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**Research Paper**

# Assessment of Relative Accuracy of Selected Total Station Instruments for a Closed Traverse Survey

EZE PROMISE I, LAWRENCE HART, AND EKE STANLEY N.
*Department of Surveying and Geomatics, Rivers State University, Port Harcourt, Nigeria*

***Abstract***
*In recent time, numerousSurveying instruments and equipment has evolved due to technological development which has impacted in some techniques of field data acquisition in Surveying and Geomatics, one of theseinstruments is the Total Station (TS) Instrument. This instrument measuresthe distances and directions between two points and automatically stores the data for retrieval and further processing. The accuracies and reliability of the (TS) instrument is of utmost important to the Surveyor and Civil Engineers during field data acquisition, hence the need of this study to assess the Relative accuracy of selected (TS) instruments in a closed traverse survey with the objective of carrying out a close traverse survey, analyze the relative angular and linear misclosures and compute the area of the land parcel surveyed. Three (TS) instruments under study includes LEICA TS02-plus, MATO MTS 802R and KOLIDA KTS-442L, The study adopted the classical method of traversing where horizontal distances and directions between series of connected lines are determined; the transit method of traverse adjustment was used to adjust the error in the traverse stations, angular and linear accuracies were computed and the size (area) of the land parcel surveyed were determined. From the results obtained, An angular accuracies of* $0^0$ *0' 9", $0^0$ 0' 14" and $0^0$ 0' 12", a linear accuracy of 1:10,344, 1:7,595 and 1: 9,000 were computed fortraverse with LEICA TS02-plus, MATO MTS 802R and KOLIDA KTS-442L (TS) instruments respectively. The findings also reveal that an area of5,268.790 sq.mtrs, 5,268.551sq.mtrs and 5268.352sq.mtrs were computed for traverse carried out with LEICA TS02-plus, MATO MTS 802R and KOLIDA KTS-442L (TS) respectively. The results indicate that all the (TS) instruments under study were very good for spatial data acquisition as it obtained the maximum angular and minimum linear accuracies for a third order control survey which is 30" and 1:5000. However, LEICA TS02-plus has the highest accuracy followed by, KOLIDA KTS-442L and MATO MTS 802R respectively.*

***Key words:****Total Station, Misclosure, Geomatics, Traversing.*

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## I. Background of Study

Surveying as a Measurement required minimumaccuracy and precision in all measurements taking to determine positions of objects on the earth surface. Accuracy in surveying is the degree of closeness between the measured value and predicted value of a quantity whereas precision is the degree of consistency in a series of observation, but we have no true value in scientific observation but most probable value which is known as the mean value of repeated observations or measurements for a quantity. In recent time, numerous surveying instrument use in spatial data acquisition has emerge as a result of technological development in surveying instrument and equipment, one of this surveying instrument is the Total Station(TS) instruments which consists of three major components such asElectronic Distance Measurement (EDM) Theodolite and Micro-Processor (Charles and Paul, 2008), and has an angular accuracyvariesfrom 1" to 20" and the distance accuracy depends up on two factors which are:Instrumental error which ranges from _+10mmto_ +2mm. Error due to the length of measurement can be from_+100mm to_+2mm per kilometer. Prior to the development and production of the TS instrument, Geospatial Scientist (Surveyors) have rely on the theodolite instrument which only measures direction while horizontal and vertical measurements are carried out with a tape or chain which is quite a herculean task. Some of the techniques and principles of field data acquisition used by Surveyors includes; chain surveying, compass traversing, triangulation, trilateration, intersection, and plane tabling (Basak, 2014).

**Types of Total Station Instrument under study and their Manufacturers**
Leica TS02 plus manufactured by Fadak Land Equipment Technology.
Mato MTS - 802R manufactured by Shanghai Sursup precision instrument co
KOLIDA KTS - 442L manufactured by Shanghai Hexin surveyinstrument company Ltd.

Figure 1.1
LEICA TS02 plus
Source: leica.com

Figure 1.2
MATO MTS 802R
Source: alibaba.com

Figure 1.3
KOLIDA KTS-442L
Source: survey.omcbd.com

**Statement of Problem**

Based on recent productions of several types of total stations instrument, the accuracy of these instruments differs because of the different manufacturer's specifications. This study is necessitated to assess and analyze the relative accuracy of selected types of total stations for a close traverse survey and to ascertain if the least count of each TS instrument is true with respect to manufactures specifications.

**Aims ofthe Study**

The aim is to assess the relative accuracy of selected types of total station instruments over a parcel of land for a close traverse survey.

**Objective of the Study**

I. To carry out a closed close traverse survey of the study area using selected total station instruments.
II. To compute the traverse and the accuracy for each of the total station instruments.
III. To examine the correlation or variation in accuracy of traverse survey for each TS instrument.

**Study Area**

The study area is a parcel of Land located within the faculty of Environmental Sciences ofRivers State University, in Port Harcourt City, Local Government Area, RiversState, Nigeria. It is located within projected coordinates of point A (275962.761mE, 530903.200mN), to point B (275855.250mE,58093 8.002mN) in UTM Zone 32N, (WGS - 84) Datum.

## II. Materials and Methods

**Instrument selection**

In principle, the choice of instrument depends on the type of survey, order of the survey, survey specification, the availability of work force, and the urgency of the job etc. instruments was be selected based on capacity to deliver and availability. The following TS instruments were selected for study

i. LEICA TS02-plus with accessories
ii. MATO MTS 802R with accessories
iii. KOLIDA KTS-442L with accessories
iv. Survey beacons,

**System selections:** HP 620 Laptop Computer with 4 gig, 64 bits (Core i3) operating system, install with relevant graphic software.

**Data acquisition**

**FieldOperations:** The field operation for this study survey job should covers Reconnaissance survey, instrument test, in-situ checks,monumentation, numbering of survey beacons and traversing.

**Reconnaissance Survey**: the study area were examined for smooth traversing, six instrument stations were selected and were inter-visible to avoid obstacles that may arise during field data observations, three control beacons were also identify within the study area.
**Instrument test**: all selected instrument were tested for horizontal and vertical collimation to insure that both axis are truly horizontal and vertical, the result of instrument test in table 2.1, 2.2 and 2.3 shows that all the instrument selected were in good condition to carry out the study.

**Table 2.1: Collimation Test for Leica TS02 Plus**

| FACE | HORIZONTAL CIRCLE READING | VERTICAL CIRCLE READING |
|---|---|---|
| LEFT | 138° 39’27 | 90° 23 41 |
| RIGHT | 318° 39 26 | 269° 36 12 |

Horizontal Collimation Error = 00° 00’ 01’ Index Error = 000 00’ 07’

**Table 2.2: Collimation Test for MATO MTS 802R**

| FACE | HORIZONTAL CIRCLE READING | VERTICAL CIRCLE READING |
|---|---|---|
| LEFT | 51° 26’ 22 | 90° 23 41 |
| RIGHT | 231° 26 24 | 269° 36 12 |

Horizontal Collimation Error = 00° 00’ 02’ Index Error = 00° 00’ 07’

**Table 2.3: Collimation Test for KOLIDA KTS-442L**

| FACE | HORIZONTAL CIRCLE READING | VERTICAL CIRCLE READING |
|---|---|---|
| LEFT | 155° 15’ 09 | 89° 49 52 |
| RIGHT | 335° 15 06 | 270° 1017 |

Horizontal Collimation Error = 00° 00’ 03’ Index Error = 00° 00’ 09’
**Control (in-situ) Check:** This was carried out to determine the reliability of the controls toboth angular and linear Accuracy. The resulting difference between observed and computed angles and distances was negligible and should confirm the in-situ of the controls, the results of control (in-situ) check for each selected TS is shown in table 3.1, 3.2, and 3.3 respectively.
**Monumentation**: All traverse stations were beaconed prior to the observations,
each selected instrument station were permanently marked by burying Pre-cast property beacon of size 18cm x 18cm x 75cm, molded in ratio of 1.3 parts of cement, 2 parts of gravel and 3 parts of sand and were later cemented and smoothened to accommodate the beacon numbers which were capped and allowed to dry before commencement of traversing the next day.
**Traversing**: Traversing was carried out on the land parcel with each selected TS instrument,during this process, two round of observations were carried out and the horizontal distances and directions between each selected stations were obtained. Each TS instrument were set up on the control station (GPS002) a backward observation (face left reading) was taking at another control station (WGPS003) and a forward observation (face right reading) was taking at station (SVGO21). Horizontal circle readings (HCR) and vertical circle readingS (VCR) were taking at both face redundantly, this process of traversing were replicated on the whole traverse process. The mean of these readings will give the interior or exterior angle of each instrument station.
**DATA PROCESSING:** Field data are normally processed after acquisition, all necessary data reductions, adjustments and computations were carried out to reflect the true geometry of the site surveyed after plan production.
**Angular reduction:** The HCR were reduced to angles and further to azimuths and finally to UTM coordinates. Let us examine the procedures in equation 2.1 and table 2.4:

Exterior angle = $FL_2 - FL_I + FR_2 - FR_1 /2$ …2.1
Where; $FL_I$ and $FL_2$ = Face Left readings of backward and forward directions
$FR_1$ and $FR_2$ = Face Right readings of backward and forward directions

**Table 2.4:Traverse Data Reduction**

| STATION | TARGET | FACE | HCR | Horizontal Angle | Mean Horizontal Angle |
|---|---|---|---|---|---|
| | WGPS 003 | L1 | $069^0$ 41’ 48” | | |
| | SVG 021 | L2 | $013^0$ 50’ 27’’ | $304^0$ 08’ 39” | |
| GPS002 | | | | | $304^0$ 08’ 41’’ |
| | SVG 021 | R2 | $193^0$ 50’ 13’’ | $304^0$ 08’ 43” | |

| | | | | | |
|---|---|---|---|---|---|
| | WGPS 003 | R1 | $249^0$ 41' 30'' | | |

**Forward Computation:** All the field books used were compiled and numbered on site to ensure that no sheet was lost. All the recorded horizontal directions were also reduced to obtain the angles between the stations. During the computation of a traverse network, forward bearings are really essential. The computation of the traverse started with points of known co-ordinates in which the initial bearings were used to initiate the bearings of other lines thus forming the traverse network. The discrepancy between the computed bearing derived using the observed angle and that computed from the co-ordinate values of the control is regarded as the angular misclosure. There is always an allowable angular misclosure in every traverse. For a third order traversing, the allowable angular misclosure is given as 30"√N. Where N = No of Stations Occupied / Traversed
Conversion of horizontal angles to azimuths should be done using the mathematical model below:
Forward Azimuth (FA) = Back Azimuth (BA) + Observed Angle (OA)
If BA + OA > 360, FA = BA + OA -360
Back azimuth = FA ± 180 (if FA > 180; BA = FA -180 else FA + 180).
Observed Angle (OA) = BA – FA for exterior angle and vise visa.

**BACKWARD COMPUTATION**

The final co-ordinates may not reflect the actual observed bearings and distance of a traverse due to the adjustments usually made in traverse computations. The bearings and distances were then computed from the final adjusted co-ordinates since they are to an extent the most probable co-ordinates of the points that will form the traverse network. The Latitude and Departure via subtraction of a co-ordinate from the subsequent one, thus the desired distance and bearing should be computed using the formula below:

$$\theta = \tan^{-1}\left(\frac{\Delta E}{\Delta N}\right) \quad \text{... 2.2}$$

$$L = \sqrt{(\Delta E + \Delta N)^2} \quad \text{... 2.3}$$

Where; θ = Forward bearing of the line
L = Horizontal distance of the line
$E$ = Eastings (m) coordinate of a point
$N$ = Northings (m) coordinate of a point
Δ = Change in Northings or Easthings coordinates

**Data Corrections:**
**Adjustment of Traverse**
To obtain final coordinates of stations, the misclosure in the easting and northing should be divided respectively by the arithmetic sum in easting and northing. This became the multiplying factor for the correction needed to be applied to obtain final adjusted coordinates.

$$\text{Correction for Latitude (N)} = \frac{\text{Total Northing Misclosure x Each arithmetic sum of latitude}}{\text{Total arithmetic sum of latitude}}$$

$$\text{Correction for Departure (E)} \quad \frac{\text{Total Easting Misclosure x Each arithmetic sum of departure}}{\text{Total arithmetic sum of departure}}$$

**Results Analysis**

**Traverse**

$$\textbf{Linear Accuracy} = \frac{\dfrac{1}{\sqrt{(\Delta N)^2 + (\Delta E)^2}}}{\textbf{TD}} \quad \text{...2.4}$$

Where; **ΔN** = misclosure in northings
**ΔE** = misclosure in eastings
**TD** = Total distance covered during traversing

## III. Results and Discussions

**Comparison of results for control (In-situ) Check**

**Table 3.1: Control ( In-situ) Check for Leica TSO2 Plus**

| **Control Station** | **Parameter** | **Computed value** | **Observed value** | **Difference** | **Remark** |
|---|---|---|---|---|---|
| WGPS 003 GPS 002 WGPS 004 | Angle | 117°01' 47.5" | 117° 01' 50.5" | 03" | Ok |
| WGPS 003 GPS 002 | Distance | 42.564 | 42.562 | 0.002 | Ok |
| GPS 002 WGPS 004 | Distance | 113.003 | 113.004 | 0.001 | Ok |

**Table 3.2: Control (In-situ) Check for Mato MTS 802R**

| **Control Station** | **Parameter** | **Computed value** | **Observed value** | **Difference** | **Remark** |
|---|---|---|---|---|---|
| WGPS003 GPS 002 WGPS 004 | Angle | 117° 01' 47.5" | 117° 01' 50.5" | 04" | Ok |
| WGPS 003 GPS 002 | Distance | 42.564 | 42.568 | 0.004 | Ok |
| GPS 002 WGPS 004 | Distance | 113.003 | 113.007 | 0.004 | Ok |

**Table 3.3: In-situ Check for Kolida KTS 442L**

| Control Station | Parameter | Computed value | Observed value | Difference | Remark |
|---|---|---|---|---|---|
| WGPS 003 GPS 002 WGPS 004 | Interior Angle | 117° 01' 47.5" | 117° 01' 50.5" | 2.5" | Ok |
| WGPS 003 GPS 002 | Horizontal Distance | 113.003 | 112.999 | 0.004 | Ok |
| GPS 002 WGPS 004 | Horizontal Distance | 42.564 | 42.58 | 0.005 | Ok |

**Check for Angular Accuracy**

In this study, angular mode of the instruments was used to carry out the observations and all observationswere manually booked with the appropriate booking sheet as a backup to the observations automatically stored in the instruments.

**LEICA T502 PLUS**

**Angular Check:** This check was done by adding all our observed angles and comparing it with the constant for checking angular misclosure, (2n+4) x 90°. Computed angle = (2 x 8) + 4 x 90° = 1800° 00'00". The total observed angle was 1799°59'51".

Misclosure = observed angles – computedangles

= 1800° 00' 00" – 1799°59'51" = 00° 00' 9"

**MATOMTS8O2R**

**Angular Check:** This check was done by adding all our observed angles and comparing it with (2n+4) x 900. Computed angle= (2 x 8) + 4 x 90° = 1800° 00' 00". The total observed angle was 1800° 00' 13.5".

Misclosure = observed angles – computedangles

= 1800° 00' 00" – 1800°00'13.5" =00° 00' 13.5"

**KOLIDA KTS-442L**

**Angular Check:** This check was done by adding all our observed anglesand comparing it with (2n+4) x 90°. Computed angle = (2 x 8) + 4 x 90° =1800° 00' 00". The total observed angle was 1799° 59' 48.5".

Misciosure = observed angles – computedangles

= 1800° 00' 00" – 1799°59'48.5" = 00° 00' 11.5"

**Assessment of Linear Accuracy for Each Total Station Instrument**

**Table 3.4: Linear accuracy for selected TS Instruments**

| **Instrument** | **Allowable** | **Obtained** |
|---|---|---|
| Leica TS 02 Plus | 1:5000 | 1:10,344 |
| MatoMTS8O2R | 1:5000 | 1:7,595 |
| KolidaKTS442L | 1:5000 | 1:9,000 |

**Table 3.5: Comparison of Linear Accuracy between Leica Ts 02 PIusand Mato MTS 802R**

| Leica TS 02 Plus | Mato MTS 802R | Difference |
|---|---|---|

| | | |
|---|---|---|
| 1:10344 | 1:7595 | 2749 |

**Table 3.6: Comparison ofLinear Accuracy between Leica Ts02 Plus and Kolida KTS 442L**

| Leica TS 02 Plus | KOLIDAKTS 442L | Difference |
|---|---|---|
| 1:10344 | 1:9000 | 1344 |

**Table 3.7: Comparison of Linear Accuracy between MatoMts 802R and Kolida KTS 442L**

| MATO MTS 802R | KOLIDA 442L | Difference |
|---|---|---|
| 1:7595 | 1:9000 | 1405 |

**Table 3.8: Assessment of Area Computation for Each ofthe Total Station Instrument**

| Instrument | Area (m2) |
|---|---|
| Leica TS 02 Plus | 5268.790 |
| Mato MTS 802R | 5268.551 |
| Kolida KTS 442L | 5268.352 |

**Table 3.81 Comparison of Area Difference between Leica Ts 02 Plus and Mato MTS 820R**

| Leica TS 02 Plus | Mato MTS 820R | Difference |
|---|---|---|
| 5268.790m$^2$ | 5268.551m$^2$ | 0.238m$^2$ |

**Table 3.82: Comparison of Area Difference between Leica Ts 02 PIusand Kolid KTS 4421**

| Leica TS 02 Plus | Kolida KTS 442L | Difference |
|---|---|---|
| 5268.790m$^2$ | 5268.35 1m2 | 0.438 |

**Table 3.83: Comparison of Area Difference between Mato MTS 802R and Kolida KTS 442L**

| Mato MTS 802R | Kolida KTS 442L | Difference |
|---|---|---|
| 5268.551m$^2$ | 5268.352m$^2$ | O.199m$^2$ |

## IV. Results Discussions

The in-situ chech results in tables 3.1, 3.2 and 3.3 indicates that all the control beacons were in position to eacc other and are reliable to both angular an linear observation. Also, an angular accuracies of $0^0$ 0’ 9”, $0^0$ 0’ 14” and $0^0$ 0’ 12”, a linear accuracy of 1:10,344, 1:7,595 and 1: 9,000 were computed for traverse with LEICA TS02-plus, MATO MTS 802R and KOLIDA KTS-442L (TS) instruments respectively. it was also noted in table 3.8 that an area of 5,268.790 sq.mtrs, 5,268.551sq.mtrs and 5268.352sq.mtrs were computed for traverse carried out with LEICA TS02-plus, MATO MTS 802R and KOLIDA KTS-442L (TS) respectively. The results indicate that all the (TS) instruments under study were very good for spatial data acquisition as it obtained the maximum angular and minimum linear accuracies for a third order control survey which is 30” and 1:5000. However, LEICA TS02-plus has the highest accuracy followed by, KOLIDA KTS-442L and MATO MTS 802R respectively.

## V. Conclusion

The classical method of field data acquisition adopted provided the necessary results needed to address the aim of the study and stated objectives, the results obtained were impressive and justify the need for the study. Observations and computations were carefully carried out unbiased and necessary precautions were taking to avoid errors of any kind that will impact on the results obtained for each TS instrument.

## VI. Recommendation

Instruments used for field data collection should be put to test to ensure their reliability to both angular and linear observations and to ensure that manufactures specification for any instrument conforms to the results gotten after test.

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