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Effects Of Sabotage On Oil And Gas Pipelines In Nigeria

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Abstract *The act of deliberate damage to oil and gas equipment and facilities has been a common phenomenon in Nigeria and has posed huge risk of economic, social and political effects on the peopleThe purpose of this study is to develop a model that can explain the cause and effect relationship between risk assessment index and sabotage effects using the Response Surface Methodology.Twenty year Secondary data was obtained from the archive of the Nigerian National Petroleum Corporation (NNPC), covering the period 1997 to 2016, capturing information on risk index, vandalism, rupture, spillage and volume. The historical Response Surface Methodology which can be applied on secondary data was employed in this study. The design expert version 7.1 was used to obtain the appropriate second order polynomial model to forecast the future occurrence of pipeline vandalism and pipeline rupture.RSM analysis shows that risk index and pipeline vandalism and their interactions have major effects on the pipeline rupture and oil spillage. The model had a p-value of < 0.0001 which is <0.005 indicates that the model is significant and a lack of fit p-value of 0.0949 which is > than 0.005 indicates that the model is significant. To validate the significance and adequacy of the model based on its ability to predict oil spillage and pipe line rupture the goodness of fit statistics was employed which shows that the rupture model and the spillage model posses adequate strengrh. Result of the study have shown that the RSM is a highly effective tool for the prediction of pipeline rupture and oil spillage .*

Keywords:

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I. Introduction

it is a sure fact that risk control strategies increase the reputation of firms and has the tendencies to reduce business failures. Disruptions in oil and gas production caused by explosions and fires outbreaks can easily lead to major economic losses, and potential hazards to humans and the environment[2]. Risk can be defined as the likelihood of specific consequences happening.studies has shown that pipeline risk is different from other plant risk because plant risk is associated with a line source rather than a series of point sources of risk [1].Intentional Damage (Sabotage), is a deliberate act of people causing damage to assess, properties and the environment. It happens due to several reasons, causing disruption in the production and distribution of petroleum products[3]. lack of employment, environmental degradation and economic backwardness in the region where the pipeline is located has been identified as the main factors leading to agitation ,violence and pipeline sabotage in the Niger-Delta region of Nigeria[4]. Sabotage effects like oil spillage and pipeline rupture results in environmental degradation, which reduces the integrity of the organization. Oil companies need to carryout proper risk assessment and hazard identification on projects so as to checkmate these man-made and natural sabotage agents and manage their risks, using appropriate technology, in order to ensure productive working practices [5]. In addition, probabilistic design techniques have also been applied to model failures in oil and gas pipelines [6]. The concept of oil pipeline vandalism and oil sabotage are vital to discourse in this piece of work and as such to highlight details of their meaning for proper understanding. First, oil pipelines are the medium through which crude oil, natural gas, and industrial chemicals are transported [7]). Oil pipelines are vital and sensible facilities that could cause unconceivable catastrophes during operation, transportation of petroleum product or maintenance without a deliberate act of vandals or saboteur. The concept of vandalism according to [7] is an illegal or unauthorised activity carried out jointly with different entities in the destruction of gas, petroleum, and chemical pipelines. vandalism can be described as as a thoughtful antagonistic behaviour of unsatisfied and corrupt individuals aimed directly to an environmental object with a destructive motive of damaging properties and causing harm[8] . Also, [9]) describe oil vandalism as a “productive force that fought against the exploration of a capacity system” across the world.

II. Research Methodology

2.1 Research design

The methodology used for analysis of pipeline risk in this study draws relevant techniques from various frameworks. The primary objective of this work involved defining the relevant factors and analyzing the sabotage effects on oil and gas industries capturing data of pipeline vandalism, pipeline rupture and fire outbreak collected from NNPC.

2.2 Method of data collection

A twenty year Secondary data was obtained from the archive of the Nigerian national petroleum corporation, covering from 1997 to 2016 was used in this research study. Interviews were also conducted to obtain first hand information on pipeline rupture and vandalism effects.

2.3 Method of data analysis

2.3.1 response surface methodology(RSM)

RSM is a set of mathematical and statistical techniques that are useful for modelling and predicting the response of interest affected by several input variables RSM also specifies the relationships among one or more measured responses and the essential controllable input factors **.**RSM can be expressed in the first order polynomial or the second order polynomial equation.

2.3.2 First-order order polynomial model

First-order model is used to describe the flat surfaces that may or may not be tilted. This model is not suitable for analyzing maximum, minimum, and ridge lines. If there is a significant lack of fit of the first-order model, then a more highly structured model, such as second-order model, may be studied in order to locate the optimum. When there is a curvature in the response surface the first-order model is insufficient. We use first-order model when the response is a linear function of independent variables. A first-order model with *S* experimental runs carrying out on *q* design variables and a single response *y* can be expressed below:

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{12} + .\beta_2 x_{12} + ... + \beta_q x_{iq} + \varepsilon_i \qquad (i = 1,2,........,\ S) \qquad (2.1)$$

The response *y* is a function of the design variables $x_1, x_2, ..., x_q$, denoted as *f*, plus the experimental error. A first-order model is a *multiple-regression* model and the b_j's are regression coefficients.

2.3.3 Multiple regression model

The relationship between a set of independent variables and the response *y* is determined by a mathematical model called regressionmodel. When there are more than two independent variables the regression model is called multiple-regression model. In general, a multiple-regression modelwith *q* independent variable takes the form of

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta_q x_{iq} + \varepsilon_i \qquad (i = 1,2,........,\ S) \qquad (2.2)$$

$$= \beta_0 + \sum_{j=1}^{q} \beta_j x_{ij} + \varepsilon_i \qquad (j = 1,2,........,\ q) \qquad (2.3)$$

WhereS>*q*. The parameter *ßj* measures the expected change in response *y*per unit increase in $x_i$when the other independent variables are held constant. The i^th^ observation and j^th^ level of independent variable is denoted by x_{ij}. The data structure for the multipleregressionmodelis shown in Table 3.6.

The multiple-regression model can be written in a matrix form $y = X\beta + e$ Where

$$y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}_{(nXl)} \qquad X = \begin{bmatrix} 1 & x_{11} & x_{12} & x_{1q} \\ 1 & x_{21} & x_{22} & x_{2q} \\ \vdots & \vdots & \vdots & \vdots \\ 1 & x_{n1} & x_n & x_{nq} \end{bmatrix}_{(nXk)}$$

2.3.4 Second order polynomial model

The second-order model is flexible, because it can take a variety of functional forms and approximates the response surface locally. Therefore, this model is usually a good estimation of the true response surface. .The second-order model includes all the terms in the first-order model, plus all quadratic terms like $\beta_{11} X_{1i}$ and all cross product terms like $\beta_{13} X_{1i}$. It is usually expressed as:

$$y=\beta_0+\sum_{j=1}^{q}\beta_{jj}x_j^2+\sum\sum{}_{kj}\beta_{ij}x_i x_i+\varepsilon \qquad (2.4)$$

$$=\beta_0+x_i'\beta+x_i'\beta x_i+\varepsilon_{ij}$$

Where $\left(x_{1i}, x_{2i}, \ldots\ldots, x_{iq}\right)$, $\beta=\left(\beta_1, \beta_2, \ldots\ldots, \beta_q\right)$

1. *Resuslts and discussion*

In this study, twenty year data on sabotage effects capturing vandalism,numbers of oil spills ,volume of spills and risk is shown in table 1

Table 1:data of sabotage effects on pipeline

Run	Risk index	Vandalism	Rupture	Spills	Volume
1	0.30	450.00	42	300	76000
2	0.20	370.00	37	282	72000
3	0.31	470.00	44	297	80000
4	0.21	390.00	39	285	65000
5	0.27	415.00	39	302	66000
6	0.29	451.00	38	303	62000
7	0.25	405.00	35	295	52000
8	0.21	370.00	37	294	72000
9	0.24	405.00	35	294	67000
10	0.25	405.00	34	293	55000
11	0.32	477.00	46	302	81000
12	0.31	480.00	43	301	75000
13	0.30	440.00	41	301	73000
14	0.25	408.00	37	298	52000
15	0.27	418.00	35	298	55700
16	0.28	414.00	39	297	53700
17	0.21	360.00	37	295	36000
18	0.20	350.00	34	293	30000
19	0.22	370.00	37	296	31000
20	0.31	480	43	300	75000

To accept any model, its satisfactoriness must first be checked by an appropriate statistical analysis output. To diagnose the statistical properties of the response surface model, the normal probability plot of residual is produced which is shown in figure 1

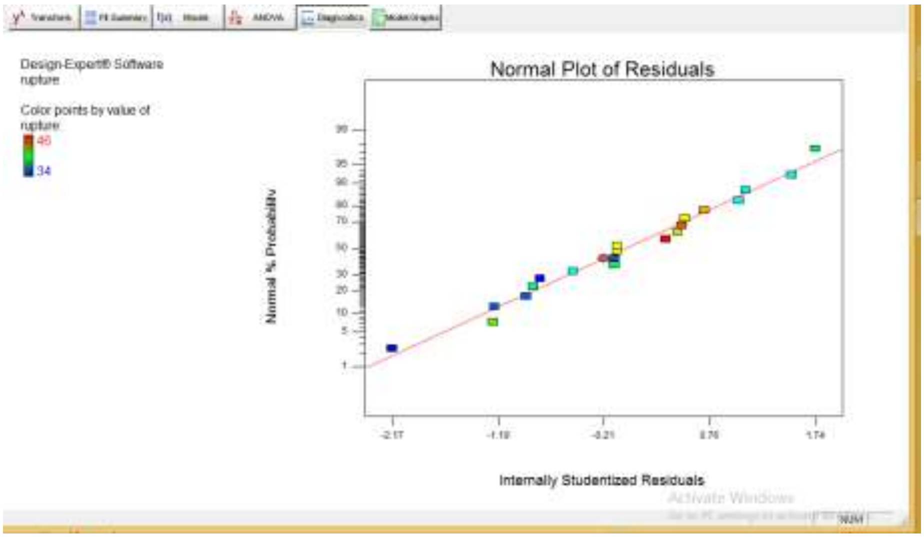

Figure 1: normal plot of residuals

It can be observed that the points follow a straight line despite the slight scatter. There is no defined pattern like an "s-shaped" curve aside the linear trend.This indicates that the residuals are normally distributed and no transformation of the response data is required for better analysis.

To validate the suitability of the quadratic model in analyzing the data, the sequential model sum of squares was calculated for the responses as presented in table 2

Table 2 : sequential sum of squares for the responses

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	30732.80	1	30732.80			
Linear vs Mean	125.18	3	62.59	0.54	0.6645	
2FI vs Linear	27.45	3	27.45	1.76	0.2044	
Quadratic vs 2FI	97.20	3	48.60	1.55	< 0.0001	Suggested
Cubic vs Quadratic	14.74	7	3.68	86.51	0.0019	Aliased
Residual	50.50	3	16.83			
Total	31018.00	20	1550.90			

The sequential model sum of squares table shows the accumulating improvement in the model fit as terms are added. Based on the calculated sequential model sum of square, the highest order polynomial where the additional terms are significant and the model is not aliased was selected as the best fit. From the results of table 1 it was observed that the cubic polynomial was aliased hence cannot be employed to fit the final model. In addition, the quadratic and 2FI model were suggesed as the best fit thus justifying the use of quadratic polynomial in this analysis

To test how well the quadratic model can explain the underlying variation associated with the data, the lack of fit test was estimated for each of the responses. Model with significant lack of fit cannot be employed for prediction.

Table 3: Lack of fit test for the responses

Source	Sum of Squares	Df	Mean Square	FValue	P-value Prob > F	
Linear	86.60	15	5.77	23.09	0.0423	
2FI	52.30	14	3.74	14.94	0.0644	
Quadratic	**29.83**	**12**	**2.49**	**9.94**	**0.0949**	**Suggested**
Cubic	19.98	8	2.50	9.99	0.0941	
Pure Error	0.50	2	0.25			

To validate the adequacy of the quadratic model based on its ability to predict its target response effects the goodness of fit statistics was presented in Table ;

Table 4: Goodness of fit statistics for the responses

Std. Dev.	2.56	R-Squared	0.952
Mean	296.30	Adj R-Squared	0.873
C.V. %	0.87	Pred R-Squared	0.775
PRESS	214.94	Adeq Precision	12.466

The optimal equation which shows the individual effects and combine interactions of the selected input variables against rupture effects is presented in equation 4.1.

$$y_1 = 125.2076 - 131.5036x_1 - 0.3974x_2 - 4.7607x_1x_2 + 4174.0800x_1^2 + 1.9824\times10^{-3}x_2^2 \quad (4.1)$$

Where

$x_1 = Risk\,index$

$x_2 = Vanadlism$

$y_1 = Rupture$

The optimal equation which shows the individual effects and combine interactions of the selected input variables against oil spillageis presented in equation 4.2.

$$y_2 = 347.3056 + 14.1824x_1 - 0.2474x_2 + 8.9775x_1x_2 - 6797.3133x_1^2 - 2.6689\times10^{-3}x_2^2 \quad (4.2)$$

Where

$x_1 = Risk\,index$

$x_2 = Vanadlism$

$y_2 = Spills$

The optimal equation which shows the individual effects and combine interactions of the selected input variables against rupture effectsis presented in equation 4.3.

$$y_3 = -1.3800\times10^6 - 1.0906\times10^7 x_1 + 1330.7710x_2 + 27143.4753x_1x_2 - 1.2626\times10^6 x_1^2 - 23.7468x_2^2 \quad (4.3)$$

Where

$x_1 = Risk\,index$

$x_2 = Vanadlism$

$y_3 = Volume$

III. Conclusion

In this study a second order polynomial has been developed to explain the effects of sabotage on pipeline facilities. The response surface methodology was employed to achieve this , various steps were taken to ascertain that the second order model was the best that can accurately explain the relationship between risk index vandalism,rupture and spillage. The sequential sum of squares,lack of fit test. Analysis of variance, goodness of fit statistics, and normal probality plot criteria were met and the second order model selected as the best model . The results has shown that the greater the risk index the more vandalism and pipeline rupture are likely to occur.

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