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Estimation of repair and maintenance cost of a tractor base on HP and working hours: Case study of Sudan

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Abstract

A field survey was carried out in Gezira Scheme, Blue Nile State and North Kordofan State, to collect the data for tractor repair and maintenance costs, and annual hours of use of four selected models of Farmtract type tractors farmtrac80 (FT80), farmtrac70 (FT70), farmtrac60(FT60) and powertrac55 (PT55). The results showed significant ($P > 0.05$) differences between repair and maintenance costs in different systems of tractors. The lowest cost was recorded in the electrical system of the tractor FT 80, while the highest cost was recorded for the engine. For the tractor (PT55) the lowest cost was recorded in the hydraulic system and the highest cost was recorded in transmission system. Different mathematical regression models were also developed for accumulated repair and maintenance cost prediction such as linear, polynomial, exponential, logarithmic and power. The power model was created. The derived models indicated that the accumulated repair and maintenance costs as percentage of initial purchase price was increased as the accumulated hours of use increased for the four selected tractor models and the mean model derived.

Key words: Maintenance; modeling; Repair; Tractor; 55HP to 80HP.

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1. Introduction

Agricultural farming systems are becoming expensive due to the high repair and maintenance costs of agricultural tractors. Tractor 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 were mainly due to age, wear and tear, accidents, materials and design error, irregular maintenance and incorrect use and repair of damages. Failures of tractor parts are inevitable due to 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, deceases engine power and life and increases exhaust emission. In Sudan, agricultural tractors introduced in early nineteen-nineties and there are many tractor makes, models and sizes now distributed between irrigated and rain-fed agricultural farms. These tractors are owned by people from both the private and public sectors and even some are owned by individual farmers and they often work for more than 1200 hours per year (FAO, 1995).

Tractors have been used in Sudan, as a power source in agriculture for many years. The total number of tractors officially imported into the country between 1984 and 1994 increased from 23,590 units to 32,096 units (FAO, 1995). In Sudan, machinery repair, maintenance, and fuel and lubricants consumption is not given enough attention. About 40% of farm machinery was out of work very quickly due to lack of proper maintenance and unavailability of genuine spare parts or using of spurious and no genuine spare parts of low prices.

Keshavarzpour has find that the data of an Agribusiness Company in Iran were used to determine regression model(s). The statistical results of the study indicated that in order to predict accumulated R and M costs of U-650 tractors with service life of 1970 h or less the power regression model $Y= 0.0377 (X/100)$ with $R = 0.982$ and to predict accumulated R and M costs of U-650 tractors with service 1.5451 2 life of 1970 h or more the polynomial regression model $Y = 0.0056 (X/100) - 0.2205 (X/100) + 6.9088$ with $R = 0.99722$ can be suitably recommended (Keshavarzpour, 2011).

Machinery costs and control are very important. Custom charges are often based upon them. No one should do custom work unless the charge will cover operating costs and use-related depreciation plus a return for one's risk and time. Ideally, all allocated per acre or hour overhead costs should also be covered by anyone offering to do custom work. The market for custom work usually does not cover all costs and is usually between the use-related costs and total costs (Lazarus, 2009).

Also(Rashidi and Ranjbar, 2011)find The statistical results of the study indicated that in order to predict accumulated R and M costs of MF-285 tractors with service life of 2275 h or less the power regression model $Y = 0.0187\ (X/100)$ with $R = 0.966$ and to predict accumulated 1.6381 R2 and M costs of MF-285 tractors with service life of 2275 h or more the polynomial regression model $Y = 0.0049\ (X/100) – 0.2228\ (X/100) + 5.0759$ with $R = 0.997$ can be properly suggested (Rashidi and Ranjbar, 2011)

Prediction of repair and maintenance costs has significant impacts on proper economic decisions making of machinery managers, such as machine's replacement and substitution (Rohani, 2011). Some mathematical relations were developed in Sudan for repair and maintenance costs estimation for agricultural tractors (Ahmed et al., 1999; Rahma 1999; Dahab and Osama 2002). They are varied in structural components due to differences in tractors specifications and conditions and locations of work, therefore, it is difficult to depend on one mathematical model for proper repair and maintenance management decisions. The aims objectives of this study were: (i) to specify the types of failures and repair and maintenance costs for different systems in the selected tractor make. (ii) to develop appropriate mathematical models relating accumulated repair and maintenance costs for the hours of use with different power sizes for four selected tractor models (iii) to compare the derived model with other existing models in the country and other countries.

2. Material and Methods

The data of the study was collected from three sites namely Gezira Agricultural scheme, Blue Nile state and North Kordofan State, which are described as follows:

2.1 Gezira Agricultural scheme

It is located in the central clay plain between the Blue Nile and White Nile of the Central Sudan. It is the first largest irrigated scheme and it covers about 9240 Km^2 or 924000 ha. Topographically the area is flat with few isolated small rocky hills (FAO, 1995).

2.2 Optimization experiments Blue Nile State

Blue Nile state lies between latitude 9.30 – 13.34 North with 33.8 – 35.15 South, approximately in area of 36,708.5 km^2 included 2500 Km^2 or 252000 Hectares. good for growing crops.

Fig. 1: Farmtrac 80HP [FT80],Farmtrac 70HP [FT70], Farmtrac 60HP [FT60] & Powertrac 55HP [PT55].

2.3 North Kordofan State

North Kordofan State lies between longitudes 21.2-23 East and 56.30 – 26 West and latitudes 36.16 – 16 North and 14 – 12 South and approximately in an area of 244,700 km2.

Table1: Technical specifications of tractors used in this study.

Description	Tractor Models			
	FT80	**FT70**	**FT60**	**PT55**
Engine power HP (KW)	72.4 HP	60 HP	50 HP	45
Maximum PTO power HP	64	52	48.8	40.8
Maximum torque (kgm)	28.8 @ 1420 RD	21.5	18.2 @ 1166 RPM	16.8
RPM	2200 RPM	2200	2000	2000
Engine type	4 stroke, perkins	4 stroke DI	4 stroke / DI	4 stroke / DI
Number of cylinders	4	3	3	3
Air cleaner	Dual dry/air cleaner	Dual air cleaner	Dry dual plate	Dry
Transmission	2WD	2WD	2 WD	2 WD
Brakes	Oil disc brakes	Oil disc brakes	Foot operated dry	Foot operated dry disc
PTO	540 @ 2115 RPM	450 @ 2115 RPM	540 @ 1810	540 @ 1810
Cooling system	Water cooling	Water cooling	Water cooling	Water cooling
Tyres front	7.5 x 16.8	7.5 x 16.8	6.00 x 16	6.00 x 16
Tyres rear	16.9 x 30	16.9 x 28	13.6 x 200	13.6 x 28

Source of data www.scortsagri.com

2.4 Tractors

There are many models of tractors working in the three states under the study. FT 80, FT70, FT 60 and

PT 55 tractors are one of the common makes available in these areas and are chosen to carry out this study. The power of these tractors mostly in the range of 45-72hp the total number of the selected tractors for the study is 100 units. The technical specifications of the four tractor models are shown in table 1.

Many sources were used to collect data concerning tractor repair and maintenance costs. Tractor owners companies, agricultural inspectors, mechanics, manufacturer's catalogues and tractors dealers. All these were interviewed and some data was collected from the field.

2.5 Data Collection

A questionnaire was prepared to collect the required data then a survey was carried out in the site of the study to interview the target sources of data. The questionnaire included following information:
Initial purchase price (SDG), Annual hours of use (hr) , Annual repair costs (SDG). Annual maintenance costs (SDG), Maintenance time (hr), Annual number of repairs, Labor cost/year (SDG) and Causes of failures and breakdowns types.

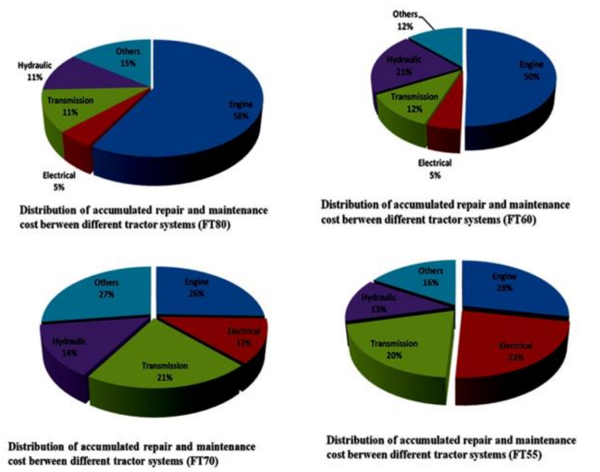

Fig. 2: Distribution of accumulated repair and maintenance of agricultural tractor for the four tractor model during 5-10 years.

2.6 Parameters calculation

2.6.1 A. Annual hours of use

The mean annual hours of use of each model were calculated. The total accumulated hours of use were calculated by summation of the total mean annual hours of use – which was calculated on the basis of effective working hours of the tractor – up to the last year of the age for each of the selected tractor model (Ward et al. 1985).

Table 2: Mean repair and maintenance costs (SDGx1000) distributor for the different system of tractor model (100) piece.

Year	Engine	Electrical	Transmission	Hydraulic	Steering	Others
			FT80			
2007	739	130	450	163	200	172
2008	1340	250	510	250	300	250
2009	3570	400	600	670	00	490
2010	4500	00	790	930	00	530
2011	6000	512	860	1025	490	670
			FT70			
2007	450	140	350	75	130	210
2008	550	230	420	320	00	320
2009	620	390	230	240	00	530
2010	640	520	600	430	300	430
2011	910	240	1000	520	450	700
			FT60			
2007	2200	150	500	150	190	290
2008	3150	210	700	450	330	220
2009	4500	450	910	700	490	450
2010	5200	580	1200	3200	600	620
2011	5900	730	1500	4000	730	290
			PT55			
2007	400	1300	200	100	100	200
2008	230	00	500	350	00	400
2009	510	00	900	790	00	600
2010	2200	2201	1202	810	350	750
2011	4050	2500	2500	1250	00	1000

2.6.2 Annual repair rate and costs determination

The annual repair costs which include spare parts prices and labor cost were recorded, and then the mean repair cost for each selected tractor model was calculated for the study period.

2.6.3 Maintenance costs calculation

The annual maintenance which includes, changing oils, greasing, cleaning, changing of filters, and labor cost for maintenance were recorded. The annual maintenance costs were calculated according to market prices of oils, greases, filters and small adjustments.

The accumulated maintenance costs were calculated by summation of the mean annual costs and time for all years for each age model of the selected tractors (Ward et al. 1985).

2.6.4 Accumulated repair and maintenance costs computation

The annual repair and maintenance costs for each age model were calculated as follows:

Annual repair and maintenance costs = annual repair costs + annual maintenance costs.

Tractors of the same models and age were grouped together and the annual repair and maintenance costs of these groups were calculated, then the annual repair and maintenance costs were expressed as percentage of the initial purchase price of the tractor model for the period of study. Statistical analysis was performed using the computer statistical package (SPSS) and excel software to perform the correlation regression relations, Regression analysis of data for all tractors was done using Version, 16.0. Linear, exponential, power and polynomial regression types were tried (Keshavarzpour, 2011)

3. Results and Discussion

Tractors systems failures and repair and maintenance distribution during the period of study

The results of data surveyed showed that the mean repair and maintenance costs of different systems for the four tractor models studied generally increased with age, but the rate of increase varies for the different systems (Table 2). However, the mean repair and maintenance cost of the four tractor models showed higher repair and maintenance costs occurred from year 5-10 (Fig. 2). The engine and hydraulic unit with for more than 60% of the total repair and maintenance cost for tractor FT80 and FT60. In general the difference between four tractors subsystems may be due to the rainfed agricultural areas must be given more breakdowns since the operation condition are different from those of irrigated areas and may be due to variation in soil type.

Table3: Regression analysis of the relation between the mean accumulated R&M cost as a percentage of purchase price and the mean accumulated hours of use on the different models.

Models	Equation	R^2
Linear	$y = 0.0089\ x - 10.26$	0.96
Logarithmic	$y = 25.0\ \text{Ln}\ x - 127$	0.87
Polynomial	$y = 16x^2 + 0.9\ x + 0.15$	0.99
Exponential	$y = 3.132^{e0.0005}$	0.77
Power	$y = (2.9\ x^{1.9})10^{-6}$	0.89

3.1 Repair and maintenance costs prediction math model development

Regression analysis of the data was carried out to represent the relation between the mean accumulated R&M cost as percent of purchase price and the mean accumulated hours of use of the four tractor models, the model of linear, polynomial, logarithmic, power and exponential with correlation coefficient of related to itself (Table 3). The highest value of correlation coefficient among the presented models is related to polynomial model with $R^2 = 0.99$ and after that power model with $R^2 = 0.89$ which is very close to the previous correlation. In the most published studies in this field, power models were found easy in calculations and gave better cost predictions than the other models.

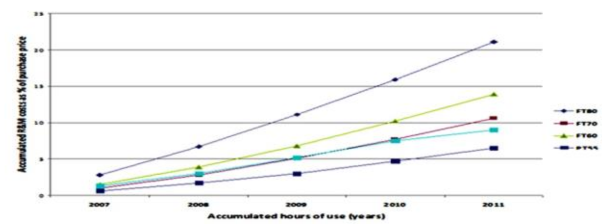

Fig.3: Compares on of accumulated R&M costs 4 tractors models.

The correlation regression method was used for data analysis. Fig.3 The power function was found to be the best fit for the four tractors models studied, and accounted for 99% of the observed variations in accumulated repair and maintenance costs for each of the four models as shown in Tables 3 and 4 .Table 5 was shown Accumulated repair and maintenance costs as percentage of initial purchase price as affected by accumulated hours of use of the selected tractors model.

Table4: Accumulated R&M costs as percentage of initial purchase price and accumulated hours of use equations for the selected tractors models.

Tractor model	Power regression model	R^2	F
FT80	$y = (5.0\ x^{1.25})10^{-4}$	0.99	167.7*
FT70	$y = (0.5\ x^{1.44})10^{-4}$	0.89	200.8*
FT60	$y = (1.0\ x^{1.39})10^{-4}$	0.96	8721.1
PT55	$y = (0.2\ x^{1.49})10^{-4}$	0.99	1907.5
Mean	$y = (1.7\ x^{1.29})10^{-4}$	0.89	363.7

Where: y = Accumulated repair and maintenance costs as % of initial purchase price. x = Accumulated hours of use.

The model of the mean accumulated repair and maintenance costs predicted in this study was compared to the other similar models from Ireland, UK and Iran as shown in Table 6 and Fig 4. It is clear that the derived model accounted for relatively lower values of accumulated repair and maintenance costs compared to the above mentioned models (Hess and Morris, 1988, Ward et al., 1985, G.M.Khoub 2008).

This variation may be attributed to the differences in spare parts prices between Sudan and the industrial countries, or may be due to variations in soil type, climate, preventive maintenance program applied and operation conditions. This lower value of repair and maintenance costs may be also due to the procurement and usage of spurious and non-genuine spare parts, variations in tractors technical specifications and lower labor charges for repairing and maintaining tractors in Sudan compared to the industrial countries.

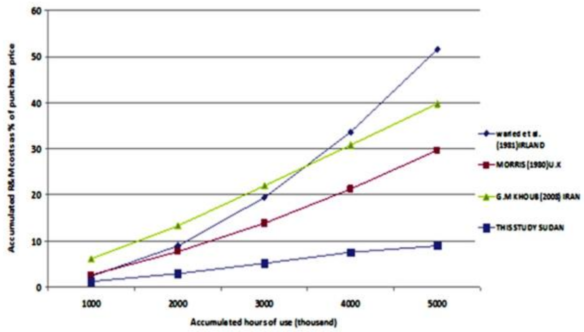

Fig.4: Comparison of accumulated R&M costs of this study with models from other country.

Table5: Accumulated repair and maintenance costs as percentage of initial purchase price as affected by accumulated hours of use of the selected tractors model.

Tractor model	Model	Repair and maintenance costs as % of initial purchase price				
		2007	2008	2009	2010	2011
FT80	$y = (5.0\ x^{1.25})10^{-4}$	2.8	6.7	11.1	15.9	21.1
FT70	$y = (0.5\ x^{1.44})10^{-4}$	1.0	2.8	5.1	7.7	10.6
FT60	$y = (1.0\ x^{1.39})10^{-4}$	1.5	3.9	6.8	10.2	13.9
PT55	$y = (0.2\ x^{1.49})10^{-4}$	0.6	1.7	3.0	4.7	6.5
Average	$y = (1.7\ x^{1.29})10^{-4}$	1.3	3	5.2	7.5	9

y = Accumulated repair and maintenance costs as % of initial purchase price.

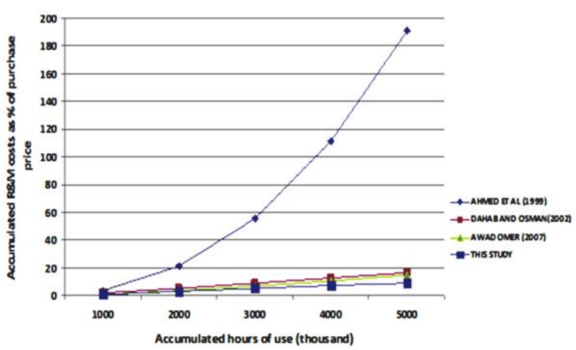

Fig.5: Comparison of estimated R&M costs of the selected with similar predication in Sudan.

When the model of this study is compared to Dahab and Osama (2002) model for repair and maintenance costs, it was clear that the estimates of the present model accounted for lower values (Dahab and Osama 2002) Up to 2011 accumulated hours of use, after which this model accounted for higher value. This may be attributed to variations in tractors specifications, ages and makes.

Table6: Comparison between the present study estimates of repair and maintenance costs as percentage of initial purchase price with other estimates from Sudan .

Source	Model	Repair and maintenance costs as % of initial purchase price				
		1000	2000	3000	4000	5000
Ward *et al.* (1985) Ireland	$y = (4.82x^{1.9}).10^{-6}$	2.4	9.0	19.5	33.6	51.4
Morris (1988) UK	$y = (9.96x^{1.48}).10^{-5}$	2.7	7.7	13.9	21.3	29.7
Khoub (2008) Iran	$y = (0.002x^{1.162})$	6.1	13.3	22.0	30.7	39.7
This study	$y = (1.7x^{1.29}).10^{-4}$	1.3	3	5.2	7.5	9

y = Accumulated repair and maintenance costs as % of initial purchase price. x = Accumulated hours of use.

The comparison between this model and Rahama (1999) prediction showed that the present model accounted for higher values of repair and maintenance costs than (Rahama1999) for all levels of conditions, operators and mechanics skills, maintenance regime followed and labor charges for repairing and maintaining tractors. The difference may also be attributed to differences in tractors technical specifications and cost computations methodology. (Table.7, Fig5).

Table7: A comparison between this study estimates of repair and maintenance costs as percentage of initial purchase price with other estimates from Sudan.

Source	Model	Repair and maintenance costs as % of initial purchase price				
		1000	2000	3000	4000	5000
Ahmed et al., (1999)	$y = (2.53x^{2.4}).10^{-7}$	4.0	21.2	56.0	111.7	190.8
Dahab & Osama (2002)	$y = (4.0x^{1.25}).10^{-4}$	2.3	5.4	8.9	12.7	16.8
Awad Omer (2007)	$y = (2.0x^{1.59}).10^{-5}$	1.2	3.5	6.8	10.7	15.2
This study	$y = (1.7x^{1.29}).10^{-4}$	1.3	3	5.2	7.5	9

Conclusion

The following conclusions were drawn from the present study: The relationship between accumulated repair and maintenance costs as percentage of the initial purchase price of the tractor (y) and accumulated hours of use (x) for the four tractor models in the three states (Gezira Agricultural Scheme, Blue Nile State and North Kordofan State) as follows:

FT80	$y = (5.0\ x^{1.25})10^{-4}$
FT70	$y = (0.5\ x^{1.44})10^{-4}$
FT60	$y = (1.0\ x^{1.39})10^{-4}$
PT55	$y = (0.2\ x^{1.49})10^{-4}$
mean	$y = (2.9\ x^{1.9})10^{-6}$

- The accumulated repair and maintenance costs increase with tractor age and hours of use.
- The predicted models for repair and maintenance costs of tractors in Sudan were lower than those of other countries.

Further studies must be carried out to cover more areas of the country and more tractors makes to achieve precise estimations for repair and maintenance costs for different types of soil under different operations conditions. The governmental companies and schemes that deal with agricultural tractors must concentrate on the effects of repair and maintenance costs determination on the economic life of agricultural tractors, and therefore must keep very precise records about them. Because the source of data was only personal contact, this model may be regarded as an approximation for repair and maintenance costs in the area of study.

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Competing Interests

Authors declare that they have no competing interests and commercial names and details of machines and equipments are for the guidelines only.

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