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Accuracy Assessment of Height Difference Using Total Station and Levelling Instrument

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ABSTRACT

Height observations are one of the most fundamental measurement types in surveying and geodetic science-related areas. This study aimed at analyzing and comparing heights of points obtained using total station and automatic level instruments. To achieve this aim, a field study was carried out within the Obanla campus of the Federal University of Technology, Akure. The total station was used to set out 20 metres of grid points over a total area of 200 metres by 100 metres within the study area. With the grid points serving as the station points, a total of 50 stations were established for this study. The data obtained from spirit levelling was reduced using the height of the instrument method. The computed accuracy for the levelling operation was 11mm, meeting the standard accuracy limits for third-order levelling. The maximum and minimum heights obtained using the automatic level instrument are 385.880m and 379.412m respectively, and 385.921m and 379.472m respectively using the total station instrument. The differences between the heights obtained using both instruments were 41mm and 60mm respectively. Statistical analysis using the independent-sample T-test at the 95% confidence level showed that there was no significant difference in the performance of the two instruments in fitting the height of points. Therefore, the Total station and spirit-level instruments can be used interchangeably for terrain height determination.

***Keywords*:** Total Station, Automatic level, spirit level, height determination

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1. INTRODUCTION

Height determination is an essential aspect of surveying that involves determining the vertical location of a point relative to a reference datum. Surveyors typically use different techniques to determine the elevation of a point, including trigonometric levelling, barometric levelling, and spirit levelling (Simbolon et al., 2017). Levelling is a widely used method for determining the elevations of ground points relative to a reference datum. It involves measuring the vertical distance between the ground point and the reference datum to obtain what is known as the reduced level. This is an important procedure that is used in various fields such as mapping, engineering design, construction, and setting out. The reference datum used in levelling is usually the mean sea level, which is assumed to be an equipotential surface. This means that points on this surface have the same gravitational potential energy. As such, the mean sea level is adopted as the reference surface for vertical control surveys (Schofield & Breach, 2007; Uren & Price, 2010).

1. 1. Leveling

Schofield and Breach (2007) opined that levelling is a technique used to determine the vertical location of a point on or beneath the surface of the earth relative to a reference datum, while planimetry refers to the horizontal position of a point relative to a coordinate system. The authors also noted that these two procedures are separate and distinct, as each involves different equipment, procedures, and techniques. This idea is further supported by Ghilani and Wolf (2014), who stated that levelling is primarily concerned with determining the elevations of ground points, whereas planimetry is focused on determining the position of those points in a horizontal plane.

The choice of height system is critical in many applications, especially those that require accurate determination of elevation. For instance, in civil engineering projects such as road construction, it is important to know the elevation of the terrain to design the road profile, drainage, and culverts. The orthometric height system is widely used in such projects as it provides a meaningful height reference that is directly linked to the earth's gravity field. However, other height systems, such as the ellipsoidal height system, are used in different applications. The ellipsoidal height system is based on the normal to the reference ellipsoid and is commonly used in satellite positioning systems such as GPS. The choice of height system depends on the application, and it is important to understand the differences between them to avoid errors in height determination (Torge, 2001).

Orthometric heights are determined by measuring the vertical distance between the point of interest and the geoid. This can be achieved through traditional techniques such as spirit levelling, trigonometric levelling, and GPS measurements (Odumosu et al., 2018). In spirit levelling, a series of measurements are taken with a level instrument, and the heights are computed based on the height of the instrument and the readings taken at the different locations. Trigonometric levelling involves measuring the angles and distances between two points and computing the height difference between them using trigonometric functions. GPS measurements use satellite signals to determine the height of a point above the ellipsoid and geoid is computed with high accuracy (Ghilani & Wolf, 2014).

The process of levelling involves using a levelling instrument to measure the vertical distance between the ground point and the reference datum. The levelling instrument consists of a spirit level and a graduated staff. The spirit level is used to ensure that the staff is held vertically, while the graduated staff is marked with a series of divisions that enable the observer to measure the vertical distance between the ground point and the reference datum. There are several methods for leveling observations in modern days, they include geometric leveling and trigonometric leveling methods (Lee & Rho, 2021). The choice of method to use largely depends on the accuracy desired, nature of the work to do and the availability of instrument to use.

1. 2. Total Station

The total station is a surveying instrument that combines the angle measuring capabilities of theodolite with an electronic distance measurement (EDM) and processing capabilities to calculate and determine horizontal angle, vertical angle and slope distance to the particular point (Lin, 2014).

The determination of the coordinates for an unknown point in relation to a known coordinate is achievable through the utilization of a total station, provided that a direct line of sight can be established between the two points (Putra et al., 2023). The process involves measuring angles and distances from the total station to the points under survey. Subsequently, trigonometry and triangulation are employed to calculate the coordinates (X, Y, and Z or northing, easting, and elevation) of surveyed points concerning the position of the total station (Reyes, 2021).

To get data on the distance of a point, the Total Station emits a wave, then the object will reflect the wave and be received back by the tool. Then the software inside the tool will automatically calculate the distance from where the tool stands to the measured point. To determine an absolute location, a total station requires line of sight observations and must be set up over a known point or with line of sight to two or more points with known location (Solomon, 2014).

2. MATERIALS AND METHODS

2. 1. Study Area

The research conducted in this study focused on a specific area within the Federal University of Technology, Akure, located in Ondo State, Nigeria. The geographical extent of the area was approximately defined by the coordinates 7°18'20.48"N, 5°7'54.29"E to 7°18'12.65"N, 5°7'57.68"E. The research area covers an estimated total land area of about 3.5 acres. It is important to note that the size of the area under investigation is valuable information, as it provides context for understanding the scope and scale of the study. Situated within the university campus, this particular area was selected due to its relevance and suitability for the research objectives (Figure 1).

The precise boundaries of the designated area were carefully defined to ensure accuracy and consistency in the data collection process.

By focusing on a specific portion of the university grounds, the investigation was conducted in a controlled environment, facilitating efficient data gathering and analysis. The chosen area, with its defined geographical coordinates and estimated acreage, serves as a foundation for further studies, providing valuable insights into various aspects of land surveying, geospatial analysis, or related fields within the context of the Federal University of Technology, Akure.

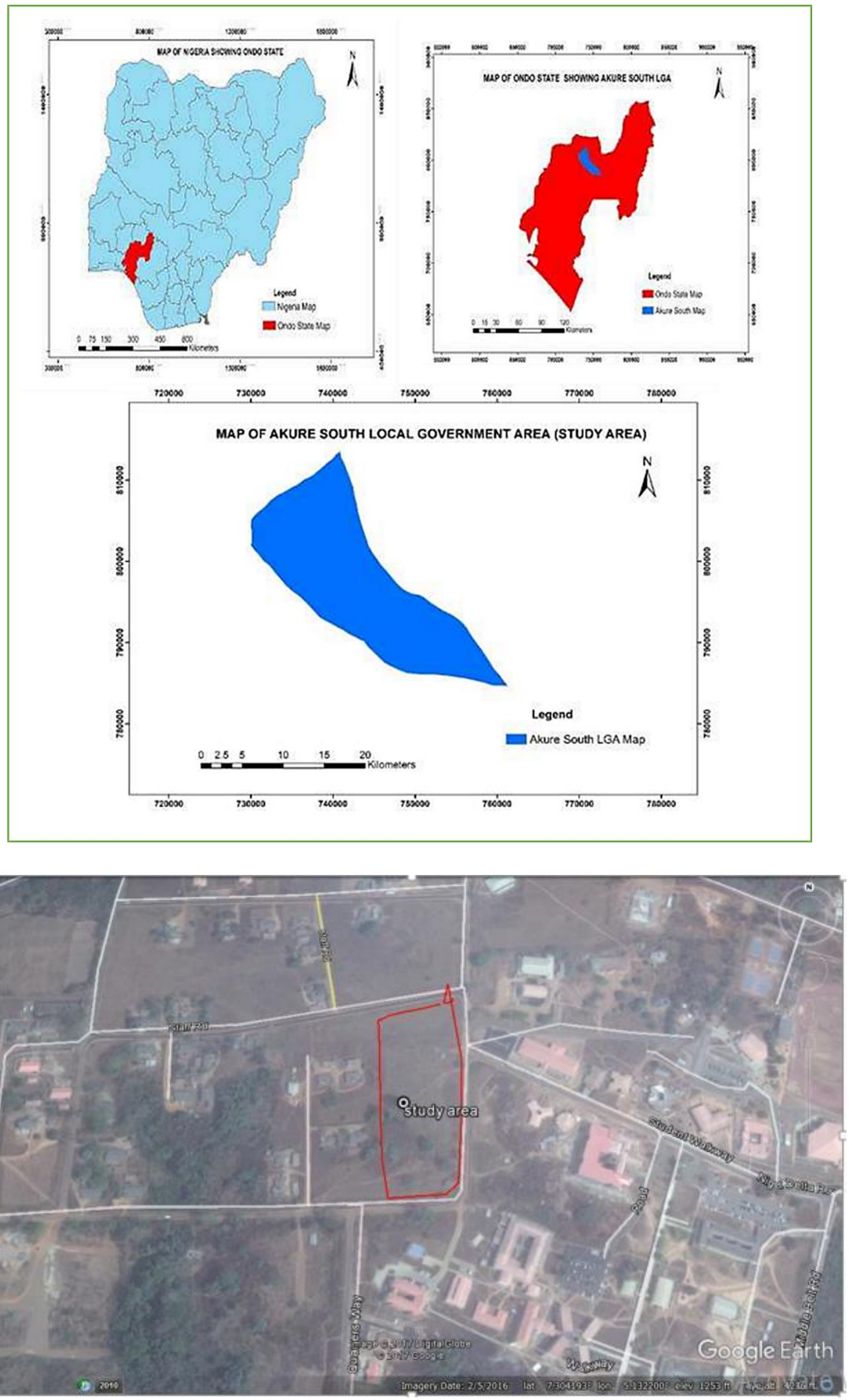

Figure 1. Showing the project location (Part of the Federal University of Technology, Akure)

2. 2. Data Acquisition

Reconnaissance is an extensive study of an entire area of consideration of a surveying project of construction which can be categorised into field and office reconnaissance. Field reconnaissance involves actual visitation to the field to have an overview of the project site, the existing control points and the type of equipment to be used for the project as well as the mode of execution. Office reconnaissance is the gathering of necessary data that will be required during the project execution e.g. coordinates of control points. Stonex R2 Plus Total Station and Leica Automatic Level were the main equipment used for the observation.

Table 1. Data Description

S/N	EQUIPMENT	USES
1.	Stonex R2 Plus Total Station	X, Y and Z coordinates of points
2.	Leica Automatic Level	Determination of the reduced level
3.	Golden Software Surfer 20.0	Contour and Generation of 3D model
4.	Autodesk AutoCAD 2007	Presentation of the boundary

2. 3. Automatic Level Instrument

The level instrument employed for the research was Leica Automatic level. Two peg test was carried out on the automatic level to check the collimation error of the instrument, the result of the two-peg test (0.002) shows the instrument is in good condition and can be used for the research.

The level instrument was set midway between peg 1 and control point SVG/G13/06. Backsight on SVG/G13/06 and foresight on peg 1, the process was repeated till all the 50 points were exhausted. The levelling was carried out in a loop using a differential method of observation. The height of the Instrument method of booking and computation was used for the recording and computation.

2. 4. Total Station

The total station instrument used (Stonex R2 Plus Total Station)underwent a two-phase check. Firstly, the vertical and horizontal angles were verified using pre-established control points within the school campus. Secondly, the electronic distance measurement (EDM) capability was tested for horizontal distances. The instrument passed all tests and was deemed suitable for use. To ensure accurate measurements, the land area was divided into a grid with 20-meter intervals. A total of 50 points within this grid were observed, marked, and recorded for future reference.

The Total station observation for the project area was carried out and the X, Y and Z coordinates of the 50 already marked points were saved in the total station memory. The total station was set on SVG/G13/06 control point and backsight on SVG/G13/07 control point and the foresight on peg 1. The height of the instrument was recorded to accurately get the height of the fore stations.

2. 5. Data processing

One significant advantage of utilizing the total station over an automatic level is its ability to provide immediate X, Y, and Z coordinates of points without requiring additional processing. Unlike an automatic level, which primarily measures vertical distances, a total station combines the functionality of a theodolite and an electronic distance measurement (EDM) device, enabling it to capture both horizontal and vertical angles as well as distances. The total station used was the Stonex R2 series, and the Stonex R2 Plus Data Exchanger software was employed to download the coordinate data from the instrument to a computer. This software is specially designed to facilitate the transfer of data from the Stonex R2 total station series, ensuring seamless integration and easy access to the collected information.

The backsight and foresight readings from the Automatic level were computed using the height of the Instrument method to get the reduced level. The error from the level instrument was 0.005 meters and was distributed evenly to the observed points. AutoCAD 2007 software was used for the plotting of the project area boundary, spot height and composite plan of the study area. Golden Software Surfer was used in the plotting of the contour map, 3D surface map as well as hill shade map of the study area

3. RESULTS AND DISCUSSION

Table 2. Total station and Automatic level heights and their differences

STATION	EASTING	NORTHING	TOTAL STATION	LEVEL	DIFFERENCE
PEG1	735491.624	807924.38	385.581	385.549	0.032
PEG2	735506.742	807912.147	385.000	384.955	0.045
PEG3	735522.656	807900.034	383.845	383.798	0.047
PEG4	735538.571	807887.92	382.514	382.47	0.044
PEG5	735554.485	807875.807	382.282	382.238	0.044
PEG6	735502.942	807940.175	381.59	381.544	0.046
PEG7	735518.856	807928.061	382.454	382.42	0.034
PEG8	735534.77	807915.948	383.178	383.13	0.048
PEG9	735550.684	807903.834	383.915	383.885	0.03
PEG10	735566.598	807891.721	385.362	385.299	0.063
PEG11	735515.055	807956.089	385.413	385.385	0.028
PEG12	735530.969	807943.976	384.167	384.13	0.037

PEG13	735546.884	807931.862	383.098	383.067	0.031
PEG14	735562.798	807919.749	382.327	382.287	0.04
PEG15	735578.712	807907.635	381.325	381.295	0.03
PEG16	735527.169	807972.003	381.688	381.636	0.052
PEG17	735543.083	807959.89	382.604	382.571	0.033
PEG18	735558.997	807947.776	383.311	383.269	0.042
PEG19	735574.911	807935.663	384.292	384.263	0.029
PEG20	735590.826	807923.549	385.921	385.88	0.041
PEG21	735539.282	807987.918	385.179	385.149	0.03
PEG22	735555.197	807975.804	384.993	384.952	0.041
PEG23	735571.111	807963.69	384.01	383.954	0.056
PEG24	735587.025	807951.577	383.213	383.173	0.04
PEG25	735602.939	807939.463	382.451	382.399	0.052
PEG26	735551.396	808003.832	382.089	382.048	0.041
PEG27	735567.31	807991.718	382.681	382.628	0.053
PEG28	735583.224	807979.605	383.392	383.346	0.046
PEG29	735599.139	807967.491	384.112	384.074	0.038
PEG30	735615.053	807955.378	384.769	384.726	0.043
PEG31	735563.51	808019.746	384.453	384.412	0.041
PEG32	735579.424	808007.632	383.63	383.591	0.039
PEG33	735595.338	807995.519	383.012	382.952	0.06
PEG34	735611.252	807983.405	382.285	382.233	0.052
PEG35	735627.166	807971.292	381.688	381.646	0.042
PEG36	735575.623	808035.66	380.563	380.502	0.061
PEG37	735591.537	808023.547	381.682	381.627	0.055
PEG38	735607.451	808011.433	381.959	381.918	0.041
PEG39	735623.366	807999.319	382.698	382.659	0.039

PEG40	735639.28	807987.206	383.543	383.509	0.034
PEG41	735587.737	808051.574	382.791	382.751	0.04
PEG42	735603.651	808039.461	381.754	381.701	0.053
PEG43	735619.565	808027.347	381.229	381.196	0.033
PEG44	735635.479	808015.234	380.723	380.677	0.046
PEG45	735651.393	808003.12	380.144	380.09	0.054
PEG46	735599.85	808067.489	379.472	379.412	0.06
PEG47	735615.764	808055.375	380.08	380.027	0.053
PEG48	735647.593	808031.148	380.135	380.081	0.054
PEG49	735647.593	808031.148	380.571	380.523	0.048
PEG50	735663.507	808019.034	381.647	381.604	0.043
Mean			**382.8163**	**382.7726**	**0.0437**
Standard Deviation			**1.6049**	**1.6088**	**-0.0039**
Variance			**2.5758**	**2.5881**	**-0.0123**

The table above shows the station Id, eastings, northings, total station height, automatic level reduced level and the difference between the total station height and the automatic level reduced level.

The comparison of the two pieces of equipment revealed variations within a specific range. The differences observed between the two pieces of equipment were found to be in the range of 0.028 to 0.062 meters. These differences indicate slight disparities in the measurements obtained from each instrument. Statistical analysis was performed to evaluate the mean, variance, and standard deviations of the observed differences. The mean difference was calculated to be 0.0437, indicating an average deviation between the measurements obtained by the two equipment. The variance, which quantifies the spread of the differences, was found to be 0.0039.

This value suggests that the variations in the measurements obtained by the two pieces of equipment were relatively consistent. The standard deviation, which provides a measure of the dispersion of the data, was determined to be 0.0123. This indicates that the differences between the measurements obtained from the two pieces of equipment had a moderate level of variability.

Overall, the results of the analysis demonstrate that there were slight variations between the measurements obtained from the two pieces of equipment. The mean, variance, and standard deviations provide insights into the magnitude and consistency of these differences, offering valuable information for assessing the accuracy and reliability of the equipment in question.

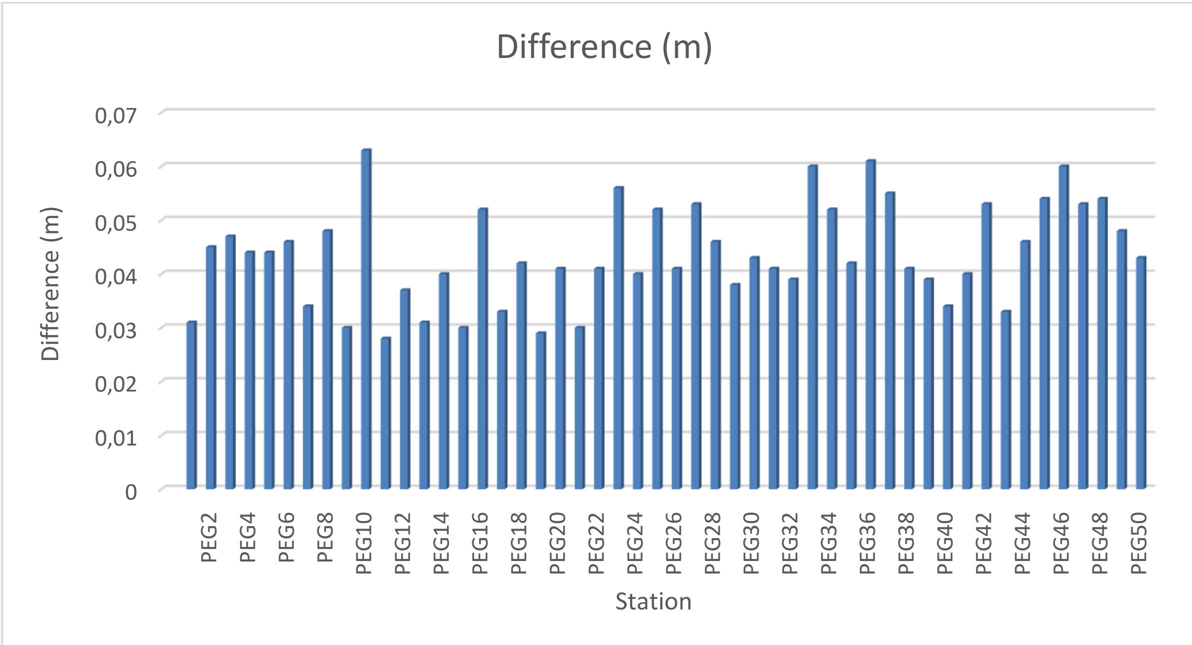

Figure 2. Figure showing the difference in the two instrument's result

The histogram presented above illustrates the distribution of deviations between the two methods being compared. The deviations are depicted in centimeters, showcasing the level of accuracy achieved by both methods. The histogram highlights that the deviations are tightly clustered and exhibit a consistent pattern.

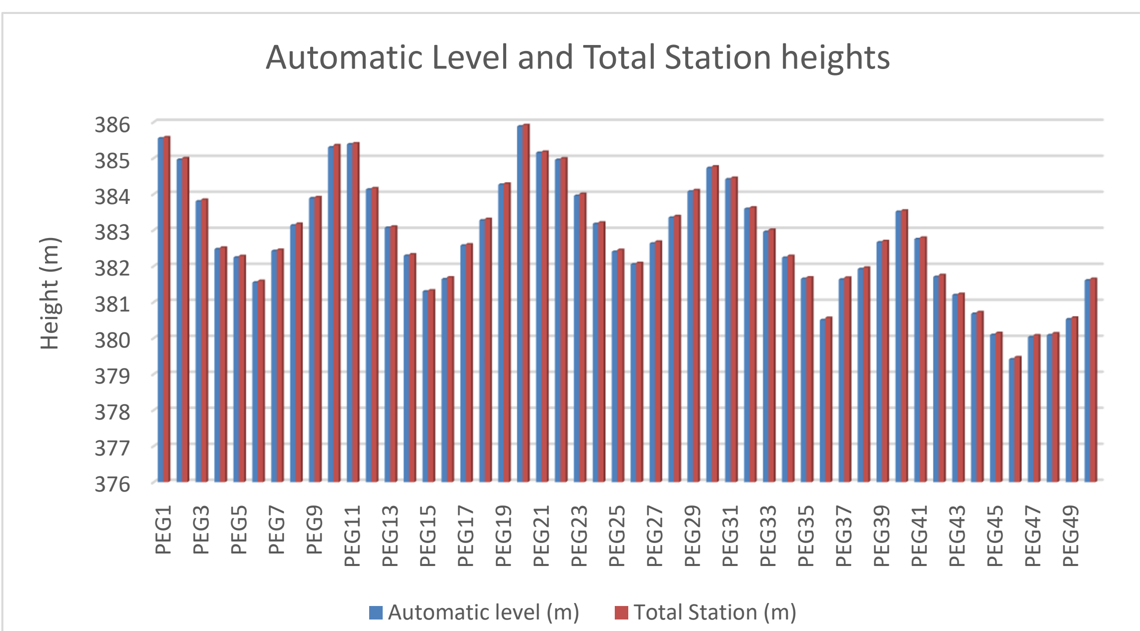

Figure 3. Showing the heights obtained from the total station and level instrument.

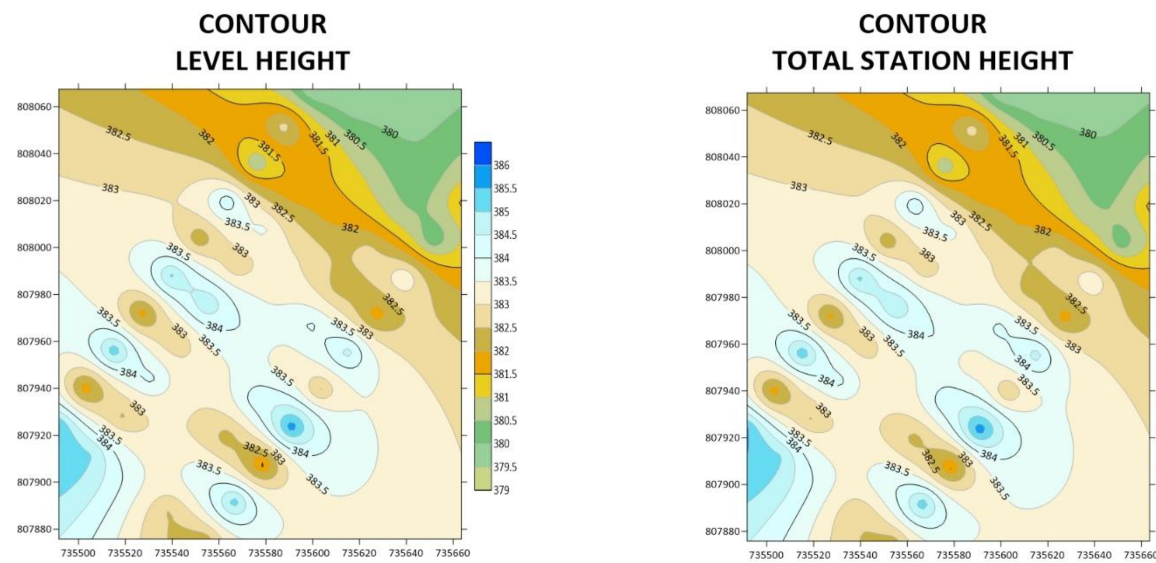

Figure 4. Showing the contour map obtained from the two instruments.

The mean of the deviations, calculated to be 0.0437m, provides an indication of the average difference between the measurements obtained from the two methods. This value signifies a small average deviation, suggesting that the two methods generally yield similar results with minimal variation.

The histogram provides a visual representation of the data, allowing for a comprehensive understanding of the distribution of deviations. By examining the histogram, one can observe the concentration of deviations around the mean value, indicating a central tendency in the measurements obtained by the two methods.

The centimeter-level accuracy exhibited by the deviations underscores the precision of the measurement techniques employed. This level of accuracy is crucial, particularly in applications that require high precision, such as engineering, construction, or geospatial analysis.

The contour maps presented above exhibit strikingly similar patterns, which serve as a testament to the high degree of precision achieved by the instruments used. The consistent and replicated patterns observed on the maps reinforce the reliability and accuracy of the measurements obtained.

The similarity in the contour patterns indicates that the instruments employed in the surveying process were able to capture the subtle variations in elevation with great precision.

This level of accuracy is crucial in applications such as topographic mapping, land surveying, and engineering, where even minor deviations can have significant implications. By displaying the contours of the surveyed area, the maps provide a visual representation of the landscape's topography and elevation changes.

The congruity in the contour lines across the maps signifies that the instruments effectively captured and recorded the elevation data, resulting in a reliable representation of the terrain.

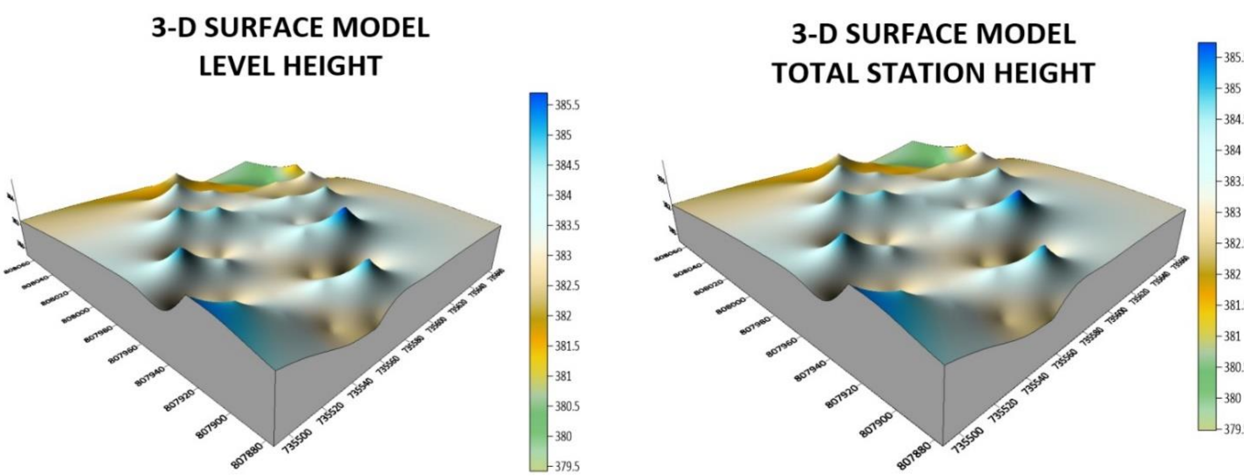

Figure 5. Showing the 3D surface map obtained from the two instruments

Statistical Analysis

A statistical investigation was carried out using Paired Two Samples as Means to test whether there is any significant difference in the performance of the two instruments for terrain height determination. The independent sample t-test is a member of the t-test family, which consists of tests that compare mean value(s) of continuous-level (interval or ratio data), normally distributed data (Hinton, 2004). The independent-sample t-test evaluates the difference between the means of two independent or unrelated groups. That is, we evaluate whether the means for the two independent groups are significantly different from each other.

Hypothesis

A hypothesis was set up and tested using an Independent – sample T-Test:

1) Null Hypothesis: H_0: There is no difference between the terrain height obtained from the total station and spirit level.
2) Alternative Hypothesis: H_1: There is a difference between terrain height obtained from total station and spirit levelling.

The null hypothesis is rejected if the calculated t value has a probability sig. (p) greater than the chosen significance level. An Independent sample T-Test was used in testing the hypothesis at a significance level of 0.05. Data analysis Package extension in Excel was activated and used in running the T-Test.

Table 3. T-Test: Two-Sample Assuming Unequal Variances

	Automatic Level	**Total Station**
Mean	382.77262	382.81628
Variance	2.588092118	2.575687471

Observations	50	50
Pearson Correlation	0.999986297	
Hypothesized Mean Difference	0	
Df	98	
t Stat	-0.135857896	
P(T<=t) one-tail	0.44610615	
t Critical one-tail	1.660551217	
P(T<=t) two-tail	0.8922123	
t Critical two-tail	1.984467455	
Sum	19138.631	19140.814
Kurtosis	-0.650407311	-0.654092657
Skewness	-0.013501967	-0.009808567
Median	382.6435	382.6895
Maximum	385.88	385.921
Minimum	379.412	379.472
Range	6.468	6.449

The statistical data provided supports our discussion by indicating a high degree of agreement and consistency between the automatic level and total station measurements. The mean values are very close, the variances are similar, and the Pearson correlation coefficient indicates a strong linear relationship. The t-test results suggest that any observed difference between the two instruments' means is likely due to random variation rather than a significant discrepancy.

4. CONCLUSION AND RECOMMENDATION

The topographic map and 3d Surface model derived from the result of the two instruments are approximately the same, hence they can be used interchangeably for topographic surveying and terrain delineation. Because of the nature of the terrain considered, it is easier and faster to use a total station compared to an Automatic level instrument. However, for projects that require higher height accuracies like engineering projects (drainage, dam, road as well as monitoring and evaluation), we suggest comparing levelling, Total station and GNSS receivers to have a clear conclusion on which one to use.

References

[1] Arora, M.K. and Badjatia, R.C. (2011), An introduction to Geomatics Engineering", 1st Edition, published by Nem Chand and Bros., Roorkee, India.

[2] Albattah, M. M. S., Al Rawashdeh, S. G., Al Rawashdeh, B. S., & Sadoun, B. (2021). Assessment of geomatics engineering techniques for landslides investigations for traffic safety. *The Egyptian Journal of Remote Sensing and Space Sciences*, 24, 805–814. https://doi.org/10.1016/j.ejrs.2021.06.007

[3] Audu, H.A.P., Tijjani, M.Y. (2017). Comparative Assessment of the Accuracy of the Elevation differences obtained from different Geomatics Techniques and Instruments. *Nigerian Journal of Environmental Sciences and Technology* Vol 1, No. 1 pp 136 - 145

[4] Ayan, T. (2001). Geodetic Network Densification in Istanbul, IGNA (Istanbul GPS Network), IV. Turkish–German Joint Geodetic Days, Berlin.

[5] Badejo, O.T., Aleem, K.F., and Olaleye, J.B. (2016). Replacing Orthometric Heights with Ellipsoidal Heights in Engineering Surveys. *Nigerian Journal of Technology* 35(4), 761-768

[6] Beshr, A.A.A.; Abo Elnaga, I.M. (2011). Investigating the Accuracy of Digital Levels and Reflectorless Total Stations for Purposes of Geodetic Engineering. *Alex. Eng. J*. 50, 399–405

[7] Chaitanya, J.S.N., Chandramouli, K., Divya, K., Hussen, P. (2023) A review study on total station. *International Research Journal of Modernization in Engineering Technology and Science* 12(2)

[8] Chella Kavitha, M.N.; Viswanath, R.; Kavibharathi, P.; Aakash, K.; Balajimanikandan, M. A (2018).Comparative Study of Conventional Surveying Techniques with Total Station and GPS. *International Journal of Civil Engineering Technology*, 9, 440–446

[9] Doma, M. I. & El Shoney, A. F. (2012). Arrangement of the redundant observations for establishment of a GPS network using "LP" method. *Journal of Engineering and Applied Science*, 59(4), 305-321

[10] Ehigiator-Irughe, R. and Konofua, S. (2016), Accuracy Standard of UNIBEN First order GNSS Geodetic Controls. *Journal of the Nigerian Institution of Production Engineers, Benin City*, Vol. 20, pp 145-149.

[11] Ehiorobo, J.O. (2002), GIS in Infrastructural Development and Management", Technical Transaction, *Journal of the Nigerian Institution of Production Engineers, Benin City*, Vol.7, No 3, pp 136-146.

[12] Eteje S. O., Ono M. N., Oduyebo O. F. (2018). Practical Local Geoid Model Determination for Mean Sea Level Heights of Surveys and Stable Building Projects. *IOSR Journal of Environmental Science, Toxicology and Food Technology* 12(6), 30-37. DOI: 10.9790/2402-1206013037

[13] Featherstone, W. E. (2002). Height systems and vertical datums: A review. *Reports on Geodesy*, 49(1), 97-107

[14] Federal Geographic Data Committee (FGDC), (1998), "Geospatial Positioning Standards", Standards for Geodetic Networks of the Geodetic Control Subcommittee of FGDC, Virginia, USA

[15] Ghilani, C. D., & Wolf, P. R. (2014). Elementary Surveying: An Introduction to Geomatics (14th ed.). Prentice Hall.

[16] Henriques, M. J., & Casaca, J. M. (2001). The history of levelling in Portugal. *Journal of Geodesy,* 74(8), 672-677

[17] Hinton, P. (2004). Statistics explained. London: Routledge.

[18] M. Abdullahi and N. A. Yelwa, (2016). Structural Deformation Monitoring Surveys of New Administrative Building of Federal School of Surveying, Oyo – Nigeria, *International Journal of Science and Technology,* vol. 6, no. 1.

[19] Idoko, A. I., Sam, A. A., & Eboigbe, A. M. (2020). Comparison of Orthometric Heights Obtained Using Total Station and Differential Global Positioning Systems (DGPS) With Precise Levels Instruments. *International Journal of Scientific & Engineering Research*, 11(9), 15-28. doi:10.9790/1813-0908011522

[20] Kumar, M. (2005). When ellipsoidal heights will do the job, why look elsewhere? *Surveying and Land Information Science*, 65(2), 91-94

[21] Lee, J., & Rho, T. (2001). Application to leveling using total station. In New Technology for a New Century International Conference FIG Working Week 2001. Seoul, Korea: FIG Conference Proceedings.

[22] Maembe, w. (2012). Potential application of Total Station Leveling as a Precise Geodetic Leveling. B.Sc. Thesis, Department of Geomatics Ardhi University, Dar es Salaam, Tanzania.

[23] Odumosu J. O., Ajayi O. G., Idowu, F. F., Adesina E. A., (2018): Evaluation of the Various Orthometric Height Systems and the Nigerian Scenario – A Case Study of Lagos State. *Journal of King Saud University – Engineering Sciences*, 30, 46-53

[24] Otakar, S. & Josef, W. (2004). Optimized Technology for GPS Height Determination. FIG Working Week 2004 Athens, Greece, May 22-27, 1-8.

[25] Otoo-Kwofie, M. (2015). Height determination and its applications in engineering surveying. *International Journal of Engineering Research and Technology,* 4(9), 262-272

[26] Putra, A. B., Arumsari, P., Cahyono, C., Sarigih, J. F. B., & Kosalim, V. (2023). Building infrastructure analysis using total station and unmanned aerial vehicle drone for surveying and modelling. In Proceedings of the 6th International Conference on Eco Engineering Development 2022 (ICEED 2022) (p. 012006). *IOP Conf. Series: Earth and Environmental Science*, 1169. IOP Publishing. https://doi.org/10.1088/1755-1315/1169/1/012006

[27] Schofield, W., & Breach, M. (2007). Engineering Surveying (6th ed.). Butterworth-Heinemann.

[28] Iduma, R. E. O., & Emakoji, M. (2023). Statistical assessment of the difference between the height differences obtained by spirit and trigonometric leveling techniques. *European Modern Studies Journal*, 7(2), 222. https://doi.org/10.59573/emsj.7(2)2023.21

[29] Simbolon, A. B. S., Yuwono, B. D., & Amarrohman, F. J. (2017). Comparatory analysis of the accuracy of registration methods between combination methods and traverse methods using terrestrial laser scanner in modeling 3-dimensional objects. *Undip Journal of Geodesy*, 6(4), 285-294. https://doi.org/10.14710/jgundip.2017.18153

[30] Shrestha, N. N. (1988). Levelling Instruction Book. Survey Department, Geodetic Survey Branch.

[31] Tata, H., Olatunji, R. I. (2020). Comparative Analysis of Change between Ellipsoidal Height Differences and Equivalent Orthometric Height Difference. *Ghana Journal of Geography*, 12(1):132-144

[32] Uren, J., & Price, W. F. (2010). Surveying for Engineers (5th ed.). Palgrave Macmillan.

[33] Vaníček, P., & Krakiwsky, E. J. (1986). Geodesy: The concepts (2nd ed.). North-Holland.