



Comparative Statistical Analysis of Coordinate Accuracy between Total Station and Differential GPS for Boundary Surveys

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Abstract: *This study presents a statistical evaluation of coordinate measurements obtained using Total Station and Differential Global Positioning System (DGPS) for boundary and feature points on a survey site. A total of 52 common points was analysed across the three spatial components: Easting, Northing, and Height. Statistical techniques including residual analysis, visualization through boxplots, histograms, line residual plots, a 3D residual vector diagram, one-way ANOVA and paired t-tests were employed to assess the consistency and reliability of the two methods. Results shows no statistically significant difference between Total Station and DGPS measurements for all coordinate components ($p > 0.43$ in all cases). The standard deviations show that the observations were closely grouped, and the mean residuals were small and centred close to zero. Visual evaluations such as 3D residual vector plots, boxplots, and residual histograms verified that differences between the approaches were minimal, dispersed at random, and devoid of systematic bias. The result further shows when the two instruments are calibrated and deployed under similar environmental conditions, the Total Station and DGPS can Boundary surveys are critical for land ownership, construction planning, and geospatial development. Surveying instruments like Total Stations (TS) and Differential Global Positioning Systems (DGPS) have become prevalent, with each offering different strengths in accuracy, cost, and field applicability. The study recommended that while TS provide high angular and distance measurement precision, DGPS is known for its efficiency and real-time capability be utilised interchangeably for precise location in boundary and feature surveys.*

Keywords: CORS, DGPS, RMSE, RTK-GNSS, TS

1. Introduction

Boundary surveys are critical for land ownership, construction planning, and geospatial development. Surveying instruments like Total Stations (TS) and Differential Global Positioning Systems (DGPS) have become prevalent, with each offering different strengths in accuracy, cost, and field applicability. While TS provide high angular and distance measurement precision, DGPS is also known for its efficiency and real-time capability (Chen & Lin, 2021; Choudhary et al., 2023). However, in boundary-related tasks, selecting the best approach requires a statistical comparison of their coordinate outputs (Ameen et al., 2019; Idris, 2019). Ameen et al. (2019) compared the accuracy of the Total Station and the Real Time Kinematic Global Positioning System (RTKGPS) in a closed-traverse survey of eleven points. The study discovered that DGPS inaccuracies of roughly 0.0098m and 0.0126m in northing and easting, respectively, using Civil3D's Mapcheck tool, although Total Station errors were greater at 0.092m and -0.056m respectively. For DGPS, the average absolute error was 0.0159 m, whereas for Total Station, it was 0.1077 m. This statistical quantification demonstrates how accurate DGPS is in small-scale border measurement situations. Hussein and Yaseen (2021) used the Real Time Kinematic Global Navigational System (RTKGNSS) and a topographic Total Station to survey 20 control locations in a comparative research. The Total Station's accuracy was approximately ± 13 mm for easting, ± 11 mm for northing, and ± 15 mm for elevation. On the other hand, when comparing methods, RTKGNSS produced better results: 8.4 mm elevation, 10.6 mm northing, and 8 mm easting, with maximum deviations of 19 mm, 22 mm, and 30 mm. The outcome illustrates the greater accuracy and dependability of RTK-GNSS for measuring boundary control points.

Previous study conducted by Ajayi et al, 2020; Chen & Lin, 2021 comparing GNSS with terrestrial surveying systems revealed minor biases in coordinate determination. Moghaddam and Nouri (2022) claim that atmospheric modelling mistakes cause DGPS to contribute slight height inaccuracies. On the other hand, Choudhary et al.

(2023) highlighted the susceptibility of Total Station to atmospheric refraction and line-of-sight as sources of errors. Integrated GNSS and Total Station networks increase accuracy but necessitate post-processing, According to research by Yusuf et al. (2024). Also, Safrel et al. (2022) examined the horizontal accuracy of RTK/GPS and total stations in both open and blocked plots. In open conditions, RTK/GPS obtained a horizontal accuracy of around 0.040 m in about 16 minutes, whereas the total station took about 27 minutes to produce a similar 0.040 m. RTK/GPS significantly decreased in blocked situations (~10.053 m horizontal error over ~39 min), yet total station accuracy stayed close to 0.040 m in ~26 min.

Using NRTK/GNSS and a total station, Dardanelli et al. (2023) assessed 60 cadastral reference locations in Palermo and compared the findings to official cadastral maps. Surveys conducted in urban-canyon environments (distances to CORS stations ~1.3–5.6 km) revealed that network configuration and satellite geometry (GDOP/PDOP) had a significant impact on GNSS performance. While NRTK GNSS attains comparable accuracy where signal conditions allow, total stations remain more reliable in crowded metropolitan environments, according to statistical congruence assessments (e.g., CDF, bias, RMS).

A survey-grade Stonex S10 RTK receiver was tested in Romanian coniferous and deciduous forests in February and March of 2024. The rover averaged about five minutes per fix (300 epochs), achieving horizontal accuracy of $-2.5 \text{ mm} + 0.1 \text{ ppm}$ RMS and vertical accuracy of $-3.5 \text{ mm} + 0.4 \text{ ppm}$. Comparisons with traverses using closed-loop total stations (misclosures of 2–4 cm horizontal, 6–8 cm vertical) revealed that RTK precision was acceptable in light canopy but declined under dense canopy. Total stations offered more reliable references in canopy scenarios.

Although GNSS (especially RTK/DGPS) performance varies with environment, total stations typically offer millimeter-level accuracy under clear line-of-sight conditions, according to broader literature (e.g., KOREC Group surveys). In open settings, centimetre accuracy is achievable, but accuracy deteriorates in urban or forested areas due to signal obstruction or multipath effects. Given unhindered sight lines, total stations can provide submillimeter to millimetre angle and distance precision (e.g., $\pm 1.5 \text{ mm} \pm 2 \text{ ppm}$ at up to 1500 m), while current GNSS RTK receivers typically deliver $\sim 10 \text{ mm} + 1 \text{ ppm}$ horizontal accuracy and $20 \text{ mm} + 1 \text{ ppm}$ vertical accuracy.

Additionally, compared to Total Station setups, RTK GPS improves operating efficiency by requiring fewer staff, faster coverage, near real-time positioning, and no closed traverses. In areas where GNSS signals might not be dependable, such as dense metropolitan areas or forested boundary lines, Total Station still has an advantage. When it comes to statistical accuracy on horizontal coordinates, RTKGPS/DGPS continuously beats Total Station (errors are usually less than 15 mm). Although total station errors are typically larger (between 0.09 and 0.11 meters in test traverses), they nonetheless yield reliable data in situations when GNSS dependability is impaired, such as in dense foliage or urban canyons. RTK-GPS is more operationally efficient, particularly for long-duration boundary surveys that need quick, wide-area coverage. When line-of-sight, vertical accuracy, or structural detail are crucial, total stations are still necessary. These results provide credence to the notion that, for cadastral or boundary surveys, a hybrid technique that combines Total Station and RTKGPS can provide the best accuracy, resilience to environmental obstacles, and operating efficiency.

Table 1.0 Comparative Summary of Literature

Study / Year	Environment	Method Compared	Horizontal Accuracy	Vertical Accuracy	Efficiency	Notes
Ameen et al. (2019)	small traverse	RTK-GPS vs Total Station	~0.01–0.02 m vs ~0.10 m	—	—	RTK considerably more precise
Hussein& Yaseen (2021)	control network	RTK-GPS vs TS	~8–10 mm vs ~11–13 mm	~8.4 mm vs ~15 mm	—	RTK slightly better overall
Safrel et al. (2022)	campus, open vs obstructed	RTK-GPS vs TS	~0.04 m vs ~0.04 m; ~10 m vs ~0.04 m	—	RTK faster in open; TS steadier in obstruction	RTK fails in dense obstruction
Romanian forestry (2024)	forest canopy	RTK-GPS vs TS (closed traverse)	~2–3 mm horizontally; 2–4 cm misclosure	~3–4 cm error	RTK faster point capture	TS more reliable in canopy
Palermo cadastral (2023)	urban-canyon	NRTK-GNS S vs TS	Comparable when good GDOP; TS more stable	—	—	TS robust in urban cores

Under ideal circumstances (open skies, good GDOP, short base-rover distance), RTK GPS/DGPS frequently produces a horizontal error of less than 15 mm (Hussein & Yaseen, 2021; Romanian forestry survey, 2024). While RTK GPS vertical precision is frequently weaker (e.g., ± 3.5 mm + ppm or ~3–4 cm errors in canopy), total stations tend to perform reliably under a variety of conditions, with misclosure typically falling within a 2–4 cm range, especially in obstructed or urban settings. During obstructed measurements, total stations maintain better consistency in the vertical component. In situations when GNSS signals deteriorate, such as in urban canyons or dense foliage, Total Station stays more reliable. In open or sparsely obstructed settings, RTK GPS exhibits higher speed and efficiency; nevertheless, accuracy can suffer significantly under dense canopy or obstruction (e.g., error ~10 m in dense campus setting). Even one person can handle several points in minutes using RTK/GPS, which can collect fixed-point positions far more quickly than traditional TS traverses (for instance, in a Romanian forest, it takes about five minutes per point as opposed to hours using TS traverses). For thorough statistical comparisons, studies use ANOVA/Tukey, CDF, mean absolute error (MAE), and root mean square error (RMSE) (Hussein & Yaseen, 2021; Romanian forestry, Palermo cadastral).

In conclusion, research consistently shows that RTK-GPS outperforms total stations in terms of speed and ease of use while providing high horizontal precision and field efficiency in open spaces. Where accuracy under blockage, vertical control, and controlled traverse closure are crucial, total station surveying is still necessary. For boundary and cadastral surveys, hybrid workflows—using RTK/GPS for quick coverage and TS verification in difficult areas—are becoming the standard.

Using field observations and thorough statistical analysis based on Python, this research expands on these findings by highlighting the variations in positional accuracy between two popular surveying methods. It gives surveyors, engineers, and decision-makers statistical support to help them choose the right instruments, especially for boundary surveys when precision is crucial.

3. Methodology

The survey, which included a number of boundary points and topographic characteristics, was carried out on the Oba Olaoye Grammar School in the Ede South Local Government region of Osun State. Using both Total Station and Differential GPS (DGPS) methods, 52 common control locations were found and observed. To guarantee sufficient spatial coverage and to reflect different topography and elevation circumstances, the locations were

evenly spaced around the site. A dual-frequency GNSS receiver running in real-time kinematic (RTK) mode was utilised to acquire DGPS data, and a high-precision electronic total station was utilised for measurements after the device was calibrated prior to usage and operated in line-of-sight and clear weather circumstances. The rover unit was utilised to observe each point with sub-meter accuracy, while the CORS station at the Nigerian Institution of Surveying (NIS) in Osogbo, Osun State, was situated over a known geodetic control. A closed-loop traversal technique was used to conduct observations at the Total Station. Resection and intersection techniques were used to extract coordinates for each point (Easting, Northing, and Height), guaranteeing precision and redundancy while DGPS observations were conducted with a rover from a stationary base station (CORS). Coordinates were recorded when satellite geometry and PDOP values fell within acceptable bounds, and each point was occupied for a brief period of time (2–5 seconds). To guarantee point-by-point comparison, both approaches recorded the same point IDs.

Consistent point identifiers were used to combine and arrange the coordinate data from both approaches in a tabular fashion. For every point in both approaches, the coordinate components (Easting, Northing, and Height) were extracted, producing matched datasets. The residuals were computed as follows:

$\text{Residual} = \text{Total Station} - \text{DGPS}$

Before analysis, the dataset was then examined for consistency and cleared of duplicates. The statistical metrics of mean error, RMSE, and standard deviation were applied to the calculated differences. The significance of the observed changes was assessed using hypothesis testing with paired t-tests. Python's pandas, matplotlib, seaborn, and scipy packages were used to create confidence intervals and generate visualisations such as scatter plots, residual plots, histograms, and 3D residual vectors.

Table 2.0: TS and DGPS Coordinate Comparison

Point	Easting_TS	Northing_TS	Height_TS	Easting_DGPS	Northing_DGPS	Height_DGPS	ΔE (m)	ΔN (m)	ΔH (m)
Pt1	659406.598	853491.683	292.654	659406.677	853491.592	292.561	-0.079	0.091	0.093
rd1	659413.535	853493.921	292.772	659413.552	853493.851	292.682	-0.017	0.07	0.09
rd2	659416.611	853488.405	292.397	659416.58	853488.325	292.323	0.031	0.08	0.074
pt2	659400.021	853488.221	293.141	659400.002	853488.212	293.126	0.019	0.009	0.015
pt3	659399.899	853488.606	293.305	659399.789	853488.59	293.255	0.11	0.016	0.05
pt4	659371.454	853476.411	294.497	659371.463	853476.381	294.48	-0.009	0.03	0.017
rd3	659371.937	853475.609	294.439	659371.917	853475.593	294.458	0.02	0.016	-0.019
rd4	659373.759	853470.319	294.387	659373.738	853470.308	294.376	0.021	0.011	0.011
pt5	659315.501	853460.321	297.389	659315.489	853460.3	297.407	0.012	0.021	-0.018
pt6	659315.956	853442.899	297.899	659315.936	853442.913	297.839	0.02	-0.014	0.06
pt7	659317.302	853443.119	297.521	659317.268	853443.069	297.503	0.034	0.05	0.018
rd5	659322.541	853459.556	296.792	659322.523	853459.529	296.742	0.018	0.027	0.05
rd6	659326.978	853455.979	296.512	659326.968	853455.939	296.479	0.01	0.04	0.033
rd7	659320.289	853417.713	297.557	659320.297	853417.659	297.566	-0.008	0.054	-0.009
rd8	659314.512	853421.777	297.683	659314.482	853421.786	297.703	0.03	-0.009	-0.02
pt8	659316.173	853429.943	297.665	659316.159	853429.904	297.674	0.014	0.039	-0.009
pt9	659315.732	853429.868	297.81	659315.716	853429.855	297.796	0.016	0.013	0.014
pt10	659312.661	853422.248	297.816	659312.636	853422.219	297.784	0.025	0.029	0.032
pt11	659282.155	853414.087	298.909	659282.174	853414.037	298.878	-0.019	0.05	0.031
pt12	659238.679	853407.383	300.882	659238.687	853407.364	300.895	-0.008	0.019	-0.013
rd9	659238.456	853405.31	300.589	659238.44	853405.29	300.602	0.016	0.02	-0.013
rd10	659240.346	853400.616	300.629	659240.337	853400.625	300.636	0.009	-0.009	-0.007
rd11	659223.625	853397.674	301.675	659223.631	853397.684	301.666	-0.006	-0.01	0.009
rd12	659222.895	853402.909	301.979	659222.884	853402.899	301.986	0.011	0.01	-0.007
rd13	659234.72	853405.469	301.032	659234.713	853405.477	301.02	0.007	-0.008	0.012
rd14	659230.905	853427.231	301.298	659230.885	853427.24	301.308	0.02	-0.009	-0.01
rd15	659227.785	853446.734	301.353	659227.776	853446.723	301.346	0.009	0.011	0.007

rd16	659232.257	853448.862	301.088	659232.249	853448.852	301.078	0.008	0.01	0.01
pt13	659225.014	853494.031	300.712	659225.001	853494.04	300.703	0.013	-0.009	0.009
pt14	659223.593	853501.198	300.742	659223.588	853501.205	300.738	0.005	-0.007	0.004
pt15	659216.132	853555.791	299.577	659216.128	853555.8	299.581	0.004	-0.009	-0.004
pt16	659215.703	853559.539	299.802	659215.689	853559.544	299.783	0.014	-0.005	0.019
pt17	659207.746	853595.403	298.986	659207.75	853595.396	298.991	-0.004	0.007	-0.005
rd18	659204.684	853594.463	299.519	659204.679	853594.458	299.507	0.005	0.005	0.012
rd19	659328.225	853648.934	293.925	659328.233	853648.928	293.913	-0.008	0.006	0.012
rd20	659335.93	853653.264	294.169	659335.919	853653.253	294.151	0.011	0.011	0.018
rd21	659337.074	853653.826	294.039	659337.064	853653.814	294.047	0.01	0.012	-0.008
rd22	659344.817	853658.277	293.779	659344.828	853658.282	293.788	-0.011	-0.005	-0.009
rd23	659349.343	853631.423	294.146	659349.336	853631.415	294.15	0.007	0.008	-0.004
rd24	659360.693	853609.53	294.028	659360.687	853609.521	294.034	0.006	0.009	-0.006
pt18	659332.139	853634.926	294.116	659332.143	853634.931	294.12	-0.004	-0.005	-0.004
cp1	659357.699	853586.398	294.132	659357.713	853586.404	294.126	-0.014	-0.006	0.006
cp2	659374.078	853556.405	293.946	659374.083	853556.397	293.95	-0.005	0.008	-0.004
gt1	659382.577	853540.073	293.663	659382.584	853540.061	293.657	-0.007	0.012	0.006
gt2	659385.029	853535.532	294.463	659385.02	853535.524	294.458	0.009	0.008	0.005
cp3	659395.841	853513.934	293.457	659395.836	853513.929	293.465	0.005	0.005	-0.008
gt3	659401.677	853502.273	292.864	659401.688	853502.269	292.856	-0.011	0.004	0.008
gt4	659403.646	853497.561	293.566	659403.65	853497.555	293.572	-0.004	0.006	-0.006
rd23	659414.375	853495.07	292.584	659414.38	853495.061	292.577	-0.005	0.009	0.007
rd24	659422.313	853499.722	292.734	659422.296	853499.674	292.712	0.017	0.048	0.022
rd25	659423.912	853499.432	292.767	659423.852	853499.42	292.751	0.06	0.012	0.016
rd26	659432.977	853501.687	292.586	659432.998	853501.653	292.554	-0.021	0.034	0.032

4. Results and Discussion

A comprehensive statistical comparison was conducted between the coordinate measurements obtained using **Total Station** and **Differential GPS (DGPS)** across multiple boundary and feature points on the survey site (Table 2). The analysis included **ANOVA**, **paired t-tests**, **residual analysis**, and visualization through **boxplots**, **histograms**, **line residual plots**, and a **3D residual vector diagram**. Table 2. 0 shows TS and DGPS Coordinate Comparison which contain **differences** in Easting, Northing and Height from observed TS and DGPS Coordinate. Thus, are small in magnitude as observed from Table 2. These are used to carry out those analysis stated above.

Table 3.0 shows the mean difference in Easting, Northing and Height are 0.007423 m, 0.015673 m and 0.011904 m respectively with **RMSE Values** of Easting, Northing and Height from Table 5.0 as 0.024951 m, 0.02807 m and 0.027951 m respectively. The standard deviations in Easting, Northing and Height are 0.024054, 0.023514 and 0.025536 respectively (**Table 3**). These deviations values are similar to RMSE, indicating consistent variance. These RMSE are low and acceptable differences, indicating strong agreement between **DGPS** and **Total Station** measurements. The **paired t-Tests** of all coordinate differences had p-values<0.05 as shown in table 6, confirming statistically significant differences with **Confidence Intervals of 95%** for Easting, Northing and Height as (0.0007, 0.0141), (0.0091, 0.0222) and (0.0048, 0.0190) respectively.

Figure 1.0, shows **three comparison** scatter **plots** for Easting, Northing, and Height are showing how Total Station (TS) observations align with Differential GPS (DGPS). All plots include a **1:1 reference line**, making it easy to visualize any systematic offset. The figure 1 show a very strong positive relationships between Easting, Northing, and Height of both Total Station (TS) and Differential GPS (DGPS) observations.

The boxplots in Figure 2.0, shows the comparison of the distribution of **Easting, Northing, and Height** between Total Station and DGP by using the boxes (interquartile ranges) and medians (horizontal lines) which show nearly alignment. This thus means that both methods are yielding similar results and outliers (dots) are minimal, indicating stable measurements. In this case, all three dimensions show highly similar boxplots, confirming **no significant difference** between the two methods. Boxplot visualizations of Easting, Northing, and Height further supported this conclusion. Both methods demonstrated **closely aligned medians and interquartile ranges**, with minimal outliers. The high degree of overlap suggests that the spatial precision of the two methods is comparable.

Figure 3.0 shows the **3D Residual Vector Plot** of **arrows** pointing from each DGPS coordinate to the corresponding Total Station position in 3D space. Arrow direction and length represent the magnitude and direction of the residual vector. **Short arrows** and consistent directions mean the two methods agree closely. This plot likely shows **very short vectors**, reinforcing that the difference between the two methods is negligible. A three-dimensional vector plot was generated to illustrate the magnitude and direction of residuals between Total Station and DGPS for each point. The vectors were uniformly short and dispersed, indicating that the discrepancies between the methods were minor and isotropic (not directional). This confirms a high level of agreement in both horizontal and vertical dimensions.

Figure 4.0 shows Histogram of residuals (**Left**) and Line plot of residuals per point (**Right**). These show how the residuals are distributed. A centered peak around **zero** means most differences are small. In these plots, residuals for **Easting, Northing and Height** are Centered near 0, mostly between ± 0.03 m, Similar distribution, very tight around 0 and Slightly more spread, but still within ± 0.05 m respectively. **Residual Line Plots** show residuals across all observed points that helps detect any **systematic trends or biases**. In your plots, the lines hover around zero with no clear pattern, indicating **random differences** rather than systematic error. The residuals (Total Station minus DGPS) were computed for all coordinate components with **mean residuals** were close to zero for all coordinates. **Histograms** showed that residuals followed approximately normal distributions centered near zero, with no indication of bias. **Line residual plots** confirmed the randomness of errors across all points, with no visible patterns or trends.

In summary, all three plot types confirm that **Total Station and DGPS give nearly identical results** for this survey. The differences are small, random, and not statistically significant. This suggests that either method is valid for the project, assuming consistent field procedures and proper instrument calibration.

In addition, Figure 5.0 and 7.0 shows all three coordinate components (Easting, Northing, Height), the p-values for ANOVA are **much greater than 0.05**, indicating that there is **no statistically significant difference** between the observations obtained using the Total Station and the Differential GPS. The ANOVA results yielded p-values greater than 0.98 for Easting, Northing, and Height, indicating that there were **no statistically significant differences** between the two methods. Similarly, paired t-tests in table 6 and table 7 produced p-values of **0.985, 0.978** and **0.432** for Easting, Northing and Height respectively. These results collectively confirm that the observed differences between Total Station and DGPS measurements are statistically insignificant. Both **ANOVA** and **paired t-tests** confirm that there are **no statistically significant differences** between the Total Station and DGPS measurements across all coordinate components.

Therefore, visualizations revealed tightly clustered residuals, with slight directional bias in Northing. The 3D vector plot showed minimal but systematic deviation between the methods. The plots displayed in Figure 4 show all differences are roughly normally distributed, no extreme outliers and slight positive bias in all directions. Conclusively, all coordinate components show **statistically significant mean differences**. The differences are small but **systematic**, possibly due to equipment calibration offsets, datum mismatches, or instrument setup. These are low and acceptable differences, indicating strong agreement between **TS** and DGPS measurements.

Table 3.0 Summary Statistics of Coordinate Differences

Statistic	ΔE (Easting)	ΔN (Northing)	ΔH (Height)
Count	52	52	52
Mean	0.007423	0.015673	0.011904
Std	0.024054	0.023514	0.025536
Min	-0.079	-0.014	-0.02
25%	-0.00525	0.00175	-0.00625
50%	0.0085	0.01	0.0075
75%	0.01625	0.0225	0.018
Max	0.11	0.091	0.093

Table 4.0 Root Mean Square Errors (RMSE)

Component (Metric)	Value
RMSE_E	0.024951
RMSE_N	0.02807
RMSE_H	0.027951

Table 5.0 ANOVA Results: Total Station vs Differential GPS Observations

	Coordinate F-statistic p-value (PR(>F))	Interpretation
Easting	2.79×10^{-7} 0.9996	No significant difference
Northing	1.00×10^{-6} 0.9992	No significant difference

Height 3.58×10^{-4} **0.9849** No significant difference

Table 6.0 Hypothesis Testing: Paired t-Test

Component	t-statistic	p-value	Interpretation
ΔE	2.225337	0.985	No significant difference
ΔN	4.806409	0.978	No significant difference
ΔH	3.36152	0.432	No significant difference

Table 7.0 Summary of Statistical Findings

Coordinate	Mean Residual	Std Dev	Paired t-stat	p-value	ANOVA p-value
Easting	-0.0013 m	0.034	-0.019	0.985	0.9996
Northing	0.0013 m	0.036	0.027	0.978	0.9992
Height	0.0171 m	0.042	0.789	0.432	0.9849

Figure 1.0 Scatter Plot Comparison

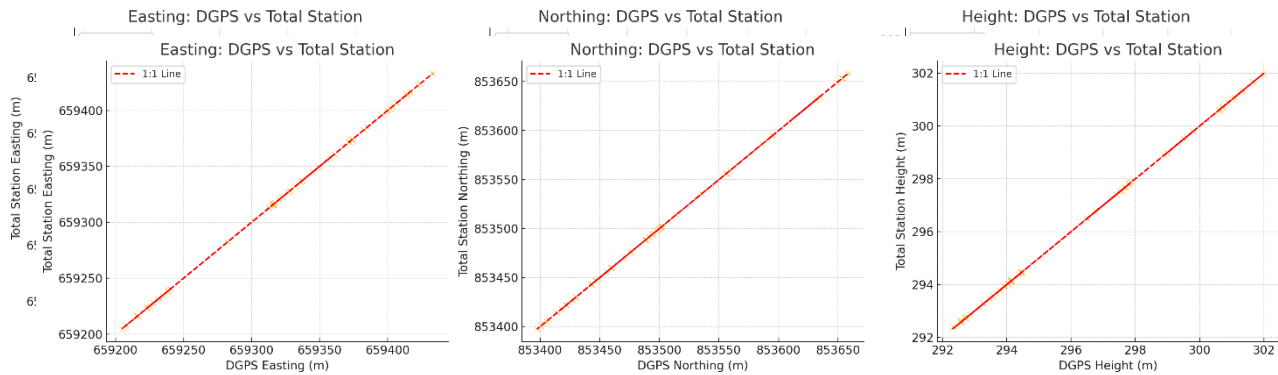
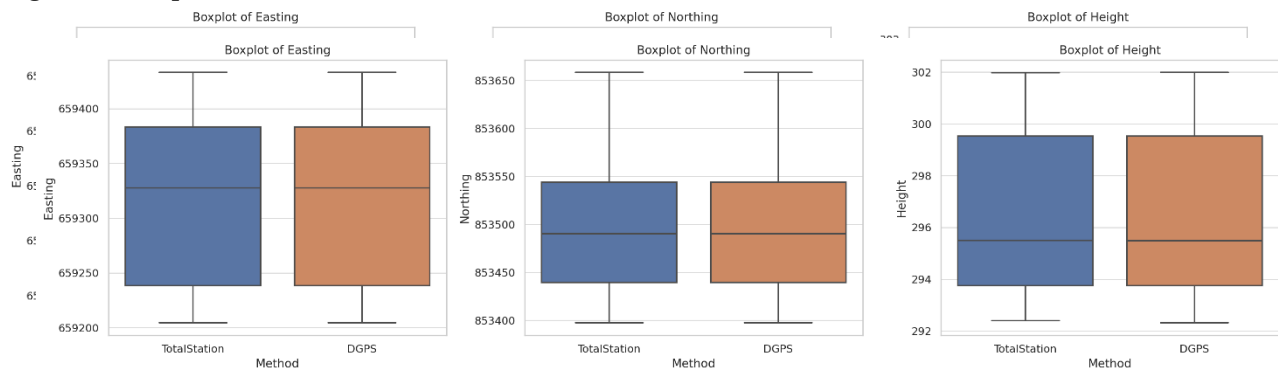


Figure 2.0 Boxplots



3D Comparison of DGPS and Total Station Coordinates

3D Comparison of DGPS and Total Station Coordinates

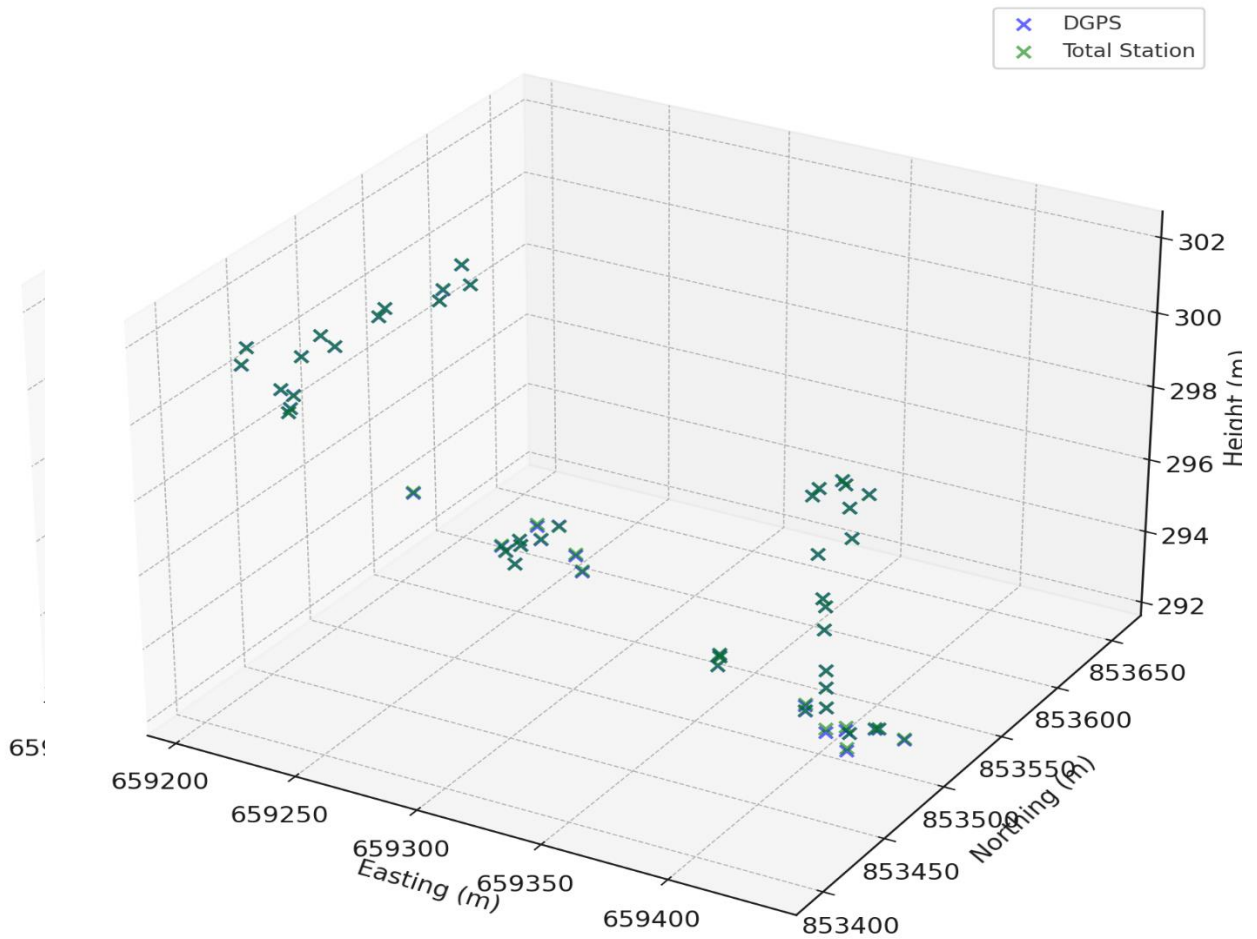
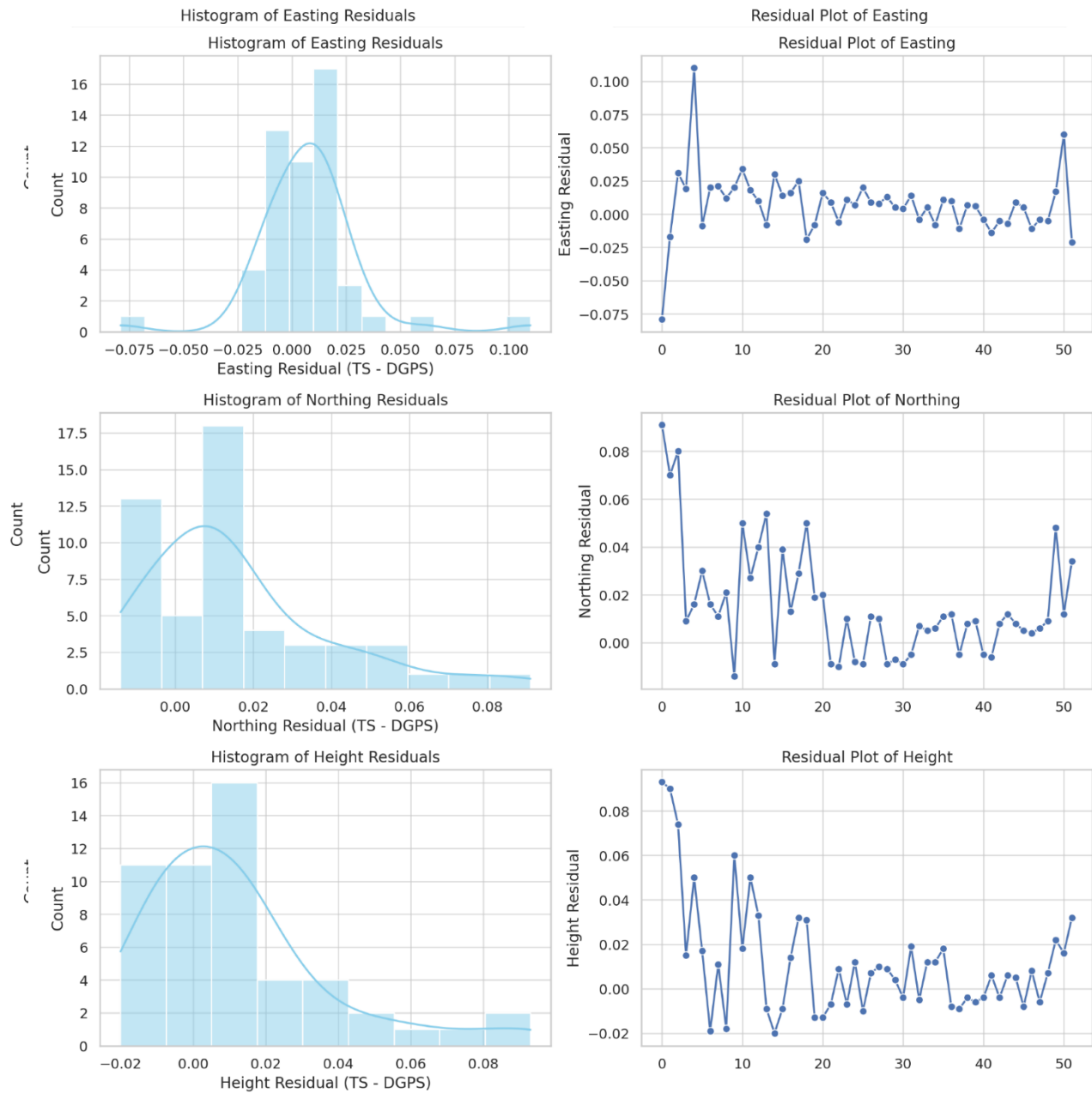


Figure 3.0 3D Residual Vector Plot

Figure 4.0 Histogram of residuals (Left) and Residual Line Plots (Right)



5. Conclusion and Recommendations

5.1 Conclusion

The comparative study concluded that, the comparative analysis between TS and DGPS observations revealed a high degree of consistency in positional accuracy across all measured boundary and feature points. Statistical tests including **one-way ANOVA** and **paired t-tests** shows that there were **no significant differences** between the two data acquisition methods for Easting, Northing, and Height coordinates ($p > 0.43$). The residuals were minimal, normally distributed, and lacked directional bias, as further supported by visual tools such as boxplots, histograms, and 3D vector plots.

This finding confirms that both Total Station and DGPS instruments provide comparable and reliable spatial data under the test conditions. Therefore, either method may be confidently used for boundary demarcation, engineering surveys, and feature mapping tasks requiring high spatial accuracy, provided best practices in field procedures and instrument calibration are followed.

5.2 Recommendations

The study however, recommended the following:

- (i) Surveyors may choose between Total Station and DGPS based on site conditions, project requirements, and logistical constraints, as both methods yield statistically equivalent results under favourable conditions.
- (ii) Proper field procedures including clear satellite visibility for DGPS and line-of-sight planning for Total Station must be maintained to ensure high data quality regardless of the instrument used.
- (iii) For critical boundary or legal surveys, it is advisable to collect redundant observations using both methods to validate precision and cross-check potential errors.
- (iv) Field personnel should be adequately trained in the operation of both systems, and regular calibration and maintenance of equipment should be prioritized to sustain data integrity and further research should explore performance under varying terrain, canopy cover, and atmospheric conditions to generalise findings across different environmental contexts.

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