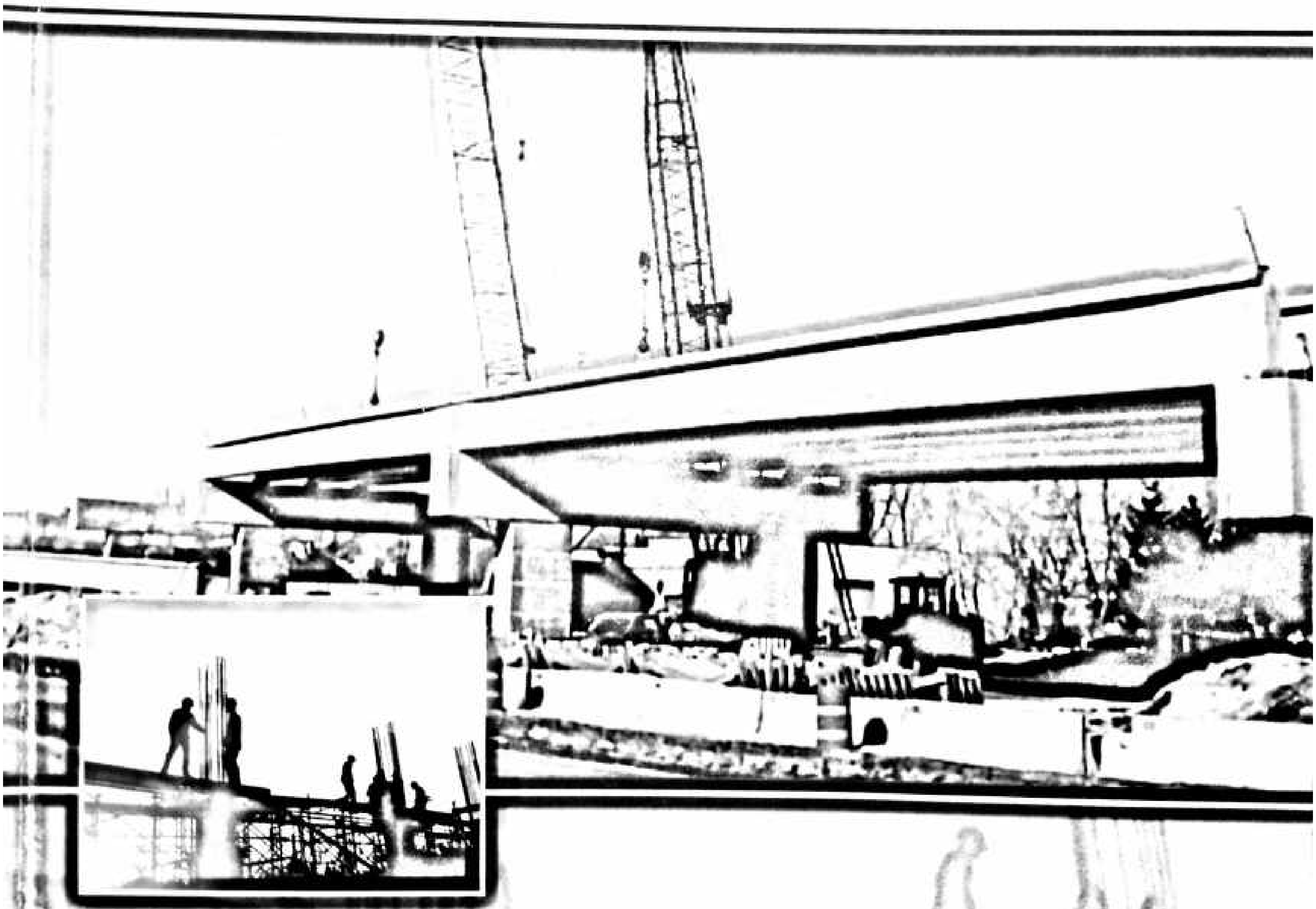
JOURNAL
OF
CIVIL AND ENVIRONMENTAL SYSTEMS ENGINEERING

UNIVERSITY OF BENIN



VOL. 17, ISSUE 1, JULY 2019

ISSN 15965538

JOURNAL OF CIVIL AND ENVIRONMENTAL SYSTEMS ENGINEERING

ISSN 15965538

FACTORS AFFECTING COST ESTIMATES FOR EARTHWORKS IN CIVIL ENGINEERING PROJECTS IN NIGERIA

[1]Chukwuemeka Patrick Ogbu and [2]Chinedu Chimdi Adindu

[1]Department of Quantity Surveying, University of Benin, Edo State, Nigeria.
[2]Department of Project Management Technology,
Federal University of Technology, Minna, Niger State, Nigeria.

Abstract
A large proportion of the Nigerian government's expenditure on capital project delivery involves civil engineering works, with greater emphasis on roadworks to create access for the conduct of economic activities by citizens. Most of the works of this scope awarded to indigenous contractors involve large volumes of cut and fill earthworks. Accurately estimating the cost of earthworks for most indigenous contractors is an arduous task owing to the stochastic nature of the input variables. This paper, therefore, seeks to identify key factors affecting the accuracy of earthwork cost estimates in civil engineering projects in Nigeria and to determine the effects of the factors on the level of accuracy of the estimates. The methodology of study involved a structured questionnaire survey of 78 indigenous contractors operating in the nation's South-East and South-South geopolitical zones. Five (5) major factors affecting the accuracy of earthwork cost estimates (contract requirements and equipment, estimator-related, microeconomic, nature of site and site-level management) were obtained by factor analysis using varimax rotation. However, based on ANOVA test of difference, the study found that the differing levels of accuracy of earthwork cost estimates are caused by contract requirements and equipment, estimator-related and microeconomic factors. Thus, the consideration of these three factors leads to higher levels of accuracy of earthwork cost estimates in civil works. The study recommends that indigenous contractors' earthwork cost estimators for civil works should give more attention to contract requirements and equipment, estimator-related, and microeconomic factors for improved accuracy of their estimates.

Keywords: *Cost estimates, civil engineering, earthworks, indigenous contractors.*

INTRODUCTION

It is widely held that estimates for earthworks in civil engineering projects are hardly accurate (Hola & Schabowicz, 2010). De Lima, et al. (2013) and Contreras, Aracena, and Chung (2012) also noted that earthwork is among the most expensive work items in road construction. The problems of earthwork cost estimates are twofold; firstly, the earthworks quantities are frequently imprecisely measured. Secondly, its unit rates are difficult to estimate due the stochastic nature of fleet productivities during earthwork operations (Rashidi, Nejad & Maghiar, 2014; Hola & Schabowicz, 2010; Simon, et al., 2000) This second problem makes equipment planning and selection critical and imperative since delays in the earthworks will not only affect the cost of the earthworks negatively, but will also delay the commencement of other succeeding construction activities (Morley, Lu & AbouRizk, 2013).

Ways to improve the accuracy of construction cost estimates, particularly, for earthworks have been of concern to numerous researchers (Skitmore, 1988; Al-Khaldi, 1990, Akintoye, 2000; Bablola & Adesanya, 2008). Different approaches to estimating earthwork costs including: expert judgement, mass-haul diagrams, deterministic methods, simulation linear/integer programming models, artificial neural network, and GPS machine guidance system, have been suggested (Jayawardane and Price, 1994; Hola & Schabowicz, 2010; Jonasson, Dunston, Ahmed & Hamilton, 2002). The most superior approach in terms of accuracy is yet unknown. Notably, most of these approaches are computer-driven and require considerable knowledge of specialised software/computer programming and construction equipment to use. The capacity of developing economies to cope is in doubt considering the low ebb of computer awareness and the preponderance of analogue system of working in most indigenous construction firms. Given this scenario, it is important to clarify the factors affecting the accuracy of earthwork cost estimates for civil engineering projects to aid the estimating practice of indigenous contractors. Factors affecting accuracy of construction cost estimates have been previously studied (Skitmore, 1988; Al-Khaldi, 1990, Akintoye, 2000). Excepting Bablola and Adesanya, (2008) which investigated the factors affecting the accuracy of estimates for electrical services, these studies were not specific to any particular construction cost item. Generally, therefore, not much is known of the factors that affect individual cost estimates of construction work items.

Earthworks constitute a significant portion of the cost of most civil engineering works (Mahamid, 2011). Its underestimation leads to a loss or a significant drop in a contractor's profit. Such an event will greatly undermine the contractor's survival, lead to project abandonment or contractual dispute (Ogbu, 2018). Estimators of indigenous contractors in Nigeria will greatly benefit from the knowledge of key factors affecting their estimates for earthworks in civil engineering projects. Suggested factors affecting accuracy of earthworks estimates in civil engineering projects are unorganised, and scattered in different studies (Skitmore, Stradling, Tuohy & Mkwezalamba, 1990; Rashidi, Nejad & Maghiar, 2014). Most of these studies are non-Nigerian, and may not reflect local realities in the country. A research gap exists for identifying and clarifying the factors that affect earthworks cost estimates in Nigerian civil engineering projects to aid estimators of indigenous contractors. This study therefore, seeks to investigate the factors affecting accuracy of earthworks cost estimates by Nigerian contractors with a view to improving the accuracy of the estimates.

Concept of Accuracy in Civil Engineering Earthworks Cost Estimates

Accuracy of a construction cost estimate is the extent to which the estimate is representative of the actual cost. Ogunlana (1989) explained estimating accuracy as the absence of error in estimate. Thus, an accurate estimate may be viewed as a situation where:

$$error\ (\%) = \frac{actual\ cost - estimated\ cost}{estimated\ cost} x100 = 0 \quad \ldots \quad \ldots \quad \ldots \quad \textit{Equation 1}$$

Estimated construction costs are hardly the same as the actual costs due to a number of factors. These factors are observably more pronounced for civil engineering earthworks cost estimation.

Skitmore and Ng (2003) regarded the accuracy of a construction cost estimate as largely dependent on the estimator's experience, competence and judgement in interpreting available construction information. Thus, certain factors affecting the accuracy of earthworks cost estimates are estimator-related. For instance, an estimator's experience and ability to use modern techniques of estimating can prove vital to the accuracy of his estimate. Cheng and Jiang (2013) compared 2D and 3D approaches to the computation of earthworks quantities, and found that the use of 3D models makes it easier to compute the quantities. Cheng and Jiang (2013) and Contreras et al. (2012) viewed the average end-area method using 2D cross-sections as more accurate when the interval between cross sections is less than 30m. In practice, the 2D cross-sections method will require numerous (often manual) iterations that end up facilitating errors. Contreras et al. (2012) suggested the use of high-resolution digital elevation model

(DEMs) derived from the light detection and ranging (LiDAR) technology for the computation of earthwork quantities. Babalola and Adesanya (2008) opined that an estimating system should be quick in operation and easy to use. In order to improve the speed and ease of earthworks estimating in civil engineering, Hajjar and Abourizk (2002) advocated the use of a simulation modelling approach (named 'Simphony') in estimating civil engineering earthworks. Similarly, Montaser, et al. (2012) demonstrated how the productivity of a fleet of earthwork equipment can be determined and optimised in near-real time. The method incorporates the use of global positioning system fixed to the earthworks equipment, simulation and use of spreadsheets in executing the computations. It is argued here that but the competence of the estimator and his chosen technology for estimating affect the accuracy of his estimates.

Earthworks estimation in civil engineering is also beclouded by difficulties in determining the outputs and optimum fleet composition for the operation. Considerable differences exist, as posited by Rashidi, et al. (2014) and *Yi and Lu (2017)*, between the productivities of construction equipment stated by the equipment manufacturers and the actual values achieved on site. Nigerian indigenous constructors normally hire equipment for civil engineering construction. In most cases, therefore, their estimators are ill-positioned to know the speed of the equipment or the abilities of their operators.

Babalola and Adesanya (2008) identified other factors affecting the accuracy of estimates to include project technicality, economic and contract requirements. Practically, the accuracy of an estimate will improve with increase in the exactitude with which these requirements are known at the time of estimating. Estimating accuracy is related to the quality of information on the contract available at the time of estimating (Chou, 2009). In many occasions, project information are scanty at the time of estimating. Sometimes, the state of a proposed site (in terms of soil profile, topography and quantity) changes between the time of estimating and project execution. In practice, it is frequently observed that the topographical survey data based on which earthwork quantities were computed do not match the state of the site at the time of commencement of the project. Inadequate research attention has so far been given to the seriousness of the impacts of such occurrences on the accuracy of earthwork cost estimates in Nigerian civil engineering projects. Figure 1 illustrates the conceptual model of this study.

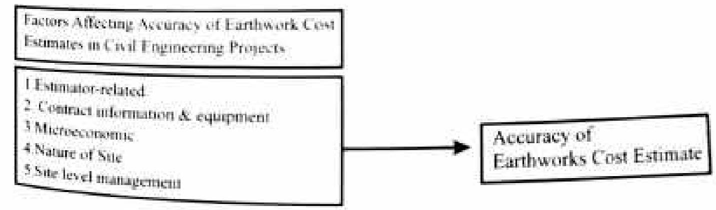


Figure 1: Conceptual Framework of the Study

Research Methodology

Variables affecting the accuracy of earthworks cost estimates in civil engineering projects were first identified through literature review. The variables (n=57) were qualitatively obtained from existing studies. However, they were collapsed into the headings 1) equipment Operator-related factors, 2) estimator-related factors, 3) information-related factors and, 4) project-related factors which closely follows the suggestion of Skitmore, et al (1990). Variables under these headings were ranked by indigenous contractors' estimators in South-South and South-East Nigeria using the scale demonstrated in Figure 2 below. The scale measures the impact of each of the identified variables on the accuracy of cost estimates for earthworks by the estimators. It ranges between 0 and 10, and makes it easy for the respondents to indicate their opinions up to one place of decimal. This approach helped to measure the responses on a near-interval scale.

Site data on the accuracy of earthworks cost estimates are difficult to obtain from the genre of firms in this study. Poor site record keeping remains a challenge in the project management skills of indigenous contractors in Nigeria. It was found more helpful to ask the professionals to indicate the percentage range of the accuracy of their earthworks estimates by stating the extent to which the initial estimate was exceeded. Thus, the accuracy of the estimates was categorised into (1) not exceeded (2) exceeded by 1 – 20% (3) exceeded by 21 – 40% (4) exceeded by 41 – 60% (5) exceeded by 61 – 80% (6) exceeded by 81 – 100% (7) exceeded by above 100% (Table 1). Using a range of accuracies reduces the urge to insert social desirability biased figures. Estimating is both an art and a science, and an estimator's cost estimate is both a function of objective data and his subjective assessments.

Figure 2: Scoring scale for impact of variables on the accuracy of earthworks cost estimates

Table 1: Accuracy of Estimates

Group	Accuracy of Estimate	Number of Respondents
1	Initial estimate not exceeded	6
	Initial estimate exceeded by:	
2	1 – 20%	9
3	21 – 40%	20
4	41 – 60%	27
5	61 – 80%	8
6	81 – 100%	5
7	above 100%.	3
	Total	78

Construction cost estimating is not restricted to any one profession in the industry. As a result, the questionnaire instrument for the study was purposively given to personnel of each contractor that was responsible for cost estimating. For this study, it was thought pertinent to restrict the survey to firms that have handled at least 3 civil engineering projects involving earthworks previously. A panel data having the names of indigenous contractors of this kind was not

found by the researchers. As a result, the study questionnaire was hand-delivered or sent through emails to indigenous contractors' estimators in South-South and South-East Nigeria. Of the 100 questionnaires sent out, 78 questionnaires fit for the analyses were returned. Data obtained for the study were tested for reliability using Cronbach's Alpha statistic at 95% confidence interval which showed $\alpha=0.909$, $p<0.000$. Hence the data was adjudged reliable and useful for the analyses.

One sample t-test was used to identify and remove variables with significantly negative mean differences from the data set. Thus, variables with means that are significantly lower than 5 were adjudged as having inconsequential effects on the accuracy of earthwork cost estimates. Eleven (11) such variables were identified and eliminated from further analyses.

Factor analysis was carried out to reduce the dimensionality of the variables and identify the major factors that affect the accuracy of the estimates. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sampling sphericity yielded acceptable values: 0.752 and $x^2 = 4245.527$ (df = 1596, $p < 0.000$). Fellows and Liu (1997) and Field (2005) posited that the minimum allowable value for the KMO test is 0.6, while Bartlett's test of sphericity should be significant at 0.05 (p ' 0.05) for a good fit factor analysis. Using the varimax rotation in Statistical Package for Social Sciences (SPSS) version 20, the factors realised through this process were saved for use in further analysis. Based on the saved factors, an analysis of variance (ANOVA) was carried out to test for differences in each of the earlier identified factors for the seven (7) estimate accuracy groups in Table 1.

Results

The result of the factor analysis is shown in Table 2. Based on the obtained scree plot (Figure 3), a 5-factor solution was determined for the analysis. The 5 factors cumulatively explain 54.05% of the variance in the variable set as shown in Table 3. Each of the factors was named following the main variables from which it was derived. Factor 1 was named "contract requirements and equipment" on account of the high loadings of project equipment and information variables under the factor. Similar reasons were adopted in naming the rest of the factors: factor 2 (estimator-related), factor 3 (microeconomic), factor 4 (site nature) and factor 5 (site-level management).

Table 2: Results of the Factor Analysis

	FACTORS AFFECTING ACCURACY OF ESTIMATES	Component				
		1 Contract requirements & Equipment	2 Estimator-related factors	3 Micro economic factors	4 Site nature	5 Site-level management
x19	Level of motivation of the operatives	0.913				
x16	Capacity of dump trucks in the fleet	0.892				
x15	Capacity of equipment like excavators, dozers, etc	0.892				
x4	Age/state of repair of the equipment to be used for the earthworks	0.877				
x45	Type of procurement contract	0.853				
x46	Type of client/Client behaviour	0.853				
x52	Contract value/sum	0.767				
x34	Site planning ability	0.766				
x44	Information on sites for borrow pits	0.767				
x18	Tests of Materials and Compaction	0.724				
x36	Ability to produce practical construction method statements	0.694				
x40	Knowledge of the local construction market	0.67				
x25	Estimator's Skill and Experience	0.600	0.776			
x28	Estimator's educational background	0.591	0.769			
x29	Estimator's professional background	0.58	0.765			
x27	Understanding of the project	0.565	0.763			
x26	Estimating technique used	0.579	0.758			
x23	Method for bringing and removing equipment from site (by trekking or by lowbed)		0.754			
x50	Allowed project duration		0.688			
x1	Uncertainty over the ability of equipment companies to deliver equipment to site at the right time			0.826		
x2	Whether the equipment to be used are owned, hired or leased by the company			0.731		
x43	Knowledge of microeconomic factors' influences on construction costs			0.663		
x6	Skill of the equipment operators			0.632		
x7	Haulage distance to and fro borrow pits			0.619		
x12	Nature of the ground on which the equipment moves (where the equipment stands on a different material from the one being worked on)					
x9	Knowledge of geotechnical characteristics of soil including bulking				0.743	
x5	Site topography				0.682	
x37	Understanding of the consultant engineer's preferences/behaviour				0.593	
x38	Skill and experience of site engineer					0.603
x41	Knowledge of client/consultants' expectations					0.533
						0.502
	Eigenvalue	13.018	3.818	3.056	2.343	2.084
	Percentage of variance explained (%)	28.928	8.485	6.797	5.207	4.63
	Cumulative percentage of variance explained (%)	28.928	37.413	44.21	49.417	54.05

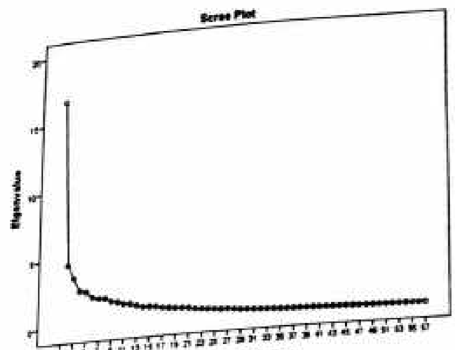


Figure 3: Scree plot for determination of 5-factor solution analysis.

Using the factors saved as variables during the factor analysis, one-way ANOVA was used to test the hypothesis that there is no significant difference in the accuracy of civil engineering earthworks cost estimates as a result of the factors. The result of the analysis is shown in Table 3. A significant difference exists among the 7 estimating accuracy groups as a result of contract requirements and equipment ($p<0.05$), estimator-related factors ($p<0.05$) and micro-economic factors ($p<0.05$). Site nature ($p=0.366$) and site-level management factors ($p=0.213$) affect the 7 groups equally and do not account for any significant differences in the accuracy of the estimates.

Table 3: ANOVA Test of Difference in the Accuracy of Cost Estimates for Earthworks in Civil Engineering Projects

FACTORS		Sum of Squares	df	Mean Square	F	Sig.
Contract requirements & Equipment	Between Groups	68.188	6	11.365	91.57	0.000
	Within Groups	8.812	71	0.124		
	Total	77	77			
Estimator-related factors	Between Groups	60.96	6	10.16	44.974	0.000
	Within Groups	16.04	71	0.226		
	Total	77	77			
Micro economic factors	Between Groups	42.579	6	7.096	14.638	0.000
	Within Groups	34.421	71	0.485		
	Total	77	77			
Nature of site	Between Groups	6.596	6	1.099	1.109	0.366
	Within Groups	70.404	71	0.992		
	Total	77	77			
Site-level management	Between Groups	8.329	6	1.388	1.435	0.213
	Within Groups	68.671	71	0.967		
	Total					

Discussion of Findings

Factor 1: Contract Requirements and Equipment

Construction contracts are unique endeavours. Each project comes with its own peculiarities. Findings from this study shows that the estimators consider the type of procurement contract, type of client and his behaviour, and contract value as having important influences on the accuracy of their estimates with level of motivation of operatives (0.913). Capacity of dump trucks (0.892), capacity of equipment like- excavators, dozers, etc (0.892), and age state of the equipment to be used for the earthworks (0.877). This result matches earlier findings by Babalola and Adesanya (2008) who studied the methods used in estimating for electrical services and found that contract requirements are among the key factors affecting the accuracy of the estimates. In this study, however, there were equal loadings for fleet and equipment-related variables with respect to capacities of the equipment, which makes it different from the studies of Babalola and Adesanya (2008). Understandably, earthworks require a significantly higher equipment cost component than electrical services. Many researchers have found equipment selection and optimisation as critical the accuracy of civil engineering earthworks estimates (Kannan, Martinez & Vorster, 1997, Yi & *Lu, 2017, Ercelebi & Bascetin, 2009*). Factor 1 points to the necessity of the estimator's grasp of the requirements of projects in relation to the available equipment for undertaking the job.

Factor 2: Estimator-related Factors

Factor 2 has high loadings in estimator-related variables like estimator's skill and experience (0.776), estimator's educational background (0.769), estimator's professional background (0.768), understanding the project (0.763), estimating techniques used (0.758). Construction estimator's skill set has been emphasised in previous studies pertaining to civil engineering. Martinez and Vorster (1997) regarded estimating as a science and an act, and observed that earthworks planning depends strongly on the experience of the estimator. Babalola and Adesanya (2008) equally identified estimator's experience as one of the factors affecting the accuracy of estimates for electrical works in Nigeria. However, an earlier related study in the UK by Akintoye (2000) did not find estimator-related factors among the 7 identified factors affecting estimating practice. Likewise, Al-Khalds (1990) found the factors affecting the accuracy of construction cost estimates in Saudi Arabia to be financing, construction parties, construction items and environment factors. Estimator related factors were excluded. Apparently, there exists some differences in the competences of estimators in the UK or Saudi Arabia and Nigeria which needs to be explored empirically. Evidently, the skill set of the estimator will have bearings on the estimating outcome which may be positive or negative. Estimators have the responsibility of evaluating the overall information on a project, and drawing meanings from them which have financial implications. The entire set of competences of the estimators is used in doing this.

Factor 3: Microeconomic factors

Microeconomic factors are those that have to do with the project's unique economic setting and local market. A good estimate will be reflective of the local setting of the project, and how things are done in that particular context. This factor was identified from the high loadings of variables such as uncertainty over the ability of equipment companies to deliver equipment to site at the right time (0.826), whether the equipment to be used are owned, hired or leased by the company (0.731), and knowledge of microeconomic factors' influences on construction costs (0.661). Microeconomic environment issues including banking systems, demand and supply, terms of credit for supply of materials, etc will assume relevance during earthworks cost estimating. Market condition, an aspect of microeconomic factors, is known to influence estimating accuracy (Akintoye, 2000; Babalola & Adesanya, 2008). Skitmore (1988) highlighted that contractor's estimators tend to give lower estimates in the 'good' years in which the contractors' workloads are high, and higher estimates in the 'bad' years when workloads are low. Estimators must be wary of locational and regional variations in microeconomic settings, and the impacts these may have on their estimates.

Factor 4: Nature of Site

Site nature relates to the nature of the soil on which earthworks equipment move, the topography of the site, and knowledge of geotechnical characteristics of soil including bulking. This factor was identified from the high loadings of variables such as - nature of the ground on which the equipment moves (0.743), knowledge of geotechnical characteristics of soil including bulking (0.682), site topography (0.593). Earthworks involves heavy equipment's movements on ground. A muddy ground will increase the rolling resistance of the ground, and reduce equipment speed and therefore, productivity. Effects of this nature, if not factored into the estimate, will reduce its accuracy. The type of surface on which an equipment moves affects its efficiency (Hola & Schabowicz, 2010). It is for this reason that Smith, Wood and Gould (2000) solicited for the availability of topographical and soil data to the earthwork cost estimator. Estimators need to know both the profile of the soil to be worked upon, and the relative elevations of points on its surface in order to make sound estimates of earthworks costs. In reality, having information alone does not amount to rightly interpreting and making informed judgements about it. This latter part will however, depend on the competence of the estimator having the information.

Factor 5: Site-level Management

Site-level management refers to the those in charge of managing operations on site. This factor was identified from the high loadings of variables such as - understanding of the consultant engineer's preferences/behaviour (0.603), skill and experience of site engineer (0.533), and knowledge of client consultants expectations (0.502). Irrespective of an estimator's efforts at factoring in other constraints, the competence and effectiveness of site leadership will matter in the performance of his estimate. Often, the contractor and consultant will maintain engineers on site to give instructions on site operations on behalf of the contracting parties. The ability of these personnel to lead, and to give sound guidance to site operatives is key to what becomes of the accuracy of any earlier established estimate. A similar factor was not found by Babalola and Adesanya (2008), Akintoye (2000) and Al-Khaldi (1990). Perhaps, the reason for this is that the cited previous studies were not specific on earthwork costs. Very often, the estimator is not the manager of construction operations. In the case of indigenous contractors in Nigeria, sometimes the estimator's engagement with the firm may have been terminated prior to commencement of site operations. Site-level managers are thus deprived knowledge of the estimator's assumptions and considerations in arriving at the estimate.

Relationship between the Factors and Accuracy of Cost Estimates for Earthworks in Civil Engineering Projects

Using the ANOVA test, it was found that while the first three factors (contract requirements and equipment, estimator-related factors, and microeconomic factors) led to significant differences in the accuracies of the estimates of the respondents, the last two factors (nature of site and site-level management) did not. A likely reason for this is that the last two factors apply to all the accuracy groups (Table 1) equally, not that the two factors are irrelevant. For example, the nature of site (in terms of soil properties and topographies) in the research area does not vary much. Likewise, it is likely that site-level management for the firms covered by the study have similar skills and experience, and behave alike as a result of high rate of construction labour mobility in the study area. Nigerian indigenous contractors have high employee turnover rates. Site supervisors are engaged when there is a job and disengaged when the project ends.

The estimator groups consider nature of site and site-level management as ubiquitous, hence the groups cannot be differentiated on the basis of these two factors. On the other hand, the degree of earthwork estimators' consideration of the first three factors will lead to differences in the level of accuracy their estimates.

Conclusions

In view of the challenging nature of earthwork costs estimating in civil engineering projects, this study examined the factors affecting accuracy of the estimates among indigenous contractors in Nigeria. Five such factors were identified using the factor analysis data reduction technique. They are: contract requirements and equipment, estimator related factors, microeconomic factor, nature of site, and site-level management. It was further revealed that the estimators' perception of impacts of nature of site and site level management on the accuracy of earthwork cost estimate is similar, irrespective of the estimator's differing levels of estimating accuracy. Consequently, there is no significant difference in the effects of nature of site and site level management on level of accuracy cost estimates for earthworks in civil engineering projects, whereas, for the other factors, there is.

One major implication of this study is that factors affecting accuracy of construction cost estimates differ for different cost items. Most previous studies tended to take wholistic views of construction cost estimates, which impaired their applicability. Future studies on accuracy of construction cost estimates should, rather than focus on all construction costs at once, specifically focus on individual cost items. Estimators of civil engineering earthwork costs in Nigeria should give attention to the all the factors identified in this study instead of considering only a narrower set of factors during estimating. It will further benefit the research community to repeat this type of study using a case study/ethnographic approach rather than a questionnaire survey in order to further validate the findings of this study or improve on them.

References

Akintoye, A. (2000). Analysis of factors influencing project cost estimating practice. *Construction Management & Economics, 18*(1), 77-89.

Al-Khaldi, Z. S. (1990). *Factors affecting the accuracy of construction costs estimating in Saudi Arabia* (Master's Degree thesis, King Fahd University of Petroleum & Minerals). Retrieved from https://core.ac.uk/download/pdf/12100195.pdf

De Lima, R. X., Junior, E. F. N., Prata, B. A, and Weissmann, J. (2013). Distribution of materials in road earthmoving and paving: mathematical programming approach. Journal of Construction Engineering and Management, 139(8), 1046-1054

Babalola, O. and Adesanya, D. A. (2008). An appraisal of the factors affecting production of cost estimate for electrical services in Nigeria, *Journal of Financial Management of Property and Construction*, 13(3), 200-208

Buchan, R. D., Fleming, E and Grant, F. (2003). *Estimating for Builders and Surveyors*, Burlington: Elsevier Butterworth-Heinemann

Cheng, J. C., and Jiang, L. J. (2013). Accuracy comparison of roadway earthwork computation between 3d and 2d methods. *Procedia-Social and Behavioral Sciences*, *96*, 1277-1285.

Chou, J. S. (2009). Generalized linear model-based expert system for estimating the cost of transportation projects. *Expert Systems with Applications*, *36*(3), 4253-4267.

Contreras, M., Aracena, P., & Chung, W. (2012). Improving accuracy in earthwork volume estimation for proposed forest roads using a high-resolution digital elevation model. *Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering*, *33*(1), 125-142.

Ercelebi, S. G., & Bascetin, A. (2009). Optimization of shovel-truck system for surface mining. *Journal of the Southern African Institute of Mining and Metallurgy*, *109*(7), 433-439.

Field A. (2005). Discovering statistics using SPSS. 2nd ed. Thousand Oaks (CA): Sage.

Flyvbjerg, B., Skamris Holm, M. K., & Buhl, S. L. (2005). How (in) accurate are demand forecasts in public works projects? The case of transportation. *Journal of the American planning association*, *71*(2), 131-146.

Hajjar, D. and AbouRizk, S. M. (2002). Unified modelling methodology for construction simulation. Journal of Construction Engineering and Management 128(2), 174-185

Hola, B. and Schabowicz, K (2010). Estimation of earthworks execution time cost by means of artificial neural networks. *Automation in Construction*, 19(2010), 570-579

Kannan, G., Martinez, J. C., & Vorster, M. C. (1997, December). A framework for incorporating dynamic strategies in earth-moving simulations. In *Proceedings of the 29th conference on Winter simulation* (pp. 1119-1126). IEEE Computer Society.

Lowe, D J, Emsley, M. W and Harding, A. (2006). Predicting construction cost using multiple regression techniques. ASCE Journal of Construction Engineering and Management, 132(7), 750-758, eScholarID:1b10328 | DOI:10.1061/(ASCE)0733-9364(2006)132:7(750)

Memon, A. H., Rahman, I. A., Aziz, A. A. A., & Abdullah, N. H. (2013). Using structural equation modelling to assess effects of construction resource related factors on cost overrun. *World Applied Sciences Journal*, *21*(5), 6-15.

Montaser, A., Bakry, I., Alshibani, A., & Moselhi, O. (2012). Estimating productivity of earthmoving operations using spatial technologies. *Canadian Journal of Civil Engineering*, *39*(9), 1072-1082.

Morley, D., Lu, M., & AbouRizk, S. (2013, December). Utilizing simulation derived quantitative formulas for accurate excavator hauler fleet selection. In *Simulation Conference (WSC), 2013 Winter* (pp. 3018-3029). IEEE.

Rashidi, A, Nejad, H. R., and Maghiar, M. (2014). Productivity estimation of bulldozers using generalised linear mixed models. Journal of Civil Engineering, 18(6), 1580-1589

Skitmore, M. (1988). Factors affecting the accuracy of engineers' estimates. In Proceedings, 10th International Cost Engineering Congress, The American Association of Cost Engineers, New York. Retrieved from http://eprints.qut.edu.au/59700/

Skitmore, R.M. and Ng, S.T. (2003) Forecast Models for Actual Construction Time and Cost. *Building and Environment* 8(8): pp. 1075-1083

Skitmore, M., Stradling, S., Tuohy, A., & Mkwezalamba, H. (1990). *The accuracy of construction price forecasts*. Technical Report, Department of Surveying, University of Salford. Retrieved from https://eprints.qut.edu.au/ 9550/1/9550.pdf

Jonasson, S., Dunston, P. S., Ahmed, K., & Hamilton, J. (2002). Factors in productivity and unit cost for advanced machine guidance. *Journal of construction engineering and management*, *128*(5), 367-374.

Love PED & Ahiaga-Dagbui DD (2018) "Debunking 'Fake News' in a Post-Truth Era: The Plausible Untruths of Cost Underestimation in Transport Infrastructure Projects" Transportation Research A: Policy and Practice, Volume 113, pages 357–368. DOI10.1016/j.tra.2018.04.019.

Mahamid, I (2011). Early cost estimating for road construction projects using multiple regression techniques. *Australasian Journal of Construction Economics and Building*. 11 (4)87-101

Odeck, J. (2004). Cost overruns in road construction—what are their sizes and determinants?. *Transport policy*, *11*(1), 43-53.

Odusami, K. T. and Onukwube, H. N. (2008). Factors Affecting the Accuracy of a Pre-Tender Cost Estimate in Nigeria, Cost Engineering; 50 (9), 32-35.

Ofori, G. (2000, November). Challenges of construction industries in developing countries: Lessons from various countries. *In 2nd International Conference on Construction in Developing Countries: Challenges Facing the Construction Industry in Developing Countries, Gaborone, November* (pp. 15-17).

Ogbu, C. P. (2018). Survival practices of indigenous construction firms in Nigeria. *International Journal of Construction Management, 18*(1), 78-91.

Ogunlana, S. O. (1989). Accuracy in design cost estimating. A Doctoral Thesis submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of the Loughborough University of Technology. Retrieved from https://dspace.lboro.ac.uk/2134/6747

Pick, J., & Sarkar, A. (2016, January). Theories of the Digital Divide: Critical Comparison. In *System Sciences (HICSS), 2016 49th Hawaii International Conference on* (pp. 3888-3897). IEEE.

Reilly, J. J. (2005, May). Cost estimating and risk management for underground projects. In *Proc., International Tunneling Conference. Underground Space Use: Analysis of the Past and Lessons for the Future – Erdem & Solak (eds). London: Taylor & Francis Group*, 533-538.

Yi, C., & Lu, M. (2017). Planning Rough-Grading Projects: CAT Handbook vs. RS Means. Computing in Civil Engineering 2017 (pp. 246-253). Retrieved from https://www.researchgate.net/profile/Chaojue_Yi/publication/317572412_Planning_Rough-Grading_Projects_CAT_Handbook_vs_RS_Means/links/5a1b9b30a6fdcc50adec8818/Planning-Rough-Grading-Projects-CAT-Handbook-vs-RS-Means.pdf

Skitmore, M., Stradling, S., Tuohy, A., & Mkwezalamba, H. (1990). The accuracy of construction price forecasts. Salford: University of Salford.