The digital management system of the tangible culture heritage for enhancing historic building governance in Malang, Indonesia

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Abstract. The development of a digital management system to support historical building assets' management process based on public participation is the latest innovation in preservation, conservation, and restoration activities of historical buildings. In line with the importance of applying Good Governance principles in the 4.0 Industrial Revolution in Malang city government, it is essential to develop a Governance Digitalization system to support sustainable tourism in heritage tourism management. This study aims to establish a digital management framework system for Tangible Culture Heritage based on HBIM to manage historical building assets in Malang. This system focuses on the cultural heritage assets of Malang City that represent the three developments in the Dutch Indies architectural style. The BIM capability implemented in historical buildings in Heritage Building Information Modeling (HBIM) terminology can bring complexity and depth of information to historical buildings towards a sustainable lifecycle heritage management framework. This research implements the 3D modeling automatic reconstruction method (3D Laser scanner) processed with Building Information Modeling (BIM) based software. The process consisted of 3 (three) stages: identifying and mapping Historical Landmark Buildings, developing 3D content models, and generating HBIM data viewer application. This study's results reveal that using 3D laser scanning technology can accelerate the recording process and object modeling of the HBIM library, offering high accuracy and efficiency in recording complex structures and architectural elements. The final result of HBIM modeling is translated into interactively present the 3D model and 2D documentation of Historic Building Information Models through the HBIM mobile data viewer.

Keywords: Urban Governance; Tangible Digitalization; HBIM; Historic Building; Malang

1. Introduction
The development of the digital management system through the conceptual framework of tangible digitization in architectural multimedia systems of historic buildings in Malang City is needed to improve good governance in preservation activities and conservation management on heritage buildings. This effort also aims to build a digital database and preserve the cultural heritage as an asset for Malang. The digital database development is in line with the UNESCO consensus in 2011, which pays attention to member countries and relevant local authorities to identify and take essential steps to implement the
Historic Urban Landscape approach. One of the critical consensus necessitates building right partnerships and local management frameworks to identify conserved buildings or landscapes and develop conservation management to coordinate various activities between different actors, both public and private [1]. Furthermore, the development of a spatial development system will refer to the rules of the Digital Platform for Urban Heritage Management. Therefore, the development of a spatial multimedia system must have complete data that contains three important information, namely historical layer data, present situation data, and future planning data.

On the other hand, architectural multimedia systems’ development to support the urban planning process based on public participation is the latest urban planning and urban design activities. The use of multimedia systems is intended as a media interaction between disseminating the concept of planning and designing the built environment and the community as users. This system’s development also aims to construct architectural information on building and urban spaces online, especially architectural information on historical buildings.

The digital management System of tangible cultural heritage is related to the tangible digitalization process. Tangible digitalization is defined as a method that creates digitally 3D modeling (virtual 3D) from tangible objects containing various kinds of physical and visual information about these historical buildings. The most recent Tangible Digitalization approach is the HBIM (Heritage Building Information Modeling) method, which is derived from the BIM method only. Initially, the BIM method was often used in the construction sector to make the construction work process efficient. Along with the increase in conservation and preservation activities of historical buildings, the BIM method has also been used to apply to historic buildings, so the term HBIM method has emerged. Various studies and practical activities have proven the HBIM method’s reliability in documenting and scanning all information on historical building objects related to metadata, such as historical data, conservation policies, and significance values [2], [3]. HBIM method has the opportunity to improve the management of historic buildings in the life cycle management stages, such as the intervention, execution, maintenance, and even dissemination of historical building conservation assets to the broader community [4], [5].

The accurate and representative 3D modeling supports efforts to develop a digital management system to preserve and preserve historic buildings. Realistic 3D building models are beneficial for simulation purposes [6], [7]. A digital survey technique is needed to produce detailed 3D models that are attractive and useful for various purposes in cultural heritage [8]. Image-based virtual 3D modeling technology currently uses three approaches, namely sketch-based modeling, for example, SketchUp; procedural grammar-based modeling; and photogrammetric-based modeling [9]. Various factors influence the choice of the 3D modeling technique, and the most determined is the cost factor [10]. On the other hand, the automatic 3D reconstruction method becomes very popular due to cheap and widely available free software [11].

The tangible digitalization method is related to utilizing automatic reconstruction 3D modeling techniques, such as 3D laser scanning and photogrammetry. 3D Laser scanning is the latest automatic 3D reconstruction technology used to accurately document and model various objects [12]. Laser scanning was considered the only viable 3D digitizing tool in the early 2000s [13]. Laser scanning has been famous as a 3D documentation technique for more than a decade [14]. Laser Scanning (TLS) is often used to record large and complex objects or sites [7]. It is often preferred and has become the definitive source for 3D data in many application areas, although it is not optimal [14].

On the other hand, compared to 3D laser scanning technology, the photogrammetric technique can also achieve small details of objects or areas as can be achieved by Terrestrial Laser Scanning (TLS) precisely [15]. Photogrammetry is the art and science of measuring, obtaining information about surface properties, determining the position of 3D points and the shape of an object, then converting it into a photo/image-based 3D model [16], [17], [14], [18]. The main photogrammetry application areas are cartography, mapping, and documentation of cultural heritage 3D models [19]. Photogrammetry uses photos or images as a source of information and integration with computer vision [20]. Computer vision is a mathematical technique that has the goal of presenting 3D models [21], [18] in an image-based...
digital form [14]. Computer vision has provided additional automatic image orientation [22] and reconstructing 3D models at different scales [11]. The integration of photogrammetry and computer vision can convert 2D photos/images into 3D models in an automatic, flexible, and good quality way. Therefore, photogrammetric technology, on the one hand, is considered easier in the availability of devices and processes compared to laser scanning technology [23].

The implementation of tangible digitalization with HBIM involves a reverse engineering solution. The parametric objects represent architectural elements mapped into laser scans and photogrammetry survey data. This process includes several steps to obtain the final product. First, the collection and processing of the laser survey data. Second, identifying historical details from a database of architectural patterns. Third, constructing the parametric components of historical objects. Fourth, correlating and mapping the parametric objects to the scan data. Fifth, the final production of the image technique and documentation. HBIM automatically generates full technical drawings to conserve structures and historic environments, including 3D documentation, perspective projections, section drawing, detailed graphics, and scheduling aspects [1], [24].

The case study of the digital management system of the tangible cultural heritage based on HBIM takes a research on historical landmark buildings in Malang, Indonesia. Tasks related to digital scanning of historical buildings in the city of Malang have been carried out through field survey methods, direct measurement, and photo shooting at the location to implement the close-range photogrammetry method of a drone device (UAV). However, digital scanning through a 3D laser scanner in historic landmark buildings, especially in Malang, has never been applied, primarily when related to the digital management system based on HBIM. Historical landmark buildings have become significant cultural heritage assets of Malang city, which marked Malang city's growth journey during the Dutch colonial period until 1935 [25]. On the other hand, the development of a digital system in these historic buildings also aims to help build a digital database for the historic building certification process, which can be more accurate and valid. Implementing the HBIM approach is very important to certify historical buildings, especially in developing a digital database to identify object libraries for all physical architectural elements. In further interest, this digital database system will be useful in the decision-making process for any preservation, conservation, and maintenance activities. Therefore, overall this research produces a conceptual framework for the Digital Management System for Tangible Culture Heritage based on HBIM.

2. Method
This research uses 3D modeling automatic reconstruction method device (3D Laser scanner), supported by AutoDesk Revit and ArchiCAD software to build Heritage Building Information Modeling (HBIM) of historical buildings Malang. The 3D laser scanner is used to conduct 3D object scanning surveys in the six historical landmark buildings. Historic landmark buildings scanning survey is carried out on the exterior and interior of the buildings. The scanning results can reconstruct the buildings' outer and inner covers, which is useful for knowing the building's geometric arrangement.

2.1 Case study
This research is focused on the types of historic landmark buildings in Malang (see Figure 1). Malang City is one of Indonesia's cities with many beautiful urban landscapes built during the Dutch colonial period. Three periods were bringing out three crucial urban landscapes in the Dutch Indies architectural style in Malang, namely the Indische Empire style in the 19th century (1850-1900), the early modern colonial style in the early 20th century (1900-1915), and the Nieuwe Bouwen style in the 20th century (1916-1940) [26]. The historical landmark buildings chosen as the research sample were historical landmark buildings that formed the Malang city's image until 1935. First, Kayutangan Church, which is the oldest Catholic church in Malang. Second, Ijen Church is a Cathedral Church in Malang City. Third, PLN Building with its Nieuw Bowen architectural style. Fourth, Frateran School, whose building is characterized by red brick paint. Fifth, the City Hall building, which is the witness to the Malang City government's history. Sixth, Tugu Square, which is a symbol of the center of colonial government during
The colonial period and after independence, has become a symbol of the upholding of Indonesian independence with the establishment of an independence monument there.

The Kayutangan Church was built in 1905 in the Neogothic style. The building's structure has a solid frame on the walls and roof that serves as a cover. The church also has large windows and doors in the walls built in skeletal construction. This element can be seen in the church's outer wall, which is supported by square-shaped wall supports. In the meantime, Ijen Church is the embodiment of Dutch Neo-Gothic architecture, so it is an ancient historical relic that started its construction on February 11, 1934, and was inaugurated on October 28, 1934. The Ijen Church is a landmark of Malang City and is
an elegant, beautiful, and sturdy building with Neo-Gothic architectural style as an influence from the Gothic style.

Meanwhile, the PLN building initially named the Electriciteit Office of Mij Aniem N. V. Malang or the Malang branch of the State Electricity Company, was built around the 1930s with the typical Nieuwe Bowen architecture with flat roofs, horizontal gevels, and a cube-shaped building volume. The Frateran School was founded on September 12, 1928. In the early period, this building functioned as an educational institution for the Ursuline nuns, which later became HCS (Holland Chinese School), until finally it was known as Frateran. It is a very distinctive building appearance that makes it a very dominant landmark building in Malang City. In the meantime, The City Hall Building was built in 1927-1929, which consists of two floors. The orientation of the building is facing north-south. Because of the location and main shape of the location, it was as if the City Hall wanted to control the JP Coen square beautifully. The building looks symmetrical, with the main door right in the middle. Above the entrance are a meeting room and a large terrace flanked by the mayor's room and the Daily Council. All traffic must go through the main door. Public related offices are located on the lower floors. The situation of the building is very supportive so that the building looks monumental and magnificent.

Meanwhile, Tugu Square is a spherical field with a fountain in the middle, which was initially named JP Coen Plein as a form of respect for Governor-General Jaan Pieterzoen Coen. JP Coen was also known as the founder of Batavia (Jakarta). A year after the independence Proclamation, an independence monument was erected in the middle of Tugu Square to undermine the exclusive Tugu Square's colonial image.

2.2 Research method
This study aims to develop a conceptual framework for spatial multimedia systems of historic buildings in Malang using the Heritage Building Information Modeling (HBIM) system. The HBIM system integrates visualization techniques of three-dimensional spatial modeling with interactive 3D geometry model 2D data packaged in an interactive mobile application system. The purpose of this research is to build a digital management framework system for the management of historical building assets in Malang, which is related to the optimization of the renovation, maintenance, and conservation processes.

![Figure 2. Research framework.](image)

The research strategy consists of three essential stages that optimize the 3D modeling automatic reconstruction method based on Building Information Modeling (BIM) software (see Figure 2). First, identifying and mapping Historic Landmark Buildings using the 3D model object automatic reconstruction process of historical buildings with 3D laser scanners (Leica RTC 360). The main objective is to collect primary data in identifying and scanning historical buildings' visual data. Second, developing BIM-based 3D content modeling of historical buildings generates a dynamic interpretative model that is accurate, measurable, and realistic. It builds an object library that accommodates geometric data, dimensions, architectural and historical information [27], [28]. Third, the development of an
interactive multimedia system for the historic building based on HBIM. This stage aims to develop the data integration of the 2D drawing and 3D model data and historical building object libraries in web-based viewer application system programming (online system). This stage is related to delivering a mobile HBIM data viewer that accommodates public access to the interests of all planning, preservation, conservation, and maintenance activities.

3. Finding and discussion

3.1 The identification and mapping of historic landmark buildings

The digital scanning process of all the historical building sample objects using a 3D laser scanner is carried out in collaboration with P.T. Leica Geosystem Indonesia. The device used to perform the scanning is the Leica RTC 360 3D laser scanner, which is the latest 3D laser scanner technology capable of laser scanning and image data capture at the same time. The choice to use this type of 3D laser scanner in scanning historical building objects is based on high time effectiveness and does not require a long time to produce digital scannings of building objects in the form of 3D point cloud data. The optimization of a 3D laser scanner can reduce the field survey's time duration in each historic building so that the survey load and field personnel will be lighter and more effective.

Figure 3. Placement location map of 3D laser scanner on each historic landmark buildings, i.e. (a) Kayutangan Church, (b) Ijen Church, (c) PLN, (d) SMK Frateran, (e) City Hall, (f) Tugu Square.

The 3D laser scanner scanning duration also depends on the building object's area and the amount of closed or isolated space. This condition resulted in various scanning points performed on each historical building object (see Figure 3). The number of record points for each historical building object is as follows (1) Ijen Church building: 47 points (2) Kayutangan Church building: 43 points (3) PLN building: 55 points (4) City Hall building: 71 points (5) Tugu Square: 15 points (6) SMK Frateran: 115 points. The survey documentation of the 3D laser scanning process in the historical buildings can be seen in figure 4.
3.2 3D content models of historic landmark buildings

The making process of 3D content models of historic landmark buildings aims to reconstruct a dynamic interpretative model that will become a digital database object library of each historic building. The 3D digital reconstruction process of historical building models involves two main software tools: Autodesk Revit and ArchiCAD. Autodesk Revit software is intended for the essential modeling and 3D point cloud data leveling of each historic building. In contrast, the ArchiCAD software is intended for the advanced modeling stage of 3D point cloud data for each historical building to produce complete and detailed 3D digital modeling. Autodesk Revit and Graphisoft Archicad software support the IFC open format that provides a high interoperability level between different BIM platforms [27]. The workflow of 3D Content Models Processing can be seen in figure 5.

Technical procedures in processing the results of 3D point cloud record data on Cyclone REGISTER 360 include (1) Download the scan data from USB and copy it to a laptop, (2) Import project 360 data into the cyclone register 360 software, (3) Merge data between one point with another point until all the data has overlapped (4) Import UTM coordinates obtained from Garmin GPS into the cyclone software (5) Process of filtering data (cleaning objects) that are not needed (6) The process of exporting data into the formats (las, e57, and lgs), which are required for post-processing in Autodesk Revit and Graphisoft Archicad software. The next stage is the primary modeling stage and the 3D point cloud data leveling of each historical building in Autodesk Revit software. The technical steps carried out include (1) Importing point cloud (RCP / RCS) Leveling, (2) leveling according to point cloud, (3) Tracing buildings, (4) Tracing detail (door tracing, glass and façade, (5) Export simple tracing results in the form of IFC (.ifc). At this stage, the data transfer interaction process with the Graphisoft Archicad software is possible. Archicad software supports the advanced modeling process and produces object library data for each historic building. The technical procedures carried out include (1) Open IFC file from Revit, (2) Tidy up the layers (unlocking, visibility), (3) Make columns and slabs, (4) Make roofs (roof, shell, and custom types), (5) Make assets (Archicad - sketch up immersion), (6) Incorporate assets (glass, doors, facade, detail), (7) Publishing arrangements (pages, scale, notation), (8) Publishing (BIMx, paper
project). The primary technical procedures result from 3D point cloud data to BIM on each historical building can be seen in figure 6.

![Figure 6. Basic and advanced modeling process in Autodesk Revit and Archicad.](image)

The Archicad software's modeling process's final result produces 2-dimensional construction digital image data and HBIM 3D model data as the object library database, which contains geometric, dimensional, architectural, and historical information. The 2-dimensional construction image data is a 2-dimensional construction detail image of a historical building equipped with the geometric shapes of space and dimension data of each historical building element. Completeness of 2-dimensional construction detail data includes building floor plan drawings, building elevations, building sections, and detailed building elements. On the other hand, the HBIM 3D model data is a visual and spatial representation of historical buildings' architectural formation. Overall, the reconstruction of historical landmark buildings through BIM software processing can be seen in Figures 7.

![Figure 7. Digital database of a dynamic interpretative object library of historic buildings.](image)

The making of each building element's parametric objects must pay attention to each historic building's architectural style. The making process of each historical building element into a parametric object library involves Geometric Descriptive Language (GDL) programming language technology. Archicad graphical software supports Geometric descriptive language (GDL) technology, an open
script-based language for creating library parts for each historical building element. This language programming technology is beneficial for building the distinctiveness of each historical building element's character. Therefore, before constructing a parametric object on each historic building element, it must first be recognized and understood the architectural style inherent in each building. The research object of six historical landmark buildings includes two Dutch architectural styles: the early modern colonial style in the early 20th century (1900-1915) and the Nieuwe Bouwen style 20th century (1916-1940). One of the oldest historical landmark buildings in the research object sample is Kayutangan Church. Kayutangan Church has a flow of Neo-gothic architectural style built in the early modern colonial style. This church has a repeating style with a Gothic style, which has experienced simplification due to its development during modernization. The most prominent characteristic is the presence of two towers on the front right and left of the building. The second characteristic is pointed decorative architecture, slender, tall, arched, and angled, which can be seen in the central doorway, windows, and stained glass. The third characteristic is the existence of small vertical windows that are arranged side by side. Meanwhile, the fourth feature used a round window (named Rozeta) on the wall above the main entrance, rose-shaped and made of colorful mosaic glass. In general, identifying the peculiarities of the architectural style's character in the elements of a historical landmark building at Kayutangan Church can be seen in Figure 8.

Figure 8. Sample of parametric object library of Kayutangan Church.

3.3 An interactive multimedia application system of the historic building
The making process of an interactive multimedia application system of the historic building is instantly available on Archicad software. Archicad provides a menu of publishing data into the BIMx Hyper-model. The complete form of 2-dimensional construction digital image data and HBIM 3D model data will be packaged in an interactive multimedia application on the BIMx application. The BIMx application is available in three types: BIMx mobile application, BIMx Web viewer, and Desktop viewer. Application users have the opportunity to actively interact with all HBIM data of historical buildings, both 2-dimensional construction data and HBIM 3D model data. The BIMx application is equipped with a navigation device that makes it easier for users to understand historical buildings’ HBIM data. Of course, the complexity of the data that users can access is the data prepared during the HBIM modeling process on Archicad.
The user interface system design in BIMx mobile application is equipped with a list of data completeness of historical building construction that has been prepared in the form of folders and subfolders. Each data in the table of the content folder is linked to interactive HBIM data, which contains 2-dimensional measured image data that is automatically linked to HBIM 3D model data. Users have the convenience to interact between the two types of data simultaneously; even users can observe a 3-dimensional constructive section of all elements and parts of the building independently. The form of the user interface design, the completeness of the navigational tool features, and the multimedia interactive application form can be seen in Figure 9.

4. Conclusion
The HBIM method for developing the Digital Management System for Tangible Culture Heritage is the latest innovation in managing historical buildings in Malang. This system and technology development aims to build an accurate digital database system that can be accessed by various parties with an interest in preservation, conservation, and maintenance activities. 3D Laser scanning is the latest automatic 3D reconstruction technology with the ability to handle complex objects and a high level of time efficiency compared to photogrammetry techniques, which on the other hand, are more manageable in the availability of devices and processes.

Implementing a digital survey device for recording historical landmark buildings with a Leica RTC 360 type 3D laser scanner can produce detailed and accurate 3D models and have high survey time efficiency. Retrieval of object record data at each point only takes about one 360° turn to record 3D point cloud data and one 360° turn to record images. Making 3D content modeling of historical buildings uses a combination of Autodesk Revit and Graphisoft Archicad software, which has a high level of interoperability due to the IFC open format's support that provides a high level of interoperability between different BIM platforms. Archicad software, the first platform to use the open BIM principle and based on parametric objects, is used to optimize all object modeling libraries for each historic landmark building. The overall dynamic interpretative object libraries for each historical landmark building are published in the interactive multimedia application system in the BIMx mobile application. This interactive multimedia system provides access to application users through friendly navigational tools to interact with 2D construction documentation data and 3D HBIM model data.

Overall, this research reveals the importance of collaborating in using a 3D laser scanner with two BIM-based software, namely Autodesk Revit and Graphisoft Archicad, in developing a digital
management system in the context of enhancing historic building governance in the city of Malang. BIMx authoring and viewer applications technology can publish an interactive Building Information Modeling (BIM) and reveal the displayed building model's construction details as an instant interactive multimedia application development technique provided by Archicad software. This study has potential limitations that could be addressed in future research. This mobile application has not accommodated the user interface design and navigation tool containing access to and interaction with the metadata handling of architectural-historical information data, including integrating historical building data into the geoinformation system. Therefore, further research is directed at advancing historic buildings' spatial multimedia systems with advanced programming.

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