DEVELOPMENT AND UTILIZATION OF AERIAL PHOTOGRAMMETRY SURVEY USING NONMETRIC CAMERA DRONE WITH OPEN-SOURCE SOFTWARE: CASE STUDY ON TUGU DAM PROJECT

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ABSTRACT

The construction of the Tugu Dam requires stone material obtained from Quarry for the main dam. The stone material for the main dam is very critical because the work on the main dam should be carried out immediately during the dry season (for work safety and quality). Preparation for material transportation at the Quarry includes calculation of the availability of material volumes, construction of haul roads, and technical plans for transport and blasting management. These activities require surveying and mapping. The project team chose the drone mapping method using the Open-Source program rather than the conventional method for accelerating the surveying and mapping work. Aerial photogrammetry survey can complete a variety of projects, such as available material calculation, blasting management, and hauling road planning. Based on cost, quality, and time analysis, drone mapping using open-source computer programs is cheaper and faster than using paid computer programs and conventional surveying methods, but using Open-source software has the disadvantage of limited features and low data accuracy with a CE90 value = 17,706 and LE90=37,126 for this study. In general, drone mapping has lower accuracy than conventional surveying methods, but the output of drone mapping which is orthomosaic maps and Digital Elevation Models can be used for the development of Building Information Modeling (BIM) and autonomous engineering.

Keywords: Aerial Photogrammetry; Dam; Nonmetric camera drone

1. INTRODUCTION

Currently, the construction of Tugu Dam, Trenggalek is carried out by PT. Wijaya Karya. Many works have been done such as the construction of dental and construction of conduit. The critical main work is the preparation of stone material in the Quarry. Preparation of stone materials includes material availability, hauling road, and blasting management. Surveying is needed to support the preparation. Surveying and preparation should be done in two months.

The existing condition of the Quarry is a hilly forest mountain. Based on that condition, the estimation of surveying works is three months. Even, if the contractor uses a conventional survey method, the contractor risk is high (unsafety condition). Based on that condition, the contractor needs advanced surveying.

An aerial mapping survey is a preferred method for conducting measurement and mapping surveys. Drones are an alternative to new technologies for mapping, especially

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aerial photography (Meiarti, 2019). Taking aerial photos with drones takes 1 day for an area of 26.27 Ha and data processing takes 3-4 days which usually takes more than 3 months ((Sutanto Samuel & Ridwan, 2016)). The mapping results can be directly used

for modeling areas, buildings, and various other construction projects. Mapping output with drones can be in the form of a Digital Elevation Model which can be directly made into contours (Arif dkk., 2018). Another output that can be produced is a three-dimensional model that has good enough detail that can be directly used in the regional development (Nitih Indra Komala, 2020). Considering that aerial mapping surveys must be carried out quickly and safely, modification work methods are needed. Modification work methods are carried out by adjusting the availability of equipment, the type of data needed in the project, and software that is easy to use and free (reducing the cost of purchasing expensive software). So, aerial mapping surveys can be done quickly, easily, and cheaply.

In this study, a drone multirotor with a nonmetric camera will be used for an aerial mapping survey. Multirotor drones are designed to complete Dull, Dangerous, and Dirty tasks. The operation is also easier than the fixed wing, where the fixed wing requires special skills both during take-off and landing. The ability to fly stationary on a multirotor drone also provides "time" for the pilot to make decisions in the maneuvering (BIMWIKA, 2021). Nonmetric cameras are cameras that are commonly used by amateurs or professionals. The quality of non-metric cameras prioritizes visual quality over geometric quality (Avicenna, 2018). So, we can use it for multipurpose, such as inspection, documentation, and mapping. It will reduce the cost of mapping work. But, the use of non-metric cameras can be used for close-range photogrammetry because it has results approaching metric cameras even though there are weaknesses in brightness that are not in accordance with actual conditions so adjustments are needed (Pratama & Hariyanto, 2013).

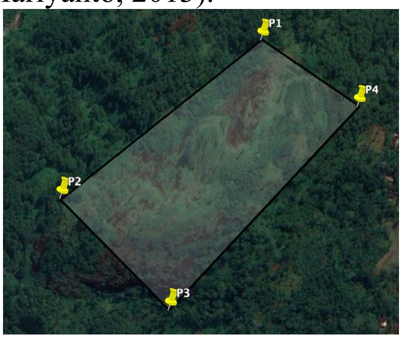

Figure 1. This is an area of interest For Quarry mapping.

Figure 2. The mapping area should cover all of areas of interest as shown in this figure.

2.1. Aerial Photo Acquisition

At the acquisition stage, aerial photos have been taken to ensure that aerial photos are appropriate and by applicable quality standards. If the photos are not good (there is fog, blur, or exposure is too high), then the survey team needs to repeat the flight mission to get quality photos. Aerial photo acquisition using an open-source program capable of compiling a flight path and communicating with the drone's autopilot system.

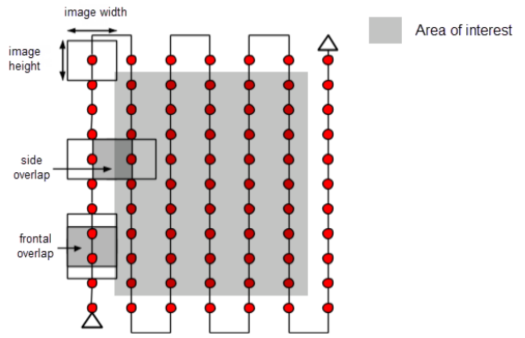

Figure 3. Flight path determines the sidelap and overlap. Sidelap and overlap is the ratio of the percentage of overlap between the aerial image and the flight path. Sidelap is overlapping sideways and overlap is the overlap between adjacent lanes. a minimum of 80% overlap and 60% sidelap (Peraturan Badan Informasi Republik Indonesia, 2020) . Overlap and Sidelap affect the level of detail of the mapping.

2.2. Photogrammetry Processing

Aerial photo processing uses Open-source programs that can be used to form orthophoto mosaics and Digital Surface Models (DSM) ((Peraturan Badan Informasi Republik Indonesia, 2020)). For this, DroneMapper was chosen for 2D processing, Meshroom for 3D processing, and QGIS for presenting and packaging the output data.

2.3. The trouble with Aerial Photogrammetry Survey

Mapping with drones carried out at Quarry encountered several problems. The most frequent obstacle is the drone signal which is often disconnected even though the distance does not exceed the drone's specifications. The team has carried out inspections regarding drones that may have malfunctioned. However, no damage was found to the drone because the drone only lost signal at the Quarry location. Drone signals that are often cut off only occur at Quarry locations with lower altitudes than Quarry (during landing and take-off). The presence of interference due to the magnetic layer and electromagnetic waves can make the drone experience a loss of controlling their presence (Jirigalatu dkk., 2020). Considering that the Quarry structure is almost entirely of Andesite material which is paramagnetic, the possibility of magnetic field anomalies that cause interference. Research on magnetic field anomalies in the presence of andesite material has been carried out in Awang Bangkal Village, South Kalimantan (Yunanto dkk., 2021). However, research regarding drone interference with the presence of Andesite material has never been carried out, but this can be used as a warning regarding mapping with drones. Another thing that becomes an obstacle is that drones are often disturbed by eagles, so flights are often stopped temporarily.

2. METHOD OF AERIAL PHOTOGRAMMETRY SURVEY USING OPEN-SOURCE SOFTWARE

In this study, aerial photogrammetry survey is close-range photogrammetry. Close range photogrammetry is photogrammetry with aerial images less than 300 m (Kafiar, 2020). So, the photogrammetry will take aerial photos of a maximum of 100 m as regulated. The stages of the aerial photography survey method that have been developed are 1) administrative preparation, 2) technical review and flight mission planning, 3) aerial photography, 4) aerial photo quality inspection, 5) photogrammetry processing to produce orthomosaic maps and digital surface models, and 6) processing of photogrammetry results. The following is the Quarry area of interest that will be mapped.

Data on the use of ELT was obtained from various relevant articles. The data processing is carried out using a narrative review method. Different types of ELT reuse will be discussed and categorized by civil engineering and geotechnical application. From these various uses, methods will be highlighted, comparing and summarizing the reuse of each sector. Articles were obtained from accredited sites such as Elsevier, Springer, Scopus, and Research Gate from 2012 to 2022. Articles obtained must meet the criteria for publication in the last 10 years, indexed journals, full-text journals, and open access journals.

3. UTILIZATION OF MAPPING METHODS WITH DRONES USING COMPUTER PROGRAMS

The mapping carried out produces an orthomosaic map and a Digital Surface Model. In preparation at Quarry, road planning and blasting management are needed so that material can be taken safely and quickly. Mapping with drones is carried out to understand and find out the measurement data in field conditions. Considering that road alignment planning requires elevation data and coordinates to determine the slope mapping with drones is very good because it will provide these data. In this way, planners can understand the natural features around Mount Lojeh, estimate the area to be made a road route, and ensure that the road alignment is easy to work on and can be used properly in the future. Before carrying out road work, the method of blasting implementation and road alignment planning is first carried out. The blasting is carried out in such a way as to minimize work accidents to the surrounding environment. Therefore, a blasting plan was made as shown in **Figure 4** and **Figure 5**.

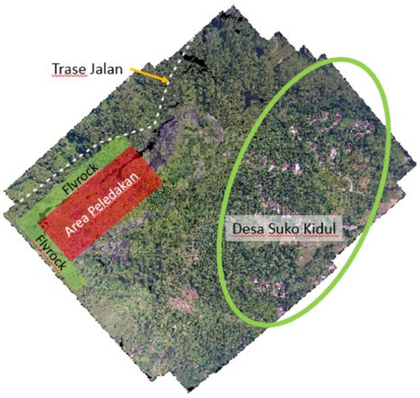

Figure 4. The scheme of blasting management is made by an orthomosaic map.

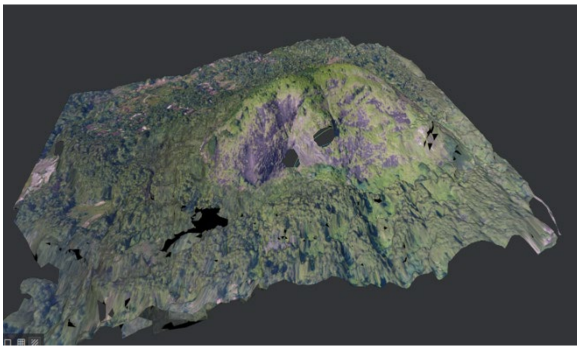

Figure 5. The 3D model shows that an extreme slope on hauling road alignment

The blasting management planning is made as shown in Figure 4, so that the flyrock does not harm settlements in Suko Kidul Village. On the other hand, a collection of flyrock will collect in the road area. Thus, road work will be efficient. However, drone mapping can show the project team that there are extreme slopes at the site of the road. Thus, the project team can make alternative blast management plans as shown in the figure below.

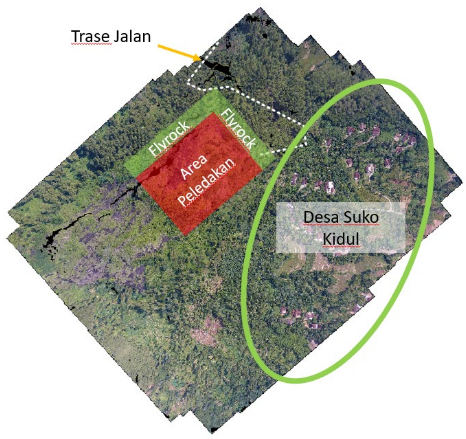

Figure 6. Alternative Scheme of Blasting Management Planning

With this alternative scheme, blasting management can be made for work safety. Mapping with drones produces elevation data in the form of a Digital Surface Model. In this way, the project team was able to analyze the longitudinal sections of the created road traces. The following is information about the slope of the road alignment.

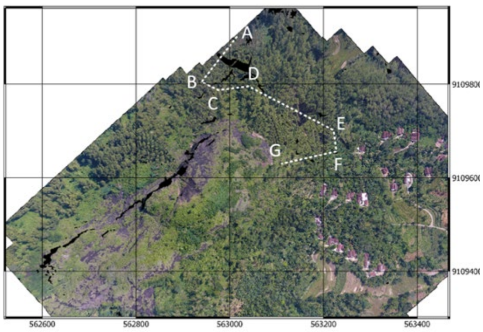

Figure 7. The layout of hauling road alignment

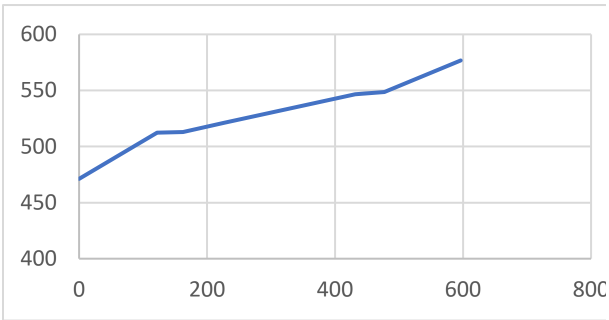

Figure 8. The long section of hauling road alignment

Table 1. Slope Percentage of Hauling Road Alignment

Point	Distance	Elevation	Slope (%)
A	0	471.174988	
B	122.0581	512.245605	33.65
C	162.2995	512.924438	1.69
D	226.7101	521.070679	12.65
E	431.4286	546.527649	12.44
F	477.1798	548.564209	4.45
G	596.28	576.736572	23.65

The data shown in Table 1 can represent the actual situation in the field. Thus, the project team can estimate the cut and fill work that will be carried out in the construction of the hauling road.

4. COMPARISON BETWEEN AERIAL PHOTOGRAMMETRY SURVEY USING OPEN-SOURCE SOFTWARE WITH CONVENTIONAL SURVEY METHOD

To compare the results between open-source computer programs and conventional survey methods, and accuracy test was carried out. The accuracy test was carried out at two points that were used as benchmarks for these locations during conventional measurements. Referring to the specifications for the accuracy of the total station (TOPCON ES-105) and water pass (TOPCON AT-B4) of ±2mm, the coordinates and elevation will be used as the coordinates of the check data in the accuracy test. The following is the calculation of the accuracy test (Badan Informasi Geospasial (BIG), 2014) and the register of the accuracy of the RBI map shown in the table below.

5. CONCLUSION

The used tire fibers can be utilized in the sector, categorized geotechnical applications, and civil engineering applications. ELT in geotechnical applications has been used in several sectors, including landfill liners. In addition, ELT can reduce the crack intensity factor in the CSB mixture. ELT itself can also increase the stability of composites.
In its application to civil engineering, ELT is often used for new sustainable materials. Based on previous research, ELT is often used as a material for making asphalt or bitumen, Pavement, laminated veneer lumber board, and lightweight aggregate for green building. The addition of ELT to asphalt is said to reduce dependence on non-renewable asphalt resources, reduce the reaction time of asphalt production and increase the effectiveness of storage stability. Using ELT as a pavement mixture can improve concrete's specific behavior, increasing the Pavement's compressive strength. Meanwhile, using ELT as a mixture of LVL boards can make LVL more economical and durable. This can be applied to producing other wood products that can be mixed with ELT. Then finally, the use of lightweight aggregate concrete for building, namely lightweight aggregate concrete, has a better resistivity than standard heavy concrete and increases the durability of the concrete aggregate itself.
The potential for the use of ELT in Indonesia is quite enormous. This is due to a large number of waste tires. At this time, waste tires have been recycled for asphalt manufacture. However, no mixing for landfill liner, LVL, and lightweight aggregate concrete has been carried out, and no research has been carried out in Indonesia. Based on the highlights and summary of this paper, it is hoped that there will be further research in Indonesia regarding applying ELT as a new sustainable material. This is expected to reduce tire waste on earth because ELT is a material that is not readily biodegradable.

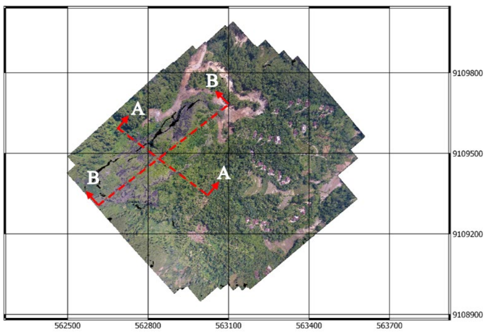

Figure 9. The layout of section A-A and section B-B Quarry for comparison between aerial photogrammetry survey and conventional survey

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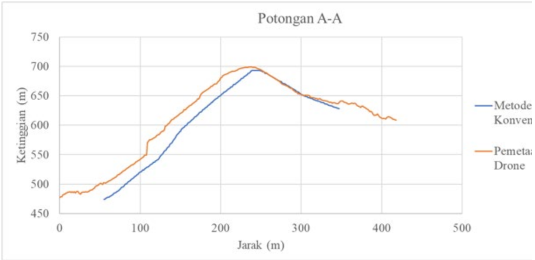

Figure 10. Section A-A represents the comparison between aerial photogrammetry survey (orange line) and conventional survey (green line)

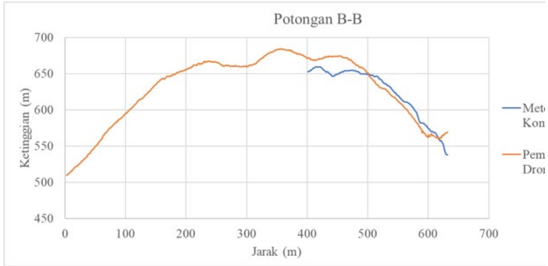

Figure 11. Section B-B represents the comparison between aerial photogrammetry survey (orange line) and conventional survey (green line)

Table 2. Horizontal accuracy test

Point ID	Point Name	(X Map)	X (Actual)	(D X)	(D X)^2	Y (Map)	Y (Actual)	(D Y)	(D Y)^2	(D X)^2 + (D Y)^2
1	LJ.1	563016.373	563014.973	1.400	1.960	9109617.138	9109605.718	11.420	130.416	132.376
2	LJ.2	563011.031	563009.404	1.627	2.647	9109612.223	9109600.508	11.715	137.241	139.888
									Sum	272.265
									Average	136.132
									RMSEr	11.668
									CE90	17.706

Table 3. Vertical accuracy test

Point ID	Point Name	Z (Map)	Z (Actual)	(D Z)	(D Z)^2
1	LJ.1	671.542	692.415	-20.873	435.682
2	LJ.2	655.432	679.453	-24.021	577.008
				Sum	1012.691
				Average	506.345
				RMSEz	22.502
				LE90	37.126

Table 4. Register CE90 and LE90 values for accuracy of RBI map

Number	Scale	Interval	Accuracy of RBI Map					
			Class 1		Class 2		Class 3	
			Horizontal (CE90)	Vertical (LE 90)	Horizontal (CE90)	Vertical (LE 90)	Horizontal (CE90)	Vertical (LE 90)
1	1:1.000.000	400	200	200	300	300	500	500
2	1:500.000	200	100	100	150	150	250	250
3	1:250.000	100	50	50	75	75	125	125
4	1:100.000	40	20	20	30	30	50	50
5	1:50.000	20	10	10	15	15	25	25
6	1:25.000	10	5	5	7,5	7,5	12,5	12,5
7	1:10.000	4	2	2	3	3	5	5
8	1:5.000	2	1	1	1,5	1,5	2,5	2,5
9	1:2.500	1	0,5	0,5	0,75	0,75	1,25	1,25
10	1:1.000	0,4	0,2	0,2	0,3	0,3	0,5	0,5

Based on the figures and tables above, it is known that the drone mapping method has low data accuracy. The horizontal error between mapping from drones with conventional methods is 11.668m with CE90=17.706m, while the vertical error between mapping from drones with conventional methods is 22.502m with LE90 = 37.126m. Based on the registers shown in Table 5. 10, the existing mapping results can be made on a map of a scale of 1:100,000 for class 3 and a map of a scale of 1:250,000 for classes 1 and 2. This very large error occurred because the mapping was carried out by uncontrolled photogrammetry in a mountainous location. In another study with a flat location, the horizontal error was 2.54 m and the vertical was 0.78 m (Prayogo dkk., 2020) However, in hilly locations, the mapping error becomes larger. Measurement error can be minimized by using the Ground Control Point (GCP). GCP is a sign that is installed before taking aerial photographs and can be seen in aerial photographs. GCP has values x, y, and z which will be used as a mapping reference. This mapping does not use GCP. This is because the manufacture of GCP is not possible at the Quarry location which is a steep hill. On the other hand, the drone mapping data is a Digital Surface Model, so a filtering procedure is needed to get the Digital Terrain Model. This also makes the vertical error very large because the resulting elevation is a surface. Currently, filtering from Open-source computer programs is available only for dense cloud filtering, while Digital Surface Model filtering is not yet available. Filtering can be done manually, where at that location the tree height is about 20 m. However, the vertical difference is still high at around 22 m. The project team needs to anticipate the low accuracy of this data with the help of other tools, for example, the use of Portable GPS or Real Time Kinematic GPS for locations that are still accessible.

6. ADVANTAGES OF AERIAL PHOTOGRAMMETRY SURVEY

Based on the specifications of the tools described previously, conventional measurements have high accuracy. However, mapping with drones has an important role in the development of the Building Information Modeling system. Mapping with drones will produce an important output, namely orthomosaic maps (natural features) that conventional measurements do not have. The orthomosaic map combined with the Digital Elevation Model will form a raster that represents the actual natural features in digital form. This raster form will often be used in Clash Detection. Clash detection is an examination of possible incompatibility between the design and actual conditions (Ramadhani, 2022).

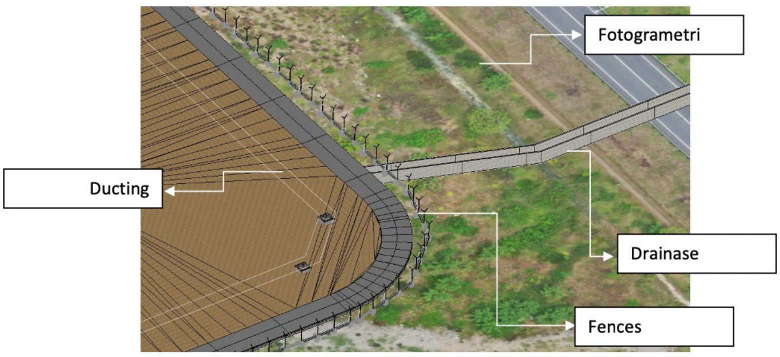

Figure 10. Clash Detection of Drainage

Another example of using drone mapping is volume monitoring. In the work of stockpiling selected material at the Dhoho Kediri Airport, volume monitoring was carried out using aerial mapping. Aerial mapping is carried out in a relatively flat location with a Ground Control Point.

The existing volume difference is 15% against the actual volume due to delayed progress due to administration and limited spatial resolution (Qolbu dkk., 2021). Ease of selecting the desired area according to the existing visuals for volume calculations can be done on the raster that has been created as shown below.

Figure 11. Volume Calculation of Selected Area

The use of rasters can also be used as a reference for excavation or embankment work. This is an autonomous engineering development that is currently being developed. In Indonesia, similar technology has been developed and applied to asphalt works at the Mandalika Circuit, West Nusa Tenggara and Dhoho Airport, Kediri (Ramadhani, 2022)

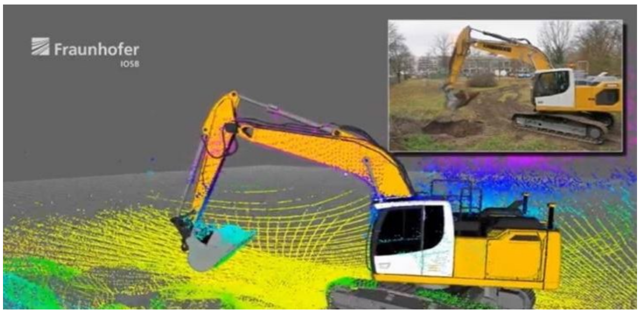

Figure 12. Engineering Autonomous

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