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ESTIMATION MODEL COST OF REPAIRS AND MAINTENANCE OF MAHINDRA TRACTORS USED IN MUNICIPAL WASTE DISPOSAL IN BAUCHI STATE, NIGERIA

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Abstract

An estimated model cost was evolved for the prediction of repair and maintenance costs of Mahindra tractors used for municipal household waste collection and disposal in Bauchi State of Nigeria. The model was derived based on data collected over a period of eight years from the Waste Management Board, Bauchi state, Nigeria. The model predicts repair and maintenance costs as a function of the tractor's cumulative use in hours. Among the five models (linear, logarithmic, quadratic, power, and exponential) produced through regression analysis, the quadratic model (R^2 = 0.99) having the highest coefficient of correlation is adjudged as the best fit for managing the tractors under the operation being used for.

Keywords: Repair and maintenance costs, prediction model, regression analysis, municipal household waste.

Introduction

Agricultural farming systems are becoming expensive due to the high repair and maintenance costs of agricultural tractors. Tractors are the main source of farm power and have nearly replaced all other machines for the most vigorous and time-consuming operations. Since agricultural tractors are used to carry out static and dynamic operations under different farm conditions, they are subject to many failures and breakdowns caused by direct and indirect factors. Tractor breakdowns are mainly due to age, wear and tear, accidents, materials and design errors, irregular maintenance, and incorrect use and repair of damages. Failures of tractor parts are inevitable due to the nature of mechanical components and harsh working conditions. Therefore, it is important that the tractor should receive regular care or maintenance to reduce failures and extra costs and to protect the machine from wearing down quickly. Poor and irregular maintenance reduces tractor reliability, increases fuel consumption, decreases engine power and life, and increases exhaust emission. With more than 80% of the total gross domestic product (GDP) in the United States provided by the service sector, engineers work on various economic decision problems in the service sector as well (Park, 2011).

The agricultural tractor usage started in 1855 for the purpose of operating threshers in the United States. By 1890-1919, the use of internal combustion engine was tried on tractors and many manufacturers started producing different makes and models for different applications including municipal household waste collection and disposal in densely populated metropolitan areas of towns and cities. Research and development are now heading for computer-operated tractors. Ahmad (2011) classified the potential to produce innovative approaches to problems through agricultural engineering practices as knowledge-based competitive machinery and process technology, food production with documented quality, production processes that are fully compatible with the environment, technology for production and utilization of renewable resources and efficient use of by-products and efficient machines to operate in optimized production systems. For example, more automated tractors and harvesters, equipped with plug-and-play electronically controlled implements, networked or autonomous, guided via telematic links with a control station. Agricultural engineers have done many studies regarding the maintenance of farm machines. Several studies were conducted in both developed and developing countries either to develop models to determine the cost during a certain period or to get absolute numbers to represent owning and operating certain equipment (Khoubbakht *et al*., 2008). Ward *et al.*, (1985) investigated the repair costs of 4-wheel and 2-wheel drive tractors for a period of 10 years and developed a cost model for each type of tractor, which revealed that there exists a clear difference between the two types of tractors. Rotz and Bowers (1991) derived a model based on equipment price and operating hours. The testing of the model showed that the costs were more realistic when the area worked was considered instead of the operating hours. More significantly, Rotz and Bowers (1991) made an attempt to collect information from companies and experts, but limited response was received. Hence, the revised models were reported with regard to maintenance costs and observed that the maintenance costs varied with operating conditions.

Some studies conducted in developing countries regarding maintenance of farm machines have been reported (Abdelmotaleb, 1993). The operating costs of the farm machines in undeveloped countries were estimated using the models of developed countries (Ward *et al*. 1985). Some researchers conducted a study in Jordan on the cost of tractor use and showed that there was a proportional increase of maintenance costs with tractor use (Khoubbakht *et al*., 2008). Thus, a model was proposed to estimate the maintenance cost of the tractor/hour/acre based on the Jordanian currency. Al-Suhaibani and Wahby (1995) made analysis of five-year record of tractors belonging to Hail Agricultural Development Company in Kingdom of Saudi Arabia and produced six types of models.

Tomantscher *et al*. (2011) developed a model for tractor engine durability which partially established means of future modelling of tractor maintenance, repair and operation. A study by Khoodbakhshian and Shakeri (2011) shown that the use of preventive maintenance (time based, condition based and predictive) engineering methods resulted in the reduction of downtime and expense by 48% and 84% respectively, with machine utilization efficiency increased by 20%. Tchotang *et al*. (2016) presented an approach for deriving a mathematical model that predicted repair and maintenance cost of farm tractors in the Gambia. As John Deere tractors are widely used by Gambian farmers, a study was conducted to predict accumulated repair and maintenance costs (Y) of the two-wheel drive JD-5403 tractor based on accumulated working hours (X). Meanwhile, Abubakar *et al*. (2013) showed that the cost of tractor spare parts replacement on MF375 had the highest percentage share (54.2%) from the total percentage cost, followed by cost of fuel (20.4%). While cost of workmanship was (13.0%), cost of lubricating oil was 10.3%, oil and fuel filter replacement had the least (2.1%). It has been established that repair and maintenance cost often increase with an increase in working hours of JD-5403 traFarm power, machinery and equipment are major cost items in agriculture. Shani *et al*. (2019) developed a mathematical model to forecast repair and maintenance of John Deer 5065e model and it was shown that the cost of tractor spare parts replacement had the highest percentage share (54.2%) from the total percentage cost, followed by cost of fuel (20.4%), labour cost (13.0%), and then cost of lubricating oil (10.3%) while cost of oil and fuel filter replacement had the least (2.1%) percentage share.

Unfortunately, similar works on tractors used in the collection and disposal of municipal household wastes in Nigeria has not been attempted hence, the present study was aimed at estimating the cost of repairs and maintenance of Mahindra tractors used in municipal waste disposal in Bauchi state, Nigeria. To achieve this, a mathematical model involving regression analysis using knowledge based analytical software (SPSS STATISTICS 21 and Excel 2016 version) was performed on the calculated data that were generated from five regression models: linear, logarithmic, polynomial, power and exponential.

Materials and Methods

Required data for producing the repair and maintenance cost prediction models were obtained from tractors belonging to the Waste Management Board in Bauchi State of Nigeria. The Board is concerned with municipal household waste collection and disposal in the Bauchi metropolitan area. This organization has about 20 tractors as of 2021 out of which fifteen are Mahindra products. Ten Mahindra tractors were selected for repair and maintenance costs analysis. The selection was done based on the durability and functionality of the Mahindra Tractor. Each tractor has a file where major repairs and maintenance undertaken were requested, discussed and finally approved for execution, as part of a management accounting system. Repair and maintenance costs data for eight years (2009-2019) were extracted from the ten tractor files. The costs data was prepared for further analysis as done for similar studies by some researchers (Khoodbakhshian and Shakeri (2011) and Ahmed *et al*., 1999). Hours of use for the tractors was found through close monitoring for two months. Daily hours of use were averaged between December, 2018 and January 2019. The daily average was then used to compute yearly hours of use. The annual hours of use for the study area were compared with ASAE recommendations and those obtained from Rashidi and Ranjbar (2011).

The obtained data were subjected to regression analysis and plots for linear, logarithmic, quadratic, exponential, and power were evaluated. The best plot that gave better prediction was suggested for the situation being studied and a comparison of similar works with other regions of the world were given.

Results and Discussion

The data extracted from the tractor files together with tractor hours of use is presented in Table 1. There was a drastic drop in R&M costs in the 7th year after carrying out major overhauls in the 6th year with a similar pattern between the 4th and 5th years.

Table 1: Average of Complete Annual R&M Costs and the Average of Annual Usage Hours of Mahindra Tractors for Different Ages

Age (Yr.)	Average of whole annual R&M costs (₦)	Average of annual usage, hours (Hr)
1	21925	2070.635
2	11680	2070.635
3	29980	2070.635
4	66000	2070.635
5	16320	2070.635
6	66330	2070.635
7	7025	2070.635
8	441862.8	2070.635

Table 2 provides information on mean accumulated usage hours and mean accumulated R&M cost as percentage of initial purchase price per unit of all tractors for different ages which were used as base data for regression analysis. It was shown that WMB tractors were working more hours than the ASAE recommendation as reported by Rashidi and Ranjbar (2011).

Table 2: Mean Accumulated Usage Hours and Mean Accumulated R and M Costs as Percentage of Initial Purchase Price per Unit of Mahindra Tractors for Different Ages

Age (Yr.)	Mean accumulated annual usage hours (Hr)		*Mean accumulated R&M costs as percentage of initial purchase price (%)
	WMB actual figures	ASAE figures	
1	2070.635	1200	0.37
2	3739.048	2400	0.56
3	5608.572	3600	1.07
4	7478.096	4800	2.22
5	9347.62	6000	3.00
6	11217.144	7200	3.66
7	13086.668	8400	3.78
8	14956.192	9600	11.44

***With the assumption that no increase in inflation within the years studied**

The summary of regression analysis results for five models for eight years data of ten WMB tractors is shown in Table 3.

Table 3: Model Summary and Parameter Estimates for Mahindra Tractor

	Model Summary					Parameter Estimates		
Equation	R Square	F	df1	df2	Sig.	Constant	b1	b2
Linear	.525	6.624	1	6	.042	-.386	.001	
Logarithmic	.257	2.079	1	6	.199	-13.563	1.963	
Quadratic	.816	11.077	2	5	.015	3.516	-.001	9.724E-8
Power	.287	2.412	1	6	.171	.007	.653	
Exponential	.526	6.672	1	6	.042	.624	.000	

Note: Dependent Variable: Repair and maintenance; Independent variable: Accumulated Hours

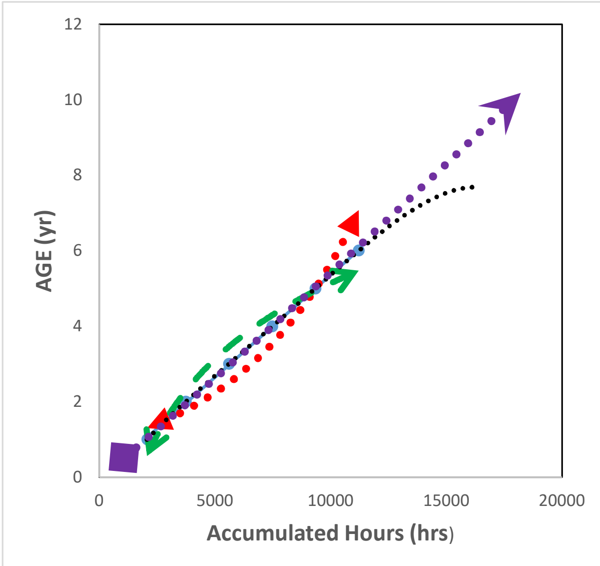

Figure 1: Plot of tractor age life and accumulated hours

From table 3 and figure 1, the quadratic model with highest R^2 value of 0.99 by far gave the best fit for the WMB data over the other four models tested. This (R^2 =0.99) reflected that the tractor cumulative use in hours adequately explain variation in repair and maintenance costs. Other studies gave different models as best fit as earlier established by Rotz and Bowers (1991) that the maintenance costs vary with condition in which the tractors are being operated. Ahmed *et al*. (1999) showed that the logarithmic regression model was best fit in Sudan. Rashidi and Ranjbar (2011) found power regression model with R^2 = 0.966 with service life of up to 2,275 hours for MF 285 tractors in Iran. However, for service life of more than 2,275 hours, they found the polynomial model with R^2 of 0.997 as the best fit. A similar study on JD-3140 tractors in Iran by Khodabakhshian and Shakeri (2011) found that the polynomial model with R^2 of 0.998 among the five models tested as the best fit.

Conclusions

The statistical results showed that the polynomial model gave better cost prediction with higher confidence and less variation than other models. The correlation between repair and maintenance costs in percent of tractor initial purchase price and tractor cumulative use in hours would best be described by a quadratic function. The produced quadratic prediction model for repair and maintenance costs for WMB in the Bauchi State of Nigeria has R^2 =0.99. Tractor cumulative use in hours was the major determinant of repair and maintenance costs. In order for the prediction models to be authentic and therefore relied upon for making correct decisions the following personnel issues should be ensured. Proper remunerations and conducive work environment for the tractor operators and supervisors be made commensurate with standard living expenses. Religious ethics which supersede any other moral behaviour should be regularly preached to all staff in the organization as enshrined in the global corporate social responsibilities.

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