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Study of Quality Control for Mapping Product: Aerial Photogrammetry Data Acquisition Using UAV (Unmanned Aerial Vehicle) Based on SNI 9135-1: 2022

Adithya Kresna Sumaamijaya [1], Muhammad Gilang Attalla[1]*

[1] The Education University of Indonesia, Majoring Geographic Information Science, Bandung, Indonesia

*Correspondence: E-mail: sumaamijaya31@upi.edu

ABSTRACT

Technological advancements in photogrammetry, particularly through the use of UAVs, have significantly transformed geographic mapping by enabling precise 3D modeling. This research investigates the quality control of mapping products acquired via UAVs, with a focus on adherence to the SNI 9135-1:2022 standard, which ensures high positional accuracy essential for reliable base maps and spatial analysis in Indonesia. Conducted at UPI, Bandung, in August 2024, the study utilized photogrammetric survey equipment and software, including UAVs, GPS, and Agisoft Metashape Pro, to ensure rigorous quality control throughout the preparation, acquisition, and processing stages. By employing indirect georeferencing with GCPs, the research ensured compliance with the standard's specifications, meticulously verifying tool specifications, flight path planning, and GCP distribution during the planning and data acquisition stages. The resulting orthophoto products achieved the required accuracy for 1:1000 scale mapping with a Ground Sample Distance of 2.1 cm. While SNI 9135:2022 offers comprehensive guidelines that enhance the accessibility and cost-effectiveness of UAV-based mapping, it also presents certain limitations. The standard's focus on nonmetric cameras may restrict its use in projects demanding extreme precision, and its implementation requires technical expertise that may not be available in all regions, particularly in remote areas, posing challenges to widespread adoption.

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1. INTRODUCTION

Currently, technological developments in mapping have revolutionized the way we manage geographic space. One of the most prominent innovations is pho-to-grammar. Photogrammetry is the art, science, and technology of obtaining information on physical objects in a space through a recording process. In the geotechnical world, photogrammetry is carried out for the purpose of mapping a certain area with more accurate accuracy and precision. This process is supported by advances in robotic and computational technologies that allow for the creation of non-terrestrial three-dimensional (3D) objects (Ihsan et al., 2021). With its ability to model 3D with high accuracy, photogrammetry can be used for topographic mapping of an area, which is very useful for landform change monitoring analysis or other acquisitions such as environmental dynamics analysis and natural resource management. The main advantage of photogrammetry using UAVs is its ability to map a large area in a short time, and it is more economical when compared to traditional survey methods.

In thematic mapping and spatial analysis, a base map is the main foundation needed. Base maps provide detailed information about an area including road networks, boundaries, topography, and other important elements. One of the essential sources in the production of base maps is orthophotos, which are upright photographs taken from the air with the camera axis almost perpendicular to the earth's surface (Ihsan & Sugandi, 2019). Orthophotos have the key benefit of providing a relatively distortion-free visual representation of the earth's surface, enabling the extraction of accurate and detailed geographic information, and allowing base maps to be produced at a consistent scale, which is essential in spatial analysis and mapping. In addition to providing geometric accuracy, the use of upright photographs also facilitates the integration of data from various sources, allowing cartographers to combine information from old maps, field survey data and satellite imagery more efficiently, ultimately contributing to the success of mapping and geo-graphic analysis projects (Cintra & Nero, 2015).

Currently, government agencies such as the Geospatial Information Agency (BIG) and the Ministry of Agrarian and Spatial Planning (ATR/BPN) attach great importance to the management of base map geospatial data. Base mapping involves the collection of basic geographic data such as administrative boundaries, topography and hydrography that are essential for the preparation of national base maps. These base maps form the basis for policymaking on infrastructure development, environmental management, and natural disaster management. Accurate and up-to-date base mapping is crucial for BIG and ATR/BPN agencies to perform their functions as reliable national geospatial data providers. The data collected not only supports government administration activities, but also serves as the foundation for the development of various economic sectors and environmental protection, which in turn contributes significantly to sustainable development and equitable development throughout Indonesia.

To accelerate the updating of base mapping using photogrammetry techniques, it is important to ensure that each stage of implementation is carried out carefully and ac-cording to high quality standards, as haste without regard to quality can result in errors in the resulting data, which in turn has a negative impact on the accuracy and usefulness of the base map (Colakoglu et al., 2021). Photogrammetry, which utilizes aerial photographs to generate ac-curate spatial data, is a highly efficient method, but the quality of the aerial imagery used determines the final mapping results; unclear or distorted imagery can lead to interpretation errors and inaccurate measurements (Junarto et al., 2020). Therefore, strict selection and

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assessment of aerial imagery, as well as proper data validation and calibration are necessary to ensure that the mapping results truly reflect field conditions. Quality testing in photogrammetry, including verification of geometric accuracy, positional accuracy, and evaluation of map scale suitability, should be conducted by comparing photogrammetric data with verified reference data or field survey results. Although accelerating the updating of base mapping is a necessity (Cirillo et al., 2022).

Quality testing of mapping products based on the Indonesian National Standard (SNI) is essential to ensure that the products produced meet the accuracy and reliability standards required in various applications. SNI provides detailed guidelines on various important aspects of mapping product quality, ranging from positional accuracy to visual quality. Positional accuracy is a key element that is checked under this standard. By complying with SNI guidelines, mapping products can ensure high accuracy in the determination of geographic coordinates. This is especially important for applications such as infrastructure planning and spatial analysis, where data precision is crucial. Accuracy ensures that the information displayed in a map or model truly reflects the real conditions on the ground, so that decisions made based on the data are accurate and reliable. In addition to positional accuracy, SNI also sets criteria for interpretation accuracy. These criteria ensure that geographical elements and man-made objects are correctly depicted in mapping products. Complying with these standards helps avoid errors that can lead to misinterpretation of data, ensuring that the mapping product is not only accurate but also informative and useful to the user. Completeness of information is also an important aspect of the SNI standard. The mapping product should include all the data necessary to achieve the overall mapping objective. This ensures that the resulting map or model does not lack important information, so it can be used effectively in various applications without losing crucial data (Junarto et al., 2020).

This research discusses the quality control procedures of photogrammetry map-ping products using UAVs. The basis for quality testing in this study uses SNI 9135-1 2022 concerning Large-Scale Geospatial Data Processing of Nonmetric Camera-Based Unmanned Aerial Vehicle Acquisition Results. The aim is to provide references to readers regarding the procedures for testing the quality of mapping products resulting from UAV acquisitions. This is done to support and ensure the quality of the resulting mapping products can be used for further analysis such as making base maps or other interests.

SNI 9135-1:2022 is a national standard that regulates the processing of large-scale geospatial data generated from nonmetric camera-based unmanned aerial vehicles. This standard is very important in ensuring that the data generated from this rapidly developing technology is of sufficient quality for mapping and spatial analysis purposes. In the context of photogrammetry, where positional accuracy and precision are crucial, SNI 9135-1:2022 provides the technical guidance needed to process geospatial data with appropriate methods, including pre-processing, data processing, and validation and verification of final results. One of the main aspects of SNI 9135-1:2022 is the emphasis on the importance of quality control in every stage of data processing. This standard regulates the use of ground control points and nonmetric camera calibration methods to minimize distortions and geometric errors that may occur during image capture and data processing. By implementing strict quality control in accordance with this standard, the risk of errors that could reduce the accuracy of mapping products can be minimized. This is especially important since data generated from unmanned aerial vehicles is often used for large-scale maps that require high accuracy. In addition, SNI 9135-1:2022 also underscores the importance of final evaluation of mapping products to

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ensure that they meet established specifications and standards. In relation to photogrammetric mapping, this means that any final products, such as orthophotos and digital elevation models (DEMs), must undergo a series of quality tests, including spatial accuracy tests and visual tests, before they are deemed fit for use (Khasanov, 2020). As such, this standard plays an important role in ensuring that the geospatial data produced is not only fast and efficient, but also has the accuracy and reliability required for critical ap-plications in mapping, planning and resource management (Ferrer-González et al., 2020).

2. METHODS

2.1. Material

The materials used in this research include photogrammetric survey equipment and a set of photogrammetric data processors as well as software to support the data processors (Stöcker et al., 2020). Table 1 shows the equipment used for the purposes of this research and Table 2 shows software required to support GNSS and photogrammetry Data Pro-cessing.

Table 1. Equipment used.

No	Tools	Designation
1	Drone	Aerial Photo Acquisition
2	Controller Drone	Drone Configuration
3	Receiver GPS Geodetic	GNSS Acquisition
4	Controller GPS Geodetic	Geodetic GPS Configuration
5	Jallon	Geodetic GPS Stand
6	Premark	GCP Point Markers for Georeferencing
7	Assessment Form	Procedural Requirements
8	Instrument Form	Procedural Requirements
9	Dosier Form	Survey Activity Report
10	Handphone	Documentation
11	Laptop	Photogrammetric Data Processing

Table 2. Data processing software.

No	Tools	Designation
1	Microsoft Excel	GNSS Data Processor
2	Agisoft Metashape Pro	Photogrammetric Data Processing
3	ArcGIS	Visualization of Mapping Products

2.2 Flowchart Research

In general, this research starts from the preparation stage, acquisition stage, and data processing stage. In this research, quality control is carried out at all stages to analyze the suitability of procedures and test the quality of a product produced. The stages are presented in Figure 1.

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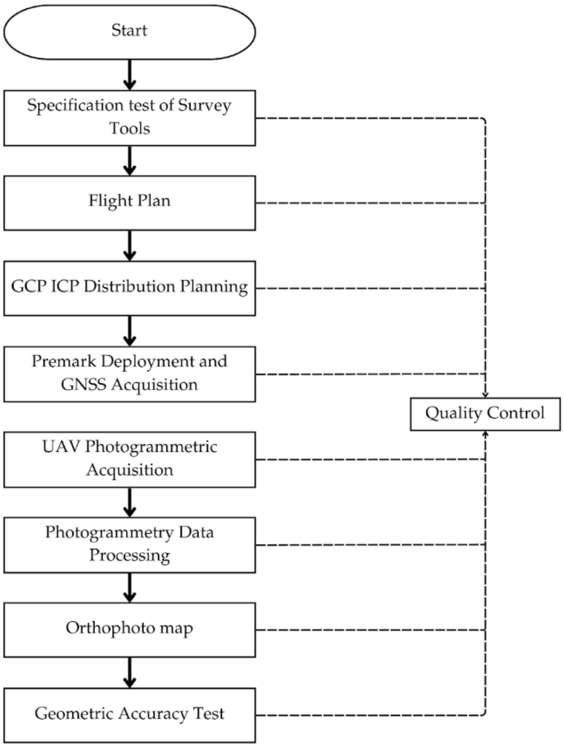

Figure 1. Flowchart Research.

2.3 Time and Location

This research was conducted in August 2024 consisting of planning, acquisition, data processing, and quality control stages. Aerial photography acquisition was carried out on August 19, 2024. This research was conducted at UPI (Universitas Pendidikan Indonesia), Bandung, Indonesia. The selection of the area of interest (AOI) of this research is not too broad because the goal is to study the quality control of mapping products. Visualization of the AOI will be presented in Figure 2.

Figure 2. Area of interest of research aerial photography acquisition.

The red dashed line is a visualization of the AOI. The AOI in figure 2, has the same length and width of about 200 m on each side. So, the area of the AOI is approximately 40000 m2.

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2.4 Preparation Stage

The preparation stage consists of tool specification testing, flight path planning, and GCP distribution planning. at this stage, the specifications of the tools used for the survey are tested. The photogrammetric survey tool specification test stage involves a series of procedures to ensure that the hardware and software used meet the accuracy and performance standards required for spatial data collection. This includes camera calibration to determine internal parameters such as focal length and lens distortion, as well as aerial or drone stability testing to ensure consistent image capture free from distortion due to vibration or movement. In addition, tests are also conducted on positioning systems such as GPS to verify the accuracy of the location recorded in each image. This process also included testing the data processing software to ensure that the algorithms used could produce accurate map products that met the required specifications. This specification test is very important to ensure that photogrammetric survey tools can produce accurate and reliable geospatial data, in accordance with applicable standards, such as those stipulated in SNI.

Flight path planning starts with determining the AOI (Area of Interest). Based on this scale, the UAV flight altitude is determined to determine the planned GSD value. The flight path is designed so that there is sufficient overlap between the images taken. This is important to ensure that the images can be properly integrated in the 3D modeling and orthophoto creation process.

2.5 Acquisition Stage

In this research, data collection involves several types of data. These include GCP coordinate data and aerial photography data.

2.5.1. GCP Coordinate Data

In this research, coordinate data collection was conducted using the Real-Time Kinematic (RTK) method to obtain highly accurate results. At this stage, Ground Control Points (GCP) stakes were installed as reference points. After the installation of the stakes, RTK measurements were made by connecting the Geodetic GPS device to the existing reference system, namely CORS Lembang station. The data collected from the RTK measurements provided high-precision coordinates for each GCP and ICP point, ensuring the accuracy of the geospatial data required for mapping and analysis.

2.5.2. Aerial Photo Data

Aerial photography was carried out using a drone type UAV with a vertical shooting method, namely the drone camera setting directed perpendicular to the ground surface. The area acquired was the distribution of the Area of Interest (AOI) in the University of Education Indonesia (UPI) campus area. Before shooting, premarks were installed on the GCP points. After the premarks were installed on all GCP point distributions, aerial photography began. The results of this aerial photography will be used in the next stage for data processing, orthophoto creation, and quality analysis using the applicable SNI.

2.6. Data Processing Stage

In the data processing stage of this research, the aerial photographs obtained were processed using two Agisoft Metashape Pro software. This process aims to produce accurate

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maps by correcting geometric distortions in the aerial images. Data processing using Agisoft Photoscan software consists of several stages that are essential to ensure the quality of the final result.

2.6.1. Add Photos

The first step in data processing was to import the captured photos into Agisoft Phtoscan. These photos were then organized by flight order, forming a logical arrangement according to the drone's flight path.

2.6.2. Align Photos

This process involves aligning the photos based on the same points that appear in multiple photos. This stage generates an initial three-dimensional model, camera positions, as well as sparse point clouds that will be used in the next stage.

2.6.3. Import GCP

At this stage, the X, Y, Z coordinates of the GCPs are imported into the software to provide a reference for the photo alignment process. With this reference, the geometric quality of the Digital Elevation Model (DEM) and the resulting orthophoto can be improved. The use of GCPs obtained from Geodetic GPS measurements is highly recommended to improve orthophoto accuracy.

2.6.4. Build Point Clouds

This stage is a very dense collection of points resulting from the processing of aerial photographs. These dense clouds are then used to build digital surface models such as Digital Surface Model (DSM), Digital Terrain Model (DTM), and orthophotos.

2.6.5. Build DEM (Digital Elevation Model)

A DEM is a digital model of the terrain produced in raster or grid format. Elevation information obtained from DEMs can be used for a variety of purposes, including topographic analysis such as cut and fill, as well as in the creation of DSMs and DTMs.

2.6.6. Build Orthomosaic

Orthophoto is an aerial photo that has been corrected for geometric distortion using DEM and GCP data. The orthophoto creation process is done after the dense clouds, mesh, and DEM creation stages are completed. Orthophoto is very important for mapping purposes that require an accurate visual representation of the mapped area.

3. RESULT AND DISCUSSION

The results of this research include an analysis of the quality control study of mapping products based on SNI 9135-1:2022.

3.1. Survey Equipment Analysis

In this research, the survey tool used mainly for aerial photography data acquisition is a drone type UAV. The drone used has specifications as described in table 3.

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Table 3. Specifications of the drone used in the research

Product Name	Focal Length	Pixel Size	Battery Capacity
Autel EVO II Pro V3	10,57	2,4 x 2,4µm	1900 mAh

Based on SNI 9135-1:2022, there are several tools required with certain specifications. These tools include non-metric cameras, GNSS receivers, IMUs, flight path generation software, and unmanned aerial vehicles. The survey equipment specifications listed in SNI 9135-1:2022 and their comparison with the tools used for the mapping survey conducted will be explained in table 4.

Table 4. Equipment specifications of nonmetric camera unmanned aerial vehicle (Nasional, 2022).

No	Equipment Type	Equipment Specifications	Tool Suitability
1	Nonmetric Camera	The camera in the digital system is equipped with the following equipment devices: a. a digital sensor with a minimum size of 12 megapixels, a maximum shutter speed of 1/50 s that has the ability to select a specific fixed lens focus value (not under autozoom conditions); b. storage media with a minimum capacity of 64 giga-bytes; c. calibrated lever arm.	Match
2	GNSS Receiver (onboard)	Supporting device (optional) principal point positioning with the following conditions: a. if equipped with IMU, it needs to be integrated through boresight misalignment correction., b. has minimal dual frequency (L1, L2) signal tracking capability for geodetical type GNSS signal recording..	Match
3	IMU	A support device (optional) used to determine the orientation of the sensor with respect to the X (omega), Y (phi), and Z (kappa) axes.	Match
4	Flight Path Generator Software	Software capable of designing flight paths according to the sensors used	Match
5	Unmanned Aerial Vehicle	The unmanned aerial vehicle used is licensed in accordance with the provisions of the laws and regulations. The air vehicle has the ability to transport and operate the entire nonmetric aerial camera system. The vehicle is also equipped with the following equipment: a. GCS; b. gimbal-integrated camera mount (optional); and c. navigation equipment for pilots and operators equipped with GNSS that enables geotagging.	Match

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In addition, there is a selection of supporting devices in aerial photo mapping based on georeferencing methods. The following is a comparison table of survey tools used with an explanation of the specifications of supporting devices for unmanned vehicles from SNI 9135-1: 2022. Table 5 displays the supporting devices required based on the georeferencing method performed.

Table 5. Selection of supporting devices based on georeferencing method(Nasional, 2022).

Georeferencing Methods	Supporting Devices	
	GNSS (onboard)	IMU
Direct Georeferencing	Required	Required
Indirect Georeferencing (Using only GCP)	Not Required	Not Required
Indirect Georeferencing (Combination of ATP & GCP)	Required	Not Required

This research used the indirect georeferencing method (using only GCPs), so no supporting equipment was required. Therefore, it can be said that in terms of survey equipment, it meets the standard specifications based on SNI 9135-1:2022.

3.2. Aerial Survey Planning Analysis

Flight path planning is related to how much AOI and GSD plan is produced. Flight path planning is fundamental to the quality of the resulting product. This relates to the sidelap and overlap rules of each aerial photo recorded. SNI 9132-1:2022 explains that the overlap must be more than 80% and the sidelap must be more than 60%. Table 6 is an explanation of the configuration used in determining the flight path, including flight height, overlap, and sidelap.

Table 6. Flight height, overlap, and sidelap configurations.

Flying Height	Overlap	Sidelap
100 m	80%	70%

The flight path designer application will automatically read the above configuration. Figure 3 is a visualization of the flight path plan obtained based on the configuration specified in table 5.

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Figure 3. Flight Path Plan Visualization.

The determination of the flight height is based on how high the expected ground sample distance (GSD) value is. The GSD value is the basis for determining how detailed the map product will be. The following is an equation in determining the GSD value (BSN, 2022).

$$GSD = \frac{T}{F} \, x \, P, \tag{1}$$

The variable T is the flying height of the drone, f is the focal length, and P is the pixel size of the camera. Based on the calculation using equation 1, the resulting GSD value of the aerial photography product is 2.1 cm. Based on this value, the aerial photography product obtained is capable of making map products with a scale of 1:1000 (Class 1). Table 7 presents the determination of the class and scale of the map based on the GSD value.

Table 7. GSD Value (BSN, 2022).

Map Scale	Class 1	Class 2	Class 3
1:5000	≤ 25	≤ 50	≤ 75
1:2500	≤ 12,5	≤ 25	≤ 37,5
1:1000[1]	≤5[1]	≤ 10	≤ 15

[1] Map product quality results include adequate scale and grade based on GSD generated.

3.3. GCP Distribution Planning Analysis

SNI 9132-1:2022 explains that there are different specifications based on the 3 georeferencing methods used. The three georeferencing methods are direct georeferencing, indirect georeferencing (using only GCP) and in-direct georeferencing (combination of ATP & GCP). The selection of the three georeferencing methods is based on the type of aerial vehicle used. If the aerial vehicle used has a GNSS system (onboard) from the principal point as well as an IMU system that works as a determinant of camera orientation direction, it can be done with the direct georeferencing method. If the air vehicle used cannot support the system, then the georeferencing method used is the indirect georeferencing method.

In this research, the indirect georeferencing method (using only GCPs) was used. The requirements for using this method are attached in Table 8.

Table 8. GCP usage requirements based on indirect georeferencing method (using only GCP) (BSN, 2022)

Georeferencing Methods	Requirements	Conformance to Requirements
Indirect Georeferencing (Using only GCP)	• The GCPs are located along the corner points that form the AOI, the perimeter, and spread out in the center of the AOI block.	Yes
	• In the direction of the flight path, the distance between GCPs is optimal: 4 air bases (4B) to 12 air bases (12B). The airbases are calculated based on the principal distance at an overlap of at least 60%.	Yes

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	• In the direction perpendicular to the flight path, GCPs are placed in the 20% overlap area.	Yes

In SNI 9132-1:2022, it is explained that the use of the indirect georeferencing method (using only GCP) has a requirement that the number of GCPs is 91 units spread evenly over the AOI with an area of 2.4 Km x 1.2 Km. Figure 4. presents an illustration of modelling the determination of GCP distribution using the indirect georeferencing method (using only GCP).

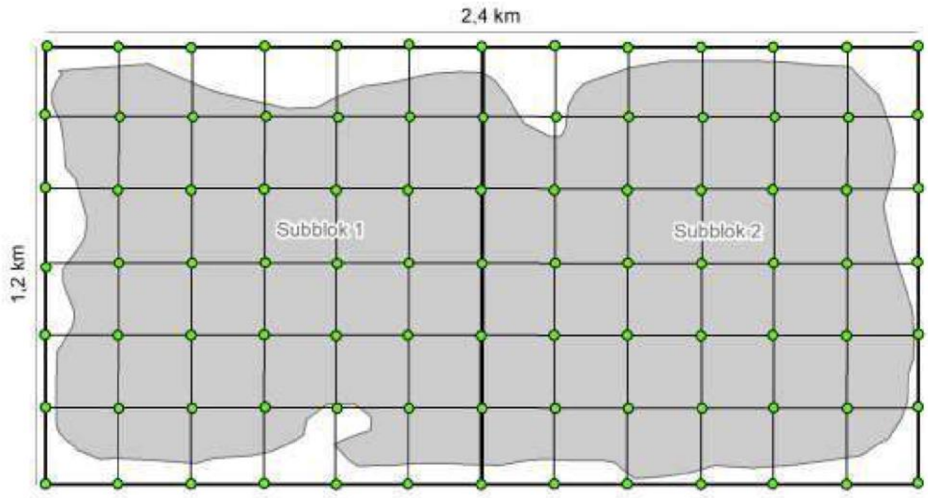

Figure 4. Illustration of determining the distribution of GCPs in the indirect georeferencing method (using only GCP) (BSN, 2022).

In this study, the area of the AOI is 0.2 Km x 0.2 Km. Therefore, the number of GCPs required is at least 4 GCPs. The visualization of the GCP distribution of this study will be presented in Figure 5.

Figure 5. Distribution of GCPs in this study.

3.4. Technical Analysis of Mapping Survey Implementation

The survey implementation includes the area of interest location assessment form, filling out the data acquisition instrument form, and the minutes of the survey implementation. In

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SNI 9132-1:2022, it is explained that in order to obtain data in accordance with the specified geometric accuracy, the survey and acquisition implementation needs to be carried out according to procedures. Table 9 shows the procedures that need to be carried out based on SNI 9132-1:2022 and its comparison with the survey conducted in this study.

Table 9. Survey implementation procedures based on SNI 9132-1: 2022 and its comparison with the survey conducted in this study (BSN, 2022).

Procedure of SNI 9132-1:2022 (BSN, 2022)	Reality of Survey Implementation
Boresight misalignment and lever arm are performed if the aerial camera system is equipped with onboard GNSS and IMU devices to support accurate direct georeferencing.	Surveyors performed camera calibration and IMU calibration. This calibration stage was successfully carried out, although the georeferencing method used was indirect georeferencing (using only GCPs).
Aerial surveys consider four main factors: wind direction, sunlight direction, terrain conditions (flat, hilly, or mountainous), and dominant objects in the AOI.	The surveyor team, especially the drafter, conducted a site assessment which included filling in the formular information on wind direction, sun direction, terrain conditions, and dominant objects in the AOI. The site assessment information will be presented in table 10.
Acquisition should not be done during the daytime to avoid strong sunlight reflections that may cause the shadow of the drone to be recorded.	Aerial photography acquisition was conducted from 14:18 to 15:08. Based on the results, no shadow of the drone was recorded.
Measurements should be taken at the same time period between different processing blocks.	Acquisition is done in only one block and on the same day, Monday, August 19, 2024.
The aerial camera is mounted on a stable mount and equipped with a gimbal and vibration damper to reduce the influence of motor vibration.	Features of gimbal stabilizer and motor vibration damper available on the drone used
GNSS base station measurements should be taken during the aerial shoot.	This measurement was not done with the GNSS RTK (onboard) method, so no GNSS base station measurements were taken.
Aerial photographs are uniquely numbered and easily identifiable.	The surveyor fills in a unique code for the flying mission performed so that the acquired data is easily identifiable.
The aerial survey should be in accordance with the flight path planning to obtain the GSD value, face-to-face and side-to-side encounters as planned.	The surveyor inputs the planned AOI on the drone controller and slightly widens it so that the orthophoto processing can match the planned AOI.
Aerial surveys were conducted with an integrated nonmetric camera system to obtain EO position and parame-ter values.	The implementation of aerial surveys is in accordance with the equipment stipulated in SNI 9132-1: 2022.
The GNSS receiver (onboard) is connected to a base station on the ground with sufficient distance or using NTRIP-CORS technology for accurate EO results.	This measurement was not done with the GNSS RTK (onboard) method, so no GNSS base station measurements were taken.
The selection of the base station location should be in the middle of the AOI.	This measurement was not done with the GNSS RTK (onboard) method, so no GNSS base station measurements were taken.
Cloud coverage is no more than 10% on each aerial photo, and the cloud-covered objects are not buildings or transportation.	Measurements were taken in clear, cloudless conditions. Also, the drone's flight height was adjusted to avoid cloud cover.
If the aerial shooting survey is interrupted, follow-up measurements are taken with an 80% match to the previous measurements.	The surveyor has set up this procedure on the drone controller.

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In general, the aerial photography acquisition process carried out is in accordance with the procedures set out in SNI 9132-1:2022. In addition, in this study, the survey implementation procedure was not only based on SNI 9132-1:2022, but also on the drone usage procedure published by Terra Drone Indonesia. In it, surveyors fill out a number of forms, one of which is the site assessment form which will be presented in table 10.

Table 10. Site Assessment of Research Location.

Section	Parameter	Keterangan[1]
Site Detail	Landowner	Universitas Pendidikan Indonesia (UPI)
	Vehicle Access	Yes
	Medical Facility Nearby	Polyclinic UPI - ≤500 m
	Security Facility Nearby	HSSE UPI - ≤500 m
Ground Assessment	Objects That May Increase the Risk	Cable, Poles, Crowd, Eagle, Building
	Mitigation	• Fly high enough to avoid interference from objects such as buildings • Selecting a landing site that is spacious and away from the crowds. • Always keep an eye on the drone's position on the controller and visually to avoid interference from wildlife.
Weather Forecast	Wind Direction	Southwest
	General Forecast	Sunny
	Sunrise/Sunset Time	Sunrise: 05.49; Sunset: 17.57

3.5. Point Clouds Formation Analysis

Point clouds are generated through the Dense Image Matching (DIM) method from aerial photographs supplemented with Earth Observation (EO) aerial triangulation results. Point Cloud is a collection of points in a certain space used in geospatial applications. Point Clouds specifications based on SNI and comparison of research results will be presented in table 11.

Table 11 Specification of point clouds based on SNI 9132-1: 2022 (BSN, 2022) and comparison of research results.

Aspects	Scale 1:5000			Scale 1:1000			Research Results
	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	
Point Density (point/m^2)	16	4	2	100	25	9	**141**
Point spacing (m)	0.25	0.5	0.75	0.1	0.2	0.375	**≤0.1**
No height data gap	Yes						**Yes**
Vertical Precision (LE90) (m)	0.5	0.75	1	0.1	0.15	0.2	**0.180274**[1]

[1] The calculation of LE90 is explained in the Geometric Accuracy Test of Orthophoto Products subchapter.

The formation of point clouds was carried out on Agisoft Metashape Pro software. Based on the results of the data processing carried out, the results obtained are as listed in table 11. Therefore, the results of the formation of point clouds carried out are sufficient for making map products with a scale of 1:1000 (class 1).

3.5. Orthophoto

Based on the processes described, from planning to data processing, the output product is an orthophoto map. Figure 5 presents the visualization of the orthophoto map.

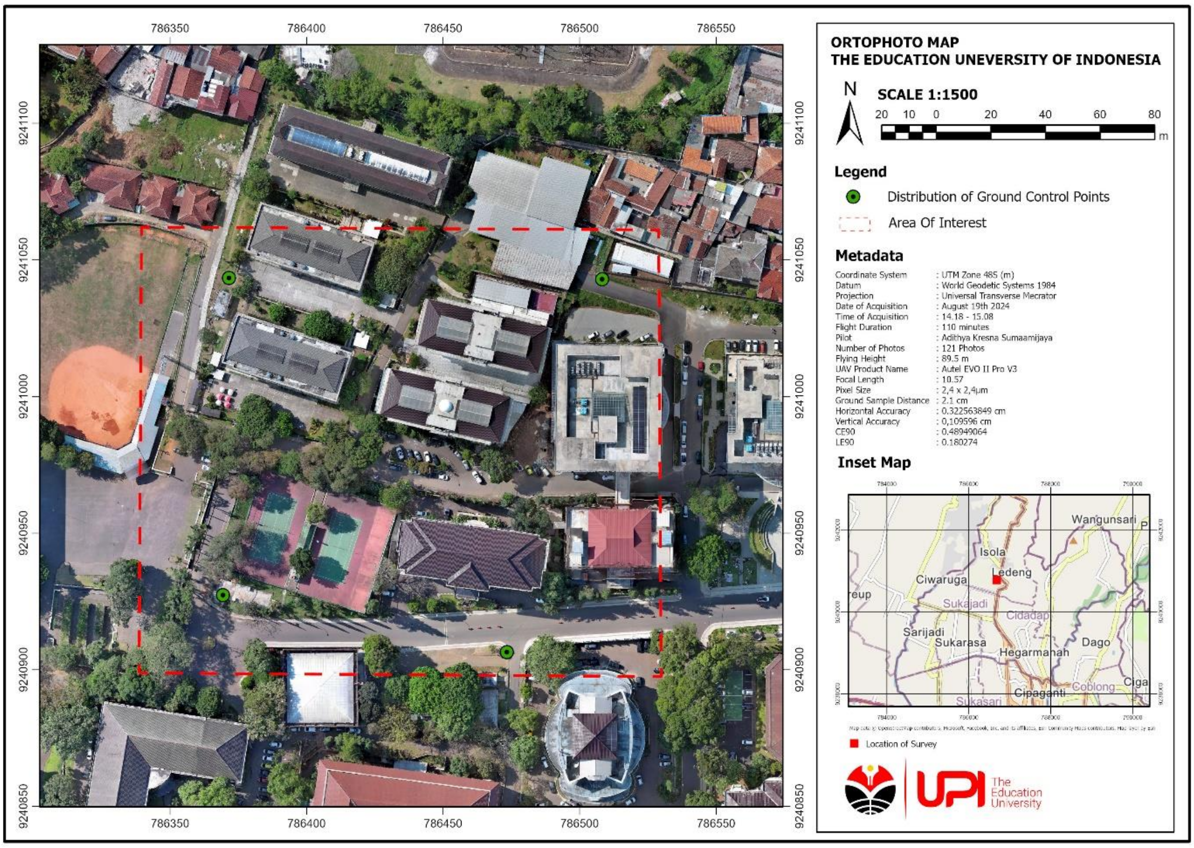

Figure 5. Visualization of the orthophoto map.

3.6. Geometric Accuracy Test of Orthophoto Products

The results of aerial photography products are tested for accuracy. This accuracy test is carried out with reference to SNI 8202: 2019 concerning Basic Map Accuracy. Table 12 presents the geometric accuracy of basic geospatial data based on SNI 8202:2019 in SNI 9132-1:2022.

Table 12. Geometric accuracy of basic geospatial data (BSN, 2015, 2022).

Skala	Class 1 (cm)			Class 2 (cm)			Class 3 (cm)		
	GSD	Horizontal	Vertical	GSD	Horizontal	Vertical	GSD	Horizontal	Vertical
1: 5000	≤ 25	≤ 75	≤ 50	≤ 50	≤ 150	≤ 75	≤ 75	≤ 225	≤ 100
1: 2500	≤ 12.5	≤ 37.5	≤ 25	≤ 25	≤ 75	≤ 37.5	≤ 37.5	≤ 112.5	≤ 50
1: 1000	≤ 5	≤ 15	≤ 10	≤ 10	≤ 30	≤ 15	≤ 15	≤ 45	≤ 20

The GSD value obtained in this study is 2.1 cm as described in table 7. In terms of GSD, the orthophoto products produced from this research are capable of being adequate mapping products with a scale of 1:1000 (Class 1). Meanwhile, the horizontal and vertical accuracy of this orthophoto product is analysed based on the distribution of GCPs. Table 13 presents the horizontal and vertical accuracy levels based on the comparison of orthophoto products with the distribution of GCPs.

Table 13. Horizontal and vertical accuracy of orthophoto products.

Label	X error (cm)	Y error (cm)	XY Error (cm)	Z Error (cm)
GCP 1	0.0128077	-0.212412	0,045282895	0.102653
GCP 2	0.174894	-0.129892	0,047459843	-0.0779714
GCP 3	-0.408587	-0.00417077	0,166960732	-0.128194
GCP 4	0.222782	0.326886	0,156486277	0.122451
		Total	0,416189746	0,048045
		Mean	0,104047437	0,012011
		RMSE	0,322563849	0,109596
		CE90/LE90	0.48949064	0.180274

To determine the amount of horizontal and vertical errors, the CE90 and LE90 calculations of SNI 8202:2019 are required. CE90 is a measure of horizontal geometric accuracy in the form of a circle radius indicating that 90% of errors or differences in the horizontal position of objects on the map with positions that are considered actual are not greater than that radius. While LE90 is a measure of vertical geometric accuracy in the form of a distance that shows that 90% of errors or differences in the height value of objects on the map with the height value that is considered actual is not greater than the distance value. The equations for calculating the CE90 and LE90 values will be presented in equations 2 and 3 (BSN, 2015).

$$CE90 = 1.5175\ x\ RMSExy, \quad (2)$$

$$LE90 = 1.6449\ x\ RMSEz, \quad (3)$$

Based on the calculation using equations 2 and 3, the CE90 value of 0.48949064, and LE90 of 0.180274 were obtained. Based on the GSD, CE90, and LE90 values obtained from the orthophoto products produced in this study, it can be concluded that the orthophoto products made are capable of being adequate for making map products with a scale of 1:1000 class 1 such as the geometric accuracy quality requirements presented in table 12.

3.7. Quality Control of Orthophoto Products

Quality control is especially important when it comes to measurement and data acquisition. Moreover, the data obtained is the basic data required for further analysis. Every stage in the acquisition process needs to be subjected to quality control and specification tests. The orthophoto products produced in this study have been tested and are in accordance with the procedures listed in SNI 9135: 2022.

Quality control is not only carried out in the data acquisition process, but quality control is also carried out at every stage, starting from the planning stage until a product is created. In the planning stage, quality control is carried out such as testing tool specifications, flight path planning, GCP distribution planning, site assessment, flight height planning, and determining georeferencing methods. This needs to be done to achieve effective and efficient work.

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At the aerial photography data acquisition stage, quality control is also carried out to ensure work safety and the suitability of the data obtained based on the planning that has been done. In this case, pre-flight and post-flight tests, GNSS measurement accuracy tests for GCPs, testing survey and data acquisition procedures, and reporting minutes and filling in measurement instruments.

After the data acquisition process, quality control is also carried out at the data processing stage. At the data processing stage, quality control is carried out in the process of forming point clouds, forming orthophotos, and testing the geometric accuracy of orthophoto quality. The geometric accuracy test for orthophoto quality is based on SNI 8202:2019.

The entire quality control procedure described has the main objective of ensuring that all flight and camera parameters are set and executed according to the mission plan. Factors such as flight altitude, camera angle, and aircraft speed must be strictly controlled to produce images that are homogeneous and in accordance with the set standards. Thus, quality control not only ensures that the data acquired meets the needs of the project, but also that the data can be further processed without the need for retakes, which would be time-consuming and costly (Pereira et al., 2021).

3.8. Analysis of the advantages and disadvantages of SNI 9135: 2022

3.8.1 Advantages

SNI 9135:2022, which regulates the processing of large-scale geospatial data from nonmetric camera-based unmanned aerial vehicle (UAV) acquisitions, has several significant advantages in improving data processing standards in Indonesia. One of the advantages is the provision of comprehensive and standardized guidelines to ensure that the resulting geospatial data has a high level of accuracy and reliability (Jiménez-Jiménez et al., 2021). The standard regulates important stages from data collection, pre-processing, to validation of results, thus ensuring consistency in the quality of data used in various applications, such as regional planning, environmental monitoring, and infrastructure development.

Another advantage is that the standard is designed to facilitate the increasingly popular use of UAV technology in geospatial mapping. With clear guidelines on the use of nonmetric cameras, SNI 9135:2022 helps optimize the results from equipment that is more affordable and accessible than conventional metric cameras. This opens up opportunities for more institutions, both government and private, to conduct large-scale geospatial mapping at a lower cost, while maintaining data quality and accuracy.

3.8.2 Disadvantages

SNI 9135:2022 has some shortcomings that should be considered, mainly related to the limited scope of the technologies covered. The standard focuses more on the use of nonmetric cameras, which although more economical, have limitations in terms of accuracy compared to metric cameras (Ahmed et al., 2022). This can be an obstacle in projects that require a very high level of precision, such as land surveying or technical mapping for construction, where this standard may not be adequate to meet very specific data accuracy needs. In addition, the implementation of SNI 9135:2022 often requires resources and technical skills that are not always available in all organizations or regions. For example, the data validation and correction processes governed by this standard require in-depth

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knowledge of geospatial technology and image processing, which not all users may have(Ferrer-González et al., 2020). This barrier can be even more pronounced in small organizations or in remote areas, where access to the resources and training required to fully comply with the standard may be limited.

4. CONCLUSION

This research analyzes quality control in mapping products based on the SNI 9135-1:2022 standard, which regulates the processing of geospatial data from the acquisition of UAVs with nonmetric cameras. The research uses the indirect georeferencing method with GCPs (Ground Control Points), ensuring that all equipment and processes used are in accordance with the specifications and procedures set by SNI.

At the planning and data acquisition stages, quality control is applied by verifying tool specifications, planning flight paths, and checking the distribution of GCPs and other parameters that affect data quality. The results of the data acquisition and processing process produce orthophoto products that are tested for accuracy, with GSD values that are qualified for 1:1000 scale mapping.

The SNI 9135:2022 standard offers comprehensive guidance and facilitates the use of UAV technology for geospatial mapping at a lower cost, while maintaining data quality. However, the standard has limitations in the scope of technologies covered, especially in terms of the accuracy of nonmetric cameras compared to metric cameras, as well as requiring technical skills that may not be available in all organizations, especially in remote areas.

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6. AUTHORS' NOTE

This research paper has no conflict of interest regarding the publication of the article. And this manuscript is free of plagiarism.

7. REFERENCES

Ahmed, S., El-Shazly, A., Abed, F., & Ahmed, W. (2022). The influence of flight direction and camera orientation on the quality products of UAV-based SfM-photogrammetry. In *Applied Sciences*. mdpi.com. https://www.mdpi.com/2076-3417/12/20/10492

Cintra, J. P., & Nero, M. A. (2015). New method for positional cartographic quality control in digital mapping. *Journal of Surveying Engineering*, *141*(3), 4015001.

Cirillo, D., Cerritelli, F., Agostini, S., Bello, S., & ... (2022). … kinematic (PPK)–structure-from-motion (SfM) with unmanned aerial vehicle (UAV) photogrammetry and digital field mapping for structural geological analysis. In *… International Journal of …*. mdpi.com. https://www.mdpi.com/2220-9964/11/8/437

Colakoglu, F. N., Yazici, A., & Mishra, A. (2021). Software product quality metrics: A systematic mapping study. *IEEE Access*, *9*, 44647–44670.

DOI: http://dx.doi.org/10.xxxxx/ijost.vXiX
p- ISSN xxxx-xxxx e- ISSN xxxx-xxxx

Ferrer-González, E., Agüera-Vega, F., & ... (2020). UAV photogrammetry accuracy assessment for corridor mapping based on the number and distribution of ground control points. In *Remote sensing*. mdpi.com. https://www.mdpi.com/2072-4292/12/15/2447

Ihsan, M., Ismail, A., & Sugandi, D. (2021). Utilization of unmanned aerial vehicle photogrammetric technology for analysis of landslide areas. *IOP Conference Series: Earth and Environmental Science*, *683*(1), 12102.

Ihsan, M., & Sugandi, D. (2019). Pemanfaatan Produk Fotogrametri Digital Untuk Media Pembelajaran. *Geografi Gea*, *115*.

Jiménez-Jiménez, S. I., Ojeda-Bustamante, W., & ... (2021). Digital terrain models generated with low-cost UAV photogrammetry: Methodology and accuracy. In *… International Journal of …*. mdpi.com. https://www.mdpi.com/2220-9964/10/5/285?utm_source=releaseissue&utm_medium=email&utm_campaign=releaseissue_ijgi&utm_term=titlelink3&recipient=info.sigzine@gmail.com&subject=ISPRS Int. J. Geo-Inf., Volume 10, Issue 5 (May 2021) Table of Contents&campaign=R

Junarto, R., Djurjani, D., Permadi, F. B., Ferdiansyah, D., Admaja, P. K., Sholikin, A. R., & Rahmansani, R. (2020). Pemanfaatan teknologi unmanned aerial vehicle (uav) untuk pemetaan kadaster. *BHUMI: Jurnal Agraria Dan Pertanahan*, *6*(1).

Khasanov, K. (2020). Evaluation of ASTER DEM and SRTM DEM data for determining the area and volume of the water reservoir. *IOP Conference Series: Materials Science and Engineering*, *883*(1), 012063.

Nasional, B. S. (2015). *Ketelitian Peta Dasar* (SNI 8202). Badan Standarisasi Nasional.

Nasional, B. S. (2022). *Pengolahan Data Geospasial Skala Besar Hasil Akuisisi Wahana Udara Nirawak Berbasis Kamera Nonmetrik* (SNI 9135-1). Badan Standarisasi Nasional.

Pereira, L. G., Fernandez, P., Mourato, S., Matos, J., & ... (2021). Quality control of outsourced LiDAR data acquired with a UAV: a case study. In *Remote Sensing*. mdpi.com. https://www.mdpi.com/2072-4292/13/3/419

Stöcker, C., Nex, F., Koeva, M., & Gerke, M. (2020). High-quality uav-based orthophotos for cadastral mapping: Guidance for optimal flight configurations. In *Remote sensing*. mdpi.com. https://www.mdpi.com/2072-4292/12/21/3625

DOI: http://dx.doi.org/10.xxxxx/ijost.vXiX
p- ISSN xxxx-xxxx e- ISSN xxxx-xxxx