NSE TECHNICAL TRANSACTION VOL.45, NO.3, JULY – SEPTEMBER 201
OLUBOLA BABALOLA

DETERMINISTIC MODEL FOR ASSESSING ELECTRICAL ENGINEERING SERVICE COST

BY

OLUBOLA BABALOLA
Obafemi Awolowo University, Ile – Ife, Osun State

Abstract

This paper developed a deterministic model for electrical engineering service cost estimation. It collected secondary cost data on cost of cost-significant electrical engineering service items, tender data and design variables. The cost data were collected for 125 projects comprising eight different building types constructed in Lagos State and the Federal Capital Territory (FCT), Abuja.

The eight building types considered were banking, commercial, housing and religious building projects. Others included educational, health, industrial and office building projects. In addition, the building projects considered were those executed between 2003 and 2008.

The design variables were building height, storey height, number of floors and number of lifts.

The cost data were updated to 2008 to account for the effect of time on money.

The updated data wee then subjected to regression analysis to first determine the strength of the individual independent variable in singly predicting the dependent variable and thereafter developed a deterministic model using Stepwise Multiple Regression analysis.

The results of the analysis revealed that cost of standby equipment and cost of special equipment were the strong predictors of the total cost of electrical engineering service installation. The model produced take the form:

Y = 7462 312.15 + 5.95 stdby cost + 1.204 speqmtcost

With $r = 0.730$ and $r^2 = 0.534$.

It is concluded that only costs of standby equipment and special equipment are strong predictors of the total cost of electrical engineering service installation and that there is a strong, positive and direct relationship between the dependent and independent variables.

Keywords: *Cost Estimates, Electrical Service, models, cost-significant, predictors.*

Introduction

There is a growing awareness that estimating efficiency and accuracy can be improved by focusing attention on the small number of cost-significant items which represent the majority of the cost.

Identification of cost-significant items led to a system of iterative estimating which requires less than thirty percent (30%) of the effort of conventional procedures, yet produces an acceptable accurate prediction of total bill value (Horner et al., 1986). This paper developed a model that will aid electrical engineering service estimators in producing accurate estimates thereby improving their services to the end-users.

Consideration of the early design stage of projects when detailed information is limited and when major decisions affecting cost are made, necessitated the need for a method of obtaining estimates with greater speed and generally accepted reliability for more effective cost control. A number of proposals aimed at improving cost estimates have been made in published papers. One of such proposals is the use of cost models.

Cost modeling is a more modern method that can be used for producing the estimated cost of a proposed construction project. The term model is referred to as a simplified description of a system to assist calculations and predictions. Models are made necessary by the complexity of reality and convey not the whole truth but a useful and comprehensive part of it. A cost model, therefore, is a way of representing and estimating the unknown cost of work in terms of available information or parameters.

In the construction industry, cost models are classified as deterministic or stochastic cost model (Al-Jibouri, 1985).

Deterministic cost model is used to produce a single value estimate for construction work while the stochastic cost model assumes that the cost of construction work is subject to uncertainty and can be estimated only within limits.

Cost Estimating Models Developed by other Researchers

Review of published literature revealed that little research has been carried out on cost models for electrical engineering service cost estimation. While many models exist for predicting total construction cost, there are few cost models for electrical service. Among the cost models developed for general construction cost is the empirical model for estimating the construction costs of public school buildings by Al-Momani (1996). Al-Momani (1996) collected data on the cost of project at the awarding of the contract stage, value of variation orders, the final area in square metres, the highest bidding cost, the actual completion date, the specified completion date and the length of time extensions. Obviously, the data collected did not include cost of electrical engineering service. In like manner, Ariyibi (1999) developed a regression cost model for estimating the cost of raft foundations. He collected data on number of floors, depth of slab, total area of slab, number of lifts, deepest beam depth, perimeter floor area ratio, tender data, Building Cost Information Service (BCIS) tender price index, location of site and bank rate for 15 projects. Again, no data was collected on electrical engineering service costs.

In addition, Al-Jibouri and Mawdesley (2001) developed a stochastic cost prediction model for construction works.

Application of the model shows that the model provides an effective control mechanism and can produce reasonable forecasts of costs. This model is not specifically on electrical engineering service costs. Ogunlana et al., (2001) applied artificial neural network (ANN) modeling to forecast the construction cost of buildings at the pre-design stage with an average error of 4.4%. This model is for general construction cost and not specifically for electrical engineering service cost. Elhag and

Boussabaine (2002) developed 12 different cost models using ANN, the average accuracy of these models ranged from 30% and 90%. Emsley et al., (2002) also developed neural network cost models that give a mean absolute percentage error (MAPE) of 16.6%. All these models are not specifically on electrical engineering service cost estimating.

The few ones on electrical engineering service cost estimating include that of Gould (1970) who produced a cost model for heating, ventilating and air-conditioning services in buildings.

Blackhall (1974) developed a regression model for passenger lifts in office buildings. Wood (1975) also produced a cost model for piped heating systems in buildings using data from 200 projects.

These two models contain only electrical work associated with mechanical engineering service and not on detailed electrical engineering works.

In addition, Swaffield and Pasquire (1996) used multiple linear regression analysis on data collected from 628 BCIS detailed cost analysis published between 1987 and 1995 to produce a model for forecasting the tender costs of mechanical and electrical (M and E) services. In doing so, they noted that the incorporation of all the numerical parameters from the analysis into the original regression model was impossible because many of the projects examined did not have a complete set of data for all the parameters.

Consequently, they could only use a complete data set for 152 from the original sample of 628. In using the model produced to predict services cost for several projects from the sample, Swaffield and Pasquire (1996) noted that the results were unsatisfactory. They attempted to improve the predicting power of the model by producing several further regression models using different permutations of the independent variables used in the previous model, an acceptable model could still not be produced. This led to their conclusion that there was not a linear relationship between services cost and the parameters collected by the BCIS. Swaffield and Pasquire (1996) concluded that the format and detail of the cost data published by the Building Cost

Information Service (BCIS) is inadequate for the production of budget estimates for M and E services, and that a method of collecting more appropriate information is required. The conclusion of Swaffield and Pasquire (1996) led to this study of developing a deterministic cost estimating model for electrical engineering service installation.

Furthermore, Wong (2002) developed a cost model for plumbing and drainage systems. He investigated the construction cost, yearly maintenance cost and yearly remedial cost of plumbing and drainage systems in buildings. Again the model included electrical engineering works associated with mechanical engineering service only which is a fragment of electrical engineering service cost.

It is obvious from the review given that there is a need for the development of an electrical engineering service cost estimating model to aid estimators in producing accurate cost estimates. In achieving this objective, a preliminary review of priced bills of quantities was carried out and it was found that there are many items of work within the electrical engineering service bill to be priced by estimators. Estimating very large number of small items has been described by Edwards and Edwards (1995) as excessive, creating the possibility for disputes. It has also been suggested by Horner and Zakieh (1996) that considerable effort is associated with pricing the large number of small items, distracting attention of the estimator away from the important items in the bills of quantities (BOQ). One way of solving the problem of estimating large number of small items is by application of the concept of 80/20 estimating rule. More recent research has shown how the 80/20 rule can be applied to the development of new, unconventional ways of estimating and controlling the cost of construction projects. The concept states that those bill items whose value is greater than the mean consistently account for 80% of the project value, but represent only 20% of the total number (Shereef 1981). The finding has allowed the development of two important techniques: iterative estimating, whose use allows the value of a bill of quantities to be predicted to an accuracy of 5% without pricing more than 30% of the items in it; and cost-significant models which can be used both to estimate and to control construction projects, yet which contain only 10-20% of the items in a conventional bill of quantities (Saket et al., 1986).

The concept of 80/20 estimating has been widely used for general construction costs and found suitable (Ashworth, 1981; Ashworth and Skitmore, 1983; Harmer, 1983 and Horner et al., 1986) but has not been applied to electrical engineering service cost estimating. Consequently, this paper used the cost of cost-significant electrical items identified by Babalola (2008) with the design variables of 125 projects to develop a cost estimating model for electrical engineering service using regression analysis.

Munns and Al-Haimus (2000) reported that research had been on-going at the Construction Management Research Unit (CMRU) of the University of Dundee since 1981 to develop cost significant, quantity significant and resource significant models, for different types of project within the construction industry including bridges, roads and supermarkets. Mok et al., (1997) opined that the preparation of cost estimates for construction projects is not an easy job, because construction projects are subject to risks and uncertainties, particularly at the inception stage, when very limited information about the project is available. However, the cost estimates prepared at this stage are usually the most important to the client. Nowadays, the cost for electrical engineering service installation contributes a significant share of the total construction cost of building projects. Thus, the accuracy of the electrical engineering service cost estimates play an important role in the total construction project cost estimates.

Efforts should therefore be geared towards finding ways of improving the accuracy of cost estimates produced for electrical engineering service.

This paper, therefore, developed a model in line with opinions of researchers. The need for the model emanated from the opinion of Birnie and Yates (1991) who noted that the ability to make good cost prediction is a very important aspect of the construction process and that of Oberlender and Trost (2001) who noted the accuracy of an estimate is measured by how well the estimated cost compares to the actual total installed cost. Also, Fortune and Lees (2001) opined that clients in the construction industry need reliable strategic project cost information. It is hoped that the deterministic cost model developed in this paper for electrical engineering service will produce cost estimates that compare favorably well with the actual total installed cost and also provide reliable strategic cost information for electrical engineering service.

Research Methodology

The aim of this paper is to develop a deterministic model for cost estimation of electrical engineering service. This was achieved by collection of secondary cost data such as tender sums, location of project, date of award and gross floor area for eight different types of building project awarded between 2003 and 2008.

The design variables that affect cost of electrical engineering service items were also collected. The design variables included building height, storey height, number of floors and number of lifts.

The eight types of building project considered were banking, commercial, housing, religious, educational, health, industrial and office building projects.

Data were collected for a total number of 125 projects constructed in Lagos State and the Federal Capital Territory, Abuja.

It is recognized that the cost data collected are based on different points in time and also on different economic conditions. It is essential that some methods of taking into account the effect of time on money and changing economic conditions be found.

Consequently, the costs of the electrical installations and the costs of the identified cost-significant items were updated to 2008 using inflation rates (Appendix E) published by the Central Bank of Nigeria (2009).

In order to determine the strength of the individual independent variable in singly predicting the dependent variable (total cost of electrical service), a linear regression was conducted for each of the independent variables and the values of R, R^2 and Adjusted R^2 as well as B-values were noted. The variables were then rated on the basis of the adjusted R^2 which gives the percentage variance in total cost of installation that may be attributable to the given variable, with the largest value placed first and the next largest second and so on. The results were as presented on Table 1.

Table 1: Rating of Variables

Variable	R	R^2	Adjusted R^2	B- Values	Ratings
Mnscost	0.04	0.002	-0.007	0.04	14
Stdbycost	0.664	0.440	0.436	0.664	1
Speqmtcost	0.304	0.092	0.092	0.304	2
Noflrs	0.045	0.002	0.006	-0.045	6
Strhgt	0.107	0.011	0.003	0.107	10
Bldht	0.010	0.00	-0.008	-0.010	15
Nolift	0.066	0.004	0.004	-0.066	9
Gfa	0.009	0.000	0.008	-0.009	16
Housing	0.141	0.020	0.012	-0141	5
Banking	0.170	0.020	0.021	0.170	3
Commerce	0.072	0.005	-0.003	- 0.072	12
Education	0.056	0.003	0.005	-0.056	8
Office	0.074	0.005	0.003	-0.074	11
Religion	0.066	0.004	-0.004	0.066	13
Health	0.154	0.024	0.016	0.154	4
Industry	0.114	0.013	0.005	0.114	7

In order to develop the model, a stepwise Multiple Regression was conducted with the first two variables (stdbycost and Speqmtcost) entered into the first block, they were considered to have at least approximately 10% explanation for the observed variance in the dependent variable (the total cost of installation), the model is thereafter evaluated. The next three (bankn, heth and hou) which had at least 1% explanation for the observed variance were entered into the next block and the model was evaluated again. In the next block, others (noflrs, ind, edu, nolift, strhgt and office) whose adjusted R^2 were less than 0.01 but were positive were entered and the model evaluated.

Finally, all others (comm., relig, maincost, bldht and gfa) were entered into the last block and the model was conclusively evaluated. The results were as presented in Table 2.

Table 2: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.730 (a)	.534	.526	43471443.41399	.534	68.642	2	120	.000	
2	.735 (b)	.540	.521	43700584.72592	.007	.582	3	117	.628	
3	.737 (c)	.543	.493	44951457.66328	.002	.083	7	110	.999	
4	.738 (d)	.545	.471	45897238.64530	.002	.103	5	105	.991	2.165

a Predictors: (Constant), speqmtcost, stdbycost
b Predictors: (Constant), speqmtcost, stdbycost, hou, bankn, heth
c Predictors: (Constant), speqmtcost, stdbycost, hou, bankn, heth, edu, noflrs, ind, nolift, stryht, offce
d Predictors: (Constant), speqmtcost, stdbycost, hou, bankn, heth, edu, noflrs, ind, nolift, stryht, offce, mnscost, comm, gfa, relig, bldht

In Table 2, the R-values are the multiple correlation coefficients between the predictors and the predicted or outcome variables. When stdbycost alone was used in Table 2, the R-value was 0.664 and when speqmt cost was added in the regression procedure, the R-value rose to 0.730 (see Table 2) with a difference of 0.066. The value of R^2 which is the value of the amount of variability in the outcome that can be accounted for by the predictors also rose from 0.440 to 0.534 while Adjusted R^2 change from 0.436 to 0.526.

In model 2, when housing, banking, and health were included, the R-value rose to 0.735 producing a change of 0.005.

The value of R^2 also rose from 0.534 to 0.540 while adjusted R^2 changed from 0.526 to 0.521. Since the Adjusted R^2 values are reducing in models 2, 3 and

4, it implies that the models could not be upheld. In addition, a look at the significance of the F change shows that it was only in the first model that the P-value was significant (sig. F change = 0.000). This confirms that only model 1 can be upheld. It also implies that only standbycost and speqmtcost were the significant joint predictors of total cost of installation while others did not significantly predict total cost. It can then be inferred that model 1 is the only model by which we can predict total cost. The parameters of the models were investigated and the results were presented in Table 3.

Table 3: Coefficients or Parameters of the Model

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	-7462312.150	4489259.041		-1.662	.099					
	Stdbycost	5.950	.558	.664	10.658	.000	.664	.697	.664	1.000	1.000
	Speqmtcost	1.204	.246	.306	4.900	.000	.303	.408	.305	1.000	1.000

This study is interested in the final acceptable model so, it includes all the predictors that make significant contribution to predicting total cost of electrical engineering service installation to produce model (From Table 3).

Y = 7462312.150 + 5.95 stdbycost + 1.204 speqmtcost

Where Y = total cost of electrical installation

Stdbycost = cost of standby equipment and

speqmtcost = cost of special equipment

The model takes the form of an equation that contains a coefficient (B) for each predictor. The B-value gives the relationship between individual contributions to predicting total cost of installation. From Table 3, the B-Value for stdbycost was 5.95 while that of speqmtcost was 1.204, showing that standby cost was a stronger predictor and that they were both positively related. From Table 3 also, the t-values test of the B-values differs significantly from zero. It can be seen that the associated P-values were less than 0.05 implying that they differ significantly from zero and that the contributions of the predictors were significant.

Conclusion

This paper has been able to develop a deterministic model for estimating cost of electrical engineering service using updated cost of cost-significant electrical service items, tender data and design variables. From the analysis carried out, it can be concluded that only costs of standby equipment and special equipment are strong predictors of the total cost of electrical installation. The deterministic model developed takes the form.

Y = 7462312.15 + 5.95 stdbycost + 1.204 speqmtcost

With coefficient of correlation (r) = 0.730 and coefficient of determination (r^2) = 0.534. It can therefore be concluded that there is a strong, positive and direct relationship between cost of electrical engineering service installation on one hand; and costs of standby equipment and special equipment on the other hand. Cost of standby equipment is a stronger predictor of the cost of electrical engineering service installation than cost of special equipment. The two variables account for 53 percent of the variations in the total cost of electrical engineering service installation.

REFERENCES

1. Al-Jibouri, S.H. (1985): Cost models for construction. Unpublished Ph.D thesis, University of Nottingham.

2. Al-Jibouri, S.H. and Mawdesley, M.J. (2001): Development and application of a stochastic based cost prediction model for construction. *Journal of Financial Management of Property and Construction*, ***6(1), 61 – 69.***

3. Al-Momani, A. (1996): Construction cost prediction for public school buildings in Jordan. Construction Management and Economics, 14, 311 317. Ariyibi,

4. O.K.(1999*):* Cost model for raft foundation. Unpublished M.Sc thesis, University of Lagos.

5. Ashworth, A. (1981): Cost modelling for the construction industry. *The Quantity Surveyor,*37, 132 – 134.

6. Ashworth, A. and Skitmore M. (1983): Accuracy in estimating, Occasional paper No. 27, Chartered Institute of building, London.

7. Babalola, O. (2008): Application of 80/20 Theory to Electrical Engineering Service *International Conference Proceedings of Project Management,* November, Malaysra, pp 486-491.

8. Birnie, J. and Yates, A. (1991): Cost prediction using decision risk analysis methodologies. Construction Management and Economics 9, 171 – 186.

9. Blackhall, J.D. (1974): The application of regression modeling to the production of a price index for electrical services. Unpublished M.Sc thesis, Loughboroug University of Technology.

10. Central Bank of Nigeria (2009): Statistical Bulletin , golden jubilee edition, CBN, Nigeria.

11. Edwards, P.J. and Edwards, M. (1995): A price-rationalized approach to item separation in the measurement of building work. *Construction* management and economics, 13, 485 – 491.

12. Elhag, T. and Boussabaine A.H. (2002): Tender price estimation using

artificial neural networks II: modeling. *Journal of Financial Management of Property and Construction*, 7(1), 49 – 64.

13. Emsley, M.W., Lowe, D.J., Roy Duff, A., Harding, A. and Hickson, A. (2002):

14. Data modeling and the application of a neural network approach to the prediction of total construction costs. *Construction Management and Economics* 20(6), 465 – 475.

15. Fortune, C. and Less, M. (2001): Systematic errors of judgment and the formulation of strategic cost advice for construction clients. *Journal of Financial management of property and Construction*, 6(2), 81 – 93.

16. Gould, P.R. (1970): The development of a cost model for HVAC installation in buildings. Unpublished M.Sc. thesis, Loughborough University of Technology.

17. Harmer, S. (1983): Identifying significant BQ items, *Chartered quantity surveyor*, 6(3), 95.

18. Horner R.M. and Zakieh, R. (1996): Characteristic items – a new approach to pricing and controlling construction projects. *Construction management and economics*,14, 241-252.

19. Horner, R.M.W., Mickay K.J. and Saket, M.M. (1986): Simple computer model of the construction process *ABSE workshop organization of the design process*, U.K. 79 – 81.

20. Mok, C.K., Tummala V.M. R. and Leung, H.M. (1997): Practices, barriers and benefits of risk management process in building services cost estimating, *Construction management and economics*, 15, 161 – 175.

21. Munnis, A.K. and Al-Haimus, K.M. (2000): Estimating using cost significant global cost models. *Construction Management and Economics, 18, 575 - 585.*

22. Oberlender, G.D. and Trost, S.M. (2001): Predicting accuracy of early cost estimates based on estimate quality. *Journal of Construction engineering and Management* 127(3), 173 – 182.

23. Ogunlana, S.O., Bhokha, S. and Pinnemitor, N. (2001): Application of artificial neural network (ANN) to forecast construction cost of buildings at the pre-design stage. *Journal of Financial Management of Property and Construction*, 6(3), 179 – 192.

24. Saket, M. M., McKay, K.J. and Horner, R.M.W. (1986): Some applications of the principle of cost-significance. *International Journal of Construction Management and Technology*1, 3, 5 – 22.

25. Shereef, H.A.C (1981): Measurement and control of labour productivity on construction, sites. Unpublished M.Sc. thesis, The University of Dundee.

27. Wong, L.T. (2002): A cost model for plumbing and drainage systems. *Facilities* 20(11/12), 386 – 393.

28. Wood, A.S. (1975): Models for estimating the cost of pipes heating systems in building. Unpublished M.Sc. thesis, Loughborough University of Technology.