

CHAPTER TWO

2.0 INRODUCTION AND LITERATURE REVIEW

2.1 Introduction

2.1.1 Surveying and Height Measurement

Surveying is a fundamental discipline in geospatial science and engineering, involving the measurement and representation of features on the Earth's surface. One of the most critical aspects of surveying is height measurement, which is essential for construction, topographic mapping, and infrastructure development. The accurate determination of height, or elevation, is necessary for flood risk assessment, land use planning, and engineering projects requiring precise leveling. Geospatial techniques have significantly improved the accuracy and efficiency of height measurement through the use of advanced instruments and technologies (Ghilani& Wolf, 2017).

Height measurement in surveying can be achieved through different methods, including spirit leveling, trigonometric leveling, barometric leveling, Total station and GNSS-based height determination. Traditional techniques such as spirit leveling involve measuring the height difference between two points using a level instrument and a graduated leveling staff. This method is highly accurate and is commonly used for establishing vertical control networks, but it is time-consuming and labor-intensive (Uren & Price, 2010).

Trigonometric leveling is another method used for height measurement, where angles and distances are observed using a total station or theodolite to calculate elevation differences. This method is particularly useful for measuring heights over long distances and rough terrain. However, its accuracy depends on factors such as

instrument calibration, atmospheric refraction, and observer experience (Kavanagh & Glennon, 2020).

Digital leveling is an advancement of traditional spirit leveling, where electronic digital levels use bar-coded leveling staffs to automatically record height differences. This method minimizes human error and provides highly accurate elevation data, making it useful for geodetic control surveys and engineering applications (Ghilani, 2021). Compared to conventional leveling, digital leveling is faster and reduces observer fatigue, enhancing productivity in large-scale projects.

Height measurements play a crucial role in civil engineering, particularly in road design, dam construction, and building foundation surveys. Errors in elevation determination can lead to improper drainage systems, unstable structures, and inaccurate volume calculations for earthworks. Hence, surveyors must carefully choose the best height measurement techniques depending on project requirements and environmental conditions (Al-Omari et al., 2019).

2.2 Digital Levelling and its Applications

Digital leveling is a modern surveying technique used to determine height differences with high precision. It utilizes an electronic digital level and a bar-coded leveling staff to automatically capture and record elevation data. Unlike conventional spirit leveling, digital leveling eliminates manual reading errors, enhances measurement speed, and improves data accuracy (Ghilani, 2021). This technology is widely used in geodetic surveys, construction projects, and infrastructure development where precise height determination is crucial.

The principle of digital leveling is based on electronic image processing. When the digital level is aimed at a bar-coded leveling staff, the instrument automatically detects and interprets the code using optical sensors. The encoded height readings are processed digitally, minimizing human error and improving measurement reliability (Kavanagh & Glennon, 2020). This automation makes digital leveling particularly useful in large-scale projects where extensive elevation data is required.

One of the key advantages of digital leveling is its ability to enhance survey accuracy. Traditional optical leveling methods are prone to human-induced errors such as incorrect readings and parallax effects. Digital levels, however, provide precise readings with minimal observer influence. Research shows that digital levels can achieve accuracy levels of ± 0.2 mm/km for first-order leveling, making them suitable for high-precision applications (Hofmann-Wellenhof et al., 2008).

Digital leveling is widely used in geodetic surveys to establish vertical control networks. These networks form the basis for various geospatial applications, including mapping, infrastructure development, and environmental monitoring. Engineers also use digital leveling to determine the precise height of benchmarks, ensuring consistency in elevation measurements across different projects (Uren & Price, 2010).

Digital leveling plays a critical role in railway and highway construction, where precise gradient control is necessary. Rail track leveling requires extreme accuracy to prevent structural deformation and ensure passenger safety. Similarly, highway engineers use digital levels to establish longitudinal and cross-sectional

profiles, optimizing road slope designs and minimizing surface irregularities (Luhmann et al., 2014).

In hydrology and environmental studies, digital leveling is used to monitor changes in water levels, land subsidence, and coastal erosion. Precise elevation measurements help in assessing flood risk zones, designing drainage systems, and studying the impact of climate change on coastal regions. By integrating digital leveling with remote sensing techniques, researchers can track environmental changes over time with high precision (Shan & Toth, 2018).

Industries such as mining and tunnel construction require highly accurate elevation measurements to ensure safety and structural stability. Digital leveling is used to monitor subsidence in underground mines and to establish reference points in tunnel alignment. Surveyors rely on digital levels to detect vertical deformations in underground structures, preventing potential hazards and ensuring proper engineering adjustments (Ghilani & Wolf, 2017).

Digital leveling is a vital surveying tool that enhances accuracy, efficiency, and reliability in height determination. Its applications span across geodetic control, construction, transportation, hydrology, and industrial surveys. By integrating with advanced geospatial technologies, digital leveling continues to play a crucial role in modern engineering and geospatial analysis. As surveying technology evolves, the adoption of digital leveling will further improve precision in elevation measurement and support the development of sustainable infrastructure.

2.3 Total Station and its Applications

Total stations are widely used in topographic surveys to generate accurate Digital Elevation Models (DEMs) and contour maps. By measuring multiple points within a terrain, surveyors create three-dimensional models that represent land features. In cadastral surveying, total stations are used to define land boundaries for legal documentation and property management (Hofmann-Wellenhof et al., 2008).

In civil engineering and construction, total stations play a crucial role in setting out building foundations, roads, and bridges. Engineers use them to establish precise control points, ensuring structures are aligned as per design specifications. Construction surveyors also rely on total stations to monitor vertical and horizontal deformations in high-rise buildings and infrastructure projects (Shan & Toth, 2018).

Total stations are essential in highway design and construction, where precise curvature, gradient, and elevation profiles must be maintained. Engineers use them to measure and stake out road alignments, cross-sections, and embankments, ensuring smooth and safe roadways. The integration of total station data with GIS software enhances transportation planning and infrastructure management (Luhmann et al., 2014).

In mining and underground tunnel construction, total stations are used to establish accurate underground reference points, ensuring tunnels are aligned correctly. They help monitor subsidence and rock movement, preventing potential hazards. The reflectorless feature in modern total stations allows measurements in hazardous or inaccessible zones, increasing survey safety (Ghilani & Wolf, 2017).

Surveyors use total stations to monitor the stability of bridges, dams, and retaining walls by tracking structural movements over time. High-precision total stations detect millimeter-level displacements, helping engineers assess whether corrective actions are needed. These instruments are crucial for long-term infrastructure safety assessments (Ibraheem et al., 2021).

2.4 Accuracy and Precision in Surveying

Accuracy and precision are essential in surveying, determining the reliability of measurements and the quality of spatial data. Accuracy refers to the closeness of a measurement to its true value, while precision relates to the consistency of repeated measurements. A surveyor may achieve high precision but low accuracy if systematic errors are present. Understanding these concepts is critical for minimizing errors and improving data reliability in engineering, construction, and geospatial applications (Ghilani & Wolf, 2017). The goal is to reduce uncertainties and ensure that surveying data accurately represents real-world conditions.

Several factors influence accuracy and precision in surveying, including instrumental errors, environmental conditions, and observer skills. Instrumental errors arise from equipment imperfections such as optical misalignments in total stations or calibration errors in GNSS receivers. Environmental conditions like temperature changes and atmospheric refraction can distort measurements. Surveyors' skill levels also impact precision, as improper handling of equipment can lead to inconsistencies (Uren & Price, 2010). By identifying and mitigating these factors, surveyors can enhance the overall quality of their data.

2.5 Surveying Techniques

2.5.1 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 (Vaniček & 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 wye 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 leveling'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 leveling'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.

2.5.2 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 leveling'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 Review on Comparison of Total Station and Leveling Instrument InHeight 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 levelling, 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 levelling 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).

Advancements in surveying technology have led to hybrid approaches combining digital leveling, total station, and GNSS measurements. Integrated techniques enhance accuracy and efficiency by leveraging the strengths of each method (Ezeokonkwo et al., 2021). For instance, combining GNSS for initial positioning and total stations for detailed height measurements improves overall survey accuracy while reducing fieldwork duration (Akanbi 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).

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.

