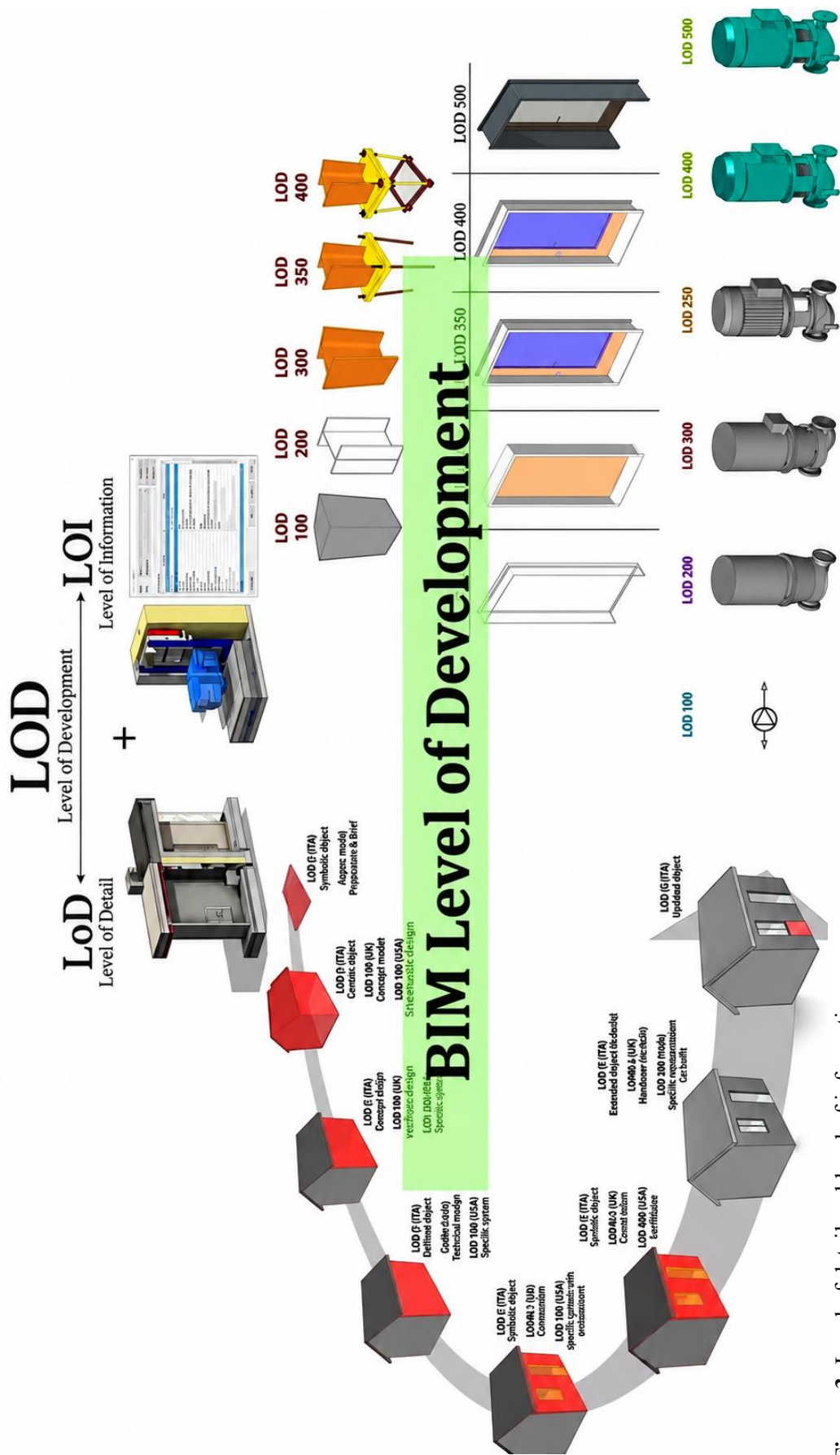


Figure 3. Level of detail and level of information.
Source: BIMCAFE

Being a World Heritage site under the listing of UNESCO (can be considered under the protected category), the site received two significant funding rounds in 1998 and 1999 for the purpose of conservation and preservation, and the reporting trend indicates that regular reporting is done based on conservation efforts by the authorities [13–21].

The integration of H-BIM in documenting Borobudur Temple has significantly advanced preservation and management, utilizing a combination of UAV (unmanned aerial vehicle) and terrestrial photogrammetry. The trends in reporting by UNESCO (World Heritage Convention) show an upward trend (as shown in Figures 4 and 5). The project produced highly detailed 3D models of the temple, capturing both its vast scale and intricate architectural details. The fixed-wing UAV provided comprehensive ortho-photos and a digital elevation model (DEM) of the site, while the hexacopter UAV delivered high-resolution imagery of the temple's structure. Terrestrial photogrammetry was employed to model delicate bas-reliefs and carvings, creating a multi-layered, interactive 3D representation. This approach facilitated an effective spatial database and a web-based visualization platform, enhancing the ability to monitor deterioration, plan restorations, and manage the site's conservation efforts [22]. The case study underscores H-BIM's transformative role in heritage conservation, offering a robust framework for documenting and preserving cultural treasures (Figures 5 and 6).

Process of Documentation

A fixed-wing UAV was used to capture the surrounding area of the Borobudur Temple (1 km × 1 km). A hexacopter was flown at a lower altitude to capture the temple (120 m × 120 m) at high resolution. Finally, terrestrial images were used to capture and digitize the model details of the temple (e.g., relief on the walls) and the technique for surveying and modeling the site (Figure 7) [23–26].

Ground Control Points (GCP) measurement, performed with Global Navigation Satellite System [1] (GNSS) or total station instruments, is fundamental for scaling and geo-referencing [2] purposes, but also to check the quality of the photogrammetric processing. As per Deni Suwardhi et al, Borobudur Heritage Conservation (BHC) set up a control network made of 84 GCP's in a local coordinate system (Figure 6 left). Later, six new GCP's were measured using geodetic GNSS double-frequency L1/L2 receivers with good distribution covering the Area of Interest (AOI), implementing rapid static differential positioning. Every GCP must be measured for at least 30 minutes to get sub-centimeter accuracy, considering an adequate distance between the master and rover receivers.

A fixed-wing UAV flew 280 m above ground to cover around 1 km² to capture ortho-photos of the surrounding area of the temple. A flight plan was prepared (Figure 6 left), with an 80-60% overlap and a planned ground sample distance (GSD) of 7 cm. The camera mounted on the platform was the Sony NEX-7 (23.4 x 15.6 mm sensor size with a pixel size of 3.9 microns) coupled with a 20 mm focal length. Five strips were designed to cover the area around the temple (Figure 6 right). Images were acquired in vertical as well as oblique mode to capture the details of the vertical façades of the temple. For the vertical images, the UAV was flown at 50 m above the ground, mounting a Sony NEX-5 camera with a 16 mm focal length. This flight aimed to map the temple at a lower scale (1.5 cm GSD on the ground) than the fixed-wing. On the other hand, oblique images were acquired flying at 20 m, 30 m, and 35 m above the ground using the same camera [27–29].

Terrestrial photogrammetry aims to capture great detail of the structure, such as reliefs in vertical walls or other decorations. A mix of parallel axis and convergent images was acquired to ensure reliable self-calibration, achieve a complete 3D reconstruction of the details, and collect suitable stereo-pairs for successive interpretations and analyses by experts. The employed camera was a Sony RX100 Sony RX100 (Figure 7).

Set of data received through the Terrestrial and Areal photogrammetry Table 1.

Reporting Trend

Reporting trend based on the frequency at which the World Heritage Committee has deliberated over this property over the past 15 years. 0 = minimum reports, 100 = maximum reports.

For more information consult the State of conservation of the world heritage forest network

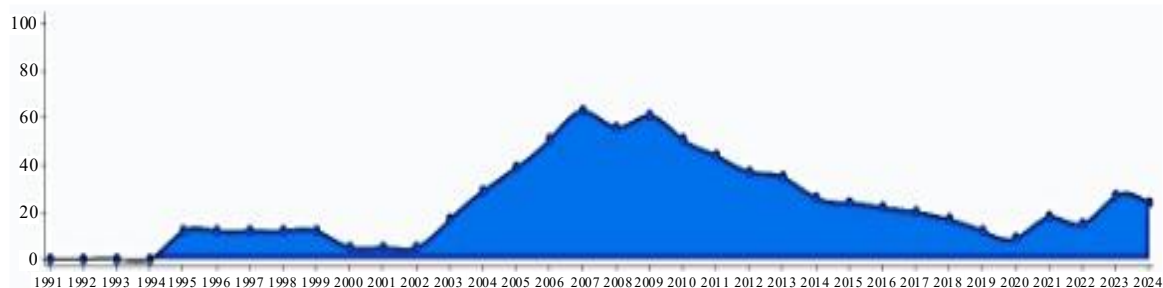


Figure 4. Reporting trend by the UNESCO (World Heritage Convention), available at <https://whc.unesco.org/en/list/592/indicators/>



Figure 5. The geographic location of the Borobudur UNESCO site (left) and some images of the temple with its stupa and bas-reliefs.

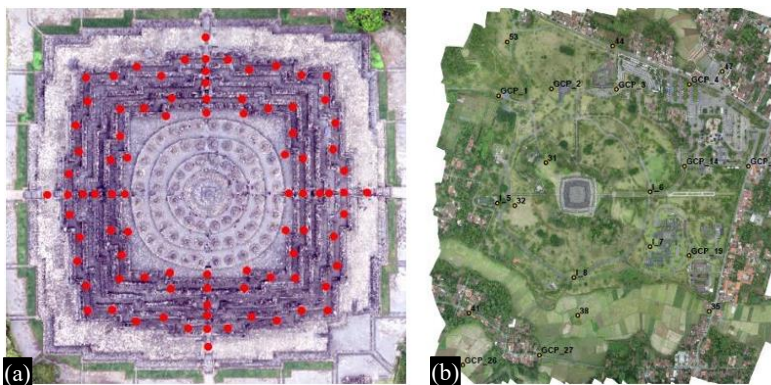


Figure 6. (a) to (b) The BHC GCPs network on the temple (Left) and the GCP's distribution for the UAV fixed-wing images (Right).

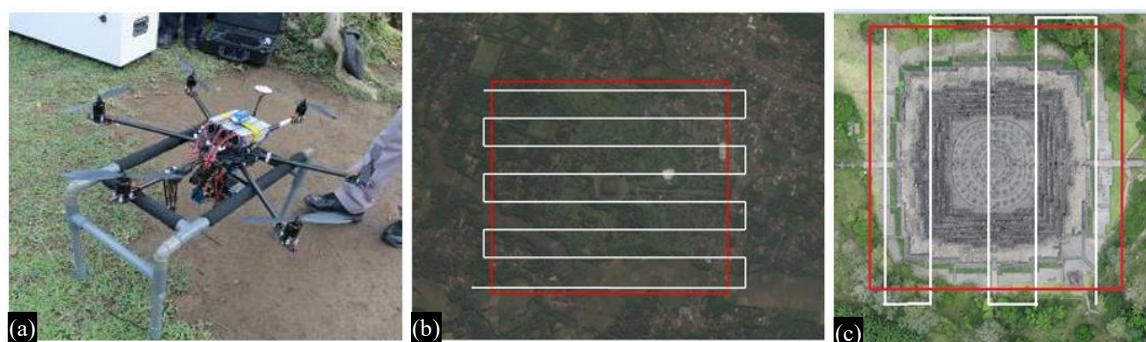


Figure 7. (a–c) The planned flight strips for the fixed-wing UAV (GSD = 7 cm) and for the hexacopter UAV (GSD = 1.5 cm).

Table 1. Data and sources of collection.

	Data	Scene	Product
LoD 0	Fixed-wing UAV	Landscape and Temple	DEM, Ortho-Scenes
LoD 1	Hexacopter UAV (nadir) [4]	Temple and Stupa	Ortho-Scenes, 3D Models
LoD 2	Hexacopter UAV (Oblique)	Stupa and ornaments	3D Models
LoD 3	Terrestrial images	Bass reliefs	3D Models

Development of Geospatial Database

The post-capture of spatial and terrestrial data and information on the development of geospatial databases plays a vital role, as it includes the design of a data model that shows which data must be included in the database and the significance of the interdependence of the data is structured.

For the Borobudur Temple, the database design process is structured into three significant phases:

1. Conceptual modeling.
2. Logical modeling.
3. Physical data modeling.

After the integration of the three modeling stages, the final model is transferred to a physical data model using the syntax of PostgreSQL or PostGIS, which follows object-relational database design. Following the database, a web-based application was designed, which includes the SDK of the data model for visualization [30–34].

3D Web-Based Management and Analysis

Through the process of data collection and database creation to visualize the data, the interpretation of the data can be done easily. The Borobudur Temple is extremely vulnerable to heavy rains, earthquakes, and volcanic activities. The site has been damaged by earthquakes, which are very strong in the vicinity of Java Island (200 km), moving the ground surface as waves with imaginable consequences for the structural integrity of the temple. The ash of volcano Merapi, which erupted very frequently in the last few years (on average every 3–4 years), covers the temple, deteriorating the ancient stones. The site was closed to visitors due to ash coming from the volcano. This makes it essential that each stone composing the temple and its outstanding reliefs be classified, indexed, and georeferenced. For this purpose, the above-mentioned methodology encouraging 3D technology represents a powerful solution for the conservation efforts needed at ancient sites.

For documentation, the process of mapping must be repeated at equal intervals and during predictive incidents (including environmental causes).

DISCUSSION

Based on the successful implementation of H-BIM at the Borobudur Temple and the insights gained from the project, this study suggests that the role of BIM in Architectural Conservation plays an important role in maintaining historic assets. Physical intervention in conservation documentation is limited to certain areas of reach in a structure and tends to be time- and labor-intensive for mapping and documentation. The implementation of BIM model generation through Scan-to-BIM technology and point clouds could result in intensive mapping and structural monitoring. Pre- and post-disaster mapping would be a significant effort that could help conservationists in decision-making and intervention planning. The expansion of multisensor techniques, including UAVs, terrestrial photogrammetry, and laser scanning, is crucial for capturing comprehensive data. This multisensor approach should become the standard in future heritage conservation projects, ensuring detailed and accurate documentation. Although this technology is cost-intensive, it could result in protecting the heritage structure. This mapping could play a significant role for unprotected structures, as per the ASI, India accounted for around 800 unprotected heritage structures in the 2015 survey. Karnataka topped the list with 177

structures in the state. The unprotected status of these structures leads to a lack of maintenance or no maintenance, which leads to degradation of the historic façades and loss of significance.

Heritage is the base of tourism in India, reflecting the cultural treasury. Iconic sites like the Taj Mahal, Jaipur's forts, and Varanasi's ghats attract millions of visitors, contributing significantly to the economy through tourism-related services and local businesses. Beyond economic benefits, heritage tourism promotes the conservation of historical monuments and traditional arts, sustains artisanal communities, and safeguards India's cultural identity. Spiritual destinations such as Rishikesh and Varanasi also draw pilgrims, merging cultural significance with spiritual exploration. Through heritage tourism, India preserves its past, fosters international goodwill, and supports sustainable regional development. One of the key areas of discussion of lost heritage and unprotected structures of historic importance could be the town of Dhanyakuria in West Bengal.

During the 1700s, when the British were decking up the city of Calcutta (now Kolkata) with flamboyant buildings, a few rich businessmen decided to set up their fairyland in the Dhanyakuria village, creating their own Europe in India. They ranged from huge bungalows to castles. The land of Dhanyakuria was once considered a land of fairy tales, but it has now turned into a collection of dilapidated structures with no significant place in the historical record, apart from being a spot for filming local regional movies [35].

Located 60 km east of Kolkata, Dhanyakuria is a historical symbol of entrepreneurial spirit and community development. In 1742, Jagannath Das and his family settled in Dhanyakuria, then part of the Sundarbans, a vast mangrove forest straddling India and Bangladesh. When Bengal (then undivided) faced raids from the Bargaris, mercenary Maratha marauders, many sought refuge outside the capital. Jagannath Das, followed by families such as Mandal, Sawoo, Gaine, and Ballav, established a new home in Dhanyakuria. These families, primarily traders and agriculturists, built grand mansions in classical European styles, featuring Corinthian and Ionic pillars, towers, and figurines, which stand today as testaments to their entrepreneurial success and financial prosperity [35–37].

The wealth generated by these families was not only invested in the magnificent structures but also in the development of educational and healthcare facilities. Among them, the Gaine, Sawoo, and Ballav families played particularly significant roles in the village's growth. Dhanyakuria's prominence as a trading and healthcare hub was further highlighted by the establishment of a station, Dhanyakuria G. Garden, on the Hasnabad-Shyambazar line of the Barasat-Basirhat Light Railway, operated by Martin Burn Company.

In 1820, Ramkishore Gaine arrived in Dhanyakuria and, along with the Sawoo and Ballav families, initiated successful ventures in trading ghee, sugar, jute, and jaggery. The village flourished, and profits were funneled into real estate and other business opportunities. Over time, members of these families pursued different occupations; however, the legacy of their contributions to Dhanyakuria's prosperity endures [36, 35].

As they flourished with Bengali (regional) culture, these large mansions had their own traditional Durga Puja (Listed under the UNESCO Intangible Cultural Heritage of Humanity, 2021) in their own Thakur Dalan (courtyard). The development followed a trend, as what one business family did was soon followed by other businessmen who settled in this locality, and the development continued. The following are the significant structures found today. According to a survey conducted by the author in January 2024. Some of the significant structures in the town are Gayen Bari Bagan Bari, Gayen Bari, Nazar Minar, Sawoo Mansion, Rashmancha, Ballav Bari, Mundul Lodge, Shyamsundar Jiu Temple, and other temples, schools, and offices. The structures are mentioned below.



Figure 8. Gayen Bari at Dhanyakuria.



Figure 9. Gayen Bari and Nazar Minar.

Gayen Bari Bagan Bari (Garden house of the Gayen family)

Gayen Bari (Bari refers to a residential house in “Bengali”) is a summer garden house built by Gopinath Gaine of the Gayen Family in the 1800s. Located on the Kolkata-Taki Road, it marks the entrance to the town (Figure 8).

The property spans 3.7 hectares of land parcel in the town. It houses an iconic gate, mansion, landscape areas, and ponds. The present condition is dilapidated, with overgrown grass and vegetation growth on the façade. The European symbols in the structure and motifs of the sculpture remain undocumented and in a degraded condition. Presently, the ownership of this property is not with the Gayen family but has been converted into an orphanage, which was later shifted to a new location due to the lack of maintenance of the structure. [36, 35].

Gayen Bari and Nazar Minar

The Gayen Bari, located in the interior of the town of Dhanyakuria, was built by Mahendranath Gaine, son of Gopinath Gaine, in the 1840s. This residential building was constructed in several phases and stands as one of the most well-maintained buildings. This building is still inhabited by the members of the Gayen family and is periodically leased out for filming movies and TV shows.

The structure features colonnades of Corinthian columns and European details. Another interesting structure within the premises of Gayen Bari is the Nazar Minar. This is like a three-storeyed watchtower with a fusion of Islamic and European architectural styles. This is similar to a watchtower built within the compound Figure 9 [35].

Sawoo Mansion

The white Sawoo Mansion stands in the lane directly opposite the Gaine Mansion. Built by Patit

Chandra Sawoo around 200 years ago, the mansion features Corinthian pillars and stucco over the window arches. Some windows are shaded, whereas others display stained-glass designs within subdivided arches. The Sawoo family, like the Gaine and Ballav families, amassed their fortune through the trade of jute, jaggery, and rice Figure 10 [37].

Ballav Bari

Ballav Bari, also known as Putul Bari, was built by Shyamacharan Ballav approximately 150 years ago. It was constructed with wealth accumulated primarily through the jute trade. Despite being smaller than other grand structures in Dhanyakuria, its architectural charm lies in its beautifully adorned white façade, featuring a mix of Indian and Western influences. The building's unique idols atop the structure earned it the nickname “Putul Bari” (House of Dolls) among the locals (Figure 11) [35, 37].

The structure not only reflects non-Indian architectural features but also contains inscriptions that are degrading beyond recovery. Restoring an entire town, such as Dhanyakuria, is complex and labor-intensive. However, using H-BIM can streamline this process by creating structured data. Tools such as PostgreSQL or PostGIS can store this data, aiding in mapping and developing visual resources for tourists. This can boost tourism, generating economic opportunities, especially for Basirhat, where tourism can support the local cottage industry and create jobs in an area lacking major industries. Using the gathered data, heritage walks could be conducted, which would generate economic opportunities for the people and help the cottage industry develop tourism products.

Tourism is a major sector of the West Bengal economy, and the state has seen a 300% increase in tourist arrivals since 2000. The tourism economy, which is considered under the Service sector in the tertiary economy, would cater to a source of local jobs and employment generation.



Figure 10. Sawoo mansion.



Figure 11. Ballav Bari and Nazar Minar of Ballav Bari.

CONCLUSION

The application of H-BIM represents a transformative approach to the documentation, preservation, and management of heritage sites. By leveraging advanced digital technologies such as UAVs, terrestrial photogrammetry, and laser scanning, H-BIM provides a comprehensive and detailed method for capturing and analyzing heritage structures. The case study of the Borobudur Temple demonstrates how these technologies can effectively document intricate architectural details, monitor structural conditions, and manage conservation efforts. The integration of H-BIM offers significant advantages, including enhanced data accuracy, improved decision-making, and the ability to engage stakeholders through interactive platforms, as discussed below.

The case of Dhankyakuria represents one of the many unprotected and unknown heritage assets that need documentation, irrespective of the status of protection. These assets, once destroyed, do not provide another chance to generate information. In conclusion, H-BIM not only enhances our capacity to protect and conserve cultural heritage but also facilitates greater public engagement and appreciation of cultural heritage. By implementing these innovative methodologies, we can safeguard the historical, cultural, and architectural significance of heritage sites for future generations, ensuring that these cultural treasures remain accessible, well-preserved, and relevant in an ever-changing world.

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Credit Authorship Statement

1. *Sayan Munshi*: Conceptualization, investigation, data curation, formal analysis, writing—original draft preparation, visualization.
2. *Devesh Mani Tripathi*: Methodology, Supervision, original draft preparation, writing—review and editing.
3. *Dr. Sumanta Deb*: Methodology, validation, writing—review and editing. conceptualization.

Declaration of Competing Interest

The authors declare that they have no competing financial interests or personal relationships that could have influenced the work reported in this study.

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