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Prognostic Model for Optimal Cost and Material Management in Nigeria Building Construction Industry

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The high rate of cost overruns of construction projects in Nigeria had led to research into developing strategies and ways to reduce cost overruns in construction project. Based on the material management system implemented in the construction project, this work developed regression models for predicting the frequency of building project cost overrun. Five (5) material management systems have been established, each consisting of four (4) main phases of material identification (MS), vendor selection (VS), procurement (PRO) and construction (CON) phases. The results showed the management system's procurement process and vendor selection phase to have the greatest impact on causing project cost overruns with 89 percent and 77 percent high-probability estimates when these phases were absent from material management systems. Nonetheless, the Material Identification had the least influence with a 40 percent likelihood forecast. This research showed that with large amounts of resources being diverted to the procurement and vendor selection process of the material management system, project cost overruns in the construction industry would be minimal.

Keywords: Material management systems; regression model; Nigeria; construction industry; cost overrun.

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1. INTRODUCTION

Building materials are an essential cost component of any construction project. The total cost of installed materials (or material value) can amount to 50 per cent or more of the total cost [1-3]. Improper handling and management of materials on construction sites has the potential to seriously hamper the expense, time, and quality performance of projects [4,5]. The successful completion of construction projects within the time frame, budget allocation and of expected quality and durability is therefore fundamentally crucial [6,7]. For construction projects, therefore, there is a need for effective materials control to avoid problems, such as delays and cost overruns in a construction project.

Construction industry is a project oriented industry. Cost overrun in the construction industry is a worldwide phenomenon [8,9]. The pace of domestic construction projects in Nigeria has significantly increased, and the cost of building projects is rising over the years [10]. Companies need to monitor the types and quantities of materials they buy, schedule which goods are to be manufactured and in what quantities, and ensure that they can satisfy current and future customer demand, all at the lowest cost possible [11]. In any of these cases making a bad decision would cause the business to lose money.Therefore there is a need to implement an appropriate technique / model of material management for cost reduction and control on construction sites.

This work provided a well-defined model of material handling for effective management of building materials and overall reduction of costs of construction projects.

2. METHODS

The study area selected for this study is Lagos State, Nigeria as shown in Fig. 1. This choice was based on the fact that the state holds a proportionate large volume of construction activities.

Questionnaire Development: The research questionnaire was prepared on the basis of literature review and a formal interview conducted among the major building management stakeholders in Nigeria. The questionnaire was developed using closed questions and was divided into four sections: demographic section containing background information about the respondents, the method of material management containing some laid out processes, and the respondent was asked to state the order in which they implemented the method adopted. Causes for efficient material management where the respondent was asked to rate the impact of 34 project costs overrun factors grouped into four (4) major material management processes for material recognition, vendor selection, procurement and construction. As the performance criterion ranging from strong influence to practically no influence, a 5-point Likert scale was used. Ultimately, the last section dealt with the reliability of the option of management process / systems by the respondents regarding cost and time. A total of 500 questionnaires were administered, and four hundred and twenty (420) correct answers were obtained and quantitatively evaluated.

The Linear Regression Model: The model was formulated using SPSS 2019 edition. Material management process/system model were developed based on the results obtained both from the questionnaire and the field survey. Statistical multiple linear regression model between the research objectives (i.e optimal material management sytem) were generated in the form of

$$\Upsilon = \beta_0 + \beta_1 X1 + \beta 2X2 + \ldots + \beta nXn + \varepsilon$$

Where

Υ represents the Dependent variable which is the optimal material management process
β_0 represents the coefficient of the dependent variable
βn represents the coefficients of the independent factors
Xn represents the independent factors
n represents the number of factors in each management process (material handling, vendor selection, procurement, construction phase)
ε represents the error term.

Fig. 1. Map of the study area (Lagos)

3. RESULTS AND DISCUSSION

Model with All Material Management Phases: The Material management processes according to Patil and Patasker, 2013 are:

- A. Construction Materials need generated from site
- B. Check availability from the company warehouse
- C. Check availability from local supplier store
- D. Inform the Procurement department
- E. Indent is generated (Purchase order)
- F. Vendor is selected from an approved list
- G. Conduct Inspection from the received stock
- H. Update the warehouse stock
- I. The requested materials are supplied on site

During the course of the study, these were grouped into four (4) phases which are Material Identification, Vendor Selection, Procurement Problem, and Construction.

Table 1 and Table2 show the model generated using SPSS for all the material management phases. The material management phases were made the independent variables while cost overrun probability was made the dependent variable. The model is predicted the probability of project cost overrun from the material management processes.

Table 1. Model showing all material management phases coefficients

	Coefficients	Standard Error	t Stat	P-value
Intercept	-0.36	0.14	1.057	0.000
Material Identification	0.094	0.054	1.465	0.000
Vendor Selection	0.26	0.017	2.067	0.000
Procurement problem	0.354	0.066	2.083	0.000
Construction phase	0.167	0.052	2.168	0.018

Table 2. Model summary showing residuals and significance level

Regression Statistics							
Multiple R	0.8851968						
R Square	0.7381018						
Adjusted R^2	0.7288305				ANOVA		
Standard Error	1.0406278		Df	SS	MS	F	Significance F
Observations	420	Regression	4	17.80144632	4.45036158	4.1096465	0.0000009
		Residual	415	449.4060638	1.082906178		
		Total	419	467.2075101			

Model Result Interpretation: Table 1 shows the multiple linear regression model coefficients for all the material management phases. From the Multiple linear regression model equation of $Y = \beta_0 + \beta_1 X1 + \beta 2X2 + ... + \beta nXn + \varepsilon$, the formulated modelwas shown as:

$$C = \beta^{\circ} + \beta 1\ \mathrm{MI1} + \beta 2\mathrm{VS2} + \beta 3\mathrm{Pro3} + \beta 4\mathrm{Con4} + \varepsilon.$$

Where

C	represents	cost overrun
β°	represents	intercept
β_1	represents	coefficient of material identification phase
MI_1	represents	material identification phase
β_2	represents	coefficient of vendor selection phase
VS_2	represents	vendor selection phase
β_3	represents	coefficient of the procurement phase
Pro_3	represents	procurement phase
β_4	represents	coefficient of the construction phase
Con_4	represents	the construction phase
ε	represents	error term

From the result from Table 1, the resultant model is written as

$$C = -0.36 + 0.094\mathrm{MI1} + 0.26\mathrm{VS2} + 0.354\mathrm{Pro3} + 0.167\mathrm{Con4} + \varepsilon$$

The model works by taking into focus the percentage completion of each of the material management phases. Due to the tendencies of contractors and project managers to fast track project time, most construction projects do not usually undergo all the processes involved in each material management phases.

On assumption that all the material management phases were dully followed, the model predicts the cost overrun probability as follows:

$$C = \frac{-0.36(100)+0.094(100)+0.26(100)+0.354(100)+0.167}{\text{Number of material management phases in model}}$$

$$C = 51.1/4 = 12.875 = 13\%$$

This means that if all material management phases are dully followed, the probability of cost overrun is merely 13%(Extremely low). Table 3 shows the ratings for chances of cost overrun.

Also, the P-values show how valid the independent variable coefficients are towards influencing the prediction of the dependent variable. A value of 0.15 and higher shows non-validity. From the results derived, all coefficients are valid.

Table 2, the regression statistics shows high values of 0.885(88.5%), 0.738(73.8%) and 0.729(72.9%) for Multiple R, R-squared, and Adjusted R respectively. This means the probability of the model being able to represent the given data and predict accurately is very high. Finally, the Significance F is very low, this means the probability of the model being insignificant/fluke is extremely low.

Table 3. Cost overrun rating

Predicted Percentage	Probability of Cost Overrun Occurrence
80 - 100	Extremely High
60- 79	High
50-60	Manageably High
30-49	Low
29-Jan	Extremely Low

Model without Material Identification Management Phase: Table 4 and Table 5 show the multiple linear regression model coefficients for the material management phases with the exception of the Material identification phase. This is intended to predict the cost overrun effect when a material management system does not have the material identification phase.

Model without Material Identification Result Interpretation: Table 4 showed the multiple linear regression model coefficients for the material management phases without the material identification management phase. From the Multiple linear regression model equation of $\mathrm{T} = \beta_0 + \beta_1 \mathrm{X1} + \beta 2\mathrm{X2} + \ldots + \beta n\mathrm{Xn} + c$. The formulated modelis:

$$C = -0.745 + 0.826\mathrm{VS1} + 0.893\mathrm{Pro2} + 0.241\mathrm{Con3} + \varepsilon$$

On assumption that all the management system phases were fully followed, the model predicts the cost overrun probability as follows:

$$\frac{C = -0.745(100) + 0.826(100) + 0.893(100) + 0.241(100)}{Number\ of\ material\ management\ phases\ in\ model}$$

$$C = 121.53/3 = 40.51 = 41\%$$

This means that if all material identification phase is removed from the material management system, the probability of occurrence of cost overrun is 41% (Low).

Also, the P-values show how valid the independent variable coefficients are towards influencing the prediction of the dependent variable. A value of 0.15 and higher shows non-validity. From the results derived, all coefficients are valid.

Table 5 showed the regression statistics shows high values of 0.794(79.4%), 0.681(68.1%) and 0.578(57.8%) for Multiple R, R-squared, and Adjusted R respectively. This means the probability of the model being able to represent the given data and predict accurately is very high. Finally, the Significance F is very low, this means the probability of the model being insignificant/fluke is extremely low.

Model without Vendor Selection Management Phase: Table 6 and Table 7 showed the multiple linear regression model coefficients for the material management phases with the exception of the Vendor Selection phase. This is intended to predict the cost overrun effect when a material management system does not have the vendor selection phase.

Table 4. Material management phases coefficients without material identification

	Coefficients	Standard Error	t Stat	P-value
Intercept	-0.745	0.252	12.567	0.000
Vendor Selection	0.826	0.032	6.243	0.000
Procurement problem	0.893	0.069	10.354	0.000
Construction phase	0.241	0.047	5.147	0.000

Table 5. Material identification exception model summary showing residuals and significance level

Regression Statistics							
Multiple R	0.794037328						
R Square	0.681687813						
Adjusted R^2	0.577949984				ANOVA		
Standard Error	0.330840087		df	SS	MS	F	Significance F
Observations	420	Regression	3	42.31592	14.1053112	8.8684	0.0009
		Residual	416	45.53335	0.10946		
		Total	419	87.84927			

Table 6. Vendor selection material management phase exception model result

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.525	0.607	6.993	0.000
Material Identification	0.453	0.068	-6.243	0.000
Procurement problem	0.787	0.121	-2.941	0.003
Construction phase	0.557	0.066	6.570	0.000

Table 7. Vendor Selection Exception Model summary showing residuals and significance level

Regression Statistics							
Multiple R	0.897854258						
R Square	0.847858862						
Adjusted R^2	0.742434768				ANOVA		
Standard Error	0.478715257		df	SS	MS	F	Significance F
Observations	420	Regression	3	31.4161512	10.472054	5.69589	0.0000
		Residual	416	95.3340117	0.22916		
		Total	419	126.750163			

Table 8. Procurement management phase exception model result

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.643	0.137	14.296	0.000
Material Identification	0.533	0.023	6.354	0.000
Vendor Selection	0.857	0.019	2.941	0.003
Construction phase	0.623	0.028	0.083	0.024

Model without Vendor Selection Phase Result Interpretation: Table 6 showed the multiple linear regression model coefficients for the material management phases with the exception of the vendor selection management phase. From the Multiple linear regression model equation, the formulated model is shown as:

$$C = 0.525 + 0.453\text{MI1} + 0.787\text{Pro2} + 0.557\text{Con3} + \varepsilon$$

On assumption that all the management system phases were fully followed, the model predicts the cost overrun probability as follows:

$$C = \frac{0.525(100)+0.453(100)+0.787(100)+0.557(100)}{\text{Number of material management phases in model}}$$

$$C = 232.2/3 = 77.4 = 77\%$$

This means that if the vendor selection phase is removed from the material management system, the probability of occurrence of cost overrun is 77% (High).

Also, the P-values show how valid the independent variable coefficients are towards influencing the prediction of the dependent variable. A value of 0.15 and higher shows non-validity. From the results derived, all coefficients are valid.

Table 7 shows the regression statistics which shows high values of 0.898(89.8%), 0.848(84.8%) and 0.742(74.2%) for Multiple R, R-squared, and Adjusted R respectively. This means the probability of the model being able to represent the given data and predict accurately is very high. Finally, the Significance F is very low, this means the probability of the model being insignificant/fluke is extremely low.

Model without Procurement Management Phase: Table 8 and Table 9 showed the multiple linear regression model coefficients for the material management phases with the exception of the Procurement Management phase. This is intended to predict the cost overrun effect when a material management system does not have the procurement management phase.

Model without Procurement Phase Result Interpretation: Table 8 showed the multiple linear regression model coefficients for the material management phases with the exception of the vendor selection management phase. From the Multiple linear regression model equation, the formulated model was shown as:

$$C = 0.643 + 0.533\text{MI1} + 0.857\text{VS2} + 0.623\text{Con3} + \varepsilon$$

On assumption that all the management system phases were fully followed, the model predicts the cost overrun probability as follows:

$$C = \frac{0.643(100)+0.533(100)+0.857(100)+0.623(100)}{\text{Number of material management phases in model}}$$

$$C = 265.6/3 = 88.5 = 89\%.$$

This means that if the procurement phase is removed from the material management system, the probability of occurrence of cost overrun would be 89% (Extremely High).

Also, the P-values show how valid the independent variable coefficients are towards influencing the prediction of the dependent variable. A value of 0.15 and higher shows non-validity. From the results derived, all coefficients are valid.

Table 9 shows the regression statistics which shows high values of 0.900(90.0%), 0.760(76.0%) and 0.555(55.5%) for Multiple R, R-squared, and Adjusted R respectively. This means the probability of the model being able to represent the given data and predict accurately is very high. Finally, the Significance F is very low, this means the probability of the model being insignificant/fluke is extremely low.

Model without Construction Phase: Table 10 and Table 11 showed the multiple linear regression model coefficients for the material management phases with the exception of the Construction phase. This is intended to predict the cost overrun effect when a material management system does not have the construction phase [12].

Table 9. Procurement management exception model summary showing residuals and significance level

Regression Statistics							
Multiple R	0.8997205						
R Square	0.7596647						
Adjusted R^2	0.5550469				ANOVA		
Standard Error	0.191661		df	SS	MS	F	Significance F
Observations	420	Regression	3	8.583241	2.86108	77.88655	0.00000
		Residual	416	15.28132	0.036734		
		Total	419	23.86456			

Table 10. Construction phase exception model result

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.334	0.42	7.968	0.000
Material Identification	0.308	0.048	5.147	0.000
Vendor Selection	0.425	0.033	6.570	0.000
Procurement problem	0.668	0.086	0.083	0.014

Table 11. Construction phase exception model summary showing residuals and significance level

Regression Statistics							
Multiple R	0.908833139						
R Square	0.8488345						
Adjusted R^2	0.803417441				ANOVA		
Standard Error	0.336135825		df	SS	MS	F	Significance F
Observations	420	Regression	3	15.57033	5.19011	65.93535	0.00000
		Residual	416	47.00271	0.11299		
		Total	419	62.57305			

Model without Construction Phase Result Interpretation: Table 10 showed the multiple linear regression model coefficients for the material management phases with the exception of the vendor selection management phase. From the Multiple linear regression model equation, the formulated model was shown as:

$$C = 0.334 + 0.308\text{MI1} + 0.425\text{VS2} + 0.668\text{Pro3} + \varepsilon$$

On assumption that all the management system phases were fully followed, the model predicts the cost overrun probability as follows:

$$C = \frac{(0.334(100)+0.308(100)+0.425(100)+0.668(100))}{\text{Number of material management phases in model}}$$

$$C = 173.5/3 = 57.8 = 58\%.$$

On assumption that all the management system phases in the model were fully followed, the model predicts the cost overrun probability as follows:

This means that if the construction phase is removed from the material management system, the probability of occurrence of cost overrun would be 58% (Moderately High) [13].

Also, the P-values show how valid the independent variable coefficients are towards influencing the prediction of the dependent variable. A value of 0.15 and higher shows non-validity. From the results derived, all coefficients are valid.

Table 11 shows the regression statistics which shows high values of 0.909(90.9%), 0.849(84.9%) and 0.803(80.3%) for Multiple R, R-squared, and Adjusted R respectively. This means the probability of the model being able to represent the given data and predict accurately is very high. Finally, the Significance F is very low, this means the probability of the model being insignificant/fluke is extremely low.

Model Validation: One of the research respondents' projectswas used for the validation of the model. The project consists of an eight-bedroom duplex located at Omolara Badaru close, Ifako-Agege, Lagos. The material management system used for the project identified from the questionnaire responses analysisincludes:

- [√] A. Construction Materials need generated from site
- [√] B. Check availability from the company warehouse
- [ ] C. Check availability from local supplier store
- [√] D. Inform the Procurement department
- [√] E. Indent is generated (Purchase order)
- [√] F. Vendor is selected from an approved list
- [√] G. Conduct Inspection from the received stock
- [ ] H. Update the warehouse stock
- [√] I. The requested materials are supplied on site

The material management system has all processes except the check availability from local store (a process under material selection phase) and the update warehouse stock, (a process under the construction phase). This project never ended up in cost overrun. From the regression model for all the material phases present which is:

$$C = -0.36 + 0.094\text{MI1} + 0.26\text{VS2} + 0.354\text{Pro3} + 0.167\text{Con4} + \varepsilon$$

And taking the vendor selection and procurement phases as 100% complete while that of Material Identification and Construction phase as 75% complete respectively, the predictive result would be:

$$C = -0.36(100) + 0.094(75) + 0.26(100) + 0.354(100) + 0.167(75)$$
$$C = 18.98\%$$

The 18.98% predictive values fall under the extremely low probability of cost overrun which was the case with the project to which this material management system was applied on.

4. CONCLUSIONS

The models result showed the procurement and vendor selection phase of the material management systems to be the single most important phase in the material management systems with their exclusion leading to high cost overruns with the probability of 89% and 77% respectively.

However, the exclusion of the material identification phase had the least influence on project cost overruns with probability of 41%.

The research showed that it is very much important for the material management systems to constitute all the material management phases for optimum effect.

However, if there arises a need to be selective in the material management systems, more attention and resources should be put into the vendor selection and the procurement phases of the material management systems, as it has the highest tendency. If these phases are not properly managed by project managres, it will lead to high project cost overrun.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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