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3D Modeling Using Drone Technology for Enhanced Building Information Modeling in Building Design

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***Abstract* — The use of cutting-edge geospatial technologies in architectural design has been rendered necessary to enhance efficiency as well as accuracy. The current study encompasses the capability of drone technology to generate high-density 3D models and advance Building Information Modelling (BIM) processes. With high-resolution aerial photographs captured by drones at Warung Rumah Agam Onyang, Bota, Perak, Pix4D was employed to generate complex 3D point clouds and digital models. Thereafter, the 3D models were imported into CAD software like Autodesk Revit, allowing for extensive visualization and analysis of the structures. Based on the outcome, the application of drone technology considerably outperforms traditional survey measures in terms of speed and accuracy of data capture. With the integration of 3D models into CAD systems, precision and accuracy of BIM improved, and better design processes and decision-making followed. Though image warping issues in areas of high vegetation and low-light constraints, they did not seriously interfere with the overall result. Testing revealed enhanced operational effectiveness, reduced labour intensity, and enhanced visualization capacity. The study points to the revolution that technology in drones can lead in maximizing BIM workflow and provides insight into the use of the same in real-world building design today.**

Keywords—Building Information Modelling (BIM), 3D models, Drone technology.

I. INTRODUCTION

With the rapid progress of building construction, it is critical to have precise and detailed 3D models that aid in effective planning, precise designing, and proper decision-making. The use of emerging technologies like drone technology and Building Information Modelling (BIM) has transformed the construction industry, leading to increased efficiency and accuracy. However, the implementation of these technologies efficiently requires rigorous research to establish their effectiveness, cost-effectiveness, and practicability in reality. Drones are notable for their mobility, accessibility, and capability to capture high-resolution data with advanced perception sensors [1].

As construction projects increasingly depend on accurate and detailed site data, integrating this information into BIM platforms is essential for achieving precision and optimizing workflows. BIM-to-drone workflows improve construction processes by utilizing BIM data to direct drone operations, including geometric and material details for flight path planning and target identification [2]. Drone technology, recognized for its ability to capture high-resolution aerial images, facilitates the creation of accurate 3D models that can be smoothly integrated into BIM systems. This integration improves visualization, design accuracy, and real-time monitoring, enabling professionals to tackle design and construction challenges more effectively [3].

II. ENHANCING BIM THROUGH INTEGRATION OF DRONE-DERIVED 3D MODELS

Nowadays, creating accurate and efficient 3D models is crucial for successful project outcomes. However, traditional methods of gathering site data for Building Information Modelling (BIM) can be slow, labour-intensive, and often lead to inaccuracies. Manual surveys may yield incomplete or incorrect data, which can result in errors when generating 3D models. These inaccuracies can adversely affect planning, design, and decision making, ultimately driving up project costs and extending timelines [4].

To overcome these challenges, there is a strong demand for innovative technologies that facilitate accurate, efficient, and cost-effective data collection. Drone technology has emerged as a viable solution, providing high mobility, efficiency, and the capability to capture high-resolution aerial images. By using software like Pix4D, these images can be transformed into detailed 3D models that faithfully represent a site's physical characteristics [5]. Additionally, integrating these models into CAD platforms such as Autodesk Revit improves visualization, analysis, and design workflows, allowing construction professionals to enhance building design processes [6].

This study aims to explore the integration of drone-based photogrammetry with Building Information Modelling (BIM) to enhance the efficiency and accuracy of building design processes. Specifically, the research investigates the generation of a 3D mesh model from drone imagery using Pix4Dmapper and its subsequent conversion for use within a BIM environment through Autodesk ReCap and Autodesk Revit. The study addresses the limitations of traditional surveying and modelling techniques by evaluating a digital workflow that combines high-resolution spatial data acquisition with intelligent design modelling.

There are some of distinction is made between the 3D mesh model produced by Pix4Dmapper and the BIM-compatible model developed in Autodesk Revit. The former is a photorealistic, georeferenced representation based on point cloud data, optimized for visualization and surface analysis. However, it lacks semantic and parametric information. In contrast, the BIM model in Revit incorporates structured, intelligent components and families such as walls, floors, and windows in which support detailed architectural design, simulation, and project documentation [7]. The transition from a purely geometric mesh to a parametric BIM model reveal the potential of integrating photogrammetric data into a comprehensive digital design environment.

Accordingly, the objectives of the study are:

a) To generate a 3D mesh model from point cloud data derived from high-resolution drone imagery using Pix4Dmapper.
b) To convert and integrate the 3D mesh model into Autodesk Revit via Autodesk ReCap, in which it could be use within a BIM environment to support enhanced architectural design workflows.

III. METHODOLOGY

A. Overview of Warung Rumah Agam Onyang

The subject selected for this study is an old colonial house known as Warung Rumah Agam Onyang (Fig. 1), located in Bota, Perak. This heritage building structure is distinguished by its historical and meaningful architectural significance, thus making it as monumental site for demonstrating the integration of drone technology and Building Information Modelling (BIM). The geographic coordinates of the site location, which based on the WGS84 reference system, are 4°17'15.8"N, 100°56'12.3"E.

Fig. 1. Warung Rumah Agam Onyang.

B. Integrated Workflow for 3D Modeling and BIM Integration

This study examines the integration of drone technology with Building Information Modelling (BIM) then to create an accurate 3D model of Warung Rumah Agam Onyang. The building as a cultural and architectural icon, represents very rich in heritage, architectural and craftsmanship, making it a so valuable for digital preservation. The study began with the collection of architectural blueprints, historical records, and background data to understand the site and prepare for fieldwork.

The success of this study relies on a structured and efficient workflow as projected in Fig. 2 Workflow Flowchart and Fig. 3 Integrated Phase Workflow, combining advanced drone systems and software tools like Pix4D Mapper, Recap Pro, and Autodesk Revit.

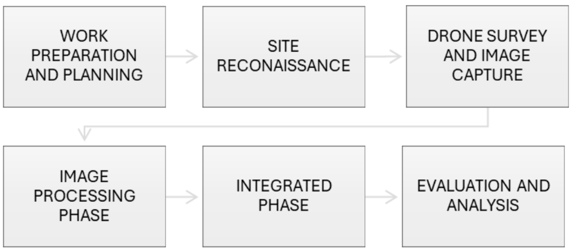

Fig. 2. Workflow flowchart.

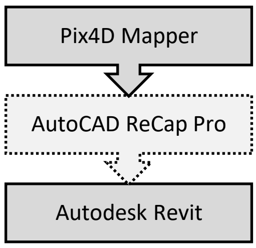

Fig. 3. Integrated phase workflow.

Work Preparation and Planning

The study begins with Work Preparation and Planning, where equipment such as the DJI Drone RTK and Satlab Rover are checked, and a clear workflow for data collection and modelling is established. Both tools underwent rigorous checks to ensure operational readiness. The Satlab SL900, offered high-precision GNSS data using both RTK and Static capabilities with multiple satellite constellations. The Phantom 4 RTK drone, equipped with a 20MP 1-inch CMOS sensor and a TimeSync system, was used to capture high-resolution, geotagged images essential for 3D photogrammetry. The Pre-flight preparations before observation are included site analysis, environmental assessments, and flight planning in order to ensure a complete and safe aerial coverage. There are four Ground Control Points (GCPs) that were placed strategically on-site and surveyed using the static GNSS method. This GNSS Method allows involvement of prolonged satellite signal data capture to improve coordinate accuracy. Later during post processed the RINEX data files downloaded from the MyRTKnet portal and then processed with SatSurv GNSS software to compute the static precise GCP coordinates.

Site Reconnaissance

The Site Reconnaissance phase is a phase that involves an inspection of the area to identify any of obstacles or limitations such as tall vegetation, nearby building object or structures, power lines, or uneven terrain (hilly slope). All these factors are very important to be highlight as it could interfere with or compromise the safety and effectiveness of drone flight operations. In addition, the reconnaissance phase also includes evaluating wind conditions, sun angle, and visibility to ensure optimal image quality during aerial data capture.

Drone Survey and Image Capture

During the observation, the Satlab SL900 GNSS receiver was employed in Static method to obtain highly accurate ground control point (GCP) coordinates. These coordinates are very essential for georeferencing the aerial images that captured by the drone. By establishing fixed spatial references on the ground, the Satlab Rover enhances the positional accuracy of the photogrammetric outputs, ensuring that the resulting 3D model aligns correctly with real-world coordinate systems. Concurrently, the DJI Phantom 4 RTK drone was deployed along pre-programmed flight paths to systematically capture high-resolution aerial imagery of the study site.

Meanwhile the building's setting, in a semi-urban area surrounded by greenery and flat terrain, provided ideal flying conditions. The drone survey included overlapping nadir and oblique images to ensure that architectural elements such as timber carvings, roofing structures, and wall geometry were captured from multiple perspectives. A total of 106 images were collected and processed using Pix4Dmapper. The software was set to the WGS 1984 coordinate system with the EGM96 geoid, and the 3D Models template was used to optimize the processing of oblique images. The workflow included three stages: initial processing (which involved keypoint extraction and georeferencing using GCPs), point cloud generation, and the creation of an orthomosaic. Critical settings such as full image scale matching and correct geolocation calibration were employed in an effort to produce precise outputs. Densified point cloud was classified in a bid to differentiate ground surfaces from other features for the support of building a Digital Terrain Model (DTM). Processed data also included a 3D textured mesh and Digital Surface Model (DSM), all of which are required for BIM integration.

Image Processing Phase

In the Image Processing phase, the images are processed within Pix4D Mapper to generate outputs such as an Orthomosaic map, 3D point cloud, and digital elevation model (DEM). These georeferenced outputs form the crucial foundation for the next step which is 3D Model Integration in integrated phase.

Integrated Phase

The results of this phase are fundamental to the building of 3D point cloud models in the upcoming stage. First, the spatially processed data, the densified point cloud and mesh with textures made in Pix4Dmapper are transferred to Autodesk ReCap Pro for finishing and turning the results into a format that can be used in BIM. Following this, the dataset is uploaded into Autodesk Revit where it matches the actual locations used in the design. Thanks to this integration, modeling in architecture can be more precise and the Building Information Modeling (BIM) environment has a better level of accuracy and greater interpretation for use in designing and planning.

To be clear, once the point cloud was exported in LAS format from Pix4D, then the data will be imported into Autodesk ReCap Pro for filtering and refinement. The RCP file result then brought into Autodesk Revit, in which the point cloud will be served as a reference for accurate modelling. By using tools within the Architecture tab, the key elements such as walls, roofs, ceilings, and stairs, the process were continued by tracing directly or manually over the point cloud. The snapping feature in Autodesk Revit allowed for precision in dimensioning and alignment, ensuring that the output model literally represented the real structure.

Evaluation and Analysis

The final step, Evaluation and Analysis, involves checking the accuracy of the 3D model, identifying any issues, and proposing improvements for future projects. This complete methodology ensures the creation of precise, high-quality 3D models that improve BIM workflows and demonstrate the value of drone technology in modern building design.

As conclusion for all above-mentioned phases, the integration of drone-derived geospatial data into the BIM platform not only enhanced the accuracy of the model but also supported future preservation and analysis of the building as a well design framework of guideline. This streamlined workflow from data capture to BIM integration, demonstrates a powerful and efficient method for documenting heritage architecture. The final 3D model provides a valuable digital asset that can be used for historical analysis, architectural design, and conservation planning, aligning perfectly with this research objectives of preserving and promoting Malaysia's cultural heritage through innovative technology.

IV. RESULT AND ANALYSIS

In this project, the Pix4D Mapper made two primary outputs: point clouds and a 3D mesh. These outputs were shown one at a time. But the 3D model could have been a lot better if the point cloud and the 3D mesh had been put together. Combining point clouds and 3D meshes could make a dataset that is very detailed. The last step works well because it mixes the precise shapes of point clouds with the rough surfaces of 3D meshes. This combination results in realistic and interesting 3D models that accurately and in high resolution simulate real-world settings. The dense point cloud (usually output from Pix4D as a *.las or *.xyz file) and the 3D mesh (usually in *.obj or *.fbx format) were brought in and cleaned up during the process. This step is very important to make sure that the noise and extra data points were deleted.

Autodesk Recap Pro was then used to change the cleansed data into formats that Autodesk can use (*.rcp/*.rcs). This step makes it easy to add data to Autodesk Revit software. The dense point cloud was usually exported from Pix4D as a *.las or *.xyz file, and the 3D mesh was commonly in *.obj or *.fbx format. These files were then imported and cleaned up to get rid of noise and data points that weren't useful. Finally, the cleansed data was changed into *.rcp/*.rcs forms that work with Autodesk so that it could be used in Revit. After the file was transformed, the point cloud was brought into Autodesk Revit to be used as a precise spatial reference for the next phase in modeling the building.

A. Result of Pix4D Mapper

Result in Point Cloud

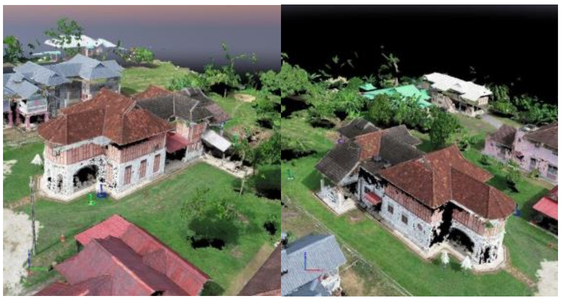

Fig. 4. Result in point cloud.

A point cloud with billions of data points was processed and used to create the 3D model of the building, which can be shown in a Fig. 4 above. A collection of spatial data points, each with timestamps, RGB colour values, X, Y, and Z coordinates, and other attribute information, makes up the point cloud itself. Based on the figure a detailed depiction of the Warung Rumah Agam Onyang features and structure was made possible using this advance and sophisticated scanning technologies to capture all these data points.

Result in 3D Mesh

The building's 3D model following 3D mesh processing is shown in Fig. 5. The final model is quite like the building's real structure. The 3D mesh, also known as an integrated 3D mesh or a reality 3D mesh, is a structurally sound and geospatially accurate representation of the building. The building's height, width, and depth are defined along the X, Y, and Z axes in this model, and which is built based on a three-dimensional polygon. Based on the model, the building's dimensions height, width, and depth are mapped along the Z, X, and Y axes, respectively, using a three-dimensional polygonal framework. In the other hand, this method facilitates precise spatial analysis and integration with Building Information Modeling (BIM) platforms. The polygonal shape structure enables the model to support further processing tasks. Overall, the model not only represents the physical geometry of the Warung Rumah Agam Onyang building but also serves as a valuable tool for spatial analysis, planning, and digital preservation.

Fig. 5. Result in 3D mesh.

B. Result of Autodesk Revit

After conversion pix4d mapper point cloud and 3D mesh using Autodesk Recap Pro, the point cloud was imported into Autodesk Revit 2025 and used as a precise reference to guide the as-built modeling process. The following key components of the Warung Rumah Agam Onyang structure were manually reconstructed such as walls, windows, doors, roof structure and pillars. The BIM model represents a partially completed yet highly accurate reconstruction of the actual building. The greenish-blue coloration of the point cloud within Revit indicates its origin as an imported scan from drone photogrammetry.

The model as shown in Fig. 6 also displays the "Reveal Hidden Elements" mode (highlighted in pink), which was activated to expose temporarily hidden categories or components. This is essential in renovation and heritage projects where overlapping or embedded features must be accessed and edited.

Figure 7 to Fig. 10 show the 3D model in Autodesk Revit from the left, rear, right and front views. These views provide a clear understanding of the model's design and structure from different angle.

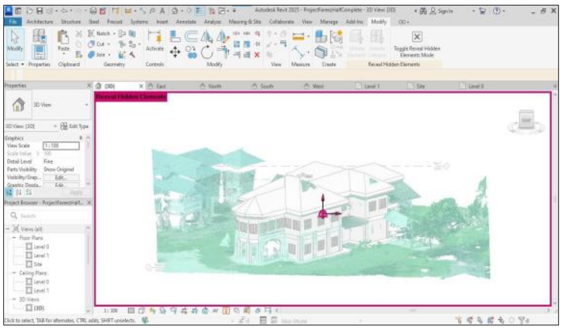

Fig. 6. Result in Autodesk Revit.

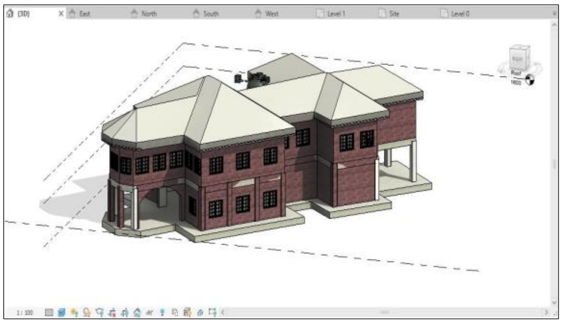

Fig .7. Left view.

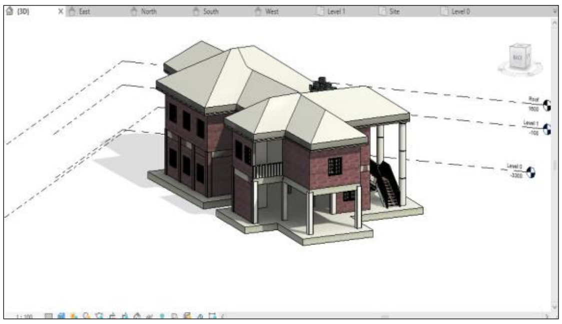

Fig. 8. Rear view.

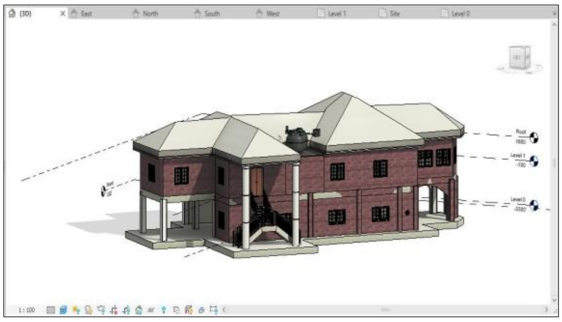

Fig. 9. Right view.

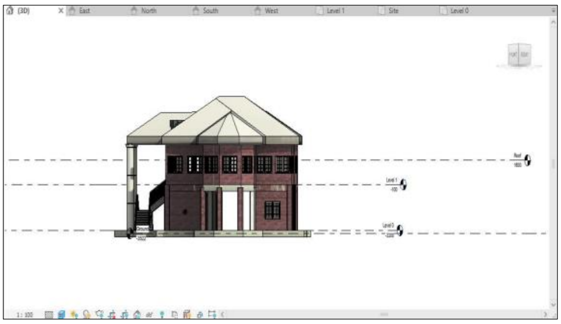

Fig. 10. Front view.

V. CONCLUSION

This study demonstrated that photogrammetry and drone technology can be used extremely well to support architectural design processes. Resolution-high drone photos allowed successful production of a complex 3D mesh model in Pix4Dmapper and the importing of this to Autodesk Revit through Autodesk ReCap. This allowed precise digital reconstruction of the building in its current state, allowing detection of any construction mistakes and generation of precise as-built models for use in future development and retrofitting. Cleaning and filtering of the point cloud data was a beneficial part of the process. It eliminated unnecessary detail and unwanted noise, enabling the modelling to be more productive and improving the quality of the final product. Cleaner data enabled the software to perform better and to produce higher-quality models with fewer errors. The process was enhanced as well by the addition of other tools such as AutoCAD, Civil 3D, and 3ds Max, all adding value in some form or another—whether for accurate drafting, site planning, or photorealistic visualization. However, all these tools together allowed for a more expansive and flexible modelling environment. In proving its aim, this study has confirmed that it is possible and worth implementing to generate a 3D mesh model from drone data and integrate it into a BIM platform. It suggests the viability of employing drone-based point cloud data and BIM software to enable more accurate, more efficient, and more informed design decision-making.

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AUTHOR CONTRIBUTIONS

Muhammad Fareez Ridzuan Bin Jumahan: Conceptualization, methodology, investigation, data curation, formal analysis, visualization.
Mohd Najib Bin Husain: Supervision, validation, writing – review & editing, project administration.
Noorsazwan Bin Ahmad Pugi: Investigation, data curation, site assessment.
Mat Nizam Bin Uti: Validation, assessment, technical review.
Haslina Bt Hashim: Writing – review & editing, methodology refinement.
Munirah Bt Radin: Supervision support, methodology advisory.

CONFLICT OF INTERESTS

No conflict of interests was disclosed.

ETHICS STATEMENTS

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org/

DATA AVAILABILITY STATEMENT

No available.

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