Nigerian Journal of Technology (NIJOTECH)
Vol. 42, No. 1, March, 2023, pp.72 - 82
www.nijotech.com

Print ISSN: 0331-8443
Electronic ISSN: 2467-8821
https://doi.org/10.4314/njt.v42i1.9

MODELLING REWORK COST FOR TETFUND BUILDING CONSTRUCTION PROJECTS IN NIGERIA

M.A. Dandajeh[1,*], A.D. Ibrahim[2], Y.M. Ibrahim[2], K. J. Adogbo[2] and H. A. Ahmadu[2]

[1] Department of Quantity Surveying, Abubakar Tafawa Balewa University, Bauchi
[2] Department of Quantity Surveying, Ahmadu Bello University, Zaria

*corresponding author (Phone Number: +234-803-428-3825. Email: smad961@gmail.com)

Article history: Received 02 June, 2022. Revised 11 November, 2022. Accepted 17 November, 2022

Abstract
Accurate predictions of rework cost enable contractors to evaluate how successful their projects are likely to be, thus, improve their operations and productivity. Studies have developed project scope-based and non-scope-based rework cost predictive models. However, researchers have criticized the accuracy of these models because of their weaknesses in giving individualistic treatments to project scope-based and non- scope-based rework cost influencing factors. This study therefore aimed at developing rework cost predictive models that combine the synergistic effects of both project scope-based and non-scope-based rework cost factors. 440 sample size was drawn from 2,638 population of Tertiary Education Trust Fund (TETfund) building projects constructed between 2009 to 2015. Data of 287 (65%) of 440 (sample size) of completed TETfund building projects on project scope factors as well as the extent of influence of the non-scope factors on cost of rework in TETfund building projects was collected. Principal Component Analysis (PCA) and Multiple Linear Regression (MLR) were used in developing an integrated rework cost predictive model. More accuracy was achieved in the integrated model through the incorporation of impact of project scope and non-scope influencing factors into rework cost prediction model, this increased the variability in cost of rework to R^2 = 0.759 (75.9%), while errors in rework cost predictions reduced by as much as 9.75%.The model serve as useful tool used to enhance accuracy of rework cost predictions for TETfund building contractors, thus reduce cost of rework for building construction projects.

Keywords: Rework cost, Project scope and non-scope factors, TETfund building projects, Principal Component Analysis, Multiple Linear Regression.

1.0 INTRODUCTION

The unnecessary effort of redoing a process that was incorrectly implemented at the first instance has become a problem affecting successful execution of construction projects as it induces cost and time overruns as well as poor safety performance [1-3]. To manage rework, it is necessary to first, identify and classify the factors that influence its occurrence [4]. Project characteristics, organizational management practices of individual firms and project management practices employed have been identified as the main factors influencing cost of rework in construction projects [5]. Project characteristics also known as project scope factors are considered to be a reliable measure of project size in terms of physical size and area of development and cost [6]. These characteristics include construction costs, project duration, gross floor area (GFA), number of stories, building type, project type, type of organisation and project location in relation to company's headquarter [5-7]. On the other hand, ineffective use of quality management practices, lack of manpower to complete tasks, setting out errors, lack of knowledge of the Design & Construction processes, ineffective use of Information.

Technology etc are some of the organizational management practices and the project management practices factors influencing cost of rework in construction projects [5, 4, 8, 9, 10]. Organizational and project management practices factors influencing cost of rework are interrelated [5], thus, merged and termed as non-scope factors in this study. Similarly, causes of rework, sources of rework and non-scope factors are used interchangeably as rework cost influencing factors in this study.

In the building industry, words like error, fault, failure, defect, quality deviation, non-conformance, quality failure, snag, and rework are used interchangeably to describe imperfections in buildings [11, 12, 13]. Rework is defined in different ways depending on the context as it means different things to different people which always suggest that client's desires were not met [13, 7]. It is worth noting that the different definitions of rework are used and therefore different methodologies applied and different conclusions drawn. Rework cost or cost of rework is defined in this study as the total costs incurred to correct constructed parts of a building that do not satisfy quality specifications or client's requirements (Dandajeh, 2021).

Rework costs have found to be 16-23% of construction costs in UK, 2.3-9.3% in Sweden, 5.6-12.4% in U.S.A and Australia, 12.45%-15.58% in Uganda, 3.35% - 4.40% in Mozambique and 5 and 13% in Nigeria and South Africa [14-15, 3]. These demonstrate that rework costs have been found to be between 2% to 25% of construction costs globally and differ from one country to another. To reduce cost of rework in construction projects, researchers have found it necessary to predict it occurrence in construction projects [16-18, 7] as accurate predictions of rework cost enable contractors to evaluate how successful their projects are likely to be, thus, improve their operations and productivity [5, 7]. The prediction will not only bring project success but also bring out the optimum mixture of significant variables that will assist towards its reduction [7, 15]. Predicting the total cost of rework with high accuracy has therefore become fundamental to the successful execution of construction projects.

Rework cost prediction commenced largely with the use of non-scope-based on one hand, and project scope-based models on the other hand [5, 16, 17, 18, 7].The accuracy of these models have been criticized based on their weaknesses in giving separate treatments to both project scope-based and non-project scope-based rework cost factors [18, 17, 7, 19, 20].It is evident therefore that existing rework cost prediction models have minimal predictive accuracies as they consider the effect of project scope and non-scope based factors separately. Consequently, there is little evidence to show that rework and its associated costs have been reduced in construction projects [21, 27, 20, 23, 24, 25, 26, 27]. To improve the accuracy of the existing models, researchers suggested that a combined treatment be given to both factors [24, 7].

2.0 METHODOLOGY

TETFund building construction projects completed between the years 2009-2015 were considered as the survey population of this study. TETFund building construction projects were chosen due to homogeneous nature of the projects (shared similar characteristics) as observed by [28] that to ensure accuracy of predictive models, homogeneity of the population sample is very important. Similarly, the implementation/execution of TETFund building projects is governed by the principles and policies of TETFund. Again, the years 2009-2015 are within the range specified experienced the same economic conditions and contractors' yearly profit within the period was reduced by 28% due to costs of rework [26]. The total number of TETFund building projects completed between the years 2009-2015 (as shown on TETFund's website) approximates to 2,638. Therefore, the survey population of the study was set at 2,638.

The sample size is computed as 314 using [29]. However, in order to maximize the amount of the study responses because of the poor response rate usually recorded in the construction industry studies [30], and based on the [31] and [32] recommendation, the sample should be increased by 40%-50% to account for lost mail. On this note, a total of 440 questionnaires were issued out to survey respondents, instead of 314 computed as the sample size.

A comprehensive literature review was first conducted to establish a foundation for this study and to support the development of a survey questionnaire. Then, a pilot study was conducted with 7 building contractors who had more than 10 years of experience in TETund building construction projects to validate the questionnaire. The finalized questionnaire was divided into three sections (A, B, and C). Section "A" requested demographic and general information from the respondents. These include information such as position/rank of the respondent and level of experience in the construction industry. In order to ensure that cost of rework is properly captured, the definition of cost of rework in this study was given in section B. In this section, respondents were asked to provide a percentage cost increase due to rework of the TETFund building projects they had experienced and the year in which the building was completed. Data on the total cost of rework and the cost incurred for each factor influencing cost of rework in each project were derived from two sources (Primary and

Secondary data): first the experience and knowledge of respondents on the rework in projects in which they participated; and second, firms' internal records on actual construction cost and progress schedule.

In section C, the table is sub-divided into two parts (1 & 2). Part 1 of section C of the questionnaire requires respondents to give basic details of the project which they have decided to use, to complete the table. The basic project details and project characteristics (project scope factors) requested include; construction cost, project duration, gross floor area of the building, number of floors in the building, facility type and the year in which building was completed. In part 2 of Section C of the questionnaire, 34 non-scope factors derived from the work of [33] as potential rework cost influencing factors in TETFund building projects were listed and respondents were asked to rate the extent to which each non-scope factor contributed to cost of rework in TETFund building projects on a 1-4 Likert type scale.

[34], reported that by using an odd number of response points, respondents may be tempted to 'opt out' of answering by selecting the mid- point. To prevent respondents from choosing a mid-way point and fence-sitting, it might be helpful not only to keep the number of response points small but also to use an even number of response points, thereby having no central point [34, 32]. The responses obtained were analysed with the use of IBM SPSS (version 25.0) software. Then, principal component analysis was used to reduce the number of variables in the study without much loss of information in the process and thus, prevent the likely occurrence of multi-collinearity and to identify the significant variables [35]. Eigen values were used to drop variables or to retain them, variables with Eigen values > 1.0 are retained and variables with Eigen values < 1.0 are dropped [36]. Only 90% of the data obtained from the survey was used for the model development, the remaining 10% was set aside and used for testing the derived model.

3.0 RESULTS AND DISCUSSION

Characteristics of projects surveyed

Table 1 presents the rank/position and years of practice experience of the respondents in which at least 78% of the respondents were professionals/personnel at the senior and middle management levels of their corresponding construction firms. Thus, the above revelation is a testimony that the responses were from a sample of qualified personnel with adequate knowledge about how their firms' construction projects were managed.

Table 1: Rank/Position and Years of Practice Experience of Respondents

Class of information		Number	Percentage
Rank/Position			
Senior management level		59	20.56
Middle management level		165	57.49
Lower management level		47	16.38
Operational level		16	5.57
	Total	287	100
Years of Practice Experience			
1-5 Years		11	3.83
6-10 Years		52	18.12
11-15 Years		130	45.30
Over 16 Years		94	32.75
	Total	287	100

Also, Table 1 shows at least 78% of the respondents had at least 11 years work experience. This indicates that majority of the respondents had the requisite experience in their work, thus, making the assessment reliable.

Testing for the appropriateness of using PCA

The significance level of this test will determine if PCA will be appropriate or not. The Kaiser-Meyer-Olkin measure of sampling adequacy and the Bartlett's test of sphericity, both of which are tests carried out to determine the appropriateness of using a PCA. The result of the test as shown in Table 2 revealed that the value is greater than 0.70, indicating that the sampling adequacy for this study was good while the Bartlett's test was highly significant ($p < 0.05$), indicating that the original correlation matrix was not an identity matrix. This confirmed that using PCA for the non-scope factors was appropriate [36].

Table 2: The KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.729
Bartlett's Test of Sphericity	Approx. Chi-Square	4231.110
	df	561
	Sig.	0.000

Table 3: Extraction of principal components

Total Variance Explained			
Component	Initial Eigenvalues	Extraction Sums of Squared Loadings	Rotation Sums of Squared Loadings

	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.967	20.493	20.493	6.967	20.493	20.493	3.184	9.366	9.366
2	4.125	12.134	32.626	4.125	12.134	32.626	3.158	9.287	18.653
3	2.458	7.230	39.856	2.458	7.230	39.856	2.663	7.832	26.485
4	1.900	5.588	45.444	1.900	5.588	45.444	2.392	7.035	33.520
5	1.603	4.715	50.159	1.603	4.715	50.159	2.300	6.765	40.285
6	1.413	4.154	54.314	1.413	4.154	54.314	2.160	6.354	46.639
7	1.357	3.990	58.304	1.357	3.990	58.304	1.854	5.453	52.091
8	1.174	3.453	61.757	1.174	3.453	61.757	1.797	5.285	57.376
9	1.131	3.325	65.082	1.131	3.325	65.082	1.639	4.819	62.195
10	1.057	3.107	68.190	1.057	3.107	68.190	1.634	4.807	67.003
11	1.001	2.945	71.135	1.001	.945	71.135	.405	.132	71.135
12	.919	2.704	73.839						
13	.827	2.432	76.271						
14	.781	2.296	78.567						
15	.749	2.202	80.769						
16	.687	2.021	82.790						
17	.601	1.768	84.558						
18	.569	1.673	86.231						
19	.546	1.606	87.837						
20	.517	1.520	89.358						
21	.442	1.300	90.658						
22	.433	1.274	91.932						
23	.370	1.090	93.022						
24	.321	.943	93.965						
25	.317	.931	94.896						
26	.282	.829	95.724						
27	.265	.780	96.504						
28	.241	.710	97.214						
29	.200	.587	97.800						
30	.181	.533	98.333						
31	.165	.484	98.817						
32	.147	.432	99.250						
33	.139	.410	99.660						
34	.116	.340	100.000						

Extraction Method: Principal Component Analysis.

Table 4: Rotated Components Matrix

Variables	Components										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Inadequate manpower to complete tasks	0.750										
Lack of client's involvement during construction	0.714										
Omissions of some activities during construction	0.576										
Incomplete design at the time of tender	0.576										
Inadequate training of employees	0.547										
Staff reallocation to other projects											
Changes made at the request of a regulatory body		0.780									
Revisions, modifications of the design initiated by the contractor/subcontractor		0.727									
Errors due to inappropriate construction methods		0.667									
Setting out errors											
Poor planning and coordination of resources			0.779								
Omissions of items from the contract document			0.722								
Changes made at the request of the contractor during construction			0.562								
Ineffective use of information technology			0.542								
Inadequate project experience				0.859							

Poor coordination of works with the design consultant				0.557							
Unrealistic scheduling of construction tasks											
Damage to other trades due to carelessness					0.751						
Changes in construction method to improve constructability					0.582						
Misunderstanding of end-user requirements						0.755					
Failure to provide protection to the works						0.747					
Changes made at the request of an end user							0.764				
Inadequate of knowledge on material performance											
Inadequate managerial and supervisory skills											
Ineffective use of quality management practices											
Insufficient knowledge of the construction process								0.762			
Changes made at the request of the client								0.682			
Poor site investigation									0.742		
Poor planning of workload											
Changes in construction method due to site conditions											
Time boxing (inadequate time allocated to complete a task or activity)										0.818	
Inadequate technical background of the company				0.539						0.615	
Poor communication with design consultants											0.770
Use of poor materials											0.561

Extraction Method: Principal Component Analysis, Rotation Method: Varimax with Kaiser Normalization

Table 3 shows the process of extracting the principal components in a principal component analysis and the eigenvalue associated with each linear component represent the variance explained by that linear component and as recommended by [36], only eigenvalues greater than 1 are considered when extracting the principal components. The first principal component accounted for the highest variance (20.493%), followed by the second component (12.134%). Only 11 out of the 34 non-scope factors (variables/linear components) had eigenvalues greater than 1 in this study, signifying that a total number of 11 principal components accounted for the total variance in the 34 variables/linear components. The total variance explained/ accounted for by the extracted principal components was 71.135 per cent, indicating that not much information (28.865 per cent) was lost in the process, and therefore, good results will be obtained when these principal components are used, instead of the whole data set.

Table 5: Selecting principal corresponding components

S/N	Principal Components	Factor Loading
1	Inadequate manpower to complete tasks	0.750
2	Changes made at the request of a regulatory body	0.780
3	Poor planning and coordination of resources	0.779
4	Inadequate project experience	0.859
5	Damage to other trades due to carelessness	0.751
6	Misunderstanding of end-user requirements	0.755
7	Changes made at the request of an end user	0.764
8	Insufficient knowledge of the construction process	0.762
9	Poor site investigation	0.742
10	Time boxing (inadequate time allocated to complete a task or activity)	0.818
11	Poor communication with design consultants	0.770

Based on the selection criterion stated in the research work of [37] and [38] as shown in Table 4, only 11 variables/linear components with the highest correlation coefficient and, thus, the principal corresponding components were selected as principal components as shown in Table 5. It is worth noting as shown in Table 5, each variable/linear component loaded differently into the respective principal components. This clearly indicates that while the correlation coefficient/factor loading of a variable/linear component may be highly significant in one of the principal components, it may not be significant in the others.

3.1 Nature and the Strength of Relationship between Cost of Rework and Project-Scope Factors

Table 6 shows the pearson product-moment correlation carried out to determine the relationship between cost of rework and project scope factors. Prior to Pearson correlation analysis of a data set, it is required to check whether the data set to be analyzed meet some basic assumptions. The result indicates that, none of the assumptions was violated, an indication that study's data satisfies basic assumptions, and hence suitable for Pearson correlation.

As shown in Table 6, it is obvious that strong and positive significant relationships exist between cost of rework and project-scope factors an indication that the project scope factors considered in this study can be used to predict cost of rework.

3.2 Development of Regression Model

Table 7 presents the results of multiple linear regression analysis performed using stepwise selection procedure at a significance level of 5 percent using cost of rework as the dependent/response variable, and a combination of the four project scope factors (cost, duration, GFA and number of floors) with the eleven principal components of the non-scope factors as the independent/explanatory variables based on the assumption that;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \varepsilon \quad (1)$$

Where:
Y = dependent or response variable (variable to be modelled),
X_1, X_2, X_n = independent variables (explanatory variables),
ε_i = residual or random error component for individual i, and
β_i = respective regression coefficients.

Also as shown in Table 7 the stepwise selection procedure was iterated through ten steps; a variable was selected for inclusion in the model in the first ninth steps, while in the tenth step, none of the remaining variables lead to an increase in R^2 in accordance with the chosen selection criteria of a 5 per cent significance level and so the process was stopped at this tenth step.

The final fitted model as shown in Table 7, comprised nine predictors; no of floor, project duration, changes made at request of the regulatory bodies, inadequate man power to complete tasks, poor communication with design consultants, misunderstanding of end-user requirements, construction cost, inadequate project experience, time boxing. The multiple correlation coefficient is 0.615 (R = 61.5%), indicating that there is a strong correlation between the observed costs of rework and those predicted by the fitted model. The fitted model was highly significant at the 5% significance level (F (9, 248) = 43.978, $P < 0.001$).

However, as indicated by the fitted model's coefficient of determination (R^2), only 61.5 per cent of the total variation in costs of rework was explained by the model, implying that as much as 38.5 per cent of the variability in cost of rework will not be accounted for when the model is used to make predictions. Although the error distribution of the model was somehow normally distributed, the homogeneity of errors of fitted model has no constant variance and the fitted model appeared to have been influenced by outliers which most likely may be responsible for the small coefficient of some of the model's predictors. Single-log transformation was used to transform the data and the influential outliers were eliminated. The results of the multiple linear regression analysis at a significance level of 5%, which was repeated following these adjustments, were shown in Tables 8 and 9.

As shown in Table 8, the final fitted model comprised seven predictors, the multiple correlation coefficient (R) and the coefficient of determination (R^2) were both very close to one (0.87 and 0.76, respectively), indicating that the observed cost of rework and the fitted model's predictions are strongly correlated, and a large proportion of the variability in cost of rework (76 per cent) will be accounted for when the model is used to make predictions. The fitted model was highly significant at the 5% significance level (F (7, 239) = 107.801, $P < 0.001$), while the variance inflation factors (VIFs) are all below 5 as shown in Tables 9 and 10, indicating the non-existence of multicollinearity between the independent variables.

3.3 Rework Cost Predictive Model

A multiple linear relationship in the form $Y = \beta_0 + \beta_1 X_1 + \beta n\ Xn$ was assumed during the modelling process. However, because the data was single log transformed, the relationship can be written as ln(Y) =

$\beta_0 + \beta_1 X_1 + \beta n\ Xn$. Therefore, the model developed after transforming backlog transformed parameters/variables was expressed as:

$$Y = (e^{13.810}e^{0.1325})\ x\ (e^{0.666NF}e^{0.1325})x\ (e^{0.019D}e^{0.1325})x\ (e^{-0.129Q1}e^{0.1325})x\ (e^{-0.102Q2}e^{0.1325})x\ (e^{-0.108Q3}e^{0.1325})\ x\ (e^{0.095Q4}e^{0.1325})\ x\ (e^{0.091Q5}e^{0.1325}) \quad (2)$$

By simplifying equation 2 further, the rework cost model can be written as:

$$Y = (e^{14.87+0.666NF+0.019D-0.129Q1-0.102Q2-0.108Q3+0.095Q4+0.091Q5}) \quad (3)$$

Where;
Y = Rework cost in millions, NF = No of floor in numbers, D = Duration in weeks, $Q1$ = dummy variable for poor communication with design consultants, $Q2$ = dummy variable for inadequate manpower to complete tasks, $Q3$ = dummy variable for misunderstanding of end-user requirements, $Q4$ = dummy variable for changes made at the request of the regulatory body, $Q5$ = dummy variable for lack site investigation

As shown in the regression results in Table 9, the amount of the variability in cost of rework explained by the model for is high (R^2 0.76). Also, as shown in Table 11, the non-scope factors which emerged as predictors of cost of rework were; poor communication with design consultants, inadequate manpower to complete tasks, misinterpretation of end-user requirements, changes made at the request of the regulatory body and lack site investigation. These predictors are different from the non-scope factors which emerged as predictors of cost of rework in the existing models developed by the previous researchers [5, 16, 8]. This is an indication that rework cost predictive models are context-specific, as no combination of non-scope factors are the same for all the models. Similarly, as shown in the regression coefficients of the fitted model in Table 10, number of floors and project duration were the project scope factors which emerged as predictors of cost of rework. This is, however, not unexpected as both scope factors have been shown by previous research works to have good predictive abilities.

Table 6: Correlation between Construction Cost of Rework and each Project Scope Factors

		Project Scope Factors			
		Construction Cost	**Construction duration**	**Gross Floor Area (GFA)**	**No of Floors**
Cost of rework	Pearson Correlation	0.642	0.784	0.605	0.849
	Sig. (2-tailed)	0.000	0.000	0.000	0.000
	N	258	258	258	258

Correlation is significant at the 0.01 level (2-tailed)

Table 7: Summary of Fitted Regression Model

					Change Statistics				
Model	**R**	**R Square**	**Adjusted R-Square**	**Std. Error of the Estimate**	**R-Square Change**	**F Change**	**df1**	**df2**	**Sig. F Change**
1	.664[a]	0.441	0.439	6060924.174	0.441	202.043	1	256	0.000
2	.710[b]	0.505	0.501	5717581.908	0.063	32.669	1	255	0.000
3	.729[c]	0.532	0.526	5568975.033	0.027	14.791	1	254	0.000
4	.744[d]	0.554	0.547	5445745.210	0.022	12.625	1	253	0.000
5	.755[e]	0.570	0.561	5359604.408	0.016	9.198	1	252	0.003
6	.764[f]	0.583	0.573	5286110.821	0.013	8.056	1	251	0.005
7	.775[g]	0.601	0.589	5184342.824	0.017	10.951	1	250	0.001
8	.780[h]	0.608	0.596	5144241.640	0.008	4.913	1	249	0.028
9	.784[i]	0.615	0.601	5112283.766	0.006	4.123	1	248	0.043

Table 8: Summary of Fitted Regression Model

					Change Statistics				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**R Square Change**	**F Change**	**df1**	**df2**	**Sig. F Change**
1	.819[a]	0.671	0.670	0.59449	0.671	499.431	1	245	0.000
2	.843[b]	0.711	0.708	0.55864	0.040	33.459	1	244	0.000
3	.852[c]	0.726	0.722	0.54486	0.015	13.500	1	243	0.000
4	.857[d]	0.735	0.731	0.53671	0.009	8.434	1	242	0.004
5	.863[e]	0.744	0.739	0.52856	0.009	8.521	1	241	0.004
6	.867[f]	0.752	0.746	0.52139	0.008	7.669	1	240	0.006
7	.871[g]	0.759	0.752	0.51458	0.007	7.398	1	239	0.007

Table 9: ANOVA Results of Regression Analysis

Statistic	Sum of Squares	df	Mean Square	F	Sig.
Regression	199.813	7	28.545	107.801	.000h
Residual	63.285	239	0.265		
Total	263.098	246			

Table 10: Regression Coefficients of Fitted Model

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
(Constant)	13.810	0.080		171.799	0.000	13.651	13.968					
Numbers of floors in the building	0.666	0.040	0.672	16.728	0.000	0.588	0.745	0.819	0.734	0.531	0.624	1.602
Project duration	0.019	0.003	0.255	6.374	0.000	0.013	0.025	0.617	0.381	0.202	0.631	1.586
Poor communication with design consultants	-0.129	0.035	-0.122	-3.747	0.000	-0.197	-0.061	-0.043	-0.236	-0.119	0.944	1.059
Inadequate manpower to complete tasks	-0.102	0.033	-0.100	-3.075	0.002	-0.168	-0.037	-0.251	-0.195	-0.098	0.953	1.049
Misinterpretation of end-user requirements	-0.108	0.034	-0.102	-3.201	0.002	-0.175	-0.042	-0.096	-0.203	-0.102	0.989	1.012
changes made at the request of the regulatory body.	0.095	0.033	0.092	2.837	0.005	0.029	0.160	0.021	0.181	0.090	0.948	1.055
poor site investigation	0.091	0.033	0.086	2.720	0.007	0.025	0.156	0.117	0.173	0.086	0.996	1.004

Table 11: Comparing model prediction with observed cost of rework

PROJECT NO	OBSERVED COST OF REWORK	PREDICTED COST OF REWORK	% ERROR	MAPE
1	₦ 3,250,000.00	₦ 3,094,076.39	-4.80%	4.80%
2	₦ 3,044,002.00	₦ 2,867,640.14	-5.79%	5.79%
3	₦ 29,142,292.00	₦ 30,922,665.99	6.11%	6.11%
4	₦ 6,650,009.00	₦ 7,564,675.43	13.75%	13.75%
5	₦ 11,407,154.00	₦ 11,722,258.17	2.76%	2.76%
6	₦ 7,054,028.00	₦ 6,022,421.63	-14.62%	14.62%
7	₦ 7,588,145.00	₦ 6,497,967.54	-14.37%	14.37%
8	₦ 6,150,819.00	₦ 6,022,421.63	-2.09%	2.09%
9	₦ 5,995,022.00	₦ 6,022,421.63	0.46%	0.46%
10	₦ 14,959,077.00	₦ 14,724,156.47	-1.57%	1.57%
11	₦ 15,914,792.00	₦ 14,724,156.47	-7.48%	7.48%
12	₦ 7,855,348.00	₦ 6,497,967.54	-17.28%	17.28%
13	₦ 35,231,418.00	₦ 38,841,506.97	10.25%	10.25%
14	₦ 38,217,865.00	₦ 33,364,399.29	-12.70%	12.70%
15	₦ 15,341,058.00	₦ 17,141,277.47	11.73%	11.73%
16	₦ 31,364,600.00	₦ 33,364,399.29	6.38%	6.38%
17	₦ 3,450,027.00	₦ 3,094,076.39	-10.32%	10.32%
18	₦ 8,328,241.00	₦ 7,011,063.79	-15.82%	15.82%
19	₦ 13,416,124.00	₦ 14,724,156.47	9.75%	9.75%
20	₦ 14,640,120.00	₦ 14,724,156.47	0.57%	0.57%
21	₦ 18,317,923.00	₦ 15,886,813.76	-13.27%	13.27%
22	₦ 5,213,828.00	₦ 6,497,967.54	24.63%	24.63%
23	₦ 3,610,356.00	₦ 3,094,076.39	-14.30%	14.30%
24	₦ 2,544,693.00	₦ 3,094,076.39	21.59%	21.59%
25	₦ 39,875,123.00	₦ 40,345,886.42	1.18%	1.18%
26	₦ 42,095,735.00	₦ 37,393,221.40	-11.17%	11.17%
27	₦ 17,645,601.00	₦ 15,294,441.20	-13.32%	13.32%
28	₦ 2,670,236.00	₦ 2,867,640.14	7.39%	7.39%

29	₦ 5,619,682.00	₦ 6,022,421.63	7.17%	7.17%
Max. Error			24.63%	
Min. Error			-17.28%	
Ave. Error			-1.21%	
MAPE			9.75%	

Table 12: Statistical Significance difference between predicted cost of rework and observed cost of rework

		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
									95% Confidence Interval of the Difference	
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**Lower**	**Upper**
Cost of rework	Equal variances assumed	0.021	0.885	0.034	56	0.973	108583.033	3233395.988	-6368687.469	6585853.536
	Equal variances not assumed			0.034	55.974	0.973	108583.033	3233395.988	-6368752.620	6585918.686

3.4 Model Testing and Validation

The regression model developed in this study was tested and validated, and the results of the test showed that the model conformed to all the four principal assumptions namely, homoscedasticity (constant variance) of the errors, normality of the error distribution, linearity of the relationship between dependent and independent variables, and independence of the errors (no serial correlation).. The model was tested for its conformity to these assumptions through the use of residual plots, histogram of residuals, partial plots of the explanatory variables and variance inflation factors, respectively. Table 12 presents the observed costs of rework and the one predicted by the model for projects (twenty-nine) not used (10%) in the model development. The regression model has an average % error of -1.21% and MAPE of 9.75%. The value of MAPE of 9.75% is within the acceptable range of $\pm$10% as reported by the previous researchers [39, 40].

As shown in Table 12, both Levene's test for equality of variance and the significance (2-tailed) value were greater than 0.05, indicating that the variability in the two sets of predictions were not significantly different (equal variance can be assumed), and there was no statistically significant difference between the means of the two sets of predictions/estimates of the model. This clearly justifies the high R^2 value of the model and shows that prediction made using the model will be reliable.

4.0 CONCLUSION AND RECOMMENDATION

Deriving from the findings of this study, Number of floors and Construction Duration' are the only project scope factors influencing cost of rework in TETFund building projects in Nigeria. The result reveals that relationship between cost of rework and project scope factors (construction cost, duration, Gross floor area (GFA) and number of floors) is positive, whereby cost of rework and each project scope factor tend to increase or decrease together in the same direction. The study indicates that the top rework cost predictors are poor communication with design consultants, inadequate manpower to complete tasks, misunderstanding of end-user requirements, changes made at the request of the regulatory body and lack of site investigation. The study also revealed that rework cost predictive models are context-specific, as no combination of non-scope factors are the same for all the models. The results confirmed that cost of rework can be predicted through the combination of project scope and non-scope factors influencing cost of rework.

Furthermore, the results demonstrated when the impact of project scope and non-scope influencing factors is incorporated into rework cost prediction model the variability in cost of rework explained by the model increase to R^2 = 0.759 (75.9%) and errors in rework cost predictions could be reduced by as much as 9.75%. Thus, more accuracy is achieved in the integrated model. TETFund building contractors in Nigeria should analyse carefully the ten rework cost predictors prior to the commencement of any TETfund building construction projects or projects with similar characteristics. The model serve as useful tool used to enhance accuracy of rework cost predictions, thus reduce cost of rework for building construction projects.

REFERENCES

[1] Love. "Influence of Project Type and Procurement Method on ReworkCosts in Building Construction Projects". *Journal of Construction Engineering and Management, 128*(1), 2002a, pp18-29.

[2] Love, A. F., Teo, P. and Morrison, J. "From Individual to Collective Learning: A Conceptual Learning Framework for Enacting Rework Prevention". *Journal of Construction Engineering and Management*, *141*(11), 2015, 05015009-05015010.

[3] Liu, Q., Ye, G., Feng, Y., Wang, C., and Peng, Y. "Case-based insights into rework costs of residential building projects in China". *Int J Constr Manage*. 20(4), 2018, pp347–355.

[4] Hwang, T. S., Hans, C., and Caldas, C. "Measuring the impact of rework on construction cost performance. *J. Constr. Eng. Manage., 10.1061/(ASCE)0733-9364*, *3*(187), 2009, pp187-198.

[5] Love, P. E. D., and Edwards, D. J. "Determinants of rework in building construction projects". *Engineering Construction & Architectural Management, 11*(4), 2004, pp259-274.

[6] Walker, D. H. T. "An Investigation into Construction Time Performance." Construction Management and Economics 13 (3), 1995, pp263–274. doi:10.1080/01446199500000003.

[7] Forcada, N., Gangolells, M., Casals, M., and Macarulla, M. "Factors Affecting Rework Costs in Construction". *Journal of Construction Engineering and Management, 143*(8), 2017. 04017032-04017031- 04017032-04017039.

[8] Love, L. R., Kim, J. T., and Kim, M. "Influence of Organizational and Project Practices on Design Error Costs". *American Society of Civil Engineers*, *28*(2), 2014, pp303-310.

[9] Ye, G., Jin, Z., Xia, B., and Skitmore, M. "Analyzing causes for reworks in construction projects in China". *Journal ofManagement in Engineering*, *31*(6), 2014. 04014097. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000347.

[10] Al-janabi, Abdel-Monem and El-Dash "Factors Causing Rework and their Impact on Projects" Performance in Egypt". *Journal of Civil Engineering and Management.* ISSN 1392-3730 / eISSN 1822-3605. *26(7),* 2020, pp666–689.

[11] Love. "Auditing the indirect consequences of rework in construction": 'A case based approach' *Managerial Auditing Journal*, *17*(3), 2002b, pp138-146.

[12] Mills, A., Love, P. E. D., and Williams, P. "Defect costs in residential construction". *J. Constr. Eng. Manage., 10.1061/(ASCE) 0733-9364(2009)*, *1*(2), 12–16.

[13] Sommerville, J., and McCosh, J. "Defects in new homes": Ananalysis of data on 1696 new UK houses. *Struct. Surv.*, *24*(1), 2006, pp6–21.

[14] Barber, P., Sheath, D., Tomkins, C., and Graves, A. "The cost of quality failures in major civil engineering projects". *International Journal of Quality and Reliability Management*, *17*(4/5) 2000, pp479-492.

[15] Abeku, D., Ogunbode, E., Salihu, C., Maxwell, S., and Kure, M. "Projects management and the effect of rework on construction works": a case of selected projects in Abuja metropolis, Nigeria. *Int J Finance Manage Pract*. 4(1), 2016, pp38–46.

[16] Love, P. E. D., Edwards, D. J., Watson, H., and Davis, P. "Rework in Civil Infrastructure Projects: Determination of Cost Predictors". *Journal of Construction Engineering and Management*, *136*(3), 2010, pp 275-282.

[17] Ayodeji, E., Oke, O., and Francis, U. "Assessment of rework cost of selected building projects in Nigeria". *International Journal of Quality & Reliability Management, 30*(7), 2013, pp799-810.

[18] Ajayi, O. M., and Oyeyipo, O. "Effect of Rework on Project Performance in Building Project in Nigeria". *International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181*, *4*(2), 2015, pp294-300.

[19] Love, P. E. D., and Sing, C. "Determining the probability distribution of rework costs in construction and engineering projects". *Structure and Infrastructure Engineering, 9*(11), 2013, pp1136-1148.

[20] Simpeh, E. K., Ndihokubwayo, R., Love, P. E. D., and Thwala, W. D. "A rework probability model: a quantitative assessment of rework occurrence in construction projects". *International Journal of Construction Management*, *15*(2), 2015, pp109-116.

[21] Ayodeji, E., Oke, O., and Francis, U. "Assessment of rework cost of selected building projects in Nigeria". *International Journal of Quality & Reliability Management, 30*(7), 2013, pp799-810.

[22] Kakitahi, J. M., Alinaitwe, H. M., Landin, A., and Rodrigues, M. A. "Comparison of contruction-related rework in Uganda and Mozombique". *Journal of construction*

Management Innovation, 4(1), 2014. pp770-781.

[23] Hwang, Zhao, X., and Goh, K. J. "Investigating the clientrelated rework in building projects": The case of Singapore. *International Journal of Project Management, 32*(4), (2014, pp698–708.

[24] Taggart, M., Koskeal, L., and O'Rourke, J. "The role of the supply chain in the elimination and reduction of construction rework and defects": *Construction Management and Economic, 32*(7/8), 2014, pp829-842.

[25] Jingmond, M., and Ågren, R. "Unravelling causes of defects in construction". *Construction Innovation, 15*(2), 2015, pp198-218.

[26] Love, P. E. D., Smith, J., Ackermann, F., Irani, Z., and Teo, P. "The Costs of Rework: Insights from Construction and Opportunities for Learning". *Production Planning and Control*, 2018. 1-40.

[27] Love, P. E. D., Teo, P., and Morrison, J. "Re-visiting quality failures in construction". *ASCE Journal of Construction and Engineering Management, 144*(2), 2018c. (ASCE)CO.1943-7862.000142.

[28] Ganiyu, B. O., and Zubairu, I. K. "Project Cost Prediction Model Using Principal Component Regression for Public Building Projects in Nigeria" *Journal of Building Performance ISSN: 2180-2106, 1*(1), 2010, 21-28.

[29] Krejcie, V. R., and Morgan, W. D. "Determining sample size for research activities". *Educational and Psychological Measurement", 30*, 1970, pp607-610.

[30] Ibrahim, A. D. "Investigating into the Knowledge Requirements of Nigerian Quantity Surveyors to Meet Future Challenges". Paper presented at the 25th Biennial Conference of the NIQS, Abuja, (2011).

[31] Salkind, N. J. "Exploring research" (3rd Ed ed.). Upper Saddle River NJ: Prentice Hall 1997).

[32] Guthrie, G. "Basic Research Mehods". New Delhi, India: SAGE Publications India pvt Ltd, (2010).

[33] Dandajeh, M. A, Ibrahim A. D, Ibrahim Y. M, Adogbo, K. J and Ahmadu, H. A. "Determination of the Influence of Rework Cost Factors on TETfund Building Projects in Nigeria" *Journal of Environmental Studies, ABU, April. 4(8*), 2019, pp136-151.

[34] Fellows, R. F., and Liu, A. "*Research Methods for Construction"*: Blackwell Science Ltd. Oxford, 1997.

[35] Maitra, S., and Yan, J. "Principal Component Analysis and Partial Least Squares; two-dimension reduction technique for regression". *In Casualty actuarial society discussion program*, 2008.

[36] Field, A. P. "Discovering statistics using SPSS" (2nd edition). London; : Sage, 2005.

[37] Dascalu, C. G., and Cozma, C. D. "The principal component analysis-method to reduce collinearity in multiple linear regression model; application in medical studies". Paper presented at the Proceedings of the 2nd WSEAS international conference on multivariate analysis and its application in Science and Engineering, 2008.

[38] Ahmadu, H. A., Ibrahim, Y. M., Ibrahim, A. D., and Muhammed, A. "Modelling building construction durations". *Journal of Financial Management of Property and Construction, 20*(1), 2015, pp65 – 84.

[39] Ogunsemi, D. R., & Jagboro, G. O. "Time-cost model for building projects in Nigeria". *Construction Management and Economics*, 2006, pp253-258.

[40] Sonmez, R. "Parametric Range estimating of Building cost using Regression model and Bootstrap". *Journal of Construction Engineering and Management, 134*(12), 2008.