Assessment and Prediction of Repair and Maintenance Costs of Tractors in Northern Nigeria

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ABSTRACT

Tractor has been identified as the central machine in the farm. The repair and maintenance (R&M) costs of farm machineries including tractors have increasingly becomes difficult to estimate and evaluate. This study focuses on the assessment and prediction of farm machinery R&M cost at the Tractor Owners and Hiring Facilities Association of Nigeria (TOHFAN). The purpose of this study is to develop a mathematical model that can predict and estimate the R&M cost (Y) of tractors with their working hours (X) based on the available data at TOHFAN. Two brands of the tractor models widely used in the country were chosen, namely, Mahindra 6005 and John Deere 5065E. Data obtained from the study were subjected to a trend analysis, thereby generating five regression models: the Linear, Logarithmic, Polynomial, Power, and Exponential models. The results of the analysis show that the Polynomial model gives a better cost estimate with higher confidence level and less variation for Mahindra 6005, while the Linear model provides a better cost estimate for John Deere 5065E. It was also established that the R&M costs of both tractors increase with the increase in working hours, which can be used in management decisions and business development.

Keywords: *Repair and maintenance (R&M) cost, farm machinery, tractors, maintenance cost forecasting, mechanized farming*

1.0 INTRODUCTION

Nigeria is blessed with an abundant land area estimated to a total of about 92.4 million ha and a population of about 167 million [1]. The Federal Ministry of Agriculture and Rural Development (FMARD) reported that the Total Arable Land is estimated to accumulate a total of 79 million ha which is equivalent to 85.5% of the total land area, of which 32 million ha (equivalent to 34.63%) has been cultivated [2]. This shows that 65.37% of the total land area is not cultivated and possesses the potentiality of carrying out farming activities. Most parts of the country experience rich soil and have been characterized to have a very climatic condition that favors agriculture, and a well distributed annual rainfall ranging from 300 mm – 4000 mm, not to mention the warm year-round temperatures.

Agriculture has been the major source of income in the olden days of Nigeria after independence 1960, before the expansion/booming of petroleum industries and its products. Lawal (2011) reported that in the 1960's, agriculture accounted for 65-70% of total export, but fell to about 40% in the 1970, and crashed to less than 2% in the late 1990s [3]. Despite of all these, the total contribution of agriculture to the gross domestic product (GDP) raised slightly to 41.84% in 2009. However, available records (data) from Nigerian Bureau of Statistics (NBS) shows the contribution of agriculture to GDP in

2012, 2013, 2014 and 2015 as 23.91, 23.33, 22.90 and 23.11%, respectively [4]. It has also been estimated by the FMARD that the farming activities account for over 70% of the population source of livelihood [2]. Most of the farming communities usually practices subsistence or peasantry farming system in which the farmers hardly produce enough to meet their individual family requirement and in rare cases only small surplus to meet the need of the non-farming population and export. It was found that 90% of farmers in Nigeria use rudimentary technology (hand tools), 7% animal-drawn tools and only 3% use engine powered technology [5]. It is also noted that poor access to modern inputs and credit facilities, poor infrastructure, inadequate access to markets, land and environmental degradation, inadequate research and extension services retard growth in the sector. Mijinyawa and Kisaiku (2006) carried out a detailed assessment of tractor hiring services in Edo state; they reported that there has been a general increase in sizes of their cultivated farmlands from below 2.5 ha to between 5 and 10 ha averagely, while the aggressive new entrants have been able to established sizeable farms of over 25 ha [6]. This has considerably increased the economic fortunes of the farming communities in Edo state.

Farm machinery is a collection of machines for farm operations and include all types of implements and devices for applying power on the farm such as plough, harrows, seeder/seed drills and planters, cultivators, harvesters, haying machines and tractors [7]. The tractor is the most important machinery because it is the prime mover for all the implements. It is the most used and most prone to wear and tear. It is also the most expensive item of all farm machinery. Several reports in farm machinery maintenance and repair cost in developing countries including Nigeria shows a greater variation in maintenance and repair cost en compared with the international standards such as the USA and UK, the factors that caused the variation, and the challenges/issues of hiring services in Nigeria, has not been recently investigated. A quite number of research and studies shows that agricultural production in Nigeria is mostly characterized by peasant farmers or small farm holders [8].

Oluka (2013) reported that the basis for high rate of machinery breakdown may be related to unsatisfactory maintenance culture in the country, moreover machines can only work effectively and efficiently if they are stored in good order which translate to a regular servicing and maintenance of the working parts [9]. It was also reported in [10] that the R&M cost is one of the most important components of the total cost of operating farm machinery and value for about 10 to 15% of their total cost of ownership. This cost tends to increase with the increase in machine hours of operation, thus making the repair cost a crucial important factor that affects the best time for farm machinery replacement. The R&M cost of the farm machinery are often difficult to evaluate due to variability in the operating conditions of the machines from one farm to another and also due to inadequate records [11].

Ijioma (2000) reported that farmers faced difficulties in obtaining the spare parts and after sale services while the scarcity of well-trained mechanics increased the breakdown rate of machinery [12]. Tractor breakdown is therefore a major limitation to the use of farm machinery on Nigerian farms.

Several reports in farm machinery maintenance cost have indicated that a high cost of maintenance in Nigeria when compared with other countries such as USA and Europe. As a result of high cost of tractors and implements, equipment ownership become more difficult for small scale farmers to acquire the machineries and hence the need for farm equipment hiring services is of interest. Yohanna (2004) attributed the low level of farm mechanization in Nasarawa states of Nigeria due to the frequent breakdown of machinery caused by the hard soil pans and rocks that normally inflict injuries and damages to the tractors and implements [13].

The aim of this research work is to develop a mathematical model that is suitable data for management and planning of R&M cost of tractors. The scope of this study is limited to assessment of R&M cost data for tractors used at Tractor Owners and Hiring Facilities Association of Nigeria (TOHFAN) Kaduna state of Nigeria.

2.0 PRELIMINARIES

2.1 Earlier Models Predictions on Repair and Maintenance (R&M) Cost

A number of mathematical equations have been developed in estimating the R&M cost, it was reported in [14] that the accumulated R&M cost (C) of the tractors and other field machines can be determined by the following equation:

$$C = P\,(RF1(x)^{RF2})\,(1+i)^{n} \tag{1}$$

Where,

C	:	Accumulated R&M cost
$RF1$, $RF2$	:	R&M cost factors
P	:	Purchase price
i	:	Inflation rate
n	:	Age of the tractor or machine
x	:	1/1000 accumulated hours of use.

Another work was carried out by Bowers and Hunt (1970) created a general formula for determining total accumulated repair costs as follows [15]:

$$TAR = ILP(RC1)(RC2)(L\%)^{RC3} \tag{2}$$

Where,

TAR	:	Total accumulated repair costs as measured at L
ILP	:	Initial list price
L	:	Life percentage of the machine at the point where accumulated repairs are to be measured
$RC1$	:	A constant which is the ratio of TAR to ILP as measured at 100% life and assumed no inflation
$RC2$, $RC3$	:	Repair cost constant that together determine the general shape of the accumulated repair cost curve

$RC2$ (L%) $RC3$ = 1.0 at L = 100%.

Morris (1988) defined the repair costs function for 50 tractors in a survey conducted in Workfolk farm (UK) as follows [16]:

$$y = (9.96\, x^{1.48})^{.10\text{-}5} \tag{3}$$

Where,

y	:	Total repair costs in percentage
x	:	Accumulated hours of use

Sabir *et al*. (1990) reported that the typical trend in R&M cost for farm machinery can be described by the following equation [17]:

$$TAR = 0.669\,(TAUH)^{1.592} \tag{4}$$

Where,

TAR	:	Total R&M cost as percentage of the list price
TAUH	:	Total accumulated use in hours of wear out life

A model was established by Ward *et al*. (1985) of the R&M cost for agricultural machinery in which it was predicted that the costs as a power function of machinery age measured in thousands of hours of machine use in the form [18]:

$$y = a(x)^b \tag{5}$$

Where:

y	:	Total accumulated repair costs as % of the list price
x	:	Accumulated hours of use as % of the machine life time
a, *b*	:	Model parameters function of machine type

Abdelmotaleb (1989) collected data about the R&M cost from a sample of tractors and combines of Iowa farm, and compared their data with the published ASAE formula for predicting the R&M cost [19]. They revealed that the predicted repair cost of the tractors is higher than that of the actual by up to 15%.

2.2 Predicting of R&M cost of Tractors in Some African Countries and Nigeria

A field survey was carried out in New Halfa area of Sudan by Nasir (2015) on R&M cost, annual hours of use and fuel consumption of some tractors [20]. Mathematical models were developed to predict the accumulated R&M cost as % of the initial purchase price (Y) related to the accumulated hours of use (X) for the tractors as follows:

$$Y = 0.05\left(\frac{X^{1.2}}{1000}\right) \tag{6}$$

$$Y = 0.01\left(\frac{X^{1.39}}{1000}\right) \tag{7}$$

$$Y = 0.05\left(\frac{X^{1.25}}{1000}\right) \tag{8}$$

The derived models indicated that the accumulated R&M cost as percentage of the initial purchase price increased as the accumulated hours of use increased for the selected tractors makes. The model of the average accumulated R&M cost predicted in this study was compared to the other similar models from USA, UK, and Ireland. It was found that the derived model accounted for relatively lower values of accumulated R&M cost compared to the above-mentioned models.

Another survey was carried out by Rahma (1999) in an irrigated farming system in Khartoum State (Umdoum) and rainfed irrigated system in Gadarif State as two different mechanized farming systems in Sudan, aiming to estimate R&M cost for tractors working at these locations regardless of the horse power and drive type [21]. She established a model for R&M cost in relation to the hours of use as follows:

$$y = 0.0704\left(\frac{x}{740}\right)^{2.366} \tag{9}$$

Where,

y	:	Accumulated R&M cost as a percentage of initial purchase price
x	:	Accumulated hours of use.

When she compared her model with the other models from Europe and America, she found out that her prediction model was lower. She attributed this to the prevailing conditions at the time of data collection, e.g., the level of maintenance in the two sites, spare parts stock and availability, lower labor charges in addition to the higher purchase prices of tractors in Sudan.

Similar study was carried out at Yundum agricultural station Gambia by Tchotang *et al*. (2017) on R&M cost analysis of the *John Deere 5403* tractor model [22]. A regression analysis was also carried out in which the results of the trend analysis show that the *Polynomial* model gave a better cost prediction result with higher confidence level and less variation, than the other models. The results further show that the R&M cost increases with an increase in the working hours. The predicted equation is:

$$Y = 0.003\left(\frac{X^2}{100}\right) - 0.07\left(\frac{X}{100}\right) + 1.2898 \tag{10}$$

Where:

Y : Accumulated R&M cost as a percentage of the initial purchase price
X : Accumulated hours of use

Abubakar *et al*. (2013) have conducted a survey at Kano metropolis Nigeria in which the study reported the R&M cost for *Massey Fergusson* (*MF375*) tractors with a view to providing decision making aids [23]. The results obtained show 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%), workmanship cost (13.0%), and then the cost of lubrication oil (10.3%) while the cost of oil and fuel filter replacement had the least (2.1%) percentage share. The following mathematical relationship was obtained after a regression analysis which gave the highest correlation and less variation as follows:

$$Y = 0.005(X)^{1.2} \tag{11}$$

Where,

Y : Accumulated R&M cost as a percentage of the initial purchase price
X : Accumulated hours of use

Obinna and Oluka (2016) carried out a survey on R&M cost of some agricultural tractors using the Enugu State Agricultural Development Program (ENADEP) as a case study [24]. The study was limited to two most available tractor models, namely, the *Massey Fergusson* (MF) and *Fiat* tractors. Investigations were focused on determining the relationship between the accumulated hours of usage and total accumulated R&M cost as well as the general fixed and operating costs of the tractors under government owned management system. The results obtained indicate that the relationship between the total accumulated R&M cost (ARM) and total accumulated working hours (AWH) of the tractor models were developed and could be expressed as:

For *MF 275*: QUOTE $Y = 0.000526\left(\frac{X^2}{1000}\right) + 0.95\left(\frac{X}{1000}\right) - 3.12$

$$Y = 0.000526\left(\frac{X^2}{1000}\right) + 0.95\left(\frac{X}{1000}\right) - 3.12 \tag{12}$$

For *Fiat*: QUOTE $Y = 0.000792\left(\frac{X^2}{1000}\right) + 1.16\left(\frac{X}{1000}\right) - 0.376$

$$Y = 0.000792\left(\frac{X^2}{1000}\right) + 1.16\left(\frac{X}{1000}\right) - 0.376 \tag{13}$$

The above equations are for *MF* and *Fiat* tractors, respectively with a service life of 12000 h. The results of this finding will be very useful in farm machinery management with regards to prediction of R&M cost of the agricultural tractors in Nigeria.

3.0 MATERIALS AND METHODOLOGY

3.1 Materials

3.1.1 Study area

The survey was conducted at Zaria local government area of Kaduna state Nigeria, where the headquarters and the mechanical workshop of the company is located. Zaria is located between latitudes 11º15'N to 11 º3'N of the equator and longitude 7º30'E to 7º45'E of green which meridian, with a total land mass of 563 km^2. Zaria has a tropical wet and a dry climate with warm weather year-round, a wet season from October to March, and the average temperature is estimated to about 28℃ and a maximum of 31℃ throughout the year, and a maximum rainfall of about 1050 mm in August [25].

3.1.2 Sources of data

Primary and secondary data regarding the tractors where collected from Tractor Owners and Hiring Facilities Association of Nigeria (TOHFAN) using their existing records and oral interviews of the tractor mechanics, operators and supervisors. The information regarding the working hours, fuel cost, operation and maintenance cost, purchase price of the tractor, etc. were collected for a period of five years starting from 2014 to 2018.

3.2 Methodology

3.2.1 Data collection

There is a total of 592 tractors as of March 2018, out of which 450 are brand new tractors from different companies comprising a total of 150 *John Deere 5065E* series tractors, 220 *Mahindra 6005* tractors, 50 *JX 75* tractors, and 20 *Massey Fergusson MF 275* tractors. The remaining 142 tractors where operational at various fields, each and every tractor comes with all its equipment comprising of a plough, ridging harrowing and a five ton tipping trailer.

It has also been observed from the available record that two brand models of the tractors have been used at TOHFAN for over five years. The working hours and R&M cost data are available with the company in their records department. The two tractor brands are:

- *John Deere 5065E* model
- *Mahindra 6005* model

The record consists of 85 *Mahindra* tractors and 11 *John Deere* tractors. In other words, to assess and predict the R&M cost of tractors use at TOHFAN, a regression analysis was performed on the available data information regarding the age, working hours and R&M cost were used as the variables for the mathematical models.

3.3 Parameters Used in the Calculation

3.3.1 Annual hours of use

The working hours of the tractors were sorted out annually best on the available records at TOHFAN for a period of five years. Each tractor was initially equipped with a GPS tracking system that shows the working hours of each tractor, thereby making the assessment easier. The mean annual working hours were calculated for each year while the accumulated working hours for a period of five years up to last year of use (age) for the selected tractors make were calculated based on Equation (14) as reported earlier [26]:

$$Xn = \sum_{i=1}^{n} xi \tag{14}$$

Where X is the accumulated operating hours for the 'n' group in hour, n is the tractor age group in year (y), x is the mean annual operating hours per group in hour per year (h/y) for the group i. The accumulated working hours, X is considered as the independent variable of the models.

The mean R&M cost of the tractors was calculated annually based on the corresponding working hours as reported in [23] using Equation (15), the accumulated R&M cost was expressed as a percentage of the list price as follows:

$$Y\text{n} = \sum_{i=1}^{n} yi \tag{15}$$

Where Y is the accumulated R&M cost based on percentage of list price for the 'n' group and y is the mean annual R&M cost based on percentage of list price for the group i. the accumulated R&M cost of the tractors expressed as a percentage of the list price (Y) was considered as the dependent variable for the mathematical models.

3.3.2 Annual repair rate and costs determination

The annual repair costs which include spare parts prices and labor cost in doing these repairs were obtained from TOHFAN on its available record, then the average repair costs for each of the selected tractor make was calculated. The cost of spare parts depends on the brand of the tractors, the available records captures the cost of items used in the major repair which is overhauling of the engine; however, it has been estimated that overhauling was done either full or partial overhaul for both the tractors between the period of five years. Other repairs done within the period of five years include gearbox problem which is developed mainly by the *Mahindra* tractors and fuel injector problem mostly developed by the *John Deere* tractors.

3.4 Maintenance Cost Calculation

The annual maintenance cost comprises of changing oils, greasing, cleaning, changing of filters, and labor cost for maintenance were estimated based on the working hours of the tractor. The annual maintenance cost was then calculated according to market prices of oils, greases, filters and small adjustments.

3.4.1 Engine oil cost

The lubricant cost was based on the procedures and schedules adapted by the company, it is averagely estimated by the operating hours of the tractors, and it requires that after every 63 hours of operation the engine oil needs to be change. Each tractor consumes about 9 liters of engine oil and hence the amount consumed was estimated annually based on the working hours.

3.4.2 Oil filters cost

The oil filter cost where estimated based on the frequency of changing the engine oil which similarly follows the schedule of lubrication cost after every 63 hours of operation, and hence the amount was calculated.

3.4.3 Labor cost

Labor cost has been obtained from TOHFAN based on the category of repair that is either minor repairs or major repairs, the standard price adapted by the company is: minor repair between ₦8000 to ₦ 12,000/operational repair and for major repair is ₦ 15,000 to ₦ 30,000 is charged per repair irrespective of the time taken. While the cost of servicing charged by the company was ₦ 2,000 per tractor done, hence the labor cost can be estimated. However, when the labor cost cannot be obtained from records it is alternatively calculated by multiplying the labor wage rate times by 1.1 or 1.2 as reported in [24] using Equation (16):

$$\textit{Labor cost} = \textit{wage rate} \times 1.1 \text{ or } 1.2 \tag{16}$$

3.4.4 Average fuel consumption cost

It has been estimated by the company the company that the average fuel consumption is based on the working hours of the tractor, it consumes an average of about 3.5 liters of diesel per hour of either harrowing, ploughing or ridging operation which is equivalent to 5.2 liters of diesel per ha. The fuel cost has been included as part of the cost components as reported in [22, 24]. However, if there are no adequate records, the average fuel consumption can be calculated using the following equations as reported in [26]:

$$Q\mathrm{avg} = 0.060 \times P\mathrm{pto} \tag{17}$$

$$F\mathrm{c} = Q\mathrm{avg} \times fp \tag{18}$$

The trend analysis was carried out on the data in order to determine the mathematical models for the R&Mcost of the studied tractors, usually five models were used to carry out the model analysis which include the followings:

(1) *Linear* model ($Y = a + b$x)
(2) *Polynomial* model (Y=a+bx+cx^2)
(3) *Exponential* model (Y=ae^{bz})
(4) *Logarithmic* model (Y=a+lnbx)
(5) *Power* model (Y=ax^b)

4.0 RESULTS AND DISCUSSION

The records under review here is for the two commonly tractor brands used at TOHFAN for the past five years comprising 85 *Mahindra 6005* and 11 *John Deere 5065E* tractors and as such, the R&M cost calculation was restricted to these two brands.

4.1 *Mahindra 6005*

The average cost of each parameter that is to be used was calculated annually while the total R&M cost and the mean annual expenses are presented in Table 1 for *Mahindra 6005* tractor models.

Table 1: The total R&M cost for *Mahindra 6005* in ₦

S/N	Parameters	2014	2015	2016	2017	2018	Mean annual expenses
1	Cost of fuel	345,609	382,600	432,848	756,768	698,544	523,274
2	Engine oil	83,430	92,340	104,490	115,830	106,920	100,602
3	Oil filters	25,750	28,500	32,250	35,750	33,000	31,050
4	Spare parts	Nil	Nil	100,000	290,000	Nil	78,000
5	Workmanship	10,300	11,400	25,000	45,000	13,200	20,980
	Total	465,089	514,840	694,588	1,243,348	851,664	753,906

Table 2 shows the mean annual R&M cost of studied tractors expressed as percentage of their total cost. It was observed that fueling cost of the tractor has the highest percentage at 69% share when compared to the other cost parameters which is possibly due to extensive working hours which denotes the commercial purposes of the tractors. It was followed by the service engine oil cost at 14% which is possibly due to engine service schedule adapted by the company. This distribution can also be seen in the piechart of Figure 1 for the *Mahindra 6005* tractors. Table 3 shows the accumulated working hours and R&M cost as a percentage of the list cost price of *Mahindra 6005* tractors.

Table 2: The mean annual R&M cost of *Mahindra 6005* tractors

Tractor model	Parameter	Cost (₦)	Percentage (%)
Mahindra 6005	Fuel	523,274	69.41
	Engine oil Cost	100,602	13.34
	Oil filter	31,050	4.12
	Spare parts	78,000	10.35
	Workmanship	20,980	2.78
	Total	**753,906**	**100**

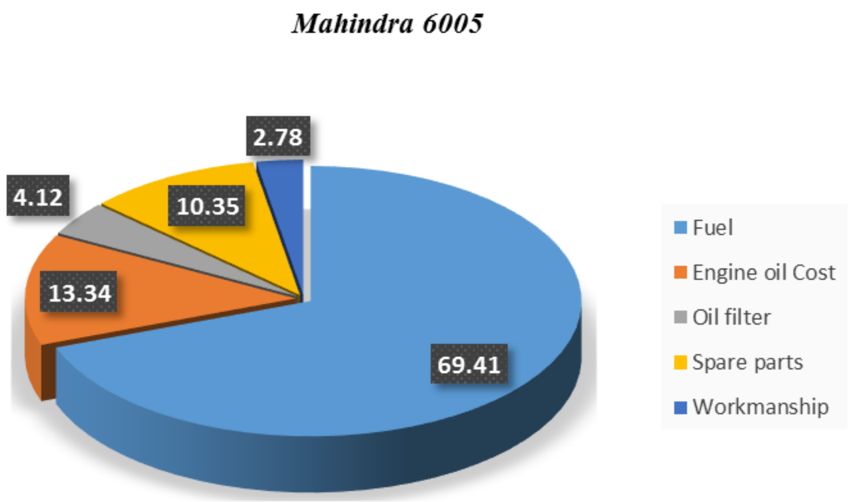

Figure 1: The mean annual R&M cost for *Mahindra 6005* tractors

Table 3: The accumulated working hours and the accumulated R&M cost as a percentage of list cost price of *Mahindra 6005* tractors

Age/years	Working hours (h)	Accumulated working hours (h)	Percentage of list price (%)	Accumulated R&M cost as a percentage of list purchase price (%)
2014	651	651	5.41	5.41
2015	720	1,371	5.99	11.4
2016	813	2,184	8.08	19.48
2017	903	3,087	14.46	33.94
2018	834	3,921	9.90	43.84

Figure 2 shows the graphical interpretation of the actual and predicted data for a period of five years, the accumulated R&M cost as a percentage of the list purchase price (ARM) against the accumulated working hours (AWH) for *Mahindra 6005* tractors using all the five model equations.

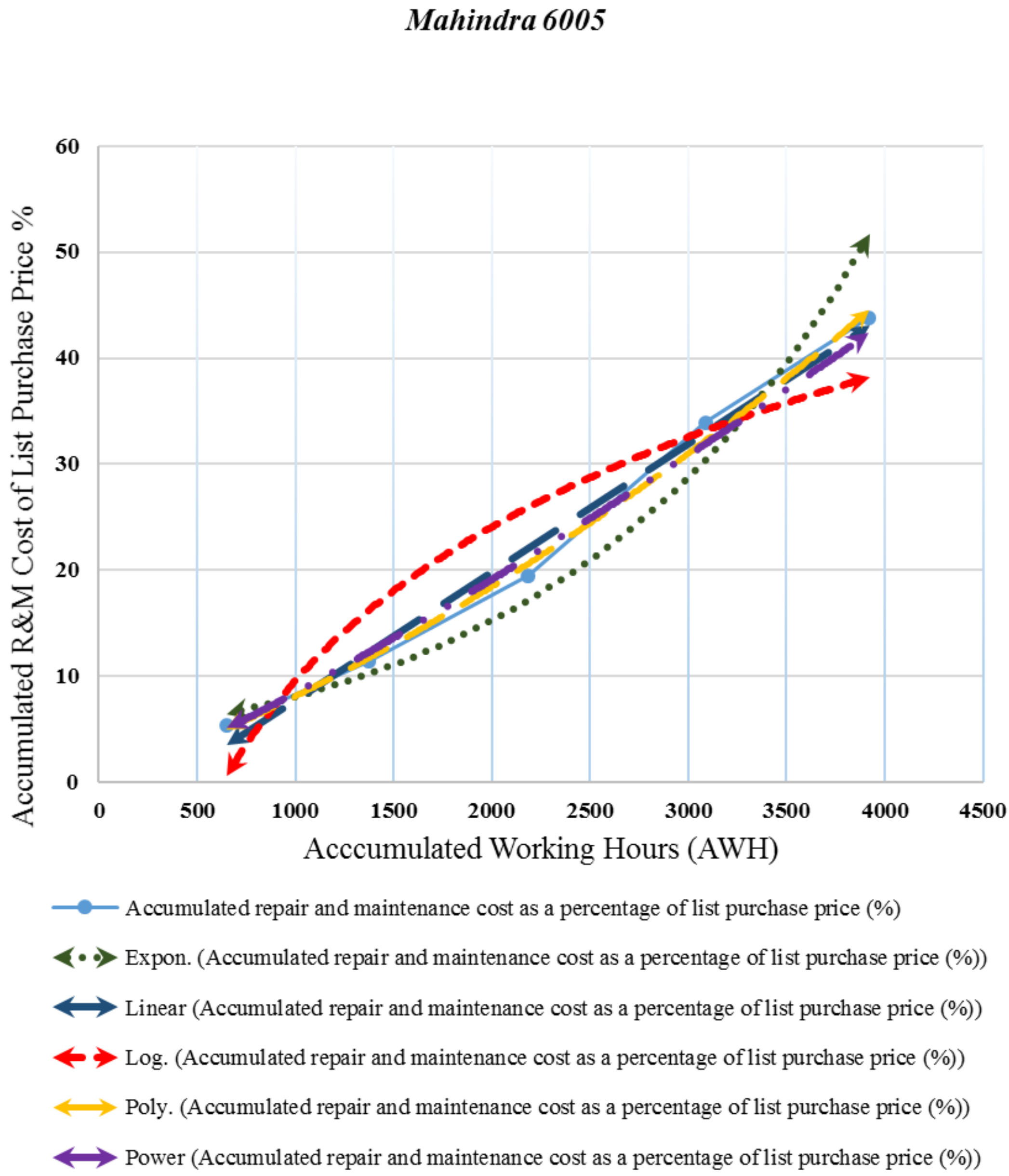

Figure 2: Comparison of the accumulated R&M cost as a percentage of the list price based on the accumulated working hours of *Mahindra 6005* tractors for different mathematical models

4.2 *John Deere 5065E*

The average cost of each parameter that is to be used was calculated annually while the total R&M cost and the mean annual expenses were presented in Table 4 for *John Deere 5065E* tractor models.

Table 4: The total R&M cost for *John Deere 5065E* in ₦

S/N	Parameters	2014	2015	2016	2017	2018	Mean annual expenses
1	Cost of fuel	318,758	359,022	419,419	693,252	624,987	483,088

2	Engine oil	76,950	86,670	101,250	106,110	95,661	93,328
3	Oil filters	23,750	26,750	31,250	32,750	29,525	28,805
4	Spare parts	Nil	250,000	260,000	Nil	Nil	102,000
5	Workmanship	9,500	10,700	12,500	13,100	11,800	11,520
	Total	428,958	733,142	824,419	845,212	761,973	718,741

Table 5 shows the mean annual R&M cost of the studied tractors expressed as percentage of their total cost. It was observed that fuelling cost of the tractor has the highest percentage at 67.21% share when compared to other cost parameters which is possibly due to extensive working hours which denotes the commercial purposes of the tractors. It was followed by service engine oil cost at 12.99% share cost which is possibly due to engine service schedule adapted by the company. This is also evident in the piechart of Figure 3 that shows the corresponding distribution. Figure 4 shows the graphical interpretation of the actual and predicted data, the accumulated R&M cost as a percentage of list purchase price (ARM) against the accumulated working hours (AWH) for *John Deere 5065E* tractors for a period of five years using all the model equations.

Table 5: The mean annual R&M cost of *John Deere 5065E* tractors

Tractor model	Parameter	Cost (₦)	Percentage (%)
John Deere 5065E	Fuel	483,088	67.21
	Engine oil cost	93,328	12.99
	Oil filter	28,805	4.01
	Spare parts	102,000	14.19
	Workmanship	11,520	1.60
	Total	718,741	100

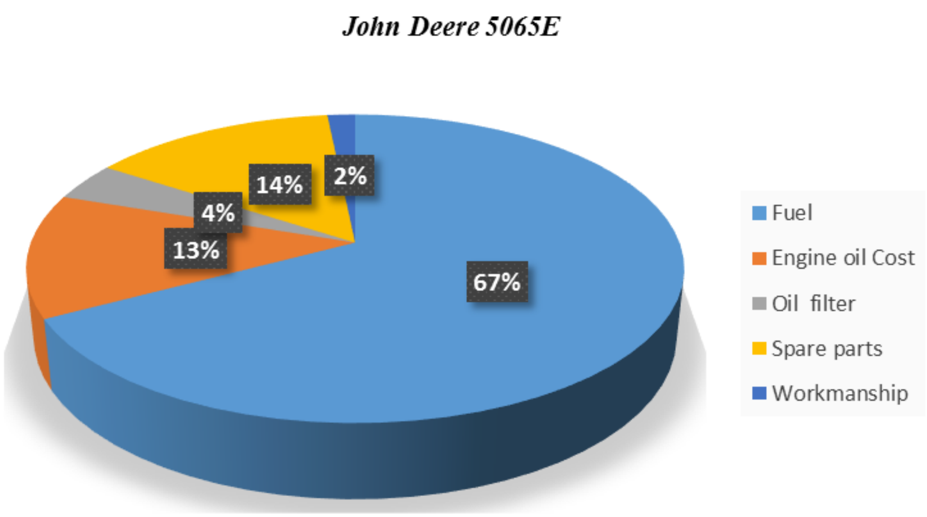

Figure 3: The mean annual R&M cost for *John Deere 5065E* tractors

Table 6 shows the accumulated working hours and R&M cost as a percentage of the list cost price of *John Deere 5065E* tractors.

Table 6: The accumulated working hours and the accumulated R&M cost as a percentage of the list cost price for *John Deere 5065E* tractors

Age/years	Working hours (h)	Accumulated working hours (h)	Percentage of list price (%)	Accumulated R&M cost as a percentage of list purchase price (%)
2014	596	596	5.43	5.43
2015	671	1,267	9.28	14.71
2016	789	2,056	10.44	25.15
2017	823	2,879	10.70	35.85
2018	744	3,623	9.65	45.5

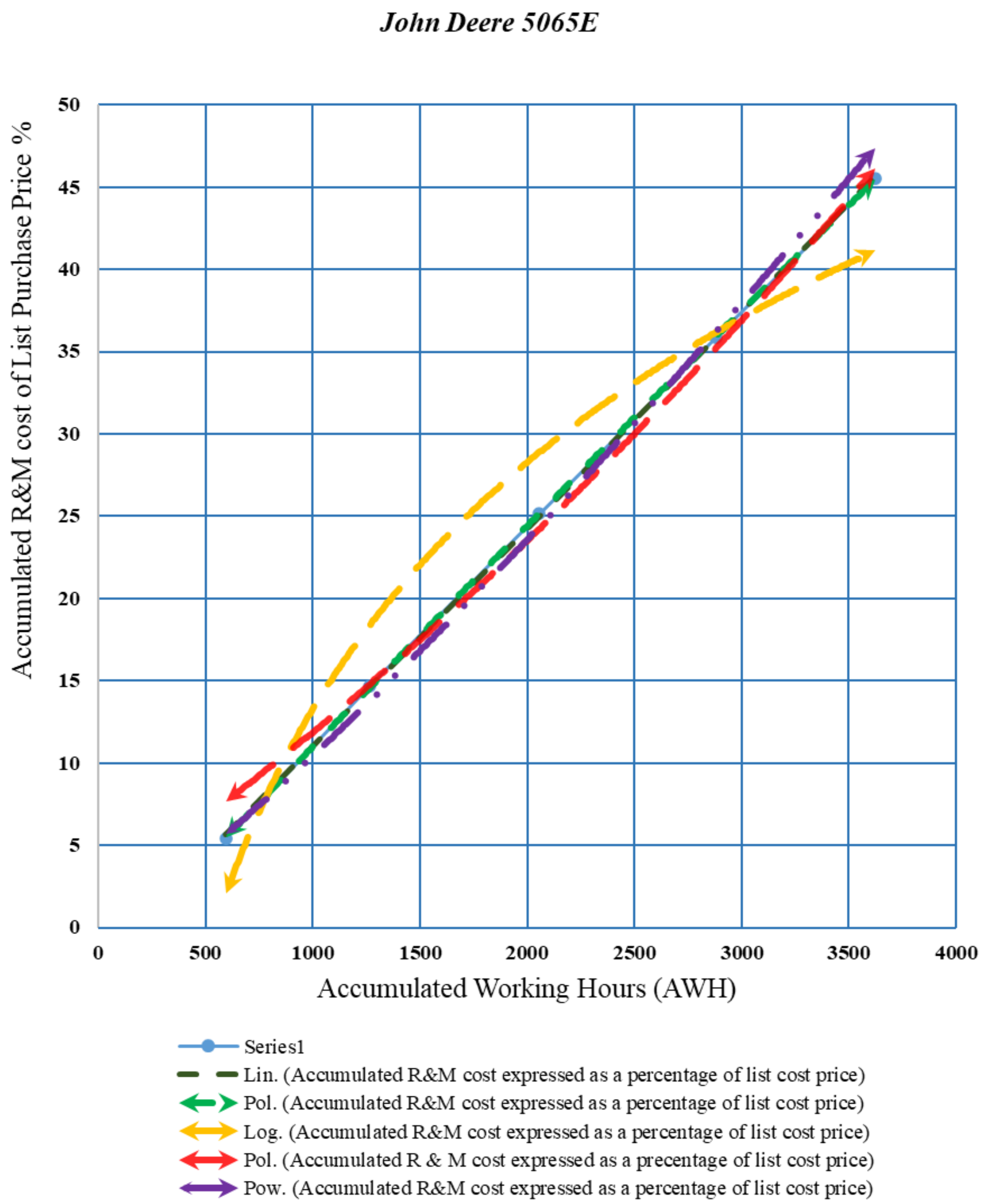

Figure 4: Comparison of accumulated R&M cost as a percentage of the list price based on the accumulated working hours of *John Deere 5065E* tractors for different mathematical models

4.2 Trend Analysis

The result obtained from the trend analysis defines the equations and the correlation coefficient of determination (R^2) values of the models used, i.e., with respect to the *Linear*, *Polynomial*, *Exponential*, *Power* and *Logarithmic* as shown in Figures 2 and 4 for the *Mahindra 6005* and *John Deere 5065E* tractor models, respectively. The results permit us to select the best model that defines the relationship and describe the obtained data based on R^2 value, the highest value of R^2 that is closed to 1 is normally selected and considered to be the best (must) fit model as reported in by Obinna and Oluka (2016) [24]. The graphs also show that the slopes of the curves generally increase as the number of hours increases and hence implying that the repair costs are low at early life of the machine, but gradually increased as the machine accumulates more hours of operation. Table 7 gives the model summary and parameter estimates for both tractors and the related equations obtained from the trend analysis using *Microsoft Excel*.

Table 7: The model trend analysis and parameters

Model	**Tractor model**	**Equation**	**Model summary** R^2	**Model parameters** *a*	*b*	*c*
Linear	*Mahindra*	QUOTE $Y = 0.012X - 4.3006$ $Y = 0.012X - 4.3006$	0.9877	-4.3006	0.0121	
	John Deere	QUOTE $Y = 0.0132X - 2.1986$ $Y = 0.0132X - 2.1986$	0.9999	-2.1986	0.0132	
Exponential	*Mahindra*	QUOTE $Y = 4.2826e^{0.0006X}$ $Y = 4.2826e^{0.0006X}$	0.9652	4.2826	0.0006	
	John Deere	QUOTE $Y = 5.0227e^{0.0007X}$ $Y = 5.0227e^{0.0007X}$	0.9094	5.0227	0.0007	
Polynomial	*Mahindra*	QUOTE $Y = 0.006\left(\frac{X^2}{1000}\right) + 7.0\left(\frac{X}{1000}\right) - 0.0055$ $Y = 0.006\left(\frac{X^2}{1000}\right) + 7.0\left(\frac{X}{1000}\right) - 0.0055$	0.9951	-0.0055	0.007	0.006
	John Deere	QUOTE $Y = 0.00\left(\frac{X^2}{1000}\right) + \left(\frac{X}{100}\right) - 2.00$ $Y = 0.00\left(\frac{X^2}{1000}\right) + \left(\frac{X}{100}\right) - 2.00$	0.9978	2.00	0.01	0.00
Power	*Mahindra*	QUOTE $Y = 0.0024(X)^{1.1804}$ $Y = 0.0024(X)^{1.1804}$	0.9925	0.0024	1.1804	
	John Deere	$Y = 0.0031(X)^{1.178}$	0.9968	0.0031	1.178	
Logarithmic	*Mahindra*	$Y = 20.921\ln(X) - 134.93$	0.8809	-134.93	20.921	
	John Deere	$Y = 21.64\ln(X) - 136.22$	0.9436	136.22	21.64	

Based on the results obtained from the trend analysis above in Table 7, it can be seen that the polynomial model for *Mahindra 6005* has the highest correlation coefficient R^2, thereby implying that the *Polynomial* model is more likely to give more accurate prediction of the R&M cost and hence it is considered. Meanwhile for the *John Deere 5065E* tractor, the *Linear* model gives the highest correlation coefficient of R^2, and as such it is deemed to give more accurate prediction of the R&M cost. The following equations show those that best fit the prediction perfectly.

For *Mahindra 6005*: QUOTE $Y = 0.006\left(\frac{X^2}{1000}\right) + 7.0\left(\frac{X}{1000}\right) - 0.0055$

$$Y = 0.006\left(\frac{X^2}{1000}\right) + 7.0\left(\frac{X}{1000}\right) - 0.0055 \qquad (19)$$

For *John Deere 5065E*: QUOTE $Y = 0.0132X - 2.1986$

$$Y = 0.0132X - 2.1986 \qquad (20)$$

4.3 Comparison of Actual and Modeled (Estimated) Data

Figures 5 and 6 illustrate the comparison between the actual and modeled data obtained by the final predictive or estimated models, i.e., *Polynomial* for *Mahindra 6005* tractor model and *Linear* for *John Deere 5065E*.

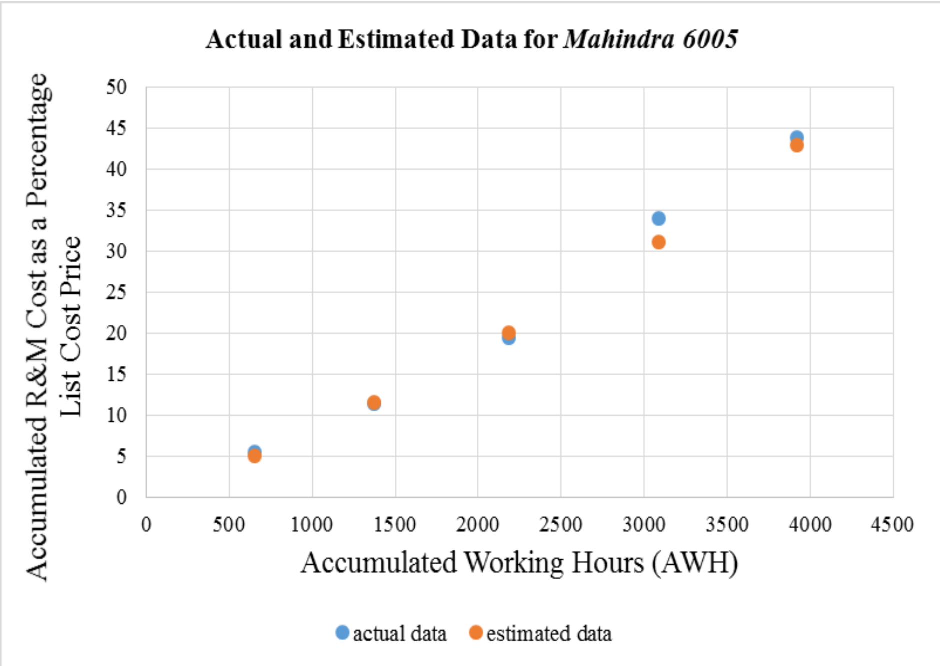

Figure 5: Comparison of actual and modeled data using *Polynomial* model for *Mahindra 605*

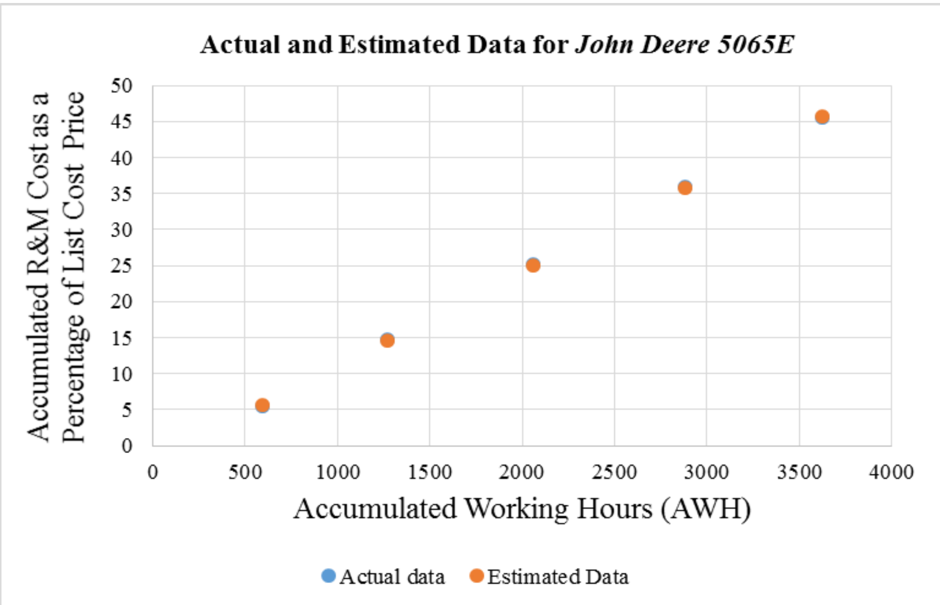

Figure 6: Comparison of actual data and modeled data using *Linear* model for *John Deere 5065E*

Figures 5 and 6 also show the actual and predicted data for both *Mahindra 6005* and *John Deere 5065E* tractors. It can be seen that the curves of the actual and estimated data show almost a similar trend for the *Polynomial* model as in the case of *Mahindra 6005* and the *Linear* model for *John Deere 5065E* seen as the best fit models. It was observed that the rate at which the R&M cost during the early lifetime of the tractors was low but later increases gradually thereafter. However, the increase in the R&M of the tractor can be attributed to various factors such as early breakdown, poor design or sub-standard production technology and unsuitable field performance in relation to the power and efficiency.

4.4 Percentage Error

It is worthy to note that the graphs from the estimated models show better and more accurate results related to the accumulated R&M cost (ARM) and accumulated working hours (AWH) for the considered tractor models in comparison to the gathered (actual) counterpart derived from the available data. This minor discrepancy amongst the two sets is possibly due to errors imminent in the documentation of the data disposition from the input errors, biased information, etc.

The magnitude of the errors in terms of percentage was determined based on the following relationships [24]:

For *Mahindra 6005* tractors:

$$Error\ (EM) = Macc - Mact \tag{21}$$

Where,

$Mact$: Actual data for *MF375*
$Macc$: Modeled (accurate) data

Tables 8 and 9 show the error values obtained by relating the R&M (ARM) cost and accumulated working hours (AWH) as a percentage of the initial cost price (%) given by the developed mathematical models and those obtained from the data collected for the studied tractors.

Table 8: The percentage error for *Mahindra 6005*

Age (Year)	Accumulated R&M cost as a percentage of the list purchase price for actual data (%)	Predicted accumulated R&M cost as a percentage of the list purchase price for the *Polynomial* model (%)	Percentage error (%)
2014	5.43	5.67	0.24
2015	14.71	14.53	-0.18
2016	25.15	24.94	-0.21
2017	35.85	35.8	-0.05
2018	45.5	45.63	0.13

For *John Deere 5065E* tractors:

$$Error\ (EJ) = Facc - F\ act \tag{22}$$

Where,

$Fact$: Actual data for *Fiat*
$Facc$: Modeled (accurate) data

Table 9: The percentage error for *John Deere 5065E*

Age (Year)	Accumulated R&M cost as a percentage of list purchase price for actual data (%)	Predicted accumulated R&M cost as a percentage of the list purchase price for the *Linear* model (%)	Percentage error (%)
2014	5.43	5.67	0.24
2015	14.71	14.53	-0.18
2016	25.15	24.94	-0.21
2017	35.85	35.8	-0.05
2018	45.5	45.63	0.13

From the above tables that depict the small error values obtained for both cases, it can be deduced that that the findings are accurate, implying that the estimated models are valid as the modeling and actual curves are almost the same.

4.5 Comparison with Other Different Models in Predicting the R&M cost

The mathematical models obtained by a number of researchers in predicting the accumulated R&M cost are presented in Table 10. It was observed that most of the developed models give a similar co-relation coefficient values, R^2 when compared with the one derived in this study. However, in terms of the model obtained from this study show very similar structure and characteristics with the ones obtained by Tchotang *et al*. (2017) [22] and Obinna and Oluka (2016) [24].

Table 10: Different models developed for R&M cost

S/N	Models developed	R^2	Source
1	$Y = 0.0003\left(\frac{X^2}{1000}\right) + 0.7\left(\frac{X}{1000}\right) - 1.29$	0.995	[22]
2	$Y = 0.000526\left(\frac{X^2}{1000}\right) + 0.95\left(\frac{X}{1000}\right) - 3.12$	0.9916	[24]
	$Y = 0.000792\left(\frac{X^2}{1000}\right) + 1.16\left(\frac{X}{1000}\right) - 0.376$	0.9899	
3	$Y = 0.005(X)^{1.2}$	0.977	[23]
4	$Y = 0.042(X/100)^{1.796}$	0.986	[26]
	$Y = 0.0002\left(\frac{X^2}{1000}\right) + 0.109\left(\frac{X}{100}\right) - 2.887$	0.996	
5	$Y = 0.05\left(\frac{X^{1.2}}{1000}\right)$	0.997	[20]
	$Y = 0.01\left(\frac{X^{1.39}}{1000}\right)$	0.999	
	$Y = 0.05\left(\frac{X^{1.25}}{1000}\right)$	0.993	
6	$Y = 0.006\left(\frac{X^2}{1000}\right) + 7.0\left(\frac{X}{1000}\right) - 0.0055$	0.9951	This study
	$Y = 0.0132X - 2.1986$	0.9999	

5.0 CONCLUSIONS

The following conclusions can be drawn from this study:

- The existing relationship between the R&M cost (Y) as a percentage of the initial cost price of tractors of tractors under review and the accumulated working hours

(X) of the tractors at TOHFAN can best be characterized by the following equations depending on the tractor model:

- For *Mahindra 6005*: $Y = 0.006\left(\frac{X^2}{1000}\right) + 7.0\left(\frac{X}{1000}\right) - 0.0055$
- For *John Deere 5065E*: $Y = 0.0132X - 2.1986$

- The R&M cost of the tractors increase with the increase in working hours of the tractors and vice versa.

- The fuel consumption rate of the tractors under study greatly affects the maintenance cost and annual hours of used and hence increasing the R&M cost

- That the principal determining component of the R&M cost of the studied tractors is their accumulated working hours as noticed from the developed model.

- The *Mahindra 6005* and *John Deere 5065E* tractors have very strong positive correlation coefficients of determination.

- Due to small error values obtained, the estimated modeling and actual data curves are almost similar, implying that the developed models are accurate and valid.

Further and advanced studies should be carried out to focus more on other relevant agricultural areas of the states and country at large. Also, other different tractor brands or models (makes) should be explored to achieve a more reliable and precise estimation of the R&M cost for varying operating conditions.

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