# Comparison of Height Differences obtained from Automatic, Digital and Tilting Level Instruments

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## ABSTRACT

*Leveling is fundamental to the profession of surveying, Civil Engineering, and other related professions. It is therefore imperative that the type of instrument used to obtain data to determine the height of point either relative or absolute for decision making are carefully selected and used interchangeably if need be. The aim of thiswork therefore is to compare height differences obtained from three different leveling instruments in other to advice on the choice of instrument base on cost, accuracy and whether the instrument can be used interchangeably. Temporary bench marks were established at a distance of 150m interval and leveling operation was carried out with the instrument setup mid-way (125m) between the forward and backward observation. The data obtained were reduced using the height of instrument method and statistical analysis using the F-distribution and ANOVA was used to analyze the data at 5% significant level. Result from the analysis shows that at 5% significant level there is no difference in the performance of the three instruments; therefore the instrument can be used interchangeably without any effect in cost and accuracy.*
***Keywords:*** *Leveling, Measurement, Performance, Instruments*

## INTRODUCTION

Leveling is one of the most widely use techniques involved in the determination of differences in heights of ground points relative to a reference datum. It is a basic operation in surveying and data obtain can be used for the designing of roads, canals, sewers, bridges, and other facilities having grad line that best suit existing topography, calculate volume of earth work and other materials, create maps that depicts general ground configurations, lay out construction projects according to planned elevations, investigate drainage characteristics of an area and study earth subsidence and crustal motion (Wolf and Ghilani, 2006).

Leveling encompasses the measurement of vertical distance relative to a horizontal line of sight. Hence it requires a graduated staff for the vertical measurements and an instrument that will provide horizontal line of sight among others in the level instrument. There are different kinds of leveling instruments that are commonly use. They are Automatic, Digital, Tilting, Dumpy and Laser levels. The automatic leveling instrument is a level that has self-leveling features such that when the three screw leveling heads have been use to level the bull-eye bubble manually, an automatic compensator takes over and levels the line of sight, keeps it leveled by the amount that the telescope is out of level. They have the merits of being rapid in carrying out leveling operations which lead to greater productivity, some are precise for first and second order survey work. Although, the automatic compensator are affected by magnetic fields which results in systematic error. The digital levels are a new generation levels that involves digital electronic technology. It has been designed to reduce human error that occurs in vertical distance measurements and it is classified as electronic because it has a pendulum compensator to level itself. With an in-built electronic gadget called a charge-couple device (CCD) that accurately reads the bar-code rod used in taking measurements and an onboard computer that compares the captured image to the rods entire pattern which is stored in the memory. When a match is found, which can be recorded manually or store digitally the equipment displays the measurement through the Liquid Crystal Display (LCD).

The tilting levels are instruments consisting of a telescope with a crosshair and a tube level. The foot screws are used to center the circular bubbles, thereby setting the telescope approximately in the horizontal plane. After the telescope has been focused on the staff, the line of sight is set more precisely to the horizontal using the highly sensitive tubular bubble and the tilting screw that raises or lowers one end of the telescope (Schofield and Breach, 2007). In a Dumpy level, the telescope and vertical spindle are cast as one piece. It consists essentially of two plates, the telescope being mounted on the upper plate screws directly on to a tripod. The two plates are held apart by three leveling screws or foot screws, and adjustments to these, enable accurate leveling of the instrument to be carried out. That is, the foot screws are used to bring the bubble to the center of its run, and thus make the axis of the bubble horizontal. In using this instrument, two conditions are important for an accurate work: (i) the axis of the bubble tube must be parallel to the line of collimation (ii) both of this must be at right angles to the vertical axis of the instrument (Bannister and Raymond, 1998 and Curtin and Lane, 1955).

Finally, a more recent instrument is the laser level; it has a laser beam projector which employs a rotating head with a mirror for sweeping the laser beam about a vertical axis. If the mirror is not self-leveling, it is provided with visually readable level vials and manually adjustable screws for orienting the projector. A staff carried by the operator is equipped with a movable sensor, which can detect the laser beam and gives a signal when the sensor is in line with the beam (usually an audible beep). The position of the sensor on the graduated staff allows comparison of elevations between different points on the terrain. With these brief explanations of the different types of leveling instruments, the one used for the purpose of this research are Automatic level sun DSC432, Leica Sprinter 100m and Wild N2-111201 tilting level.

The specifications as published by the manufacturers are as shown below;

Leica sprinter 100m (Digital Level): Accuracy (Height measurements)
Electronic measurement with sprinter aluminum barcode staff: 2.0mm
Optical measurement with standard aluminum E-scale/Number staff: 2.5mm
Standard Deviation for single staff reading: 0.6mm (electronic) and 1.2mm (optical) at 30m
Distance accuracy (Standard Deviation): 10mm for Dd”10m Distance in m*0.001for D>10m
Compensator: magnet damped pendulum compensator with electronic range monitoring.

Tilt warning range (electronically): ±102
Compensator range (mechanically): ±102
Setting accuracy: 0.8" max. (Standard deviation)
Magnet field sensitivity: <10"
Automatic level sun DSC432:
Wild N2-111201 tilting level:

In Surveying and Civil Engineering profession, various instruments are used to perform one function or the other; some of them still perform the same functions but only differ in version and name. Among these instruments include tilting, automatic and digital levels thus there is need to compare height differences between the three instruments in other to advice on the choice of instrument base on cost and accuracy. Comparison of height differences obtained from three different leveling instruments in other to advice on the choice of instrument base on cost and accuracy was the aim of this study. Specifically, it aims at:

i carrying out instrument check of the three selected instruments
ii Using the instrument to carry out leveling observation within a selected area of at least 1.000Km
iii Computing the data obtained using the height of instrument method
iv Carrying out analysis on the computed data in order to ascertain the aim of the project

Based on the above, the study shall establish whether ther are significant differences in the performance of the three leveling instruments observed.

## METHOD

The study covered a distance of 1.050km$^2$ from legislative quarter's roundabout along Sani Abacha bye pass towards Aliero housing estate, Birnin Kebbi, Kebbi State, Nigeria. It is situated at latitude 12$^0$ 26' 57.4"N to 12$^0$ 27' 10.32" and longitude 04$^0$ 13' 33.65" to 040 14' 05.83", directly behind the Waziri Umaru Federal Polytechnic. This stage of the research involves the proper steps taken to achieve the desired result. It includes both the office and site reconnaissance, various checks on the instruments and methods of data collection

***Planning:*** This is otherwise known as Reconnaissance, it includes the office and field planning.

***Office Planning:*** Here is the choice of the instrument to be used for the research. It was determined base on the frequency of the use of the instrument within the environment and cost of purchase of the instruments.

***Field Planning:*** It involves the decision on the site to be used, the nature of the terrain, traffic, and vegetation. A base map of the area was used to determine the site, a control point was selected whose height has been pre-determine and conformed to be in good order.

***Checks on the instruments:*** The following checks were carried out on the leveling instruments; (i) Collimation Error, (ii) Parallax Error, and (iii) Collimation Error.

Collimation Error occurs when the collimation axis is not truly horizontal when instrument is level. If Level instrument is set up, leveled and the line of sight or collimation is not truly horizontal, it will sweep out a cone as it is rotated, this cone will be either above or below the horizontal plane. This error can be detected and minimized by two peg test and regularly keeping sight distance roughly equal. Parallax occurs when the focusing screw and the eyepiece is done incorrectly. This condition can be detected by moving the eye to different parts of the eyepiece when reading the staff. If different readings are obtained then parallax is exist. The three instruments were tested for both collimation and parallax error and found to be in proper adjustment. This led the observations.

***Observational Procedure:*** To perform a research of this type, field work is necessary, as such the field work explained below gives a detailed explanation of how each of the instruments used in turn to carry out the research..

***Tilting Level:*** The instrument was set up midway at a distance approximately 75m from the back sight and foresight; all necessary temporary adjustments were performed, parallax removed and sighting begun. The instrument telescope was turned and pointed towards the staff at the back sight (Temporary Benchmark TBM whose height is known), and bisection was made. The tilting screw was turned such that the U shape was brought to coincide, and reading was then taken from the leveling staff and recorded. The telescope was then turn to foresight and the same procedure was carried out, at all instance, the distance between the instrument and staff is 75m and the U shape was used at every bisection before reading the staff. This procedure continued until the work was close at the starting point such that it defines a close loop. The total distance covered was1.050Km. Below is shown the picture of a typical tilting level.

PLATE 1: Tilting level, Wild NK2

This more modern type of level is now in general use. It has a compensator which consists of an arrangement of three prisms. The two outer ones are attached to the barrel of the telescope. The middle prism is suspended by fine wiring and reacts to gravity. The instrument is first leveled approximately with a circular bubble; the compensator will then deviate from the line of sight by the amount that the telescope is out of level.

1. Wild of Canada Limited, 881 Lady Ellen Place Ottawa Ontario, Wild Heerbrugg, Switzerland, N2-111201
2. Automatic level, Sun DSC432
3. Leica Sprinter 100m, Art No. 738933, S/No. 2001130, power; 12v6v = 0.3Amax, CH9435 Heerbrugg, manufactured 2004 in Singapore

***Automatic Level:*** The tripod was setup at approximately 75m between the backsight and foresight with the top close to horizontal, and the instrument was mounted on the tripod using the tripod screw to tighten it. Aligning was made behind two of the foot knobs, the instrument was leveled using the circular bubble, looking down through the mirror, first getting the left-right tilt centered by turning the two lateral knobs simultaneously in or out, then front-to-back by turning the opposite knob until a perfect centering is achieved.

**PLATE 2:** Automatic level SUN DSC 432

**Digital Level:** The tripod was set up at a distance approximately 75m between the backsight and the foresight and the legs extended to a suitable length to ensure that the tripod head is approximately leveled. The tripod shoes were treaded firmly into the ground to ensure stability. It was mounted on the tripod by screwing the tripod screw onto the base of the instrument; three leveling foot screws were used to Centre the circular bubble in order to level the instrument. The instrument was Power on, and was used optically with a bar code leveling staff, its distance laser beam, data storage, and computations are only available with power. The ID number, reduced level for the initial Bench mark and precision were inputted in the instrument appropriately. Bisection was made to the backsight Temporary Bench Mark (TBM) whose value is known and clearance of parallax was made, the measuring trigger key was pushed and the bar code on the staff determines height and distance which was displayed on a highly visible LCD. This readings were recorded and the telescope turned to face the staff at the foresight, bisection was made on the proceeding, and the same procedure continued until the work was closed back at the TBM on the starting point. Just like the tilting level the instrument is always set at approximately 75m from the backsight and foresight stations.

**PLATE 3:** Digital level, Leica Sprinter 100

This Wild NK2 tilting level is an accurate, quick to use instrument for top quality work. It features a reversible tubular level and telescope, which allows the divergence between the line of collimation and the bubble tube axis at two staff readings (180º apart) to be automatically eliminated by taking the mean of the two readings. The main disadvantage of tilting levels is that before each reading is made, the tubular bubble must be set correctly. This is due to the absence of a compensator. The precision of a 1km double leveling run is quoted as ±2mm. The sensitivity of the level bubble is 30"/2mm and the accuracy of leveling the line of sight is ±0.75".

## RESULTS AND DISCUSSION

**Table 1:** Reduced level for the three instruments.

| Chainages | Automatic Level | Digital Level | Tilting Level |
|---|---|---|---|
| 0+000 | 99.967 | 100.003 | 100.008 |
| 0+150 | 99.880 | 99.831 | 99.836 |
| 0+300 | 100.034 | 100.071 | 100.076 |
| 0+450 | 100.855 | 100.888 | 100.854 |
| 0+600 | 101.735 | 101.773 | 101.740 |
| 0+750 | 102.552 | 102.591 | 102.565 |
| 0+900 | 103.291 | 103.361 | 103.331 |
| 1+050 | 104.043 | 104.114 | 104.082 |

**Table 2:** Extract from Reduced Level for Calculation

| | Automatic Level | Digital Level | Tilting Level | |
|---|---|---|---|---|
| | 1.967 | 2.003 | 2.008 | |
| | 1.880 | 1.831 | 1.834 | |
| | 2.034 | 2.071 | 2.076 | |
| | 2.855 | 2.888 | 2.854 | |
| | 3.735 | 3.773 | 3.740 | |
| | 4.552 | 4.591 | 4.565 | |
| | 5.291 | 5.361 | 5.331 | |
| | 6.043 | 6.114 | 6.082 | |
| **TOTAL (t)** | **28.357** | **28.632** | **28.49 0** | **T=85.479** |
| **MEAN** $(\bar{x})$ | **3.544625** | **3.57900** | **3.56125** | $(\bar{x})$ **= 3.561625** |
| $t_i^2/n_i$ | **100.5149311** | **102.473928** | **101.4600125** | |

$$T^2/N = 304.4441434$$

The objective is to test whether there is any significance difference in the performance of these leveling instruments (Automatic, Digital and Tilting Level).

$H_0$: $U_1 = U_2 = U_3$

$H_1$: at least two of the mean are not equal.

$\alpha = 0.05$ was chosen as the significant level.

$$BSS = n\sum_{i=1}^{k}\left(\bar{x} - \bar{X}\right)^2 = \left[\sum_{i-1}^{k}\left(T_i^2/n_i\right) - T^2/N\right]$$

$$S_1^2 = \frac{BSS}{K-1} \quad Where \quad N = \sum_{i=1}^{k} n_i$$

$$BSS = \frac{28.357^2}{8} + \frac{28.632^2}{8} + \frac{28.490^2}{8} - \frac{85.479^2}{24}$$

$$= 100.5149311 + 102.473928 + 101.4600125 – 304.4441434$$

$$BSS = 304.4488716 – 304.4441438 = 0.0047278$$

$$s_1^2 = \frac{0.0047278}{2} = 0.0023639$$

$$TSS = \sum_{i=1}^{k}\sum_{j=1}^{nf} x_{ij}^2 - \frac{r^2}{N} \; or \; \sum_{i=1}^{k}\sum_{j=1}^{nj}\left(x_{ij} - \bar{X}\right)^2$$

TSS = 118.875129 + 121.428282 + 120.087822 – 304.4441434

= 55.9470896

WSS = TSS – BSS

WSS = 55.9470896-0.0047278 = 55.9423618

$$s_2^2 = \frac{WSS}{N-K} = \frac{55.9423618}{21} = 2.66392199$$

The ration F was computed as $F = \frac{S_1^2}{S_2^2}$

$$F = \frac{0.0023639}{2.66392199} = 0.001$$

Having F distribution with $V_1 = (k-1)$ and $V_2 = k(n-1)$

$V_1 – (3-1)$, $V_2 = (N-k) = (24-3) = 21$

$F_á$ = 3.47 from the statistical table

The critical region is therefore determined by $F_{(1-á)}(V_1, V_2)$ i.e

Reject the null hypothesis (H0) if $F > F_{(1-á)}$

F = 0.001 and $F_{(1-á)}$ = 3.47

Formulas obtained from Olubodun O. A (2001).

Accept the null hypothesis there is no significance difference between the observations.

For academic studies and engineering works, it is required to determine height differences between points or the height of points for applications in measurements of national or local networks, vertical applications of bridge, dam and infrastructures, maintenance and control measurements, determination of vertical crustal movements, motorway, railway, sewerage and pipe line measurements. Height determination can be classified as geometric leveling, trigonometric leveling and GPS/leveling depending on the type of instruments used or the methods applied. They have advantages and disadvantages. The purpose of this research is to compare various leveling instrument for achieving the desire goal and to ascertain if these instruments can be used interchangeably were necessary, the instruments are Automatic Level, Digital Level and Tilting Level. To fulfill the aim of this study, leveling operation was carried out with the three instruments at a distance of 150 meter interval from the forward and backward observation for a distance of 1.050Km, the result obtained were deduced and analyzed, the conclusion was that the instruments have no significant differences at 5% significance level

## CONCLUSION

From the analysis above we conclude that there is no significant difference between the values obtained from the observations of heights. We therefore conclude that there are no significant differences in the performance of the three leveling instruments at 5% significant level. Considering the result obtained from the analysis, the instrument can be used interchangeably without any effect on cost and accuracy. The deduced result can be analyzed using the same method but at 1% significance level. The research can also be performed with difference atmospheric condition such as during the winter and summer.

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