Journal of Railway Transportation and Technology
Vol. 1 No. 1 (2022) 20-27
p-ISSN:2830-0491 e-ISSN: 2830-6680
https://doi.org/10.37367/jrtt.v1i1.6

Comparison of UAV Drone and Online Terrain Model for Railway Route Planning

Wahyu Tamtomo Adi[1], Adya Aghastya[1], Nanda Ahda Imron[1], Nurul Fitria Apriliani[1], Izza Anwer[2], Porntep Puangprakhon[3]

[1]Construction and Railway Technology, Indonesian Railway Polytechnic Madiun
Jl. Tirta Raya, Pojok, Nambangan Lor, Manguharjo, Madiun, Jawa Timur 63161, Indonesia

[2]Department of Transportation Engineering and Management, University of Engineering and Technology Lahore, Pakistan Grand Trunk (G.T.) Road, Bahghpur, Lahore, Punjab 39161, Pakistan

[3]Civil Engineering Department, Mahanakorn University of Technology, Bangkok, Thailand
140 Cheum-Sampan Rd., Nong Chok, Bangkok 10530, Thailand

Article Info

Article history:
Received 27 January 2022
Revised 19 February 2022
Accepted 13 March 2022

Keywords:
UAV Drone,
DEM,
OnlineMaps,
Railway,
Routes,

ABSTRACT

This research aimed to compare Digital Elevation Model (DEM) results from UAV Drone Survey with online DEM with a study case a railway route planning from Semarang to Demak in Central Jawa. This research used the UAV Drone survey for primary data, which was processed using Agisoft Metashape software. The DEM results were compared with DEM from GoogleEarth, BING, SRTM, ASTERGDEM and DEMNAS using Global Mapper software. The methodology for the comparison was conducted graphically by generating contour drawing for each model and statistically by comparing the elevation and cut-fill volume differences along the railway routes. The results showed that the UAV Drone Survey DEM had met the standard accuracy needed. The online DEM comparison with UAV Drone results showed that DEMNAS and ASTER GDEM have a stronger correlation with other DEM resources. The finding suggested for careful consideration before using open-source DEM Data for preliminary and Detail Engineering Design, especially for railway infrastructure projects.

Corresponding Author:
Wahyu Tamtomo Adi
[1]Indonesian Railway Polytechnic
Jl. Tirta Raya, Pojok, Nambangan Lor, Manguharjo, Madiun, Jawa Timur 63161, Indonesia
Email: tamtomo@ppi.ac.id

1. INTRODUCTION

Representation of terrain surface in the Digital Elevation Model (DEM) can be obtained from many online resources. Digital Elevation Model (DEM) is a quantitative illustration of terrain and is critical for Earth technological know-how and hydrological applications [1]. Google Earth was one of the widely used online DEM data. It was suitable for planning large areas, cadastral, city planning, and land classification, which measured the accuracy of google earth Elevation with a case study on the North Coast of Egypt [2]. Better accuracy was found in terrain with a slight slope. Furthermore, the Google Earth Terrain model can be used for low-cost preliminary studies after being tested with references data. Google Earth can be used for hydrological modeling. This result was obtained after comparing the Terrain model from mountainous, hilly, and flat areas based on Google Earth with SRTM90 and ASTER data [3].

DEM data can be obtained and processed with the help of well-known software such as Global Mapper, which can be connected to various resources of online DEM such as SRTM, ASTER GDEM, and so on. The accuracy of various DEM Data obtained by Global Mapper has been evaluated in Uzbekistan [4]. BIM applications such as Autodesk Infraworks can be used to get Earth 3D Model from BING Maps, to be used in the design process for making the 3D representation of construction projects [5].

Compared with free or relatively low-cost sources of data, recent technology of surveying enabled to get the terrain model effectively and efficiently by using UAV Drone. Unmanned aerial vehicle (UAV) sensors and platforms in the form of remote sensing devices are currently used in almost every application (e.g., agriculture, forestry and mining) that requires information to be observed from an overhead or tilted view in order to obtain high-resolution spatial data [6], [7]. DEM from UAV Drone result accuracy was good enough to map railway lines and surrounding areas [8]. UAV Drone was used in inspecting and maintaining Railway Infrastructure [9]. Measurements using UAV can get an accuracy of up to 1 mm to 10 m. It can be effectively used for between 10 m to 10,000 m areas with a correlation between target area and target accuracy [10].

Mapping with UAVs also possesses the ability to produce accuracy which is good enough to form the basis for detailed planning, the results for a horizontal scale of 1: 1000 class 1 with an accuracy of 0.2 m and a vertical scale of 1: 1000 class 1 with an accuracy of 0.2 m [11]. DJI Phantom 4 UAV can meet the class 3 accuracy standard for a 1: 1,000 scale map of the base map position error with a 90% confidence level with 50 cm for horizontal and 1m for vertical accuracy [12]. UAV Drone results also provide the information on trees height and terrain model with an accuracy of 3 to 6 pixel or 0.5 to 2.5m [13].

The accuracy of DEM is significant to produce engineering design for infrastructure which need terrain models such as road[14], railway[15], grading plan [16], and other earthworks [17] [18] project. With the results of the UAV Drone DEM model proven to be a useful resource for civil engineering applications [19], the available online source DEM needed an assessment of how reliable compared to the previous one. Therefore, this study compared various online source DEM with the UAV Drone Survey results. The case study for this research is in Middle Java, Indonesia, on a conceptual design for a railway line reactivation.

2. RESEARCH METHOD

Primary data for this study were obtained through a survey using UAV drones to collect photos and video documentation along the alignment in the Semarang-Demak reactivation route. The survey result was processed using Agisoft Metashape software to create Digital Elevation Model. This result was compared to DEM, obtained from online map resources, using Global Mapper software along the railway route.

2.1 UAV Drone Survey at the Railway Route

The railway line from Semarang Station to Demak Station was not used since 1986. According to Indonesian Railway Masterplan [10], this regional line will be activated in phases II and III from 2015 to 2024. According to field survey results, only 1% of the existing track was in good condition, 6% was damaged, and 90% was covered by the settlement, changed its function to become a highway, and classified as prone to floods. The reactivation of this route would require high costs and increase the potency of conflicts of interest. Instead of using the existing line, this research survey was conducted on a new railway route seen in Figure 1.

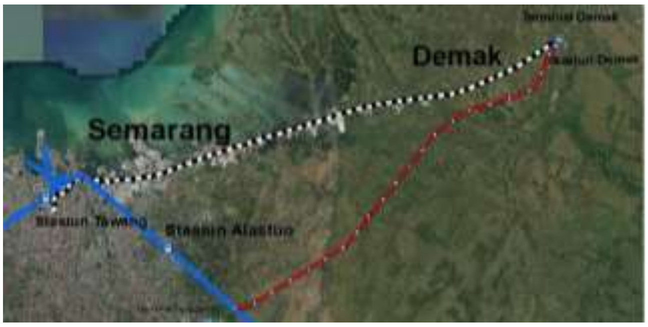


Figure 1. Field Survey Route (Source Data from Google Earth)

Figure 1 shows the Route Comparison Map between the Existing Semarang-Demak (Route A) and the Semarang - Alastuo - Demak as an Alternative (Route B), indicated by the red line. This study continues by conducting a field mapping survey using UAV Drone to Route B by technical criteria consideration.

The survey process along the 23 km long route includes 11 GCP placements measured using GPS Geodetic to improve the accuracy [20]. The UAV Drone Sky Walker 1900 flight path was planned with Mission Planner. The survey process includes drone Takeoff and Drone Control using Remote Control to approach the destined route before continuing to automatic flight mode according to the flight path. All processes from takeoff and landing were monitored by remote control.

2.2 Data Processing

The photos obtained by UAV Drone survey of the routes were processed using Agisoft Metashape Software which used the Structure from Motion (SfM) to reconstruct aerial photo blocks into photo mosaics and Digital Surface Model (DSM). Processing stages include importing photos, aligning photos, building dense clouds, classifying ground points, building mesh, building textures, building DEMs, and generating contours [3][21].

The terminology of DEM can be separated into Digital Surface Model (DSM) and Digital Terrain Model (DTM) [22]. The DTM model is obtained by maximizing the software function of classifying ground points with a max angle of 15º and a maximum distance of 1 m.

2.3 DEM Analysis

Many resources can give a Digital Elevation Model (DEM) of the earth's surface at the regional location for railway route planning. The accuracy of the data for the online DEM map, especially in Indonesia, needs more comprehensive discussion. The available elevation data has a spatial resolution of 1 Arcsecond or 30 meters. This study collected DEM from the various resource which was available online. DEM models from Google Earth, BING, SRTM, and ASTER GDEM were chosen, which were compared by a previous study [23][24][25].

The DEM results from the UAV Drone process were compared with online resource DEM by using Global Mapper Software [4]. Analysis of topographic conditions graphically for planning railway routes based on satellite imagery and photogrammetry was conducted by generating elevation and volume using Autocad Civil 3D software which has proven reliable for terrain analysis [26] [27] [28].

3. RESULTS AND DISCUSSION

3.1. DEM Model from UAV Drone Survey

The results of data processing show that the value of X error (cm) is 45.6438, Y error (cm) 34.2165 Z error (cm) 2.94986 and XY error (cm) 57.0449, and Total (cm) 57.1211. The RMSEr and RMSEz values were used to determine the CE90 and LE90 values. CE90 and LE90 values. CE90 and LE90 are measurements of horizontal geometric accuracy, which are defined as the radius of a circle and vertical distance value where 90% error or difference of horizontal position and height value of the object on a map with position and altitude value which is assumed to be no bigger than that value. CE90 = 1.5175 x RMSEr =0.866 and LE90 = 1.6499xRMSEz = 0.0486.

Figure 2. UAV Drone DEM Result

This map accuracy class is class 3 horizontal accuracy for 1: 2500 scale or Class 1 for 1: 5000 scale, and Class 1 vertical accuracy for 1: 1000 scale. Following National regulation [11], this results in a horizontal accuracy of 1.00 meters and a vertical accuracy of 0.200 meters. As in Figure 2, DEM and contours created using the Global Mapper show good characteristics of the existing terrain, including the river model along the UAV Drone route.

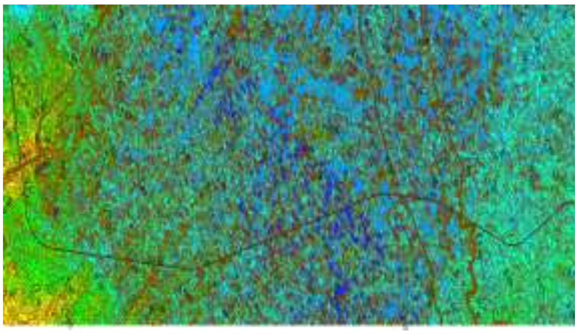
3.2. DEM Model from Online Data

A well-known online map due to its free and ease of access is DEM Map from GoogleEarth. Google earth uses the Shuttle Radar Topography Mission (SRTM). The accuracy of SRTM data can range from 5 to 10 meters, depending on where the map is positioned on the earth's surface. The Google Earth DEM map results in the form of Grid Elevation Data (Geotiff) can be imported into the Global Mapper software to produce the image in Figure 3(a). The figure shows a more general elevation value than the following maps. The difference in data accuracy with SRTM with the actual position offers a 90% error. In Indonesia, a part of (Eurasia), the accuracy is horizontal at 8.8 m, absolute vertical at 6.2m, and relative vertical at 8.7m [25].

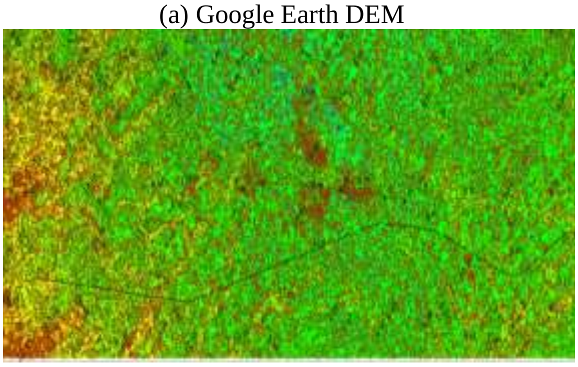
National Digital Elevation Model, namely DEMNAS, was implemented in Indonesia in 2018. This National DEM (Vertical Datum EGM2008) was built based on several data sources, including IFSAR (5m resolution), TERRASAR-X (5m resolution), and ALOS PALSAR (11.25m resolution), by adding Masspoint data from stereo-plotting results [29]. The spatial resolution of DEMNAS was relatively high, namely 0.27 Arcsecond or 8 meters. Thus, in Indonesia, we can use DEMNAS data to obtain more detailed altitude information. The following Figure 3(b) shows the results of DEMNAS map processing for the location of this railway line.

Another DEM map that can be obtained using software is by using Autodesk Infraworks [30] by using the Model Builder. It provides publicly available data sources and creates a 3D model for a few minutes, which provides not only terrain and imagery data but also road, building, and water data for an area of up to 200 square kilometers. Figure 3(c) shows digital DEM based on BING Maps obtained by using Autodesk Infraworks Software. The DEM model, as in the figure, can be brought to be used for the design process by other CAD software such as Autocad Civil 3D. The design results can also be integrated with the project in Infrawoks to get the animation model needed so that it is more widely used in planning.

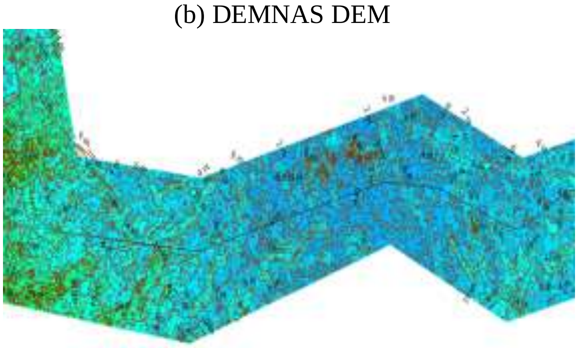
(a) Google Earth DEM



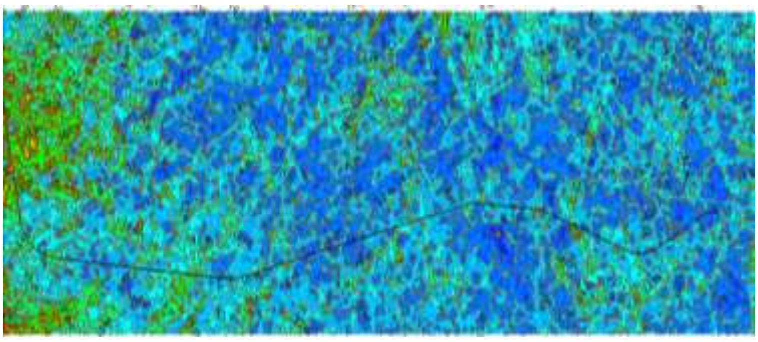
(b) DEMNAS DEM



(c) BING Maps DEM



(d) SRTM DEM



(e) ASTER-G DEM

Figure 3. The Results of Various Available Online DEM Contour

DEM data from the Shuttle Radar Topography Mission (SRTM) and Advanced Spaceborne Thermal Emission Radiometer-Global Digital Elevation Model (ASTER GDEM) can be obtained by using the Global Mapper or USGS Earth Explorer [4]. SRTM DEM, as in Figure 3(d) widely used because it can be downloaded for free. SRTM DEM for the Indonesian region has a level with an accuracy of 90 meters (3 Arcsecond). Like SRTM, ASTER GDEM, as in Figure 3(e), can also be used online with an accuracy level of up to 1.5 arc second or as large as 45 meters and has covered nearly 99% of the earth's surface area. The development of ASTER GDEM is considered more accurate than SRTM in mountainous areas that have steep land slopes [23] although SRTM data has a better vertical accuracy of 3.926 to 7.748 meters [24].

3.3. Comparison of Drone Map Results and Online Maps

Further examination of the shape of the land surface along the railway route can be seen by creating a longitudinal profile along the paths on various DEMs that have previously been obtained. This process can be done using the Global Mapper and Autocad Civil 3D. Figure 4 shows the comparison of DEM elevation along the center of the railway route in the form of a longitudinal profile of the surface.

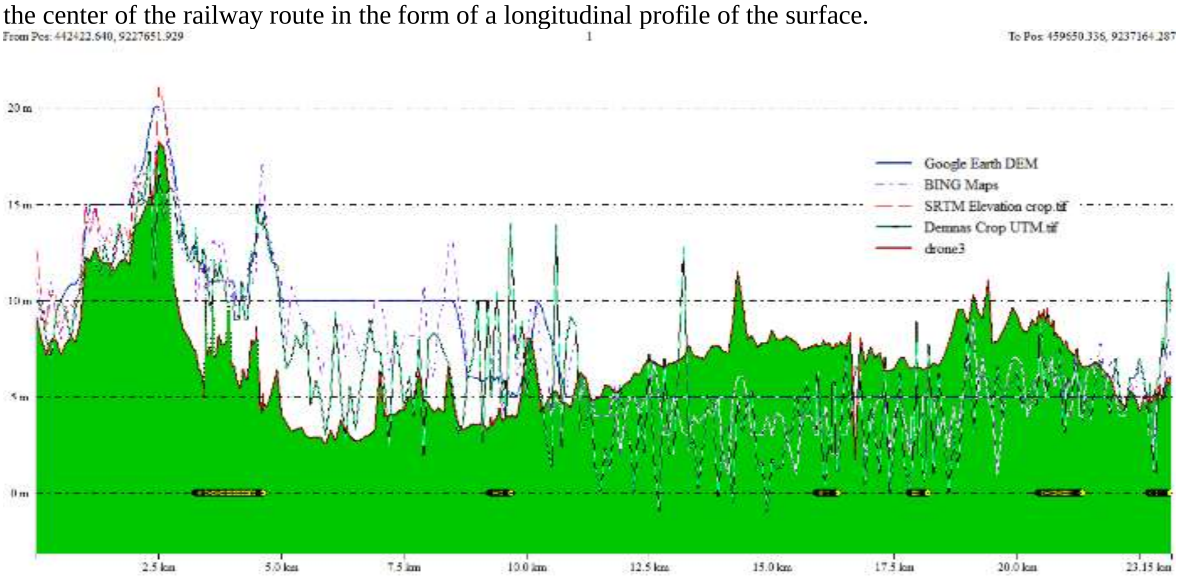


Figure 4. Comparison of DEM Elevation

The comparison from Figure 4, in general, shows a variation of model elevation along the railway route. These results demonstrated the necessity to further review the accuracy of the existing satellite-based maps to be used for railway planning. This might indicate that the Terrain Model Map in the location does not yet have the accuracy expected to be used as a reference for detailed engineering planning. Detail Engineering Drawing still required a survey using a Total Station or GPS Geodetics which produces higher accuracy.

Further comparisons can be made to check how far the differences between one map and another. In this case, checking was conducted by calculating how much the difference in total volume occurs between several maps. Volume comparisons were made by finding the difference in volume on the results of the land surface obtained previously by cutting the surface by 25 meters on the left and right along the center of the Railway Route. The results are shown on the following Table 1.

Table 1 - Comparison of Volume Results

No	Comparison Surface	Fill Volume	Cut Volume	Total Volume	Mean High Difference
1	Google Earth - Drone	2,464,714.60	3,985,681.60	6,450,396.20	0748
2	BING - Drone	3,496,206.40	4,145,535.20	7,641,741.60	0.280
3	SRTM - Drone	3,458,073.40	4,114,734.20	7,572,807.60	0283
4	ASTERGDEM - Drone	155,862.03	6,584,565.10	6,740,427.13	3327
5	DEMNAS - Drone	4,368,400.30	3,188,158.60	7,556,558.90	-0.524

Table 1 compares the UAV Drone Model and the online DEM by volume differences generated by Autocad Civil 3D software . It offers a significant difference in each map compare to DEM from UAV Drone. These results indicated the necessity to examine the accuracy of existing satellite-based maps in the Central Java location. The Terrain Model Map in Indonesia does not have the precision needed to be a reference for Detailed Engineering planning. DED still requires a survey using a Total Station or other tools that have higher accuracy.

3.2. Statistical Analysis

Statistical analysis was performed using SPSS version 24.0 program. The first analysis performed was the normality test as a classic assumption test to determine further analysis to be completed. The normality test was performed using *Kolmogorov-Smirnov* Method, as shown in Table 2.

Table 2 - Normality Test

Kolmogorov-Smirnov One-SampleTest								
		DRONE	ASTERGDEM	BING	DEMNAS	G EARTH	SRTM
N		927	927	927	927	927	927
Normal Parameters[a, b]	Mean	7.0380	10.2437	7.2517	6.3923	7.7405	7, 2086
	Std. Deviation	2.7339	3.1834	3.8333	3.9993	3.6974	3,7970
Most Extreme Differences	Absolute	.141	.143	.150	.085	.303	,113
	Positive	.141	.143	.150	.085	.303	,113
	Negative	- .068	-.087	-.103	-.045	-.229	-,079
Test Statistic		.141	.143	.150	.085	.303	.113
Asymp. Sig. (2-tailed)		.000[c]	.000[c]	.000[c]	.000[c]	.000[c]	.000[c]

Table 2 shows the normality test results showing that the data can follow a normal distribution if the significance value is > 0.05. Using the significance value of all elevations from UAV Drone, ASTER GDEM, BING Infraworks, DEMNAS, SRTM, and Google Earth, which value < 0.05, it can be concluded that all elevation data are not normally distributed. Therefore, the data will be analyzed by using a non-parametric test.

Non-parametric data analysis was conducted by using the *Spearman rank* test of correlation. This analysis aimed to determine the level of the relationship, the direction of the relationship, and whether the relationship between the drone elevation data and the other five elevation data was significant. The level of relationship was determined from the result of a correlation coefficient. The results of the correlation analysis are shown in Table 3.

Table 3 - Correlation Test

Comparison of	Sig.	Correlation Coefficient
Drone and ASTERGDEM	0.000	0.389
Drone and BING	0.181	0.044
Drone and DEMNAS	0.000	0.334
Drone and G.EARTH	0.765	-0.100
Drone and SRTM	0.044	0.066

The significance value shows that the data with a significant relationship are Drone-ASTERGDEM and Drone-DEMNAS because of the Sig. value <0.05. The correlation coefficient value shows the level of the relationship between the two variables. A greater coefficient of correlation means a strong relationship between data. Drone with ASTERGDEM and DEMNAS data has a correlation coefficient of 0.389 and 0.334 which means that the two data have a fairly strong correlation level. The correlation between the Drone data and the other four data the level of correlation is weak, even very weak. The direction of the relationship seen from the correlation coefficient has a positive or negative value.

The subsequent analysis was done by using the Kruskall Wallis test aimed to determine whether there is a statistically significant difference between two or more groups of variables. The analysis results are shown in Table 4.

Table 4 - *Kruskall Wallis*

Test Statistics[a, b]	
	ELEVATION
Chi-Square	710.696
df	5
Asymp. Sig.	.000
a. Kruskal Wallis Test	
b. Grouping Variable: Methods	

Decision-making of the test *Kruskall Wallis* requires the sig. value < 0.05 or chi-square count > chi-square table. Therefore, based on Tabel 4 above, there are significant differences between variables. The result shows that Sig. Value < 0.05 and chi-square count (710.696) > chi-square table (11.07). It can be concluded that there is a significant difference between the elevation data tested.

4. CONCLUSION

The comparison results between the photogrammetric map and the online terrain model map show significant differences in each map. This indicates that it is necessary to further examine the accuracy of the existing maps at the study location to be used as a basis for planning the railway line. DEM data obtained online were generally DSM, in which the elevation model includes a land cover which produces differences in results compared to DTM. Based on the results of this study, the authors also suggest that further research can compare existing data with topographic survey results of the covered area, for example, by using a Total Station. However, this research requires a large amount of money.

ACKNOWLEDGEMENTS

The writer would like to thank all parties who contributed to this research from data collection, processing, and analysis. Any suggestion which will contribute for improving this paper is welcomed.

REFERENCES

[1] S. Mukherjee, P. K. Joshi, S. Mukherjee, A. Ghosh, R. D. Garg, and A. Mukhopadhyay, "Evaluation of vertical accuracy of open source Digital Elevation Model (DEM)," *Int. J. Appl. Earth Obs. Geoinf.*, vol. 21, no. 1, pp. 205–217, 2012, doi: 10.1016/j.jag.2012.09.004.

[2] K. L. A. El-Ashmawy, "Investigation of the Accuracy of Google Earth Elevation Data," *Artif. Satell.*, vol. 51, no. 3, pp. 89–97, 2016, doi: 10.1515/arsa-2016-0008.

[3] M. Faisal, A. Rani, and N. Rusli, "The Accuracy Assessment of Agisoft PhotoScan and Pix4D Mapper Software in Orthophoto Production," *Geomatics Res. Innov. Compet. Gric*, vol. 1, no. August, pp. 1–5, 2017.

[4] K. Khasanov and A. Ahmedov, "Comparison of Digital Elevation Models for the designing water reservoirs: A case study Pskom water reservoir," *E3S Web Conf.*, vol. 264, 2021, doi: 10.1051/e3sconf/202126403058.

[5] V. T. Tran, H. H. Nguyen, T. L. Chu, and L. T. Mai, "BIM application for the design consultant on the irriga- tion and hydropower projects in Vietnam," pp. 1205–1206, 2020.

[6] D. Turner, A. Lucieer, and C. Watson, "An automated technique for generating georectified mosaics from ultra-high resolution Unmanned Aerial Vehicle (UAV) imagery, based on Structure from Motion (SFM) point clouds," *Remote Sens.*, vol. 4, no. 5, pp. 1392–1410, 2012, doi: 10.3390/rs4051392.

[7] H. Yao, R. Qin, and X. Chen, "Unmanned aerial vehicle for remote sensing applications - A review," *Remote Sens.*, vol. 11, no. 12, pp. 1–22, 2019, doi: 10.3390/rs11121443.

[8] H. M. R. Manatunga, U. I., Munasinghe, N., & Premasiri, "Development of a Methodology to Map Railway Lines and Surrounding Land Use using UAVs," no. September, 2017.

[9] P. Lesiak, "Inspection and Maintenance of Railway Infrastructure with the Use of Unmanned Aerial Vehicles," *Probl. Kolejnictwa - Railw. Reports*, vol. 64, no. 188, pp. 115–127, 2020, doi: 10.36137/1883e.

[10] D. A. Leonid Nadolinets, Eugene Levin, *Surveying Instruments and Technology*. CRC Press, 2017.

[11] A. F. Tarmizi, "Uji Akurasi Ketelitian Peta Orthofoto Menggunakan Pesawat UAV untuk Tata Guna Lahan (Studi Kasus: Kec. Purworejo, Kab. Purworejo)," *ITN Malang*, no. 1, 2019.

[12] A. P. Susetyo, D. B., Perdana, "Uji Ketelitian Digital Surface Model (DSM) sebagai Data Dasar dalam Uji Ketelitian Digital Surface Model (DSM) sebagai Data Dasar dalam Pembentukan Kontur Peta Rupabumi Indonesia (RBI)," *Semin. Penginderaan jauh 2015*, vol. 1, no. October, pp. 299–306, 2015.

[13] C. A. Rokhmana, "The Potential of UAV-based Remote Sensing for Supporting Precision Agriculture in Indonesia," *Procedia Environ. Sci.*, vol. 24, pp. 245–253, 2015, doi: 10.1016/j.proenv.2015.03.032.

[14] S. Moser, V., Barišić, I., Rajle, D., & Dimter, "Comparison of different survey methods data accuracy for road design and construction.," 2016.

[15] W. T. Adi, Y. Wiarco, R. Prihartanto, and A. Aghastya, "Sosialisasi Penerapan Penggunaan UAV Drone untuk Survey Pemetaan pada Bidang Jalur Perkeretaapian," *Madiun Spoor (JPM)*, vol. 1, no. 2, pp. 46–51, 2021, doi: 10.37367/jpm.v1i2.184.

[16] J. Kim, S. Lee, J. Seo, D. E. Lee, and H. S. Choi, "The integration of earthwork design review and planning using uav-based point cloud and bim," *Appl. Sci.*, vol. 11, no. 8, pp. 1–14, 2021, doi: 10.3390/app11083435.

[17] M. Akgul, H. Yurtseven, S. Gulci, and A. E. Akay, "Evaluation of UAV- and GNSS-Based DEMs for Earthwork Volume," *Arab. J. Sci. Eng.*, vol. 43, no. 4, pp. 1893–1909, 2018, doi: 10.1007/s13369-017-2811-9.

[18] S. Il Cho, J. H. Lim, S. B. Lim, and H. C. Yun, "A study on dem-based automatic calculation of earthwork volume for BIM application," *J. Korean Soc. Surv. Geod. Photogramm. Cartogr.*, vol. 38, no. 2, pp. 131–140, 2020, doi: 10.7848/ksgpc.2020.38.2.131.

[19] S. Siebert and J. Teizer, "Mobile 3D mapping for surveying earthwork projects using an Unmanned Aerial Vehicle (UAV) system," *Autom. Constr.*, vol. 41, pp. 1–14, 2014, doi: 10.1016/j.autcon.2014.01.004.

[20] Y. Taddia, F. Stecchi, and A. Pellegrinelli, "Coastal mapping using dji phantom 4 RTK in post-processing kinematic mode," *Drones*, vol. 4, no. 2, pp. 1–19, 2020, doi: 10.3390/drones4020009.

[21] J. Leo Stalin and RPC. Gnanaprakasam, "Volume Calculation from UAV based DEM," *Int. J. Eng. Res.*, vol. V6, no. 06, pp. 126–128, 2017, doi: 10.17577/ijertv6is060076.

[22] Q. Zhou, "Digital Elevation Model and Digital Surface Model," *Int. Encycl. Geogr. People, Earth, Environ. Technol.*, no. March, pp. 1–17, 2017, doi: 10.1002/9781118786352.wbieg0768.

[23] M. Rexer and C. Hirt, "Comparison of free high resolution digital elevation data sets (ASTER GDEM2, SRTM v2.1/v4.1) and validation against accurate heights from the Australian National Gravity Database," *Aust. J. Earth Sci.*, vol. 61, no. 2, pp. 213–226, 2014, doi: 10.1080/08120099.2014.884983.

[24] a P. Ozah and O. Kufoniyi, "Accuracy Assessment of Contour Interpolation From 1 : 50 , 000 Topographical Maps and Srtm Data for 1 : 25 , 000 Topographical Mapping," *Archives*, pp. 1347–1354, 2006.

[25] E. Rodríguez, C. S. Morris, and J. E. Belz, "A global assessment of the SRTM performance," *Photogramm. Eng. Remote Sensing*, vol. 72, no. 3, pp. 249–260, 2006, doi: 10.14358/PERS.72.3.249.

[26] W. T. Adi and A. Aghastya, "Penggunaan total station dan AutoCAD Civil 3D untuk perencanaan grading," *J. Perkeretaapi. Indones.*, vol. 1, no. 2, pp. 149–159, 2017.

[27] C. Arango and C. A. Morales, "Comparison between multicopter UAV and total station for estimating stockpile volumes," *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch.*, vol. 40, no. 1W4, pp. 131–135, 2015, doi: 10.5194/isprsarchives-XL-1-W4-131-2015.

[28] J. Cooke, "Terrain Modeling , Contouring and Analysis in AutoCAD Civil 3D".

[29] A. Julzarika and Harintaka, "Indonesian DEMNAS: DSM or DTM?," *AGERS 2019 - 2nd IEEE Asia-Pacific Conf. Geosci. Electron. Remote Sens. Technol. Underst. Forecast. Dyn. Land, Ocean Marit. Proceeding*, pp. 31–36, 2019, doi: 10.1109/AGERS48446.2019.9034351.

[30] S. Chen, Z. Tang, H. Zhou, and J. Cheng, "Extracting Topographic Data from Online Sources to Generate a Digital Elevation Model for Highway Preliminary Geometric Design," *J. Transp. Eng. Part A Syst.*, vol. 145, no. 4, p. 04019003, 2019, doi: 10.1061/jtepbs.0000212.