DIRECT COSTS PREDICTION OF STRUCTURAL ELEMENTS OF SMALL AND MEDIUM RISE BUILDINGS

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Abstract
The failure of cost anticipation and allocation in construction is attributable to ignorance of the nature and values of elemental direct costs in developing countries. This study aims at providing bases for precise and simplified prediction and management of direct costs of structural building elements for labour-only contracts. The objectives of the study are to identify quantitative variables influencing direct costs of structural building elements and develop cost prediction models for small and medium rise buildings. A total of 216 low and medium rise building projects were used for analyses. Data were obtained from cost records and published data. Tools used for data analyses were descriptive and standard regression analyses. The results show that the six models developed have adjusted R^2 ranging between 0.742 and 0.830 indicating high degree of prediction dependability. Of the eleven variables reliably used to predict the direct costs of six structural building elements the gross floor area, bid price and labour prices made the strongest unique contribution to the direct costs. It is recommended that direct costs should be predicted with elemental cost models adopted for simplified project planning, accurate cost prediction, and ease of overhead allocation among low and medium income families who mostly use labour only contract system.

Key words: Building elements, construction, direct costs, prediction model, regression

INTRODUCTION

Buildings are major products of the construction industry which serve as life support systems, provide shelter, enhance productivity, and embody our culture. They could be incredibly expensive to build and maintain, hence the economics of building is a vital and complex issue throughout the life of a building. Cost has been seen as a foremost consideration in project delivery and regarded as one of the most important criteria of project success Memon, Rahman, Abdullah, and Abdu Azis (2010). The high costs of buildings, continuous failure of cost and other performance considerations of projects have placed researchers on continuous search for alternative procurement systems, construction methods, cost estimation/prediction and control methods. Ogunde and Fagbenle (2012) also noted that the downturn in the Nigeria economy between 1985 and 1999 had created recession in the construction industry that makes clients and consultants think of cheaper ways of achieving constructions. This led to modifications of existing project execution systems in favour of labour-only and direct labour systems. In a labour-only system clients are involved in the purchase of materials while leaving the management of the labour and construction to the contractor who gets paid for the costs of engaging the labour and his profit (Adenuga and Akinsola, 2007). The economic downturn, cost failure, tenancy problems, among others have made private clients out of frustration to commence occupation of partially completed buildings. The partial occupation occurs mostly when the structural building elements (foundation, floor, wall, frame, doors and windows and roof) are completed, while the finishing and other work items are done gradually, especially among low and medium income families in Nigeria (Ujene, 2012).

The unreliability of the cost anticipation and prediction has been a serious problem in the construction industry which at most times has been attributed to inadequate understanding of components, values and dynamics of construction cost on the part of cost advisers (Juodis and Stalioraitis, 2006). Clients' dissatisfaction in Nigerian construction industry like most developing countries has most often been linked to the fact that they are often compelled to pay for unbudgeted increase in project costs at varying degrees due to unreliable cost anticipation, estimation and control (Ujene, Idoro and Mbamali, 2013). The cost failures add to the frustration caused by the poverty level of most low and medium income families. The poverty level of most Nigerians according to Daramola, Alagbe, Aduwo and Ogbiye (2005) makes it difficult for them to own houses, contributing to the current housing deficit in Nigeria estimated at between 12 million and 16 million homes (Alagbe, 2010), amidst the ever growing population with growth rate of over 3.2 percent or 5.6 million people per annum (Obi and Ubani, 2014).

The emphasis of researches on total construction cost may continue to make building affordability elusive to average citizens of developing nations, except the concepts and values of costs are broken down into elements which can be appreciated and easily affordable overtime by the average citizens. In order to advance a broader understanding of the components of total construction costs, this study focuses on the view that the cost elements comprise material, labour, plant and machinery costs, administration costs and other expenses which are categorized into direct costs and indirect costs. The direct costs which are costs traceable to an activity or work item vary from about 65 percent to 93 percent of the total project costs, while the indirect costs comprise a smaller percentage of the total constructions (Chitkara, 2006). Yigezu (2008) in support of this assertion opined that direct costs cover the largest portion of the total project cost and these costs can be budgeted, monitored and controlled far more effectively than the indirect costs. This enormous contribution of direct costs to the total construction costs and the fact that they are easier to budget, monitored and controlled far more effectively than the indirect costs calls for attention in the planning, allocation and management of construction costs (Ujene and Achuenu, 2013). Some consequences of poor cost anticipation and estimation are cost overrun, delay and abandonment of projects, loss of profit, bankruptcy and insolvency by contractors. Other consequences are loss of quality, clients' dissatisfaction and disputes among stakeholders (Oyewobi, Ibironke, Ganiyu, and Ola-Awo, 2011; Ogunsemi and Aje, 2006). In order to address the problems associated with costs appreciation and anticipation among the average citizens as well as other cost failures as noted by Ogunsemi and Jagboro (2006) and Amusan (2011), this study advances an understanding of the nature and values of direct cost, with a view to developing regression models for predicting the direct costs of structural building elements which often enable low and medium income families to commence partial occupation of uncompleted buildings.

Objectives of the study

This study focused on six structural building elements namely; substructure, floor, walls, frames, openings [doors and windows], and roofs. The objectives were to identify quantitative direct cost variation factors available to cost advisers prior to construction and also develop models to predict the average total direct costs of the structural elements in low and medium rise buildings using the identified factors. The models would assist practitioners in prudent anticipation, allocation and control of costs, leading to improved cash flow management and project success in developing countries. The growing preferences for labour-only procurement system among most private developers who desire to execute their projects in elemental phases through labour-only contractors, calls for simplified cost anticipation and allocation approaches. The focus on low and medium rise buildings is because the low and medium income families do not usually have the financial capabilities to finance high rise projects. This study will assist labour-only advocates to reliably anticipate and allocate the substantial aspects of costs to different building elements to aid job execution in phases as most of the average citizens do not have all the money to execute building projects to practical completion at continuous work progression, hence commencing partial occupation after completion of the structural elements used in this study.

LITERATURE REVIEW

Building Elements: A building element is defined as a major component common to most buildings which usually performs a given function, regardless of the design specification, construction method, or materials used (Ferry and Brandon, 1991; Bowen and Charette, 1991 and Charette and Marshall, 1999). Elemental classification ensures consistency in economic evaluation of building projects over time and from project to project, and it enhances project management and reporting at all stages of the building life cycle and provide the necessary cost information for the analyst to evaluate building alternatives in a cost-effective manner (Charette and Marshall, 1999). Mbamali (2003) observed that the possible groupings of elements are usually based on the cost importance of the item, the ease of separation; both in measuring from sketch drawings and in analyzing from bill of quantities and comparability of the chosen list with those used by others for similar purpose. This study adapted the classification by the Royal Institution of Chartered Surveyors (RICS) which is the most widely accepted list of elemental categorisation (Mbamali, 2003), with emphasis on the elements which contribute significantly to strength.

Concept of Direct Cost: Costs in construction are usually viewed in terms of owner/clients cost and contractor's cost. Hendrickson and Au (2003) opined that cost to the client represents the expenditure incurred in purchasing the land, carrying out feasibility studies, designing, constructing, maintaining running, periodic rehabilitation and other owner's expenses. While the contractor's production cost is a representation of the financial involvement in the process of organising the resources such as labour, material, plants and the overheads incurred in the management of the project (Achuenu and Ujene, 2006 and Warsame, 2006). Chitkara (2006) in corroboration of previous studies observed that the elements of building cost include labour, materials, plant and machinery costs and other expenses. These costs for ease of estimation are grouped into direct and indirect costs. Several studies have opined that direct costs are those costs which relate to a specific item or product and thus vary proportionally with output. These costs can be identified with the execution of an item of work or activity, and therefore not counted if the item of work or activity has not been performed. These studies have identified sub components of direct cost as; materials costs, labour costs, plant and equipment costs and other direct expenses (Car, 1989; Clough, Sears, and Sears, 2002; Al-Shanti, 2003; Lock, 2003; Chitkara, 2006; Osei-Tutu and Adjei-Kumi, 2008; Yigezu, 2008; and Dykstra, 2011). The 'other direct expenses' in the classification by Chitkara (2006) are observed to cover the sub-contact costs and others as noted by Clough *et al.* (2002). Chitkara (2006) in an earlier study noted that the direct costs constitute over 65% of the total project costs. Yigezu (2008) in support of this assertion opined that direct cost cover the largest portion of the total project cost and these costs can be budgeted, monitored and controlled far more effectively than the indirect costs.

Construction Costs Variation and Prediction

It was observed that literature is not very replete on direct costs of building elements, however previous studies on variation of components of total construction costs have shown that material is a major proportion of the total project costs which has been established to range between 45% and 70% of total cost (Olubodun,1989; Mezue, 1992; Ene, 1997; Ayeni, 1997; Ojimelekwe and Agbo ,1999; Skoyles, 2000 and Akanni, 2007). Labour being another important component of total construction cost was estimated to range between 30% and 40% of the project costs on a typical building project (Ogunpola, 1974; Ayeni (1997). Another vital component of total cost is plants; this Chitkara (2006) observed that in a mechanized building project, the equipment costs can vary from 5% to 10% of the direct costs, whereas in highway construction projects the plants and equipment costs can get as much as 40% of the project direct costs. Several studies have been carried out to predict total construction costs, Collier (1990) carried out a study of a conceptual approach to estimating construction cost with three groups of variables namely; cost components, building parameter and the total construction costs. The study used the relationship between the cost component group and the building parameter group to select the three variables of total area of building, perimeter of the building and the number of occupants as the independent variables to predict the dependent variable which is construction cost. Achuenu (1999) in a study that assessed and predicted the cost overrun of public office building, identified the four variable groups namely: building elements, initial costs of elements, final costs of elements and cost overrun. The study used the relationship between the building elements and their initial contract sums and final contract sums to predict cost overrun of public building projects in Nigeria. Phaobunjong (2002) in a study of parametric cost estimating model for conceptual cost estimating of building construction projects identified three variable groups which were classified as; actual variables, predictors and the predicted variable. The actual variable is made up of two variables namely; building gross square footage (GSF) and number of floor levels (FLOOR). The predictor group is made up of three variables namely; TGSF = Log of Building gross square footage (GSF), TGFL = Log of Number of floor levels (FLOOR) and Space usage ratio (RATIO) these were used to predict the building cost per gross square foot of floor area ($perGSF). Lowe, Emsley and Harding (2006) in a study that developed model for predicting construction cost using multiple regressions identified four variable groups namely; project strategic variables, design related variables and site related variables. The study shows that the variables in the project strategic variables, design related variables and site related variables all have direct relationship with the construction cost and the model was developed on the basis of the relationship among the variables. Wheaton and Simonton (2006) in a study of the secular and cyclic behavior of true construction cost identified three variable groups which shows that number of stories, units in the project, total area frame type and year of construction are directly related to log of construction costs per square foot, while the construction cost per square foot is directly related to its log. The established relationship thus was the basis for developing model for the cost prediction. Joudis and Stalioraitis (2006) in an analysis of statistical characteristics of construction costs identified two groups of variables which indicated that bid price, cost variation, duration and profit variation have direct influence on the construction cost hence were used as independent variables to predict total construction costs. Windapo and Iyagba

(2007) modelled the determinants of housing construction costs in Nigeria and shows that the level of construction costs can be determined by factors such as cost of building materials, interest rate, property price (land), foreign exchange rate, labour cost, national disposable income and money supply. Ganiyu and Zubairu (2010) developed a project cost prediction model using principal component regression for public building projects in Nigeria. The study identified 38 variables under three groups namely; design related variables (13), time/cost related variables (8) and project parties experience related variables (17). The selected factors were found to have direct relationship with project costs and hence used for project cost predictive model. The above studies were all based on the prediction of total construction costs; hence did not make any distinction between direct and indirect cost. This study found it necessary to provide an insight to the simplification of projects cost by utilizing the direct cost components of structural elements for accurate cost anticipation, allocation and control for developers.

CONCEPTUAL FRAMEWORK OF THE STUDY

The main thrust of the study was to identify the relationships between the dependent and the independent and intervening variables as the basis for the development of the model for predicting the direct costs of building elements as presented in Figure 1.0. The framework contains four groups of variables namely: building elements, direct cost components, direct cost variation factors and direct costs.

Building Element Variables: This variable group has six variables of structural building elements. They are classified into two groups namely: substructure and the superstructure consisting of five variables- floor, wall, frame, doors and windows and roof. These elements are considered most important by many private clients, to enable partial occupation of building due to financial challenges among low and medium income families.

Direct Cost Variation Factors: Direct cost variation factor group contains the identified internal and external factors responsible for cost differential over place and time. A total of 80 variables were identified from literature and focused group discussion. These were classified into ten variable groups namely: design, environmental, tendering, construction parties, construction, construction resources, financing, macroeconomic, procurement and performance related factors**.** From the 80 variables, the study identified 20 measurable variables which are readily available prior to construction and have direct influence on construction cost changes were adopted for modelling and measured as shown in Table 1.

Direct Cost Component Variable Group: This group of variables are four elements of direct costs namely: labour cost, material cost, plant cost and direct expenses. The variables are the main components of direct costs of building projects (Chitkara, 2006) and were adapted for evaluating the contribution of direct costs to the total elemental costs.

Direct Cost Variable Group: The variables of direct costs are made up of total direct cost of direct material costs, direct labour costs, direct plant costs and other direct expenses for the six selected elements, hence the variables are: direct costs of substructure, floors, walls, frame, doors and windows and direct costs of roof.

Relationship between the variables of the study

From the theoretical review, there seemed to be is a strong relationship between the stated variables. Phaobunjong (2002), Chan and Park (2005) and Chitkara (2006) show that, the components of direct costs of a building are derived from and classified according to the elements in the building. The direct cost components of the elements directly contribute to the total direct cost of the building revealing a very strong relationship. The level of contribution is however directly influenced by the internal and external factors which have also been established to have strong relationship with the costs components. These relationships formed the basis of the conceptual framework of the study presented in Figure 1.

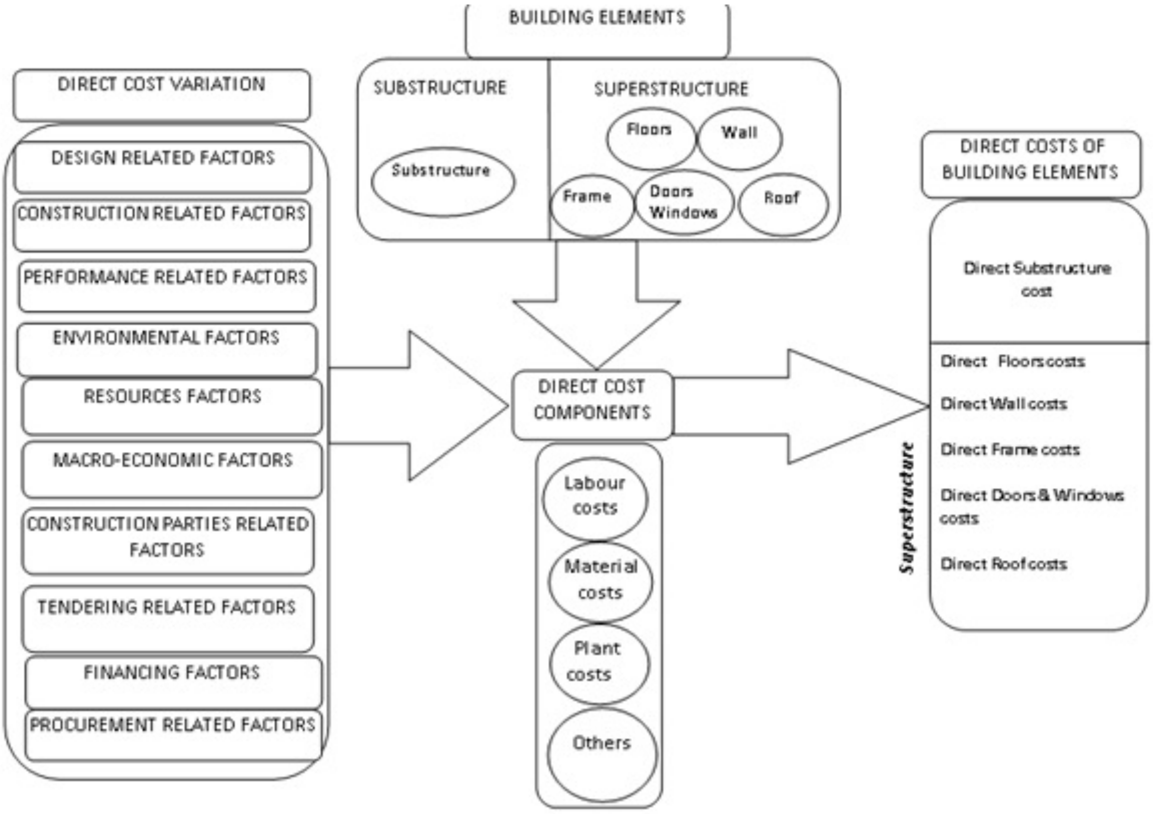

Figure 1: A conceptual model for predicting the direct costs of building elements over places and time.
Source: Field Work as at 2011

METHODOLOGY

Twenty independent variables found to be conspicuous, quantitative, readily available before construction commences and having significant relationship with the dependent variables were adapted from the groups of factors in the conceptual framework for the models as described in Table 1. Although some variables found in literature were slightly modified in line with the aim of the study and the prevailing situation in the study area, the authority from which the direct cost factors were culled or adapted are shown in Table 1.

Based on the twenty independent variables selected for the standard regression analysis, 216 public building projects (cases) were sampled to conform with, N > 50 + 8m where m is the number of cases as given by Tabachnick and Fidell (2007) for calculating sample size (N) requirements, taking into account the number of independent variables to be used especially for standard regression which is more reliable. Data were obtained from records of costs directly expended by the contractors on material, labour, equipment and other expenses on the elements of low and medium rise buildings, which are mostly within the financial capabilities of the low and medium income families.

Table 1: Model variables, coding and Sources

Model Variable (Independent)	Code	Sources of adopted variable
Gross Floor Area	X1	Somez (2004)
No of Floors	X2	Ibrahim(2003), Lowe et al. (2006)
Building Height	X3	Lowe et al. (2006)
No of Specification & Design Error	X4	Memon *et al.* (2010), Amusan (2011), Dosumu and Adenuga, (2013)
Bid Price	X5	Skitmore and Patchell (1990), Joudis and Stalioraitis (2006), Lowe *et al.* (2006)
Contract Period	X6	Eshofonie (2008), Ganiyu and Zubairu(2010), Memon *et al* (2010), Joudis and Stalioraitis (2006)
Soil Strength	X7	Memon, Rahman, Abdullah and Abdu-Azis (2010),
Site Topography	X8	Lowe et al (2006), Omole and Owoeye (2012).
Average Material Price	X9	Eshofonie (2008), Memon *et al.* (2010), Amusan (2011)
Average labour Price	X10	Eshofonie (2008), Windapo and Iyagba (2007) Memon et al. (2010)
Transportation costs	X11	Al-Juwaira(1997), Eshofonie (2008)
Ratio of Plot Undeveloped	X12	Spillane *et al.* (2011)
Level of Infrastructure	X13	Adefila and Bulus (2014)
Exchange Rate	X14	Eshofonie (2008), Memon, et al. (2010), Windapo and Iyagba (2007)
Prime Lending Rate	X15	Eshofonie (2008), Nnanna (2010), Ojo and Awodele (2013)
Inflation	X16	Memon, et al. (2010), Ojo and Awodele (2013)

Real Gross Domestic Product	X17	Ojo and Awodele (2013)
Unemployment Rate	X18	Ojo and Awodele (2013)
Nominal Minimum Wage	X19	Nwude (2013)
Level of Planning	X20	Eshofonie (2008), Memon *et al.* (2010), Amusan (2011)

The cost values were obtained from projects executed between 1999 and 2010, and normalised to a common base of cost per gross floor area (Dikko, 2002), hence prediction of total elemental costs are in costs per square meter. Reliability test was then carried out on the data obtained. The Cronbach's Alpha values for the reliability test were 0.727, 0.736, 0726, 0.702, 0.803, and 0.711 for the data for substructure, floors, walls, frame, doors/windows and roof respectively. This indicates that the data collected are highly reliable and thus suggests a good inner consistency, since the values of Cronbach's Alpha are desirable with the range higher than 0.5 (Gliem and Gliem, 2003).
The method used was the standard multiple regression involving preliminary assessment to ensure that conditions of linearity, homoscedasticity, independence of error terms, normality of the error distribution and multicollinearity are not violated. The criteria were; the tolerance values were all greater than 0.10, variance inflation factor (VIF) all less than 10 and condition indexes – all less than 30. A maximum Cook's distance less than 1 also meant that any case of outlier in the variables would not cause problem to the model. In this regression procedure variables were entered into the regression equation at once. Each independent variable was then assessed in terms of the unique amount of variance it accounted for. Thereafter the factors that did not significantly improve the regression model were dropped. The criteria used to determine the significance of the factor in the model were the p-value, comparison of the closeness of fit (using mean square error-MSE) and prediction performance of the model with and without the factor (using index agreement-IA, and coefficient of determination-R^2).

All other values were obtained from the regression result while the index of agreement was computed from Equation (1) following Ul-Saufie, Yahya, Ramli, and Hamid (2011).

$$I.A = 1 -\{\sum^{n}_{i=1} (P_i - O_i)^2 / \sum^{n}_{i=1}(|P_i - {}^{-}O|+ |O_i - {}^{-}O|)^2\} \text{ ....Equation (1)}$$

Where P_i = predicted value of case i; Oi = observed value of case i; O = mean values of Oi

An index of agreement close to 1 implies a very good prediction model. The regression analyses were then carried out, after preliminary analysis for each with all the 20 variables. With appropriate Mean square error (MSE), Index of Accuracy (IA) coefficient or determination (R^2) and significance level (p-value), variables that did not contribute significantly to the models were eliminated in steps and the final variables in the models are presented in Table 2.

PRESENTATION OF RESULTS

Table 2 shows a summary of results of the standard regression analyses of the six building element indicating the constants, coefficients ,operation steps and significance of the variables in the various models of substructure, floors, walls, frames, doors and windows, and roofs, which are discussed hereafter.

Table 2: Final variables and their coefficients in the models

Variables/ Constant	Substructure	Floor	Wall	Frame	Doors and Windows	Roof
Constant	– 835.222	– 5782.555	– 247.374	–4166.430	231.702	687.772
X1	– 1.867	– 1.918	– 2.324	-1.510	- 2.623	– 1.214
X2	+ 539.498	+ 5221.289	NS	+ 2046.081	+ 508.605	NS
X3	NS	NS	NS	NS	NS	NS
X4	NS	+146.599	+ 71.451	+ 329.414	NS	+ 59.942
X5	+ 2.837E-5	+ 3.850E-5	+4.329E-5	+ 2.851E-5	+ 4.473E-5	+1.915E-5
X6	NS	NS	NS	NS	NS	–19.060
X7	NS	NS	NS	NS	NS	NS
X8	+756.140	NS	+ 424.737	NS	+ 325.871	+ 312.954
X9	NS	NS	NS	+ 6.506E-2	NS	+ 0.029
X10	+ 3.787	+ 0.792	+ 2.014	+1.405	+ 1.351	+ 1.728
X11	NS	+ 7.789	+ 4.416	NS	+ 2.851	NS
X12	NS	NS	NS	NS	NS	NS
X13	NS	NS	NS	NS	NS	NS
X14	NS	NS	NS	NS	NS	NS
X15	NS	NS	NS	NS	NS	NS
X16	NS	– 89.387	NS	– 83.391	NS	– 58.435
X17	NS	NS	NS	NS	NS	NS

X18	NS	NS	NS	NS	NS	NS
X19	NS	NS	NS	NS	NS	NS
X20	– 1722.537	NS	NS	NS	- 815.766	- 1399.052
Operation Steps	Seven	Six	Seven	Six	Six	Four
F-value	121.484	150.941	160.383	135.429	127.260	69.830
Observed P-value	0.001	0.001	0.001	0.001	0.001	0.001
Observed R	0.882	0.914	0.906	0.906	0.900	0.868
Adjusted R^2	0.771	0.830	0.816	0.814	0.804	0.742

NS= Not Significant, hence dropped

Substructure model: After six steps of operation, the seventh regression model of the substructure, which included 6 variables, had IA of 0.931, with R^2 of 0.777. The MSE increased from 3970132.148 to 4007927.144, while all the variables left have p-values < 0.05 hence all the variables left contribute significantly to the model. Therefore the accepted optimal and final regression model for the direct costs of substructure can be represented as;

$$T_{DC.\ SUB} = - 835.222 – 1.867X_1 + 539.498X_2 + 2.837E\text{-}5X_5 + 756.140X_8 + 3.787X_{10} – 1722.537X_{20}$$

The model implies that number of floors, bid price, site topography, material prices and labour prices have positive effect on the total direct cost of substructure and can increase direct costs. On the other hand, gross floor area, and level of planning have negative effect on the direct costs of substructure and can reduce direct costs. The negative coefficient of the floor area is similar to the finding by Wheaton and Simonton (2006) in a study of the secular and cyclic behavior of true construction cost. The study argued that such outcome is expected because there is economy of scale in construction, and the cost per square foot typically declines as the overall size of the project increases due to increased efficiency of repetitive works arising from large size of project. It was also observed that larger project can exert market pressure on the purchase and assembly of material on site. This is also expected since the direct costs were evaluated per gross floor area; an increase in gross floor area will certainly decrease the direct cost per floor area in line with the findings of Wheaton and Simonton (2006).

From the results computed F statistics of 121.484 with an observed significance level of 0.001 less than 0.05 implies rejection of the hypothesis that there was no significant linear relationship between the variation factors used as predictors and the direct costs of substructure. From the result a correlation coefficient (R) of 0.882 showed a strong linear relationship between the independent variables and direct cost of substructure as measured by the correlation between the observed and predicted values of the total direct costs of substructure, while a coefficient of determination (R^2) of 0.777 and adjusted R^2 of 0.771 indicates that about 77.1% of the variance in the direct costs of substructure may be accounted for by the variables in the model. The result of the analysis also showed that, labour prices (beta value = 0.750) made the strongest unique contribution to explaining the dependent variable, followed by bid price (0.421), gross floor area (-0.397), site topography (0.112), number of floors (0.093) and level of planning (-0.081).

Floor model: After five operations, the sixth step of the floor model showed that the IA changed slightly from 0.959 to 0.958, while R^2 reduced from 0.837 to 0.836. MSE changed from 5170107.032 to 5474648.400 while all the variables left have p-values < 0.05 hence all the variables left contributed significantly to the model. Therefore the accepted optimal model was model MR6 and the final regression model for the direct costs of floor can be represented as;

$$T_{DC.\ FLR} = - 5782.555 – 1.918X_1 + 5221.289X_2 + 146.599X_4 + 3.85E\text{-}5X_5 + 0.792X_{10} + 7.789X_{11} – 89.387X_{16}$$

The model implies that, number of floors, number of specification and design errors, bid price, labour prices and transportations have positive effect on the total direct cost of floor and can increase direct costs. On the other hand, gross floor area, and inflation have negative effect on the direct costs of floor and can reduce direct costs in line with Wheaton and Simonton (2006).

A computed F statistics of 150.941 with an observed significance level of 0.001 less than 0.05 implies rejection of the hypothesis that there is no significant relationship between the variation factors used as predictors and the direct costs of floor. From the result, a correlation coefficient (R) of 0.914 shows a strong linear relationship between the independent variables and direct cost of floor as measured by the correlation between the observed and predicted values of the total direct costs of floor, while a coefficient of determination (R^2) of 0.836 and adjusted R^2 of 0.830 indicates that about

83.0% of the variance in the direct costs of floor may be accounted for by the variables in the model. The results of the analysis also show that, number of floors (beta value = 0.662) made the strongest unique contribution to explaining the dependent variable, followed by bid price (0.433), gross floor area (-0.309), labour prices (0.119), number of specification and design errors (0.100), Transportations costs (0.096), and inflation (-0.068). The results show that the seven variables make significant unique contributions to the total direct cost of floors.

Wall model: After six steps of operation, the seventh regression model (MR7), which included 6 variables had IA reducing to 0.940 and R^2 reduced to 0.822, while MSE was increased from 1620485.666 to 1635743.677. Results show that variables left have p-values < 0.05 hence all the variables left contribute significantly to the model. Therefore the accepted optimal model is model MR and the regression model for the direct costs of wall can be represented as;

$$T_{DC.\ WAL} = -\ 247.374 - 2.324X_1 + 71.451X_4 + 4.329E\text{-}5X_5 + 424.737X_8 + 2.014X_{10} + 4.416X_{11.}$$

The model implies that, number of specification and design errors, bid price, site topography, labour prices and transportations have positive effect on the total direct cost of wall and can increase direct costs. On the other hand, gross floor area has negative effect on the direct costs of wall and can reduce direct costs.

From result of analysis, the computed F statistics of 160.383 with an observed significance level of 0.001 less than 0.05 implies rejection of the hypothesis that there is no significant relationship between the modelling factors and the direct costs of wall in the zone. From the result, a correlation coefficient (R) of 0.906 shows a strong linear relationship between the independent variables and direct cost of wall as measured by the correlation between the observed and predicted values of the total direct costs of wall, while a coefficient of determination (R^2) of 0.822 and an adjusted R^2 of 0.816 indicates that about 81.6% of the variance in the direct costs of wall may be accounted for by the variables in the model. The results of the analysis also show that, bid price (beta value = 0.900) made the strongest unique contribution to explaining the dependent variable, followed by gross floor area (-0.692), labour prices (0.559), transportations (0.101), number of specification and design errors (0.090) and site topography (0.088). The results show that the six variables make significant contributions to the total direct cost of wall.

Frame model: The result of the sixth regression model shows that the p-values of all the variables are less than 0.05 hence all contribute significantly to the model. Therefore the accepted optimal model is model MR6 and the final regression model for the direct costs of frame can be represented as;

$$T_{DC.\ FRM} = -4166.430 - 1.510X_1 + 2046.081X_2 + 329.414X_4 + 2.851E\text{-}5X_5 + 6.506E\text{-}2X_9 + 1.405X_{10} - 83.391X_{16}$$

The model implies that number of floors, number of specification and design errors, bid price, material prices, and labour prices have positive effect on the total direct cost of frame and can increase direct costs. On the other hand, gross floor area, and inflation have negative effect on the direct costs of frame and can reduce direct costs.

The result shows the computed F statistics of 135.429 with an observed significance level of 0.000 less than 0.05 implies rejection of the hypothesis that there is no significant relationship between the modelling factors and the direct costs of frame in the zone. From Table 5.32 a correlation coefficient (R) of 0.906 shows a strong linear relationship between the independent variables and direct cost of frame as measured by the correlation between the observed and predicted values of the total direct costs of frame, while a coefficient of determination (R^2) of 0.820 and R^2 adjusted of 0.814 indicates that about 81.4% of the variance in the direct costs of frame may be accounted for by the variables in the model. The results of the analysis also show that, bid price (beta value = 0.405) makes the strongest unique contribution to explaining the dependent variable, followed by number of floors (0.338), gross floor area (-0.307), number of specification and design errors (0.284), Material prices (0.259), Labour prices (0.266), and inflation (-0.080). The result shows that all the seven variables are significant and make contributions to the total direct cost of frame.

Doors/Windows model: The result of the sixth regression model shows that the p-values of all the variables are less than 0.05 hence all the variables contribute significantly to the model. Therefore the accepted optimal model is model MR6 and the final regression model for the direct costs of doors and windows can be represented as;

$$T_{DC.\ DOR\&WIN} = 231.702 - 2.623X_1 + 508.605X_2 + 4.473E\text{-}5X_5 + 325.871X_8 + 1.351X_{10} + 2.851X_{11} - 815.766X_{20}$$

The model implies that numbers of floors, bid price, site topography, labour prices and transportations have positive effect on the total direct cost of doors and windows hence can increase direct costs. On the other hand, gross floor area, and level of planning have negative effect on the direct costs of doors and windows and can reduce direct costs.

The result shows a computed F statistics of 127.26 with an observed significance level of 0.000 less than 0.05 implies rejection of the hypothesis that there is no significant relationship between the modelling factors and the direct costs of doors and windows in the zone. From Table 5.35, a correlation coefficient (R) of 0.900 shows a strong linear relationship between the independent variables and direct cost of doors and windows as measured by the correlation between the observed and predicted values of the total direct costs of doors and windows, while a coefficient of determination (R^2) of 0.811 and adjusted R^2 of 0.804 indicates that about 80.4% of the variance in direct costs of doors and windows may be accounted for by variables in the model.

The results of the analysis also show that, bid price (beta value = 1.15) made the strongest unique contribution to explaining the dependent variable, followed by gross floor area (-0.964), labour prices (0.463), number of floors (0.152), Transportations (0.083), site topography (0.080), level of planning (0.066). The optimum model from the result shows that all the variables left have significant contribution to explaining the dependent variable.

Roof model: The result of the fourth regression model shows that the p-values of all the variables are less than 0.05 hence all the variables contribute significantly to the model. Therefore the accepted optimal model is model MR4 for roof and the final regression model for the direct costs of roof can be represented as;

$$T_{DC.\ ROF} = 687.772 – 1.214X_1 + 59.942X_4 + 1.915E\text{-}5X_5 – 19.060X_6 + 312.954X_8 + 029X_9 + 1.728X_{10} – 58.435X_{16} - 1399.052X_{20}$$

The model implies that, number of specification and design errors, bid price, site topography, material prices and labour prices have positive effect on the total direct cost of roof, hence can increase direct costs. Conversely, gross floor area, contract period, inflation and level of planning have negative effect on the direct costs of doors and windows and can reduce direct costs.

From the results a computed F statistics of 69.830 with an observed significance level of 0.000 less than 0.05 implies rejection of the hypothesis that there is no significant relationship between the modelling factors and the direct costs of doors and windows in the zone.

From the result, a correlation coefficient (R) of 0.868 shows a strong linear relationship between the independent variables and direct cost of doors and windows as measured by the correlation between the observed and predicted values of the total direct costs of doors and windows, while a coefficient of determination (R^2) of 0.753 and adjusted R^2 of 0.742 indicates that about 74.2% of the variance in the direct costs of roof may be accounted for by the variables in the model.

The results of the analysis also show that, labour prices (beta value = 0.572) made the strongest unique contribution to explaining the dependent variable, followed by bid price (0.475), gross floor area (-0.432), material prices (0.202), level of planning (-0.110), contract period (-0.105), inflation (-0.098), number of specification and design errors (0.0) and lastly site topography (0.077). The optimum model from the result shows that all the variables left have significant contribution to explaining the dependent variable.

DISCUSSION OF RESULTS

A total of twenty quantitative factors were identified and a total of six models were developed to predict the direct costs, one for each structural element. A total of eleven variables that contributed to different direct cost of elements were used for the models developed with standard regression. The smallest number of variables used was six in substructure and wall, seven in floor, frame and doors/windows, while the largest was nine in roof. The results of the study show that three variables (gross floor area, bid price and labour price) were used in all the models, three variables (transportation, inflation and level of planning) were used in three of the models. Material price was used in two models, while contract period was used in only one model.

The study shows that the adjusted coefficients of determination (Adjusted R^2) vary between the lowest (0.742) in the model for the roof and the highest (0.830) in that of floor. These values are high representation of the rate of which the variables account for the variance in the direct costs in the models. These are higher than the best R^2 of 0.41 reported by Chan and Park (2005), 0.661 by Lowe, Emsley and Harding (2006) and 0.20 by Ganiyu and Zubairu (2010), but comparable to the range of 0.50 to 0.86 reported by Wheaton and Simonton (2007).

The study also shows that three variables made the strongest unique contribution to explaining the direct costs of the elements, these are namely; gross floor area, bid price and labour prices, while specification and design error and inflation made the least unique contribution to explaining the direct costs of the elements. The study observed that seven variables were prominently dropped from all the models either due to multicolinearity among themselves or due to insignificant contribution to the models; especially the macro economic factors irrespective of their correlation with the direct costs were highly correlated among themselves.

This can be explained from the fact that some of the variables, though in themselves may not have exerted significant influence on the direct cost, yet do correlate well with a number of significant variables that do. Another explanation to the effect of inter-correlation is the difficulty of knowing which of the variables is making the strongest unique contribution to the model, hence such variables can be represented by anyone in the group.

Another significant finding of the study is that some variables exerted negative influence on the direct costs of the elements as against what one would have ordinarily expected. The variables are namely gross floor area, contract period and inflation rates. The negative influence of the gross floor area is similar to what was reported by Wheaton and Simonton (2007), this was firstly attributed to the fact that there is an economy of scale in all construction, and cost per square area typically declines as the overall size of the project increases. This is because larger projects typically have increased productivity due to increased efficiency of repetitive work. Secondly, larger projects also often can exert market pressure on the purchase and assembly of materials on site. Ordinarily, normalization of the direct costs was achieved by expressing the costs per total gross floor area. This implies that an increase in the floor area in the long run will decrease the ratio of cost to gross floor area.

The negative influence of contract period can be explained from the fact that when projects are made to be delivered ahead of schedule, more costs are usually incurred to speed up the work so as to meet up with the urgency of the expected delivery period. In a similar manner the negative influence of the inflation rate is also attributable to the fact that when inflation is high, there are increased uncertainties which discourages developers, such that the drop in the level of construction forces down cost of construction. The high coefficients of determination recorded during modelling are suggestion of the reliability and accuracy of the models.

CONCLUSIONS AND RECOMMENDATIONS

In building construction, cost variation factors that are investigated comprehensively are often used to explain the change of construction costs over place and time. By taking note of the value and nature of such quantitative cost variation factors it is possible to make precise forecasts of the future values of the direct costs of building elements, and develop a deeper understanding of construction costs resulting from prices of resources and influencing factors. Incorporating such an understanding and prediction into cost anticipation and allocation will help practitioners to manage construction costs to the satisfaction of low and medium income families. The models developed in this study capture the main structural elements considered most important by the low and medium income earners with the various direct costs determinants. The approach provides a simplified approach which will enable practitioners to determine the total direct costs of each structural element, and hence determine the labour and profit values accruable to each structural element from which percentage estimate of project overhead can be estimated when using labour only contract system. While our analysis has only considered direct costs which do not necessarily cover the entire construction costs, they do have total cost implications as they represent about 70% and above especially in direct labour and labour only systems where substantial amount of project risks are shared by the clients thereby reducing the contractors overhead cost components of the project. An understanding and use of the elemental models will help to reduce the problem associated with consistent cost failure and frustration leading to partial occupation in the event of inability to finance the project to practical completion. The results of the study establish a high level of reliability of the six models developed to predict the direct costs, of each structural element with high coefficient of determination. The models utilize a total of eleven variables, which appeared at different proportions in the models developed using standard regression. The study also shows that three variables namely; gross floor area, bid price and labour prices made the strongest unique contribution to explaining the values of the direct costs of the structural elements.

The study therefore recommends that practitioners should adopt this elemental approach to cost anticipation and allocation because it helps to simplify planning and enhance cost management at different phases of work items especially when using labour only delivery system. The study also advocates that practitioners should use the developed models for prediction of direct costs of the selected building elements in Nigeria, from which the overhead cost component of the project can be estimated as percentage of the direct costs and hence, accurately forecast the total construction cost for the low and medium rise buildings among low and medium income families.

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