Integration of land survey data using aerial photogrammetry method on 3 dimensional bim (Building Information Modeling) Modeling

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Abstract. The use of UAV (Unmanned Aerial Vehicle) in land surveys and the implementation of BIM (Building Information Modeling) in the construction world has begun to be used frequently, both in the manufacture of infrastructure and building structures. The purpose of this study was to determine the effectiveness of the use of UAV in land surveys with parameters of cost, quality and time, and to find out whether the land survey can be integrated with a 3-dimensional design with applications related to BIM. This study uses secondary data in the form of aerial photo data and 3-dimensional BIM design data, which produces some data such as 3-dimensional data from the layout of a land using UAV, with a fairly good level of effectiveness compared to previous studies. In addition, the results of the integration of a 3-dimensional map of a land survey using a UAV with a 3-dimensional design of the BIM method can provide a visualization of the design form with actual conditions in the field.

Keywords: UAV, BIM, Integration, 3-dimensional modeling, photogrammetry

1. Introduction

With the development of technology in the modern world, many things have developed with the advancement of technology in all aspects of life. One of those affected by technological modernization is the AEC industry or what is called Architecture, Engineering, and Construction. With the development of this technology, it can overcome several problems in the AEC (Architecture, Engineering, and Construction) industry such as difficulties in coordinating and exchanging information from one stakeholder to another, and from difficulties These difficulties can cause various problems that occur in project work, such as misinterpretation which can lead to additional costs and processing time, delays in project work or project work delays, or so that it can produce work results that are not in accordance with the specified quality.

From the problems that arise, various techniques or methods in construction work have developed accompanied by technological developments. Some of the techniques or methods that are affected by technological modernization in parts of construction works are the structural modeling method using the BIM (Building Information Modeling) method and the land surveying data collection method using the UAV (Unmanned Aerial Vehicle) [1]. With the development of technology, the world of surveying has also followed technological developments, namely by carrying out construction work using drones, called the aerial photogrammetry method [2]. Modeling of the structure of a building has developed with applications that can display the shape of the structure in 3D (3D). Modeling with 3 dimensions can also be accompanied by various types of data from a project that can facilitate the project team in analyzing the work of a project and the error factors that can occur at the modeling stage of a structure. Building Information Modeling (BIM) is the process of creating and managing 3-dimensional (3D) building data during its development. Building Information Modeling (BIM) is a complex multiphase process that gathers input from project team members to model the components and tools that will be used during the construction process to create a unique perspective of the building process [3].
Building Information Modeling (BIM) operations can be performed with a variety of available applications, such as Revit, Navisworks, Tekla BIMsight, BEXEL Manager, ArchiCAD, SketchUp, and many other applications. The use of this application is not only able to display the 3-dimensional shape of a structure, but also can display other data needed both in the maintenance process after project work (post-project) or also when project work is in progress.

Advances in surveying technology have evolved from the way ground level elevations can be sampled: from land surveys using theodolites and Total Stations (TS) to aerial and satellite surveys utilizing photogrammetry and more recently aerial laser scanning known as Light Detection and Ranging (LiDAR) [4]. According to Hernandez [4], the use of aerial photogrammetric survey methods has begun to be compared and replaces terrestrial survey methods slowly following the times, where aerial photogrammetric survey methods are considered quite effective in their use. Photogrammetry is the art, science and technology of obtaining reliable information about objects and the physical environment, through the process of recording, measuring and interpreting photographic images, in which the geometric aspects of aerial photography such as angles, distances, coordinates, and so on are the main factors [5]. Photogrammetry is often done using unmanned aerial photography technology or commonly known as Unmanned Aerial Vehicle (UAV). Mapping technology using an Unmanned Aerial Vehicle (UAV) or often called an unmanned aircraft is a type of aircraft that is controlled by a remote control system via radio waves. UAV is an unmanned system (Unmanned System) which is an electromechanical-based system that can carry out programmed missions with the characteristics of a flying machine that functions remotely by the pilot or is able to control itself, using the laws of aerodynamics to lift itself. In mapping aerial photos, it is necessary to know the points and have a reference to the ground coordinates of the location where the measurement is carried out. These points are called Ground Control Points (GCP) or control points [5]. Ground Control Point (GCP) serves as an allied point that connects the map coordinate system and the photo coordinate system. From this GCP, the photo map will have the appropriate coordinates and be tied to the measurement area. GCP measurements usually use terrestrial measurements and must be tied to a base station that is used as a premark when the aircraft is taking aerial photographs [6].

2. Research Methodology

2.1 Research Location

The location that will be applied to the research by the author is at the location of package 1 which is a connection road from West Java International Airport (BIJB) Kertajati to the 2.2 kilometer kertajati-cikopo-palimanan toll road which is part of the package carried out by PT. PP persero, whose test point is the use of both construction work methods, namely 3-dimensional BIM (Building Information Modeling) and land/soil survey using UAV (Unmanned Aerial Vehicle) is located on project package 2 which is the scope of work of PT. ACSET Indonusa, Tbk., The toll road project area stretches between 6°42’03” south latitude and 108°10’19” east longitude. Figure 1 shows Kertajati Toll Road Map.

![Figure 1. Kertajati Toll Road Map](image-url)
2.2 Stage of Research

Figure 2 shows the research methodology. The following are the stages carried out in this research:

1. Stages of Literature Study Discussion

   The discussion stage of the literature study is the stage of using the standards that apply in Indonesia, previous studies or journals that are used as the basis for making this research.

2. Stages of Collecting Data

   The data collection stage is the stage of collecting the main data used in this study, namely there are 2 (two), aerial photo data taken using UAV (Unmanned Aerial Vehicle) and 3-dimensional BIM (Building Information Modeling) design data.

3. Stages of Analyzing Data

   The data analysis stage is the processing stage of the data that has been collected and analyzing the results of the processed data. The stages of analysis carried out in the study are as follows:
   a. Processing raw aerial photo data into 3-dimensional topographic map data.
   b. Comparing the effectiveness of using 2 different types of UAV (Unmanned Aerial Vehicle) based on the parameters of cost, quality, and time.
   c. Perform 3-dimensional BIM (Building Information Modeling) modeling with 2-dimensional CAD (Computer Aided Design) drawing data.
   d. Perform integration of land survey data using UAVs with 3-dimensional designs using BIM-related applications.

![Figure 2. Research Methodology](image-url)
3. Result and Discussion
3.1 Processing Land Survey Data From UAV

a. Collecting Data
In the aerial photo data processing, the data used are aerial photo data, control point coordinate data (Ground Control Point), and applications that can be used to process these data. The data used is the result of using a UAV with the DJI Phantom 4 RTK type with the specifications as shown in Table 1.

| Specifications                          | Description                                                                 |
|-----------------------------------------|-----------------------------------------------------------------------------|
| UAV Type                                | Quadcopter                                                                  |
| Mapping Accuracy                        | Mapping accuracy meets ASPRS Accuracy Standard requirements for Digital Orthophotos Class |
| GSD (Ground Sampling Distance)          | \( \frac{H}{36.5} \) cm/pixel \( \text{where } H = \text{Relative Flight Height in metre} \) |
| Maximum Speed                           | 31 – 36 Mph/50-58 Kph                                                      |
| Vertical speed (Ascending)              | 5-6 m/s                                                                     |
| Vertical Speed (Descending)             | 3 m/s                                                                       |
| Maximum Heights                         | 6000 m                                                                      |
| Flight Durations                        | +/- 30 minutes per battery                                                  |
| Mode GNSS (Global Navigation Satellite System) | (GPS+BeiDou+Galileo (Asia))                                              |
| Sensitivity distance to object           | 0.2-7 m                                                                     |
| Camera Sensors                          | 1” CMOS; Effective pixels: 20 M                                             |
|                                          | +/- 0.1 m (vertical) /mode RTK (Real Time Kinematic) active                 |
|                                          | 0.1 m – 0.5 m (Vertical) /mode RTK (Real Time Kinematic) not active         |
| Accuracy in flight                      | +/- 0.1 m (horizontal) /mode RTK (Real Time Kinematic) active               |
|                                          | 0.1 m – 0.5 m (Horizontal) /mode RTK (Real Time Kinematic) not active       |
| Camera Lens                             | FOV 84° ; 8.8 mm / 24 mm (35 mm format equivalent:24 mm)                    |
| Battery Capacity                        | 5870 mAh                                                                    |
| UAV Weight                              | 1391 gram                                                                   |

Here are some examples of aerial photo data obtained using a UAV which can be seen in Figure 3.

![Figure 3. Aerial’s Photograph](image)
b. Data Processing

After obtaining the required data using a UAV on a land survey, the next step is to process the data using an application that can process these data. The application used is the Agisoft Metashape Pro application which will convert a series of aerial photos into a unit that forms a 3-dimensional map, which can be seen in Figure 4 to Figure 7.

![Figure 4. Aerial’s Photograph Point](image1)

![Figure 5. Aligning Photos’s and GCP Coordinates](image2)

![Figure 6. DEM (Digital Elevation Model)](image3)

![Figure 7. Orthorectified 3-Dimensional Map](image4)

From the results of processing the aerial photo data, the following are the results of the accuracy of the control points horizontally, vertically and the total accuracy which can be seen in Table 2.

| Lable  | X error (cm) | Y error (cm) | Z error (cm) | Total (cm) |
|--------|--------------|--------------|--------------|------------|
| GCP001 | 14,1043      | 10,0274      | 16.83        | 24,1398    |
| GCP002 | 26,9258      | 17,048       | 30,1884      | 43,8973    |
| GCP003 | -57,2034     | -5.97768     | -51,1862     | 76,9935    |
| GCP004 | 0.902731     | -0.976978    | 0.979744     | 1.65206    |
| GCP005 | 0.498762     | 0.139541     | -2.08751     | 2.09276    |
| GCP006 | -0.332166    | -0.323428    | 1.05495      | 1.15233    |
| GCP007 | 26,4979      | 20,6682      | 1.28825      | 33,6299    |
| GCP008 | 3.26227      | 20,3397      | -3.48427     | 20,8922    |
| GCP009 | -34.7069     | -50.6466     | 8.92197      | 62,0423    |
| GCP010 | 24.0779      | 40.668       | -10.4177     | 48.3959    |
| GCP011 | 13.9975      | -9.21472     | -0.44035     | 16.7641    |
| GCP012 | -27.798      | 0.297653     | 13.8911      | 31.0769    |
| GCP013 | 23.8312      | 4.90264      | -11.8799     | 27.0757    |
| GCP015 | 23.4821      | -43.3432     | -7.741       | 49.8995    |
| GCP016 | -237.538     | 106.619      | 8.33842      | 260.502    |
3.2 Minimum Standard Compliance Analysis and Effectiveness Comparison Based on Cost, Quality and Time Parameters

In the analysis of meeting the minimum standards of the use of UAVs in this study, it is necessary to use the standard as a reference point whether this research produces data that is in accordance with the needs regulated by the rules in force in Indonesia. Therefore, the standard used is a technical guide from the National Land Agency regarding the use of UAVs in making work maps on a land. These technical guidelines are used as the minimum standard for the use of UAVs in this study, so that it can be seen whether the research carried out has entered the minimum standards of the applicable provisions in Indonesia, which can be seen in Table 3.

| Parameter                          | Standards                                                                 | Minimum Value | Unit     | Result                                      |
|------------------------------------|---------------------------------------------------------------------------|---------------|----------|---------------------------------------------|
| **Cost**                           |                                                                           |               |          |                                             |
| Camera vocal lens                  | Optional                                                                  |               |          | Integrated with the UAV                     |
| Drone Pilot Certificate            | Ter-Sertifikasi oleh FASI (Federasi Aero Sport Indonesia)                  |               |          |                                             |
|                                    | or APDI (Asosiasi Pilot Drone Indonesia)                                   |               |          |                                             |
| External GPS                      | Optional                                                                  |               |          |                                             |
| GCP (Ground Control Point) Amount | 5                                                                         | unit          |          | 23 Unit                                     |
| GSD (Ground Sampling Distance) Value | ≤5                                                           | cm/pixel      |          | 2.61 cm/pix                                |
| **Quality**                        |                                                                           |               |          |                                             |
| Camera Lens                        | 22-80                                                                     | mm            |          | 24 mm                                       |
| GPS System                         | Optional                                                                  | unit          |          | GPS+BeiDou+Galileo High-Sensitivity GNSS Module |
| Flight Altitude Horizontal Accuracy | >50                                                                      | m             |          | 107 m                                       |
| Vertical Accuracy                  | ≤10                                                                       | cm            |          | 39.83 cm                                    |
| Flight Altitude                    | Optional                                                                  | m             |          | 2.61 cm/pix                                |
| GSD (Ground Sampling Distance) Value | Optional                                                                  | cm/pixel      |          | 107 m                                       |
| **Time**                           |                                                                           |               |          |                                             |
| Drone Pilot Certificate            | Ter-Sertifikasi oleh FASI (Federasi Aero Sport Indonesia)                  |               |          |                                             |
|                                    | or APDI (Asosiasi Pilot Drone Indonesia)                                   |               |          |                                             |
|                                    | -                                                                         |               |          | None                                        |

Table 3. Compliance with Minimum Standards Based on the National Land Agency
After analyzing the fulfillment of minimum standards based on regulations or standards that apply in Indonesia, then we can then compare the effectiveness of this study with previous studies using different types of UAVs. The results of the comparison based on the parameters of cost, quality and time can be seen in Table 4.

### Table 4. Comparison of Meeting the Minimum Standards of the National Land Agency

| Drone Type       | Parameter                      | Standards                                      | Unit       | Result                                      |
|------------------|--------------------------------|------------------------------------------------|------------|---------------------------------------------|
| DJI Phantom 4 RTK| Cost                           | Camera vocal lens                              | Unit       | Integrated with the UAV                     |
|                  |                                | Drone Pilot Certificate                         | -          | None                                        |
|                  |                                | External GPS                                   | Unit       | GPS+BeiDou+Galileo High-Sensitivity GNSS Module |
|                  | Quality                        | GCP (Ground Control Point) Amount              | Unit       | 23 Unit                                     |
|                  |                                | GSD (Ground Sampling Distance) Value           | cm/pixel   | 2.61 cm/pix                                |
|                  |                                | Camera Lens                                    | Mm         | 24 mm                                       |
|                  |                                | GPS System                                     | Unit       | GPS+BeiDou+Galileo High-Sensitivity GNSS Module |
|                  |                                | Flight Altitude                                | m          | 107 m                                       |
|                  | Time                           | GSD (Ground Sampling Distance) Value           | cm/pixel   | 2.61 cm/pix                                |
|                  |                                | Flight Altitude                                | m          | 107 m                                       |
|                  |                                | Drone Pilot Certificate                         | -          | None                                        |
|                  | Cost                           | Camera vocal lens                              | Unit       | Integrated with the UAV                     |
|                  |                                | Drone Pilot Certificate                         | -          | None                                        |
|                  |                                | External GPS                                   | Unit       | Integrated with the UAV                     |
|                  | Quality                        | GCP (Ground Control Point) Amount              | Unit       | 4 Unit                                      |
|                  |                                | GSD (Ground Sampling Distance) Value           | cm/pixel   | 3.28 cm/pix                                |
|                  |                                | Camera Lens                                    | Mm         | 20                                          |
|                  |                                | GPS System                                     | Unit       | GPS Integrated to UAV                       |
|                  |                                | Flight Altitude                                | m          | 75 m                                        |
|                  | Time                           | GSD (Ground Sampling Distance) Value           | cm/pixel   | 3.28 cm/pix                                |
|                  |                                | Flight Altitude                                | m          | 75 m                                        |
|                  |                                | Drone Pilot Certificate                         | -          | None                                        |

After comparing compliance with the standards of the rules or standards that apply in Indonesia in the table above, the next step is to compare the costs and time used in this study with previous studies. The following is a comparison table of the time and costs required in this study, which will be described in Table 5.
### Table 5. Comparison of Initial Cost Required

| Drone Type       | Description          | Unit Price (Rp.) | Total Unit | Sub-total (Rp.) |
|------------------|----------------------|------------------|------------|-----------------|
| DJI Phantom 4 RTK | Initial Purchase Price | 239.000.000      | 1          | 239.000.000     |
|                  | Additional Battery   | 2.285.000        | 8          | 18.280.000      |
|                  | Signal Booster       | 4.999.000        | 1          | 4.999.000       |
|                  | Alientech            |                  |            |                 |
|                  | Total                |                  |            | **262.279.000** |
| DJI Phantom 3 Professional | Initial Purchase Price | 71.045.747       | 1          | 71.045.747      |
|                  | Application          | 11.500.000       | 1          | 11.500.000      |
|                  | Additional Battery   | 2.700.000        | 1          | 2.700.000       |
|                  | Total                |                  |            | **85.245.747**  |

The time required in this study as shown in Table 6 is different due to the different areas. Therefore, so that comparisons can be carried out in a balanced manner, the area needs to be converted. Table 7 and Table 8 show a conversion for the area area along with a comparison of the time from data collection to data processing.

### Table 6. Comparison of Time Required

| Drone Type       | Description       | Duration (s) | Area Coverage (m²) |
|------------------|-------------------|--------------|--------------------|
| DJI Phantom 4 RTK | Acquiring Data    | 3.641        | 992.721,4          |
| DJI Phantom 3 Professional | Acquiring Data | 390         | 46.029             |

### Table 7. Research Time Conversion

| Drone Type       | Description       | Duration (s) | Area Coverage (m²) |
|------------------|-------------------|--------------|--------------------|
| Actual Time      | Acquiring Data    | 3.641        | 992.721,4          |
|                  | Acquiring Data    | 390          | 46.029             |
| Converted Time   | Acquiring Data    | 3.641        | 992.721,4          |
|                  | Acquiring Data    | 8.411,25     | 992.721,4          |

### Table 8. Comparison of the total time required

| Work Process   | Unit  | DJI Phantom 4 RTK | DJI Phantom 3 Professional |
|----------------|-------|-------------------|----------------------------|
| Acquiring Data | Second| 3.641             | 8.411,25                   |
| Transfer Data  | Second| 420               | 900                        |
| processing Data| Second| 57.540            | 383.035,305                |
| Total          | Second| **61,601**        | **392.346,555**            |

### 3.3 BIM 3-Dimensional Modeling Analysis

3-dimensional modeling analysis with BIM-related applications is a 3-Dimensional design based on 2-Dimensional drawing data using CAD. Here are some 2-Dimensional image data used in 3-Dimensional modeling with BIM related applications.
From the images used, here are some examples of 3-Dimensional designs using the allplan application, which is a 3-Dimensional infrastructure modeling application which can be seen Figure 10, Figure 11 and Figure 12.

After completing the 3-Dimensional design of the project, the data can be used in the integration process with 3-dimensional aerial photo data.

3.4 Analysis of Land Survey Data Integration Using UAV on 3-Dimensional Modeling BIM
The analysis of the integration of these two construction work methods uses some data from the survey method with 3D BIM modeling data. The data used from aerial photography is DEM (Digital Elevation Map)
Model) data as a contour plan, orthomosaic data which is a visualization of aerial photo data. While the
3-Dimensional modeling of BIM will be converted into another file extension so that it can be inputted
into different applications. The data used and the results of the integration process of the two
construction work methods can be seen from Figure 13 to Figure 17.

**Figure 13.** DEM (*Digital Elevation Model*)

**Figure 14.** Orthomosaic Data

**Figure 15.** Contour Lines from DEM Data

**Figure 16.** DEM Integrated with Orthomosaic Data

**Figure 17.** Integrated Aerial Photo Data with BIM 3D Model

4. **Conclusion**

The following are the conclusions of the research conducted:

a. The difference in efficiency against different costs is the DJI Phantom 4 RTK UAV with a cost of
Rp. 262,279,000, - with a DJI Phantom 3 Professional UAV at a cost of Rp. Rp. 85,245,747, -
because the features possessed by each UAV are different, and the additional requirements added
to the initial capital such as additional batteries are different.

b. The time difference required is far from the two different types of UAV, namely the use of the DJI
Phantom 4 RTK type UAV it takes 61.601 seconds or 17.11 hours, and the DJI Phantom 3
Professional type takes 392.346.555 seconds or 108.98 hours.

c. Based on the price comparison between the UAVs used in this study, they are much more
expensive, but more effective in the time required for their use and produce a more accurate
accuracy where the GSD (Ground Sampling Distance) in this study is 2.61 cm/pixel, while the GSD (Ground Sampling Distance) in the previous study was 3.28 cm/pixel.

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