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Impact of Critical Delay Factors on Project Cost Overrun in Offshore Fabrication in Nigeria: A Case Study.

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ABSTRACT
Cost overruns are major problems that face fabrication industry in Nigeria and can lead to numerous negative effects such as project delay, abandonment, and poor-quality delivery. This research focuses on evaluating various factors responsible for delay impact on the cost of fabrication processes in fabrication industries. It involves the use of stochastic methods in the acquiring of relevant data. The effect of time overrun on completion cost of construction project was evaluated using regression analysis, carried out on MS Excel and MATLAB. Significant factors that contributed to cost overrun were change order, change in drawing, material/fabrication delay, design development, and change in specifications. The significant factors are the severe factors that are responsible for delay, which impacts negatively on the financial status of fabrication industries. The result showed that, out of the six critical delay factors (the predictors), only three were statistically significant upon the dependent variable (cost overrun), as they showed a p-value less than the alpha(α) level of .05. It was observed that most of these delays had high level of occurrence and were attributed to lapses on the company owners and contractors utilized for projects. This research provides a basis for oil and gas fabrication companies to reduce frequent time overrun of the critical delay factors caused by clients, consultants and contractors through monitoring and controlling them to keep cost overrun at bay.

KEYWORDS: Critical Delay, Cost, Regression Analysis, Fabrication, Project.

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1. INTRODUCTION

Nigeria is a country in West Africa which is located between the Sahel to the North and the Gulf of Guinea to the South. It has a land area of about 924770sq km," (Miller *et al.,* 2013) "and it is made up of 36 States and a Federal Capital Territory. The population of Nigeria is estimated at 180 million (Adeyemo, 2018). The country plays a significant role in the socioeconomic, political, and cultural arena of the African continent" (Mansfield *et al.,* 1994).

Ihua *et al.* (2009) states that "Nigeria expends about $8 billion annually in servicing its oil and gas operations. Sadly, a significant proportion of this amount is paid to foreign contractors for services like fabrication and engineering procurement; resulting in capital flight and leaving very little to developing the country's industrial base." However, "the passage into law of The Nigerian Oil and Gas Development Act 2010 has opened a wide horizon of opportunities for Nigerian investors in the fabrication business."

"Most construction projects are complex and require the support of the design and construction profession" (Ogunsemi & Jagboro, 2006). Therefore, "a realistic time for execution of project will reduce the possibility of disputes between state agency and the contractors" (Al-Momani, 2000). The construction industry is enormous, unstable, and requires huge capital costs. A remarkable component of hazard in the business is the way where debates and claims are woven through the fiber of the development cycle.

The sort of agreement utilized is regularly founded on a general endeavor to allot (frequently moving) the dangers of the work to the gatherings in question. A specific measure of hazard should forever be perceived and acknowledged. Hazard must be moderated - it can't be dispensed with.

There are numerous explanations behind delays including an absence of correspondence across the plan development interface, and between the different development associations conveying the venture (Afshari *et al.*, 2011; Khoshgoftar *et al.*, 2010). Postponements can likewise be supported by helpless task from the executives, especially assuming the customer doesn't make installments to the project worker as set out in the agreement or tries to slow down/defer such installments (Fallahnejad 2013; Sepasgozar *et al.*, 2015).

Niazi and Painting (2017) proposed that there are work driven postponements, a deficiency of talented laborers, or where the project worker names unpracticed specialists to complete the work. The fundamental driver of postponements in development are project worker's monetary troubles and uncontrolled changes made by the customer. It is surrendered that there are other causal factors, for example, extreme climate conditions and changes to unofficial laws that can prompt deferrals, and which the undertaking partners have little command over (Al-Hazim *et al.*, 2017).

Although various studies have researched the causes affecting delays in projects in Nigeria, these studies have always centered on government infrastructural projects for the public such as building of schools, hospitals, roads etc., with limited mathematical model mainly on overall project delay impact on cost overrun. This study intends to deviate by concentrating on the private sector sponsored projects in Steel Fabrication for Oil and Gas Industries, with case study on recently completed projects within the last eighteen (18) years, including IKIKE project fabricated in Aveon Offshore Limited's yard, which is also regulated by Government policies. A mathematical regression model was established which is generalizable to the fabrication industries in Nigeria and beyond

The aim of this research is to study the critical delay factors associated with fabrication projects in the oil and gas fabrication industry of Nigeria and find a solution that will minimize or eliminate those factors that could cause problems in fabrication projects execution.

2 MATERIALS AND METHODS

The materials used in this research consist of organizational records collected from the organization and the website, journals, and questionnaire distributed to get the views of the respondents.

2.1 Materials

In this research, the mixed method was used. Primary data was obtained from Aveon Offshore Limited (AOL) through unstructured interviews with personnel in the oil and gas fabrication Company, carried out through conversations, observation of the case study, and phone calls. Secondary data was collected from various relevant books, articles of various authors, journals, and previous research work, Aveon's project records from the Project Controls Department, and relevant information online. The instrument for data collection for this study is a self-structured questionnaire. The questionnaire was rated on a modified 4- point Likert Scale. Data collected was analyzed using Microsoft Excel and Matlab (R0218). Data obtained from the questionnaire was subjected to statistical analysis. For this research, there were two levels of analysis: Ranking Analysis, Correlation and Regression Analysis.

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2.2 Analytical Model

Prior to subjecting the data to regression analysis, the data collected was assessed for the most critical factors of delay using the calculated t-statistics to rank the weight of delay impact on fabrication project. This was analyzed using Student's t-test as shown in equation (1). The following equations are useful in assessing the relations (Gupta, 2012).

$$t = \frac{\bar{x}-\mu}{s} \times \sqrt{n} \quad (1)$$

Where:
$\bar{x}$ = Mean of the sample
μ = Hypothetical means of the population
n = Sample size
S = Standard deviation of the sample

To calculate the correlation analysis, the equation is as shown in equation (2)

$$r_{ab.c} = \frac{r_{ab}-r_{ac}r_{cb}}{\sqrt{(1-r^2{}_{ac})(1-r^2{}_{cb})}} \quad (2)$$

Where:
r = coefficient of Partial Correlation between variables a and b while holding c constant

To calculate the multiple regression, the equation is as shown in equation (3)

$$y = b_o + b_1 x_1 + b_2 x_2 + b_3 x_3 + e \quad (3)$$

Where:
x = Independent Variables (Delay elements)
y = Dependent Variable (Cost of fabrication)
b_1 = Regression Coefficient / Slope Parameters
b_o = The 'y' Intercept / Regression Constant
e = Error

To find the slope, the equation is as shown in equation (4)

$$b_1 = \frac{(\sum y)(\sum x_2)-(\sum x)(\sum xy)}{n(\sum x^2)-(\sum x)^2} \quad (4)$$

Where:
x = Independent Variables (Delay elements)
n = Sample Size

To calculate the intercept, the equation is as shown in equation (5)

$$b_0 = \frac{n(\sum xy)-(\sum x)(\sum y)}{n(\sum x_2)-(\sum x)^2} \quad (5)$$

Where:
b_0 = The 'y' Intercept / Regression Constant

To calculate the statistical significance in the model, the equation is as shown in equation (6)

$$t = \frac{(\bar{x}-\mu_0)}{\left(\frac{s}{\sqrt{n}}\right)} \quad (6)$$

Where:
$\bar{x}$ = Sample Mean
μ_0 = Hypothesized Population Mean
s = Sample Standard Deviation

The null hypothesis (H0) and alternative hypothesis (H1) is as written below:

Hypothesis H01 = There is no relationship between critical delay factors and the cost of offshore fabrication projects
Hypothesis H11 = There is a relationship between critical delay factors and the cost of offshore fabrication projects.
Hypothesis H02 = There is no significant effect of critical delay factors on the cost of offshore fabrication projects
Hypothesis H12 = There is a significant effect of critical delay factors on the cost of offshore fabrication projects.

3. RESULTS AND DISCUSSION

The data collected was subjected to ranking analysis as shown in Table 1 and 2, to properly identify top ownership of factors responsible for delays.

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The objective of this ranking analysis is to determine the most critical variables that will be used for the regression model.

Table 1: Level of Significance on Responsibility

Responsibility of Delay Factors	Mean	Standard deviation	T-value	Rank (based on t-value)
Economic Problems	3.6053	0.4904	27.7861	1
Changes in Law and Regulations	3.1842	0.4519	18.6650	2
Local Content Policies	3.3421	0.5766	18.0044	3
Safety Rule	3.5263	0.8836	14.3200	4
Bad Weather (Heavy rainfall, wind, etc)	3.4211	0.9100	12.4781	5
Host Community Hostility	3.3421	0.9286	11.1803	6
Financial Process	3.3684	1.0899	9.8235	7
Labour Dispute and Strike	3.1316	0.9538	8.1638	8
Inspections	3.2105	1.1545	7.5877	9
Transportation Delays	3.0789	1.1596	6.1552	10
Financial Difficulties	2.9474	1.2596	4.3788	11
Lack of High Technology	2.7895	1.0075	3.5424	12
Inadequate Planning & Scheduling	2.7632	1.0147	3.1974	13
Material/Fabrication Delays	2.7895	1.3254	2.6927	14
Scheduling Management	2.7105	1.1487	2.2595	15
Shop Drawing Development/Approval	2.6842	1.0321	2.2005	16
Poor Managerial Skills	2.6842	1.0321	2.2005	16
Poor Supervision	2.5789	1.0950	0.8889	18
Contract Modification	2.5461	1.1728	0.4841	19
Staffing Problems	2.5000	0.9135	0.0000	20
Lack of Coordination on-site	2.5000	0.9135	0.0000	20
Incomplete Documents	2.3947	1.3722	-0.9458	22
Material Procurement	2.3421	1.4053	-1.3852	23
Lack of Qualified Craftsmen	2.3684	0.7430	-2.1832	24
Poor Subcontractor Performance	2.3421	0.8065	-2.4138	25
Delayed Payments	2.0526	1.3800	-3.9967	26
Construction Mistake	2.2632	0.6783	-4.3049	27
Underestimation of Productivity	2.2105	0.7336	-4.8649	28
Defective Work	2.2105	0.6158	-5.7954	29
Labour Injuries	2.1842	0.5570	-6.9902	30
Equipment Availability	2.1579	0.5411	-7.7948	31
Changes in Drawings	1.6316	1.2271	-8.7252	32
Changes in Specifications	1.5526	1.1668	-10.0101	33
Change Order	1.5526	1.0216	-11.4335	34
Design Development	1.1842	0.6849	-23.6838	35

The t-values of who owns the Responsibility of the various delay factors were calculated and ranked in Table 1. The Table shows that causes of delay with t_{cal} greater than critical t-table value, $t_{.05\infty}$ (1.645) are mostly that of government or shared responsibilities. These are economic problems, changes in law and regulations, local content policies, safety rule, natural factors, host community hostility, financial process, labour dispute and strike, inspections, material/fabrication delays, scheduling management, shop drawing development/approval

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and poor managerial skills which are mostly attributable to government or shared responsibilities. Those causes of delay with t_{cal} less than the critical t-table value, $t_{.05\infty}$ (1.645) are within the responsibilities of contractor and owner. They include poor supervision, contract modification, lack of coordination on-site, material procurement, incomplete documents lack of qualified craftsmen, poor subcontractor performance staffing problems delayed payments construction mistake underestimation of productivity defective work and labour Injuries, equipment availability, changes in drawings, changes in specification, change order and design development.

The overall top six delay factors which are most significant causes of delay in fabrication projects in Aveon that can equally be generalized in oil and gas fabrication industry are shown in Table 2

Table 2: Category of Major Causes of Delay

Cause of Delay	Variable Assigned	Category
Change Order	x_1	Design related
Changes in Drawings	x_2	Design related
Material/Fabrication Delays	x_3	Construction related
Material Procurement	x_4	Construction related
Design Development	x_5	Design related
Changes in Specification	x_6	Design related

The most critical delay factors, their frequency of occurrence and responsibility owners are summarized in Table 3.

Table 3: Chances of Occurrence of Critical Delay Factors

Cause of Delay	Chances of Occurrence	Responsibility	Type of Delay
Change Order	Likely to Almost certain	Owner to Contractor	Excusable-compensable to Concurrent
Changes in Drawings	Likely to Almost certain	Owner-to Contractor	Excusable-compensable to Concurrent
Material/Fabrication Delays	Likely to Almost certain	Government to Shared	Excusable-Compensable to concurrent
Material Procurement	Likely to Almost certain	Owner to Contractor	Excusable-Compensable to concurrent
Design Development	Likely to Almost certain	Owner to Contractor	Excusable-Compensable to concurrent
Changes in Specification	As likely as not to unlikely	Owner to Contractor	Excusable-Compensable to concurrent

3.1 Correlation Analysis between Change Order Delay and Cost Overrun

The correlation coefficient (*r*) between Engineering delay due to change order (*x1*) and Cost Overrun (*y*) is 0.436. This shows that there is a moderately weak linear relationship between them. The scatter plot between Change Order and the Cost Overrun is shown in Figure 1.

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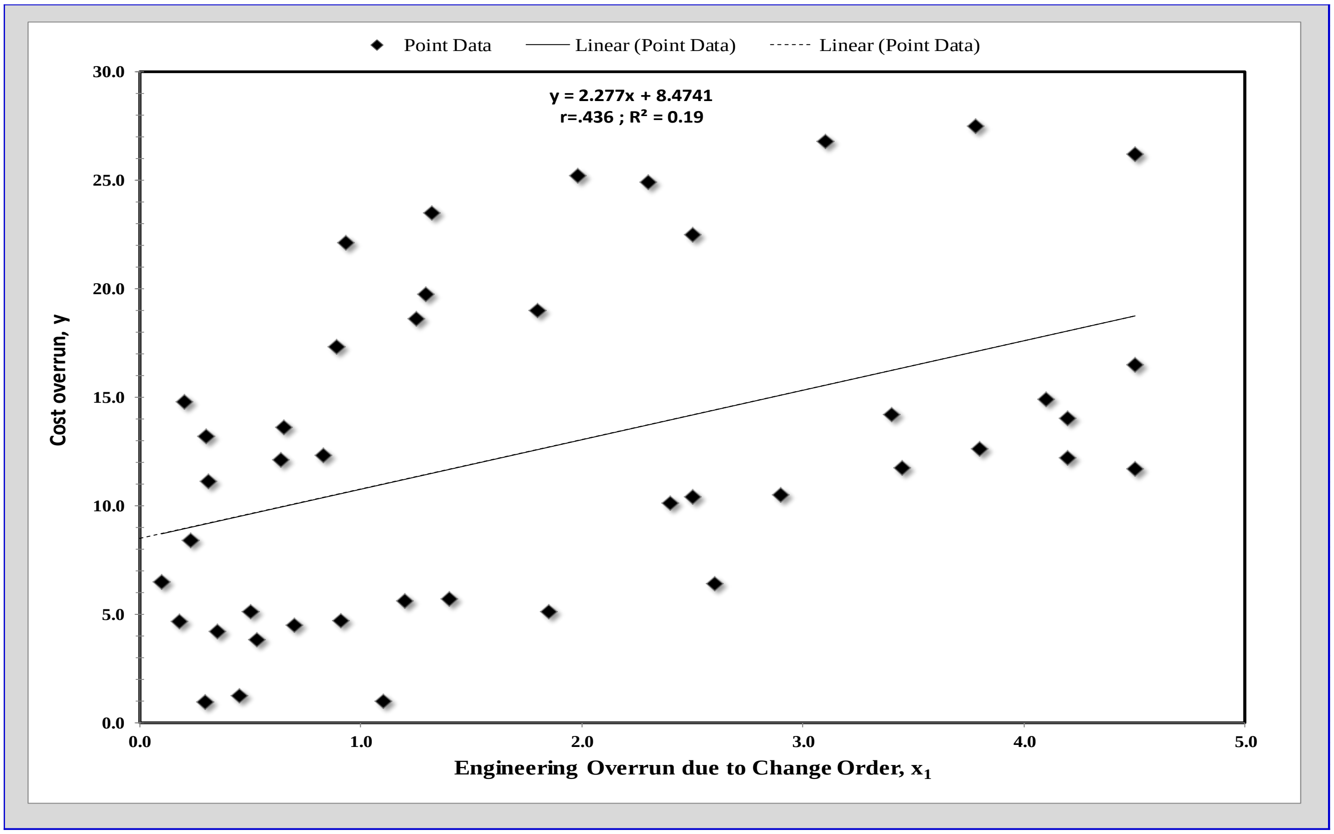

Figure 1: Scatter Plot for Change Order and Cost overrun

The line of best fit indicates a linear relationship because it is straight. It also rises from left to right which means that the cost overrun increases as change order increases, which also indicates a positive correlation; however, the correlation is moderately weak because the points are arranged loosely but linearly, and the value falls below the chosen critical coefficient value, **0.75**. This variable, x_1, did not possess potential explanatory strength to the variables of dependent variable, and therefore was excluded from the regression model equation after regression.

3.2 Correlation Analysis between Change in Drawing and Cost overrun

The correlation coefficient (r) between Change in Drawing, $(x2)$ and Cost Overrun, (y) is 0.787. This shows that there is a very strong linear relationship between them. The scatter plot between change in drawing and the cost overrun is shown in Figure 2.

The line of best fit indicates a linear relationship. It also rises from left to right which means that the cost overrun increases as change in drawing increases, which also indicates a positive correlation. Also, the correlation is very strong because the points are arranged closely and linearly, and the value is greater than the chosen critical coefficient value of **0.75**. This variable, x_2, possessed potential explanatory strength to the dependent variables, and so, was included in the regression model equation after regression analysis

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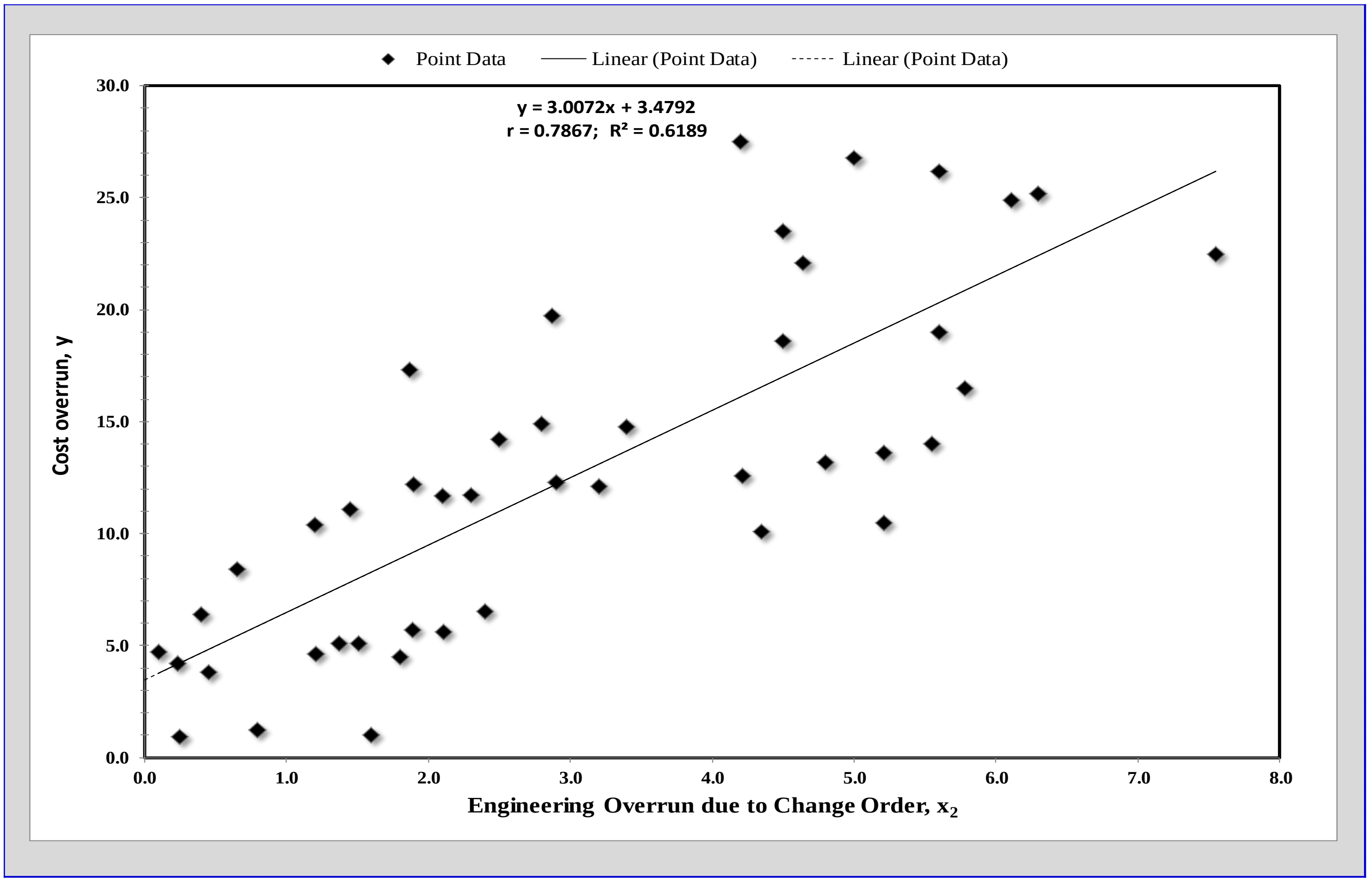

Figure 2: Scatter Plot for Change in Drawing and Cost overrun

3.3 Correlation Analysis between Material/Fabrication Delay and Cost overrun

The correlation coefficient (r) between materials/fabrication *(x3)* and Cost Overrun, (y) is 0.521. It therefore shows that there is a moderately weak linear relationship between them. The scatter plot between materials/fabrication and the cost overrun is as shown in Figure 3.

The line of best fit indicates a linear relationship. It also rises from left to right which means that the cost overrun increases as the delay in fabrication due to change in material/fabrication increases, which also indicates a positive correlation; however, the correlation is moderately weak because the points are arranged loosely but linearly, and the value falls below the chosen critical coefficient value, **0.75**. This variable, x_3, did not possess potential explanatory strength to the variables of dependent variable, and therefore was excluded from the regression model equation after regression analysis

3.4 Correlation Analysis between Material Procurement Delay and Cost overrun

The correlation coefficient (r) between material procurement delay (x_4) and Cost Overrun (y) is 0.788. It therefore shows that there is a very strong linear relationship between them. The scatter plot between material procurement delay, and the cost overrun is shown in Figure 4.

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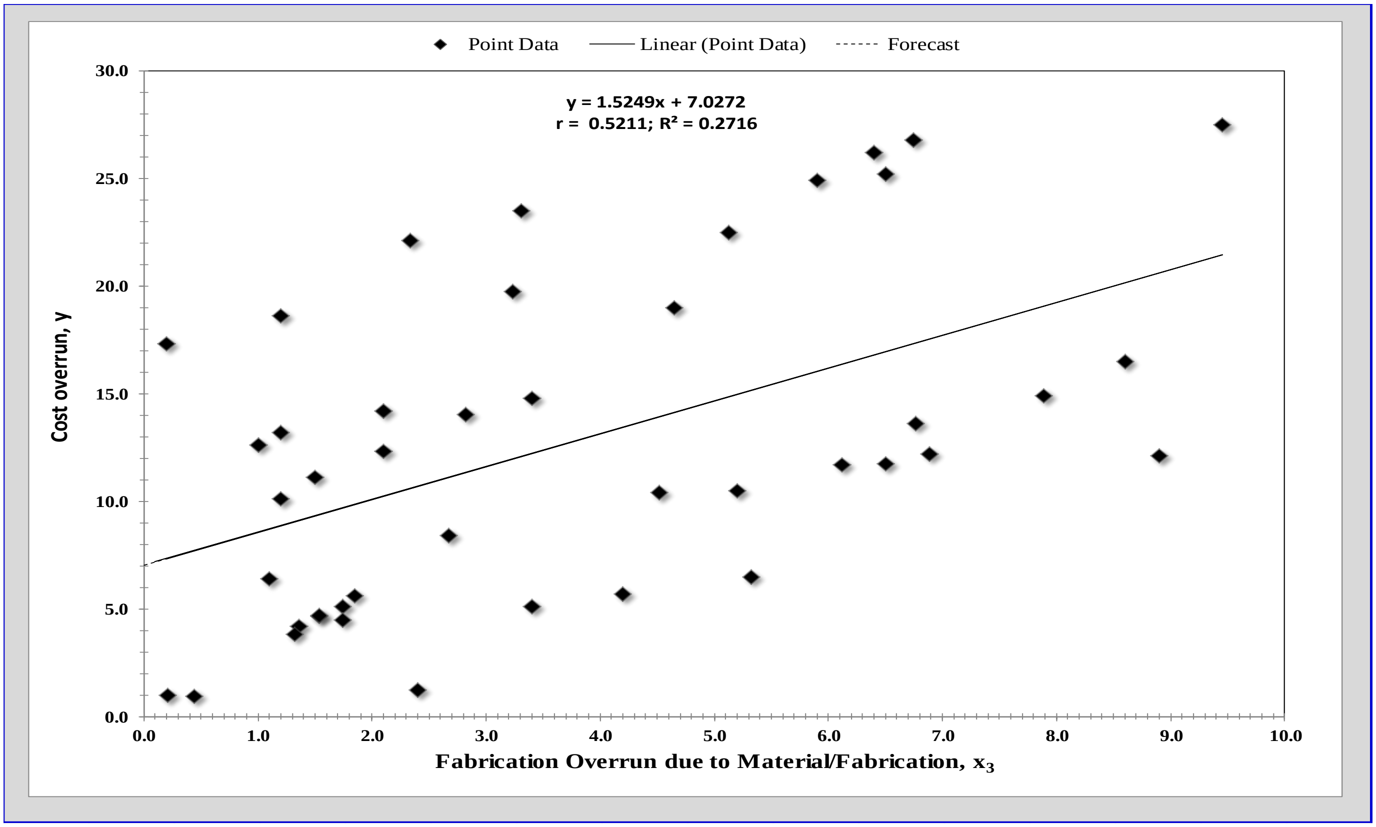

Figure 3: Scatter Plot for Material/Fabrication and Cost overrun

The line of best fit indicates a linear relationship. It also rises from left to right which means that the cost overrun increases as material procurement increases, which also indicates a positive correlation. Also, the correlation is very strong because the points are arranged closely and linearly, and the value is greater than the chosen critical coefficient value of **0.75**. This variable, x_4, possessed potential explanatory strength to the variables of dependent variable, and therefore was included in the regression model equation after regression analysis.

3.5 Correlation Analysis between Design development Delay and Cost overrun

The correlation coefficient (r) between Design Development Delay(x_5) and Cost Overrun (y) is 0.798. It therefore shows that there is a very strong linear relationship between them.

The scatter plot between design development and the cost overrun is shown in Figure 5.

The line of best fit indicates a linear relationship because it is straight. It also rises from left to right which means that the cost overrun increases as design development delay increases, which also indicates a positive correlation. Also, the correlation is very strong because the points are arranged closely and linearly, and the value is greater than the chosen critical coefficient value of **0.75**. This variable, x_5, possessed potential explanatory strength to the variables of dependent variable, and therefore was included in the regression model equation after regression analysis.

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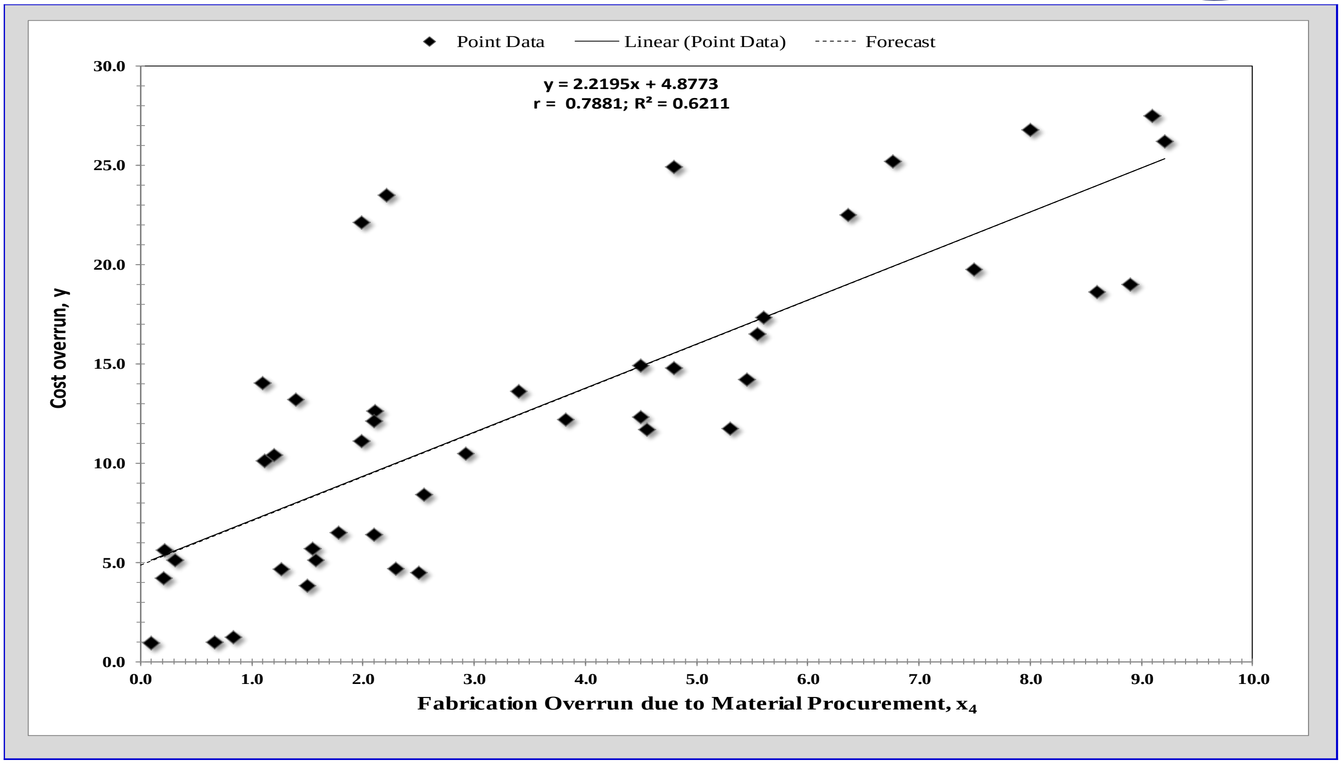

Figure 4: Scatter Plot for Material Procurement and Cost overrun

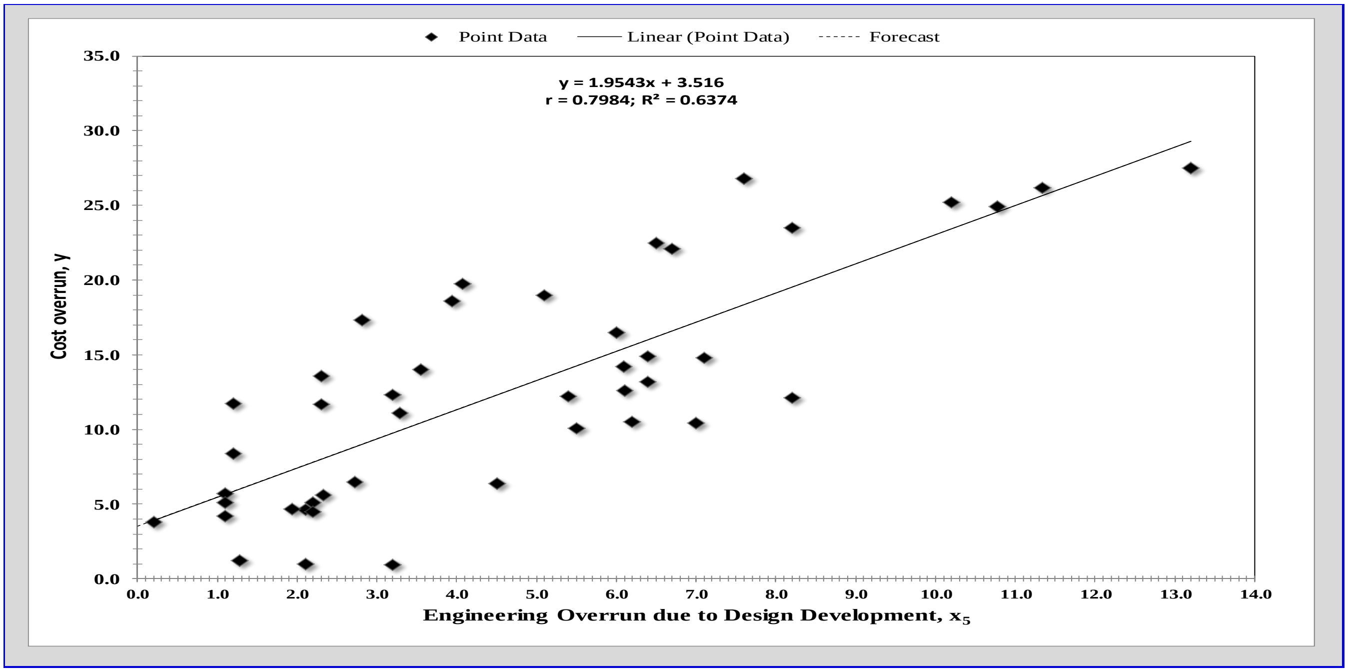

Figure 5: Scatter Plot for Design Development Delay and Cost Overrun

Journal of Newviews in Engineering and Technology (JNET)
Vol 4, Issue 1, April 2022
Available online at http://www.rsujnet.org/index.php/publications/2022-edition
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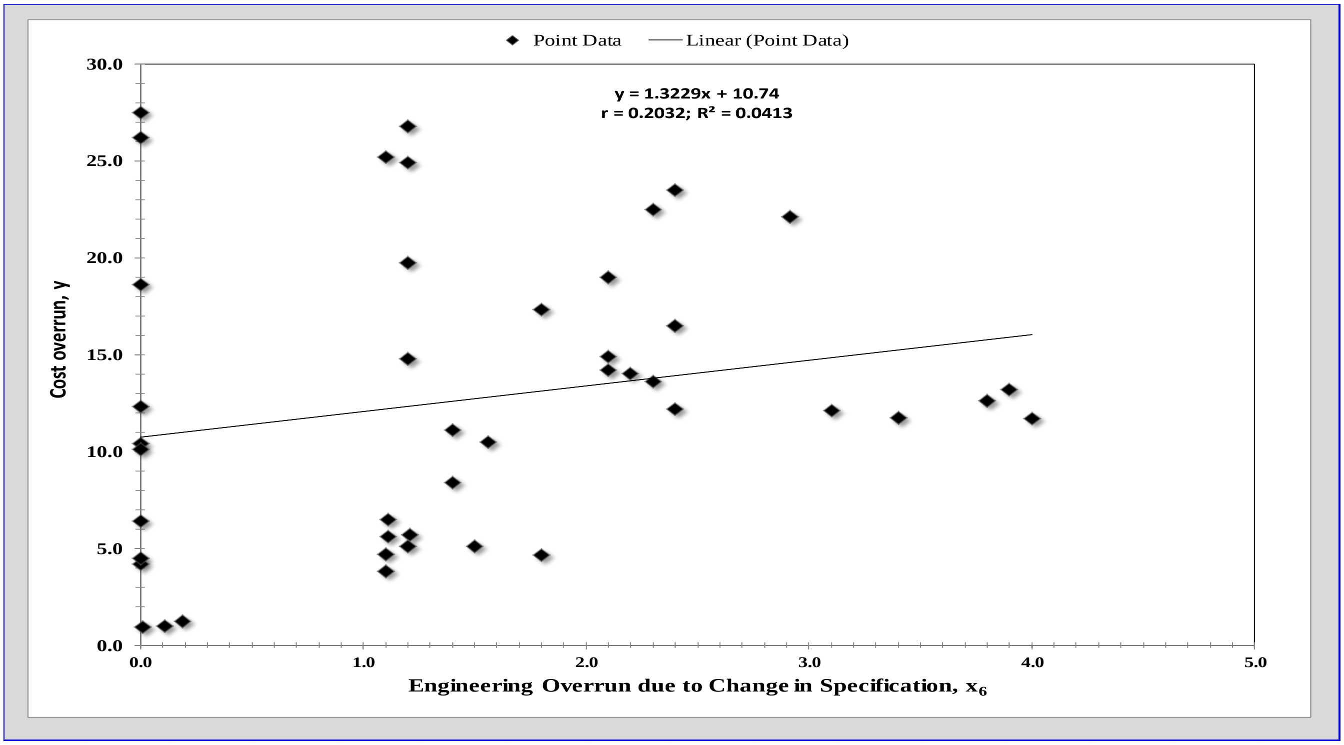

Figure 6: Scatter Plot for Change in Specification and Cost overrun

3.6 Correlation Analysis between Change in Specification and Cost Overrun

The correlation coefficient (r) between Change in Specification (x_6) and Cost Overrun (y) is 0.203; it therefore shows that there is a very weak linear relationship between them. The scatter plot between change in specification and cost overrun is shown in Figure 6.

The line of best fit indicates a linear relationship because it is straight. It also rises from left to right which means that the cost overrun increases as change in specification increases, which also indicates a positive correlation; however, the correlation is very weak because the points are arranged loosely but linearly, and the value falls below the chosen critical coefficient value, **0.75**. This variable, x_6, did not possess potential explanatory strength to the variables of dependent variable, and therefore was eventually excluded from the regression model equation after regression analysis.

3.7 Multiple Regression Analysis

A stepwise multiple regression and Analysis of Variance (ANOVA) was carried out for the variables x2, x4, x5, and coded on Matlab and the result obtained is as shown in Table 4 and 5.

Table 4: Regression Model

	Estimate	Standard Error	Test Statistics	PValue
(Intercept)	0.67248	0.85911	0.78276	0.43838
x2	1.186	0.3074	3.858	0.00040672
x4	1.1781	0.20112	5.8577	7.4931e-07
x5	0.90514	0.19377	4.6711	3.3556e-05

Number of observations: 44, Error degrees of freedom: 40
Root Mean Squared Error: 2.84

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R-squared: 0.869, Adjusted R-Squared 0.859
F-statistic vs. constant model: 88.4, p-value = 1.07e-17

Table 5: Analysis of Variance Result

	df	*SS*	*MS*	*F*	*Sign. F*
Regression	3	2145.179	715.060	88.444	1.07E-17
Residual	40	323.396	8.085		
Total	43	2468.575			

The results of the regression in Table 4 and 5 indicated that the three predictors (independent variables) explained 8.69% of the variance (R2 = 0.90, F (3,40) = 88.444, *p* = 1.07E-17). Table 4 showed engineering delay due to change in drawing, x2 (b2 = 1.186): as engineering delay due to change in drawing increases by one unit, fabrication cost overrun increase by 1.186 units. Material procurement x4 (b4 = 1.178): as Material procurement increased by one unit, fabrication cost overrun went up by 1.178 units. Engineering delay due to design development, x5 (b5 = 0.905): as design development delay increased by one unit, fabrication cost overrun went up by 0.905 units.

From Table 4, F= 88.44 at p = 0.000. Since the p values of the predictors were all less than 0.05, then there is a relationship between critical delay factors examined and the cost of offshore fabrication projects. It showed strong evidence against the null hypothesis. The null hypothesis, H02, is rejected, and the alternative hypothesis, H12, is retained.

The final predictive model is: $\boldsymbol{y} = 0.672 + 1.186\boldsymbol{x}_2 + 1.178\boldsymbol{x}_4 + 0.905\boldsymbol{x}_5$

4. CONCLUSION

The aim of this work is to study the critical delay factors associated with fabrication projects in the oil and gas industry of Nigeria and develop a generalized mathematical model that relates the cost and the critical delay factors. This aim may be said to have been accomplished as explained below.

The first objective was to identify the causes of critical delays in projects. It could be concluded that out of thirty-five (35) delay factors (independent variables) identified, only six (6) has significant delay impact on cost of fabrication if they are delayed and they are change order, change in drawings, design development, change in spec, material procurement and material/fabrication.

The second objective was to establish the rate of occurrence of the delay factors and the responsible parties. It could be concluded that all the six independent (delay factors) variables are almost likely to occur except there is change in specification. High occurrence rate of most of the factors identified to significantly impact fabrication processes are because of the delays caused by the owners or contractors or both. The Government are the least to be blamed for delays in the fabrication industries.

The third objective was to establish a mathematical expression that will describe the relationship between cost and the various critical delay factors. It could be concluded that a mathematical model was established which three out of the six dependent variables were included in the model. These three variables have the p-values less than the critical value 0f 0.05

It is recommended that designer ought to guarantee convenient arrangement of drawings to upgrade the exactness of the amount assessors' assessment of activities' monetary ramifications and diminish variety claims by worker for hire because of indistinct drawings and particulars. It is recommended that client should start the process of procurement materials for projects and expedite delivery before and during fabrication stage. Alternative sources, like local suppliers or vendors should be identified and used as alternative source if the material is available locally. Future researchers should consider including activity free floats and total as one of the independent variable factors to see the impact on cost overrun.

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