Asian Journal of Advanced Research and Reports

15(8): 48-63, 2021; Article no.AJARR.76457
ISSN: 2582-3248

Determination of the Topography and Draining of the Site for the Benin City Bus Rapid Transit (BRT) Station

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJARR/2021/v15i830418
Editor(s):
(1) Dr. Fagbadebo Omololu Michael, Durban University of Technology, South Africa.
Reviewers:
(1) Diogo Botelho Correa de Oliveira, Federal University of Pernambuco, Brazil.
(2) Hassan Kamil Jassim, University of Thi-Qar, Iraq.
Complete Peer review History: http://www.sdiarticle4.com/review-history/76457

Original Research Article

Received 25 August 2021
Accepted 04 November 2021
Published 09 November 2021

ABSTRACT

The reconciliation of engineering designs that do not have survey information, that involve accurate configuration of the proposed constructions at their respective locations on-site requires first a topographic survey to obtain the perimeter survey plan, which in turn, shows the area, shape, perimeter and orientation of the site; spot heights plan showing the existing ground levels thereby used to decide on suitable gradients and determine appropriate finished ground surface, coordinates of the turning points of outlines of the proposed constructions and their respective elevations. For that reason, this study determines the topography and drains the site for the Benin City Bus Rapid Transit (BRT) station in Oredo Local Government Area of Edo State. A topographic survey was carried out to produce topographic plans. The accuracy of the survey was computed to determine its reliability. The perimeter survey plan was plotted using AutoCAD Civil 3D Land Desktop Companion 2009 to present the area, shape, perimeter and orientation of the site. The TIN method was used for the computation of the volume of earthworks. The existing and the finished ground surfaces, vector, as well as the flow direction plans, contour plans and the 3D surface maps were plotted using Surfer 11 to show graphically the existing and the proposed topography of the site. A network of drainages was established to drain the site. The study has shown that the site can be drained in two ways, into the moat behind it and existing drainage along Obakhavbaye.

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Keywords: BRT; topography; draining; rapid; transit; bus; volume; earthworks.

1. INTRODUCTION

Over the years, Edo State has no befitting Central Motor Park (CMP) where vehicles are taking to any part of it (the state). The Godwin Obaseki administration has decided to build a Bus Rapid Transit (BRT) Station in the state, precisely in Benin City, being the state capital. That fulfils one of his numerous agendas of making the transportation sector of the state a functional one, possible for the people of the state to get to any part of it easily at a low cost and serves as a source of income, as well as Internally Generated Revenue (IGR) for the state. [1] has established that transportation infrastructure serves as the backbone of extensive economic activities in any given geopolitical entity. According to [2], an efficient transportation system can improve the productivity of the economy and has a broader role in shaping development and the environment. The site selected for the BRT station is located along Obakhavbaye Street in Oredo Local Government Area of the state. It is bounded by a moat at the back. Obakhavbaye Street is off Oba Market and Plymouth Roads, close to Ring Road in Benin City. Ring Road is the centre of the city, hence the site, as well as the BRT station is strategically located. The prime location of the station is necessary for the efficient performance of the transportation system [3]. Work is presently ongoing at the site. The design of the ongoing BRT station was done by a Lagos State-based consultant, who has done very well but failed to carry out the topographic survey of the site to obtain the actual size, shape, perimeter and the relief of the terrain, as well as topography of the site. Thus, he did not put into consideration the draining of the site. The surface water on the site can be drained into existing drainage along Obakhavbaye Street and a moat behind the site. Lack of drainage system has caused the deformation of several buildings and failure of roads. One of the St. Mary Dedication International School buildings located along Sapele road in Benin City has undergone deformation as a result of the percolation of surface water within its premises due to lack of drainage system [4]. According to [5], drainage quality is an important parameter which affects the highway pavement performance. The excessive water content in the pavement base, sub-base, and sub-grade soils can cause early distress and lead to a structural or functional failure of pavement. Drainage is the most important aspect of road design. Proper design of drainage is necessary for the satisfactory and prolonged performance of the pavement [5]. During the rainy season, the condition of the proposed site is a deplorable one because of the undulation nature of its topography (See Fig. 1).

Fig. 1. Nature of the proposed site during the rainy season

The consultant acquired a Google Earth image of the site from where he obtained the shape and area of the site. Most times positions of points on the earth surface and orientations of site plans from Google Earth are not accurate. It is because the data from Google Earth are globally based. Google Earth uses a global spheroid, WGS 84 ellipsoid. Also, imagine the entire world being viewed at a glance on a PC screen of dimensions 50cm by 30cm [6]. If a point is not clicked accurately with the computer cursor may give a significant error, thereby affects the size, shape, perimeter and orientation of any closed shape or polygon. The error will affect the shapes, sizes and orientations of the proposed constructions relative to the actual shape, size and orientation of the site. Fig. 2 shows the size, perimeter, orientation and shape of the original layout plan, as well as the configuration of the proposed constructions.

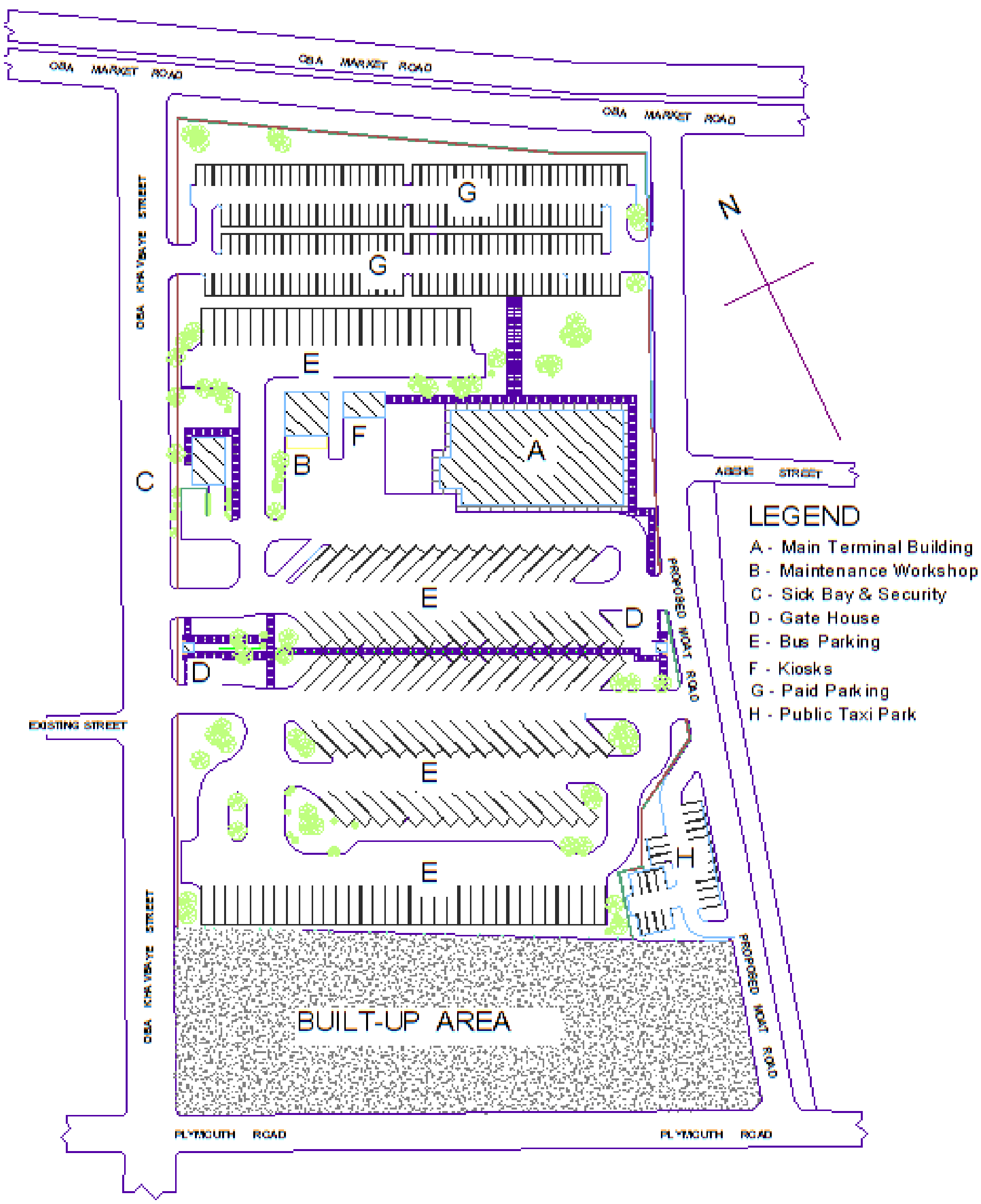

Fig. 2. Size, perimeter, shape and orientation of the consultant site plan
Source: [7]

Spot heights were not also acquired to determine the topography of the site. Therefore, the draining and the reconciliation of the contents of the layout plan became a problem. To solve the problem, as well as draining the site and setting out the contents of the layout plan (main terminal, buildings, maintenance workshop, sickbay, shops and parking lots which require laying of kerbs and paving stones, as well as interlocks) accurately at their respective positions by the contractor (Pekuric Limited, an indigenous contractor that based in Benin City), a topographic survey of the site needs to be carried out to obtain the site actual area, shape, perimeter, orientation and topography. Consequently, this study presents the determination of the topography and draining of the site for the Benin City Bus Rapid Transit (BRT) station. A topographic survey usually entails perimeter survey, spot height survey and detailing [8,9] to produce a perimeter plan, vector, spot heights, and contour maps of the site, which in turn, used to determine suitable gradients to ensure proper vertical alignments of the proposed constructions, and the determination of the volume of earthworks and draining of the site.

1.1 The Study Area

Benin City is the capital of Edo State in Southern Nigeria. It is a City approximately 40 kilometres north of the Benin River. The City is linked by roads to Asaba, Sapele, Siluko, Okene, and Ubiaja and is served by air and the Niger River Delta ports of Koko and Sapele. The City consists of three Local Government Areas, Oredo LGA, Ikpoba Okha LGA and Egor LGA. It has a total population of 1,782,000, according to the 2021 NPC projection. It covers a total area of about 1,204 km². Benin City is bounded by UTM zone 31 coordinates 660000mN and 712500mN, and 770000mE and 815000Me [10]. Figs 3 and 4 show the maps of the study area.

1.2 Topographic Survey

A topographic survey exercise is carried out to determine the positions of points such as property boundaries and details, as well as natural and manmade features and their respective elevations relative to the mean sea level or the geoid to produce either a topographic plan or map depending on the size of the area and the applied scale. The relief, as well as the topography of the project site, is depicted using contours and spot heights [12]. Topographic surveying is one of the most demanded operational workflows needed for mapping and engineering geospatial application scenarios. Understanding terrain topology is a critical skill set that has to be developed by any surveyor who involves in topographic data collection [13]. The topographic survey and boundary plan can be merged into one survey plan or shown on separate survey plans. Architects require a topographic survey to prepare proper site plans and design buildings or decide where a proposed building can and cannot be constructed on the property. Engineers need a topographic survey to prepare site grading plans, erosion and sediment control plans, drainage plans, site servicing plans, soil management plans, fill control plans, suite alteration plans and storm water management reports. Topographic surveys may also be used when creating drainage ditches plans, grading or other features, using the natural landscape as the basis for such improvements. Specifically, in engineering surveys, the processes involved include traversing, levelling and detailing. Field surveying technique using total station is usually adopted as a traditional method for planimetric survey and mapping of urban and rural areas [14]. The exercise involves the establishment of vertical and horizontal controls, Temporal Benchmarks (TBMs) and the evaluation of the volume of earthworks.

Studies have been carried out on topographic surveys by researchers in Nigeria and various parts of the world. In Nigeria, [15] determined and examined the factors responsible for and the implications of non-revision of 1:50,000 topographic maps in Nigeria and further concluded that it has caused many problems in the planning and implementation of developmental projects in the country. [16] established the Topographic Information System of Federal School of Surveying, Oyo East Local Government, Oyo State, Nigeria using the existing topographic map of the study area, as well as the GIS technique. [8] carried out a topographic survey of Divine Hectares Estate, Enugu Lifestyle and Golf City, Nigeria, to produce its (the estate) layout plan, set out land parcels, proposed buildings positions and roads alignments, and designed levels of proposed constructions. In other parts of the world, [9] compared the accuracy of the topographic survey and photogrammetric method in plan production in University Teknologi, Malaysia, inferred that there is no significant difference between the two methods in terms of accuracy.

[17] assessed and evaluated the positional accuracy of topographic maps and plans of different editions in Banja Luka, Bosnia and Herzegovina to show the study area quality of existing topographic maps and plans. [18] compared three methods of volume computations, grids, contours and Triangulated Irregular Network (TIN) methods. The comparison result shows that the contours method is far less accurate than the other two methods, which resulted in their deriving a model to improve its (contours method) accuracy.

1.3 Positions/Coordinates and Area Computations

In surveying, positions, as well as coordinates of boundaries points, are accurately computed, as well as adjusted before use for area computation. In most cases, when a total station is used in the coordinate mode and the closure error is very small, the coordinates are usually downloaded from the instrument and used for whatever purpose they are intended for without adjustment. The closure errors in northing and easting are used to compute the linear/relative accuracy of the survey. The minimum accuracy required for this type of survey must be within the tertiary or third-order (minimum of 1:3000) as stipulated by the Surveyors Council of Nigeria (SURCON). If the accuracy is within the stipulated order then the coordinates are used for back computation to obtain the bearings and distances of the boundaries lines and the area of the site. The positions of points are determined relative to other stations whose coordinates are known. That is to say, if the bearing and distance of a point from a point whose coordinates are known then, the position of the station can be computed. The models for the computation of rectangular coordinates given by [19] are

$$N_B = N_A + \Delta N_{AB}$$
$$E_B = E_A + \Delta E_{AB} \qquad (1.1)$$

Where,
N_A = Northing of known point A
E_A = Easting of known point A
N_B = Northing of unknown point B
E_B = Easting of unknown point B
$\Delta N_{AB} = D_{AB} \times \cos \alpha_{AB}$ = Change in northing between points A and B (Latitude)
$\Delta E_{AB} = D_{AB} \times \sin \alpha_{AB}$ = Change in easting between points A and B (Departure)
D_{AB} =Horizontal distance from station A to B
α_{AB} = Azimuth of station A to B

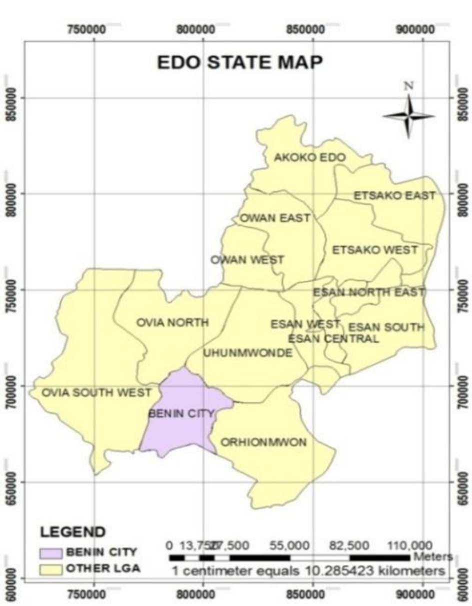

Fig. 3. Map of Edo State

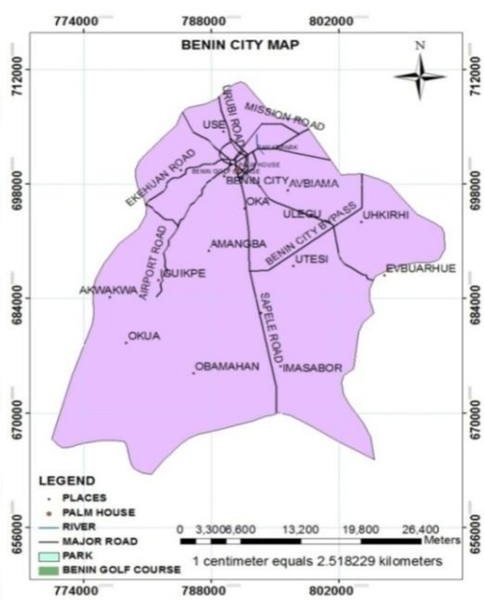

Fig. 4. Map of Benin City
Source: [11]

Having computed the coordinates, the differences in northing and easting between the computed and the known coordinates of the closure station are used to compute the linear, as well as the relative accuracy of the survey. The model used for the computation of the relative accuracy of a closed traverse given by [19] is

$$\text{Relative Accuracy} = \frac{1}{\sigma / D} \tag{1.2}$$

Where,

$\sigma = \sqrt{\sigma_N^2 + \sigma_E^2}$ =Closure Error

σ_N^2 =Closure error in northing squared

σ_E^2 =Closure error in easting squared

Also, having computed the relative accuracy and found it to be within the tertiary order, the coordinates are used to compute the bearings and distances of the traverse lines and the area of the site. The models for the computations of bearing and distance are respectively [19]

$$\text{Bearings}\,(\alpha_{AB}) = \tan^{-1}\left(\frac{\Delta E_{AB}}{\Delta N_{AB}}\right) = \tan^{-1}\left(\frac{\text{Departure}}{\text{Latitude}}\right) \tag{1.3}$$

$$\text{Distance}\,(\text{D}_{\text{AB}}) = \sqrt{(\Delta N_{AB})^2 + (\Delta E_{AB})^2} \tag{1.4}$$

Where,

$\Delta N_{AB} = (N_B - N_A)$ = Change in northing between points A and B

$\Delta E_{AB} = (E_B - E_A)$ = Change in easting between points A and B

The area of the site is computed using [20]

$$\text{Area} = \frac{1}{2}\begin{bmatrix} ((N_A \times E_B) + (N_B \times E_C) + (N_C \times E_D) + \ldots + (N_n \times E_A)) \\ -((E_A \times N_B) + (E_B \times N_C) + (E_C \times N_D) + \ldots + (E_n \times N_A)) \end{bmatrix} \tag{1.5}$$

Where *N* and *E* are respectively northing and easting (coordinates) of boundaries stations. For effective application of equation (1.5), the first set of coordinates must be at the end of the list as the site is a close loop.

1.4 Height Computation with Total Station

The total station measures a slope distance and applies sine and cosine to compute horizontal distance, position and elevation. The horizontal distance and the bearing/azimuth from the instrument station to the observed point are used for the computation of the coordinates of the observed station using equation (1.1). The total station uses the trigonometric levelling method for height determination [21, 22]. The measured slope distance and either the angle of elevation or depression, that is, the vertical angle measured either above or below the horizontal plane, is used to compute the horizontal distance and elevation. The vertical distance between the horizontal plane and the prism is added to the prism height to obtain the vertical distance between the horizontal plane and the observed point. Since the height of the instrument is measured and inputted in the total station, the elevation of the horizontal plane is the sum of the instrument station elevation and the instrument height. The elevation of the observed point is obtained by subtracting the vertical distance between the horizontal plane and the observed point from the horizontal plane elevation. It is the case where an angle of depression is measured (See Fig. 5). In the situation where an angle of elevation is observed, and the observed point is on a hill or higher than the instrument station, the vertical distance between the horizontal plane and the prism is added to the elevation of the horizontal plane to obtain the elevation of the prism. The elevation of the observed point is obtained by subtracting the prism height from the elevation of the prism. Studies [22-26] have shown that the total station levelling and the spirit levelling (geometric levelling) are used interchangeably for the establishment of temporary benchmarks (TBMs) and topographic survey.

1.5 Volume of Earthworks Computation

The volume of earthworks is computed to determine the quantity of cut and fill materials. In most cases, this quantity is usually evaluated together with the proposed pavement. When a template is defined and the thicknesses of the pavement materials are specified, the volume of cut and fill materials are obtained directly using some engineering and survey software. In the case where a template is not used for the computation, the volumes of the pavement materials are computed using the site area since their thicknesses are always consistent. If the surface area of the site is known, then each of their volumes is computed by multiplying the surface area by the numerical value of the thickness. Most software such as AutoCAD Civil

3D Land Desktop Companion and AutoCAD Civil 3D use the Triangulated Irregular Network (TIN) method for volume computation. GIS software also apply the TIN method, but were not used in this study as they do not have the capability of creating two surfaces, as well as stratums for volume computation. According to [18], a TIN surface comprises the triangles that form a triangulated irregular network. The TIN lines form the triangles that make up the surface triangulation (See Fig. 6).

The TIN data structure is a piecewise linear interpolation of a set of points in x, y, z coordinates, resulting in non-overlapping triangular elements of varying size. Although, several methods exist, the Delaunay triangulation is a preferred technique since it provides a nearly unique and optimal triangulation [29-32]. The computation of the volume of earthworks is done using three different sets of models regarding the relationship between each triangle surface area and the design elevation [33]. Where the three vertices of the triangle are above the design elevation, there is a cut, as well as an indication of excavation. The model used for the computation of the volume of cut/excavation is [33]

$$V_{Cut} = \frac{(h_a + h_b + h_c)}{3} S_{TIN} \tag{1.6}$$

Where,

V_{Cut} = Volume of cut

S_{TIN} = Surface area of TIN triangle

h_a, h_b, h_c = Elevation differences between the TIN triangle vertices elevations and design elevation

Where the three vertices of the TIN triangle are below the design elevation, there is a fill. The model used for the computation of the volume of fill is [33]

$$V_{Fill} = \frac{(h_i + h_j + h_k)}{3} S_{TIN} \tag{1.7}$$

Where,

V_{Fill} = Volume of fill

h_i, h_j, h_k = Elevation differences between the TIN triangle vertices elevations and design elevation

In the case where one vertex of the TIN triangle is above the design elevation (cut) and the other two vertices are below the design elevation (fill), the following models are respectively used.

$$V_{Cut} = \frac{1}{3} S_{TIN} h \tag{1.8}$$

Where *h* is the perpendicular distance from the pick of a triangular pyramid to the surface of the TIN triangle. Equation (1.8) is used where a pyramid shape is formed.

$$V_{Fill} = \frac{D_{tq} h}{6} (2D_{st} + D_{uv}) \tag{1.9}$$

Equation (1.9) is applied where the two TIN triangle vertices are below the design elevation, as well as where a wedge shape is formed by the two surfaces. The complete details of equations (1.8) and (1.9) are in [33].

1.6 Vertical Curve Computations with Gradients

According to [34], a vertical curve provides a smooth transition between two tangents grades. There are two types of vertical curves summit and valley vertical curves. The curvature, intersection and tangent of a vertical curve are respectively represented with PVC, PVI and PVT. The length of a vertical curve, L is the distance between PVC and PVT measured along the horizontal plane. The PVI is at the midpoint between PVC and PVT along the horizontal plane. In the specification of a highway's vertical alignment, the elevations of points along the highway's centerline are required. The vertical curves are parabolic in form. The parabolic curve has been used for calculation because it has a constant rate of change of slope and equal curve tangents on both ends of the curve. Note that an uphill is expressed in a positive gradient while a downhill is expressed in a negative gradient. A vertical curve starts at the point of vertical curvature (PVC) and ends at the point of vertical tangent (PVT). The length of the highway between PVC and PVT is L. The initial and final grades are denoted by G_1 and G_2 respectively, expressed in %. Based on the equation of a parabolic curve, the vertical offset *y* at any distance *x* from the projected initial gradient is [34]

$$y = \frac{G_2 - G_1}{100L} x^2 \quad (1.10)$$

Negative values of *y* mean downward offset from the projected tangent PVC (as in the case of crest vertical curves) while positive values of *y* mean upward offset from the projected tangent from PVC (as in sag vertical curves). The highest or lowest point on the curve is computed using [34]

$$x' = \frac{LG_1}{G_1 - G_2} x^2 \quad (1.11)$$

$$y' = \frac{LG_1^2}{200(G_1 - G_2)} \quad (1.12)$$

2. METHODOLOGY

The survey started with the monumentation of temporal benchmarks (TBMs). Three TBMs were monumented and used as reference stations within the project site (See Fig. 7).

The orientation of the survey, as well as the coordinates and heights of TBM1 and TBM2 were obtained with a handheld GNSS receiver as there were no controls and Benchmarks (BM) within the project area. Having done the orientation of the survey using the coordinates and heights of TBM 1 and TBM 2, the corrected coordinates and height of TBM 2 were obtained. Subsequently, those of TBM 3 were also determined and the observation closed back on TBM 1. The observation was carried out with a Sokkia Set 530R total station. The coordinates and heights of the boundaries stations (6 points) (perimeter survey) were obtained relative to those of the TBMs. The survey of the boundaries points respectively started and closed at TBM 1 and TBM3. Afterwards, spot height observation was carried out to determine the topography of the site. A total of 296 points were observed. The random method of spot heights acquisition was used as it has the advantage of portraying the true topography of undulating areas. With the random method, local depressions and hills can the measured at random. The existing features were not observed as it was earlier said that they would be demolished. The spot height survey was carried out at five different instrument stations as there were many vehicles (buses) parked, existing buildings and an overhead water tank on the site. The observation also started from TBM 1 and closed at TBM 3. All the observations were done using the Sokkia Set 530R total station.

The coordinates of the observed points were computed using equation (1.1), while their respective elevations were computed as detailed in section 1.4. The linear accuracy of the benchmarks, perimeter and the spot heights surveys were computed using equation (1.2). The final bearings and distances of the boundaries lines were respectively computed using equations (1.3) and (1.4). The area of the site was computed with equation (1.5). The perimeter and spot heights plans were plotted with AutoCAD Civil 3D Land Desktop Companion. The plotted spot heights were used to create an existing surface, being stratum 1 with the application of the Triangulated Irregular Network (TIN) method. Having created the existing TIN surface, series of existing longitudinal profiles were created. About 21 existing longitudinal profiles were created as the site covered a wide area. A finished ground profile was created using each of the existing ground profiles. When plotting the finished ground profiles, suitable gradients and curve lengths were chosen and used to compute their parameters. The parameters used for the plotting of the vertical curves were computed with equation (10) while the high and low points on the curves were respectively computed using equations (1.11) and (1.12). Fig. 8 shows one of the plotted existing and finished ground profiles.

The coordinates and elevations of points along the centerline of the 21 finished ground profiles were generated at 20m intervals and used to create a finished ground TIN surface (stratum 2). The existing and the finished ground surfaces (strata 1 and 2) were used for the computation of the volume of earthworks. The earthworks volume was computed using equations (1.6), (1.7), (1.8) and (1.9). The existing and finished ground profiles and the volume of earthworks were all done using AutoCAD Civil 3D Land Desktop Companion 2009. The existing and the finished ground data were exported to Surfer 11 and used to create/plot the existing and finished ground digital terrain models, vector/flow direction and contour plans.

3. RESULTS AND DISCISSION

Table 1 presents the computed benchmarks, perimeter and spot heights traverses relative accuracy, site area and perimeter. It is to determine the reliability of the acquired data and the size and perimeter of the site. The survey type is within the tertiary order. The minimum accuracy required for a tertiary order survey is 1: 3000. It is seen from Table 1 that the accuracy of the benchmarks survey, perimeter survey and the spot heights survey are respectively 1: 21000, 1: 19000 and 1: 18000. The accuracy of the elevations obtained from the spot heights traverse was not mentioned as studies [22-26] have shown that the trigonometric levelling method used by total stations is of the same accuracy with that of spirit levelling. Comparing the presented accuracy with the minimum allowable accuracy shows the high reliability of the acquired data thus were accepted and used for the necessary computations and production of plans. It can also be seen from Table 1 that the area of the site is 2.209 Hectares, which implies that the site has a total size of 2.209 Hectares. It can again be seen from Table 1 that the perimeter of the site is 609.851m. It implies that the site is bordered by a total length of 609.851m.

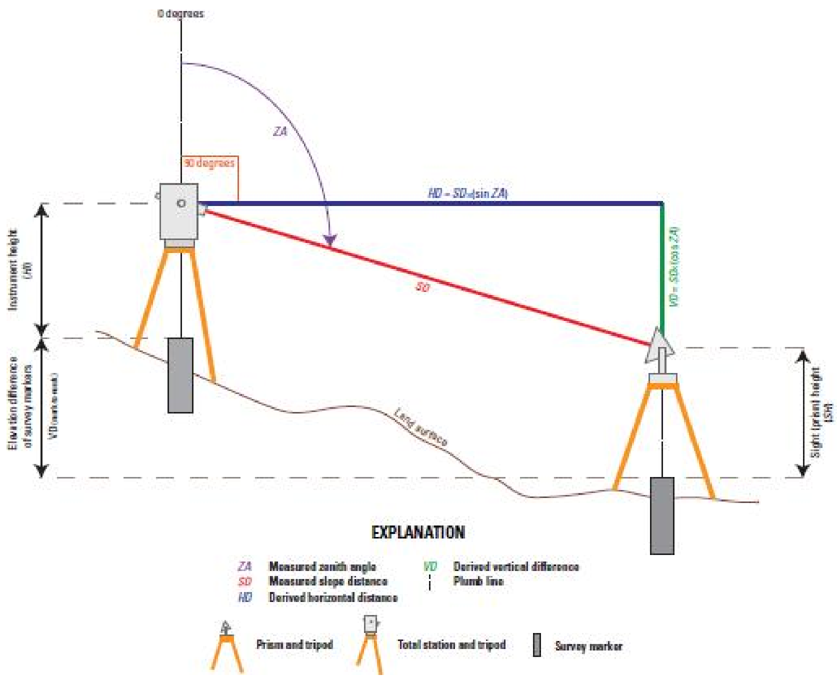

Fig. 5. Geometry of a total station measurement: trigonometric levelling
Source: [27,28]

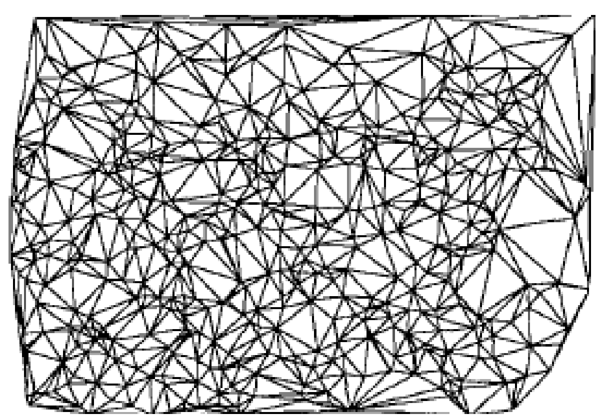

Fig. 6. Triangulated Irregular Network (TIN)
Source: [29]

Fig. 7. Monumented Benchmarks (TBMs)

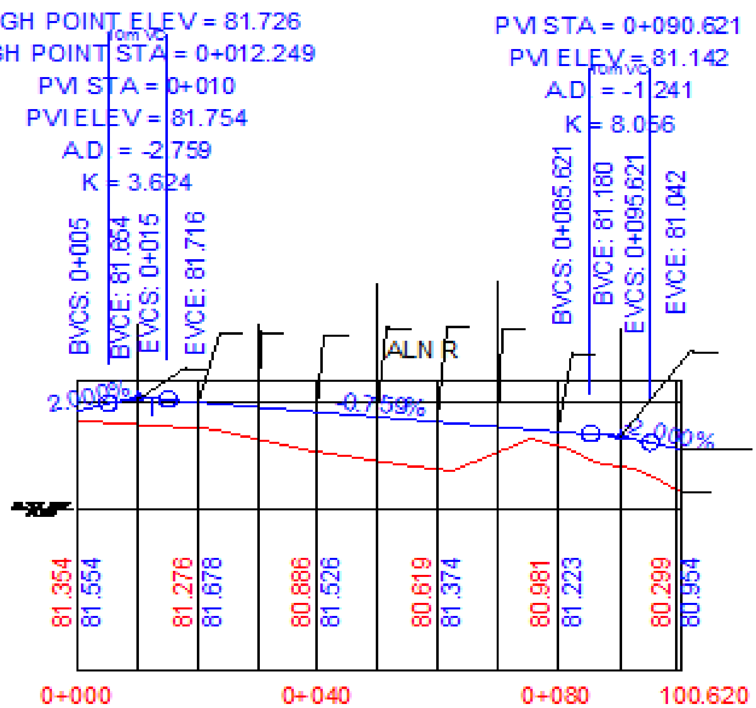

Fig. 8. Plotted existing and finished ground surfaces

Table 1. Computed traverses/surveys accuracy, site area and perimeter

Traverse Relative Accuracy, Site Area and Perimeter				
Benchmark Traverse	Perimeter Traverse	Spot Heights Traverse	Area (Hectares)	Perimeter (m)
1:20000	1:18000	1:17000	2.209	609.851

Table 2: presents the computed earthworks volumes. It is to show the amount of cut, fill, and their net in cubic metres. The actual fill volume on the site is far more than the computed one. The quality of the material at the lower part of the site was not good and needed replacement. It necessitated the taking away of about 240 trailer loads of unsuitable material, and it required replacement before applying the computed volume. The application of the fill volume is necessary for the part of the site topography that requires an increase. In Table 2, the cut volume is 459.482m3, the fill volume is 3237.571m3, and the net is 2778.089m3. It implies that about 86% of the computed earthworks volume is for fill, while 14% is the amount of cut. The net quantity

is obtained by subtracting the cut amount from the fill volume. Here, the net amount is not considered because the cut volume is unsuitable and not used. It also implies that the net earthworks volume is the summation of the quantity of the unsuitable material removed from the site and the computed fill volume.

Fig. 9 presents the perimeter survey plan of the site. It is to determine the site actual shape, orientation and the final configuration of its contents. Also, Fig. 10 presents the drainage flow pattern of the site. It is to show how the site is drained. From Fig.9, it can be seen that the site is bounded by six sides which is different from the one shown in Fig. 2. It shows that the site is a six-sided figure with none of the angles is 90°. Also, from Fig. 9, it can be seen that the site is oriented from the north towards the east. It implies that the site is oriented in the northeast direction. This orientation, which is the actual orientation, is similar to the one shown in Fig. 2. Again from Fig. 9, it can also be seen that the marked parking space in the frontage of the main terminal, building (A), given in Fig. 2, is not shown in Fig. 9. It is because the actual size of the site could not accommodate all the contents of Fig. 2, resulting in the removal of some of the proposed constructions. It implies that the size of Fig. 2, the original site plan is larger than the actual size of the site. Also, in Fig. 9, it is seen that there are drainages along the perimeter of the site and at the frontage of the main terminal. Drainage A is the collector drainage. From Figs 9 and 10, 70% of drainage B volume, 80% of drainage D volume and 100% of drainage E volume discharge into drainage A. Drainage E was introduced to collect the terminal, building roof water. 80% of the water within the site, between drainage E and drainage D flows directly into drainage A. Drainage A discharges into an existing moat behind the site's concrete wall fence. The moat is parallel to drainage A. 20% of drainage D volume and 30% of drainage B volume discharge into drainage C. Drainage C discharges into an existing drainage along Obakhavbaye Street. It means that about 80% of the water on the site can be drained into the moat behind it while the other 20% flows into the existing drainage along Obakhavbaye Street.

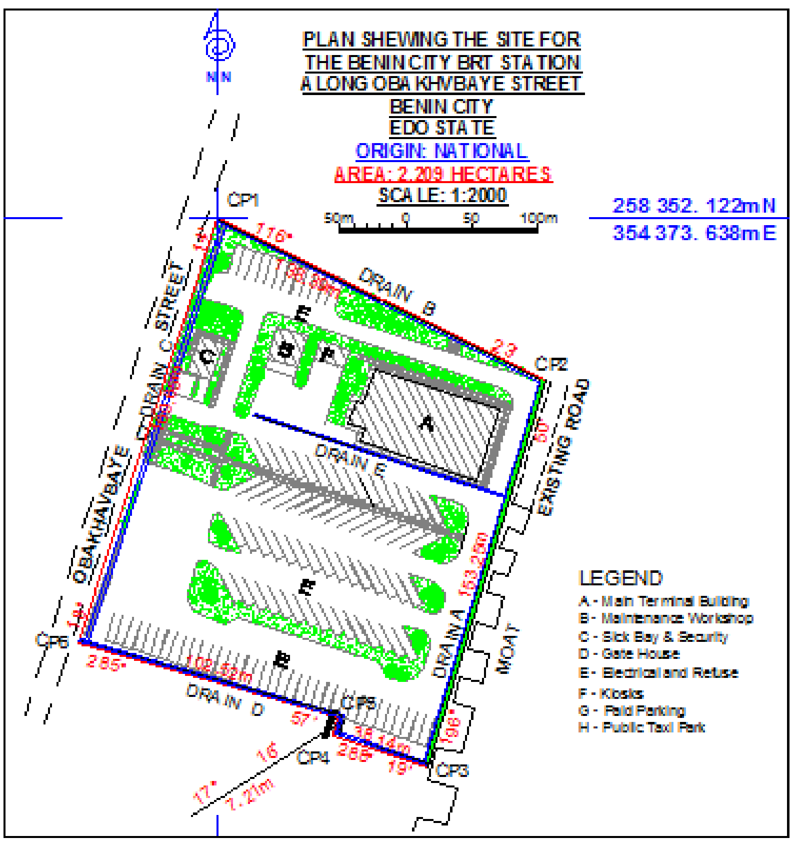

Fig. 9. Perimeter survey plan of the site

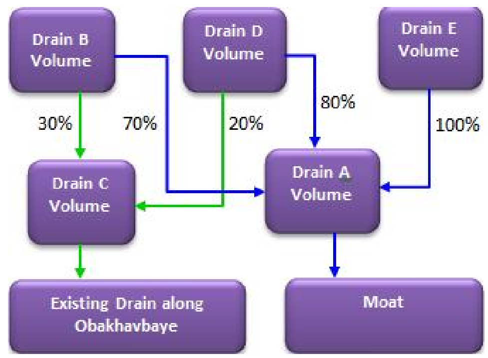

Fig. 10. Drains flow pattern

Table 2. Computed earthworks volumes

Site Volume Table	Site	Stratum
Unadjusted	Central Park	Existing Ground Surface Finished Ground Surface
Method: Composite		
Cut (cu.m)	**Fill (cu.m)**	**Net (cu.m)**
459.482	3237.571	2778.089

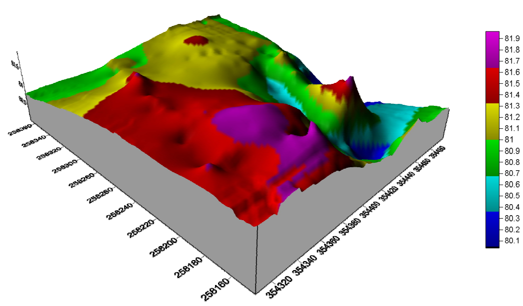

Fig. 11. Existing Ground 3D Surface of the Site

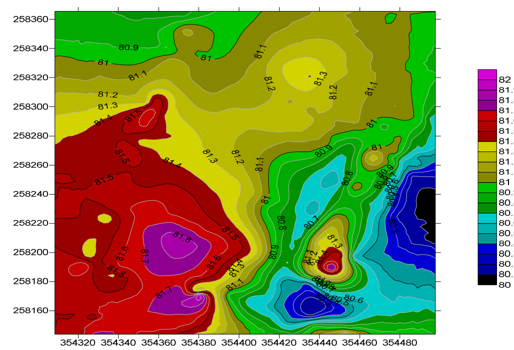

Fig. 12. Existing Ground Contour Map

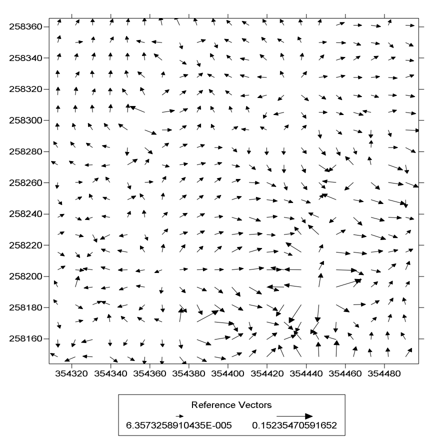

Fig. 13. Existing Ground Flow Directions/Vector Map

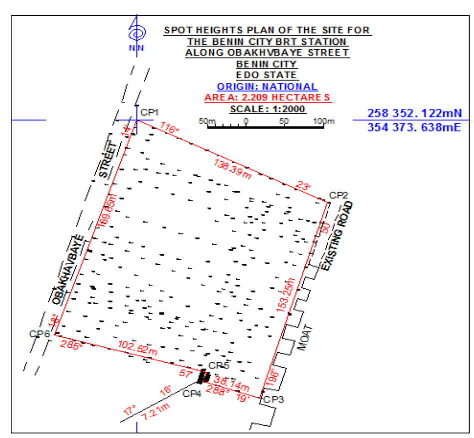

Fig. 14. Spot Heights Plan

Figs 11, 12 and 13 present the existing 3D surface, contour plan and vector plan of the site. It is to show the existing topography of the site. Also, Fig. 14 presents the spot heights plan of the site. It is to show the range of elevations on the site. From Figs 11, 12 and 13, it can be seen that there are depressions at the bottom left and right of the site. At the right, the depression bordered a hill, and it is the lowest part of the site. On the top right side, there is also a hill from which water flows in all directions. Also, there is a hill at the bottom centre from which water flows to the left, right and centre of the site. Again, at the top left side starting from the middle left side, there is a relatively flat surface, slopping towards the top left side. It shows the undulating nature of the existing topography of the site. It also depicts its deplorable condition during the rainy season. From Fig. 14, the minimum and the maximum elevations of points are respectively 80.105m and 82.081m which implies that the existing elevations within the site range from 80.105m to 82.081m.

Figs 15, 16 and 17 present the finished ground 3D surface, contour and vector plans of the site. It is to show, graphically, the finished ground surface and how the site is drained. It can be seen from Figs 15, 16 and 17 that there is a crest running from the bottom to the top of the site, slopping to the left and right of the site. Also, the top right-hand side slopes to the bottom right side, where the lowest point is located. The water at the lowest point of the site flows into the moat behind the site. Also, the bottom left side slopes to the top left side. The water at this point flows into the drainage along Obakhavbaye Street. It implies that the site is drainable in two different ways.

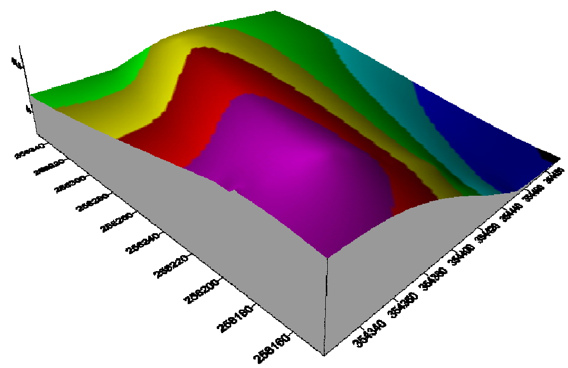

Fig. 15. Finished ground 3D surface of the site

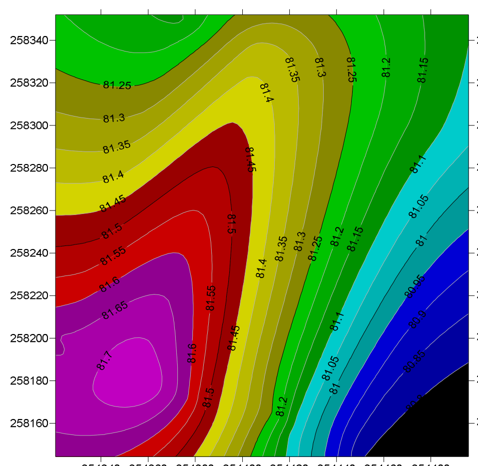

Fig. 16. Finished Ground Contour Map

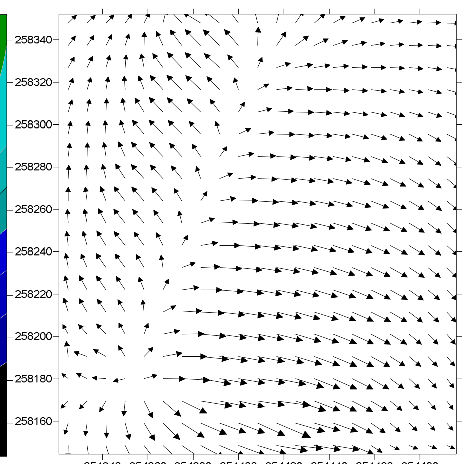

Fig. 17. Finished Ground Flow Directions/Vector Map

4. CONCLUSION

The study has determined the volume of earthworks and the perimeter survey plan of the site showing the final configuration of the proposed constructions. It has also determined the existing and the finished ground surfaces of the site by producing its vector plans, as well as the flow direction maps, contour maps and its 3D surface maps. It has again shown that the site is drainable through two outlets, into the moat behind the site and the drainage along Obakhavbaye Street using the determined finished ground surface and the established network of drains.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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