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SURVEYING AND GEOINFORMATICS PROFESSION AND CONSTRUCTION INDUSTRY: A CASE STUDY OF BAZE UNIVERSITY TEACHING HOSPITAL (BUTH) ABUJA, NIGERIA

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ABSTRACT

The aim of this study is to examine the place of Surveying and Geoinformatics in the construction industry with BAZE University Teaching Hospital (BUTH) as a case study. The study adopts a practice-based case study approach drawing on Engineering Survey data, construction records, and site operations at BUTH. The major First Order Survey instruments used for the execution of the project are Differential Global Positioning System (DGPS), Leica 307 Total Station and Automatic Level. The angular misclosure recorded for the entire survey is 00^{o} 01' 30" while the linear accuracy for the survey is 1:12,281. The findings show that Surveying was involved from the planning to the completion and maintenance stages. Surveying input proved most critical at setting out or construction layout, foundation and construction stages. The scale of height variation was properly managed. The BUTH project shows that the early control establishment reduced the setting-out errors; and the continuous monitoring helped detect column deflections before they became structural issues. BUTH project show that Surveying is required to ensure the integrity and efficiency of any construction project is ascertained. Hence, it can be concluded that this study reinforces or illustrates the centrality of Surveying in the construction and building industry.

Keywords: Mapping, Topography, Engineering Survey Data, Construction Records, Formwork, Alignment

INTRODUCTION

Surveying is the science of taking measurement of both natural and artificial features on Earth, beneath the Earth (Morakinyo, 2025a; Ojinnaka, 2007) and above the Earth (Morakinyo, 2025a, d; Morakinyo, 2024a) and present them in their vertical positions (Morakinyo, 2025c; Morakinyo, 2024c). Surveying and Geoinformatics answers three (3) major questions of where (i.e. the specific location of a feature), how in relation to the size i.e. dimension of a feature, and what, which is referring to the nature of an object (the configuration, terrain, type, height, depth etc.) (Umbugala & Morakinyo, 2023). Surveying is the only profession that produces and manages geospatial data (Morakinyo & Sunmonu, 2025; Morakinyo, 2024b). Therefore, Surveyors are known for the provision of reliable, accurate measurement and geospatial data collection services (Mwaura, 2023). Globally, the role of surveying profession in several industries and sectors cannot be over emphasized. For example, Surveyors play an important role in the built environment (Bag et al., 2019); engineering, construction, and real estate (Mwaura, 2023); land use planning and development (Jarvis & Gouthro, 2015); environmental management and resources exploration (Alicaway et al., 2023); mapping of coastal and marine environment (Ojinnaka, 2007; Morakinyo, 2003). Surveyors are geo-location experts that ensure any engineering and construction project (Clark et al., 2018) are designed, supervised and executed to their specifications and to the professional ethics of all professions involved in the construction industry (Jiang et al., 2022).

Surveyors are the producer and manager of all geospatial data (Morakinyo & Sunmonu, 2025; Morakinyo, 2023). Geospatial data provide the specific information about a specific feature and event such as the exact location (Coordinates) of an object, its size or dimension, nature or characteristics (Lei et al., 2024). Globally, a location has its specific coordinate value assigned to it which can be expressed in the form of geodetic coordinate (Latitude and longitude) or plane coordinate (Northing and Easting or X and Y) (Ojinnaka, 2007). Geospatial data are obtained from various fields of Surveying and Geoinformatics activities such as Engineering Surveying, Hydrography, Remote Sensing, Photogrammetry, Geodesy and Geodynamics, Geospatial Information System (GIS), and Cadastral Surveying (Morakinyo & Sunmonu, 2025). Geospatial information is primarily grouped into two forms namely vector data and raster data (Silva-Coira, 2020). All data that define points, lines and polygons etc. are vector data; and they are used to represent objects like buildings, roads, waters bodies, etc. (Feng, and Koch, 2024). Raster data are acquired in the form of row and column, for example satellite data, airborne data from aircraft and drones, photographs etc. (Gong, 2017).

Surveying provides the critical link between the exact design engineering and precise on the ground layout of facilities (Parkinson, 2017). The role of surveying technologies in enhancing Surveying profession has been extensively discussed by various experts. For example Liu et al. (2020) found that using Total Station instrument has significantly improved the accuracy and efficiency of Surveying by reducing errors in the data collection and improved the accuracy of the final survey results. Smith & Tait (2020) examined the impact of unmanned aerial vehicles (UAVs) on Surveying. The study found that UAVs have improved the speed and accuracy of data collection, particularly in the areas that are difficult to access; reduced the time and cost required for data collection. De La Cruz and Gil (2019) investigated the use of Global Positioning System (GPS) technology in Surveying and found that it improved the accuracy and efficiency of data collection; enabled Surveyors to collect data on large areas quickly and accurately; reducing the time and resources required for data collection.

In addition, Han et al. (2019) and Ardent et al. (2019) discussed that the use of Geographic Information Systems (GIS) has improved the analysis and visualization of survey data by enabled storing, managing large amounts of data, analyze data more effectively, and present data in a more accessible and understandable way. Dale & McLaughlin (2019) used drones for land surveying; and identified the associated challenges as regulatory issues, safety concerns, and limitations in data processing capabilities. They suggested that Surveying professionals need to be aware of these challenges and adopt appropriate safety measures to ensure the safe and effective use of drone technology in Surveying.

Ho et al. (2016) concluded that the use of GPS and GIS have greatly enhanced the accuracy and efficiency of Surveying work by managing complex data generated. Furthermore, El-Mowafy et al. (2021) indicated that the integration of 3D laser scanning, GPS, and UAVs has revolutionized Surveying, making it more efficient and accurate. However, Adan et al. (2018) suggested that Surveying professionals need to adapt to these technological changes and acquire the necessary skills to remain relevant in the industry. Thus, the role of surveying professionals in a dynamic world is evolving due to technological advancements, increasing demand for sustainable development, and the growing importance of data management and analysis.

Worldwide, Surveying and Geoinformatics technologies have been employed in the construction industry. Bognot et al. (2018) integrated UAVs images, and GIS for monitoring the building construction progress performance based on 3D as-built model of the building and the methodology yielded satisfactory results. Rezouki & Rasheed (2012) developed an application with GIS to report Bill of Quantities for construction projects. Bansal and Pal (2008) also used GIS for evaluation of building cost and its visualization. Altuwaijri (2015) employed GIS to create digital elevation models (DTM) and Triangulated Irregular Network (TIN) in order to view the physical land surface in 3D, evaluate the project cost, terrain analysis, 2D and 3D visualization, and route or site selection.

Furthermore, Zhong et al. (2004) applied GIS-based visual simulation methodology to concrete dam construction processes; and Kaushal & Srivastava (2009) adopted the same GIS for infrastructural development. Sharma et al. (2018) employed GIS for location-based planning and scheduling of highway construction projects in a hilly terrain. Bansal & Pal (2008), Seo & Kang (2006) and Poku & Arditi (2006) also employed GIS based for roadway construction planning and for generating, evaluating and visualizing construction scheduling and progress control. In addition, France-Mensah et al. (2017) used GIS visualization for highway maintenance and construction planning. Obaidat et al. (2018) integrated GIS and PAVER system for efficient pavement maintenance management system (PMMS). Furthermore, Kumar & Bansal (2016) adopted a GIS-based methodology for safe site selection of a building in a hilly region. Irizarry et al. (2013) and Kang & Hong (2015) integrated GIS and Building Information Management (BIM) to improve the visual monitoring of construction supply chain management and for effective facility management data integration.

BAZE University Teaching Hospital (BUTH) is a private owned institution, and the first largest private hospital by landmass in Africa; BUTH was designed to be a first class hospital in Nigeria that compete with the foreign hospitals in the Western Worlds like United Kingdom, United State of America, Germany, France, Canada etc. The following construction criteria are considered: (1) All Surveying methods required are of First Order specifications; (2) All designs (Architectural and Engineering) aimed at the international specifications for smart buildings; (3) All construction materials were imported from the oversea except sand and cement and (4) Zero error tolerance for the construction. The construction of BUTH with the specifications stated above represents the crucial knowledge gap in this study which most prior studies have not addressed. The crucial importance of this research is that it helps to inform the public the critical foundational roles that Surveying and Geoinformatics plays in every segment of the construction industry particularly the building construction. There are three principal research questions for this study: (1). How crucial is Surveying and Geoinformatics profession to the construction/ building industry? (2) What are the roles of Surveying and Geoinformatics professional (Land Surveyor) in the construction/ building industry? (3) What are the essential geospatial (Engineering Survey) data required for the construction in the construction/ building industry? Therefore, the aim of this study is to examine the place of Surveying and Geoinformatics in the construction/ building industry with BUTH as a case study. The following are the objectives for this research: (1) Establishment of control points within BAZE University campus; (2) Production of topographical map of the site; (3) Production of Digital Terrain Model (DTM) of the site; (4) Setting out on the ground the designed plans/ working drawings produced by the Architects, and Civil, Mechanical and Electrical Engineers based on the topographical survey map produced by the Surveyor; (5) To provide all geospatial (Engineering Survey) data required for the construction of the BUTH building from the setting out stage to the final stage.

MATERIALS AND METHODS

Study Site

BAZE University is located at the plot 686, Cadastral Zone C 00, Jabi Airport Road Bypass (Ring Road), behind National Judicial Institute (NJI), Abuja Municipal Area Council (AMAC), Federal Capital Territory (FCT), Abuja, Nigeria. It is located between the Latitude 09° 00' 11.63" to 09° 00' 36.36" N and the Longitude 07° 24' 09.79" to 07° 24' 26.01" E. The Teaching Hospital is within the University; and is built for the training of Medical students.

Figure 1: (A) Map of Nigeria in Africa; B) BUTH within BAZE University, FCT, Abuja, Nigeria

Methods

Surveying and Geoinformatics professional play a significant role in the successful execution and completion of any construction project. Their expertise ensures that projects are built accurately on ground according to the design plans and working drawings; legally based on their professional ethics, and efficiently with zero tolerance to error. For this project, the Survey professional methods adopted for the successful construction and completion of BUTH Complex are discussed here.

Equipment used

The following Survey equipment were employed in the execution of this project: Total Station (LEICA, 307) and its accessories; six sets of prisms with targets; six tribrach with 2 spindles; six tracking rods; six small tape; six pair Motorola Walkie Talkie; tribrach with spindle; 100m steel tape (4); ranging poles (10); Leica Automatic level with full accessories (2); Levelling staff (10); cutlass (5) and hammer (6).

Establishment of Global Positioning System (GPS) Control Stations Within BAZE University Campus

Having identified the control to be used (PB/FCT/4732) at about 300 m distance to the construction site, the GPS control stations were established within the BAZE University campus in order to adequately control the construction activities. The parameters used for the establishment of these controls are the following:

Origin: Universal Transverse Mercator (UTM) Zone 31
North: UTM North
Datum: Minna Datum

Control Transfer

Hi-Target Static GPS was used for the transfer of control from PB/FCT/4732 to the BAZE University campus. BAZE1 and BAZE2 are the First Order established Controls; and the same GPS was used for the transferring of Controls from BAZE1 and BAZE2 to the construction site to assist in traversing, levelling and heighting during the construction processes. The master GPS was mounted on PB/FCT/4732 while the rovers were moved from BAZE1 to BAZE2. For the construction activities the master GPS was mounted on BAZE1 and the rovers moved on all other required points (Table 1).

Table 1: Coordinates for the Established Horizontal and Vertical Controls

ID Number	Horizontal controls		Vertical control
	Northing (m)	Easting (m)	Height (m)
BAZE1	995936.117	324689.428	425.127
BAZE2	995911.136	324678.565	420.222

Instrument Test

Horizontal and Vertical Collimation Error Test for Total Station (Leica 307)

The horizontal collimation error test for Total Station (Leica 307) used for the study was carried out. From instrument station A, a target at station B was bisected on both face left and right; and the horizontal and vertical angle readings were recorded for each face (Table 2).

Table 2: Horizontal and Vertical Collimation Error Test

From station	Instrument face	Horizontal reading	Difference	Vertical reading	Sum	To station
A	Face left	000°50’ 02”		087°47’ 38”		B
A	Face right	180° 50’ 06”		272° 12’ 28”		B
			180° 00’ 04”		360° 00’ 06”	

The difference between the two horizontal angle readings computed is shown in Table 2. Theoretically, for any instrument to be free of horizontal collimation error, the difference should be 180º. The result obtained from Table 2 show that the Total Station has a collimation error of 2 seconds i.e.

$$\frac{180^{o} - 180^{o}00'04''}{2} = 00^{o}00'02''$$

This can be considered good for the project.

The vertical collimation test for Total Station (Leica 307) was also carried out to ensure that the horizontal axis of the instrument is truly horizontal. With the same instrument at station A, and a target at B was bisected, vertical circle readings (VCR) were taken on both faces and recorded accordingly as shown in the Table 2. The sum of the two vertical angle reading was computed (Table 2). The half of the difference between the sum of the two reading and complete circle of 360°is the vertical collimation error for the instrument i.e. 00° 00’ 06” / 2 = 00° 00’ 03”. Hence, the vertical collimation error recorded for Total Station (Leica 307) used for this study is 00° 00’ 03”. The results of the two tests conducted for Total Station (Leica 307) used show that the two errors obtained were minimal, and that the collimations of the instrument were in order.

Linear Calibration of Total Station (Leica TCR 307)

The Total Station (Leica TCR 307) has an inbuilt electronic distance-measuring device (EDM) that measured both horizontal and slope distance in metric or imperial units. This remove the need to manually reduce slope distances to horizontal. In average atmospheric conditions, the EDM has a range of 3km with 1 prism and up to 5km with 3 prisms. For the purpose of this project, calibration of the Leica TCR 307 was done on the First Order Controls BAZE1 and BZ6 (served as baseline) established within the University. The horizontal distance from BAZE1 to BA6 was measured with the Total Station 10 times (Table 3). The difference between the measured and the computed distances give the negligible difference. Therefore, it was confirmed that the instrument was in good working condition. The difference between the mean of the measured distances and the computed distances is + 0.002. The measured distance between BAZE1 and BZ6 is shown in the Table 3.

Table 3: Linear Calibration Result for Total Station (Leica TCR 307)

S/N	Measured distance (m)	Computed distance (m)	Difference (m)
1.	150.649	150.651	0.002
2.	150.648	150.651	0.003
3.	150.647	150.651	0.004
4.	150.650	150.651	0.001
5.	100.649	100.651	0.002
6.	100.650	100.651	0.001
7.	100.649	100.651	0.002
8.	100.648	100.651	0.003
9.	100.648	100.651	0.003
10.	100.650	100.651	0.001
	Sum =		0.022
	Mean =		0.002

Level Instrument Test (Two-peg Test Method)

When the level instrument is properly levelled, its part called Compensator will create horizontal line of sight, which enable height readings to be taken on a graduated staff making height difference between points to be determined. The Two-peg test method was used to determine if the line of sight of the level instrument used for the study is truly horizontal. Two points A and B of 40m apart were chosen on a level ground, with a levelling staff vertically held at each point. Level instrument was set-up midway between the two staves positions, back sight and fore sight reading were made to them respectively as shown in Figure 2A and the difference between them was computed. Also, the instrument was taken to a point Y, which is 10m away from B and 50m from A. The readings were taken to the staves still held vertically at points A and B as shown in Figure 2B. Table 4 shows the readings obtained.

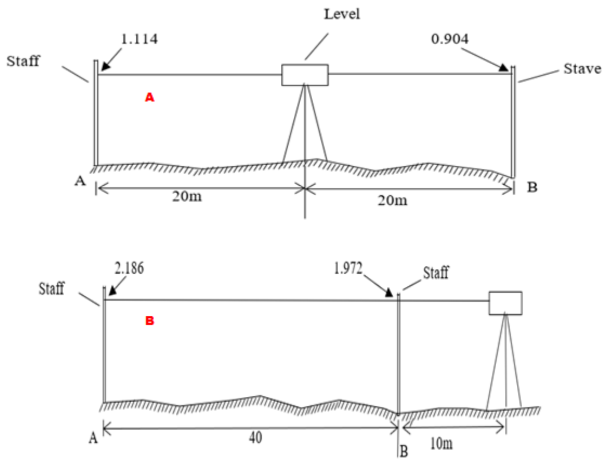

Figure 2: Test of Level Instrument with a Change in Instrument Position

Table 4: Result of Two-peg Test

Sight	Back sight (m)	Fore sight (m)	Diff. in height (m)	Distance (m)
A	1.114			20
B		0.904	A-B = 0.210	20
A	2.186			50
B		1.972	A-B = 0.214	10

The difference between the two set of readings i.e. 0.214−0.210 = 0.004m is negligible. Therefore, the level is in good working condition.

Geospatial Data for Mapping of the BUTH Construction Site

Topographical Mapping of the site

The two major Surveying operations for mapping using ground survey method are traversing and levelling.

Establishment of Boundary Controls and Other Works Controls Networks

The traverse method started by setting the Total Station on BAZE1 and the targets set on BAZE2 and CP1 respectively. Leica TCR 307 was set up properly, well levelled and the required data for working are fed into the instrument. The Total Station was back sighted to the target mounted on BAZE2 on face left and pressed the appropriate buttons. The angle, horizontal distances, change in Northing, change in Easting, Northing, Easting and height were measured, recorded and stored within the instrument. The instrument face was changed to right and the same operation was repeated. From BAZE1, as many points that were accessible were measured before moving the Total Station to the next point. This same procedure was repeated for all the points and the traverse was closed back on BAZE2.

Measurement of boundary Controls (Table 5) was done and the traverse points were mostly marked with iron rod that was painted with red colour paint. True horizontal distances were measured directly with the Total Station from the field. During traversing, targets were accurately vertical, and movement around the instrument was adequately controlled.

Table 5: Boundary Controls for the BUTH site

S/N	Control ID	Northing (m)	Easting (m)	Height (m)
1.	BZ1	993532.647	325070.127	13.585
2.	BZ2	993664.100	324959.825	10.000
3.	BZ3	993573.082	324851.354	08.170
4.	BZ4	993562.796	324793.014	06.520
5.	BZ5	993523.514	324801.363	05.680
6.	BZ6	993494.856	324730.434	05.770

Major controls required for the setting out of any Engineering works are divided into three (3) namely (i) Horizontal controls (Latitude and Longitude, or Northings and Eastings, or X and Y) which are for fixing of positions of points; (ii) Vertical controls (Heights of points, or Datum, or Zs or Hs), they are used for determination of levels or heights on site; and (iii) Works controls which are used for the control of construction processes e.g. vertical alignment of buildings, control of embankment, slopes, excavations etc. For BUTH project, all these major Controls were properly established with First Order Accuracy Survey instruments.

Bearing Deduction

The basic formulae for bearing deduction are;

Bearing $(\theta) = \tan^{-1}(\Delta E / \Delta N)$ (1)

Distance $(L) = \sqrt{(\Delta E^2 + \Delta N^2)}$ (2)

Where;

ΔE = Difference in the Eastings of initial controls;

ΔN = Difference in Northings of initial controls.

The initial forward bearing was reduced, 180^0 was subtracted from it to give backward bearing (BB). The observed horizontal angle (OA) was added to the BB to give the forward bearing (FB) of the first traverse line. That is;

FB = BB + OA (3)

Where the angular result is more than 360^0, 360 is subtracted from it in order to obtain the forward bearing of such line.

Partial Coordinates and Provisional Coordinates

Partial coordinates are change in the Northings (ΔN) and change in the Eastings (ΔE). They are obtained by using the corrected bearing (θ) and the horizontal distance (L) in the mathematical relations;

$\Delta N = LCos\theta$ (4)

$\Delta E = LSin\theta$ (5)

Provisional coordinates are the uncorrected coordinate (N_i) and (E_i). They are obtained by applying partial coordinates ΔN and ΔE to the initial or previous station Northings N_o and Easting E_o respectively.

$N_1 = N_o \pm \Delta N_1$ (6)

$E_1 = E_o \pm \Delta E_1$ (7)

However, the computed provisional coordinate of the last traverse leg that supposed to be equal to the given coordinate was not. The misclosure of 0.052m and 0.012m were found for both Northings and Easting respectively.

Transit Rule

This method was used for the distribution of the linear misclosure to obtain the final corrected coordinate. Transit Rule is given as;

For Northing;

$$\text{Correction} = \frac{\text{Total error in Northing} \times \text{individual line arithmetic sum}}{\text{Total arithmetic sum of Northing}} \quad (8)$$

For Eastings;

$$\text{Correction} = \frac{\text{Total error in Easting} \times \text{individual line arithmetic sum}}{\text{Total arithmetic sum of Easting}} \quad (9)$$

Topographical Survey for the BUTH Construction Site

The topographical survey of the site is required in order to conduct detailed site surveys for the mapping of the site terrain. It involves delineation of the boundaries of the site, total area and dimension of the site, produce contours that define the nature of the site terrain, and other existing features within the site. Topographical Survey involves traversing and levelling methods of surveying operations. The traversing method procedures required has been discussed under the establishment of boundary controls and other controls networks section. The levelling processes involved are discussed in the next section.

Levelling/ Heighting of the Boundary Beacons

The boundary pillars were heighted using the spirit levelling method. This is necessary because the boundary pillars served as Control during the grid line levelling. This was achieved using the Leica Automatic Level instrument by placing the levelling staff on the BAZE1 Control with the height of 425.127m. The level after temporary adjustment was then set at a convenient location where a lot of points can be observed. The staff was read for each of the specific location and the readings recorded for points until it was impossible to take any reading again. The instrument position was changed with the staff still remained at the last observed point. The first reading taken to the staff at BAZE1 is called Back Sight; the last reading taken at the same station is called Fore Sight reading while all others between the Back Sight and the Fore Sight are Intermediate readings. After the Fore Sight reading, the instrument station is changed to another convenient location. The temporary adjustment of the Level instrument was carried out, with the staff still remaining at the last position (Fore Sight); and the measurement commenced at the second station with the reading taken to the staff at the last point. This reading is Back Sight for the second station. The staff was placed on the boundary pillar BZ1, the reading was read recorded; and the same processes was carried out round the boundary and finally closes back on the BAZE2 control. The computation for perimeter levelling commenced from Control BAZE1 with the height 425.127m. Table 6 show part of the acquired levelling data.

Table 6: Part of Levelling Data for Height Differences

Back sight	Intermediate sight	Fore sight	Height of instrument	Reduced level
1.40			426.527	425.127
	1.67			424.857
	2.32			424.207
	3.52			423.007
3.42		4.40	425.547	422.127
	4.22			421.327
	1.65			423.897
	1.90			423.647
	2.61			422.937
	1.65			423.897
	2.00			423.547
	1.79			423.757
	1.31			424.237
	2.09			423.457
	2.66			422.887
1.66		4.42	422.787	421.127
	2.40			420.387
	3.00			419.787
	3.40			419.387
	3.77			419.017
	2.50			420.287
	3.51			419.277
	3.60			419.187
	2.99			419.797

Back sight	Intermediate sight	Fore sight	Height of instrument	Reduced level
	3.32			419.467
	2.45			420.337
	3.31			419.477
	3.11			419.677
	4.53		422.787	418.257
	2.48			420.307
	2.76			420.027
	2.94			419.847
	2.93			419.857
	2.74			420.047
	2.05			420.737
	1.54			421.247
	1.82			420.967
1.66		3.00	421.447	419.787
	3.36			418.087
	4.21			417.237
	4.28			417.167
	4.12			417.327
	3.98			417.467
	3.63			417.817
	4.53			416.917
	4.72			416.727
	4.96			416.487
	5.00			416.447
	4.76		421.447	416.687
	4.70			416.747
	4.09			417.357
	3.57			417.877
	3.74			417.707
	4.65			416.797
	4.99			416.457
	4.86			416.587
	4.77			416.677

Grid Heighting

The North side of the boundary line was adopted as the base line for spot heighting. Each of the grid line was pegged out in order to assist in the tracking of each of the grid line. All grid lines were set out in a North-South direction from the peg positions on the baseline. The grid lines ran across the entire width of the boundary lines. Each line was pegged at an interval of 5m. The coordinate for each of the point tracked were pre-determined and uploaded into the Total Station. Each of the grid line position was given a unique identification number. Figure 3 show examples of grid lines of 5 × 5 m adopted for this project. The choice of 5 × 5 m grid lines helps to provide sufficient details about the terrain of the BUTH site.

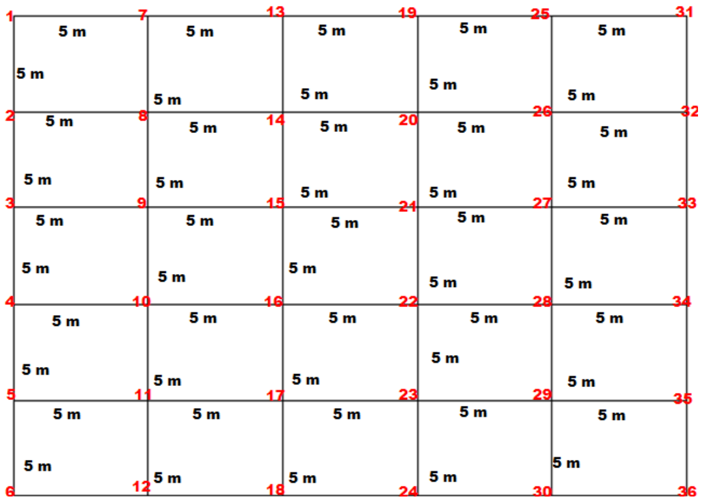

Figure 3: Grid Levelling at 5m Intervals

The gridlines levelling were achieved using tacheometry survey method (Morakinyo, 2025c). Total Station was used for the tacheometry survey in which the instrument was mounted on BZ2 and it's (X, Y, Z) coordinate were uploaded into the instrument. The height of instrument and tracking rod were measured and stored into the Total station. The referenced station BZ1 coordinate were also uploaded. Then, the tracking of each point was done throughout the grid lines. The tracking was done in 2 loops, to provide check on the acquired data. Data acquired were down loaded and processed for the topographic drawing. This involves the processing and manipulating various data obtained from the field using various basic Surveying principle and mathematical formulae in order to obtain the desire topographical data, and later produce topographic plan.

The computations for grid levelling take their reference from heighted perimeter beacons and base line points and closed on another perimeter points. Misclosures were checked for the conformity with the accepted limit before they were being distributed proportionally to the number of foresights or change-points. The basic formula for checking levelling misclosure is;

$$24\text{mm}\sqrt{K} \tag{10}$$

Where,
K = Total distance leveled in km.

Production of Topographical Maps and Digital Terrain Model (DTM)

The X, Y, Z data obtained was prepared in the MS-Excel. This was converted into script file, and ran in the AutoCAD environment. Details were joined with the aid of the annotation ascribed to each detail. The traverse lines, bearing and distances for the boundary were all shown with red colour. The plan was plotted to a scale of 1:1,000.

The software used to obtain DTM of BUTH site is Surfer (Morakinyo, 2025c). The software displayed the contour on the spot heights with the aid of the X, Y, Z data exported into its environment through the MS-Excel format and saved as "filename.dat". This file "filename.dat" was finally processed using kriging method as the grid method for contour generation. The thickness of the contour lines, contour interval, colour and font size were all set. With these setting, contour lines were generated and exported into the AutoCAD environment.

Setting Out/Construction Layout Stage

Setting out is the processes of transferring the positions and levels of new construction projects that have been designed and recorded on working plans to the ground. Setting out involves the correct positioning of works on the ground in accordance with the dimensioned plans or drawings and their dimensional control during erection or construction. It is the primary duty of Surveyors to translate construction plans into the physical reference points on the ground on site. The processes of setting out involve marking the exact positions on the ground where structures will be built. These points are the basis for the construction processes which ensured the construction follows the intended design and specifications.

The setting out plans required for the construction of any project in the built environment industry are (i) Survey plan from the original site surveys; (ii) Working drawings produced by Architects, and Civil, Mechanical and Electrical Engineers showing the location and form of a new construction sited on the survey plan; (iii) Setting out plan showing relationship between the existing controls and the pegs (work controls) defining the positions and levels of the new works; and (iv) Record plans, or as-built plans, or as-laid plans, or updated plans showing how works was finally set out and showing all necessary modification or deviation from original working drawings.

For BUTH, the setting out on ground of design building points and their elevations and all forms of setting out required was carried out using traversing and levelling methods with the same instruments discussed; and they were connected to the existing Controls points established for the same purposes.

Foundation Stage/Elevation and Grading

In this section, the specified criteria for the construction of BUTH were enforced. The boundary points, columns points and all other required locations points and their elevations or depth on the ground as specified by the working drawing plans were carefully established and connected to the established Controls using the same traversing and levelling methods. This stage is crucial because the final results of the construction are dependent on this section. All measurements required for proper drainage and structural integrity of the building, proper elevations and grading, proper out flows of water from the building, prevention of potential water damage and foundation issues, correct positions and heights for the foundation of the BUTH, roads, and landscaping of the site are provided.

Construction Stage

This is the state where the actual construction activities take place. For this project, accurate measurements required for positioning and elevations of columns, beams, heights/ depths of points, slopes, floor, windows, doors, lintels, lighting points, car parks etc. and others and their general alignment were carried out here using the two methodologies of traversing and levelling. The specifications of the instruments used were applied in order to obtain the expected accuracy.

However, the major challenge encountered at this stage is the deflection of the columns due to the resting of the concrete pouring equipment on the column formworks while casting the columns.

Monitoring and Verification

At every stage of the construction of BUTH, continuous monitoring procedures were practiced in order to ensure the goal of zero error tolerance set for the project. Several positions of formworks for columns and beams that were deflected were immediately corrected. Errors were discovered with the elevations of part of the floor; and some windows, doors, lintels, lighting points and cladding positions and were corrected immediately. Every component of the BUTH building was continuously checked for their proper location and elevation to ensure that the criteria set for the construction and the specifications of the instruments used are ascertained.

Documentation and Records

For this project, details of all Surveying records of measurements and findings are kept and maintain. The significance of these documents is that they are used for the future modifications, references, maintenances of the building, and help to resolve any issues that may arise after the construction is completed.

The summary of stages of Surveying and Geoinformatics professional activities required for the construction of BUTH are presented in the form of flow chart in Figure 4.

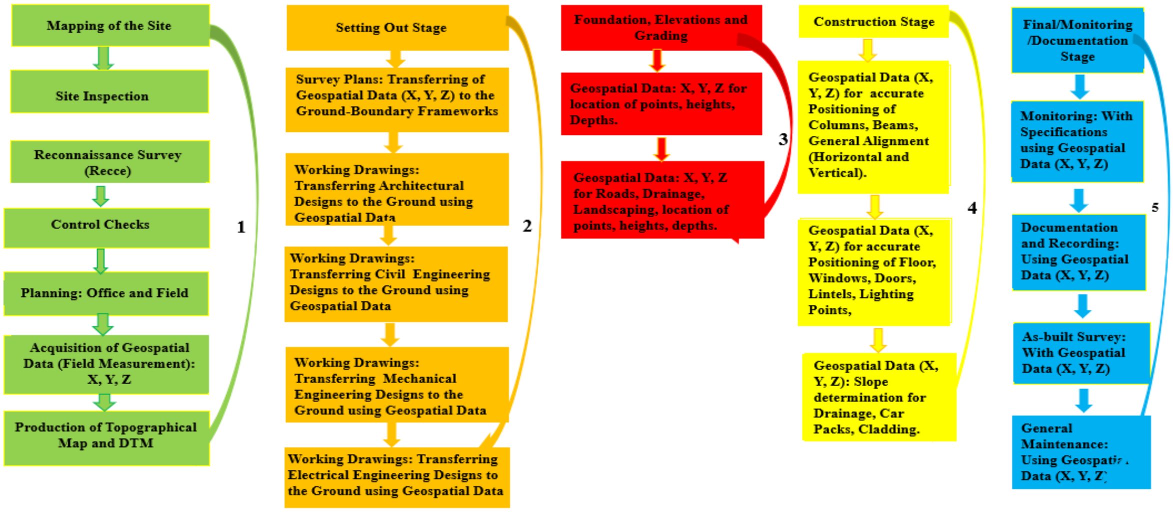

Figure 4: Summary of Stages (1-5) of Activities of Surveying and Geoinformatics Profession Required for the Construction of BUTH.

RESULTS AND DISCUSSION

Establishment of Boundary Controls and Other Works Controls Networks

Analysis of Results

Bearing Misclosure:

The traverse started from BAZE1 and closed on known bearing line (BAZE2), the deduced closing bearing must be equal to the computed initial bearing. However, due to some unavoidable errors the angular misclosure of $-00^o\ 00'\ 02''$ was recorded. This was checked to ensure its permissible limit using the formula;

Permissible error (PE) = $30''\sqrt{n}$ (11)

Where,

n = Number of station

i.e. $PE = 30''\sqrt{9} = 30'' \times 3 = 00^o\ 01'\ 30''$

This signifies that the error obtained fall within the permissible error.

Linear Accuracy of the Traverse

The difference between the coordinate of the control station and the computed coordinate gives a closing error called linear misclosure. These misclosures were subjected to linear accuracy test to check for its permissibility.

This is given by;

Linear Accuracy

$$= \frac{\sqrt{(Error\ in\ Northings)^2 + (Error\ in\ Eastings)^2}}{Total\ Distance} \quad (12)$$

$$= \frac{\sqrt{(0.049)^2 + (0.011)^2}}{603.241\ \text{m}}$$

$= 1{:}12{,}281$

The result of 1:12,281 recorded as linear accuracy show that the error recorded from the survey for linear measurement is permissible.

Accuracy for the Levelling

Misclosures recorded for levelling observations are presented in Table 8

The accuracy obtained for traverse and levelling were compared with the allowable accuracy as it was contained in the Survey specification for the First Order Traverse. The results obtained are presented in Table 7 for traversing; and Table 8 for levelling. Table 7 shows the analysis of results obtained for the traverse as compared with the allowable limits while Table 8 is for the levelling results. The result show that the attained accuracy compared with the allowable misclosure indicated that the project was properly executed.

Table 7: Analysis of Results for Traversing

Observation type	Allowable	Obtainable	Remark
Angular	00°01' 26.6"	00°00' 39"	Satisfactory
Linear	1: 3,000	1:36,535	Satisfactory

Table 8: Analysis of Results for Levelling

Observation Type	Distance(m)	Accuracy		Remarks
		Allowable	Obtainable	
Primary loop	650	0.022	−0.003	Satisfactory

Topographical Map and DTM of the BUTH Site

Figure 5 is the topographical map of the site produced for the construction of BUTH. The map shows the boundary locations (points) and the total area of the site (2.329 HA), and contours of the terrain and its contour interval (0.5 m). Figure 6 is the complete contour map of the site showing the spot heights i.e. different heights of locations within the site. Figure 7 show the DTM i.e. the 3-dimensional model of the site which provides information about the elevation, slope, and other topographic features of the terrain of the site. The height difference within the site is 12.001 m which informed the decision of the BAZE University Management to include the basement to the design of the building.

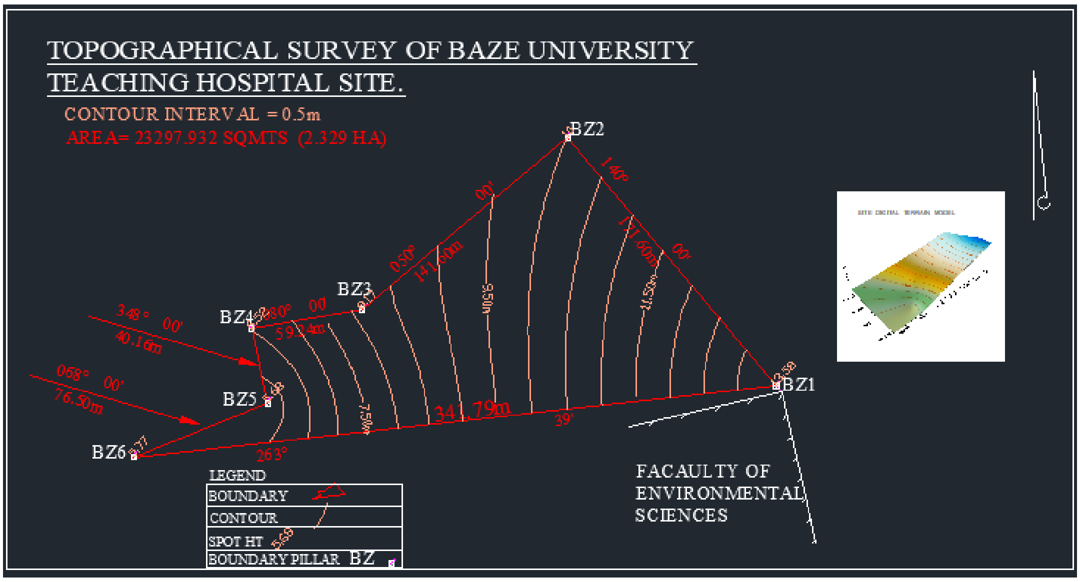

Figure 5: The Topographical Map of the BUTH Site

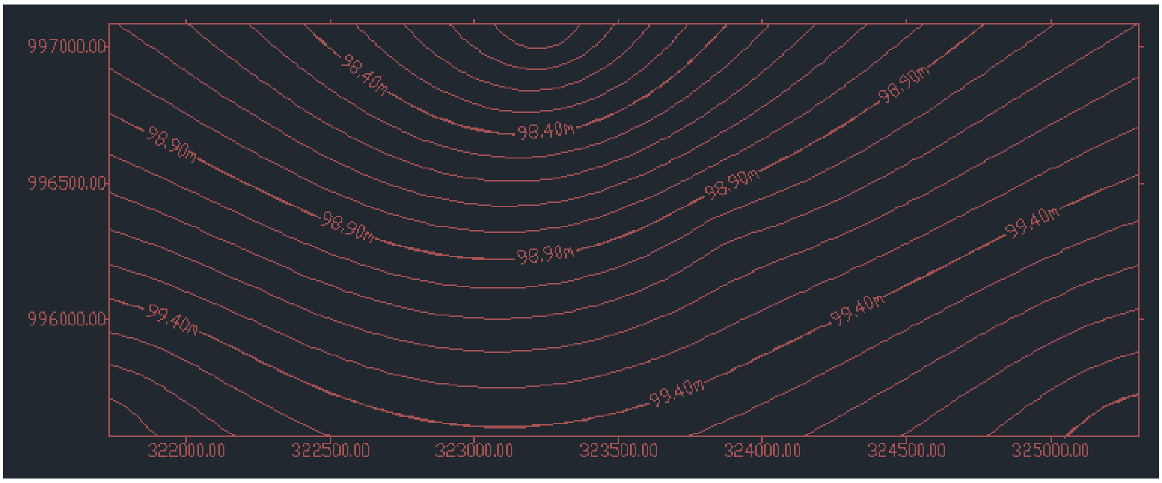

Figure 6: The Contour Map of the BUTH Site

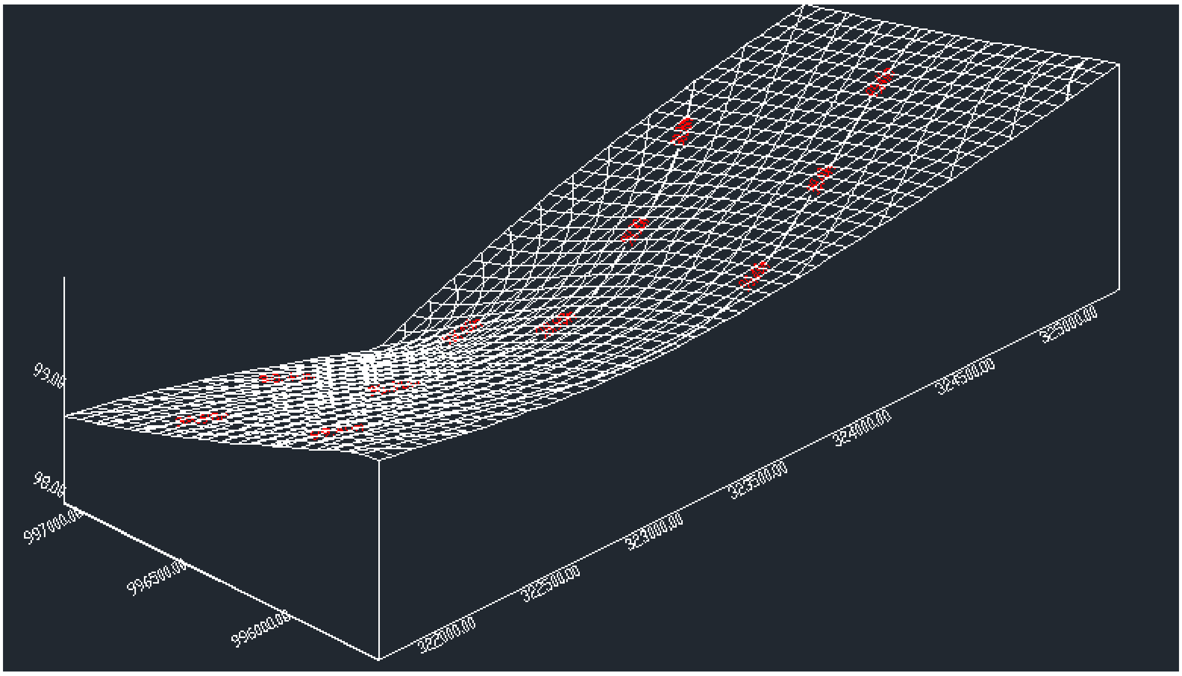

Figure 7: The Digital Terrain Model (DTM) of BUTH Site

Setting out/Construction Layout Stage

The framework for the setting out for the construction of the BUTH building is shown in Figure 8. The accurate positioning of these points determined the success of the subsequent processes and the entire construction procedures. The setting out of all other points, heights, depths, slopes and levels were connected to this framework (Figure 8). Figure 9 show the Architectural design of the layouts for the septic tank.

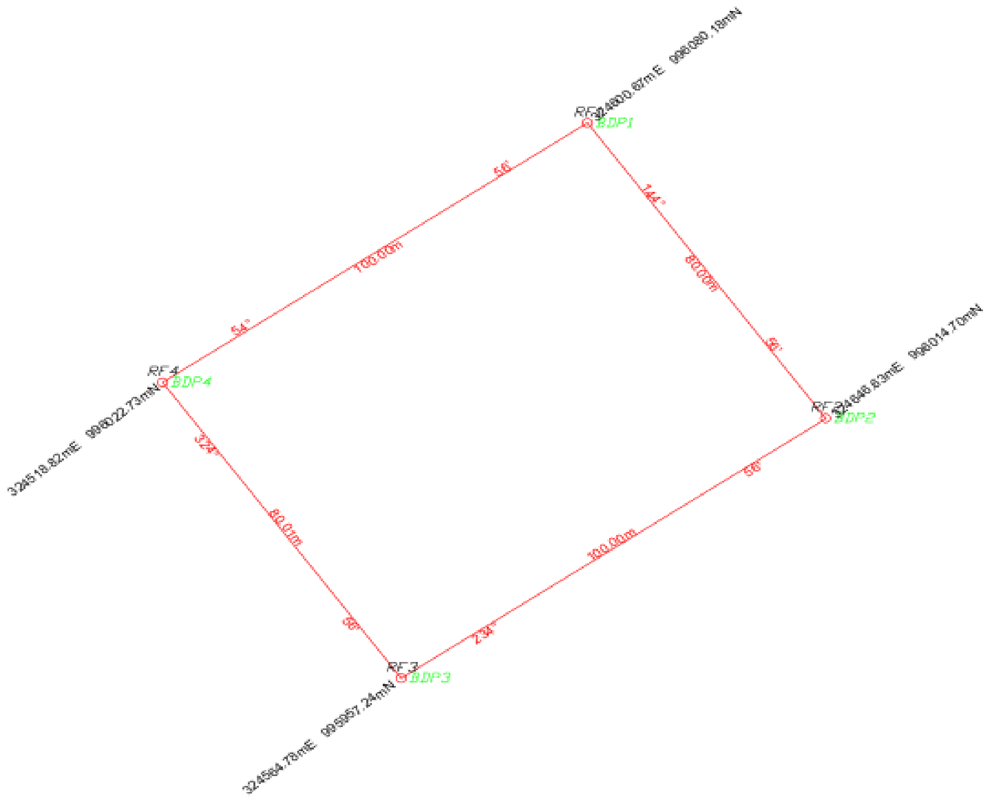

Figure 8: Boundary Points for the Setting Out of BUTH

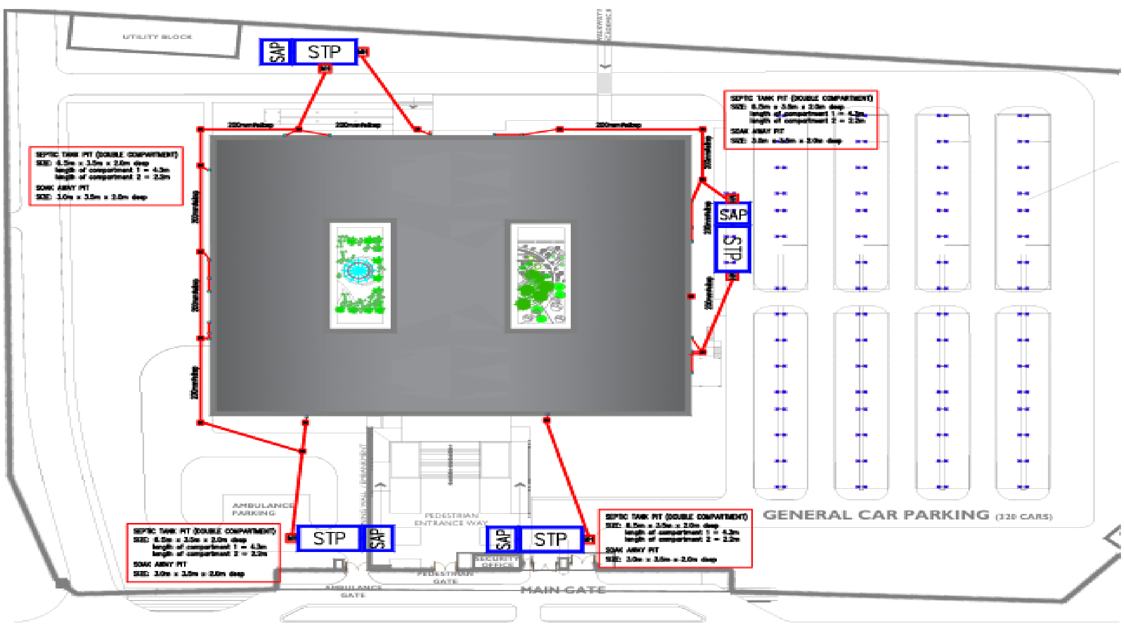

Figure 9: Architectural Design of the Layout for the BUTH Septic Tank

Foundation Stage/Elevation and Grading

Figure 10 shows various activities carried out by Surveyors at this stage. Figure 10A show a Surveyor given the heights or levels within the site. Figure 10B shows the positions and heights/ depths of columns produced by Surveyors. Figures 10C and D presented the position of columns and the heights of the concrete on the ground after the concrete have been poured.

Figure 10: Acquisition of Engineering Survey Data by Surveyor

Construction Stage
Figure 11 shows the progress of activities at the construction site. Figure 11A show the completion of foundation floor, and columns for the first floor. Figure 11B, C and D show the construction of formworks for the first floor in which the horizontal and vertical alignments for all points were carefully checked and ascertained by the Surveyor. For BUTH building, the continuous checking of horizontal and vertical positions of formworks, columns, beams, and all other features were carried out to ensure the correction for deflection error. Figure 12 presented the Architectural design of the layout of the column deflection for the basement floor plan; and Figure 13 shows the Architectural design of the layout for the column deflection for the ground floor plan.

Figure 11: Construction Activities at Various Levels

Figure 12: Architectural Design of the Column Deflection for Basement Floor Plan

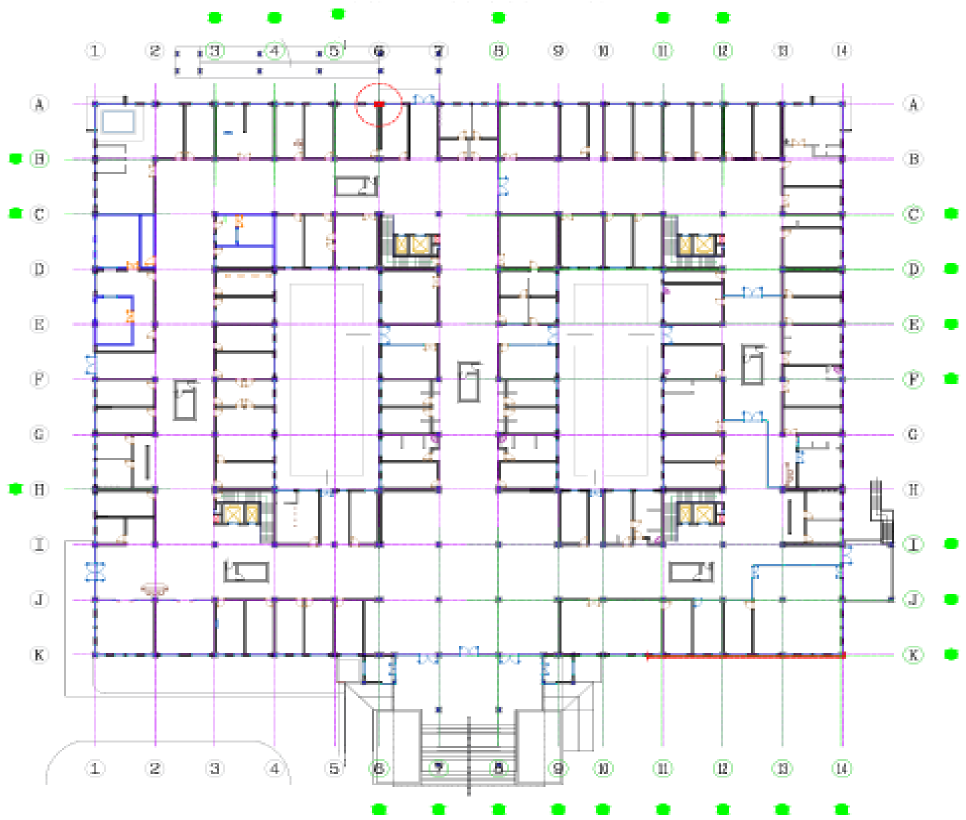

Figure 13: Architectural Design of the Column Deflection for Ground Floor Plan

Figure 14 show further progress on the construction of the BUTH building which include fixing of windows, doors, and cladding of external walls. The accurate locations and levels for these features were provided and fixed by Surveyors using the Leica 307 Total Station and the Automatic Level instrument.

Figure 14: Cladding Activities at Various Stages

Completion/Final Stage

Figure 15 show the as-built column deflections for basement and ground floors plans of BUTH. This is to enable comparison between the initial original design plans and working drawings used for the construction of the building; and the final design plans and working drawings obtained from the final construction of BUTH.

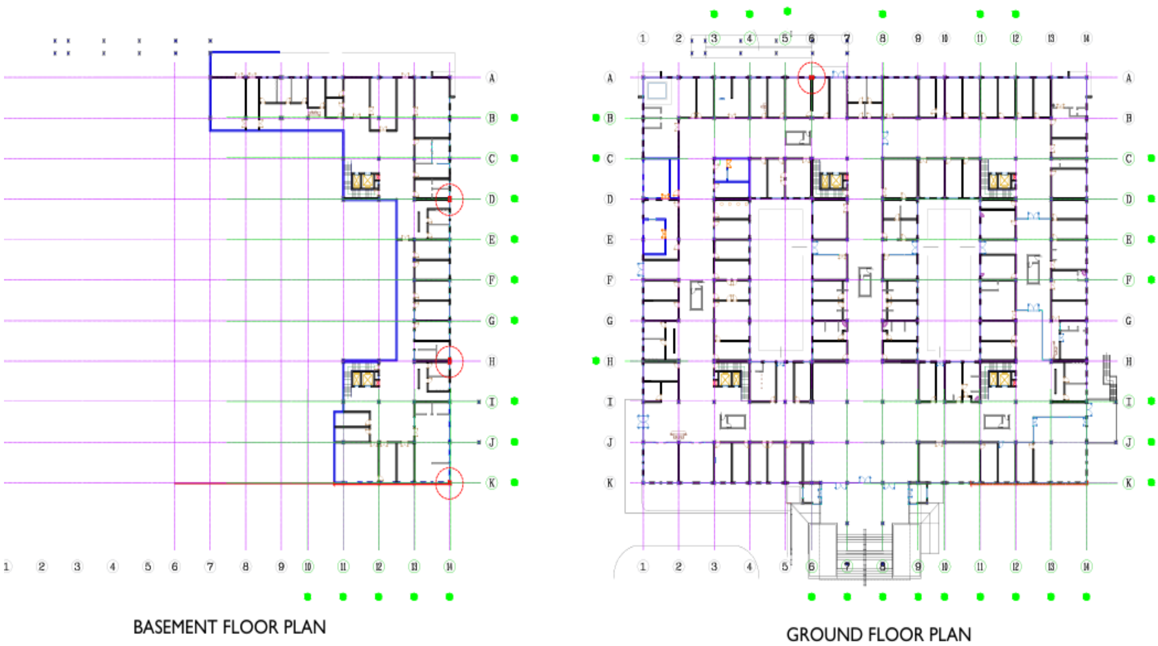

Figure 15: As-built Column Deflections for BASEMENT and Ground Floor Plans

Figure 16 show the finishing of the BUTH project at different levels. Figure 16A show the front of the teaching complex, Figure 16B shows the left side and part of the back of the building while Figures 16C and D shows both the right and left sides of the building. Figure 17A presented the Architectural design model of the building before the commencement of the physical structure. Figure 17B shows the as-built BUTH complex i.e. the final completion of the BUTH including landscaping. The entire construction processes covered a period of Thirty Four months from February, 2020 to November, 2022.

Figure 16: Finishing at various levels

Figure 17: (A) Architectural Design Model; and B) As-built BUTH Complex

Based on the specifications and accuracy of the DGPS, Leica 307 Total Station and the Automatic Level used, gross and instrumental errors were reduced to the minimum. The Leica 307 angular (horizontal calibration error of 00 00 02" and the vertical error of 00 00 03") and the linear error of 0.002m were recorded. The Automatic Level error is 0.004m. The angular misclosure and the linear accuracy for the entire Survey are 00^{o} 01' 30" and 1:12,281 respectively. However, there are practical challenges encountered on site such as improper alignment of the columns and beams; deflection of the columns formwork during column casting; mistake of misinterpretation of levels by other built professionals involved; mistake of misinterpreting the working drawing plans; and inability to achieve the goal of zero tolerance; etc. Hence, there are small practical deviations or alterations from the original design plans during the construction processes; and the adjustment made during the construction stages slightly altered the final completed BUTH complex. Therefore, the As-built plans are slightly different from the original designed plans used for the commencement of the project.

CONCLUSION

The construction of smart BUTH complex was guided by the criteria set at the beginning of the construction proper. However, the practical challenges encountered were overcome by prompt response of Surveyors and other professionals involved. The BUTH show the following: (1) The early control establishment reduced the setting-out errors; (2) The continuous monitoring helped detect column deflections before they become structural issues; and (3) Proper measurement of elevations caused the addition of basement to the final designed plans of the BUTH. This study presents the critical roles of Surveying in the construction of BUTH complex; and that Surveying ensured the integrity and efficiency of any construction project is ascertained. Hence, it can be concluded that this study reinforces or illustrates the centrality of surveying in the construction and building industry.

The following recommendations are made: (1) There is a need for professional collaborations among Surveyors and other professionals in the built industry in order to increase efficiency and professionalism; (2) Strict enforcement of individual professional laws and regulations among professionals in the construction industry for prevention of overlap functions; and (3) Professionals in the built environment should be used for any environmental development projects in Nigeria.

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