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COMPARATIVE ANALYSIS OF VOLUME USING TOTAL STATION AND WATERPASS IN CITRA CITY SENTUL HOUSING ROAD PROJECT

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Abstract

In Civil Engineering work, precisely determining the volume of excavation and embankment is critical to ensuring accurate work planning, efficient pricing, and seamless project execution. The estimated cost of the project budget is determined through volume calculations. This investigation aims to determine the volume of excavation and embankment by employing both Total Station and Waterpass, as well as AutoCAD Civil 3D software. The Citra City Sentul Housing Road was the subject of the study. The Average Cross-section is employed to determine the volume of excavation and embankment, and the results are analyzed using the standard deviation value. The volume of excavation and embankment is greater when calculated using Total Station than when calculated using Waterpass. There is a slight discrepancy in the standard deviation of the two instruments, specifically in the volume of excavation with Total Station (0.03%) and Waterpass (0.02%), as well as in the volume of embankment (0.02%) and 0.01%, respectively. Consequently, Waterpass has been demonstrated to be more precise than Total Station, despite Total Station being more expeditious in the measurement process.

Keywords: Excavation and Landfill, Total Station, Waterpass, Standard Deviation

Introduction

Assessing the elevation of sites on the Earth's surface can be accomplished by various methods, ranging from the least accurate, Barometry, to the most precise, flatness measurement. (Oliver A P L, 2022; Srikanth et al., 2025; Torres et al., 2018; Ummah, 2019; Wagner, 2016). Assessing elevation variations in civil engineering is crucial for different projects, including the development of roadways, railroads, docks, ports, and other civil engineering endeavors. (Fauzan et al., 2021; Mallela et al., 2019; Mills, 2000; Mohammed et al., 2021; Nadzir & Irfansyah, 2024; Saptiadani, 2022; Shodiq et al., 2020; Slattery et al., 2012; Tang et al., 2019). As the period progresses, numerous tools have evolved, enabling the appropriate selection of equipment and procedures and facilitating effective work in alignment with the requisite accuracy and concerns of time, energy, and cost efficiency. (Priyadinata & Siregar, 2022; A. B. Putra et al., 2023; A. W. S. Putra et al., 2024; Sarasanty & Asmorowati, 2023; Setiawan et al., 2023; Simbolon & Aputra, 2023; Turalaki et al., 2018; Ulfah et al., 2023; Yulianto et al., 2024).

A Total Station is an optical and electronic device utilized in surveying or construction activities. (Adi & Aghastya, 2017; Chigbu et al., 2019; A. B. Putra et al., 2023; Tulloh et al., 2020). The instrument is a theodolite combined with an Electronic Distance Measuring (EDM) component to ascertain the distance and slope from the device to a specific location. (Deakin, 2016; Gbedu et al., 2023). The utilization of a Total Station yields commendable precision, comparable to the measurement data obtained with a Waterpass, and remains within SNI tolerance limits. (Bagas, 2023).

The goal of this study is to establish the level of accuracy in the calculation of excavation and embankment volumes, which are measured using Total Station and Waterpass equipment and calculated manually and with AutoCAD Civil 3D (Adi & Aghastya, 2017; Ariyanto, 2021; Chigbu et al., 2019; Davenport & Voiculescu, 2015; Siebert & Teizer, 2014; Tang et al., 2019).

According to the computed standard deviation of the height difference measurement, the Total Station is suitable for measuring height differences in civil engineering projects that do not demand extreme precision. Furthermore, utilizing a Total Station for height difference measurement is more cost-effective, as it requires only a quarter of the time needed for measurements with a Waterpass. (Mulyani & Tampubolon, 2021).

Based on BIM (Building Information Modeling), Autodesk's AutoCAD Civil 3D makes it possible to replicate all information in an infrastructure project into three dimensions, hence generating planning in a short period. (Faisal et al., 2024; Fauzan et al., 2021). All inside the AutoCAD Civil 3D program, AutoCAD Civil 3D enables civil infrastructure experts to enhance project delivery, more consistently examine data and processes, and more quickly react to project changes. (Ariyanto, 2021).

Research Methods

This approach determines the volume by employing cross-sections with the distance between the sections in a direction that is perpendicular to the location where the research is being conducted. (Brinker & Minnick, 2012; Purwati, 2020; Saptiadani, 2022; Sari, 2022; Shodiq et al., 2020). The method that is being utilized for the research is the average cross-section method, also known as the average end area method. (Andries, 2017). During the research, a case study was carried out at the Citra City Sentul Housing road project. The Chardonnay cluster is the place where the work was carried out. The road is 850 meters in length and 5 meters wide. The length of the road is 850 meters. Both the Total Station and the Waterpass were used to collect the coordinate data. Based on the location of the research, as shown in Figure 1.

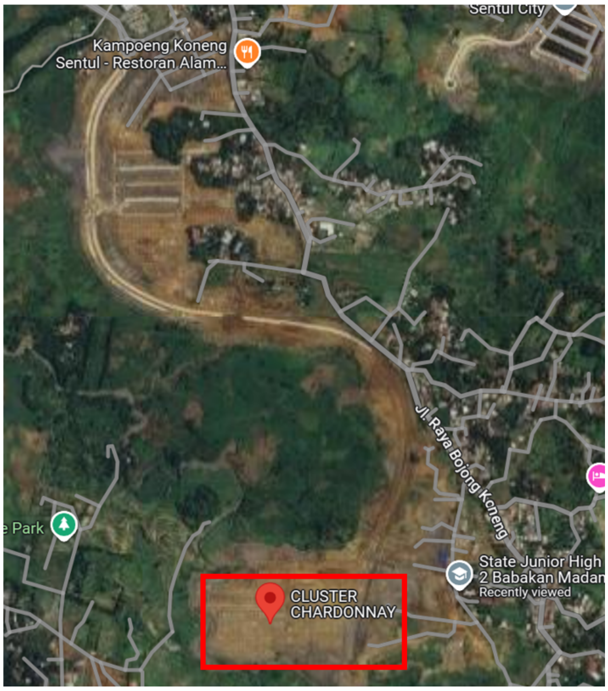

Figure 1. Chardonnay Cluster Project Location

The flowchart employed in this investigation encompasses the phases necessary for the calculation of the standard deviation of excavation and embankment volumes, commencing with volume analysis.

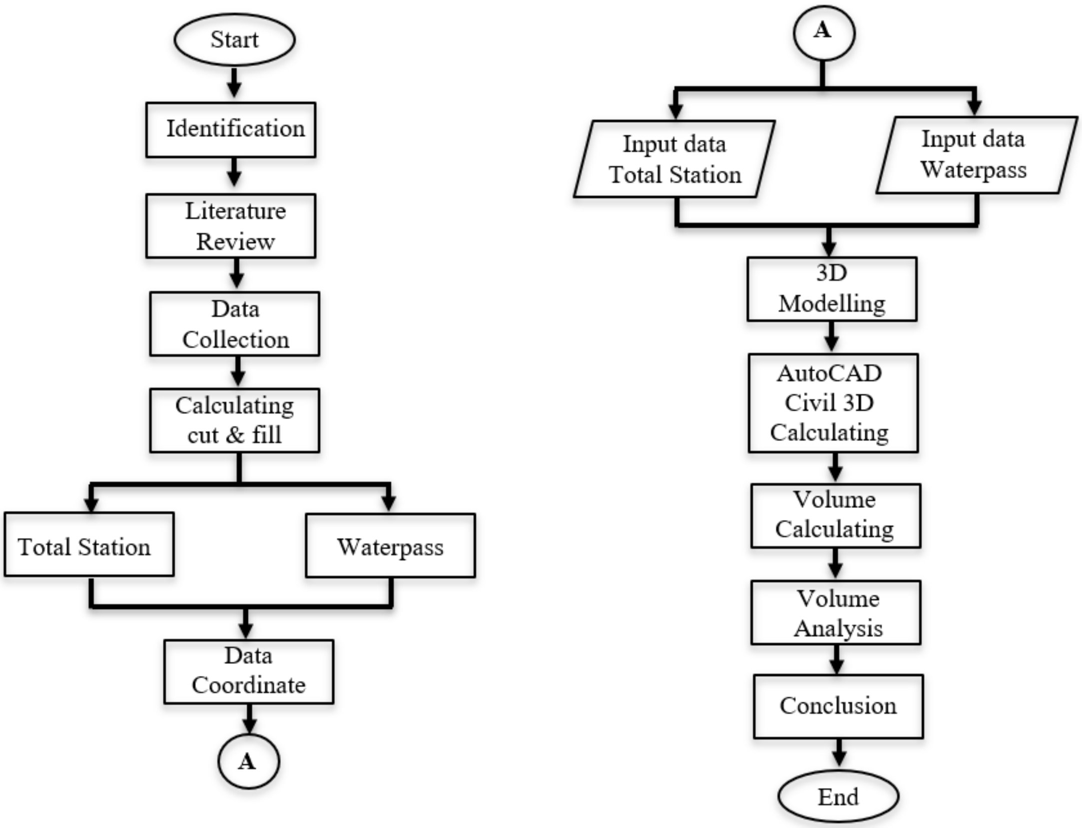

Figure 2. Research Flow Chart

Research Results and Discussion

The topographic measurements conducted represent the outcomes of monthly progress, derived from measurements and data collection executed through the cross-section method using Total Station type N and Waterpass instruments. (Elsaidy & Brussel, 2021). The measurements conducted in the field indicate that the total area of land utilized is 37,106.74 m^2, with the area allocated for the existing road measuring 27,560.48 m^2. The subsequent stages of design formation using AutoCAD Civil 3D are outlined below.

Input data from the Total Station

The coordinate data acquired from the Total Station is analyzed using Microsoft Excel, as shown in Table 1.

Table 1. Data Coordinate of Total Station

DATA MC 0				
Point	East	North	Elevation	Description
326	708812.016	9269430.491	419.977	MC0
327	708825.990	9269423.419	421.200	MC0
328	708806.560	9269410.871	416.396	MC0
329	708819.384	9269404.467	419.966	MC0
330	708831.437	9269398.577	420.919	MC0
331	708801.487	9269394.02	416.231	MC0
332	708815.483	9269387.844	418.782	MC0
333	708829.147	9269382.288	421.079	MC0
334	708798.511	9269373.876	416.626	MC0
335	708810.874	9269366.939	419.225	MC0

Generate a distribution of MC0 and current road data from Total Station to AutoCAD Civil 3D to ascertain the magnitude of excavation and embankment activities.

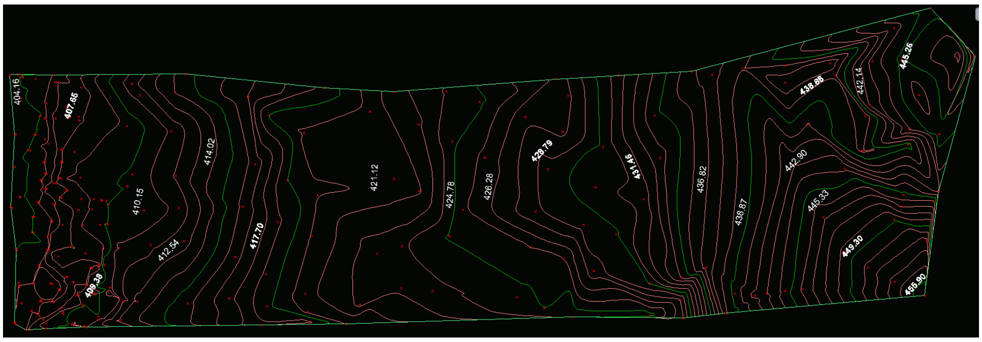

Figure 3. Output Coordinate of MC0

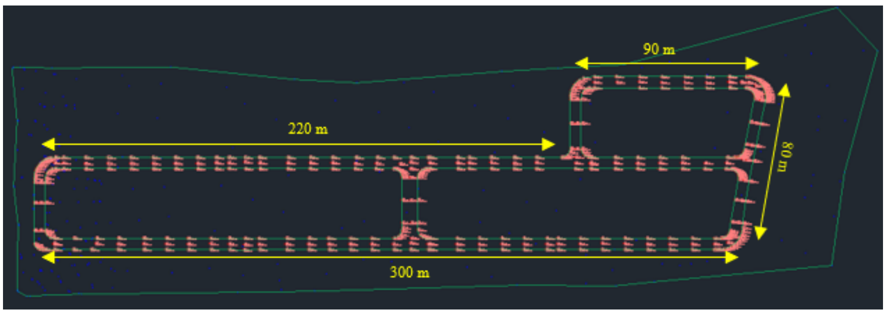

Figure 4. Output Coordinate of Existing Road

The following phase, which comes after the creation of the street view through the use of coordinates, is to establish an alignment by generating a line for the segment to ascertain the STA of the road.

After establishing the road alignment, the volume of excavation and embankment is assessed. Upon gathering the requisite data, calculate the excavation and embankment volumes using the average cross-section method in Microsoft Excel. The results of the volume calculations are displayed in Table 2 as follows.

Table 2. Cut and Fill Volume Calculation for Total Station

STA	Length (m)	Area (m^3)		Volume (m^3)	
		Cut	Fill	Cut	Fill
0+000	0	29.18	0	0	0
0+010	10	33.91	0	315.45	0
0+020	10	35.06	0	344.85	0
0+030	10	29.16	0	321.10	0
0+040	10	22.43	0	257.95	0
0+050	10	16.35	0	193.90	0
0+060	10	10.53	0	134.40	0
0+070	10	2.17	0.18	63.50	0.90
0+080	10	0	6.79	10.85	34.85

The Total Station volume generates a total excavation volume of 3,932.20 m^3 and an embankment of 13,402.40 m^3 in the calculation. The capacity in Table 3 is the result of the calculation of the Waterpass volume.

Table 3. Cut and Fill Volume Calculation for Waterpass

STA	Length (m)	Area (m^3)		Volume (m^3)	
		Cut	Fill	Cut	Fill
0+000	0	29.10	0	0	0
0+010	10	33.81	0	314.57	0
0+020	10	34.99	0	344.04	0
0+030	10	29.15	0	320.71	0
0+040	10	22.47	0	258.08	0
0+050	10	16.39	0	194.27	0
0+060	10	10.51	0	134.48	0
0+070	10	2.10	0.20	63.07	0.98
0+080	10	0	6.85	10.52	35.21

The calculated final volume for the excavation, as per Table 3, was 3,914.14 m^3, while the embankment volume was 12,963.16 m^3.

Standard Deviation Calculation

Following the computation of excavation volume and embankment using the Total Station and Waterpass, the standard deviation was calculated to determine the variance between the two instruments. The outcomes of the standard deviation calculation are detailed in Table 4 as follows.

Given the excavation volume data of 314, 658, 979, and 1237, the standard deviation for this set of volumes can be calculated as follows. (Uren & Price, 2018; Wagner, 2016):
To begin, determine the average ($\overline{y}$) using the formula provided:

$$\bar{y} = \frac{314 + 658 + 979 + 1237}{4}\ \mathrm{m}^3 \qquad 1)$$

Calculate the difference between the squares and then put the values together to complete the calculation.

$(314\text{-}797)^2 = 233289$
$(658\text{-}797)^2 = 19321$
$(979\text{-}797)^2 = 33124$
$(1237\text{-}797)^2 = 193600$
Total = 479334

Next, to calculate the total of the squares, divide it by n-1.

$$\frac{479334}{4-1} = 159778\ \mathrm{m}^3 \qquad 2)$$

Subsequently, square it.

$$Sd = \sqrt{159778} = 399\ \mathrm{m}^3 \qquad 3)$$

The calculated standard deviation is 399.7 m³.

Table 4. Standard Deviation Calculation Results

	Cut (m^2)	**(%)**	**Fill (m^2)**	**(%)**
DS TS	89.34	0,03	122.047	0,02
DS WP	88.84	0,02	110.675	0,01

The computation revealed that the Total Station deviation on the excavation was 89.34 m3 with a percentage of 0.03%, and the embankment was 122,047 m3 with a percentage of 0.02%. Both of these figures are based on excavation. After that, the Water Pass tool generated a standard deviation of 88.84 cubic meters for the excavation, which had a percentage of 0.02%, and 110,675 cubic meters for the embankment, which had a percentage of 0.01%, with the same proportion. The data presented above was collected from the average excavation and embankment work with a minimum distance of 10 meters. Although the percentage figures appear to be the same at first glance, the values of each tool are quite varied, particularly concerning the embankment work. After seeing the final findings, the author can draw conclusions based on the accuracy of the two tools that produced Water Pass as a more accurate tool in calculating the volume of excavated soil and embankment. The pros and cons between Total Station and Water Pass in the real project can be seen in Table 5.

Table 5. Comparison between Total Station dan Water Pass

Aspect	**Total Station**	**Water Pass**
Functionality	Integrates electronic distance measurement (EDM), angular measurement, and data processing. Utilized for measuring horizontal and vertical angles, slope lengths, coordinates, and three-dimensional mapping. Integrates with CAD/GIS applications.	Using a telescopic lens and a leveling staff, height discrepancies are measured and horizontal levels established. Only vertical measurements are allowed.

Accuracy	Exceptional precision (e.g., ±2 mm for distance, ±1-5 arcseconds for angles). Appropriate for extensive distances and accurate topographic assessments.	Precise at short distances (e.g., ±1-3 mm per kilometer), but cumulative inaccuracies increase with distance. Optimal for localized elevation adjustments
Efficiency	Pros: Quick data collection, particularly with robotic models (single-user operation). It covers big regions with few setups. Cons: Extended first setup (leveling, calibrating). Requires power or batteries	Pros: Easy to set up in small spaces. No need for power. Cons: Frequent shifting takes time and is not good for big projects.
Cost	Expensive at the outset, the necessary software and instructions are.	Affordable, minimal maintenance.
Project Scale	For small projects (landscaping, foundations), a Water Pass is affordable and sufficient.	For large projects (highways, urban planning), a Total Station is fast, versatile, and handles complex data well.
User Skills	Necessitates technical training for operation and data analysis	Easy for beginners and low-tech situations.
Environmental Factors	Weather (rain, fog) and electronic malfunction are sensitive.	Durable in adverse environments (dust, humidity) without electronic components.
Data Handling	Direct digital data export to CAD/GIS, reducing manual errors.	Manual documentation, susceptible to human error
Portability dan Durability	Voluminous, delicate electronics.	Lightweight, resilient, and easily transportable.
Line of Sight & Obstacles	Can measure around barriers by adjusting the prism.	Demands unobstructed sight lines; impediments require repositioning

Upon completing this research, numerous references emerge that examine the precision of the Total Station and Water Pass. For instance, the study by Mulyani & Tampubolon (2021) explores the comparative accuracy of Total Station and Water Pass, revealing that both instruments achieve a standard deviation of 0.01 mm with Water Pass, whereas Total Station records a standard deviation of 0.02 mm. The study conducted by Bagas in 2023 examines the comparative elevation accuracy of Total Station and Water Pass methodologies in assessing the irrigation conditions of the secondary river Kedunggede in Bekasi. The precision of the two instruments utilizing Total Station is closely aligned with that of Water Pass in determining height discrepancies, exhibiting a variance of 17.320 mm, which remains within the acceptable limits set by SNI standards. The previous study (A. W. S. Putra et al., 2024) presented a comparative analysis of distance measurements utilizing the Theodolite and Water Pass on sloping terrain at Akmil. The findings revealed that the standard deviation for the Water Pass tool was 0.02 mm, whereas the Theodolite tool exhibited a standard deviation of 0.03 mm. The measurement duration demonstrated greater efficiency when employing the Theodolite, achieving a time reduction of one-third compared to the Water Pass tool. Using Total Station dan Water Pass in a certain project still benefits compared to advanced methods such as Lidar, Google Earth, as seen in Table 6.

Table 6. Benefits of using Total Station dan Water Pass compared to advanced methods such as Lidar, Google Earth, Drone, and Others

Aspect	Total Station	Water Pass
Precision and Accuracy in Particular Contexts	Total stations surpass LiDAR and Google Earth in projects requiring sub-centimeter precision, such as structural alignment, boundary delineation, or deformation monitoring, due to their superior resolution (±5–10 cm for LiDAR, meters for satellite images).	For localized vertical leveling (e.g., floor slabs, drainage systems), the Water Pass gives immediate, error-free height differences without LiDAR or drone photogrammetry.
Small-scale project cost-effectiveness	Ideal for home building, small farms where modern technologies are overkill, and LiDAR and drones demand expensive upfront expenditures (equipment, software, training).	
Accessibility in Low-Tech or Remote Settings	Operate in offline settings in remote locations (such as mountainous regions and jungles) with minimal infrastructure and no need for software updates, whereas Google Earth depends on internet access and current imagery, which can often be outdated in rural areas.	
Legal and Regulatory Compliance	Numerous countries mandate ground-truth measurements from Total Stations for legal documentation (e.g., land titles). LiDAR or satellite data independently may not satisfy legal requirements.	
Validation and Error Reduction	Advanced techniques such as LiDAR may exhibit systematic inaccuracies (e.g., signal interference, challenges in vegetation penetration). Total stations and Water Pass offer empirical validation. Building inspections frequently require manual verification using Water Pass or Total Stations to ensure compliance.	
Site and Environmental Constraints	LiDAR and drones struggle in crowded urban settings (e.g., beneath bridges, indoors) or forests with thick canopy covers. Total stations use prisms to measure around barriers.	Water Pass works in wet, foggy, or dusty circumstances where drones and LiDAR may fail.
Quick and Easy Routine Tasks	Setting up a Total Station is a more efficient method than analyzing LiDAR data when it comes to actions that are performed daily, such as daily leveling on a construction site.	Water Pass does not require coding or GIS expertise, making it accessible to field workers with basic training.
Culture and Heritage Preservation	Sensitive Locations: Total stations provide a non-invasive method for documenting heritage structures (e.g., temples, archaeological monuments), while LiDAR drones may require licenses or pose a risk of damage.	
Power and durability	Function without batteries or charge (the water levels are entirely mechanical). Essential in areas with inconsistent power supply while using LiDAR/Drones: Reliant on power and susceptible to failures in severe temperatures or humidity.	

Learning and Skills Development	Total stations and Water Pass are critical for training surveyors in key principles (angles, leveling, error analysis) before going on to sophisticated equipment.

This research establishes a scientific foundation for decision-making in surveying and construction procedures while enhancing the geomatics engineering literature through a contextual comparison analysis. It theoretically addresses the information gap about the efficacy of classical tools in the high-tech era. The consequences encompass enhanced efficiency, cost savings, and risk avoidance in infrastructure and environmental initiatives. Integrating these two elements renders this research relevant to scholars and professionals in the domain.

Conclusion

Excavation and embankment work yielded a total of 87 data points for the standard deviation of both instruments. The author concludes that the Water Pass is more precise in calculating the volume of excavation and embankment than the Total Station tool, which has a larger ratio than the Water Pass f 0.01% in excavation and embankment work, even though the difference in standard deviation from the excavation work of the two tools produces a volume comparison of 0.03% and 0.02%. Similarly, the two tools produce a volume comparison of 0.02% and 0.01% in embankment work. To determine the actual field situation, data was collected from a distance of 10 meters or 5 meters during the data collection process. For subsequent research, data were collected from a distance of 5 meters. The borrow pit or trapezoidal method can be employed in conjunction with comparable software to compare the results of the excavation and embankment work volume calculations. This study establishes a foundational understanding of the roles of conventional and modern instruments in volume measurement; however, it remains limited by gaps in external validation and the adaptation of current technologies. It is necessary to compare the results of volume measurements using Total Station, LiDAR, and GNSS in the same project to evaluate the cost-time-accuracy efficacy. This is a continuation of the results of the studies that have been conducted.

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