Evaluation of Maintenance Management Strategy for Oil Field Equipment: A Case Study of Wireline Pressure Testers

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Abstract—**Maintenance management strategy has been an important tool in oil servicing firms. Presently, the oil servicing firms in south-south Nigeria are faced with the challenges of choosing the best and suitable approach in implementing maintenance management strategy as a tool for improving equipment performance. The research work deployed a sectional survey of two oil servicing firms in Port Harcourt, namely Company X and Company Y, respectively. A target population of 1847 staff of the firm were enlisted, and then further streamlined to 194 maintenance management staff. The primary data was collated through a structured questionnaire and analyzed using descriptive statistics. A stratified purposive sampling with a sample size of 135 was used to select both senior and junior staff of both firms for analysis. The outcome of the research findings revealed that there is a similarity in the maintenance management strategy activities of Company X and Company Y. Firstly, the Study revealed that Company X uses a combination of reliability centred maintenance, preventive maintenance and corrective maintenance program. At the same time, the management of Company Y practices preventive and corrective maintenance programs. Also observed are the challenges in the quest to implement the maintenance strategies. These challenges highlighted by the respondents are: maintenance personnel, tools and materials, and maintenance/operation disturbance are the major maintenance problems faced. The study recommends that management in both oil servicing firms need to practice effective maintenance management policies and increase human (skilled personnel) capital development.**

Keywords– **Maintenance Strategy, tool Management, Maintenance implementation, Equipment performance**

I. INTRODUCTION

Engineering equipment maintenance and reliability challenges have drawn the attention of industrialists and researchers all over the continent as a result of the complexity and innovation of modern technologies, a continuous evolution of sophisticated technologies deployed in the oil and gas sector. These system or equipment used in the petroleum industry requires very high reliability, maintainability and availability due to mission, business and critical nature of their operations. The oil and gas sectors are presently a capital and technology-intensive industry, which deals with sophisticated equipment of different range.

Rivers State, Port Harcourt in particular, has pockets of multi-national oil companies and servicing oil and gas firms that operate equipment ranging from Seismic equipment, injectors used in rig operation, and production facilities in both on-shore and offshore. The necessity to improve and strengthen the maintenance management team at various stages of equipment maintenance is essential for the effective operation of the equipment/system to improve production as well.

Maintenance refers to a set of activities performed to ensure that a tool, machine or system is in good working condition. This could be done through following rules for proper usage, repairing and replacing broken components as needed.

This primitive concept of maintenance management simplifies and links the ideology of maintenance to ancient farmers and builders when they deployed simple machine tools to facilitate and enhance their nascent professions. The evolving nature of maintenance management philosophy has always been in pari-passu with the ever-emerging technology innovations in designing simple equipment and machines which have metamorphosed to sophisticated, complex, and indispensable systems.

Onshore and offshore equipment like the wireline sophisticated in design and require proper maintenance to keep up to its expected performance. Critical failures on this equipment might induce a significant threat to personnel safety, production facility, and environment. To sustain operation efficiency and maintain reliability, translate to minimizing maintenance cost. Presently, corrective maintenance and preventive maintenance approach on onshore and offshore installations and facilities are widely practiced to reduce downtime of equipment at the same time increasing reliability. The predictive maintenance approach is strictly based on condition monitoring technologies and is becoming more acceptable and more popular in the oil and gas industries.

Wireline service is usually deployed on oil and gas well, which requires lowering the tools (equipment) into the well with the aid of wire for reservoir evaluation and well intervention. The wireline formation testers are an essential tool used in the oil and gas industry for good logging. Its core function is to give detailed records of well log formation either through physical measurement made by the wireline tools lowered to the buttonhole of the well or through visual inspection of samples (geological logs) brought to the surface.

The various oil and gas companies have different types of wireline formation testers design to analyze real-time fluid characteristics, monitoring of mud-filtrate contamination combined with precise flow control that captures single phase and low contamination samples. PVT sample quality can only be achieved through the deployment of precise flow control and contamination monitoring.

Hence different oil servicing companies deploy different technology like the Company Y Reservoir Description Tool (RDT), Baker Hughes Reservoir Characterizations Instrument (RCI), and lastly, Company X Modular Formation Dynamic Testers (MDT). The maintenance of this Wireline Formation Testers for these companies is therefore crucial because inadequate equipment maintenance management can lead to inefficient operation of the system, which will result in loss of revenue and time.

The huge problem/challenges associated with the maintenance management system cannot be overlooked in this modern era. Maintenance challenges have resulted in the non-availability of equipment, which has affected the business operations of oil servicing companies such as Company X and Company Y. Some of the key performance indicators or decision variables for poor maintenance strategy, including but not limited to reduced revenue and profitability associated with inflated cost. These multi-national companies perform business operations using highly sophisticated and capital intensive equipment that requires regular maintenance of these assets to extend their lifespan for effective operations. The urgent need for maintainability is becoming more critical than ever due to the alarmingly high cost of repair and operation of the equipment. Therefore, the need for proper maintenance is vital as it does not only minimize the cost of maintenance and operation but ensures the optimal availability of equipment and high performance of the component.

This research work is geared towards developing a better maintenance management strategy that can accommodate and manage the maintenance practices of oilfield equipment (Wireline Formation Testers).

Therefore, it is necessary to carry out a comprehensive comparative analysis of the existing maintenance management strategy of both Company X and Company Y and identifies loophole of both companies to come up with a better template of reducing equipment downtime in-field operation to serve the interest of both the worker, (Staff) and management respectively.

A) Aim and Objectives of the Study

The study aims to evaluate a maintenance management strategy for oil field equipment (Wireline Formation Testers) through a comparative analysis of the existing maintenance management practised in Company X and Company Y.

The following objectives will guide the course of the Study:

(i) To identify and assess existing maintenance management system on oilfield equipment in selected oil servicing firms in River State, Nigeria.

(ii) To assess the effect of maintenance problems and obstacles concerning productivity and performance in carrying out maintenance of equipment.

(iii) To ascertain the effect of the computerized maintenance management system (CMMS).

(iv) Identify the influence of maintenance work order concerning management productivity.

B) Research Questions

From the above objectives stated, the research work seeks to find answers to the following questions.

(i) What is the effect of maintenance program on management performance?

(ii) To what extent is the effect of maintenance problems and obstacles with respect to productivity and performance in carrying out maintenance?

(iii) What is the effect of the computerized maintenance management system (CMMS) on the company's return on investment?

(iv) To what extent do the maintenance work order influence management productivity in the selected oil servicing company?

The study will assist oil servicing firms in Nigeria to develop proper work organization, maintenance management policy, and maintenance cultures in a direction that will provide enabling environment to work efficiently and reduce the risk of equipment failure during operation. The Study will also guide researches and students of engineering management that need empirical data and theoretical framework on the effect of maintenance management strategy for oil field equipment using wireline formation testers as a case study.

The research work focuses on the impact of maintenance management strategy for oil field equipment on selected oil servicing firms. Contextually, the study focuses on the maintenance practices, management system, and any maintenance issues relating to availability, maintainability and reliability of oilfield equipment for Company X and Company Y Wireline Formation Testers.

II. METHODOLOGY

A) Introduction

This section discusses the various techniques employed in this research study. It will encompass the overall research design and plan that will aid the process of data acquisition or collection and the various range of approaches employed to collate the data. In summary, this season will comprise of research design and development, the primary and secondary source of data collection, description of research instrument intended for this research work, and the target population of the study. It also includes the sample size determination, the sampling techniques that will be adopted, reliability and validity of the instrument (questionnaire) and the computer statistical software tools (SPSS) for data analysis.

B) Research Design

The survey research design will be adopted for this research study because it gives an overview and relatively fast ways of collecting data and information from the target population (respondents).

C) Source of Data

For this research work, the data for this study will be obtained from two sources, specifically. Namely for the secondary and primary sources.

Primary Sources

The primary sources of data for this research work will form the basis of data analysis. Two (2) tools for data collection were used. A structured questionnaire was the main instrument of data analysis. The secondary tool for data collection was an open-ended interview with the management staff of the maintenance department of both Company X and Company Y.

Secondary Sources

The use of related literature and existing works by earlier researchers will be the secondary sources of data. The materials specifically used for secondary data extraction for this research work will be magazines, textbooks, internet and most importantly, recent related journals on this research topic, respectively.

D) The population of the Study

The target population for this research work include but not limited to the following staff of Company X and Company Y Service Company. The population will consist of both Senior and junior maintenance management staff of the selected oil servicing firms. The total population for the study is estimated to be between 1500 – 1850 from the oil is chosen servicing firms in Rivers State South-South Zone at Nigeria, which will include Company X and Company Y.

TABLE I: STAFF POPULATION BREAKDOWN OF THE SELECTED OIL SERVICING FIRMS IN SOUTH-SOUTH, NIGERIA

S/N	Name of Oil Servicing Firm	Senior Staff	Junior Staff	Total Population
1	**COMPANY X**	115	990	1105
2	**COMPANY Y**	72	670	742
	TOTAL			1847

Source: Field Survey from the Oil Servicing Firm, 2019.

TABLE II: MAINTENANCE DEPARTMENT BREAKDOWN OF THE SELECTED OIL SERVICING FIRMS IN SOUTH-SOUTH, NIGERIA

S/N	Name of Oil Servicing Firm	Maintenance Senior Staff	Maintenance Junior Staff	Total Population
1	**COMPANY X**	29	92	121
2	**COMPANY Y**	20	53	73
	TOTAL			194

Source: Field Survey from the Oil Servicing Firm, 2019.

III. SAMPLE SIZE DETERMINATION

From previous experience and research from existing and reviewed literature, it is too expensive and challenging to study the total population. Instead, a section or sample of the larger group known as population sample will be selected in such a manner that it will give an exact representation of the entire population size for the research work. To arrive at an appropriate number of quantifiable sample sizes in terms of senior and junior employees, Cochran (1963) sample size evaluation using the statistical formulation for a sample population of the two servicing oil firm will be adopted to obtaining the sample size for this research work.

Thus according to the Cochran (1963), it can be stated mathematically as:

$$n = \frac{Z^2 Npq}{Ne^2 + Z^2 pq} \tag{1}$$

Where n represents the sample size of the servicing oil firms.

N represents the total population of the servicing oil firms

Z represents the Normal Distribution of the servicing oil firms

P. represents the proportion of population likely to be included in the Sample Size which can be assumed to 0.5

q. represents the proportion of the population not likely to be included in the sample size, which can be assumed to be 0.5.

e. represent a margin of error.

$$= \frac{(1.96)^2 \, x\, 194 \, x\, 0.5 \, x\, 0.5}{194 \, x\, (0.04)^2 + (1.96)^2 (0.5)(0.5)}$$

$$= \frac{3.84 \, x\, 194 \, x\, 0.25}{194 \, x\, 0.0016 + 3.84\,(0.25)}$$

$$= \frac{186.3176}{0.3104 + 0.96} = 146.6606$$

n = the sample size evaluated

This sampling method is called a stratified sampling method which gives a fair and balance/unbiased representation of the total population size (the designated oil servicing firm's staff). According to the Bowley's (cited in Enebeli et al. [17]) proportional distribution formula, the number of allocated units and employees in each staff/firm stratum represents the population size which is directly proportional to the total sample size. The same number is inversely proportional to the overpopulation size under Study.

Mathematically it can be represented as:

$$x_h = \frac{X_h n}{N} \tag{2}$$

Where each variable

n represents the total sample size

x_h represents the number of units designated to each staff/firm category

X_h Represents the numbers of employees in each of the staff/firm stratum in the population.

N represents the overall population size under investigation. Hence the proportion allocation for each oil servicing company will be evaluated using equation (2) as expressed above.

From $xh = nX_h/N$

1. **Company X=** $\frac{121x\ 147}{194} = 91.7$

2. **Company Y**= $\frac{73 \, x \, 147}{194} = 55.3$

$$\sum xh = 91.7 + 55.3 = 147$$

Similarly, the proportional allocation for each stratum of staff can be evaluated as:

1. **Company X** Maintenance Department
   a. Senior Management Staff = $\frac{29 \, x \, 147}{194} = 21.9$
   b. Junior Maintenance Management Staff = $\frac{92 \, x \, 147}{194} = 69.7$
2. **Company Y** Maintenance Department
   a. Senior Maintenance Management Staff = $\frac{20 \, x \, 147}{194} = 15.2$
   b. Junior Maintenance Management Staff = $\frac{53 \, x \, 147}{194} = 40.2$

$$\sum xh = 21.9 + 69.7 + 15.2 + 40.2 = 147$$

TABLE III: MAINTENANCE STAFF POPULATION BREAKDOWN OF THE SELECTED OIL SERVICING FIRMS

S/N	Name of Oil Servicing Firm	Total Population	Sample size
1	COMPANY X	121	92
2	COMPANY Y	73	55
	TOTAL		147

Source: Field Survey from the Oil Servicing Firm, 2019.

IV. DESCRIPTION OF THE RESEARCH INSTRUMENT FOR CONDUCTING THE SURVEY

The instrument or tool for data collection will be a structured questionnaire called the EOMMSFOFE questionnaire (Evaluation of Maintenance Management Strategy for Oil Field Equipment). The structured comprises of four sections: the questions in section A contains general information about the research topic of the understudy. The research work adopted a four-point Likert Scale format, i.e., strongly agreed, agreed, strongly disagreed and disagreed, which comprises of 44 questions in the structured questionnaire.

A) Observation Survey

Though the primary source for data collection was the use of a research instrument (EOMMSFOFE). Also, careful observation was made to have direct observation of the maintenance facilities of the selected oil servicing firms.

B) Open-ended Interview Schedule

Although it almost proved futile, few respondents agreed to an oral interview where a structured schedule form was used to gather more information for the research work, especially areas that were captured in the questionnaire.

V. TECHNIQUES FOR DATA ANALYSIS

The collected data were analyzed and presented in percentages and tables. Spearman Rank Order correlation coefficient for testing the reliability of the instrument. A Micro software package called SPSS (Statistics Package for Social Science) was used to compute and analyze the structured questionnaire response from each respondent.

The mathematical expression for Pearson Production Moment correlation coefficient for a given sample data is represented by "r" where:

$$r = \frac{n(\sum XY) - (\sum X)\,(\sum Y}{\partial[[h\sum X^2 - (\sum X)^2][n\sum Y^2 - (\sum Y)^2]} \quad (3)$$

Where

r represents the Pearson correlation coefficient

X represents the value in the first set of data

Y represents the value in the second set of data

n represents the total number of value.

Similarly, since regression analysis will be done on the relationship between the dependent and independent variable, we introduce a regression expression given as:

Regression Equation

$$(Y) = a + bx \quad (4)$$

Where;

$$\text{Slop } (b) = \frac{[(N\sum XY - (\sum X)(\sum Y)]}{[(N\sum X^2 - (\sum X)^2]} \quad (5)$$

$$\text{Intercept } (a) = \frac{[(\sum Y - b(\sum X)]}{N} \quad (6)$$

Where

X and Y represent both dependent and independent variables

b represents the regression line

X represents the first score

N represents the number of values or elements

a represents the intercept point of the regression line concerning the Y-axis

$\sum$Y represents the sum of the second scores

$\sum$X represents the sum of the first scores

$\sum$XY represents the sum of the product of first and second scores respectively

$\sum X^2$ represents the sum of the square of first scores, respectively.

A) Research Instrument Validity

According to Onwumere [42], who defined the validity of a research instrument as the degree to which an evaluating instrument (questionnaire) on application performs the desired purpose for which it was designed. For this research, the researcher ensures that the research instrument measure and validates the conceptual, theoretical and empirical view they are supposed to measure. Therefore, an adequately structured questionnaire with pre-test conduct of every question contained in the structured questionnaire was executed to ensure each research question was valid. During the cause of designing the research question, the instrument (questionnaire) was administered to experts in the oil and gas industry and academia who made some necessary correction and validated the instrument so that the instrument can serve the purpose for which it was designed to measure.

B) Reliability of the Questionnaire (Research Instrument)

According to Borden et al. [11], they define reliability as a measure and ability to produce and replicate the same or similar results when performed repeatedly under identical condition. To validate the instrument reliability, the test-re-test method was used in which six copies of the structured questionnaire was distributed to the two Oil servicing firm understudy, three copies to each firm. The questionnaire was collected and re-distributed back the second time: the results of the test-re-test were determined using the standard Spearman Rank Correlation Coefficient.

TABLE IV: SPEARMAN RANK ORDER CORRELATION COEFFICIENT FOR TESTING THE RELIABILITY OF THE INSTRUMENT

Questionnaire Item	Rank 1	Rank 2	D	d^2
1	6	4	2	4
2	5	3	2	4
3	8	5	3	9
4	7	5	2	4
5	4	1	3	9
6	3	2	1	1
7	2	1	1	1
8	7	3	4	16
9	5	1	4	16
10	4	2	2	4
11	3	1	2	4
12	4	2	2	4
13	5	2	3	9
14	3	1	2	4
15	6	2	4	16
16	8	6	2	4
17	7	5	2	4
18	4	1	3	9
19	3	2	1	1
20	6	3	3	9
			$\sum d^2$	132
			N	20
			n^3	8000
			n^3-n	7980

Where $r = 1 - \frac{\partial \sum d^2}{n^3 - n}$

$$r = 1 - \frac{6\Sigma d^2}{n^3 - n}$$

$$r = 1 - \frac{6 \times 132}{8000-20}$$

$$r = 1 - \frac{6 \times 132}{7980}$$

$$r = 1 - \frac{792}{7980}$$

$$r = 1 - 0.09924812$$

$$r = 0.90$$

VI. RESULTS AND DISCUSSIONS

A) Data Presentation and Analysis

The information extracted from the structured questionnaire was purposively administrated to the staff of Company X and Company Y in South-South, Rivers State of Nigeria. A stratified sample size analysis was used to estimate a total of one hundred and forty-seven structured questionnaires (147) which was distributed to both senior and junior staff of Company X and Company Y, respectively.

TABLE VI: COMPARATIVE ANALYSIS OF THE TYPES OF MAINTENANCE STRATEGIES PRACTISED BETWEEN COMPANY X AND COMPANY Y

87 - Respondents		Breakdown Mtce	Corrective Mtce	PM Mtce	PDM	TPM	RCM
Company X	Strongly Agree	0.0	0.0	36.8	27.6	25.3	73.6
	Agree	19.5	65.5	51.7	0.0	28.7	16.1
	Strongly Disagree	59.8	31.1	0.0	44.8	0.0	9.2
	Disagree	18.4	2.3	11.5	6.9	19.5	0.0
	% Missing – No Answer	2.3	1.1	0.0	20.7	26.5	1.1
	Valid Percent	97.7	98.9	100.0	79.3	73.5	98.9
	Total	100.0	100.0	100.0	100.0	100.0	100.0
48 - Respondents		Breakdown Mtce	Corrective Mtce	PM Mtce	PDM	TPM	RCM
Company Y	Strongly Agree	0.0	18.8	81.2	0.0	18.7	0.0
	Agree	16.7	58.3	16.7	18.7	39.6	37.5
	Strongly Disagree	58.3	0.0	0.0	0.0	18.7	43.8
	Disagree	18.7	18.7	0.0	75.0	18.8	18.7
	% Missing – No Answer	6.3	4.2	2.1	6.3	4.2	0.0
	Valid Percent	93.7	95.8	97.9	93.7	95.8	100.0
	Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: SPSS Generated results from field Survey of the Oil Servicing Firm, 2019.

Table V shows distributed copies of one hundred and forty-seven copies (147) with ninety-two distributed to Company X and fifty-five administrated to Company Y using stratified sample size techniques. A total of Eighty-seven and forty-eight were retrieved from both companies.

B) Results and Discussions

Research Question 1:

To assess the influence of the maintenance program concerning performance in selected oil servicing firms in Nigeria.

TABLE V: DISTRIBUTED QUESTIONNAIRE TO COMPANY **X** AND COMPANY **Y**.

Selected company in Rivers State	Questionnaire Administered	Questionnaire Retrieved	Valid Respondents %	Invalid Respondents %
COMPANY X	92	87	94.60%	5.40%
COMPANY Y	55	48	87.27%	12.73%
TOTAL	**147**	**135**		

Table VI shows the types of maintenance used and to what extent each of them has been used: Breakdown, Corrective, Preventive, Predictive Maintenance, TPM and RCM.

A significant 59.8% of the respondents (Company X) strongly disagreed that breakdown maintenance is not practised and has little or no influence on their maintenance program and performance. 18.4% of the respondents disagreed, and only 19.5% agreed. However, 58.3% of the respondents from Company Y strongly disagreed. Also, 18.7% disagreed that breakdown maintenance is not part of their maintenance management program and has no significant influence on productivity. In comparison, 16.7% agreed that it is part of the company's maintenance program.

The findings are positive in the use of corrective maintenance, as 65.5% of the respondents (Company X) agreed that corrective maintenance is among its maintenance program and has a significant influence on performance. However, 31.0% strongly disagreed, while 2.3% disagreed. However, approximately 18.7% of the respondents from Company Y strongly agreed, 58.3% agreed, and 18.7% disagreed that corrective maintenance is part of their maintenance management program and has a significant influence on productivity.

The results also indicate that in both companies (Company X and Company Y), preventive maintenance has the highest percentage values and is used extensively (Strongly agreed and agreed), compared to other types of maintenance (breakdown, corrective, predictive maintenance, TPM and RCM). It was rated a high degree of use and more preferable (most especially in Company Y), and RCM was rated high in Company X because the major benefit of this strategy is a reduced probability of equipment breakdown and unexpected breakdown.

Although the results of the survey indicate that both companies extensively use preventive maintenance, there is still a small amount of utilization of predictive and breakdown maintenance which can cause equipment failure. Whereas in maintenance optimization approach, increasing preventive maintenance should decrease the need for predictive and breakdown maintenance.

However, despite the analysis which shows the higher the degree of utilization of PM and RCM, the better the improvement of equipment available that could be expected, the results also show that there is still lack of practice of TPM among the respondents. In terms of comparison, more respondent's shows that they have implemented RCM in Company X (89.7 per cent - strongly agreed and agreed) as compare to Company Y (37.5 per cent - Agreed). The lack of practice of TPM and RCM could also be interpreted as a lack of a "total and comprehensive" maintenance approach. There is a need to understand why Company Y and similar companies are yet to adopt highly effective TPM and RCM programmes.

In Company X, over the whole sample analyzed, 54.0 per cent (cumulative) have practised TPM and 89.7 per cent (cumulative) RCM. As for Company Y, 58.3 per cent (cumulative) have practised TPM and 37.5 per cent (cumulative) RCM. The results show that more respondents Company Xhave to implement Reliability Centered Maintenance (RCM) compare to Company Y while both are almost at the same level in the implementation of Total Productive Maintenance (TPM).

Research Question 2:

To assess the existing problems in carrying out equipment maintenance concerning productivity and maintenance.

Table VII: Comparative Analysis of Major Problems and Obstacles in Maintaining of Wireline Formation Testers between Company X and Company Y

Keys

A - Maintenance personnel, B - Time Consumption, C – Cost, D - Tool/Materials

E - Technique/Procedure, F - Operations disturbance, G - Inadequate Procedure,

H - Management Commitment

In terms of the major problems and obstacles faced in maintaining wireline formation testers, as shown in Table VII in both companies (Company X and Company Y), most of the problems and the obstacles listed are rated as "strongly agreed and agreed". The results also show that the three aspects which are; maintenance personnel, tools and materials, and maintenance/operation disturbance have the highest cumulative percentage values, which indicate the most frequent problems encountered in maintaining the equipment.

From Table VII, 19.5% of the respondents (Company X) strongly agreed that sophisticated tools and materials used to execute all maintenance activities are not readily available, and this has a significant effect on productivity and performance. 59.8% of the respondents agreed, while 17.2% disagreed.

On the other hand, 64.6% of Company Y respondents agreed that sophisticated tools are used but are not readily available in the location and are made available when the situations become so critical. However, 20.8% of the respondents disagreed.

TABLE VII: COMPARATIVE ANALYSIS OF MAJOR PROBLEMS AND OBSTACLES IN MAINTAINING OF WIRELINE FORMATION TESTERS BETWEEN COMPANY X AND COMPANY Y

87 - Respondents		A	B	C	D	E	F	G	H
Company X	Strongly Agree	20.7	5.8	0.0	19.5	0.0	18.4	0.0	0.0
	Agree	50.6	10.3	27.6	59.8	37.9	44.8	0.0	14.9
	Strongly Disagree	8.0	40.2	43.7	0.0	52.9	0.0	39.1	37.9
	Disagree	18.4	37.9	14.9	17.2	9.2	33.3	60.9	34.5
	% Missing – No Answer	2.3	5.8	13.8	3.5	0.0	3.5	0.0	12.7
	Valid Percent	97.7	94.2	86.2	96.5	100.0	96.5	100.0	87.3
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
48 - Respondents		A	B	C	D	E	F	G	H
Company Y	Strongly Agree	0.0	0.0	10.4	0.0	18.8	29.2	12.5	0.0
	Agree	58.3	39.6	18.7	64.6	20.8	43.8	0.0	16.7
	Strongly Disagree	16.7	39.6	37.5	0.0	14.6	0.0	70.8	47.9
	Disagree	25.0	18.7	16.7	20.8	25.0	16.6	14.6	27.1
	% Missing – No Answer	0.0	2.1	16.7	14.6	20.8	10.4	2.1	8.3
	Valid Percent	100.0	97.9	83.3	85.4	79.2	89.6	97.9	91.7
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Lack of proper planning is a maintenance challenge as 18.4% of Company X respondents strongly agreed that there is interruption during maintenance and operation of the equipment, and this has affected performance, productivity and the rate at which work is done. However, 44.8% agreed while 33.3% disagreed.

In Company Y, 29.2% of respondents strongly agreed, 43.8% agreed, and 16.7% disagreed respectively.

The troubleshooting methods employed and to what extent each of the methods is used. The results show that in both companies, "Root Cause Analysis" is the most frequently used compared to the other troubleshooting methods such as Failure Mode Effectiveness Analysis (FMEA), Fault Tree Analysis (FTA) and Cause and effect analysis (Fishbone). On the other hand, Fault Tree Analysis (FTA) is the least 13(14.9%) /11(22.9%) method used by both companies. However, to optimize the benefit of using these troubleshooting techniques, the maintenance personnel should be trained so that they could learn the required knowledge and competencies in carrying out their maintenance duties.

The three tasks which are considered very important and given very high emphasis are directly dealt with the equipment maintenance. Both companies (Company X and Company Y) placed more emphasis on 'monitoring the equipment status','performing preventive maintenance work' and 'maintaining equipment in operation' This is considered as of the primary function of the maintenance department used.

49.4 per cent and 58.3 per cent (cumulative) of the respondents (Company X and Company Y) agree (strongly agreed and agreed) that the culture of the organization affects maintenance strategy of the equipment. Also, tools and equipment used in maintenance affect maintenance activities and this is another factor affecting the implementation of maintenance strategies. The respondents (Company X 59.8 per cent and Company Y 56.3 per cent) from the various companies are clear indications of how tools and equipment are critical to maintenance activities. Lack of tools could be a big challenge in the implementation of the maintenance strategy.

Contribution of the maintenance effort to productivity and performance improvements of equipment, in both companies, the results show that the maintenance effort contributes the highest percentage in the improvement of maintenance cost reduction in Company X (56.3%). They were followed by the improvement of equipment availability and quality (59.8percent) as compare to Company Y, which are 43.8 per cent and 42.6 per cent.

Research Question 3:

To ascertain the effect of the computerized maintenance management system (CMMS). Table VIII shows the Comparative Analysis of the Utilization of Computerized Maintenance Management System Modules between Company X and Company Y

In general, Computerized Maintenance Management Systems (CMMS) assists in managing a wide range of information on the maintenance workforce, spare-parts inventories, repair schedules and equipment histories. In fact, in maintenance, there has been an increasing movement toward CMMS (L.

Swanson, 2002). Concerning the degree of CMMS module used, the analysis employed in Table IX identifying the level and the most extensive CMMS module used. From the results, the CMMS modules could be classified from both companies:

TABLE VIII: COMPARATIVE ANALYSIS OF THE UTILIZATION OF COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM MODULES BETWEEN COMPANY X AND COMPANY Y

87 - Respondents		Work Order	Preventive Mtce	Failure Diagnosis	Repair History	Equipment Part	Manpower Planning	Inventory Control
Company X	Strongly Agree	20.7	48.3	9.2	35.6	19.5	18.4	26.4
	Agree	67.8	35.6	47.1	48.3	50.6	44.8	43.7
	Strongly Disagree	0.0	0.0	18.4	11.5	19.6	0.0	0.0
	Disagree	10.3	11.5	11.5	0.0	5.7	28.7	4.7
	% Missing – No Answer	1.2	4.6	13.8	4.6	4.6	8.1	25.2
	Valid Percent	98.8	95.4	86.2	95.4	95.4	91.9	74.8
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
48 - Respondents		Work Order	Preventive Mtce	Failure Diagnosis	Repair History	Equipment Part	Manpower Planning	Inventory Control
Company Y	Strongly Agree	39.6	39.6	18.8	6.3	18.8	8.3	16.7
	Agree	39.6	54.2	62.5	68.7	58.3	52.1	31.3
	Strongly Disagree	8.3	0.0	0.0	0.0	0.0	0.0	31.3
	Disagree	12.5	2.1	8.3	10.4	10.4	31.3	0.0
	% Missing – No Answer	0.0	4.1	10.4	14.6	12.5	8.3	20.7
	Valid Percent	100.0	95.9	89.6	85.4	87.5	91.7	79.3
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

In Company X, modules which are extensively used are:

- Work order planning and scheduling (88.5percent)
- Preventive maintenance planning and scheduling (83.9 per cent)
- Equipment repair history (83.9 per cent)
- Inventory control (74.7 per cent)

In Company Y, modules which are extensively used are:

- Preventive maintenance planning and scheduling (93.8 per cent)
- Equipment failure (81.3 per cent)
- Work order planning and scheduling (79.2 per cent)
- Inventory control (79.2 per cent)

This finding has some similarities to the case study results carried on the use of CMMS in both companies. The results indicate that many benefits accrued from the CMMS implementation, the higher the degree of utilization of CMMS, the better the improvement of equipment available that could be expected.

Research Question 4:

Does Maintenance Work Order Significantly Influence Management Productivity?

TABLE IX: COMPARATIVE ANALYSIS OF WORK ORDER HISTORICAL DATA BETWEEN COMPANY X AND COMPANY Y

87 – Respondents		Downtime	Maintenance/Craft Hours	Required Materials
Company X	Strongly Agree	12.6	19.5	16.1
	Agree	60.9	59.8	54.0
	Strongly Disagree	0.0	0.0	1.2
	Disagree	9.2	17.2	10.3
	% Missing – No Answer	17.3	3.5	18.4
	Valid Percent	82.7	96.5	81.6
	Total	100.0	100.0	100.0
48 – Respondents		Downtime	Maintenance/Craft Hours	Required Materials
Company Y	Strongly Agree	43.8	0.0	12.5
	Agree	27.1	66.7	41.7
	Strongly Disagree	8.3	4.2	25.0
	Disagree	14.6	8.3	6.2
	% Missing – No Answer	6.2	20.8	14.6
	Valid Percent	93.8	79.2	85.4
	Total	100.0	100.0	100.0

One of the keys for successful maintenance management system is work orders. Work orders are registered documents which are used to collect necessary maintenance information. The above table addresses issues such as:

- The percentage of the total amount of work orders processed in the system that are tied to an equipment number as it concerned downtime.
- The percentage of the total number of maintenance man-hours (work carried out that is covered) that are reported to a work order.
- The percentage of the total amount of material required for equipment maintenance available for historical data analysis- follow up.

From the results in Table IX, the findings are positive in the use of work orders to carry out maintenance activities. 12.6% of Company X respondents strongly agreed that recorded downtime has a significant influence on management productivity, and it is covered in the maintenance history of the equipment. 60.9% of the respondents agreed, and 9.2% disagreed.

On the other hand, 43.8% of Company Y respondents strongly agreed, 27.1% agreed, 8.3% strongly disagreed, and 14.6% disagreed respectively.

Hours dedicated to equipment maintenance is also encouraging as Table IX shows that 19.5% of the respondents (Company X) strongly agreed that craft hours have significantly influence on management productivity and it is covered in the maintenance history of the equipment, 59.8% agreed, and 17.2% disagreed.

In Company Y**,** 66.7% of respondents agreed, 4.2% strongly disagreed, and 8.3% disagree respectively. The results also show that 16.1% of the respondents (Company X) strongly agreed that required materials have a significant influence on management productivity, and it is covered in the maintenance history of the equipment. 54.0% of the respondents agreed, 1.2% strongly disagreed, and 10.3% disagree. While 12.5% of Company Y respondents strongly agreed, 41.7% agreed, 25.0% strongly disagreed, and 6.2% disagreed respectively

VII. CONCLUSIONS AND RECOMMENDATIONS

A) Conclusions

The research work examined the impact of maintenance management strategy for oil field equipment of two oil servicing firm in the southern region of Nigeria, namely Company X and Company Y, in Rivers State, Nigeria. The research work particularly identifies and assess existing maintenance management system on oilfield (Wireline formation testers) equipment, the effect of maintenance problem concerning productivity and performance, the impact of the computerized maintenance management system (CMMS) and the influence of work order on management productivity in the two selected oil servicing firms respectively.

Realizing the research as mentioned above aim and objectives, a detailed descriptive analysis was utilized in interpreting the one hundred and forty-seven (147) structured questionnaire administered to the respondent of the two oil-producing firms. The forty-four (44) item structured questions were coded, analyzed and sorted, Frequency distribution and Percentage table were employed in analyzing and interpreting the extracted information from the questionnaire using statistical package for social sciences (SPSS) version 24.4.

The descriptive analysis identified the maintenance management strategy practised by Company X and Company Y. It highlighted a slight difference between Company X and Company Y with respect to how they practice maintenance strategy. Company X focused on reliability centred maintenance, preventive maintenance, corrective maintenance program while the management of Company Y practices preventive and corrective maintenance programs.

A comparative evaluation between Company X and Company Y on maintenance problems, troubleshooting techniques, management responsibilities on maintenance, maintenance challenges and performance reveals that maintenance personnel, tools and materials, and maintenance/operation disturbance are the major maintenance problems faced. At the same time "Root Cause Analysis" is the frequently used troubleshooting techniques for both companies.

The Study showed the CMMS module operated by Company X, which are: work order planning and scheduling, preventive maintenance planning and scheduling, equipment repair history, and inventory control on spare parts replacement.

On the other hand, Company Y operates more on preventive maintenance planning and scheduling, equipment failure, work order planning and scheduling, and inventory control. It was observed that both firms operate almost on similar CMMS Modules. The main difference is that Company X tends to operate on more modules than Company Y.

Finally, the comparative result reveals that both Company X and Company Y work order significantly influence management productivity.

The findings of the research work conclude that to achieve an improved maintenance strategy for an oil field equipment (Wireline Formation Testers), oil-producing firms in Nigeria should be more flexible in their approach to maintenance management strategy. They should allow for the change in a maintenance program to accommodate the dynamic nature of their field operation and ability to quantify timeline. Also, the implementation of maintenance strategy as a productive technique will increase equipment reliability and availability.

The maintenance management strategy seeks to improve equipment performance to boost production and minimize the non-value activities in the operation process

B) Recommendations

Based on the response of this research work, the following recommendations are offered below:

i). Oil servicing firms within and outside Rivers State by extension should embrace and ensure effective maintenance management policies. Such an approach can bring maximum return on investment, increase equipment reliability and availability, and serve as a tool (maintenance strategy) for attaining optimal productivity.

ii). Findings from the research work were able to establish a positive relationship between maintenance management strategy and oil servicing firm approach to implementing it as a tool for the realization of their maintenance policy. Hence, oil servicing firms in Nigeria should constantly review their maintenance management policies to accommodate a pattern of maintenance template that can evaluate and monitor the exponential decline of oil field equipment and recommend a maintenance activity.

iii). Oil servicing firms should adopt an improved maintenance management policy as a mechanism that can enhance equipment availability. Additionally, maintenance personnel team should consist of multi-skilled personnel who can efficiently solve problems and meet organizational goals.

iv). The oil servicing firms in Nigeria should adopt an efficient maintenance management system as it the fundamental and essence of successful maintenance strategy for oil field equipment.

There has been little research carried out in the aspect of the maintenance management system of Wireline Formation Testers in Company X and Company Y. This Study is, therefore, important as it addresses the need for this kind of research in the oilfield sector. Maintenance management strategy is a maintenance philosophy that utilizes some basic sets of management programs to improve oil field equipment performance and reduce downtime.

The work presented here fills a significant gap in the oil-servicing contexts. It presents current information to the body of knowledge and can provide guidelines for the maintenance department as far as oil-servicing companies are concerned.

Hence, this work concludes that, for oil servicing firms in south-south of Nigeria to attain this feat, they must holistically implement and observe maintenance management strategy as a comprehensive tool to achieve overall equipment performance to increase productivity

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