

Assessment of Merged Methods of Booking and Determining Reduced Levels (Rise and Fall Methods with Height of Collimation) in a Longitudinal/Profile Levelling Surveying

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***Abstract-** Basically, booking and determination of Reduced Level (RL) in levelling survey is fundamental in engineering surveying for profile levelling, cross-sectional levelling, establishing vertical controls etc. The two conformist methods—Rise and Fall Method and Height of Point of Collimation (HPC) Method—each have strengths and limitations in accuracy, speed, and error detection. This paper proposes and assessed a merged computational approach that combines both methods in a single field book format to leverage arithmetic checks of both systems, reduce blunders, and improve reliability. Field tests shows a possibility that the merged method could reduce booking errors by a significant level and still maintains accuracy of $\pm 0.008\text{mm}$. The paper outlines procedures, mathematical formulation, advantages, limitations, and practical applications.*

***Keywords:** Reduced Level, Leveling, Rise and Fall Method, Height of Collimation, Surveying*

I. INTRODUCTION

Levelling is a branch of surveying, the object of which is has to do with finding the elevation of a given point with respect to the given or assumed datum and to establish a point at a given elevation with respect to the given or assumed datum. Baričević, S. et al. (2023), also explained that levelling is the measurement of geodetic height using an optical levelling instrument and a level staff or rod having a numbered scale. Common levelling instruments include the spirit level, the dumpy level, the digital level, and the laser level.

Simbolon et al., 2017 in Olawuyi and Osisanya, 2024, pointed out that one single aspect of surveying is that it has to do with levelling operations or height determination which involves determining the vertical location of a point relative to a reference datum. This

idea is further supported by Ghilani and Wolf (2014), who stated that in surveying, levelling is primarily concerned with determining the elevations of ground points.

Trigonometric levelling, barometric levelling, and spirit levelling techniques, were mostly what Surveyors applied to determine the elevation of a point; other types of levelling operations include: simple levelling, Differential levelling, Fly levelling, longitudinal or profile levelling, cross-sectional levelling and check levelling (Basak N. N., 2014).

Levelling is an important procedure that is used in various fields such as mapping, engineering design, construction, and setting out. It is a broadly used method for determining the elevations of ground points relative to a reference datum. Adebayo, A. U. et al. (2023); is of the view that levelling encompasses measuring the vertical distance between the ground point and the reference datum to obtain what is known as the reduced level.

Ultimately, the mean sea level has been adopted as the reference surface for vertical control surveys; 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. (Olawuyi et al., 2024 in Schofield & Breach, 2007; Uren & Price, 2010).

The choice of height system is critical in many applications, especially those that require accurate determination of elevation. Reduced Level (RL) literally means the vertical distance of a point above or

below a given datum, usually Mean Sea Level. While Leveling is the procedure of determining the relative heights or elevations of points on the earth's surface. Punmia, (2018) mentioned that in surveying, reduced levels (RLs) are commonly determined using two methods:

1. Height of Instrument (HI) Method
2. Rise and Fall Method

Both methods are used in leveling operations to determine elevations of points relative to a benchmark, but they differ in procedure, accuracy checks, and applications. The procedure of levelling comprises using a levelling instrument to measure the vertical distance between the ground point and the reference datum. The levelling instrument comprises 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 aid 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. The choice of method to use largely hang on the accuracy desired, nature of the work to do and the convenience and availability of instrument to use. (Lee & Rho, 2021).

Over the eras there is nonexistence of a typical field procedure that chains both the rise and fall methods with the height of collimation methods for booking, reduced level arithmetic checks and computational adjustments. Regardless of extensive use of both the Rise and Fall Method and the Height of Collimation of Height of Instrument Method, existing surveying practice and literature treat them as mutually exclusive choices (Chandra, A. M. 2018). Uncertain gaps which this creates includes:

- (a) Inadequate Error Detection in Standard Height of Instrument Method of Height of Point of Collimation Method HPC

Schofield & Breach (2007) note that height of Instrument Method is “prone to undetected blunders” when numerous intermediate sights are involved, yet no recognized solution is prescribed beyond dealing with such issues. The HPC method's lone arithmetic

check, $\sum BS - \sum FS = \text{Last RL} - \text{First RL}$, only verifies the overall loop. It does not validate intermediate RLs. A booking error on an intermediate sight can pass the check but still produce wrong RLs for critical points. But with the rise and fall method simultaneously performed with the height of Instrument method such gaps or arithmetic error could reduce to minimum level or even completely detect such errors and avoid them (Bannister, A., Raymond, S., & Baker, R. 2019).

- (b) Nonexistence of Incorporated Field Book Design Depicted Both Columns of HPC and Rise and fall Methods

There is no available prototype that amalgamates Height of Instrument with Rise and Fall's level booking, reduced level computational adjustment flow row-by-row and arithmetic checks. It is either Rise and Fall on its own or Height of Instrument on its own which is the current standard field book setups provided from professional bodies, including the Nigerian Institution of Surveyors (2019). However, with the merged methods provided, it provided fast and easy checks and error detection, which further enhances the credibility of the final adjusted reduced level obtained.

- (c) Exercise and Theoretical with Conceptual Disconnect

Students are taught both methods as separate topics, which obscures their mathematical equivalence. The gap leaves graduate able to compute RLs by either method, but unable to cross -verify work efficiently on site. This contributes to the industry problem where booking blunders are often discovered only during office reduction, triggering costly re-surveys. However, with the proposed hybrid or merged method available it could eliminate this students training and conceptual disconnect as both methods would simultaneously be practiced on same level field book.

- (d) Deficiency of Measurable Assessment Under Field Conditions*

Most literature reviewed compared the methods theoretically but provide little data on trade-offs in real projects. There is insignificant available research quantifying errors missed when crews choose HOC

over Rise/Fall, or testing merged method of rise and fall with the HPC approaches.

Ultimately, the major objective of this research study is mainly to assess, develop and validate a merged method that integrates Rise and Fall arithmetic checks with HOC computational procedure for RL determination.

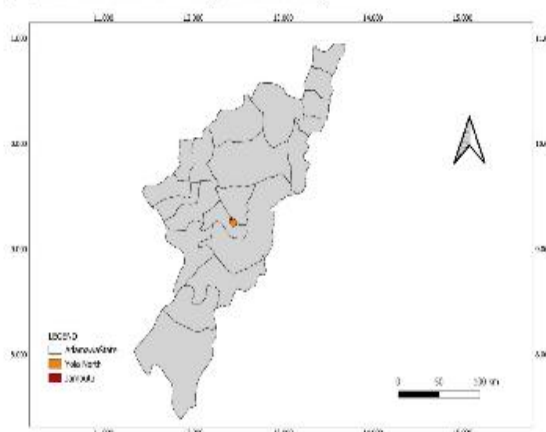
II. MATERIALS AND METHODS

3.0 Study Area:

(a) Nigeria showing Adamawa State



(b) Adamawa State showing Yola North & Jambutu



(c) ASPY School of Environmental Sciences (SES), Jambutu Campus



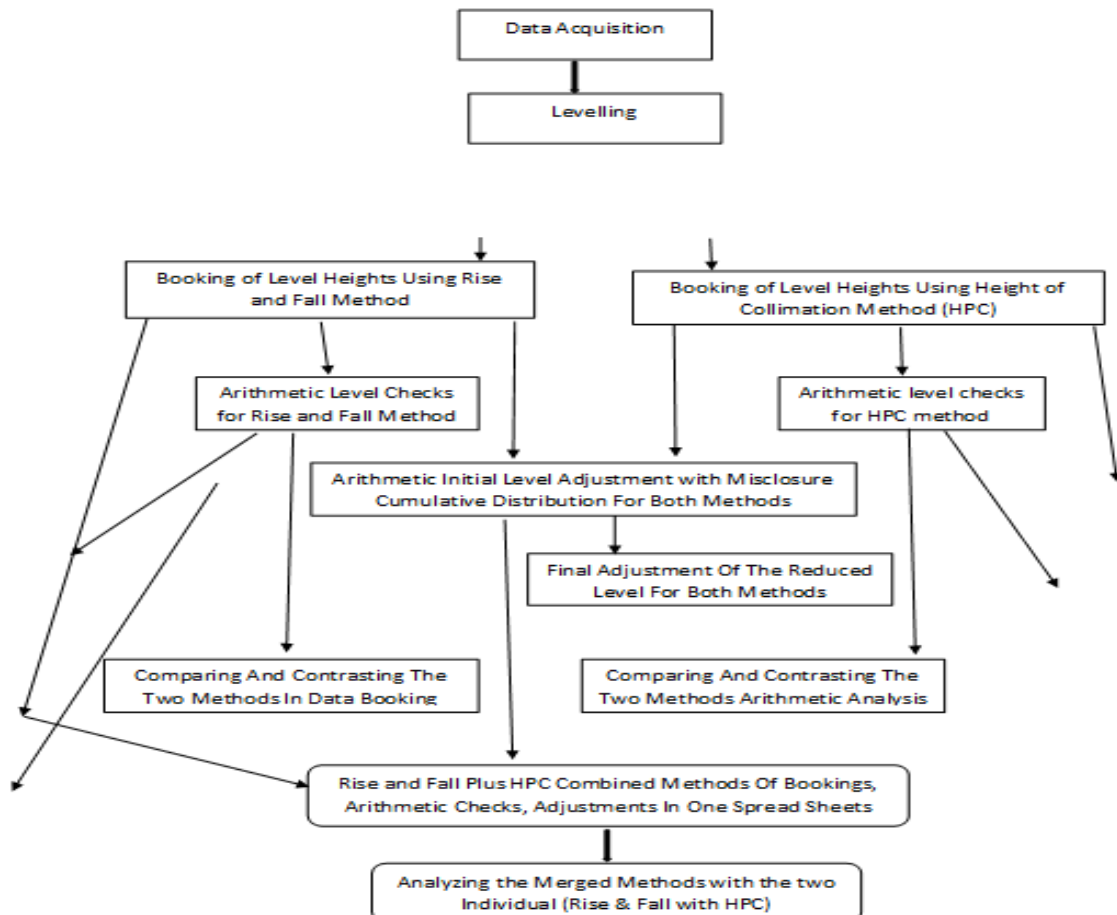
Study Area: ASPY School of Enviromental Sciences (SES) Jambutu Campus, Yola North LGA, Adamawa State.

Figure 1: Map showing the location of the study area — (a) Nigeria and Adamawa State, (b) Adamawa State showing Yola North LGA and Jambutu Ward, and (c) ASPY School of Environmental Sciences (SES), Jambutu Campus.

The research study was carried out within the State Polytechnic Yola, School of Environmental Sciences Jambutu Campus, located in Adamawa State, Nigeria. The geographical extent of the area was approximately defined by the coordinates (WGS 84): Longitude 9028ii011 N (9.466940N), Longitude 120 0115811E (12.032780E) and corresponding to UTM Zone 33N, Eastings 210,450m E to 211,180m E, and Northings 1046850m N to 1047420m N. The Campus covers about 22.5 hectares of land area with an approximate perimeter of about 2.05km². The research study area covers an estimated profile length of about 110 meters; which basically was the profile red line approximately indicated and it a length on the campus from small to the main gate of the campus. Indeed, it is worth pointing out the longitudinal length of the study area investigated provided valued data and information for

understanding the scope and scale of the research. Primarily located within the Jambutu campus of the state own prestigious Polytechnic, this particular area was designated due to its significance and suitability for the research objectives by concentrating on this portion of the Polytechnic area, the study was performed in a controlled environment, enabling efficient data gathering and analysis. The chosen area, with its defined geographical coordinates could serves as a foundation for further studies, providing valuable topography and reduced levels insights into various aspects of surveying and analysis of reduced level heights of points.

**Flowchart
Adopted
Methodology**



2. 1. Data Acquisition

This starts with a reconnaissance survey which basically was a widespread study of the entire area under consideration. Basically in a surveying, reconnaissance survey has been classified into field and office reconnaissance. Field reconnaissance involves actual visitation to the field to have an overview of the project site, taking into cognizance visibility and accessibility, the existing Temporary Bench Marks points available as well as the mode of execution (Ceylan, A., Inal, C., & Sanlioglu, I. 2013). While the Office reconnaissance largely was concerned with the gathering of necessary data that will be required during the project execution e.g. the type of equipment to be used for the research study, available Bench Marks or Temporary Bench Marks (TBMF and TBML which is from a length on the campus small gate to the main gate, with the route/profile painted red on the study area) values within or nearby the study area and any existing topographical maps available etc. and Leica Automatic Level were the main equipment used for the observation.

2.2 Equipment Used

1. Leica Automatic Level; for determination of the reduced level

2. Levelling Staff; which provides values of heights of points observed on it

2.3 Two peg test

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 levelling was carried out in using a simple method of observation. The Rise and fall method, then the height of the Instrument method and later on the merged methods of the two methods was performed of their bookings and reduced levels adjustments computations were carried out.

The backsight, intermediate sights and foresight readings from the Automatic level were computed using the height of the Instrument method to get the reduced level. The error or the misclosure from the initial reduced level obtained level was 0.008 meters and was cumulatively distributed evenly to the observed points.

Flowchart Adopted Methodology

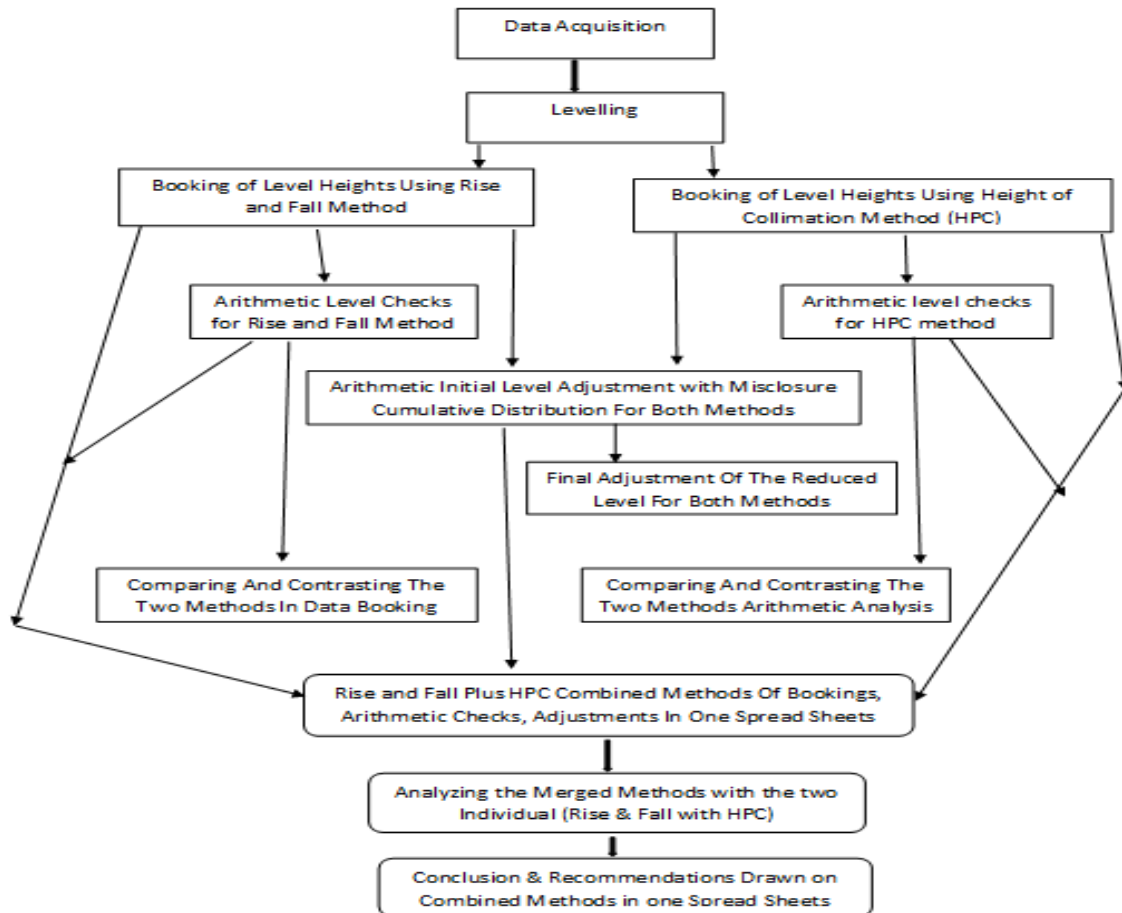


Figure 4.0: Methodology Chart

2.4 Height of Instrument Method or Height of Collimation Method

For this method, Height of Collimation Method or the Height of the Instrument (H.I.) was determined and computed for each setting of the instrument by adding Back Sight (B.S.) to elevation of Bench Mark (B.M.). Reduced level of Change Point (C.P.) was then computed by subtracting Fore Sight (F.S.) from H.I. While the next setting, H.I. was obtained by adding B.S. taken on Change Point (C.P.) to its Reduced Level (R.L.). This process continues till R.L. of the last point (Fore Sight) was obtained by subtracting staff reading from the height of the last setting of the instrument. (David C and J Clendening; 2011). Intermediates points, R.L.s of them were calculated by subtracting Intermediate Sight (I.S.) from Height of Instrument (H.I.) for that setting. Entries are made in the field book with all the initial reduced level

adjustment and the final adjusted reduced values are shown in the table below:

Height of Instrument (H.I.) = R.L. of a B.M. + B.S. reading on that B.M.

R.L. of other staff stations = Height of Instrument (H.I.) – I.S./F.S. readings

After completing above calculations, it is checked for correctness by arithmetical check.

BS	IS	FS	HPC	INITIAL RL	ADJ	REMARKS	
4.193			84.676	80.483	0	80.438	TBM 1
	4.507			80.169	0.002666667	80.172	
	4.327			80.349	0.002666667	80.352	
	3.865			80.811	0.002666667	80.814	
	3.964			80.712	0.002666667	80.715	
4.205		2.428	86.453	82.248	0.002666667	82.251	
	3.192			83.261	0.005333333	83.266	
	3.294			83.159	0.005333333	83.164	
2.676		3.232	85.897	83.221	0.005333333	83.226	
		3.783		82.114	0.008	82.122	TBM 2
11.074	23.149	9.443					

Height of Point of Collimation (HPC) Or Height Of Instrument Method

2.5 Arithmetical Check

The difference between the sum of the Back Sights (B.S.) and the sum of the Fore Sights (F.S.) should be equal to the difference between Reduced Level (R.L.) of starting Bench Mark (B.M.) and Reduced Level (R.L.) of the closing point as determined by levelling.

$$\sum B.S. - \sum F.S. = \text{Last R.L.} - \text{First R.L.}$$

Note: This check verifies only the calculation of R.L. and not the correctness of R.L. This also offers a check for Height of Instrument (H.I.) and R.L.s of Back Sight (B.S.) and Fore Sight (F.S.). The arithmetic check does not involve Intermediate Sights (I.S.)

2.6 The Rise and Fall Method

In this method, the difference of level between the two consecutive points is obtained by comparing the staff readings taken from the same setup of the instrument. This difference indicates whether next point is at Rise or Fall than the previous one. If staff reading is greater, the point is at Fall. If staff reading is smaller, the point is at Rise.

R.L. of any point is found by adding or subtracting the respective Rise or Fall values from the R.L. of the previous point. This procedure is repeated until the last point is reached.

Difference in level between the two consecutive points in Rise and Fall method is: = First staff reading - Second staff reading = $\pm$ Rise / Fall

Note: When the second reading is subtracted from the first one, the positive result means the Rise and the negative result means Fall.

R.L. of any point = R.L. of the previous point + Rise / - Fall of that point. Use positive sign for Rise and negative sign for Fall. After completing the above calculations, it is checked for correctness by arithmetical check.

Also after all the entries are made in the field book with all the initial reduced level adjustment and the final adjusted reduced values including the arithmetic checks are shown in the table below:

BS	IS	FS	RISE	FALL	INITIAL RL	ADJ.	ADJED. RL	
4.193					80.483		TBM (1) 80.483	
	4.507			-0.314	80.169	0.002666667	80.172	
	4.327		0.18		80.349	0.002666667	80.352	
	3.865		0.462		80.811	0.002666667	80.814	
	3.964			-0.099	80.712	0.002666667	80.715	

4.205		2.428	1.536		82.248	0.002666667	82.251	
	3.192		1.013		83.261	0.005333333	83.266	
	3.294			-0.102	83.159	0.005333333	83.164	
2.676		3.232	0.062		83.221	0.005333333	83.226	
		3.783		-1.107	82.114	0.008	82.122	TBM(2)
11.074	23.149	9.443	3.151	-1.622				

Rise and Fall Method of Reduced Level

2.7 Arithmetical Check

This arithmetical check also provides check only for calculations and not the result.

In this, the differences between the sum of B.S. and sum of F.S., the sum of Rise and the sum of Fall and the R.L. of Last point and R.L. of First point should be equal.

$$\sum \text{B.S.} \sim \sum \text{F.S.} = \sum \text{Rise} \sim \text{Fall} = \text{Last R.L.} \sim \text{First R.L.}$$

[That is, $\sum \text{B.S.} - \sum \text{F.S.} = \sum \text{Rise} - \sum \text{Fall} = \text{Last R.L.} - \text{First R.L.}$ or

$$\sum \text{F.S.} - \sum \text{B.S.} = \sum \text{Fall} - \sum \text{Rise} = \text{First R.L.} - \text{Last R.L.}]$$

This method provides a complete check on the Intermediate Sight (I.S.) also, since all the sights are covered in the arithmetic check.

III. MERGED RISE AND FALL WITH HPC METHODS OF REDUCED LEVELS CALCULATIONS AND ADJUSTMENTS TABLE

The levelling field work was carried out between a length sequence level of two Temporary Bench Marks. That is after all the need be reconnaissance survey and all the necessary level instrument temporary adjustment, levelling and setting the level instrument on a convenient position (INST1), the field work commenced as follows

- A back sight BS of 4.193m reading taken on the first Temporary Bench Mark (TBMF), where the foot of the levelling staff vertically held with the Dumpy Level Instrument set up at a convenient level instrument position one (INST1)

- The levelling staff was then moved to new points 1 to 4 and similar level height were taken in turns as intermediate sights points (IS) of 4.507m, 4.327m, 3.865m and 3.964m in that order.
- However, in order to reach points 6 a convenient change point labeled (INST2) as Level Instrument position 2, i.e a change point (CP) was carefully selected due to the topography of the study area. The levelling staff was then moved to point 5 (Pt. 5) and it had a reading of 2.428m serving as the fore sight reading (FS); with the level instrument still setup at INST1.
- Then the levelling staff still held on Pt.5, the level instrument was then moved to INST2 and once more another level height reading on that same Pt.5 taken; and the reading was 4.205m and served as a BS reading.
- The levelling staff was then moved to Pts. 6 and 7, where the values of 3.192m and 3.294m were recorded and a fore sight reading of 3.232m respectively on Pt 8 taken to serve as the third position of a change point CP, were recorded as intermediate sights readings and a fore sight reading.
- Once again due to the topography of the area, the level instrument was then shifted to a more convenient position (INST3), and on that same Pt. 8 staff position another reading was taken as BS and a value of 2.676m was recorded and this field work was rounded with a Fore sight reading of 3.783m taken on the Last Temporary Bench Mark (TBML).

The final or the last levelling staff reading position was a point of known reduced levels RL, since levelling works needs to start and end on known reduced level positions else its impossible to determine misclosure or detect accuracy allowable or not and to compute and make adjustments of any levelling field work

sequence. See columns 1, 2, 3 and 10. Of the table below.

For the Rise and Fall technique or method the adjusted reduced level RL was computed as follows

First Rise and Fall Computations: (all values are in meters)

Pt.1 (TBM F) = $4.193 - 4.507 = -0.314$ (Fall)
Pt.2 = $4.507 - 4.327 = 0.18$ (Rise)
Pt.3 = $4.327 - 3.865 = 0.462$ (Rise)
Pt.4 = $3.865 - 3.964 = -0.099$ (Fall)
Pt.5 = $3.964 - 2.428 = 1.536$ (Rise)
Pt.6 = $4.205 - 3.192 = 1.013$ (Rise)
Pt.7 = $3.192 - 3.294 = -0.102$ (Fall)
Pt.8 = $3.294 - 3.232 = 0.062$ (Rise)
Pt.9 (TBML) = $2.676 - 3.783 = -1.107$ (Fall) as shown columns 4 and 5

Then, the Initial Reduced Level Computations:
 $-0.314 + 80.483$ (TBMF) = 80.169 Initial RL (Pt.1)
 $0.18 + 80.169 = 80.349$ Initial RL (Pt.2)
 $0.462 + 80.349 = 80.811$ Initial RL (Pt.3)
 $-0.099 + 80.811 = 80.712$ Initial RL (Pt.4)
 $1.536 + 80.712 = 82.248$ Initial RL (Pt.5)
 $1.013 + 82.248 = 83.261$ Initial RL (Pt.6)
 $-0.102 + 83.261 = 83.159$ Initial RL (Pt.7)
 $0.062 + 83.159 = 83.221$ Initial RL (Pt.8)
 $-1.107 + 83.221 = 82.114$ Initial RL (Pt.9) TBML column 7

For columns 8 & 9 of Adjustments Computations and Adjusted Reduced Level were computations as follows:

Misclosure = Initial Last RL – Known RL
 $= 82.114 - 82.122 = -0.008$

Since we had 3 instrument positions, we then divide this misclosure by 3 and then distribute it cumulatively and then the results was added to the initial reduced level column to get the final adjusted reduced levels as shown in columns 8 and 9.

However, from the merged form of Reduced Level, HPC method involves:

First Step

First BS + TBMF = First HPC

$4.193 + 80.483 = 84.676$ 1st HPC (in similar manner the other 2 HPC values obtained)

$4.205 + 82.248 = 86.453$ 2nd HPC

$2.676 + 83.221 = 85.897$ 3rd HPC see column 6

Second Step

This involves computing for the initial reduced level shown in column 7 of the above table. The computational process is by subtracting each of the intermediate sights IS and the fore sights from each of the established change point HPC as shown below:

$84.676 - 4.507 = 80.169$ Initial RL Pt.1

$84.676 - 4.327 = 80.349$ Initial RL Pt.2

$84.676 - 3.865 = 80.811$ Initial RL Pt.3

$84.676 - 3.964 = 80.712$ Initial RL Pt.4

$84.676 - 2.428 = 82.248$ Initial RL Pt.5

$86.453 - 3.294 = 83.261$ Initial RL Pt.6

$86.453 - 3.232 = 83.159$ Initial RL Pt.7

$85.897 - 3.783 = 83.221$ Initial RL Pt.8

$85.897 - 3.783 = 82.114$ Initial RL Pt.9 (TBML)

For the final Stages, columns 8 and 9 which are arithmetic adjustments and the final adjustments of the reduced levels. Since the levelling operation starts and closed on known bench mark points, the misclosure was determined first as follows:

3.0 Differences between the Last Reduced Level and that of known Reduced level (BML)

$82.122 - 82.114 = +0.008$

Since we 3 instrument positions, the misclosure obtained was the divided by 3 and then cumulatively distributed as shown in column 8, and finally the misclosure added to the values of each reduced level point, in order to obtain the final reduced levels of each point. This displayed in column 9 of the table

BS	IS	FS	RISE	FALL	HPC	INITIAL RL	ADJUSTMENT	ADJUSTED RL	REMARKS
4.193					84.676	80.483	0	80.483	TBM (F)
	4.507			- 0.314		80.169	+0.002666667	80.172	Pt. 1
	4.327		0.18			80.349	+0.002666667	80.352	Pt. 2
	3.865		0.462			80.811	+0.002666667	80.814	Pt. 3
	3.964			- 0.099		80.712	+0.002666667	80.715	Pt. 4
4.205		2.428	1.536		86.453	82.248	+0.002666667	82.251	Pt. 5 (CP)
	3.192		1.013			83.261	+0.005333333	83.266	Pt. 6
	3.294			- 0.102		83.159	+0.005333333	83.164	Pt. 7
2.676		3.232	0.062		85.897	83.221	+0.005333333	83.226	Pt. 8 (CP)
		3.783		- 1.107		82.114	+0.008	82.122	TBM (L)
11.074	23.149	9.443	3.151	- 1.622					

Arithmetic Checks =

$$1. \sum BS - \sum FS = \sum BS - \sum FS = \sum BS - \sum FS = 1.631m$$

$$2. \sum IS + \sum FS + \sum RL \text{ EXCEPT THE FIRST} = \sum (FIRST HPC \times 5) + (SECOND HPC \times 3) + (THIRD HPC \times 1) = 768.636$$

$$3. \sum BS - \sum FS = 1.631m$$

$$4. \text{Last Reduced Level} - \text{First Reduced Level} = 1.631m$$

$$5. \sum RISE - \sum FALL = 1.631m$$

$$6. \sum IS + \sum FS + \sum RL \text{ EXCEPT THE FIRST} = 768.636$$

$$7. \sum (FIRST HPC \times 5) + (SECOND HPC \times 3) + (THIRD HPC \times 1) = 768.636$$

IV. ASSESSMENT, ANALYSIS AND COMPARISON

4.1 Comparison between Height of instrument and Rise and Fall methods of Determining Reduced Levels

Characteristics	Height of Point of Collimation HPC of Height of Instrument (HI) Method	Rise and Fall Method
Recording Style	Focuses on HI values	Focuses on rises and falls between points
Preferred Use	Quick leveling operations	High-precision leveling operations
Suitability	Suitable for simple projects and profile leveling	Suitable for precise engineering works
Error Detection	Errors may be difficult to trace	Errors are easier to detect
Accuracy Check	Limited arithmetic check	Complete arithmetic check available

Field Work	Requires fewer calculations	Requires more calculations
Speed of Calculation	Faster and simpler	Slower and more detailed
RL Computation	$RL = HI - \text{Staff Reading}$	$RL = \text{Previous RL} + \text{Rise} - \text{Fall}$
Formula	$HI = RL + BSHI$ $BSHI = RL + BS$	$\text{Rise/Fall} = \text{Previous Reading} - \text{Current Reading}$ $\text{Rise/Fall} = \text{Previous Reading} - \text{Current Reading}$
Principle	Computes the height of the instrument first, then determines RLs	Determines RLs by comparing consecutive staff readings

4.2 Analysis of Contrast in terms of Similarities on the Methods (HPC and Rise and Fall Method)

- Back Sight, Intermediate Sight and Fore Sight; both methods require these staff readings
- The two methods employed the use of Levelling Staffs and Level Instruments

iii. The two methods must satisfy their arithmetic checks after the Initial RL computations

iv. Ultimately, the two techniques determine reduced level to a benchmark(BM)

4.3 Analysis of Contrast Based on Differences Between the two Methods (HPC and Rise & Fall)

Feature	HPC Method	Rise and Fall
Accuracy and Precision	The HI Method is faster but less rigorous in detecting computational errors.	The Rise & Fall Method is generally more reliable because each observation is checked individually, making mistakes easier to identify
Steps in Computations	$HI = RL + BSHI$ $RL = HI - \text{Staff Reading}$ $RL = HI - \text{Staff Reading}$	$\text{Rise} = \text{Previous Reading} - \text{Current Reading}$ $\text{Rise} = \text{Previous Reading} - \text{Current Reading}$ $\text{Fall} = \text{Current Reading} - \text{Previous Reading}$ $\text{Fall} = \text{Current Reading} - \text{Previous Reading}$ RLs are then computed incrementally.
Checks Arithmetically	$\Sigma BS - \Sigma FS = \text{Last RL} - \text{First RL}$ $\Sigma BS - \Sigma FS = \text{Last RL} - \text{First RL}$	$\Sigma \text{Rise} - \Sigma \text{Fall} = \text{Last RL} - \text{First RL}$ $\Sigma \text{Rise} - \Sigma \text{Fall} = \text{Last RL} - \text{First RL}$ The Rise & Fall Method provides a more comprehensive verification because every change in level is accounted for.
Employed /Use	Preliminary surveys Route leveling Construction works requiring quick results	Precise engineering surveys Control leveling High-accuracy projects

4.4 Merits of the Merged Methods

Faster computational procedures with height of Instrument method

Better arithmetic error checking analysis and assessments provides the rise and fall methods

In most engineering projects and surveying field work materials both methods are widely employed. From the above table it's been assets that the Height of Instrument Method is preferred where speed and simplicity are required, while the Rise & Fall Method is preferred where accuracy and error checking are critical. In practice, surveyors may combine both methods in one level book to obtain rapid computations alongside reliable arithmetic checks.

4.5 Findings:

The two methods did provide identical Initial RL and final adjusted RL values when level bookings are correctly booked in their field books, computed and adjusted. Though the Height of Instrument method appears to be simple and faster, but the rise and fall method gives stronger internal error detection and furthermore, the rise and fall intermediate computations had a few observed discrepancies which indeed points out its sensitivity to human error. The study largely investigated two conventional levelling bookings, determination of RL and final adjusted reduced level; this the rise and fall method with the HPC method. Both method were applied on same profile length of about 110meters; which starts and ends a temporary Bench Mark (TBMF and TBML). Basically, the research study involves mainly collection of field data that includes BS, IS, FS, with HI, then computations and adjustment of initial RL and Final RL using both method individually and then merging the two together on a single work field book. Followed by verification of results using arithmetic checks plus assessing and contrasting these based on arithmetic checks and computational efficiency of the 3 methods.

Based on the findings of this study, the following conclusions were made:

Accuracy of Results: Both the Rise and Fall method and the Height of Instrument method produce the same final Reduced Levels when properly applied. Therefore, in terms of final RL accuracy, both methods are equally reliable. **Error Detection:** The Rise and Fall method is more effective in detecting computational and booking errors due to its complete arithmetic check system. This makes it more suitable for precision engineering works. **Computational Efficiency:** The Height of Instrument method is more

efficient and faster for field and office computations, especially in projects involving many intermediate points

Practical Application:

The choice of method depends on the nature of the project. Precision-critical projects favor the Rise and Fall method, while time-sensitive field operations favor the H.I. method. Both methods remain essential in surveying practice and complement each other in ensuring accurate levelling results. Hence with the enormous quality in levelling operation provided by these two methods, when merged together produced a far more hybrid method that at once provides a far more reliable reduced level results in terms arithmetic checks reliability as it combines all the two methods of checks together, and more importantly displaying one more verified final RL outcome from two procedural approach.

Based on the findings of this study, the following recommendations are made:

1. Use rise and fall method for precision work; that is where projects where high accuracy and error detection are critical, such as engineering design, control surveys, and research applications and preferably adopt the use of height of instrument method for field efficiency: that is where such as preliminary surveys and construction setting-out, and the merged method available, both qualities of precision and efficiency are encompassed in it, making the levelling operations for more solid in terms of less human error.
2. Instrument regular calibration, which of course will involve the adoption of more modern Digital Tools as they are more or less error free, which will lead to more training of Surveyors

This study reinforces the understanding that:

- The differences which mainly lies in computational approach, efficiency, and error detection capability of the two methods (Rise and Fall with HPC) has been captured and merged in one single field book; which indeed has improved error detection capability thereby improving reliability and efficiency of the final adjusted RL obtained. Hence, merged method proper application of either method ensures reliable

engineering results. This hybrid method also will enhance students learning both methods on the field and applications in a short period of time

- Levelling remains a fundamental operation in surveying and civil engineering. The Rise and Fall method and the Height of Instrument method are both essential tools that, when properly applied, ensure accurate and reliable determination of Reduced Levels. Their combined use enhances both precision and efficiency in engineering practice.

Future research can focus on: application of GNSS-based height determination versus optical levelling, or on the Use of automation and AI in surveying computations or further still on the development of software tools for automatic Rise and Fall computation or even on the analysis of error propagation in large-scale levelling networks

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