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Research Article

The Comparison of Traverses Adjusted by Non-Rigorous and Rigorous Methods of Adjustment

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In geodetic surveying, the adjustment of traverses has long been a topic of discussion and analysis. Scholars have posited that the adjustment of traverses can be approached either non-rigorously through methods such as the Bowditch or Transit techniques, or rigorously through more advanced methods. Empirical evidence has consistently indicated that the rigorous adjustment of surveying data yields results of superior accuracy compared to non-rigorous methodologies.

This research endeavour is dedicated to a comprehensive comparison of traverse adjustments within a specified sector of the Federal University of Technology Owerri. The study focuses specifically on a closed loop traverse comprising twelve station points, characterized by inter-point distances spanning the range of 200 meters to 300 meters. The primary instrument employed for this traverse was the Total Station. The traverse underwent scrutiny to ensure closure, and it was found to be well within acceptable limits. Subsequent computations involved both non-rigorous techniques, specifically the Bowditch and Transit rules implemented within an Excel platform, and rigorous methodologies, specifically the employment of the Adjust software based on the least squares' principle.

The basis for comparison in this study primarily revolves around the computed standard deviation of the adjusted parameters, along with a meticulous assessment of the disparities in the individual coordinates derived from non-rigorous approaches. Significantly, the Transit method emerges as the superior choice, demonstrating a greater degree of accuracy when juxtaposed with the Bowditch method. Consequently, this research underscores the recommendation for the adoption of the Transit method over the Bowditch approach in the context of traverse adjustments.

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Introduction

In geodetic surveying, the quest for precision and accuracy is a perpetual pursuit. Since time immemorial, surveyors and geodesists have grappled with the challenge of adjusting traverses to yield the most reliable results. This enduring challenge has led to the development of various techniques, with proponents on both sides of the rigorous versus non-rigorous adjustment debate.

In this era of technological advancement and increasing demands for spatial accuracy, the choice of traverse adjustment methodology has significant implications. The two main contenders in this arena, the Bowditch and Transit methods, have been central to the discourse. While tradition and practicality have often favored these non-rigorous approaches, the relentless march of progress in surveying technology has ushered in more sophisticated techniques, notably the application of least squares adjustments (Rigorous adjustment). Despite the enduring debate surrounding these methodologies, one resounding consensus emerges from empirical evidence: rigorously adjusted traverses consistently deliver superior accuracy. The era of simply settling for acceptable levels of precision is giving way to a new standard, one characterized by the relentless pursuit of excellence.

It is within this context that our research unfolds. In the hallowed precincts of the Federal University of Technology Owerri, we embarked on a rigorous exploration to shed light on the age-old debate. Our endeavor was no less than a meticulous comparison of traverse adjustments, a head-to-head duel between traditional non-rigorous methods and the advanced, precise approach dictated by least squares principles.

A closed loop traverse, comprising a network of twelve station points, formed the focal point of our investigation. These points, strategically positioned with varying inter-distances, beckoned as the proving ground for our surveying instruments, most notably the Total Station.

But our study went beyond mere data collection and measurement. It ventured into the realms of statistical analysis and computational prowess, with Excel-driven Bowditch and Transit methods pitted against the formidable Adjust software, guided by the tenets of least squares adjustment. The goal? To unearth the nuances and subtleties that underpin these adjustment techniques, to unravel the mysteries of precision and accuracy in the world of geodetic surveying.

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In the pages that follow, we present a symphony of empirical evidence, statistical precision, and resolute conclusions. Our research is a testament to the relentless pursuit of precision in the age-old art of geodetic surveying—a pursuit that takes us beyond tradition and into the exactitude, promising a future where accuracy knows no bounds.

Materials and Methods

In preparation for our study within the confines of the Federal University of Technology Owerri (FUTO) environment, a reconnaissance survey was conducted. This critical preliminary step involved assessing various factors that would influence the accuracy and success of our project. These factors encompassed visibility between reference points, meteorological conditions, project planning, and the selection of suitable peg materials to prevent deterioration due to exposure to environmental elements over the project's extended duration. It is important to underscore that the reconnaissance phase significantly contributes to enhancing the accuracy, longevity, and stability of the survey monuments.

Our research relied on two sources of data: primary and secondary. The primary data, essential for our study, were directly collected in the field. These included critical parameters such as horizontal angles, distances, coordinates, and directions. In tandem with primary data, we also drew upon secondary data sourced from diverse outlets, including the internet, published articles, textbooks, and unpublished materials.

The instrumental apparatus employed for this project is categorized into two key domains: hardware and software requirements. Our hardware arsenal included a HP Laptop (HP 650 Notebook PC, Intel (R) Pentium 64-bit OS), a printer, a flash drive, a South NTS-362R_6 Total Station complete with its accessories, tracking rods, reflectors (two), a tribrach, cutlasses, field books, and an umbrella. On the software front, we harnessed the power of Microsoft Word, Microsoft Excel, AutoCAD and the Adjust software to facilitate data management, computation, and adjustment processes.

The foundation of our traverse network design was guided by principles outlined by R. E. Moore in his seminal work on control surveys and survey markers in 1978. Key tenets included the requirement for homogeneity, a reasonable number of redundancies, well-shaped individual figures, even station spacing, and direct measurement connections between adjacent pairs of stations. The ratio of the longest to shortest length in the network was diligently maintained below five, ensuring optimal design for accuracy. To achieve the desired precision, accurate a priori estimates of instrument accuracies were paramount, considering both random and systematic errors likely to occur in field conditions.

For marking and monumentation, we adopted a meticulous approach. Wooden pegs were selected over iron due to their resistance to rust. These pegs were driven approximately 0.5 meters below the surface, with a fraction exposed above ground to prevent disturbance. To mark reference points precisely, nails were affixed to the pegs. A comprehensive list of stations and their respective locations was compiled to guide the marking process.

In the traverse phase, we executed a closed loop traverse, commencing from control points FUTO001 and FUTO003. The Total Station was stationed at FUTO003, while a reflector was positioned vertically at FUTO001. Backsight readings were recorded initially, followed by foresight readings at the first traverse point, with measurements taken on both the left and right faces. This procedure continued until closure was achieved back at the control points. Throughout the traverse, external angles were measured, and distances were tracked using the Total Station.

Computation played a central role in our methodology. Misclosure checks were performed to assess the quality of the data. Linear misclosure was computed as the square root of the sum of departure and latitude misclosures. Angular misclosure was determined by comparing measured angles with the geometrically correct total for the polygon. Allowable Accuracy (AA) was calculated based on the number of instrument stations. Linear Accuracy was computed using differences in Northing and Easting coordinates between property beacons.

To carry out adjustment, we leveraged Microsoft Excel for non-rigorous methods (Bowditch and Transit) and subsequently exported the results to the Adjust software for rigorous adjustment via the least squares approach. This facilitated a comprehensive comparison of the adjustment

Results

Table 1 shows field data: distances and horizontal angles, as well as approximate unadjusted coordinate as Easting and Northing. The approximate unadjusted coordinates were then adjusted using the Bowditch rule and transit rule. The computed adjustments using Bowditch rule and Transit rule are presented respectively in table 2 and table 3. The known azimuth, computed azimuth, angular error of closure and corresponding angular corrections are given below.

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Known azimuth at last station	174° 29' 34''
Computed azimuth	174° 29' 34''
Angular error	000° 01' 47''
Angular correction per station	000° 00' 7.6''

	E(m)	**N(m)**
FUTO 003	503599.732	153303.132
FUTO 001	503611.982	153176.079

Known Coordinate

	E(m)	**N(m)**
FUTO 003	503599.684	153303.132

Computed unadjusted Coordinate for known control

Standard Error (Sx)	0.0010
Standard Error (Sy)	0.0010
Linear Error of Closure	0.0644 m
Total Distances	3336.675 m
Relative Error of Closure	1 / 51776.530

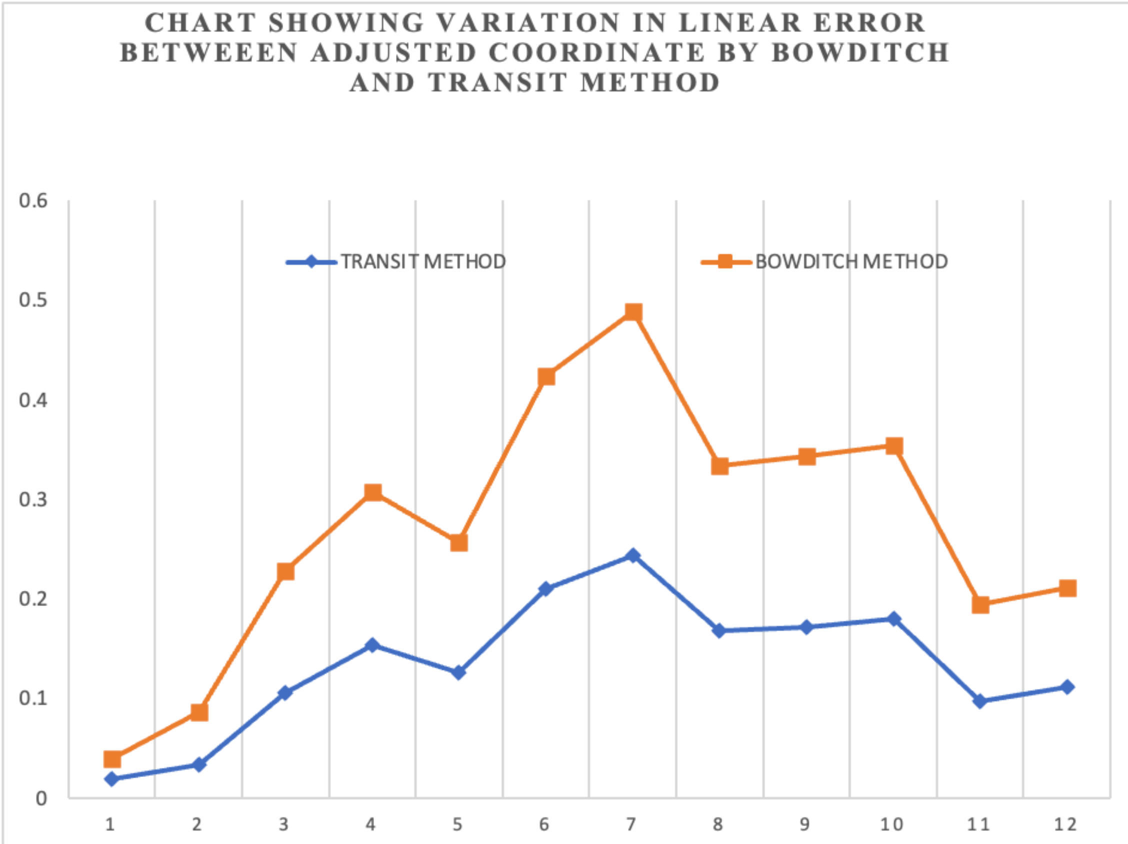

Figure 4.1. Variation in linear error between adjusted coordinates by Bowditch and Transit method.

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Tables

STN FROM	HORIZONTAL ANGLES	DISTANCE	FORWARD AZIMUTH	UNADJUSTED COORDINATE		STN TO
				EASTING	NORTHING	
F001	068 29 55	274.153	062 59 28	503856.232	153300.563	OOS1
OOS1	199 44 47	263.88	082 44 15	504117.992	153333.919	OOS2
OOS2	220 28 00	348.45	123 12 15	504409.552	153143.099	OOS3
OOS3	263 00 10	294.97	206 13 25	504279.212	152878.489	OOS4
OOS4	242 14 44	199.12	268 28 09	504080.162	152873.169	OOS5
OOS5	051 51 03	202.70	140 19 12	504209.582	152717.169	OOS6
OOS6	260 01 22	157.71	220 20 42	504107.492	152596.969	OOS7
OOS7	293 59 11	226.32	334 19 53	504009.462	152808.949	OOS8
OOS8	103 50 25	229.94	258 10 18	503784.402	152753.819	OOS9
OOS9	198 19 29	136.33	276 29 47	503648.952	152769.239	OOS10
OOS10	297 04 39	262.36	033 34 26	503794.032	152987.829	OOS11
OOS11	068 16 57	280.52	281 51 23	503467.862	153056.299	OOS12
OOS12	286 15 39	279.82	028 07 02	503599.684	153303.089	F003

Table 1. Observed values and unadjusted coordinates.

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STN	EASTING	NORHING
OOS1	503856.241	153300.601
OOS2	504118.010	153333.981
OOS3	504409.573	153143.189
OOS4	504279.314	152878.565
OOS5	504080.271	152873.205
OOS6	504209.744	152717.256
OOS7	504107.686	152597.036
OOS8	504009.591	152801.008
OOS9	503784.553	152753.820
OOS10	503649.096	152769.212
OOS11	503794.119	152987.872
OOS12	503467.934	153056.269

Table 2. Coordinates Generated by Bowditch Rule

STN	EASTING	NORTHING
OOS1	503856.242	153300.598
OOS2	504118.012	153333.961
OOS3	504409.576	153143.169
OOS4	504279.315	152878.563
OOS5	504080.273	152873.187
OOS6	504209.745	152717.246
OOS7	504107.687	152597.031
OOS8	504009.590	152801.017
OOS9	503784.554	152753.818
OOS10	503649.098	152769.201
OOS11	503794.119	152987.873
OOS12	503467.936	153056.254

Table 3. Coordinates Generated by Transit Rule

STN	UNADJ EASTING	UNADJ. NORTHING	ADJUSTED EASTING	SX	ADJUSTED NORTHING	SY
OOS1	504117.992	153333.919	503,856.234	0.0134	153,300.581	0.0263
OOS2	504409.552	153143.099	504,117.998	0.0167	153,333.930	0.0563
OOS3	504279.212	152878.489	504,409.531	0.0205	153,143.074	0.0901
OOS4	504080.162	152873.169	504,279.204	0.0462	152,878.457	0.0775
OOS5	504209.582	152717.169	504,080.155	0.0467	152,873.143	0.0617
OOS6	504107.492	152596.969	504,209.569	0.0599	152,717.132	0.0729
OOS7	504009.462	152808.949	504,107.461	0.0720	152,596.939	0.0625
OOS8	503784.402	152753.819	504,009.444	0.0526	152,800.933	0.0522
OOS9	503648.952	152769.239	503,784.382	0.0561	152,753.824	0.0316
OOS10	503794.032	152987.829	503,648.928	0.0545	152,769.260	0.0266
OOS11	503467.862	153056.299	503,794.026	0.0310	152,987.845	0.0336
OOS12	503599.684	153303.089	503,467.859	0.0253	153,056.335	0.0135

Table 4. Adjusted coordinates using least squares method

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STN	STANDARD DEVIATION	
	Distance (m)	Angular ('')
OOS1	0.0001	22.0
OOS2	0.0001	20.4
OOS3	0.0001	19.5
OOS4	0.0001	22.2
OOS5	0.0001	23.4
OOS6	0.0001	22.0
OOS7	0.0001	21.1
OOS8	0.0001	23.2
OOS9	0.0001	22.4
OOS10	0.0001	21.6
OOS11	0.0001	23.6
OOS12	0.0001	21.1

Table 5. Standard deviation of the adjusted distance and angles

STN	DIFFERENCE IN COORDINATES		DISTANCE (m)
	dE (M)	dN (M)	
OOS1	-0.007	-0.02	0.02119
OOS2	-0.012	-0.051	0.052393
OOS3	-0.042	-0.115	0.12243
OOS4	-0.11	-0.108	0.154156
OOS5	-0.116	-0.062	0.131529
OOS6	-0.175	-0.124	0.214478
OOS7	-0.225	-0.097	0.245018
OOS8	-0.147	-0.075	0.165027
OOS9	-0.171	0.004	0.171047
OOS10	-0.168	0.048	0.174723
OOS11	-0.093	-0.027	0.09684
OOS12	-0.075	0.066	0.099905

Table 6. Difference in coordinates between least squares adjusted coordinates and Bowditch rule

STN	DIFFERENCE IN COORDINATES		DISTANCE (m)
	dE(M)	dN(M)	
OOS1	-0.008	-0.017	0.01878829
OOS2	-0.014	-0.031	0.0340147
OOS3	-0.045	-0.095	0.10511898
OOS4	-0.111	-0.106	0.1534829
OOS5	-0.118	-0.044	0.12593649
OOS6	-0.176	-0.114	0.20969502
OOS7	-0.226	-0.092	0.2440082
OOS8	-0.146	-0.084	0.1684399
OOS9	-0.172	0.006	0.17210462
OOS10	-0.17	0.059	0.17994721
OOS11	-0.093	-0.028	0.09712363
OOS12	-0.077	0.081	0.11175867

Table 7. Difference in coordinates between least squares adjusted coordinates and Transit.

Discussion

With the coordinates of the least squares adjustment (Table 4) held as a standard for comparison, the corresponding coordinates from the Bowditch and Transit methods of adjustments were compared (Table 6 and 7). Difference in coordinates were obtained by subtracting the coordinates generated by each method (Bowditch or Transit). These differences (error) were converted into distances to form linear error. The linear error was used to show the error margin of the resultant coordinated gotten from each method of adjustment (Bowditch or Transit). The individual linear error was used to form a linear error chart which graphically displays the basic difference between the Bowditch method and the Transit method.

From the Graph and tabulated coordinate, it can be deduced that the Transit method of adjusting traverses produces more precise coordinates than that of the Bowditch method.

Also, by subtracting coordinates of Bowditch and Transit method from Least squares coordinates and averaging, the Bowditch method had a higher value of 0.137395, while the Transit method was 0.135035. This also indicates that the Transit method produced less errors than the Bowditch methods.

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