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Empirical Model for the Validation of Estimated Completion Time of Construction Projects and Their Value of Variation

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Abstract:- Variation has a significant effect on the cost and time of delivery of construction projects. It has been ascertained from this study that the nature of variation allows for addition, omission or alteration in design, time and ultimately cost. To account for these effects, some fundamental contractual variables or parameters, like initial contract sum, value of approved variation time, final contract sum, estimated completion time, value of variation as determinants of variation where investigated. An empirical model was generated to show the recurrence relationship between estimated completion time ($\wp$) and values of variation (Λ) vide a field sampling experimentation. Hypothetical findings have been observed on the logical dependence of these parameters to show that there is a significant relationship between these two variables.

Keywords:-Estimated completion time, value of variation, variation order, final contract sum, final completion time.

I. INTRODUCTION

There are many reasons why variations occur. As noted by Mohammad, CheAni, Rakmat and Yusof (2010) they may be due to extra work caused by surface conditions, errors in contract documents, additional quantities of works or materials, reduction of work, or lack of proper communication between the parties. They postulated further, that needs of the owner may impose change to the parameters of the project, and technological developments may alter design and the choice of the engineer. The architect's reviews of the design may bring about changes to improve or optimize the design and hence the operation of the project (Ireland, 2007). All these factors and many others necessitate changes that are costly and generally unwelcomed by all parties (Koushki, Al-Rashid and Kartam, 2005). Egwunatum (2001) noted that the nature of construction projects demands extensive planning, and entails evaluating societal compliance and needs, carrying out feasibility and viability appraisal, preparing designs and determining cost of proposed development or infrastructure. Egwunatum (ibid) emphasized that in carrying out these fundamental assessment, one is bound to integrate variation, going by its frequent occurrence in modern contractual arrangement. The reason for this is that few if any contract runs their normal course without need to modify the work shown in the contract documents which is a major feature of variation (Oladapo, 2007; Hassel, Josephson, Langstrom, Sauk-Kopriip and Hughes, 2005). This involves changes to decision and designs, implying order of additions and/or omissions after a contract is let (Ashworth and Hogg 2008). In summary, the prevalence and inevitability of variations raises questions as to the extent to which they reflect legitimate and important changes in the work or reveal inadequacies in decision-making and interactions in the design and construction process.

II. DEFINITION OF TERMS

According to Mohammad et al (2010), there is no single definition of what constitutes a variation. This is owing to the perspective of the various continental building and construction standard forms of contract and their measurement and evaluation codes (Uff, 2005; Patrick and Toler 2008; Finsen, 2005). This study strongly rely on the Joint Contract Tribunal (JCT) of 1980 as revised in JCT 2005, institute of Civil Engineers (ICE) of 1979 as revised in ICE 2001 and the standard form of building contract in Nigeria (1990) as revised in 2000 to harmonize variation definition as;

1.0 The alteration or modification of the design, quality or quantity works as shown upon the contract drawings and described by or referred to in the contract bills, including but not limited to:
1.1 The addition, omission or substitution of any work.
1.2 The alteration of the kind of standard of any of any of the materials or goods to be used in the works.
1.3 The removal from site of any work executed, materials or goods brought thereon by the contractor for the purpose of the works other than work materials or goods which are not in accordance with the contract.

2.0 The addition, alteration or omission of any obligations or restrictions imposed by the employer in the contract bill with respect to;
2.1 Access to the site or use of any specific part of the site
2.2 Limitations of working space
2.3 Limitations of working hours
2.4 The execution or completion of the work in any specified order but not including;
3.0 Nomination of a sub-contractor to supply and fix materials or goods or execute works of which the measured quantities have been set out and priced by the contractor in the contract bills for supply and fixing or execution by the contractor.

In summary, Arian (2005) and Arian and Pheng (2005) noted that one distinguishing characteristics of variation is that it an obligation which a quantity surveyor should price before the Engineer/Architect issues the relevant instructions or orders, to effect the variation.

Experiment

In most construction projects it is difficult to reconcile the initial contract sum and final contract sum. This is principally owing to the fact that the contract has been infested by variation. The formative reason for this assertion is that few, if any variation has no effect on the contract sum. Therefore, this study aims at experimenting the effect of variation on the cost of construction project based on statistically tested model from field experimentation of variation dependent parameters. This will be done by regressing the linear and non-linear relationship between Estimated Completion Time (ECT) and Value of Variation (VOV), for projects within the range of N5million ($0.33million) to N1billion ($6.6million) and above.

The hypothesis to be tested in this work is;
H_o: There is no significant relationship between the estimated completion times (ECT) and the value of variation (VOV) of construction projects.
H_1: There is a significant relationship between the estimated completion times (ECT) and value of variation (VOV).

Apparatus

Personal Interviews

Experts in the field of construction technology and management in the capacity of the Engineer, Quantity surveyor, Architects and project managers were subjected to questions.

These interviews were aimed at evaluating the respondent's level of understanding on the subject of variation, so as to confide in their response for the primary data. The second reason for the personal interview was to ensure that the answers they give properly reflect what they had in mind.

Personal Observation

To earn the confidence of the researcher and the reliability of the data collected, personal observations of the files and records were requested from the respondents. Among all the professionals, the Quantity Surveyors were most resourceful in that they permitted access to the records of past completed projects.

Questionnaire

The questions posed in the questionnaire were quite objective and targeted, but in the course of analysis not all the questions was analysed as those like type of organization which have no direct relevance on the result of the study will be eliminated. The questions were twenty five in all to make up the primary data, while appendix – A attached to the questionnaire makes up the secondary data, though both data will form a fair assessment of the study.

III. ANALYTICAL TECHNIQUES

The analysis of variance was used for the inferential statistics. The Pearson correlation coefficient was used to estimate the correlation matrix presented in this research. The models were analysed by methods of regression using ordinary least square techniques based on two packages from SPSS version 19.0.In the process of the analysis, questions reflecting the problems which this study aimed at solving were built-up and made out in codified spreadsheet. The questionnaire were in two main sections, one inquired into the professional competence and experience of the respondent, while the second part tried to ascertain the professional involvement and various issues raised as causes in the incidence of variation together with their various implications and remedies looking at the contract as a whole. In testing the hypothesis if $F_{calculated}$ is greater than F_{table} then the hypothesis is rejected which means that there is a significant difference between the variables. But if F_{cal} is less than F_{tab}, we will accept the null hypothesis. Hypothesis testing were carried out at 5% significant level ($\propto = 0.05$). The Pearson correlation coefficient will be estimated and the correlation range used in the estimate was $-1 \le r_{xy} \ge 1$. The analysis of variance (ANOVA) was used for the decision index which will be presented in tables (Kumar, 2005 and Walliman, 2005). The standardization of the various models generated depends on their various coefficients of the variables. Each coefficient has their central standard error (S_E) for each model. The Durbin-Watson (DW) Test was also employed to check the decision generated by the model from its regression coefficient square. This was done by estimating thus: if $R^2 >$ DW then the model in question has spurious regression doubt (Pallant, 2005).

IV. RESULTS

Following the field experimentation the table below presents at a glance the cost information of the projects listed with various variations and the time frame for the variations award.

Nomenclature

ψ	=	Initial Contract sum	
ζ	=	Final Contract sum	
Λ	=	Value of Variation	
$\wp$	=	Estimated completion time	
$\mathcal{F}$	=	Final completion time	
$\Im$	=	Approved variation time	
$\Re$	=	Ratio of cost	$= \frac{\psi}{\zeta}$
$\mathfrak{H}$	=	ratio of time	$= \frac{\Im}{\mathcal{F}}$

Table 1:

s/n	ψ	ζ	Λ	$\wp$	$\mathcal{F}$	$\Im$	$\Re$	$\mathfrak{H}$
1.	23317047	30077862	7760815	12.00	15.00	3.00	.78	.20
2.	5000000	8212231	3212331	4.00	7.00	3.00	.61	.43
3.	33997000	36097321	2100321	13.00	19.00	6.00	.94	.32
4.	3.97E+08	5.72E+08	1.75E+08	36.00	47.00	11.00	.69	.23
5.	3.00E+08	3.13E+08	13000000	47.00	57.00	10.00	.96	.18
6.	2.12E.08	3.25E+08	1.13E+08	23.00	51.00	8.00	.65	.19
7.	5333617	8373022	3039405	20.00	24.00	4.00	.64	.17
8.	21046717	25339000	4292283	19.00	21.00	2.00	.83	.10
9.	13667086	16789401	22314.75	26.00	27.00	1.00	.81	.01
10.	6.35E+08	7.07E+08	72226254	38.00	42.00	4.00	.90	.10
11.	14200735	16317200	2116465	27.00	29.00	2.00	.87	.07
12.	3.20E+08	4.11E+08	91214799	16.00	22.00	6.00	.78	.27
13.	3600000	5000000	1400000	10.00	13.00	3.00	.72	.23
14.	1.50E+08	1.33E+08	17400000	28.00	20.00	5.00	1.13	.21
15.	3000000	3030000	30000.00	4.00	6.00	2.00	.99	.33
16.	1100000	1270000	170000.0	12.00	14.00	2.00	.87	.14
17.	1600000	2350000	7500000.0	24.00	60.00	36.00	.68	.60
18.	1000000	1300000	300000.0	12.00	28.00	16.00	.77	.57
19.	850000.0	1.36E+09	51000000	104.00	20.00	14.00	.82	.33
20.	2.81E+08	2.85E+08	4000000	36.00	48.00	12.00	.99	.25
21.	9.05E+08	1.00E+09	5000000	52.00	43.00	13.00	.95	.21
22.	2.01E+08	2.38E+08	36490811	69.00	72.00	3.00	.85	.01
23.	3.07E+08	4.11E+08	1.04E+08	31.00	40.00	9.00	.75	.23
24.	87705977	9.92E+08	1.15E+08	66.00	78.00	12.00	.09	.15
25.	7.49E+08	9.09E+08	1.60E+08	104.00	125.00	21.00	.82	.17
26.	1.62E+09	2.03E+09	4.16E+08	100.00	121.00	21.00	.80	.17
27.	8.18E+08	9.37E+08	1.19E08	27.00	39.00	12.00	.87	.31
28.	3.97E+08	5.72E+08	1.75E+08	36.00	47.00	11.00	.69	.23
29.	7.11E+08	8.73E+08	1.62E+08	82.00	89.00	7.00	.81	.08
30.	18000000	2000000	2000000	104.00	128.00	24.00	.00	.19
31.	38000000	42000000	4000000	156.00	192.00	36.00	.90	.19

Model Specification

A simple regression and correlation, matrix models was formulated for this study. The model is specified below:

$$\wp = \beta_0 + \beta_i (\Lambda) + \varepsilon t$$

Where; β_0 and β_i, $i = o, 1$, are parameters to be estimated.

ε_t is the error term that is identically and independently distributed with mean zero and variance zero.

Data Analysis and Presentation of Findings

This section presents an in-depth appraisal and analysis of the results obtained from the field survey. In the presentation of the field experiment, there are various simplified tables and figures, which were generated from the more elaborate table of figures 2.0. In the course of this data analysis, thirty-one (31) completed projects were unbiasly selected from among the forty-one (41) returned questionnaires were presented for this analysis.

Sampling Method, Procedure and Size

The stratified random sampling technique was adopted in selecting the construction projects for this study. The entire data collected was for completed and abandoned projects with the Niger-Delta region of Nigeria. Two sets of data were collected, which were the primary and secondary data. The primary data source was from the questionnaires, which intend to respond to reliability of the respondent's experience, while the secondary data source was from the client's and contractor's data bank. The sampling covered the years between 2000 and 2014. With a total number of 80 questionnaires distributed. Uwerhiavwe (2007) noted that in stratified sampling, the sizes of sub-sample from each stratum must be proportional to the sizes of the respective strata by $\frac{n_1}{N_1} = \frac{n_2}{N_2} = \ldots\ldots\ldots = \frac{n_k}{N_k} = \frac{n}{N}$ so that if a sample of size '*n*' is to be proportionally allocated to the strata of a population of size N, the sample size for the i_{th} stratum will be giving by $n_i = n.\frac{n}{N}$. So that if a sample of size '*n*' is to be proportionally allocated to the strata of a population of size N, the sample size for the i_{th} stratum will be giving by $n_i = n.\frac{N_i}{N}$. In order to achieve this, list of relevant professionals in public service, multinational construction companies and private practice in three (3) states of Niger–Delta were obtained from ministerial gazette and professional bodies. The general sample size was determined from $n = \frac{n^1}{1+\frac{n^1}{N}}$, where n = sample size; $n^1 = \frac{S^2}{V^2}$ (Aje 2008).

N = Total population, V = standard error of sampling distribution = 0.05 estimated from $V_{\mu st} = \sum_h^k \frac{N_h^2}{N^2}(1 - f_n)\frac{S_h^2}{n_k}$

P = Proportion of population element that belongs to the defined strata computed from the proportional allocation.

The table below gives the questionnaire response rate at a glance.

Table 2:

Type of organization	Total number of sent out	Number returned	Return rate	Remark
Construction company	30	18	60%	Good
Private practicing firm	20	8	40%	Fair
Public service	30	15	50%	Average
Total	80	41		

Discussions

Analysis was carried out between the estimated completion time (ECT) and value of value (VOV) based on the data Extrapolated from the secondary data and the information supplied gave the result in the following table.

Table 3:

Variable	Mean	Standard deviation
$\wp$	43.16	37.35
Λ	615452.73	896336606.26
N = 31		

From the result above, it shows that average variation value within the limit of contract sum in this research is within the range of sixty to sixty-five million naira (N60,000,000 – N65,000,000 i.e. $39,4736.84 - $427631.58) has an average completion time of forty-three weeks. The total estimated completion time has a standard deviation of 37.35 this goes to show that the mean time for the above variation range is outrageous suggesting that there is no time gain in the variation range. The correlation between the $\wp$ and Λ is presented in matrix form as:

	$\wp$	Λ
$\wp$	1.000	0.354
Λ	0.354	1.000

Since the matrix is symmetrical about the diagonal, it goes to show that there is a moderate correlation between the two variables. This is interpreted as: if there is increase in contract sum due to variation there is the tendency for the completion time to be increased. From the mean result and standard deviation, it is evident that the value of variation can be used to adjust the estimated completion time. From the correlation result, a model is presented between Λ and $\wp$ based on the regression that aims to show the relationship between the two variables.

The multiple regression (R) on Λ against $\wp$ = 0.35418

R^2 = 0.12544

Adjusted R^2 = 0.09529

Standard Error on Λ = 35.52351

The analysis of variance on Λ gave

Table 4:

	D_F	***S_S***	***M_S***
Regression	1	5250.28614	5250.28614
Residual	29	36603.90741	1262.20370

This gives F_{tab} = 4.15962 and F_{signif} = 0.506

The Equation is frustrated by the standard errors associated with the coefficient of each variance, which must be off-set if the model is to be generalized. The standard errors are: 7.7815 for 34.0778 and 7.2366 X 10^{-3} x 10^{-7}

The generation of coefficient gave:

Table 5:

Variable	**β_0**	**$S_E\beta_0$**	**β_1**	**T**	**Sig T**
Λ	1.4759 x 10^{-7}	7.2366 x 10^{-8}	0.3542	2.040	0.0506
Constant	34.0718	7.7815		4.379	0.0001

Having generated the coefficient, the mathematical model between $\wp$ and Λ is given as;

$$\wp = 34.0778 + 0.00000014759\ \Lambda$$

This equation is consistent for construction projects between the estimated completion time and the value of variation. Since it is a linear relationship when the value of variation is injected into the equation the estimated completion time can be determined. To test the confidence of the Equation, the Durbin-Watson (DW) test is used to determine it.

If adj R^2 = 0.09529}

Dw = 0.82448}

Since DW > adj R^2 then the equation has a positive auto regression, showing that the equation is consistent. The Durbin-Watson is estimated from the Residual statistics below:

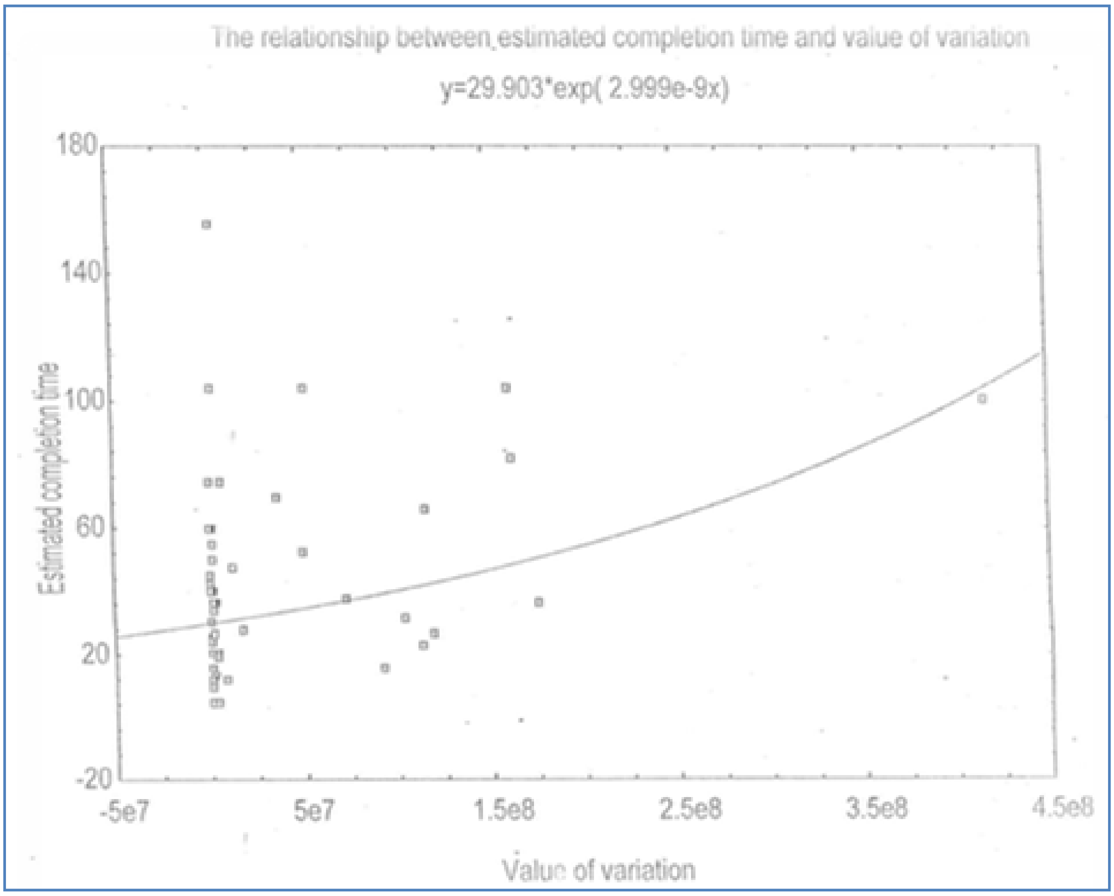
Table 6:

	Min	***Max***	***Mean***	***Std. Dev.***	***N = observation***
PRED	34.0811	95.4995	43.1613	13.2291	31
RESID	-31.5402	121.3319	0.0000	34.9304	31
ZPRED	-0.6864	3.9563	0.0000	1.0000	31
ZRESID	-0.8878	3.4152	0.0000	0.9832	31

Total cases = 31

Durbin-Watson Test = 0.82448

Table 7:



Hypothesis Testing

The hypothesis to be tested has been stated under analytical techniques and the method adopted for this test is the statistical technique of Analysis of Variance (ANOVA).

H_o: There is no significant relationship between the estimated completion time (℘) and value of variation (Λ).

H_1: There is a significant relationship between the estimated completion time (℘) and value of variation (Λ).

At 5% significant level ($\propto = 0.05$). The ANOVA table is therefore presented in summary as calculated by the researcher based on respondent information from the secondary data.

Summary of Table

Table 8

Groups	Count	Sum	Average	Variable
Column 1	31	1338	43.161	1395.140
Column 2	31	1.91×10^9	6.146×10^7	8.02×10^{15}

ANOVA Table

Table 9:

Source of variation	SS	Df	MS	F	R_{value}	F_{crit}
Between groups	$5.86\text{x}10^{16}$	1	$5.86\text{x}10^{16}$	14.606	0.000317	4.0012
Within groups	$2.41\text{x}10^{17}$	60	$9.01\text{x}10^{15}$			

From this ANOVA table, the F-calculated is equal to 14.606 which is greater than the F-table. Based on this, the hypothesis is rejected. Because this hypothesis is rejected, we therefore accept the alternative hypothesis (H_1), showing that there is a significant relationship between the estimated completion time (℘) and value of variation (Λ) when tested at 5% significant level. When the null hypothesis (H_0) is rejected it therefore expressly implied that the alternate hypothesis (H_1) is the auto-correlated hypothesis. The Durbin-Watson (DW) value is therefore tending to zero (o) showing that the spurious doubt level of this alternate hypothesis (H_1) is minimal. Hence, the alternate hypothesis can be stated thus. There is a significant relationship between the estimated completion time ($\wp$) and value of variation (Λ) given by the relationship:

$$\wp = 34.0778 + 0.00000013759\ \Lambda$$

The error which makes the null hypothesis not to be accepted has been emphasized by the constant and the coefficient of Λ when the error of the relationship is injected into the equation. From this ANOVA result and going by the alternate hypothesis acceptance, it means that value of variation can be used to predict the estimated completion time ($\wp$) of a construction project.

V. CONCLUSION

From this study it has been deduced that there is a significant relationship between the estimated completion time ($\wp$) of construction projects and their values of variation (Λ), should variation be ordered in the project. This assertion is statistically compliant which made the linear and exponential relationship valid such that either of the variables can be interchanged to determine the other.

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