Estimating Cost of Earthwork Using Computerized Visual Display Approach

By

Zitta, N[1], Aliyu, M. R[2], Peter, E. U[2]., Ayuba, Y[1].
[1]Dept of Survey and Geoinformatics, FUT Minna
[2]Dept of Surveying and Geoinformatics, MAUTECH, Yola
[2]Dept of Surveying and Geoinformatics, MAUTECH, Yola
[1]Dept of Survey and Geoinformatics, FUT Minna
Email: zitta.nanpon@futminna.edu.ng

ABSTRACT

Removing and filling of earth materials to achieve the desired formation level is one of the principal tasks in any road construction project. These activities involve significant cost of excavating, hauling and placing of earth materials at a suitable place along the designed route. This research is aimed at developing a Computerized Visual Display Approach that allows earthwork cost to be estimated from a mass haul diagram. About 1.5km length of route was selected within FUT-Minna main campus. The field observation was carried out using Total Station (Hi-Target Total Station), the data were processed majorly using AutoCAD Civil and Visual Basic (VB.net) was used in developing a computer program that allows earthwork cost to be estimated from mass haul diagram. The result indicated that the road has two curves of very larger radius (locating between chainage 00+00 and 00+400 while the other one is located between chainage 01+150 and 01+525). The maximum point on the mass haul diagram was at chainage 650m with computed volume and estimated cost of 79928.83m³ and 159857.67USD while the minimum point on the mass haul diagram was at chainage 900m with computed volume and estimated cost of 109620.83m³ and 219241.67USD, respectively. Also, the cumulated volume of cut and fill along the route were +9544.50m³ and -1573.86m³ respectively and earthwork cost at any given volume can be predicted using Earthwork Cost Prediction Graph (ECPG). It was recommended that the developed software should be subjected to intensive modifications that allows creation of comprehensive database of the estimated cost and be made public for global criticisms and value addition.

KEYWORDS: Earthwork, Cost estimation, Mass haul Diagram (MHD) and Computerized Display Approach

INTRODUCTION

During construction operation (most especially in road construction), several attempts are made towards bringing the natural earth surface to a particular desired formation level but as efforts are put together in achieving the needed formation level, one of the principal task required is the cutting and the filling of earth materials along the designed route. The design tasks required to define where the roadway material is to be obtained, where it will be placed, the direction in which it will be hauled, the amount of effort required to transport the material to its desired location and the amount of material to be excavated. All these are collectively known as the Earthwork (WYDOT, 2011). Earthwork activities requires significant costs and the need to accurately estimate this cost has attracted some challenges (like visual

inter-connectivity between earthwork and its cost). Petroutsatou et al. (2006), based on acquired data, established a correlation between geotechnical and construction parameters and estimating cost for road tunnel using multiple regression. Sonmez (2004) adopted regression analysis and neural networks to develop conceptual cost estimates of building projects. Actual budgeting process in highway construction was considered by Han et al. (2008), where two-tiered cost estimation models of highway construction projects was arrived at. Mahamid (2013) developed linear regression models for predicting the costs of road construction activities based on one hundred (100) set of data collected in Palestine. More so a multiple regression technique was developed by Mahamid (2013) for early cost estimation models in road construction projects.

In another related development, Lowe et al. (2006) developed linear regression models to predict the construction cost of buildings. Gangavarapu et al. (2003) considered fuel costs, time delay costs, and vehicle depreciation costs in a comparative analysis of open and trenchless technologies in terms of costs arising from traffic disruption. Based on studies conducted by the American Society of Civil Engineers (ASCE) and the American Water Works Association (AWWA), nation's water pipe infrastructure will need to be replaced in the near future, as most of these buried pipelines are reaching the end of their designed service life (AWWA, 2012; ASCE, 2013). Easa (1988a) assumes that the unit hauling cost was linearly proportional to the hauling distance and the unit cost of purchase and excavation for the borrow area was constant. Also Easa (l988b) presented a quadratic programming model of earthwork allocation, in which the last term of the objective function indicating the total cost of purchase and excavation of materials from borrow areas, was a linear function of the quantity used. Easa (1987, 1988a) also developed a linear programming model to reduce the cost of earthwork allocation and to minimize haulage distance. An operational research model to minimize earthmoving cost by optimizing the distribution of cut and fill quantities was introduced by (Christian and Caldera 1988). Kang et al (2006) proposed a Four Dimensional (4D) models for simulating the movement of earthwork activities at the intermediate stage of the construction process in civil engineering projects. Platt (2007) pointed out that the continuity of earthwork activities did not work with predetermined object simulation associated with 4D CAD technology and suggested that dividing the earthwork into discrete objects would be a possible solution. In their development of cost prediction models, Wilmot and Cheng (2003) developed a model for forecasting highway construction costs in Louisiana. Oberlender and Trost (2001) focused majorly on improving prediction accuracy by deriving four determinants influencing the accuracy of an early cost estimates using a multiple regression model. Earthwork activities have unique characteristics (cutting and filling), and it involves significant costs of haulage between cut and fill sections in construction project. These activities also influence the sequencing of the rest of the activities of the construction project (Askew et al., 2002).

Cost estimate is the prediction of the most likely total cost that is required to execute a particular project especially road construction. It is a significant factor against which the success of a project (engineering project) is measured. An accurate and complete cost estimate goes a long way towards supporting the success of a project within its approved budget. Literatures has shown that previous studies failed to establish visual linkage(s) between earthwork and its cost (which is the pillar that holds any engineering projects). However, the aim of this research is to use a computerized approach using Visual Basic (VB.net)

programming language for estimating earthwork cost from a mass haul diagram and carry out comparative analysis between manual and computer technique for earthwork cost estimate from a mass haul diagram.

MATERIALS AND METHOD

This section shows the various steps used in achieving the aim of the study. The procedure is as shown in the Flow Chart of methodology as shown in Figure 1 below.
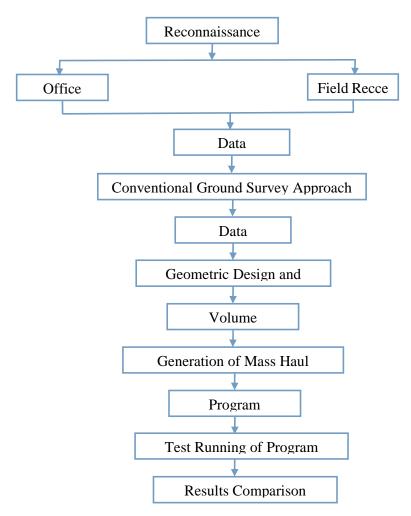

Figure 1: Flow chart of Methodology

Study Area

This project was carried out within FUT-Minna Main Campus, located at Gidan Kwano, along Minna-Bida expressway, Minna, Niger State (Figure 2). The project covered about 1.5km (1500m) of proposed road within the University Main Campus and the soil type within this area was majorly sandy soil mostly covered with shrubs
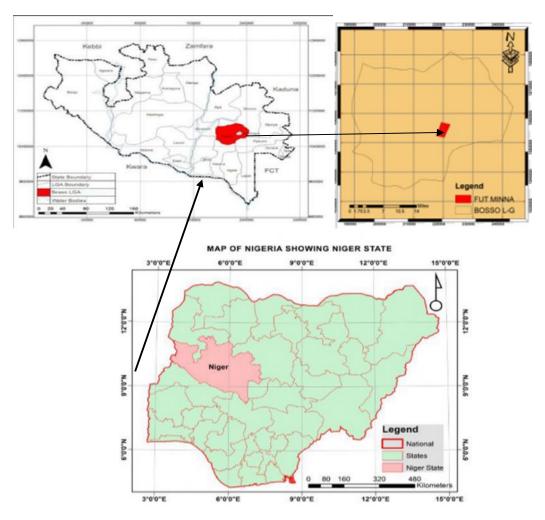
Figure 2. Map of study area

Materials

The hardware used in the research include a Hi-Target GNSS receiver (Total Station model) for capturing field data over a distance of about 1.5km a Hp Laptop computer with 2.00 GB of RAM and 500 GB HARD disk and Hp 1005 model A4 printer while the software includes Microsoft word excel, CivilCAD and Microsoft visual studio 2015 (vb.net).

Data processing

A digital techniques for plan plotting was adopted for this research which is efficient for calculating and making better adjustment automatically as desired by the user. It has many advantages over the analogue technique in term of time consumption, accuracy and precision.

Production of longitudinal and cross sectional profiles/ volume computation

The acquired point data were uploaded into the computer in an excel spreadsheet format from the Hi-Target Total Station GNSS receiver. Sorted and arranged in a pattern of points, easting, northing, height and description (PENZD) in rows and columns. The data was saved in a format (with space delineated) and imported into CivilCAD software to generate the horizontal and vertical alignments of the road. Tangents were applied at any sharp intersection to display the slope and tangents. Cross-sections were created by generating road data for existing ground level at all stations. The road type used in this research is a one

Carriage Way and the designated formation level was designed based on the gradient between consecutive stations. The software automatically computed the volume (based on average end area method) of cut and fill for each section.

Generate mass haul diagram (MHD)

Mass haul diagram comprises of two perpendicular axes (the cumulative volume and the station).The cumulative volume is plotted along the vertical axis (lift) and the stations are plotted along the horizontal axis (lead). The cumulative volumes were computed from the calculated volume of cut and fill for each section (portion between two successive stations). Mathematically, Cumulative volume = volume of cut + volume of fill. Volume of cut is taken to be positive and that of fill is taken to be negative. However, an interface was created with the software so that, the values for mass ordinate and the distance could be entered directly and the cumulative volume is computed, stored and displayed automatically. A plotting button was also included on the interface and the MHD is plotted automatically at the click of the plot graph button.

Earthwork cost estimation approach

Using an efficiently and economically agreed cost unit or unit cost factor (assuming that the cost of hauling $1m^3$ of earth material over 1m is 2.00 USD) considering a uniform type of material along the route. A program code was developed (VB.net), with the unit cost incorporated to estimate and display the cost at any given point on the mass haul diagram. For example when the pointer is on point 'A' (the software automatically computes the volume of earthwork from the starting point of the graph to point 'A' based on Simpson's rule and multiplied by unit cost to give the estimated cost). Therefore, the positional parameters of point A on the MHD is defined by the volume of earthwork, and the corresponding earthwork's cost. The program is flexible for editing of unit cost of earth work and new MHD parameters could be substituted. Furthermore, the cost obtained with this approach were compared with the manual approach and the results demonstrated some high degree of similarities numerically as shown in Table 1 below.

RESULTS AND DISCUSSION

Results

Plotted MHD with excel

MHD is a graph that describe the cumulative volume of earth material that is moved over a given distance usually from the beginning of the road. It tells how much quantity of earth material that is to be excavated, the direction in which it should be moved and the likely cost that could be involved (Figure 3).
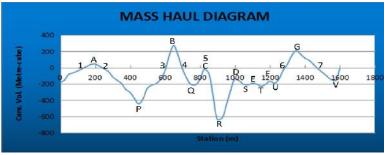

Figure 3: MHD plotted using Microsoft excel

Data Input Interface

The interface was created using Microsoft visual studio 2015 (vb.net) that allows users to input directly the parameters for plotting mass haul diagram (Figure 4).
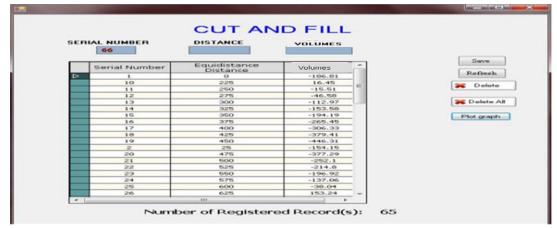

Figure 4: Data input interface

Visual Outlook of the Software

Figure 5 presents the visual outlook of the software showing the computed volume and the corresponding estimated cost at 200m.
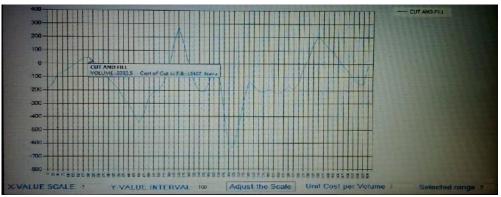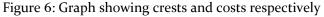

Figure 5: Visual outlook of the software

Graph of Various Crest against their Respective Cost

Figure 6 presents a display of estimated cost at each peak (crest) on the MHD

Figure 6: Graph showing crests and costs respectively

Graph of Various Troughs against their Respective Cost

Similarly the estimated cost at each troughs on the MHD is displayed in Figure 7 and 8.
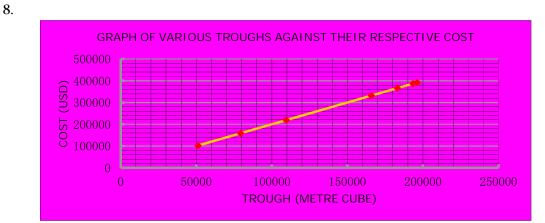

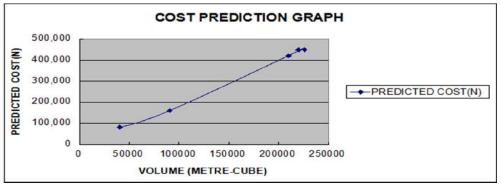Figure 7: Graph showing troughs and cost respectively

Figure 8: earthwork cost prediction graph (ECPG)

Graphical Illustration of the Results Obtained with the Software

Figure 9 shows the results (earthwork volumes and their corresponding estimated cost) obtained with the software at some selected stations.
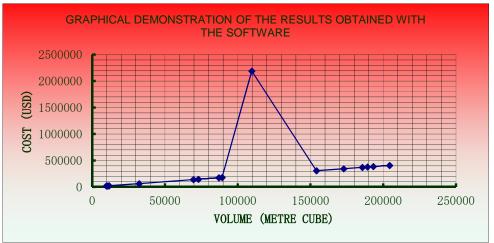

Figure 9: Graph of results display by software

Graphical Illustration of the Results Obtained Manually

A graph to show the results (earthwork volumes and their corresponding cost) obtained manually at some selected stations is presented in Figure 10.
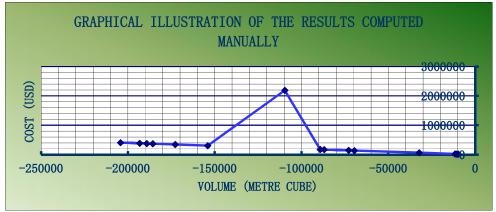

Figure 10: Graph of results computed manually

Comparative Display of Cost by Both Methods

A comparative result of cost by computer based approach and manual based on volume of earthwork is presented in Table 1 below.

Table 1: Comparative display of costs by both methods

Station	Computer based approach Vol (m³)	Cost($)	Manual based approach Vol (m³)	Cost($)
100	10588.42	21176.83	-10588.41667	21176.8333
200	9703.5	19407	-9703.5	19407
300	11540	23080	-11540	23080
400	32238.33	64476.67	-32238.33333	64476.6667
500	69553.75	139107.5	-69553.75	139107.5
600	86982.25	173964.5	-86982.25	173964.5
700	72920.92	145841.83	-72920.91667	145841.833
800	89292.33	178584.67	-89292.33333	178584.667
900	109620.83	2191241.7	-109620.8333	2191241.67
1000	154068.83	308137.67	-154068.8333	308137.667
1100	172784.75	345569.5	-172784.75	345569.5
1200	193219.17	386438.33	-193219.1667	386438.333
1300	204304.67	408609.33	-204304.6667	408609.333
1400	189104.83	378209.67	-189104.8333	378209.667
1500	185670.17	371340.33	-185670.1667	371340.333

DISCUSSION

Based on the theory of mass haul diagram, positive slope indicates cut while negative slope indicates fill. Figure 3 revealed that between point 1 and 2, cut starts from point 1 and the positive ordinate become maximum at A. This marks the termination of cutting operation and from A, the ordinate started decreasing, meaning that filling starts from A continuously to

point B. The volume of earth cut from 1 to A is employed in filling from A to 2. Therefore, between sections 1 to 2, the volume of cut is equal to the volume of fill. This line 1-2 is called balancing length. Also, from the graph it can be seen that cutting begins from point P and it continues to point B, filling starts from B to Q, cutting starts from Q to 5 and so on. In the case of section 1 to 2, the volume of cut is hauled in the forward direction and also in the case of section 4 to 5, the materials excavated from Q to 5 is hauled backward to fill the region Q to 4 and therefore, length Q to 4 becomes another balancing length. The data entering environment created is to allow users input the parameters needed to plot the mass haul diagram directly as shown in Figure 4. The interface was developed in such a way that, the entered data can be saved, deleted, refreshed and the mass haul diagram can be plotted automatically by clicking plot graph button. The interface is equipped with digital counter (that automatically counts the number of entered data). The data are entered in the space provided at the top of the environment and is automatically displayed in the designed table.

Figure 5 shows the demonstration of the output interface of the software displaying the total earthwork volume from the starting point of the route to the point at which the computer mouse is pointing. The working principle of this software is, as the mouse (pointer) is pointed at a station (200m) for example on the graph, the software automatically select the sectional volumes between zero chainage and 200m. Simpson's rule is used to compute the volume within this interval and multiply the computed volume by the unit cost (2.00USD) and display these two computed parameter at this station. At the right bottom of the interface, the number of selected sections is shown and the unit cost is also displayed.

Figures 6 and 7 displays estimated earthwork costs at the crests and troughs of the MHD respectively. The graph shows that, the estimated earthwork costs and the volume at the crests are linearly related, meaning that it can be used to predict earthwork cost at any given volume. While the volumes at the troughs and the estimated cost were also examined. The result shows that earthwork cost increases as the volume of earth materials increases and vis-a-vis. It also indicated that, the graph can be reliably used to predict earthwork cost at any given volume of earth materials.

The graph of some predicted cost of earthwork against some given volume of earth materials is shown in Figure 8. The Earthwork Cost Prediction Graph (ECPG) clearly indicated that, earthwork cost truly increases as volume of earthwork becomes larger and vis-a-vis. Although the graph shows that the relationship between the predicted cost and the given volume is not a perfect linear relationship, as indicated by the graph because it appeared a little bit curved.

Figure 9 is a demonstration of how the two computed parameters (volume and the cost estimated) behaves with the developed software. In this case readings were taken at every 100m throughout the whole length of the route and the corresponding volume and cost at each station were estimated. The obtained results were plotted to see the behavior of the computed volume and the estimated cost. Figure 10 shows the manual computation as confirmed by the output generated from the software. The graph obtained is the same but in opposite direction. The reason being that, the volume of earthwork computed manually were all negative (but the obtained values were equal to those obtained from the software). However, the volumes generated with the software were deliberately made positive so that cost estimation will not be negative in order to be real and meaningful to users.

CONCLUSION

The advancement in Computer Technology has made various Survey computations and analysis (like earthwork estimation) easier, faster and interface friendly compared to the conventional techniques. In this paper, it was proved that the cost of earthwork can be estimated from mass haul diagram coupled with the aid of simple programming knowledge (created with Visual Basic.net). The study indicated that the maximum point on the mass haul diagram occurred on chainage 650m with computed volume and estimated cost of 79928.83m³ and 159857.67USD respectively. Also the minimum point on the mass haul diagram was on chainage 900m with computed volume and estimated cost of 109620.83m³ and 219241.67USD respectively. The cumulated volume of cut and fill along the route were +9544.50m³ and -1573.86m³. A total of sixty (60) stations were marked along the center line of the route, fifteen (15) stations were selected and examined for the purpose of this research. The volume and the cost at these stations were computed manually and the obtained results were compared with those obtained with the software. The manual and the computerized techniques of estimating earthwork's cost indicated a very high reasonable degree of similarities but the manual approach was noticed to be time consuming, stressful, laborious and very slow in terms of output rate. The study also confirmed that, earthwork cost can be predicted with the aid of ECPG.

Based on the findings, the following recommendations are suggested in order to make this work globally competitive:

1. The developed software could be improved by extending and modifying the codes to automatically create a comprehensive database table of the estimated cost.
2. The software developed can be made public for open criticism by relevant expertise in order to make it globally competitive

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