APPROPRIATE COST-SIGNIFICANT MODEL FOR MECHANICAL ENGINEERING SERVICES COST ESTIMATING

By

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Abstract

The importance of accurate estimates has been widely recognized for many years. Efforts had been made by researchers to improve upon the cost estimates produced for general construction works with little attention given to the production of accurate cost estimates for mechanical engineering service.

This paper therefore develops a cost-significant regression cost estimating model for mechanical engineering service using tender figures, cost of cost-significant mechanical items and design variables. Cost data for 123 mechanical engineering service works for eight different types of building project awarded between 1993 and 2008 in Lagos State and Federal Capital Territory, Abuja were collected and used for the analysis.

The cost data collected were updated to 2008 using inflation rate in order to account for the effect of time on money and the changing economic condition in Nigeria. The updated data were then subjected to regression analysis to produce the cost-significant estimating model. The results of the analysis showed that there is a strong and direct relationship between cost of mechanical engineering service on one hand and design variables and cost of cost-significant mechanical items on the other hand.

The developed model was tested with known sample data. The result of the test showed that the developed model produced estimates with co-efficient of variation (CV) of 1.33% which is an improvement on the 5-9% CV specified as being achievable in practice.

Keywords: *Model, Cost-significant items, Cost estimating, Design variables, Mechanical Engineering service*

Introduction

A large number of construction cost estimating techniques are available to estimators. These techniques had been described in many standard textbooks on cost estimating [Bentley (1987); Buchan et al., (1991); Kwaye (1994); Smith (1995) and Ashworth (1999)] . Daschbach and Apgar (1988) buttressed the fact that cost estimating methods have been developed for preparing estimates of various types and for various purposes.

However, the more modern method used for the production of cost estimates of a proposed construction project is 'cost model' because it gives a better representation of construction costs than the conventional cost estimating methods by providing the true determinants of construction costs. The term "model" is a simplified description of a system used for the calculation of estimated costs. Al-Jibouri (1985). Eldin (1989) and Bowen (1993) classified all the single-price rate and the multi-price rate methods as "price models" while Bowen and Edward (1985) noted that models only represent reality and do not become reality. A cost model can therefore be defined as a system of estimating the unknown cost of construction works using relevant information and parameters. The term is generally referred to as unconventional approach to estimating and forecasting (Beeston, 1983). In construction works, the cost models are used for planning, providing budget amounts and predicting the costs of construction as well as providing basis for project cost control.

One of the major aims of research in construction cost estimating is to develop techniques that can help estimators/contractors in tendering for and in winning building contracts.
The developed techniques allow subjective decisions to be replaced by objective decisions taking into consideration clearly formulated and articulated objective functions. It is against this background that this paper sets out to develop an appropriate cost- significant estimating model for mechanical engineering service to aid the production of accurate cost estimates for this aspect of construction works.

The Development of Cost Models

In construction industry, cost models are classified as 'deterministic' that produces a single value estimate or 'stochastic' that assumes that the cost of construction work is subject to uncertainty and can be estimated only within limits (Al-Jibouri, 1985). The major research into the development of cost models included the work of Raffery (1987) who noted that there was little order or formal direction to current cost modeling research. Raffery (1987) considered development in building cost modeling and noted that they have taken place in three distinct generations based on historical developments. These are First Generation, Second Generation and Third Generation models. The First Generation models, according to Raffery (1987), included superficial method, the storey enclosure, elemental estimating and the appropriate quantities while the Second Generation models included such models developed by Buchaman (1969) who produced a cost model for reinforced concrete frames in buildings and by Neale (1973) who produced a cost model for houses built by a private contractor for private sale. Others included the works of Baker (1974) and Coates (1974) that produced a cost models for residential apartment schemes for old people and an estimating cost model for laying motor way drainage using porous pipes, helpline pipes and asbestos pipes respectively. Ashworth (1977) and Bowen (1982) also produced cost models for man-hours calculation for brickworks and a regression model to predict the cost of the structural frame in buildings respectively. The Second Generation models, according to Bowen (1993), were characterized by their deterministic nature and the applications of mathematical statistical techniques.

Furthermore, Raffery (1987) mentioned the works of Wilson (1982), Mathur (1982) and Erwin et al., (1991) under the Second Generation models. Eldin (1989) noted that researchers took advantage of computer applications and statistical analysis in particular, in relation to computer simulation to produce cost models for construction works. The third generation models were discussed by Raffery (1987) mainly from the view point of a shift in quantitative techniques (from deterministic to probabilistic).

In like manner, Newton (1991) researched into the classification of cost modeling using descriptive primitives to classify 50 reviewed cost models. He proposed a basic classification system with which to set out the overall topology of cost modeling as a distinct subject and to provide the much needed points of reference on which individual research contribution would be located. The descriptive primitives used were relevance (specific or non-specific), units of measurement (abstract, finished work, as-built), cost price, approach (micro, macro) and time-point (feasibility, sketch, detailed, tender, throughout non-construction). Others included model (simulation, generation, optimization), technique (dynamic, programming, linear programming, Monte Carlo simulation regression and so on), assumption, (explicit, implicit) and uncertainty (deterministic or stochastic).

The classifications of models by Raffery (1987) and Newton (1991) included few mechanical engineering service cost models. It follows therefore that there is need for the development of mechanical engineering service cost model. More so that engineering design has high level of influence on project cost (Barrie and Paulson, 1992 cited in Chang 2002).

Groen and Tan, 1977; Daschbach and Apgar, 1988; Ntuen and Mallik, 1989; Klumpar 1990; Shash and Khaldi, 1992; Law, 1994; Al-Jibouri and Mawdesley 2000 and Ogunlana et al., 2001 buttress the fact that most research efforts have been devoted to the development of estimating cost models for general construction works with less attention paid to cost estimating model for mechanical engineering service. Consequent upon this observation and considering the fact that Babalola (2006) had established that there was a wide variation in cost estimates produced for mechanical engineering service coupled with the finding of Chang (2002) that cost variation of construction constitutes a major problem in construction project, it follows therefore that there is the need to develop a cost estimating model for mechanical engineering service which this paper aimed at.

In addition, this paper originated from the 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 construction cost and led to the identification of cost-significant items. This, in turn, has brought about a system of iterative estimating which requires less than thirty percent of the effort of conventional procedures, yet produces an acceptably accurate prediction of total bill value (Horner et al., 1986). It was noted by Horner and Zakieh, (1996) that considerable effort is associated with pricing large number of small items, distracting the attention of the estimator away from the important items in the Bill of Quantities (BOQ). Beeston, (1983) also highlighted the problems associated with trying to predict the price of these items accurately.

Cost-significant model was then suggested by Horner and Zakieh, (1996) and Munns and Al-Hamus (2000) as one way of overcoming the criticisms of the amount of detail contained within the traditional BOQ. Numerous researchers (Barnes and Thompson, 1971; Ashworth; 1981; Seeley, 1981; Ashworth and Skitmore 1983; Harmer, 1983) have observed and commented upon the fact that twenty percent of the measured bill items contribute eighty percent of the total measured bill value. These findings conform to the 80/20 rule established by Vilfredo Pareto. The twenty percent of the items which have the highest value are generally referred to as the cost-significant items. All the listed research endeavours into cost-significant models were majorly on general construction works with none in published literature on mechanical engineering service installation.

From the foregoing, it can be concluded that researchers have addressed themselves to the issue of general construction works with few research on mechanical engineering service. Hence the need for cost-significant estimating model for this aspect of construction works that is normally estimated for by specialist estimators and installed by specialist subcontractors as distinct from general contractors. The importance of the developed model cannot be over emphasized because Fortune and Lees (2001) noted that clients in the construction industry need reliable strategic project cost information. The developed model will aid mechanical engineering service estimators in producing accurate estimates, which a survey carried out by Anderson and Tucker (1994) and Babalola (2006) revealed that the estimates produced for mechanical items are inaccurate, thereby improving their services to the end users.

Research Methodology

To achieve the objective of this paper, secondary cost data were collected from quantity surveyors whose clients were satisfied with the services they rendered as identified by Babalola (2006). The data collected included tender figures for mechanical engineering service awarded between 1993 and 2008 in Lagos State and the Federal Capital Territory, Abuja. Cost data for 123 mechanical service works comprising eight different building types were collected. The building types included housing, banking, commercial, educational, office, religious, health and industrial projects. In addition to these, design variables such as storey height, building height, number of floors, number of lifts and gross floor area were collected for each of the building projects.

The cost of each cost-significant mechanical item identified by Babalola (2008) for each building type was also collected. The identified cost-significant items for mechanical engineering service are sanitary and fire-fighting installations for banking, commercial and educational projects. Others include sanitary installation for housing project while religious project has fire-fighting and borehole installations as cost-significant items. Furthermore, health and industrial projects have sanitary, fire-fighting and special equipment as cost-significant items. It is recognized that the cost data collected were based on different points in time and also on different economic conditions. Hence, the tender figures and the cost of each cost-significant item were updated to 2008 using inflation rates published by the Central Bank of Nigeria (see Appendix A). This step was taken in order to account for the effect of time on money and the changing economic condition in Nigeria. All costs are in Nigerian naira (#).The summary of the input data are presented in Table 1.

Table 1: Summary of Input Data showing Project Factors

Project Factors	Number
(A) Tender figures (#)	
0 – 25,000,000	109
25,000,000 - 50,000,000	6
50,000,000 - 75,000,000	3
75,000,000 – 100,000,000	3
100,000,000 – 125,000,000	2
(B) Project Type	
Housing	26
Banking	22
Commercial	15
Educational	10
Office	20
Religious	10
Health	10
Industrial	10

(C) Number of Floors	
1 - 2	67
3 - 4	43
5 - 6	12
7 - 8	1
(D) Storey Height (m)	
3 - 4	99
5 - 6	24
(E) Building height (m)	
0 – 5.00	17
5.10 - 10.00	53
10.10 – 15.00	35
15.10 – 20.00	15
20.10 – 25.00	2
25.10 – 26.00	1
(F) GFA (m^2)	
0 – 1000	81
1001 – 2000	36
2001 – 3000	6
(G) No. of lifts	
1	10
2	10

The updated tender figures were regressed against the updated costs of the cost-significant items and the design variables using the Statistical Package for Social Sciences (SPSS) 16.0 for window to produce the regression cost model (output shown in Appendix B):

Y = -6.267E6 - 0.027sancost + 6.352 firecost – 0.927liftcost – 12.312 borehole + 1.363 speqmtcost – 1.192E7noflrs -4.868E6stryht + 3.359E6bldht - 1.262E6nolift +2855.288gfa +1.997E7hou +7.302E6 comm + 6.239E6edu +2.353E7 offce +2.184E7relig + 5.95148.345 heth +5.532E6 ind.

with coefficient of correlation of 0.739 and coefficient of determination of 0.545

where

Y=updated total cost of installation
sancost = cost of sanitary installation
firecost = cost of fire installation
liftcost = cost of lift installation
borehole = cost of borehole installation
speqmtcost = cost of special equipment
noflrs = number of floors

stryht = storey height
bldht = building height
nolift = number of lifts
gfa = gross floor area
hou = housing project
comm. = commercial project
edu = educational project
offce = office project
relig = religious project
heth = health project and
ind = industrial project.

Model Testing

Any developed model has to be subjected to testing and found to produce accurate and reliable cost estimates before it can be used for estimating purpose. Consequently, the next step taken after the development of the regression cost-significant model for mechanical engineering service was to fit the equation into known sample data. The details of the test cases are shown in Table 2 while the results of the tests are shown in Table 3.

Table 2: Details of Test Cases (Updated cost in Naira #)

Type of Project	Sanitary Cost (#)	Fire Cost (#)	Borehole Cost (#)	Lift cost	Storey Height	Building Height (m)	Special Equipment Cost (m)	No. of Floors	No. of Lift	GFA (m^2)
Housing	651,993.55				3.00	7.20		2		524
Housing	422,548.07				3.00	4.10		1		306
Housing	939,889.62				3.00	7.40		2		608
Housing	664,252.48				3.00	6.80		2		512
Commercial	1,463,688.76	2,899,564.50			3.00	6.80		2		1020
Commercial	427,671.76	905,208.33			3.00	7.00		2		630
Educational	4,669,847.28	10,966,812.98			3.00	16.90		5		1560

Office	2,606,584.96	1,190,165.88		8,069,600	3.00	26.40		.8	2	3344
Office	1,546,561.02	1,219,472.29		4,776,000	3.00	20.00		6	2	2280
Office	847,827.00	1,540,385.10		4,584,000	3.00	19.70		6	2	2592
Religious		1,653,367.99	2,716,134.32		6.00	7.30		1		425
Religious		629,066.58	287,133.00		5.80	7.00		1		386
Religious		2,251,781.02	2,522,000		4.00	9.80		2		752
Health	1,782,442.75	2,637,404.58			3.00	7.30	78,875,000	2		648
Industrial	1,650,000	3,700,000			6..00	7.10	52,400,000	1		650
Industrial	800,820.00	2,957,062.69			6.00	7.00	9,720,000	1		426

Table 3: Model Testing

Actual Cost of Installation (#) (a)	**Updated cost of Installation (#) (b)**	**Predicted Cost of Installation (#) (c)**	**Standard Deviation $(c-b)^2$**
5,433,279.60	814,991.94	922,367.09	1.1528×10^{10}
4,466,222.80	669,933.42	551,380.53	1.4055×10^{10}
6,563,475.03	1,174,862.03	1,524,438.08	1.2220×10^{10}
10,253,974.63	840,825.92	1,022,559.04	3.3027×10^{10}
32,500,955.36	5,817,671.01	6,723,107.87	8.1982×10^{11}
16,520,342.67	2,478,051.40	2,553,625.22	5,711,402.269
50,321,581.20	7,548,237.18	5,278,859.74	5.1501×10^{12}
193,866,101.64	22,488,467.79	31,410,719.75	7.9607×10^{13}
112,165,873.17	9,197,601.60	11,961,035.48	7.6366×10^{12}
165,532,101.11	8,400,733.46	7,700,673.32	1.5328×10^{12}
36,721,302.23	6,573,113.10	5,907,304.45	4.4330×10^{11}
9,125,757.07	1,376,363.56	1,493,966.72	1.3831×10^{10}
45,296,240.78	5,254,363.93	6,203,197.43	9.0029×10^{11}
617,457,061.07	92,618,559.16	89,718,069.81	8.4128×10^{12}
467,078,189.33	70,061,728.40	78,720,887.20	7.4980×10^{13}
297,131,452.59	16,045,098.44	15,548,152.75	2.4696×10^{11}
Total	251,898,652.30		$1.7992 \times 10^{14} \div 16 = 1.1245 \times 10^{13}$

			$\sqrt{1.125 \times 10^{13}}$

$$\text{Coefficient of Variation (CV)} = \frac{3,353,396.755}{251,898,652.30} \times 100\%$$

$$= 1.3313\%$$

From Table 3, the regression cost- significant model developed produced estimates with a coefficient of variation of 1.3313%.

Evaluation of Findings

The regression cost-significant model developed produced cost estimates with a coefficient of variation of 1.33 percent which is an improvement on the 5 to 9 percent specified as being achievable (Lorenzoni ,1986; Skitmore, 1986).

It is expected that the adoption of the developed model (with none in existence before now) will aid mechanical engineering services estimators in producing accurate estimates which presently is assessed as being inaccurate (Anderson and Tucker (1994) and Babalola (2006) at reduced time. Most importantly, that Oberlender and Trost (2001) had noted that the accuracy of an estimate is measured by how well the estimated cost compares to the actual total installed cost.

The regression cost-significant model developed produced coefficient of correlation (r) of 0.739 indicating a strong and direct relationship between the variables. The developed model also produced coefficient of determination (r^2) of 0.545 indicating that 55percent of the variability in the cost of mechanical engineering installation is accounted for by cost of cost-significant mechanical items and design variables. These figures are high and indicate a strong correlation between tender figures, the cost of cost-significant items and the design variables implying that there is no other variable to be included in the model. It is noticed from the result of the analysis that banking project was excluded from the regression equation. This variable was excluded because it does not have any significant contribution to the effectiveness of the model in the prediction of the dependent variable (Morenikeji, 2006). Consequently, banking project was excluded in the model testing.

Conclusion

The paper developed a cost-significant regression model with the inclusion of tender figures, cost of cost-significant mechanical items and design variables for mechanical engineering services. The developed model when tested on known data for seven different building project types, namely housing, commercial, educational, office, health, religious and industrial building projects, produced cost estimates with coefficient of variation (CV) of 1.33 percent which is an improvement on the 5 to 9 percent CV suggested as being achievable in practice. There is a strong, positive and direct correlation between tender figure, cost of cost-significant items and design variables. It is therefore concluded that the developed cost-significant regression equation:

Y = -6.267E6 - 0.027sancost + 6.352 firecost – 0.927liftcost – 12.312 borehole + 1.363 speqmtcost – 1.192E7noflrs -4.868E6stryht + 3.359E6bldht - 1.262E6nolift +2855.288gfa +1.997E7hou +7.302E6 comm + 6.239E6edu +2.353E7 offce +2.184E7relig + 5.95148.345 heth +5.532E6 ind.

with coefficient of correlation of 0.739 and coefficient of determination of 0.545 produces accurate cost estimates for mechanical engineering service.

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APPENDIX A

Inflation Rate (%)

Year	Inflation Rate (%)
1993	57.2
1994	57.0
1995	72.8
1996	29.3
1997	8.5
1998	10.0
1999	6.6
2000	6.9
2001	18.9
2002	12.9
2003	14.00
2004	15.00
2005	17.9
2006	8.2
2007	85.4
2008	11.6

Source: Central Bank of Nigeria (2008)

APPENDIX B

Descriptive Statistics

	Mean	Std. Deviation	N
Totcost	1.7894E7	6.31291E7	123
sancost	2.1657E6	7.60862E6	123
firecost	3.2771E6	7.04991E6	123
Liftcost	4.6363E5	1.56622E6	123
borhole	5.3829E4	2.78430E5	123
Speqmtcost	4.8640E6	1.60155E7	123
Noflrs	2.5935	1.45893	123
Stryht	3.6480	1.01266	123
Bldht	9.8460	4.50117	123
Nolift	.2439	.59149	123
Gfa	8.9302E2	535.86038	123
Hou	.1951	.39792	123
Bankn	.2033	.40406	123
Comm.	.1220	.32857	123
Edu	.0813	.27441	123
Offce	.1626	.37051	123
Relig	.0732	.26148	123
Heth	.0813	.27441	123
Ind	.0813	.27441	123

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	ind, sancost, bldht, borhole, edu, firecost, comm, heth, nolift, stryht, liftcost, speqmtcost, relig, gfa, hou, offce, noflrs[a]	.	Enter

a. Tolerance = .000 limits reached.

b. Dependent Variable: totcost

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.738[a]	.545	.471	4.58972E7

a. Predictors: (Constant), ind, sancost, bldht, borhole, edu, firecost, comm, heth, nolift, stryht, liftcost, speqmtcost, relig, gfa, hou, offce, noflrs

b. Dependent Variable: totcost

ANOVA[b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	2.650E17	17	1.559E16	7.400	.000[a]
	Residual	2.212E17	105	2.107E15		
	Total	4.862E17	122			

a. Predictors: (Constant), ind, sancost, bldht, borhole, edu, firecost, comm, heth, nolift, stryht, liftcost, speqmtcost, relig, gfa, hou, offce, noflrs

b. Dependent Variable: totcost

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-6.267E6	4.967E7		-.126	.900	-1.048E8	9.222E7
	sancost	-.027	.577	-.003	-.046	.963	-1.172	1.118
	firecost	6.352	.676	.709	9.393	.000	5.011	7.693
	liftcost	-.927	4.073	-.023	-.228	.820	-9.003	7.150
	borhole	-12.312	23.368	-.054	-.527	.599	-58.647	34.023
	speqmtcost	1.363	.415	.346	3.282	.001	.539	2.186
	noflrs	-1.192E7	2.267E7	-.275	-.526	.600	-5.687E7	3.304E7
	stryht	-4.868E6	1.187E7	-.078	-.410	.683	-2.841E7	1.868E7
	Bldht	3.359E6	6.426E6	.240	.523	.602	-9.382E6	1.610E7
	Nolift	-1.262E6	2.062E7	-.012	-.061	.951	-4.215E7	3.963E7
	Gfa	2855.288	14013.868	.024	.204	.839	-24931.623	30642.200
	Hou	1.997E7	2.170E7	.126	.920	.359	-2.305E7	6.300E7

comm	7.302E6	2.060E7	.038	.354	.724	-3.355E7	4.816E7
Edu	6.239E6	2.211E7	.027	.282	.778	-3.760E7	5.007E7
Offce	2.353E7	3.731E7	.138	.631	.530	-5.045E7	9.751E7
Relig	2.184E7	2.846E7	.090	.767	.445	-3.459E7	7.827E7
Heth	595148.345	2.747E7	.003	.022	.983	-5.387E7	5.506E7
Ind	5.532E6	2.341E7	.024	.236	.814	-4.089E7	5.195E7

a. Dependent Variable: totcost

Excluded Variables[b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	bankn	.[a]	.	.	.	.000

a. Predictors in the Model: (Constant), ind, sancost, bldht, borhole, edu, firecost, comm, heth, nolift, stryht, liftcost, speqmtcost, relig, gfa, hou, offce, noflrs

b. Dependent Variable: totcost