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RESEARCH ARTICLE

Model for Optimization of Repair and Maintenance Fund for Mechanization of Agriculture in Anambra State of Nigeria

Onuorah CM, Umeghalu ICE and Nwajinka OC

(Department of Agricultural and Bioresources Engineering, Faculty of Engineering, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria)

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***Corresponding Address:**
chinwikemoses@gmail.com

ABSTRACT

A good maintenance management of agricultural machines helps in extending the useful life of a machine that will result to optimized agricultural productivity. Repair and maintenance of farm machines are costly especially in Anambra State where virtually all agricultural machines and implements are imported. The spare parts are scarce and costly; furthermore, fuel, oil and labour costs are expensive. There is need to optimize the repair and maintenance fund for availability of machines and implements for successful agricultural operations. The primary and secondary data of both the accumulated working hours and repair and maintenance costs were subjected to regression analysis. The polynomial model with the expression $AWH = 6E\text{-}07ARM^2 + 0.0039ARM - 2.3488$ was chosen for giving the highest coefficient of determination (R^2) with the value $R^2 = 0.99$, which best describes the given data. Also, the study shows that the mean time before failures (MTBF) and tractor availability were decreasing with increase in working hours while mean time to repair (MTTR) was increasing instead of decreasing. This study aims at finding model that best optimizes repair and maintenance cost of agricultural machineries fo mechanization of agriculture in Anambra State of Nigeria.

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INTRODUCTION

A good repair and maintenance management helps to extend the useful life of agricultural machine. It is therefore pertinent to adopt a good maintenance system that should include timely replacement of parts when they are due. According to Onwualu *et al.* (2006) the effective use of agricultural machinery is considerably dependent on the maintenance management of the machines. To ensure highly productive work, prevent premature wear and failure, a system of scheduled preventive maintenance and repair must be established for farm machinery (Onwualu *et al.*, 2006; Ezeoha and Akubue (2010).). Repair and maintenance of farm machineries involves both minor and major repairs which are costly. Thus, there is need to optimize repair and maintenance fund for sustainable agriculture mechanization.

Tractor is of very important in agricultural mechanization as it is a major source of power in agricultural operations (Abubakar *et al.* 2013; Pishbin, 2014; Dahab *et al.* 2016; Gautam and Shrivasta, 2017). According to Folaranmi (2014) agricultural mechanization is the art of using machineries to hasten production, accomplish task and reduce fatigue and human labour in order to produce better quality goods and services. Mechanization of agriculture requires that machineries and implements will be efficiently managed with involves costing, machine selection, procurement, repair and maintenance (Nwuba, 2009; Kienzle *et al*. 2013). Costing is of great importance in machinery management, as all other components revolve around it. The objective of mechanization of agriculture is to maximize output with minimum input (Adama, 2013). One of the most important costs influencing profit in farming is the cost of owning and operating machinery and implements. The cost of tractor repair and maintenance influences the returns of farm businesses; this is because, tractor is the center point of agricultural mechanization (Abubakar *et al.* 2013). The cost of owning and operating farm machinery represent 35 to 50% of the total cost in agricultural production when the cost land is excluded (Abubakar *et al.* 2013). In recent years, exorbitant prices of new agricultural machines and implements, spare parts, oil and fuel, lubricants and labour has made farmers to pay inadequate attention to repair and maintenance of agricultural machines and implements. However, good management of repair and maintenance of farm machines and implements can positively influence their availability. This can be achieved by making smart decisions about how to manage farm machinery; when to trade-in and how much capacity to invest (Edward, 2015).

Despite Nigeria's rich agricultural resources endowment, agricultural sector has been growing at a very low rate. It has been the policy of the Federal Government of Nigeria and States to import agricultural machines to boost food production and raw materials for industries in the country (Oluka and Nwani, 2013). Maintenance of these agricultural machineries is very important towards achieving the expected results of increasing the farm productivity (Onyeagba and Oluka, 2016). However, according to Onwualu *et al*. (2006), agricultural machines and implements imported into Nigeria do not work up to their rated hours due to poor maintenance culture. When they breakdown, they are boarded off before their rated useful life, resulting to huge financial losses to farmers. In some cases, agricultural machines that require minor repair to keep them going are poorly managed, and subsequently allowed to depreciate further, thus increasing the cost of repair and maintenance. Tractor and implements utilizations in agricultural activities and their proper management will optimize agricultural productivity (Nkakini and Etenero, 2019). Also, accurate prediction of repair and maintenance cost trends is critical in determining the optimum economical life of agricultural machinery as well as making smart decisions for their replacement and general farm management (Hunt, 2001). Tractor breakdown can be very expensive not only from the stand point of the expenditure necessary to effect repair, but also because of the disastrous effect on crop productivity and the fact that idle operators and staff must be paid (Musa Abbas *et al*., 2011). The rate at which farm machineries breakdown in developing countries such as Nigeria is more serious than in the developed countries (Gautam and Shrivasta, 2017). One major problem farmers face in the field is sudden stoppage machines due to failure of parts of machinery. Repairs of failed or broken down agricultural machinery are very expensive (Hunt, 1971), because the breakdowns consume spare parts, man power and loss of production (Dodson, 1994). Jacobs *et al*. (1983) also noted that economically, agricultural machinery breakdown can be very expensive as a result of the lost working hours.

In Nigeria, very limited studies have been carried out in areas of repair and maintenance of farm machineries (Onyeagba and Oluka, 2016). Jekayinka *et al*. (2005) investigated tractor maintenance practices and costs in Nigeria based on cumulative working hours. Onyeagba and Oluka (2016) also conducted a study on repair and maintenance of MF and Fiat tractors in Enugu state, Nigeria and developed mathematical model for prediction of their repair and maintenance. Abubakar *et al*. (2013) also determined the repair and maintenance cost for MF 375 tractors in Kano metropolis, Nigeria. The poor repair and maintenance culture in the country is as of the exorbitant costs. This study therefore aims to develop a model for optimization of repair and maintenance fund in Anambra State of Nigeria for sustainable mechanization of agriculture in the state.

MATERIALS AND METHODS

Description of Study Area and Data Collection

The survey was carried out in Anambra State. Anambra State is located in the South East Geopolitical Zone of Nigeria. It lies between Latitude 6.2209° N and Longitude 6.9370° E. The State is made up of 21 local government areas, with four agricultural zones which are: Anambra zone, Aguata zone, Awka zone and Onitsha zone. Primary data were collected using structured questionnaires which were administered to private tractor owners and operators while secondary data were collected from Anambra State Agricultural Development Program headquarters at Awka. The survey studied 37 tractors of different makes, model and rated power in terms of their annual working hours, annual repair and maintenance cost which included the cost of spare parts, labour costs, oil and fuel filter, lubrication and fuel, annual breakdown were for the period covering 2012 to 2021.

The data collected were analyzed using regression models. The model with the highest coefficient of determination (R^2) was selected as the model that best describe the data. Hence, the model was selected as the prediction model for the study.

Determination of Regression Model for Repair and Maintenance Prediction Cost

Determination of regression model for repair and maintenance cost prediction for this study requires that the following should be obtained; which are the mean annual working hours and the mean annual repair and maintenance cost. The accumulated working hours for each year was determine by the addition of the previous year accumulated working hours to the mean annual working hours of the year under review. The formula for calculating this is shown in Equation (1)

$$X_n = \sum_{i=1}^{n} x_i \quad (1)$$

Where:
X = the accumulated working hours of the tractors,
n = the tractor age group in year,
x = the mean annual working hours for group i.
The accumulated repair and maintenance cost of the tractors as percentage of price list was calculated using Equation 2 below.

$$Y_n = \sum_{i=1}^{n} y_i \quad (2)$$

Where:
Y = the accumulated repair and maintenance cost as a percentage of price list,
y = the mean annual repair and maintenance as a percentage of price list for group i.
X was considered as the independent variable while Y was dependent variable for the regression analysis performed on the data using Excel2007. Five models as shown in equations (3-7) were used for the trend analysis.

$$Y = a + bx \quad Linear \quad (3)$$

$$Y = a + bx + cx^2 \; Polynomial \quad (4)$$

$$Y = ae^{bx} \quad Exponential \quad (5)$$

$$Y = a + lnbx \; Logarithmic \quad (6)$$

$$Y = ax^b \; Power \quad (7)$$

Where:
a, b and c are numerical values
Y = dependent variable
x = independent variable

Determination of Availability, Mean Time Before Failures (MTBF) and Mean Time To Repair (MTTR)

Mean Time Before Failure (MTBF)

This is the mean time between failure occurrences. This can be calculated in two ways;

$$MTBF = \frac{1}{\lambda}\ ; \quad (8)$$

Where;
λ = failure rate
Alternatively,

$$MTBF = \frac{total\ expected\ working\ hours}{total\ number\ of\ failures} \quad (9)$$

Mean Time To Repair (MTTR)

The average time it takes to troubleshoot and repair each failed tractor to normal condition

$$MTTR = \frac{total\ Downtime}{total\ number\ of\ failures} \quad (10)$$

RESULTS AND DISCUSSION

Determination of Annual Repair and Maintenance Cost and Mean Annual R&M Cost

Fig. 1 presents the result of the calculated mean annual repair and maintenance cost. The figure shows that the cost of replacing spare parts of the tractor had the highest percentage share of 53%, followed by workmanship with 22%, fuel cost 18%, lubricant 4% and oil and fuel filter 3%. This is in agreement with the report of Theodore *et al.* (2017), but disagrees with Abubakar *et al.* (2013) which stated that fuel consumption is the parameter with the second highest percentage cost. The least cost was obtained from oil and fuel filter parameter valuing 3%.

Determination of Mathematical Model to Predict the Repair and Maintenance Costs of the Studied Tractors

Table 1 shows the accumulated working hours and accumulated repair and maintenance cost as a percentage of price lists of the studied tractors in Anambra state. The accumulated repair and maintenance costs (dependent variable) and accumulated working hours (independent variable) for the studied tractors and their different ages (yrs) were used as database for the trend function analysis, regression analysis and development of mathematical model.

Results of the Trend Function Analysis using Excel

A trend function analysis was carried out using Excel 2007, this was to enable us establish models for predicting repair and maintenance cost of the studied tractors. Excel 2007 helps to create scatter plots and overlay line on the chart.

The trend analysis result outlining the equations of these five models: exponential, linear, logarithmic, polynomial and power and their coefficient of determination (R^2 values) are presented in Fig. 2. These results presented allow the selection of the relationship that seems to best describe our data on the R^2 value. The closer the R^2 value to 1, the better the line that fits the data. The value of coefficient of determination (R^2) also permits us to select the best prediction model for the study. Also, in Fig. 2,

Table 1: Accumulated Working Hours and Accumulated Repair & Maintenance Cost Percentage for the studied tractors

Year	Accumulated Working Hours	Accumulated R&M Cost As % Of Price List
1	1067	1.66
2	2051	4.09
3	2611	7.22
4	3458	15.52
5	4216	22.47
6	4901	30.96
7	5511	34.47
8	6406	39.85
9	7171	49.06
10	8014	62.49

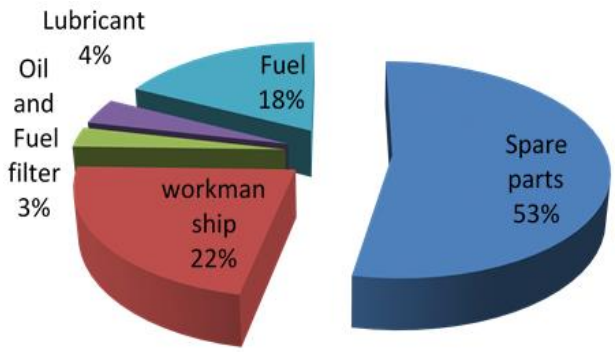

Fig. 1: The mean annual Repair and Maintenance cost for the studied tractors

it was observed that the slope of the curve increases with the increase in the number of working hours. This is an indication that in the early life of the tractors, the cost of repair and maintenance are low, but increases rapidly as they accumulate more working hours.

The highest value of coefficient of determination among the models was observed to be the polynomial model with the value of 0.99. This is an indication of its high conformity with the actual data trend in comparison with agreement with results obtained by (Theodore *et al.* 2017). It was therefore selected as the final model for the prediction of repair and maintenance cost for the present study. Hence, equation 4.1 is the prediction model for the present study.

$$AWH = 6E - 07ARM2 + 0.0039ARM - 2.3488 \quad (11)$$

Where:
AWH = accumulated working hours
ARM = accumulated repair and maintenance cost

Comparison of Actual Data and Modeled Data by the Predictive Model

Fig. 3 illustrates the comparison between the actual data obtained by the final predictive model (polynomial) for the studied tractor.

The figure shows that the actual data and modeled data have very little differences in their curve. It can be seen that the rate of accumulated repair and maintenance costs for the studied tractors at earlier life of them was low and fairly similar. However, trend of repair and maintenance cost was rapidly increasing thereafter. Differences in increasing rate of repair and maintenance costs may be attributed to the facts like quality in design and manufacturing, inherent deficiencies and also incompatible field operations to their power and efficiencies.

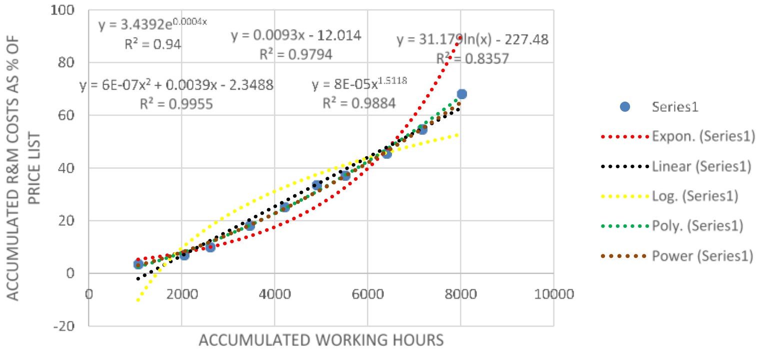

FIG. 2: Comparison of accumulated repair and maintenance cost as percentage of list price based on accumulated working hours of the studied tractors using excel.

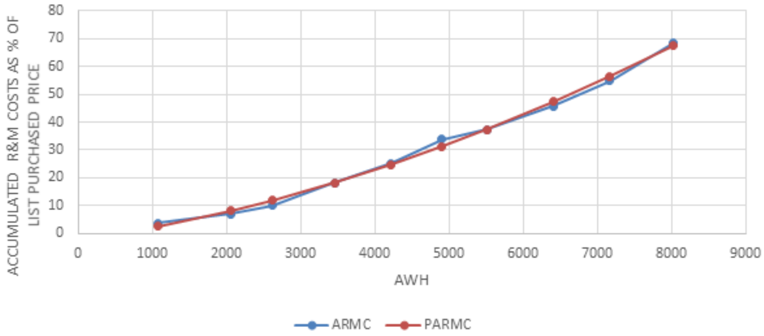

Fig. 3: Comparison of Actual Data and Modeled Data using Polynomial Model

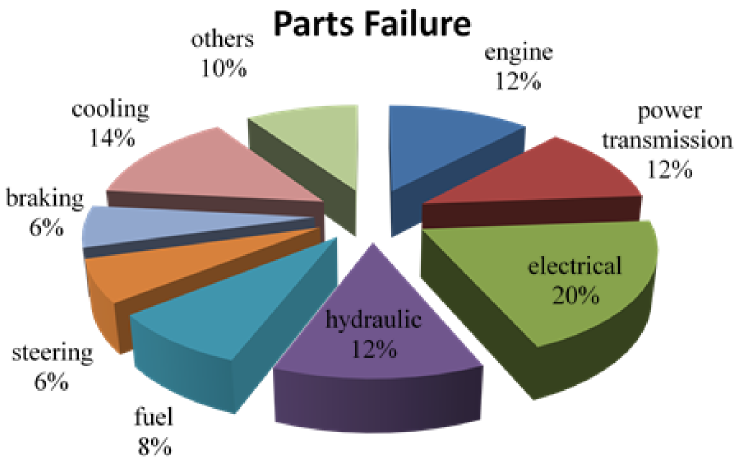

Fig. 4: Failure types and their distribution.

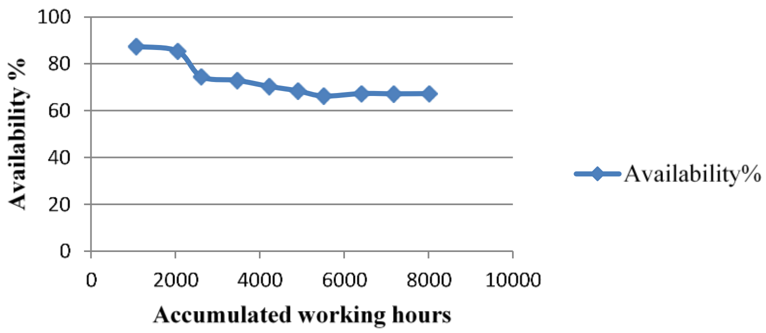

Fig. 5: Comparison of Availability based on Accumulated Working Hours.

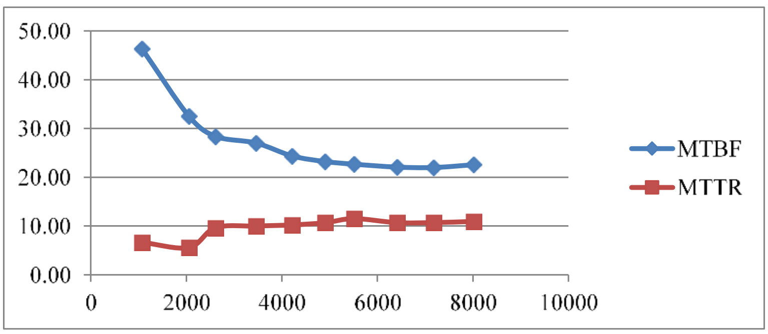

Fig. 6: Comparison of MBTF and MTTR based on Accumulated Working Hours.

Failure Types and their Mean Annual Percentage Distribution

Fig. 4 presents the average distribution of failure percentage after the ten years. The electrical systems have the highest percentage failure with 20% of the mean annual distribution as shown in the chart. The cooling system was observed to be the second highest percentage failure with 14%, followed by the Engine, Power transmission and hydraulic 12%. While brake and steering systems have the least percentage failure with 6%. The electrical system failure generally could be due to the short life of battery and Dynamo in the tractors.

Availability of Tractors

Fig. 5 presents the graph of this annual availability of the studied tractors. In the first two years, it was observed that the tractor availability was above 80%, after it started going down. This is not good record enough for a tractor manager. Although it never dropped below 60% but it indicates that the repair and maintenance system is bad. Probably, the downtime is always higher than expected hours required to be fixed. Staying longer before fixing the tractors reduces the availability of the tractor and at the same time reduces the expected profit for the year.

Determination of MTBF and MTTR

Fig. 6 shows MTBF and MTTR curves. From the first year, it was observed that the MTBF dropped from 46.39 hours it was to 32.56 hours in the second year. Subsequently, as the accumulated working hours was increasing, the MTBF was decreasing except in the 10^{th} year when it seemed to be an improvement in the management. The MTBF increased with about 57 minutes. It was also observed that unlike the MTBF, the MTTR was increasing after the decrement in the second year. An increment should have been a good thing but in the case of MTTR, it is not.

DISCUSSION

The following types of factors such as: type of operation, farm working condition, skill of operators, tractor make/model, number and type of sample under study, data documentation accuracy, repair and maintenance management, tractor working hours, quality of materials such as fuel quality, spare parts quality, oil and fuel filter quality, etc, skill of the mechanic, storage system (open or closed), tractor age, etc., generally influence the repair and maintenance cost prediction, as well as its reliability.

Mean Time Before Failure as defined in the literature is the time between two failures. That is, it is the time the tractors will have to work before breakdown/failure. Hence, there is need for this to be on an increasing rate instead of decreasing as presented in Fig. 6. The reduction shows that there is problem with the general tractor management in the state.

MTTR is the mean time between two successful operations. That is, the time required for the tractor to be fixed and get back to work. What it means is that MTTR should be low/decreasing in a good management system. The least hours waited for the tractors to be fixed were not even in the first year but the second year. Unfortunately, the subsequent years experienced increase in the MTTR, which isn't good enough for the management.

Both the decrement and increment of MTBF and MTTR respectively can be as a result of the following: Negligence to preventive maintenance practices (e.g. checking of oil, fuel, water, etc), Inadequate mechanic workshop in the vicinity, Unavailability of repair parts, Lack of tractor knowledge by the operators, Lack of maintenance data, Age of the tractor, etc.

In summary, MTTR and MTBF are two indicators for critical decision making. MTBF is an overall indicator of reliability and effectiveness/efficiency; and should be as long as possible if proper management is done. If the MTBF increases post preventive maintenance, it is a sign of improvement in the quality of the processes. MTTR should be as short as possible and it indicates corrective action of the process. To aid MTTR in been as short as possible, locating a repair and maintenance workshop in a place where every farmer can asses it.

Conclusion

The following conclusions were drawn from the study:

Repair and maintenance costs of the study as a percentage of price lists in Anambra can be accurately predicted using the model below:

$$AWH = 6E-07ARM2 + 0.0039ARM - 2.3488$$

The tractor accumulated working hours is the major determining factor of the repair and maintenance costs of the model developed.

Repair and maintenance cost increases with increase in working hours.

It is recommended to carry out a comparative study of different tractor makes and models with their respective power ratings in Anambra state in order to develop a standard cost model to predict the repair and maintenance cost. It is also recommended that agricultural machinery managers in Anambra state should make use of the result from this study as it is very useful in machinery management, especially for budgeting of repair and maintenance costs and preventive maintenance scheduling.

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