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PROJECT COST PREDICTION MODEL USING PRINCIPAL COMPONENT REGRESSION FOR PUBLIC BUILDING PROJECTS IN NIGERIA

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Abstract

Major problem in Nigeria construction industry is that building contracts are completed at sums much higher than estimated cost, hence the need to develop predictive cost model that capture factors affecting project cost using principal components regression, through set objectives: to identify factors contributing to project cost; examine the importance of the factors and develop cost predictive model. Literature review on the study indicated that nature of clients, professional involved in a project and their decision regarding design, function, duration, technology and implementation have significant effect on the overall project cost. Data for the study are obtained through random sampling of public building projects completed in Nigeria after 1995. The study identifies six most significant factors to project cost among the design related variables as: Level of design complexity; level of construction complexity; level of technological advancement; percentage of repetitive element; presence of special issues and scope of work. Three factors among time/cost related factors as Importance for project to be delivered; time allowed by the client and his representative for bid evaluation; need for the project to be completed. Client, consultant and contractor's experience on similar project; adequacy of contractor's plants and equipments are most significant among project parties experience related factors. The selected factors were used for cost predictive model.

Keywords: Building, Cost, Model, Prediction, Principal components.

Introduction

A successful project means that the project has accomplished its technical performance, maintained its schedule and remained within budgetary costs. However, there has been a greater awareness of cost prediction by prospective building clients because of the prevailing economic condition which has placed severe restrictions on the availability of capital and thus made it essential to ensure that whatever amount is available is judiciously utilised to secure best economic advantage.

In these days of ever increasing costs, the majority of promoters of building projects are insisting on jobs being designed and executed to give maximum value for money. Hence, Quantity Surveyors are employed to an increasing extent during the design stage to advice designers on the portable cost implications of their design decision. All these have geared building clients to demand for improved and refine cost control tools from their professional advisers, to provide a balanced cost in all parts of the building as well as an accurately forecast overall cost (Seeley 1993). In the same vein, Lowe, Emsley and Harding (2006) also explained that construction clients require early and accurate cost advice, prior to site acquisition and the commitment to build, to enable them to assess the feasibility of the proposed project, this is performed by construction contract price forecasters (usually Quantity Surveyor).

A client is very much concerned with quality, cost and time and wants the building to be soundly constructed at a reasonable cost and within a specified period of time. For these reasons, it is incumbent upon an Architect who may or may not be supported by Quantity Surveyor to exercise the greatest care and skill in the design of the project with constant checks on cost. Songer and Molenaar (1997) have identified a list of metrics that measure and compare the performance of construction projects. Other studies (Akintoye 2000; Chan, Ho and Tam (2001) identified the determining factors and assessed their impacts on project cost. Therefore integrated efforts of the various parties and their decisions regarding the design, technology and implementation of the project can have significant effect on the overall project cost. Therefore, it can be seen that the need for a virile construction industry cannot be overemphasized. Thus, there is urgent need to address some of the fundamental problems plaguing its growth and viability, one of which is spate of uncertainties brought by the prevalent wide discrepancies between planned and actual construction cost due to lack of effective prediction cost models. However, this study seeks to replicate the research conducted by (Chan and Park 2005) in Singapore using Nigeria as case study. The research aims to (i) to identify the factors that contribute to project cost (ii) to examine the importance of the identified factors based on the significance of their contribution (iii) to develop a predictive project cost model from the selected components using principal components technique.

The subsequent sections review the previous work relating to the research title, present the data and discuss the results of the statistical analysis. Finally, conclusions were drawn from the results of the empirical study.

Previous Work

Cost modelling is described by Willis and Ashworth (1987) as a modern technique to be used for forecasting the estimated cost of a proposed construction project. Ferry and Brandon (1991) defined it as one symbolic representation of a system expressing the content of that system in terms of the factors which influence its cost.

Cost model based on space/functional unit is described by Dikko (2002), as the simplest types of cost models. They generally use information generated from past projects and such information are discounted into cost per unit of utility and used as a basis for estimating cost of future projects. These cost models have the obvious drawback of being too simplistic, extremely difficult to adjust for changes in any of the key variables and generally have low level of reliability. Elemental planning as opined by Khroswowhahi and Kaka (1996) is the most established logical approach to estimating. However, it demands considerable resources and it is not possible to develop solution at an early stage. According to Dikko (2002), elemental cost planning based model is based on BCIS (British Cost Information System) format. He explained further that, the approach was originally developed for application to building projects only, which are sub-divided into functional elements.

Skitmore, Strading, Tuohy and Mkwezalamba (1990) are of the opinion that cost modelling could be based on the following methods; in place quantities and descriptive models. According to Skitmore et al (1990) methods based on in-place quantities seem to have reached the limit of their development with accuracy insufficient for estimate or for cost advice at design stage.

Newton (1991) identified regression analysis and neural networks as two modelling techniques, which have been used to develop models to estimate the cost of buildings. However, predominantly, these models rely on the use of historic (but recent) cost data. Early example of the use of regression analysis as a forecasting tool are provided by McCaffer (1975) and McCaffer, McCaffrey and Thrope (1984), while a more recent application is provided by Trost and Oberlender (2003). A review of the application of regression analysis to construction price forecasting is presented by Skitmore and Patchel (1990). likewise, Elhag and Boussabaine (2001; 2002) modelled tender price estimation using artificial neural networks while Emsley, Lowe, Duff, Harding and Hickson (2002) applied a neural network approach to the prediction of total construction costs. The findings of their research showed that the major benefit of the neural network approach was the ability of neural networks to model the nonlinearity in the data. The model obtained gives a mean absolute percentage error (MAPE) of 16.6%, which includes a percentage (unknown) for client changes. Raftery (1993) proposed probabilistic form also referred to as the cumulative probability functions. Skitmore (2002) describes an empirical method for the construction of model that presents in this form (which he referred to as 'Raftery Curves') for the tender price forecast.

Lowe et al (2006) asserted that the inappropriate nature of raw cost as a valid predictor of project cost can be demonstrated by comparing the results of a simple forward stepwise regression using raw cost with those obtained when using the other three variables.

Chan and Park (2005) asserted that project cost depends not only on a single factor but a cluster of variables related to the characteristics of the project and the construction team. Technological and project design requirements preset by the client's desired level of construction sophistication play an important role in determining the cost of the project.

Research Method

This study was designed to investigate into the factors that determine cost of construction project and to develop a predictive cost model. The target population for the study were the three main construction industry participants i.e. clients, consultants and contractors and construction projects that had already been completed formed the basis for data collection. And to ensure accuracy of predictive models, homogeneity is very important. Since construction projects fall into different categories such as building, civil, heavy engineering among others, the study focused on building works. The study adopts simple random sampling technique to capture the targeted population for the study.

From the existing literature on determinants of project cost estimation, a total of 15 determinants relating to the project, the construction team and the contractor were selected out of 38 determinants factors displayed on table 1 below.

Appropriate methods of data analysis were very necessary to be able to accurately process the data collected from field survey. Data analysis, where necessary could involve the use of multiple analytical techniques to facilitate the ease of communicating the results while at the same time improving its validity (Ajayi, 1990). Based on this assertion, two methods of analysis were employed for the study; Principal Component Regression for purposes of selecting a small number of principal components that contributes satisfactorily to variation in y and which could be used for estimation. Finally, multiple regression models (linear and non-linear) were employed for predictive purposes. Specifically, the regression models used in this study includes simple linear, semi-log and double-log.

$$Y = a_0 + a_1X_1 + a_2X_2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. a_nX_n + e \text{ ------------------------------ } (i)$$

$$Ln\ Y = a_0 + a_1X_1 + a_2X_2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. a_nX_n + e \text{ -------------- } (ii)Ln$$

$$Y = a_0 + a_1LnX_1 + a_2LnX_2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. a_nLnX_n + e \text{ -------------- } (iii)$$

Analysis and Result

Table 1 showed the descriptive statistics of data for the research, the respondents were required to score the identified factors that are been considered as determinants of cost of building project using a Likart scale of 5 – 1 that is '5 denoting very important and 1 denoting not important'. However, table 2 shows the aggregation of the respondent's responses as percentage of the total number of responses received on each of the questions asked on the questionnaire.

Extracting Components

This research adopts the use of PCA in analysing the raw data for the purposes of extracting the factors that contributed significantly to cost of building projects. Kaming et al (1997) explained that the total number of factor estimated by the model (common factor) is equal to or less than the total number of variables involved. Table 3, 4, and 5 shows the extracted number of factor from PCA for design related, time/cost related and experience of project parties related factors based on their contribution to cost of building project. However, the most significant factors that contribute to project cost are those whose eigenvalues are greater than or equal to 1(eigenvalue ≥ 1), because eigenvalues is a measure of the contribution of a variable to the principal components. From table 2, 3 and 4, the extraction sum of square loading of the factor analysis for design related factors indicates six (6) factors out of thirteen (13) factors with eigenvalues of 3.068 for factor 1 to 1.001 for factor 6, Time/Cost related factor indicates three (3) factors out of eight (8) factors with eigenvalues of 2.394 for factor 1 to 1.074 for factor 3 and Experience of Parties to the Project factors indicates five (5) factors out of seventeen (17) factors with eigenvalues of 4.357 for factor 1 to 1.301 for factor 5. However, those factor with eigenvalues greater than or equal to 1 are considered in the extraction process.

The output in table 2, 3 and 4 shows the extraction factor loading greater than 0.500 and their respective communalities (h^2). The criterion for factor loading was that any variable with absolute value > 0.500 in the component matrix belong to the component. Factor loading are simply the correlation coefficient between an original variable/determinant and an extracted factor. Also, the average communalities (h^2) which explain the variance in the variables accounted for by the extracted factor is 75%, 64% and 69% for Design related, Time/cost related and Experience of Project Parties related factors respectively.

Selecting Principal Components for Cost Modelling

Further to extraction of principal components, those components that contributed significantly to the factors were selected for purposes of regression analysis which needs to be carried out on the selected components for model development otherwise it will be the same as regressing on all the variables/factors.

However, the study adopts the criterion of selection used in (Kaming et al. 1997, and Chan & Park 2005). This criterion include selecting the principal component whose eigenvalues and the percentage variance is more than the average eigenvalues and the percentage cumulative variance of the factor.

Based on the above criteria, from table 2, 3 and 4, six components are extracted from 13 variables pertaining to Project Design. The cumulative percentage variance explained by the six components is 75% and percentage variance explained by each of the components are displayed on table 5. Taking the significance of contribution of each variable into account (based on their respective percentage variance) and in comparison with the average eigenvalues (1.314), the first two components contributed significantly (accounted for 36% of the variance), thus those variables with eigenvalues higher than the average eigenvalues were selected to be included in the model. Hence, 6 out of 13 variables were selected.

Within the component of Time/Cost factors, three components was extracted, having a cumulative percentage variance of 64% the average eigenvalues (3.34), Thus 3 factors with relatively higher eigenvalues than the average eigenvalues was selected to be included in the model. Among the factors relating to experience of project parties, five components that amount to 69% of the variance are extracted and first two components whose eigenvalues are higher than average (1.748) account for 43% of the variance. Six out a total of seven variables are selected for the model estimation. All the variables selected are presented in table 5.

Cost Prediction Model

In pursuance of the research objectives, Final cost prediction model was developed using principal components regression method on the component presented in table 5. Table 6 reports the estimated effects of the individual variables on the project cost. From the result of the analysis, the Final Project Cost (FPC) prediction model comprises of fourteen significant variables and one variable was excluded from the model.

The result of the analysis presented on table 7 shows that the variables accounted for 20% and 24% of the total variance of project cost as indicated by R^2 and adjusted R^2 value respectively. The F. Ratio indicated that the variables are significant at 5% significant level.

The regression model can be represented as;

$$F.COST = 216.57 - 12.24 * FAC15 + 7.26 * FAC4 - 24.98 * FAC11 + 8.77 * FAC1 + 4.28 * FAC7 + 2.22 * FAC6 - 5.58 * FAC8 + 2.76 * FAC5 + 5.82 * FAC13 - 15.61 * FAC3 - 20.80 * FAC9 + 5.86 * FAC2 + 9{,}77 * FAC12 + 1.85 * FAC14 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..(4.1)$$

The model implies that, adequacy of contractor's plant and equipment, contractor's experience on similar type of project, time allowed for project bid to be evaluated, level of technological advancement and client commitment to timely completion of the project have negative effect on the cost of project and can reduce project cost. But percentage of repetitive work, level of design complexity, importance for project to be delivered, project scope, percentage of special issues, communication among project team, level of construction complexity, contractor experience on similar size of project and contractors prior working relationship with clients increase cost of building projects.

Discussion of Result

Based on the information gathered from literature search, Thirty Eight factors were identified and used for the study. However, Chan and Park (2005) used fifty nine variables out of which nine were regarded as dummy variables and some others were related to contract conditions in the study area. Other studies on the research indicated that nature of clients and the professionals involved on a project and their collective decision regarding the design, function, duration, technology and implementation of the project have significant effect on the overall project cost (Akintoye, 2000: Chan et al. 2001: Lowe, et al 2006).

The study indicates six most significant factors among the design related variables as major contributor to cost of public building projects. And time/cost related factors indicated three factors. It also showed five factors contributed significantly to project cost among the project parties experience related factors. These amounts to fifteen factors and all these factors were used for the model estimation.

The model has an R^2 and adjusted R^2 value of approximately 20% and 24% respectively. These results compare favourably with past research on cost estimation/prediction model as evidenced by reported values of R^2 of 20.8% (Skitmore *et al*., 1990), 27.9% (Lowe, 1996) and 41% (Chan and Park, 2005). Also, similar model developed using Neural Network showed an R^2 value of 58.6% (Emsley, et al 2002).

Conclusion

This research centered on developing predictive cost model for public building projects using principal components regression. The technique is applicable for purposes of reducing large number of variables required for the estimation.

The research has shown that project cost depends largely on factors related to; adequacy of contractor's plant and equipment, contractor's experience on similar type of project, time allowed for project bid to be evaluated, level of technological advancement and client commitment to timely completion of the project, percentage of repetitive work, level of design complexity, importance for project to be delivered, project scope, percentage of special issues, communication among project team, level of construction complexity, contractor experience on similar size of project and contractors prior working relationship with clients.

The study has been able to develop a predictive cost model using the fifteen selected factors that exhibit a significant effect on project cost and these factors accounted for 23.8% of the model. Further research is required for the model to be fully appreciated.

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Table 1: Factors that determine cost of building project

Factors	Percentage				
	N.I	S.I	M.I	V.I	E.I
DESIGN RELATED					
X1-Level of design complexity	-	-	17	51	32
X2-Level of construction complexity	-	-	22	44	34
X3-Level of technological advancement	-	12	20	46	22
X4-Level of specialization required of contractors	2	-	27	44	27
X5-Percentage of repetitive elements	17	32	34	15	2
X6-Presence of special issues	10	22	29	32	7
X7-Type of specification	-	2	17	49	32
X8-Extent to which bid documents allow additions to scope	2	17	32	34	15
X9-Flexibility of scope of works when contractor is hired	-	10	42	39	10
X10-Project scope definition completion when bids are invited	5	7	34	39	15
X11-Design completion(by owner) when bids are invited	5	15	34	32	15
X12-Design Decision made (by owner) when bids are invited	2	24	20	34	20
X13-Design completion when budget is fixed	-	8	22	46	24
TIME/COST RELATED					
X14-Importance for project to be completed within budget	-	2	17	32	49
X15-Importance for project to be delivered	-	2	22	42	34
X16-Time given to consultant to evaluate bids	24	17	34	27	20
X17-Extent to which contract period is allowed to vary	-	17	44	24	15
X18-Importance for project to be completed on time	-	2	10	46	42
X19-Bidding environment	5	39	17	24	15
X20-Consultant’s level of construction sophistication	-	24	27	46	24
X21-Owner’s level of construction sophistication	5	10	27	44	15
PROJECT PARTIES EXPERIENCE RELATED					
X22-Consultant experience with similar project	-	2	22	42	34
X23-Owners experience with similar project.	7	15	29	24	24
X24-Consultant staffing level to attend to contractor	-	8	29	29	34
X25-Owners staffing level to attend to contractor	17	12	44	20	7
X26-Contractor’s experience with similar type of projects	-	5	12	49	34
X27-Contractor’s experience with similar size of project	2	7	17	49	24
X28-Contractors experience with project in Nigeria	2	5	29	44	20
X29-Subcontractor experience and capability	-	27	29	34	10
X30-Communication among project team	15	15	27	27	17
X31-Contractor’s prior working relationship with the owners	12	17	37	32	2
X32-Contractor prior working relationship with consultant	7	15	39	24	17
X33-Contractor track record for completion on time	-	-	22	59	20
X34-Contractor track record for completion on budget	-	5	22	37	37
X35-Contractor track records for completion on quality	-	7	17	34	42
X36-Contractor staffing level	2	7	17	44	29
X37-Adequacy of contractor plant and equipment	-	-	36	32	32
X38-Magnitude of change orders in contractor past project	-	24	54	17	5

Key: N.I (Not Important), S.I (Slightly Important), M.I (Moderately Important), V.I (Very Important), E.I. (Extremely Important)

Table 2: Factor loading of design factors to cost of project - extracted

	Variable	Factors						
		DF1	DF2	DF3	DF4	DF5	DF6	h^2
1	Level of design complexity	0.540						0.813
2	Level of construction complexity	0.520						0.788
3	Level of technological advancement	0.714						0.742
4	Level of specialization required of contractors	0.500						0.581
5	Percentage of repetitive elements		0.742					0.722
6	Presence of special issues		-0.603					0.906
7	Type of specification		0.659					0.620
8	Extent to which bid documents allow additions to scope			0.597				0.719
9	Flexibility of scope of works when contractor is hired			-0.507				0.847
10	Project scope definition completion when bids are invited				0.709			0.812
11	Design completion(by owner) when bids are invited				0.600			0.642
12	Design Decision made (by owner) when bids are invited					0.626		0.741
13	Design completion when budget is fixed						-0.569	0.736

Table 3: Factor loading of time/cost factor - extracted

	Variables	Factors			
		TF1	TF2	TF3	h^2
1	Importance for project to be completed within budget	0.67			0.618
2	Importance for project to be delivered	0.757			0.752
3	Time given to consultant to evaluate bids	0.793			0.698
4	Extent to which contract period is allowed to vary	0.508			0.622
5	Importance for project to be completed on time	0.612			0.707
6	Bidding environment		0.719		0.53
7	Consultant's level of construction sophistication		0.719		0.459
8	Owner's level of construction sophistication			-0.659	0.697

Table 4: Factor loading for project parties experience factor - extracted

	Variables	Factors					
		EP1	EP2	EP3	EP4	EP5	h^3
1	Consultant experience with similar project	0.537					0.577
2	Owners experience with similar project	0.703					0.780
3	Consultant staffing level to attend to contractor	0.589					0.783
4	Owners staffing level to attend to contractor	0.600					0.825
5	Contractor's experience with similar type of projects	0.536					0.774
6	Contractor's experience with similar size of projects	0.690					0.761
7	Contractors experience with project in Nigeria	0.694					0.611
8	Subcontractor experience and capability	0.520					0.677
9	Communication among project team		-0.650				0.781
10	Contractor's prior working relationship with the owners		-0.593				0.738
11	Contractor prior working relationship with the consultant		0.662				0.651
12	Contractor track record for completion on time		0.585				0.612
13	Contractor track record for completion on budget			0.510			0.591
14	Contractor track records for completion on quality			0.628			0.634
15	Contractor staffing level						0.502
16	Adequacy of contractor plant and equipment						0.693
17	Magnitude of change orders in contractor past project						0.633

Table 5: List of selected components for model estimation

Factor 1 (FAC1)	Level of design complexity
Factor 2 (FAC2)	Level of construction complexity
Factor 3 (FAC3)	Level of technological advancement
Factor 4 (FAC4)	Percentage of repetitive element
Factor 5 (FAC5)	Percentage of special issues
Factor 6 (FAC6)	Project scope
Factor 7 (FAC7)	Importance for project to be delivered
Factor 8 (FAC8)	Time allowed for bid evaluation
Factor 9 (FAC9)	Importance for project to be completed on time
Factor 10 (FAC10)	Client experience in construction project
Factor 11 (FAC11)	Contractor's experience on similar type of project
Factor 12 (FAC12)	Contractor's experience on similar size of project
Factor 13 (FAC13)	Communication among project team
Factor 14 (FAC14)	Contractor's prior working relationship with client
Factor 15 (FAC15)	Adequacy of contractor plant and equipment

Table 6: Estimates of regression parameter from analysis of principal component variables

Variable	Coefficients	Std Error	t-statistics	Significant level
(Constant)	216.57	138.97	1.56	0.131
FAC1	8.77	22.49	0.39	0.700
FAC2	5.86	23.11	0.25	0.802
FAC3	-15.61	16.87	-0.93	0.363
FAC4	7.26	16.70	0.44	0.667
FAC5	2.76	16.80	0.16	0.871
FAC6	2.22	13.13	0.17	0.867
FAC7	4.28	15.90	0.27	0.790
FAC8	5.58	17.58	-0.32	0.753
FAC9	-20.80	16.09	-1.29	0.207
FAC11	-24.98	19.80	-1.26	0.218
FAC12	9.77	15.81	0.62	0.542
FAC13	5.82	20.72	0.28	0.781
FAC14	1.85	15.38	0.12	0.905
FAC15	-12.24	19.69	-0.62	0.540

Significant at 5% significant level

Table 7: Regression results of principal component variables

Model	R^2	Adjusted R^2	F.Cal	df1	df2	Sig
1	19.50%	23.80%	0.451	14	26	0.94

a. Predictors: (Constant), FAC15, FAC4, FAC11, FAC1, FAC7, FAC6, FAC8, FAC5, FAC13, FAC3, FAC9, FAC2, FAC14.
b. Dependent variable: FCOST