Development of Models to Predict Oil and Gas Pipeline Vandalism Parameters in Nigeria

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ABSTRACT

Pipeline vandalism has been a major problem affecting the productivity of the oil and gas industries in Nigeria. This paper has developed multi linear regression models to predict the risk index as influenced by vandalism. The outlier and normality test was conducted on the data to determine the data integrity. The MLR model was developed possessed satisfactory diagnostics results of good coefficient of determination, minimum regression and residual errors. The MLR Predicted results show a regression error of 0.030406. A regression plot was produced to further check for the models strength and accuracy. The statistical diagnosis indicates that the MLR model is fair but a better and advanced model can be used to predict the vandalism parameters.

Keywords: modelling, oil, gas, pipeline, vandalism, parameters, predict, Nigeria

INTRODUCTION

Oil and gas are exhaustible resources gifted by nature, which has a high international marketability value compared to other mineral resource in Nigeria. Petroleum products serve as fuels to the world economy thereby giving the oil industry power to control the political and economic stability of nations. Oil and gas processes are labelled as the most complex and delicate of all international corporate activities because the resources determines a country’s wealth, international reputation, and power [¹]. Nigeria is identified as one of the highest petroleum producers in the world with the largest gas reserves in Africa. Problems such as poor maintenance, external interference affects the turnover on production. Nigeria’s major means of transporting crude oil and gas products is the pipeline channels, transporting liquefied petroleum gas (LPG) from the refineries to other depots located across the country [²]. These pipelines, through which majority of petroleum products are transported across the country have been experiencing unceasing failures in recent years due to both internal and external factors [³]. To provide protection and prevent destruction of the pipeline assets the Nigerian National Petroleum Company has secured a 3.5 m wide right of way on each side of pipelines before they were laid, research studies has shown that the pipelines network in Nigeria are exposed to so much failure and vandalism conditions [⁴]. Some of the common unfavorable conditions that Nigerian pipelines are exposed to includes in corrosion, external interference, poor operational capacity. In addition, it is noteworthy to highlight the uniqueness of some pipeline failure factors to the Nigerian case. In the Niger-Delta region for example, a substantial number of pipeline failures can be credited to external interference, in the form of sabotage and pilferage who deliberately vandalize...
pipeline systems in other to steal petroleum products [5]. Studies were conducted to rank the factors influencing the vandalism and failure of oil and gas pipelines in Nigeria. Nigeria has suffered increased pipeline destruction, kidnappings and militant coups of oil facilities in the Niger-Delta. The Movement for the Emancipation of the Niger-Delta (MEND) has been identified as the leading group attacking oil assets for political reasons, demanding a restructuring of oil wealth and control of resources in this area. The insecurity and continuous kidnappings of oil workers in this sector has caused oil and gas investors to shut down operations in Nigeria. The results of the militant and rebel activities has significantly affected the nation’s economy, leading to huge financial and environmental losses, in the terms of product loss, equipment replacement and clean-up cost of oil spills [6]. The production capacity per day in Nigeria in the year 2010 was about 2.9 million barrels but as a result of attacks on oil infrastructure, daily crude oil production has reduced to a range of 1.7 million to 2.1 million barrels (NNPC, 2010). Some crimes are viewed as normal crime in Nigeria because of corruption. Pipeline rupture is one of the causes of pipeline incidents in Nigeria, but the oil and gas industry and the Nigerian government are quick to point at the citizens as the ones responsible for the pipeline vandalisation with improper or no investigations [7]. Another problem bringing down the productivity of oil and gas operations is the institutional corruption at all levels of authority and the extensive bribery with impunity. Investigations on oil spillage in Nigeria confirmed that oil companies often blame oil spills on vandalism in order to get out of paying compensation when in fact corroded pipes are the cause [8].

**Research Design**

The focus of the study is to develop a model that can explain the relationship between pipeline vandalism parameters in oil and gas producing areas. Twenty-three (26) years secondary data was collected from NNPC for use. To assess the adequacy of the data, selected preliminary analysis, namely; outlier detection and test of normality were conducted. Upon validation of the data, advance statistical analysis techniques, namely; least square linear regression, to evaluate the performance of the statistical models, a regression plot of output was generated and the coefficient of determination (R²) was calculated.

**Data Collection**

<table>
<thead>
<tr>
<th>Run</th>
<th>Risk index</th>
<th>No. of vandalization</th>
<th>No. of rupture</th>
<th>No. of spills (tons)</th>
<th>Volume (barrels)</th>
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<tr>
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<td>51,273</td>
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<tr>
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<td>505.00</td>
<td>30</td>
<td>390</td>
<td>95,345</td>
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</table>
Twenty-six years secondary data covering from 1990 to 2016 on risk index, pipe vandalism, pipe rupture, oil spill and oil volume obtained from the archive of the Nigerian national petroleum corporation annual report bulletin of operations was used in this study. As presented in table 1.

**Method of data analysis**

**Multiple Linear Regression Model**

To apply multiple linear regression models, the independent variables that influences risk index were thoroughly filtered and analyzed. The selected independent variables include:

i. No. of vandalization \( (X_1) \)

ii. No. of Rupture \( (X_2) \)

iii. No. of Spills \( (X_3) \)

iv. Volume of oil \( (X_4) \)

The dependent variable is risk index.

To ascertain the dependence of the selected independent variables on the dependent variable, multiple linear regression models was applied to generate a regression equation of the form:

\[
y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \epsilon \quad (1)
\]

where:

\( X_1, X_2 \ldots \ldots \ldots \ldots X_n = \) the selected independent variables

\( Y = \) the dependent variable (Rate of accident),

\( \beta_0, \beta_i = \) the regression constant;

\( \epsilon \) is the deviation.

**RESULTS AND DISCUSSION**

**Outlier Analysis Result**

Results of the computed percentiles for both the dependent and independent variable is presented in Table 2.

<table>
<thead>
<tr>
<th>Risk Index</th>
<th>Percentile</th>
<th>5</th>
<th>10</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>90</th>
<th>95</th>
</tr>
</thead>
</table>
| Using the weighted average definition, the 25th percentile (Q₁) for risk index was observed to be 0.210 while the 75th percentile (Q₃) was observed to be 0.300. Adopting the labeling rule equation presented in (2) and (3), the lower and upper bound statistics were calculated as follows:

\[
\text{Lower bound} = 0.210 - (2.2(0.300 - 0.210)) = 0.012
\]

\[
\text{Upper bound} = 0.300 + (2.2(0.300 - 0.210)) = 0.498
\]

The extreme value statistics of risk index which shows the highest and lowest number of risk index is presented in Table 3.
From the result of Table 3, it was observed that the highest value of risk index was 0.300 which is lower than the calculated upper bound of 0.498. The lowest value of risk index was observed to be 0.200 which is greater than the calculated lower bound of 0.012. To be devoid of outlier, no risk index data should be greater than the calculated upper bound or lower than the calculated lower bound. Therefore, since no risk index data is greater than the calculated upper bound of 0.498 or lower than the calculated lower bound of 0.012, it was concluded that the risk index data employed in this analysis are devoid of possible outliers.

Normality test of Risk Index Data

Result of the normality test is presented in Figure 1.

From the result of Figure 1, the following observations were made:

i. For normality, the skewness coefficient should not be greater than 1 and the kurtosis should not be greater than 3. A skewness coefficient of 0.12982 and a kurtosis value of 1.45750 as observed in Figure 4.7 indicate that the risk index data is normally distributed.

ii. Jarque-Bera test value of 2.34478 and a probability (p-value) of 30.96% as observed in Figure 4.7 indicates that the risk index data is not normally distributed. A value of JB greater than 10 means that the null hypothesis has been rejected at the 5% significance level. In other words, the data do not come from a normal distribution. Since the Jarque-Bera test value is less than 10 and the (p-value) is greater than 5% significant value, the null hypothesis was rejected and it was concluded that the risk index data is not from a normal distribution.
Development of a Multiple Linear Regression Model

The null and alternate hypothesis for the linear regression was formulated as follows;

H0: P < 0.05 model is significant and relationship is linear
H1: P > 0.05 model is not significant and relationship is not linear

To assess the significance of the regression model, one-way analysis of variance was used. To validate the regression results and determine the exact relationship between the dependent and independent variables, selected goodness of fit statistics, namely; coefficient of determination ($R^2$), adjusted (R-Square) value were employed. The dependence of the dependent variable on the selected independent variables was evaluated using the coded least square regression equation presented as follows;

\[
\text{(Risk Index)} = C \text{ NOS NOR NOV Volume} \]

(2)

The coded regression equation was implemented using Eviews statistical software and results obtained are presented in Table 4.

Table 4: Output of Regression Analysis

From the result of Table 4 the following observations were made

i. With a regression (p-value) of 0.6847, it was concluded that the regression analysis was not significant at 0.05 degree of freedom. Hence, it was concluded that the relationship between risk index and selected sets of independent variables such as number of vandalization, number of spills, number of rupture and volume is not linear.

ii. Independent variables, namely; number of spills and number of vandalization were observed to have a very strong influence on the risk index with a probability (p-value) of 0.0338 and 0.0004 respectively.

The poor regression terms such as coefficient of determination and adjusted coefficient of determination was apparently due to the fact that the variables are not from a normal probability distribution.

Using the result of Table 4 the overall regression equation was thereafter generated and presented as follows;

\[
\text{(Risk Index)} = 0.030079 - 0.000167 (\text{Spills}) - 0.001026 (\text{Rupture}) + 0.000685 (\text{Vandalization}) + 1.38E-07(\text{Volume})
\]

(3)

The estimated regression parameters of equation (3) are presented in Table 5.
Result of Table 5 shows that the estimated values of regression parameters are fairly good an indication that the exact relationship between the dependent variable (risk index) and the selected independent variables (number of vandalization, number of spills, number of rupture and volume) cannot be determined using linear regression model. Using the regression model presented in equation 3, the predicted risk index using the sets of independent variables is presented in Table 6.

To assess the strength of the regression model, a regression plot of output between the observed risk index and regression predicted risk index was obtained and presented in Figure 3.
3.2 DISCUSSION

The multi linear regression model was developed in this study to predict the risk index among pipeline vandalism parameters, the outlier and normality test shows that the data is correct and good enough for modeling without error, the coefficient of determination values and mean square error values shows the strength of the model developed. Predictions were made with the developed model, showing a good correlation between the observed data and the predicted.

4. CONCLUSION

This study shows the successful use of multilinear regression model to analyze pipeline vandalism parameters and predict risk index in the oil and gas industries. The MLR Predicted results shows a regression error of 0.030406. A regression plot of output between the observed risk index and regression predicted risk index was produced to further check for the models strength and accuracy. The statistical diagnosis indicates that the MLR model is fair but a better and advanced model can be used to predict the vandalism parameters.

REFERENCE

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