

**A PROJECT REPORT**

**ON**

**COMPARATIVE EVALUATION OF ACCURACY AND  
RELIABILITY OF DIGITAL LEVELLING AND TOTAL  
STATION EQUIPMENT TO DETERMINE THE HEIGHT  
MEASUREMENT**

**BY**

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## **CHAPTER TWO**

### **2.0 BASIC CONCEPT AND LITERATURE REVIEW**

#### **2.1 Basic Concepts**

Height, as a fundamental concept in surveying, refers to the vertical distance of a point relative to a defined reference surface, such as the mean sea level, the geoid, or a local datum (Torge & Müller, 2012). In the context of evaluating digital levelling and total station equipment at Kwara State Polytechnic, height is a critical parameter, as both tools are designed to measure it—albeit through different methods. Understanding height’s role is essential for assessing how accurately these instruments capture elevation data needed for campus planning and infrastructure development.

In surveying, height is typically categorized into orthometric height, which is measured along the plumb line relative to the geoid, and ellipsoidal height, which is referenced to a mathematical ellipsoid approximating the Earth’s shape (Vaníček & Krakiwsky, 1986). Digital levelling excels at determining orthometric heights by directly measuring height differences, making it a go-to tool for precise levelling tasks. At Kwara State Polytechnic, where elevation data informs construction, this distinction helps evaluate whether digital levelling meets geodetic standards.

Total stations, on the other hand, measure height indirectly by combining distance and angle data, often yielding ellipsoidal heights when paired with GPS or adjusted to orthometric heights through additional computations (Anderson & Mikhail, 1998). This versatility makes total stations valuable for three-dimensional surveys, but their accuracy in height measurement depends on factors like trigonometric calculations and instrument setup, comparing this to digital levelling’s direct approach offers a practical angle for the this project.

Historically, the concept of height has been central to surveying since ancient times, with tools like the Egyptian merkhet and Greek dioptra used to establish elevations

for monumental constructions (Bomford, 1980). Modern surveying builds on this legacy, refining height measurement through instruments like digital levels and total stations. For Kwara State Polytechnic, this evolution underscores the importance of testing contemporary tools against the timeless need for reliable height data.

Height measurement is heavily influenced by the reference datum chosen, as inconsistencies between local and global datums can skew results (Schofield & Breach, 2007). In Nigeria, where national geodetic networks may not fully align with international standards, tools like digital levelling and total stations must be evaluated for their ability to adapt to local height systems. This is particularly relevant for the polytechnic, where campus-specific datums might be in use.

Environmental conditions also affect height determination, as atmospheric refraction can bend light paths, impacting optical and electronic measurements (Uren & Price, 2010). In Ilorin's tropical climate, with its heat and humidity, both digital levelling and total stations face challenges that could alter their height accuracy. Understanding these effects is key to assessing the tools' reliability in the polytechnic's setting.

The precision of height data is crucial for applications like flood risk assessment, road grading, and building foundations, all of which are pertinent to Kwara State Polytechnic's infrastructure needs (Featherstone & Kuhn, 2006). Digital levelling's strength lies in its ability to provide fine-scale height differences, while total stations offer broader spatial context. Comparing their performance in delivering usable height data ties directly to practical outcomes for the institution.

Height also intersects with geodetic surveying, where it is adjusted within control networks to ensure consistency across large areas (Ghilani & Wolf, 2014). For the polytechnic study, this means testing whether digital levelling and total stations can produce height measurements that integrate seamlessly with geodetic frameworks, a factor influencing their reliability for academic and professional use.

Ultimately, height as a basic concept bridges theory and practice, serving as a measurable benchmark for technological performance (Bannister et al., 1998). For Kwara State Polytechnic, exploring height through the lens of digital levelling and total station equipment offers insights into their accuracy and reliability, supporting both campus development and the broader surveying discipline.

### **2.1.1 Types of height**

In surveying, height is a pivotal concept defined relative to various reference surfaces, and understanding its types is crucial when comparing digital levelling and total station equipment at Kwara State Polytechnic. The primary height types—orthometric, ellipsoidal, dynamic, and geoidal, each offer unique perspectives on elevation, influencing how these tools are evaluated for accuracy and reliability (Torge & Müller, 2012). This framework is essential for assessing their performance in delivering height data for the polytechnic's academic and infrastructural needs.

**1. Orthometric Height:** This measures the vertical distance from a point to the geoid along the plumb line, accounting for gravitational variations (Vaníček & Krakiwsky, 1986). Digital levelling directly determines orthometric height by measuring precise height differences and referencing them to a geoid-based datum. At Kwara State Polytechnic, this makes digital levelling ideal for establishing accurate elevations for construction benchmarks and topographic profiles.

**2. Ellipsoidal Height:** Defined as the distance from a point to a reference ellipsoid, ellipsoidal height is a geometric measure commonly derived from satellite systems like GPS (Hofmann-Wellenhof et al., 2008). Total stations calculate ellipsoidal heights through trigonometric levelling, using slope distances and angles, often requiring GPS integration for precision. For the polytechnic, this capability supports large-scale mapping and coordinate-based projects.

**3. Dynamic Height:** This adjusts orthometric height for gravity differences, ensuring consistency in applications like water flow analysis (Bomford, 1980). Neither digital

levelling nor total stations directly measure dynamic height; their outputs (orthometric or ellipsoidal) need post-processing with gravity data to compute it. While less common at Kwara State Polytechnic, dynamic height could apply to specialized engineering studies.

**4. Geoidal Height:** Geoidal height, or geoid undulation, is the separation between the geoid and the reference ellipsoid at a given point, reflecting the Earth's irregular gravitational field (Featherstone & Kuhn, 2006). It isn't directly measured by digital levelling or total stations but is derived by combining their outputs—orthometric height from digital levelling and ellipsoidal height from total stations—with geodetic models. At the polytechnic, understanding geoidal height aids in reconciling these measurements for geodetic accuracy.

## **2.2 Surveying Instruments**

### **2.2.1 Level Instrument**

Level instruments have long been a cornerstone of surveying techniques, primarily used to determine height differences between points on the Earth's surface, making them indispensable for establishing elevations in projects like those at Kwara State Polytechnic (Schofield & Breach, 2007). These instruments operate on the principle of creating a horizontal line of sight, allowing surveyors to measure vertical distances relative to a reference datum. In the context of comparing digital levelling and total station equipment, understanding the level instrument's role provides a baseline for assessing modern advancements in height determination.

The traditional optical level, one of the earliest forms of level instruments, consists of a telescope with crosshairs mounted on a tripod, paired with a levelling rod to read height differences (Uren & Price, 2010). Surveyors use it by setting up the instrument between two points, ensuring it is levelled with a built-in spirit bubble, and then recording rod readings to calculate elevation changes. This technique, known as differential levelling,

remains a fundamental skill taught at institutions, forming the basis for more advanced methods.

Digital levelling, a modern evolution of the level instrument, enhances this technique by incorporating electronic sensors and barcode rods, automating the reading process (Anderson & Mikhail, 1998). Unlike optical levels, digital levels display measurements directly, reducing human error and speeding up data collection. For the polytechnic, this advancement makes digital levelling a key focus of study, as its precision in determining orthometric heights supports detailed topographic surveys and infrastructure planning.

The technique of levelling with these instruments involves a systematic process: setting up the level, taking backsight readings to a known elevation, and foresight readings to the point of interest, then computing the height difference (Kavanagh & Mastin, 2013). This method, whether manual or digital, ensures a closed loop of measurements to check for errors, a practice critical for reliability in applications at Kwara State Polytechnic, such as grading roads or designing building foundations.

Level instruments excel in establishing orthometric heights, which measure vertical distance from the geoid along the plumb line, aligning with geodetic surveying principles (Vaníček & Krakiwsky, 1986). Digital levelling, in particular, ties directly into this by providing high-accuracy data that can be referenced to local or national datums. For the polytechnic's study, this capability positions the level instrument as a benchmark for evaluating total stations, which use a different approach to height determination.

Environmental factors, such as atmospheric refraction and temperature gradients, can affect level instrument accuracy by bending the line of sight (Ghilani & Wolf, 2014). Digital levels mitigate some of these issues with automated corrections, but in Ilorin's tropical climate, both optical and digital levelling face challenges that the study can assess. This makes the technique's reliability a key point of comparison with total stations, which rely on trigonometric calculations less sensitive to refraction.

Historically, levelling with instruments like the dumpy level or optical level was labor-intensive, requiring skilled operators to achieve precision (Bomford, 1980). The shift to digital levelling reflects technological progress, reducing training time and enhancing efficiency—advantages that Kwara State Polytechnic can leverage for both educational and practical purposes. This historical perspective highlights why evaluating digital levelling's accuracy against total stations is relevant to modern surveying education.

The versatility of level instruments extends to their use in establishing control networks, where a series of benchmarks forms a reference for larger surveys (Featherstone & Kuhn, 2006). Digital levelling's ability to produce consistent height differences makes it ideal for this task at the polytechnic, supporting campus-wide elevation frameworks. In contrast, total stations offer a broader spatial approach, suggesting a complementary rather than competitive role in such networks.

In practical applications, levelling with these instruments underpins tasks like flood risk assessment and site preparation, critical for infrastructure development (Torge & Müller, 2012). Digital levelling's precision ensures reliable data for these purposes, while its comparison with total stations in the study can reveal trade-offs between speed, accuracy, and cost—factors influencing equipment choice in resource-limited settings like Nigeria.

### **2.2.2 Total Station**

The total station is a highly advanced surveying technique that integrates electronic distance measurement (EDM), angular measurement, and data processing into a single instrument, revolutionizing modern surveying practices (Anderson & Mikhail, 1998). Widely used for determining both horizontal and vertical positions, it is a key tool in the comparative evaluation of accuracy and reliability at Kwara State Polytechnic. Its ability to provide comprehensive spatial data makes it a versatile technique for mapping, construction, and educational purposes in surveying.

A total station operates by combining a theodolite's angle-measuring capabilities with an EDM to measure distances, allowing surveyors to calculate coordinates and heights trigonometrically (Schofield & Breach, 2007). The instrument emits a laser or infrared beam to a reflector, records the return time, and computes the slope distance, which, paired with vertical and horizontal angles, yields precise 3D positions. At Kwara State Polytechnic, this technique supports tasks like campus layout and topographic surveys, offering a contrast to the elevation-focused digital levelling.

The technique of using a total station involves setting up the instrument over a known point, sighting targets (prisms or reflectorless surfaces), and recording measurements, often stored digitally for real-time analysis (Uren & Price, 2010). This process, known as traversing or resection, establishes control points across a site, making it efficient for large areas. For the polytechnic study, this efficiency is a critical factor in assessing total stations against the more labor-intensive levelling methods.

Total stations determine ellipsoidal heights primarily, derived from their coordinate system, though orthometric heights can be approximated with datum adjustments or geoid models (Hofmann-Wellenhof et al., 2008). This dual capability distinguishes them from level instruments, offering flexibility for geodetic and engineering applications at Kwara State Polytechnic. The study can thus evaluate how well these height outputs align with practical needs like infrastructure design.

Historically, the total station emerged in the late 20th century as electronic technology advanced, replacing separate theodolites and EDM devices with an integrated solution (Bomford, 1980). This evolution reflects a shift toward automation and precision, reducing fieldwork time and operator effort—advantages that Kwara State Polytechnic can leverage for both training and project execution. Its modern relevance makes it a compelling subject for accuracy comparisons with digital levelling.

Environmental conditions, such as atmospheric interference or terrain obstacles, can affect total station measurements, though reflectorless models mitigate some challenges



(Ghilani & Wolf, 2014). In Ilorin's tropical climate, factors like heat haze or vegetation may test the technique's reliability, providing a real-world context for the polytechnic study. This contrasts with levelling's sensitivity to refraction, highlighting different strengths and weaknesses.

The total station technique excels in establishing three-dimensional control networks, integrating horizontal and vertical data into a unified framework (Featherstone & Kuhn, 2006). At Kwara State Polytechnic, this capability supports comprehensive campus mapping and ties into geodetic systems when paired with GPS, offering a broader scope than levelling's vertical focus. The study can assess how this integration enhances overall survey accuracy.

Practically, total stations are used for staking out construction sites, monitoring structural deformations, and creating detailed maps—applications directly relevant to the polytechnic's infrastructure goals (Kavanagh & Mastin, 2013). Their multifunctionality, however, comes with higher costs and training demands compared to digital levelling, a trade-off the study can explore in terms of reliability and resource efficiency.

In educational settings, the total station technique teaches students advanced surveying skills, from data collection to software integration (Torge & Müller, 2012). Its complexity offers a rich learning opportunity, preparing graduates for industry demands, while the study's comparison with digital levelling can inform curriculum development by highlighting practical performance differences.

### **2.3 Literature Review on comparison of Total Station and Levelling Instrument Techniques in Height determination**

Surveying plays a fundamental role in geospatial science, civil engineering, and construction by providing precise measurements for infrastructure development. Height determination is a critical aspect of surveying, influencing topographic mapping, engineering projects, and geodetic applications (Ghilani & Wolf, 2017). Various

surveying techniques, including digital leveling, total station, and Global Navigation Satellite System (GNSS), are commonly employed for height measurement, each offering different levels of accuracy, efficiency, and reliability.

Digital levelling is a widely used method for height determination due to its high precision. It employs a digital level and barcode staff to minimize human errors and enhance measurement accuracy (Uren & Price, 2019). Digital leveling is particularly useful for projects requiring precise vertical control, such as road construction, dam engineering, and bridge foundations (Bannister et al., 2020). However, its efficiency is limited by fieldwork duration and operational constraints in rough terrains.

Total station surveying integrates electronic distance measurement (EDM) with angular observations to determine height differences efficiently. It offers rapid data collection, making it suitable for large-scale surveys (Kavanagh & Glennon, 2020). Although total stations provide relatively high accuracy in both horizontal and vertical positioning, factors such as atmospheric conditions, instrument calibration, and operator skill can influence measurement reliability (Abidin, 2021).

Comparative studies have shown that digital leveling remains the most accurate technique for height determination, particularly for short-range applications (Al-Kasasbeh et al., 2018). However, total station surveys offer a balance between accuracy and efficiency, making them suitable for engineering surveys where speed is essential (Darmawan et al., 2019). In infrastructure projects, the choice of surveying technique depends on factors such as required accuracy, project scale, and environmental conditions. For example, construction projects requiring sub-millimeter accuracy often rely on digital leveling, whereas topographic mapping and land surveys benefit from the versatility of total stations (Bello et al., 2023). Therefore, surveyors must carefully evaluate the trade-offs between precision, cost, and operational efficiency (Adeoye et al., 2022).

The increasing use of automation and artificial intelligence in surveying is further improving height determination accuracy. Modern total stations and digital levels feature automated data processing, error correction algorithms, and real-time data integration with GIS platforms (Saleh et al., 2021). These advancements contribute to better decision-making in engineering and geospatial applications.

Recent studies have also explored the impact of environmental conditions on the accuracy of surveying techniques. For instance, temperature fluctuations and atmospheric refraction can affect EDM measurements in total stations, leading to minor deviations in height calculations (Mahmood et al., 2022).

The role of human expertise in surveying remains crucial, despite technological advancements. Proper instrument calibration, error mitigation strategies, and data validation are necessary to ensure accurate height determination results (Kumar et al., 2023). Training and continuous professional development help surveyors optimize instrument use and apply best practices for error minimization in diverse field conditions (Nguyen et al., 2023).

In conclusion, height determination remains a critical aspect of surveying, with different techniques offering varying degrees of accuracy and efficiency. Digital levelling provides the highest precision, total stations offer a balance between speed and accuracy. Additionally, environmental conditions, cost considerations, and human expertise play vital roles in ensuring the accuracy and reliability of height measurements. A comparative evaluation of these methods helps surveyors select the most suitable technique for their specific needs, ensuring optimal results in geospatial and engineering projects (Bannister et al., 2020).

Research comparing the two instruments also indicates that total stations are better suited for topographic surveys where both height and horizontal positioning are needed simultaneously. Schofield (2001) explains that total stations allow surveyors to capture

three-dimensional spatial data in a single setup, whereas levelling instruments require separate processes for horizontal and vertical measurements. This makes total stations more practical for large-scale mapping projects.

Another major factor scholars consider is the ease of data integration with modern surveying technologies. Hofmann-Wellenhof et al. (2008) note that total stations can be integrated with Geographic Information Systems (GIS) and Global Navigation Satellite System (GNSS) data, allowing for seamless geospatial analysis. Levelling instruments, while accurate, are less adaptable to such integrations unless used in conjunction with GNSS receivers.

Comparative studies also reveal differences in the application of these instruments in different terrains. Researchers such as Uren & Price (2010) argue that levelling instruments are best suited for flat or gently sloping terrain, where accurate benchmark elevations can be established. Total stations, on the other hand, perform better in rugged and mountainous areas, where direct levelling may be difficult or impractical.

In terms of cost analysis, various scholars have pointed out that levelling instruments are generally more affordable than total stations. Kavanagh & Bird (2009) mention that traditional levelling instruments have a lower initial cost, making them a cost-effective solution for small projects. However, the time-consuming nature of levelling surveys may offset this cost advantage in large-scale projects, where total stations provide a quicker alternative.

A study by Ghilani & Wolf (2017) compared the reliability of height measurements from both instruments and found that while levelling instruments consistently produced highly accurate results, total stations exhibited minor variations due to EDM-related errors. However, advancements in total station technology, such as improved angular encoders and compensators, have significantly enhanced their accuracy in height determination.

The effect of atmospheric conditions on measurement accuracy has been widely studied. Hofmann-Wellenhof et al. (2008) explain that total stations require careful consideration

of temperature, pressure, and humidity adjustments to minimize EDM errors. Levelling instruments, being optically based, are less sensitive to these factors, making them more reliable in extreme weather conditions.

Scholars also examine the role of error correction techniques in height determination. Uren & Price (2010) highlight that both instruments require regular calibration and error checks to ensure accuracy. Total stations need periodic adjustments to their EDM units and angular measurement systems, while levelling instruments must be checked for collimation errors and bubble alignment.

The use of total stations for deformation monitoring has been extensively researched. Ghilani (2017) states that while levelling instruments are the preferred choice for precise settlement studies, total stations offer the advantage of monitoring both vertical and horizontal displacements simultaneously. This makes total stations more versatile in projects such as bridge movement analysis and landslide monitoring.