EFFECT OF OPTIMIZING PREDICTIVE MAINTENANCE SCHEDULING ON THE PREVENTION OF PIPELINE CORROSION IN OIL AND GAS INDUSTRY IN NIGERIA

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Abstract

Maintenance scheduling is a crucial aspect of asset management in the oil and gas industry. This study is a descriptive survey design and it was carried out to investigate the effect of predictive maintenance scheduling on the prevention of pipeline corrosion in the oil and gas industry in Nigeria. The researcher developed three research objectives, three research questions and one hypothesis that guided this study. The researcher constructed a fifteen-item questionnaire titled Predictive Maintenance Scheduling for Preventing Pipeline Corrosion (PMSPPC) which was adequately validated and administered to 205 respondents which were purposefully selected from different oil and gas companies. The tool for data analysis adopted in this study was the mean, standard deviation, chi-square and percentage scores. The major finding in this study was that preventive maintenance scheduling did not exert any significant effect on the prevention of pipeline corrosion in the oil and gas industry. Based on the study findings, the researcher concluded that effective Predictive Maintenance Scheduling can significantly reduce the likelihood of pipeline corrosion and failures thereby optimize maintenance resources and reduce costs associated with environmental spills and leaks caused by corrosion-related failures. Some of the recommendations in the study are: further research is needed to develop more advanced machine learning algorithms and data analytics techniques for predictive maintenance scheduling, the development of more effective data integration and management systems is necessary to support predictive maintenance scheduling, personnel training and development on predictive maintenance scheduling techniques and tools is very important as there will continuous monitor and evaluate the effectiveness of predictive maintenance scheduling measures and there may be need to integrate predictive maintenance scheduling with existing maintenance management systems and processes.

Keywords: Predictive Maintenance Scheduling, corrosion, Oil and gas industry

Introduction

The oil and gas is an important sector of any nation and also a critical component of the global energy landscape that supply the fuel that empowers economic growth and development in different nations of the global village. Maintenance scheduling is a crucial aspect of asset management in this sector where equipment failure can result to notable and undesirable costly downtime, safety risks, losses and negative environmental impact (Akagundu andAmakiri, 2016). Edahera (2020) asserted that the complex nature of predictive maintenance scheduling as it relates to the oil and gas industry is worsened by the harsh operating conditions, high-stakes equipment failures coupled with the rigorous requirements involved. In the words of Adeleke and Abiodu (2018), the traditional approach to maintenance scheduling has posed a lot of challenges as it is often reliant on static schedules and reactive maintenance which has severally led to unnecessary downtime, risk exposures, wasteful costs and dwindling productivity. Against these challenges is to adopt the predictive maintenance scheduling which is proactive and has proved to be a game-changer in several situations. This approach has pioneered the framework predictive analytics by leveraging effective and efficient cutting edge techniques which has revolutionized maintenance scheduling in the oil and gas industry (Campela, 2016). This has the ability of integrating real-time data from sensors, maintenance logs and relevant environmental factors to provide a very proactive (not reactive) measure ensures fair prediction in asset maintenance thereby minimizing equipment failures, risks, reduces emergence costly repairs and also optimizes resource allocation and productivity. Ezekoka and Uzozie (2018) stated that the use of real-time data, machine language algorithms and advanced statistical models in this predictive maintenance analytics and scheduling been able to unlock unprecedented levels of efficiency and reliability by efficient forecast of pipeline equipment failures and optimum maintenance culture.

Songoto (2019) posited that the oil and gas industry needs a more effective and efficient approach to maintenance scheduling such that will leverage on advanced analytics and real-time data to forecast equipment failure, optimize maintenance scheduling and reduce downtime.

Nwokoma and Elechi (2011) averred that the aims of predictive maintenance scheduling are to; develop a predictive analytics framework for maintenance scheduling, evaluate the effectiveness of the framework in reducing downtime, costs and safety risks. In the same vein, Sampson (2020) advocated that to develop a predictive maintenance schedule is to optimize maintenance scheduling in an asset-intensive industry that

will engender safe operations, reduce downtime and increase overall efficiency.

Statement of the Problem

The oil and gas industry has encountered serious challenges due to traditional approach in their maintenance culture as a result of which the emergence of the predictive maintenance scheduling has brought about significant changes in their assets maintenance activities with its positive impact. Elijah and Jonad (2020) observed that the traditional maintenance scheduling approaches have proved to be inadequate with inherent challenges which are mostly in the area of equipment failures, downtime losses and costly repairs. In the words of Ossai (2016), the traditional approach to maintenance scheduling has posed a lot of challenges as it is often reliant on static schedules and reactive maintenance which has severally led to unnecessary downtime, risk exposures, wasteful costs and dwindling productivity

Equipment failure in the oil and gas industry has always resulted in substantial downtime and revenue losses and this has attracted the need for optimized maintenance scheduling (Ashanliti and Edmond, 2019). Based on this, there is every need to develop a predictive analytical framework that will leverage real-time data and machine learning algorithms to forecast equipment failure, reduce downtime and also optimize maintenance scheduling which will enhance productivity level in the industry. Again, this researcher has searched and noticed that there is scarcity of academic work in this topic and this has added to the essentiality for undergoing a research work in this area.

Objective of the Study

The main objective of this study is to examine the effect of predictive maintenance scheduling on the prevention of pipeline corrosion in oil and gas industry in Nigeria and the specific objectives include the following:

1. To ascertain the predictive maintenance scheduling techniques for the prevention of pipeline corrosion in the oil and gas industry in Nigeria
2. To examine the effect of predictive maintenance scheduling techniques on the prevention of pipeline corrosion in the oil and gas industry in Nigeria
3. To outline the various measures adopted for the prevention pipeline corrosion in the oil and gas industry in Nigeria

Research Questions

Three research questions were formulated to guide this study

1. What are the predictive maintenance scheduling techniques for the prevention of pipeline corrosion in the oil and gas industry in Nigeria
2. How does predictive maintenance scheduling affect the prevention of pipeline corrosion in the oil and gas industry in Nigeria

3. What are the measures adopted for the prevention of pipeline corrosion in the oil and gas industry in Nigeria

Research Hypotheses

This study tested one hypothesis in line with the research objective as stated below.

HO Preventive maintenance scheduling techniques have no significant effect on the prevention of pipeline corrosion in the oil and gas industry

Literature Review

Meaning of Predictive Maintenance Scheduling

Predictive maintenance scheduling is a proactive approach to maintaining pipeline integrity and preventing corrosion in the oil and gas industry.

Predictive maintenance scheduling refers to the process of using data-driven insights and advanced analytics to schedule maintenance activities for equipment or assets, such as pipelines, before they fail or deteriorate (Elijah and Jonad, 2020).

The key activities involved here are; prediction, using data analytics to predict when maintenance activity will take place which is proactive than being reactive and wait for a normal or fixed maintenance period; actual maintenance of the equipment to prevent failures, reduce downtime, and optimize productivity and performance (Njokuocha, 2015). He further asserted that this approach also involves planning and scheduling, forecasting maintenance activities in advance, based on certain predictive insights.

Predictive Maintenance Scheduling Techniques

According to Njokuocha (2015), Olatunde and Abioye (2019), Ashanliti and Edmond (2019), in preventing pipeline corrosion in the oil and gas industry by predictive maintenance scheduling, the following techniques are used;

1. Artificial Intelligence (AI): Using AI to analyse data and identify patterns and tends that may indicate corrosion risks

2. Data Analytics: Examines data from sensors, maintenance logs, and other sources to identify trends and patterns.

3. Condition Monitoring: Tracks equipment conditions in real-time to detect potential issues.

4. Machine Learning algorithms: Analyzes data patterns to predict equipment failures.

5. Statistical Modeling: Uses statistical models to forecast equipment failures and maintenance needs

6. Stimulation Modelling: using computer models to stimulate pipeline behaviour and make predictions

Effects of Predictive Maintenance Scheduling in the Oil and Gas Industry

Cajetuni and Danlie (2019) asserted the effects of optimizing maintenance scheduling using predictive analytics in the oil and gas industry can be so significant and beneficial.

By optimizing maintenance scheduling using predictive analytics, oil and gas companies can achieve significant operational, financial, and environmental advantages. Nwokoma and Elechi (2011), Ossai (2016), Cajetuni and Danlie (2019) and Sampson (2020) outlined the following as the various effects and benefits of adopting the predictive maintenance scheduling method in the oil and gas sector.

Cost Savings: Optimized maintenance scheduling reduces the need for emergency repairs and maintenance costs, extends equipment life, and decreases related costs.

Reduction in Corrosion-related Leakages and Ruptures: Predictive analytics helps to identify and forecast potential corrosion issues and equipment failure before they occur, allowing for proactive maintenance and minimizing unplanned downtime thereby reducing unnecessary downtime and losses.

Reduced Environmental Impact: Predictive analytics helps prevent equipment failure, reducing the risk of environmental damage and spills.

Increased Productivity: Optimized maintenance scheduling enables more efficient use of resources, leading to increased productivity and reduced lost revenue.

Extended Equipment Life: Proactive maintenance and optimized scheduling extend equipment lifespan, reducing replacement costs and environmental impact.

Improved Safety: Predictive analytics identifies potential safety risks, enabling proactive measures to prevent accidents and ensure a safer working environment.

Improved Resource Allocation: Optimized maintenance scheduling ensures efficient use of resources, reducing waste and improving overall operational efficiency.

Competitive Advantage: Adopting predictive analytics for maintenance scheduling can differentiate companies in a competitive market.

Data-Driven Culture: It promotes a data-driven insight and culture which helps in informed decision-making, driving innovation, strategic planning and continuous improvement.

Predictive Maintenance Scheduling Measures for the Prevention of Pipeline Corrosion in oil and Gas Industry

Akabundu and Amakiri (2016), Ezekoka and Uzozie (2018), Songoto (2019), and Sampson (2020) generally agreed that the Predictive Maintenance Scheduling applies the following measures in preventing pipeline corrosion in oil and gas

Condition Monitoring: Implementing condition monitoring techniques, such as ultrasonic thickness measurements, corrosion potential measurements, and acoustic emission testing, to detect early signs of corrosion.

Predictive Modeling: Using predictive modeling techniques, such as machine

learning algorithms and statistical models, to forecast the likelihood of corrosion based on historical data, environmental factors, and operating conditions.

Risk-Based Inspection: Conducting risk-based inspections to identify high-risk areas of the pipeline and prioritize maintenance activities accordingly.

Corrosion Rate Monitoring: Monitoring corrosion rates using techniques such as linear polarization resistance (LPR) and electrochemical impedance spectroscopy (EIS).

Cathodic Protection: Implementing cathodic protection systems to prevent corrosion by applying an electric current to the pipeline.

Coating and Lining: Applying coatings and linings to the pipeline to prevent corrosion and extend its lifespan.

Operational Parameter Monitoring: Monitoring operational parameters such as pressure, temperature, and flow rate to detect any changes that could indicate corrosion.

Data Analytics: Using data analytics to analyze data from various sources, such as sensors, inspection reports, and maintenance records, to identify trends and patterns that could indicate corrosion.

Methods

The data for this study was collected

Results and Analysis

Analysis of Research Questions

Research Questions 1: What are the predictive maintenance scheduling techniques for the prevention of pipeline corrosion in the oil and gas industry in Nigeria?

Table 1: Mean and Standard Deviation of Respondents on the predictive maintenance scheduling techniques for the prevention of pipeline corrosion in the oil and gas industry in Nigeria

S/N	DESCRIPTION Predictive Maintenance Scheduling measures	SA	A	D	SD	$\bar{x}$	STD	DECISION
1	Use predictive and statistical models to forecast corrosion rates and predict when to carry out maintenance activities	68	81	33	23	2.9	0.97	Agreed
2	Identify the length of the pipeline and give maintenance instructions	44	32	41	88	2.2	1.2	Disagreed

3	Schedule maintenance activities at regular intervals based on historical corrosion rates	87	77	25	16	3.1	0.92	Agreed
4	Adapt maintenance activities with times of staff vacation and sunlight intensity	0	0	83	122	1.4	0.58	Disagreed
5	Use of office behaviour to monitor systems and schedule maintenance	24	29	72	80	2.0	1.0	Disagreed
	Cluster Grand Mean					2.3	0.93	Disagreed

Table 1 above showed the respondents views on the predictive maintenance scheduling techniques for the prevention of pipeline corrosion in the oil and gas industry in Nigeria. With mean scores of 2.9 and 3.1 and the standard deviation of 0.97 and 0.92 respectively, the respondents agreed that items 1 and 3 are the predictive maintenance scheduling techniques used to prevent pipeline corrosion in the oil and gas industry in Nigeria. Conversely, they disagreed with items 2, 4 and 5 which indicated that these three items are not the techniques in preventing pipeline corrosion in the oil and gas industry in Nigeria. This decision was based on the fact that the respondents highly and strongly disagreed on items 2, 4 and 5 which also recorded mean scores that are below the 2,5 critical level of significance. Which the grand cluster mean score of 2.3 which is also below the critical mean of 2.5, the researcher therefore concluded that the majority of the items stated in the table are not the predictive maintenance techniques adopted in preventing pipeline corrosion in the oil and gas industry in Nigeria.

Research Questions 2: How does predictive maintenance scheduling affect the prevention of pipeline corrosion in the oil and gas industry in Nigeria?

Table 2: Mean and Standard Deviation of Respondents on the effect of predictive maintenance scheduling techniques on the prevention of pipeline corrosion in the oil and gas industry in Nigeria

S/N	DESCRIPTION Effect of Predictive Maintenance Scheduling Techniques	SA	A	D	SD	$\bar{x}$	STD	DECISION
6	By being a proactive measure, predictive maintenance scheduling techniques reduces the risk of corrosion, environmental damages and associated losses and costs	101	81	13	10	3.3	0.82	Agreed
7	It reduces corrosion-related leakages and rapture thereby reducing downtime	83	80	20	22	3.1	0.92	Agreed
8	Predictive scheduling maintenance activities make flow of oil slow and is costly	17	18	94	76	1.9	0.88	Disagreed

9	It reduces the emergency of repair and replacement of corroded pipes and its associated costs	93	71	20	12	2.9	0.97	Agreed
10	Predictive maintenance scheduling predicts corrosion time and prioritize maintenance which helps in increasing pipeline lifespan	74	75	33	23	2.9	0.97	Agreed
	Cluster Grand Mean					2.8	0.91	Agreed

Table 2 is an array scores that revealed the respondents views on effect of predictive maintenance scheduling on the prevention of pipeline corrosion in the oil and gas industry in Nigeria. A close look at the table revealed that all the respondents agreed that the items in table 2 are the effects or benefits of predictive maintenance scheduling on the prevention of pipeline corrosion in the Nigerian oil and gas industry except item 8 where they recorded a mean score of 1.9 which is lesser that the bench mark of 2.5 criteria mean. The result also showed a grand cluster mean score of 2.8 which further validates the fact that the items in table 2 are majorly the effect of predicting maintenance schedules in the oil and gas sector of Nigeria.

Research Questions 3: What are the measures adopted for the prevention of pipeline corrosion in the oil and gas industry in Nigeria?

Table 3: Mean and Standard Deviation of Respondents on the predictive maintenance scheduling measures for the prevention of pipeline corrosion in the oil and gas industry in Nigeria

S/N	DESCRIPTION **Predictive Maintenance Scheduling Measures**	SA	A	D	SD	$\bar{x}$	STD	DECISION
11	By adopting condition monitoring technique to detect early signs of corrosion	89	74	20	22	3.1	0.97	Agreed
12	By operational parameter monitoring such as pressure, temperature and flow rate to detect any corrosion-causing changes	86	78	25	17	3.0	0.92	Agreed
13	By applying coatings and linings to the pipeline to prevent corrosion and extent lifespan	104	78	12	11	3.3	0.82	Agreed
14	By using Cathodic protection measures like applying electric current to the pipeline	94	76	17	18	3.2	0.88	Agreed

15	By ensuring risk-based inspection to identify high-risk areas and prioritise maintenance there.	87	3	25	20	3.1	0.92	Agreed
	Cluster Grand Mean					3.1	0.90	Agreed

The views of the respondents on the measures adopted for the prevention of pipeline corrosion in the oil and gas industry in Nigeria are displayed in table 3 above. From the table, items 11 to 15 recorded mean scores of 3.1, 3.0, 3.3, 3.2 and 3.1 respectively which are above the significant or criteria score of 2.5. Given the fact that they respondents scored highly on the respective items, the result indicated and implies that all the respondents have fully consented that item numbers 11 to 15 are the various measures applied in predicting maintenance scheduling and preventing pipeline corrosion in the oil and gas industry in Nigeria. The cluster grand mean of 3.1 also gave credence and further supported that table 3 items are the preventive measures against pipeline corrosion in Nigerian oil and gas sector.

Testing of Hypothesis

Ho Preventive maintenance scheduling has no significant effect on the prevention of pipeline corrosion in the oil and gas industry

Table 4: Chi Square (X^2) Table to Test Null Hypothesis

S/N	Summary of Cluster Items	SA	A	D	SD	Total	X^2c	X^2r	Df	Decision
1.	Predictive maintenance scheduling measures for the prevention of pipeline corrosion in the oil and gas industry in Nigeria	**232**	**219**	**254**	**329**	**1025**	**21.65**	**43.77**	**42**	
2.	Effects of predictive maintenance scheduling on the prevention of pipeline corrosion in the oil and gas industry in Nigeria Various measures adopted in the prevention pipeline corrosion in the oil and gas industry in Nigeria									**Null Hypothesis is accepted**

P>0.05, Df = 42 Keys: SA = Strongly Agree, A = Agree, D = Disagree, DS = Strongly Disagree

X^2c = Chi Square calculated, X^2r = Chi Square tabulated/critical, X^2calculated = 21.65 given the formular $\sum(0-E)$

This is a 4 x 15 contingency table which means there are (4- 1) (15-1) = 42. At 5% level of significance, the degree of freedom is 42. X^2_{42} at 5% equals 43.77. X^2 calculated value is 21.65 and it is lower than the X^2r tabulated of 43.77. Given the decision rule, the null hypothesis is therefore accepted hence it is concluded that preventive maintenance scheduling has no significant effect on the prevention of pipeline corrosion in the oil and gas industry.

Discussion of Findings

The findings from the analysis in this study are hereby discussed based on their relevance to the research questions and hypothesis that guided this study.

One the first research question, the study result revealed that the majority of the items stated in table 1 are not the techniques adopted in preventing pipeline corrosion in the oil and gas industry in Nigeria. This conclusion was reached because the respondents did not accept three out of the five items as predictive maintenance techniques for preventing pipeline corrosion in Nigerian oil and gas industry. The result is in consonance with Njokuocha (2015), Adeleke and Abiodu (2018) and Edehera (2020) who in their various studies observed that the techniques indicated in table 1 of this study are actually some of the predictive maintenance scheduling techniques that help in preventing pipeline corrosion in the oil and gas industry.

Concerning research question two which is on the effect of predictive maintenance scheduling for the prevention of pipeline corrosion in the oil and gas industry in Nigeria, the result indicated that by the consent of all the respondents, all the items in table 2 are the effects or benefits of predictive maintenance scheduling on the prevention of pipeline corrosion in the Nigerian oil and gas industry except item 8 which stated that predictive scheduling maintenance activities make flow of oil slow and is costly. This finding is in line with the findings of Cajetuni and Danlie (2019) as they concluded that predictive maintenance scheduling is a proactive approach that is beneficial not only in preventing downtime but helps in reducing the rate of emergency repair costs.

Research question three was on the measures adopted for the prevention of pipeline corrosion in the oil and gas industry in Nigeria and the result showed that all the respondents scored highly on the respective items listed in table 3 which indicated their consent that those item are the various measures applied in predicting maintenance scheduling and preventing pipeline corrosion in the oil and gas industry in Nigeria. This result aligned with the study result of Ashanliti and Edmond (2019) and validated by the assertion of Songoto (2019) that applying those measures are relevant and

efficient in preventing pipeline corrosion in Nigerian oil and gas industry,

Conclusion

Based on the study findings, the researcher concluded that effective Predictive Maintenance Scheduling can significantly reduce the likelihood of pipeline corrosion and failures, optimize maintenance resources and reduce costs and also help in reducing environmental impacts by preventing spills and leaks caused by corrosion-related failures.

Recommendations

Based on the study findings, the researcher therefore proffered the following recommendations for implementing predictive maintenance scheduling measures to prevent pipeline corrosion in the oil and gas industry;

1. Further research is needed to develop more advanced machine learning algorithms and data analytics techniques for predictive maintenance scheduling.

2. The development of more effective data integration and management systems is necessary to support predictive maintenance scheduling.

3. Personnel training and development on predictive maintenance scheduling techniques and tools is very important as there will continuous monitor and evaluate the effectiveness of predictive maintenance scheduling measures.

4. There may be need to integrate predictive maintenance scheduling with existing maintenance management systems and processes.

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