OpenAccessPub

Review Article

Journal of Agronomy Research ISSN: 2639-3166

Freely Available Online

Effect of Hours of Use and Age in Years in Estimating Repair and Maintenance Costs for Two Sizes of Agricultural Tractors in Northern Sudan

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Keywords:

Repair and Maintenance; purchase price, Hours of Use, Age, Tractor, New Halfa.

Received: Jun 18, 2021

Accepted: Oct 13, 2021

Published: Oct 16, 2021

Editor:

Abubaker Haroun Mohamed Adam, Department of Crop Science (Agronomy), College of Agriculture, Bahri University- Alkadaru- Khartoum -Sudan

DOI: 10.14302/issn.2639-3166.jar-21-3875

Abstract

Repair and maintenance cost is considered as one of important items for machinery management and selection. The present study was carried out in Dongola area for tractor repair and maintenance costs estimation. The data was collected from records of Elshimalya Company for Agricultural Inputs. Forty four tractors rep resenting two sizes of tractors, 75hp and 150hp used in the area were selected for this study. Based on the data collected, regression correlation analysis was carried out and mathematical models were derived to predict the accumulated repair and maintenance (R and M) costs as percent of purchase price in relation to accumulated hours of use and age (years) for each tractor size, and also for the two sizes collectively. Five model forms (linear, logarithmic, polynomial, power and exponential) were derived and the power function was found the best fit to explain the relation. The accumulated Rand M costs as percent of purchase price (Y) was increased as the accumulated hours of use (x) and age (g) of the tractor in years were increased. A high correlation was found between the accumulated R and M cost and both accumulated hours of use and tractor age in years (Average $R^2 = 0.93$).

It was concluded that the power function was the best fit for repair and maintenance cost estimations and the following relations may be used as an average for estimation of the accumulated R

and M costs as percent of purchase price (Y) with accumulated hours of use (x) and age (g) of the tractor: $Y=0.028x^{0.662}$ (mean) $Y=12.294g^{1.276}$ (mean).

Introduction

Agricultural tractor is one of the most important energy and power sources in agricultural mechanization[1]. It requires high initial capital investment. The introduction of modern technology during the last century resulted in rapid growth of farm production. Tractors and farm machinery are important samples of this modern technology[2]. Tractor costs have great influence on farm business profit. Knowledge of tractor costs for farm operations has a prime importance in making management plans and decisions especially in comparing different tractor types and models thereby assisting in the selection of a more appropriate farm tractor. Costs of owning and operating farm machinery represent 35% to 50% of the costs of agricultural production when the land is excluded[3]. The repair and maintenance (R&M) cost is an important item in the costs of ownership and operation. R&M cost is a function of machine age and use[4]. In general, the costs other than those for R&M usually decrease with increasing usage, but the reverse is true with respect to R&M costs. The cost of R&M is usually about 10% of the total cost; as the machine age increases the cost increases until it becomes the largest cost item of owning and operating the farm machines[5]. Agricultural engineers have carried many studies regarding R&M 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 [6,7,8,9]. Using of American and European mathematical relations to estimate R and M costs in under developed and developing countries produced unrealistic and misleading results and therefore, these countries developed their own mathematical models[10,11,12]. Poor and irregular maintenance reduce tractor reliability, increases fuel consumption, deceases engine power and life and increases exhaust emission[13].

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[14]. 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)[14]. 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 un availability of genuine spare parts or using of spurious and non-genuine spare parts of low prices. There are some prediction models for tractors repair and maintenance costs in the Sudan were developed[15,16,17]. They decided that the correlation between repair and maintenance costs as a percent of tractor initial purchase price and the tractor accumulated hours of use would be best described by a power function equation. There were variations between these models in the predictions for the different tractors. They were varied in structural components due to differences in tractors specifications and conditions and locations of work, therefore, the present study was carried to develop computer models for repair and maintenance costs estimation in relation to hours of use and age for two sizes of diesel engine agricultural tractors in Dongla area.

Materials and Methods

Materials

The data of the study was collected from Dongola area-northern Sudan. The soil is sandy and clay particles, characterized by very low perm ability, deep cracking when dry, poor in nitrogen and organic matter. The climate of the area is classified as dry desert zone.

There are many makes of tractors working in the area, but the Massey Ferguson, tractors are the most common makes available in the area, and are chosen to

carry-out this study. Their sizes are mostly in the range of 75–150hp. The total number selected for this study was (44), from which twenty two were (75hp), and the other twenty-two were (150hp). The tractor's technical specifications are shown in Table (1) below.

Many sources were used to collect data concerning tractors repair and maintenance costs they included Elshamalia Company of Agricultural input, Mechanics, Engineers, Agricultural Engineers, individuals and operators, and the workshops. The resources were interviewed,

Methodology

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 information about: Tractor age, model and make, initial purchase price ($), annual hours of use (hr), annual area covered (fed), annual repair costs ($), annual maintenance costs ($), annual number of repairs, labor cost/year ($).

Parameters Calculation

Tractor Systems Failures and Repair and Maintenance Distribution

The total costs of repair and maintenance for the different tractor systems and types were carried out by summation of failures during the period of study and calculating the costs of repairing and maintenance for the systems and the two types of tractors.

Annual Hours of Use

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 make[9].

Accumulated Repair and Maintenance Costs Computation

The annual repair and maintenance costs for each age were calculated as follows: Annual repair and maintenance costs=annual repair costs +annual maintenance costs.

Tractors of the same type 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.

The total accumulated repair and maintenance costs as a percentage of initial purchase prices were calculated by summation of mean annual repair and maintenance costs as a percentage of initial purchase prices for all years in the age of the selected tractors[9].

Statistical Analysis

Using the SPSS computer program, the relationship between the accumulated annual repair and maintenance costs as a percentage of initial purchase price and accumulated annual hours of use was computed.

Results and Discussion

Tractor Systems Failures and Repair and Maintenance Distribution

It was observed the average repair and maintenance costs of different systems for the two tractor size generally increased with age, but the rate of increase varies for the two sizes. However, the mean R&M cost of the two tractor types showed relatively higher repair and maintenance costs occurred from year 2 and decreased in year 3 after that increased at years 4 and 5 (Table 2 and Fig. 2). The engine and fuel systems accounted for more than 53% of the total accumulated R & M costs of the two tractor sizes when five years ownership was considered (Fig. 1). The distribution of the accumulated R & M cost of different tractor systems was almost similar for the two types, but the hydraulic system R & M cost of type (150hp) was higher compared with the 75hp type.

Development of Repair and Maintenance Costs Prediction Models

Regression analysis of the data was carried out to present the relation between the mean accumulated R&M cost as percent of purchase price and the mean accumulated hours of use of the two tractor types, on the

Table 1. Specifications of tractors used

Item	Tractor (A)	Tractor (B)
Country of make	UK	Brazil
Engine rated power	75 hp	150 hp
Engine speed rpm	2200	
Drawbar power	63.2 hp	127.5 hp
Engine type	4-cyl. Diesel	4-cyl. Diesel
PTO rpm	540/1000	540/1000
Fuel tank capacity	33.6 gal.	61 gal.
Base weight		5670 kg
Clutch	Hydr. Wet multi-disc	Hydr. Wet multi-disc
Brakes	independent hydraulic wet disc	independent hydraulic wet disc
Chassis	2WD	4WD
Steering	Hydraulic Electro-hydraulic,	Hydraulic Electro-hydraulic,

Table 2a. Repair and Maintenance costs distribution for different tractor systems **(A)**150 hp tractor

Age	Engine	Transmission	Hydraulic	Fuel	Other
1	66353	83532	49778	114960	19120
2	109415	139647	83185	834564	38220
3	138072	165570	102735	111855	44140
4	165140	218095	120365	81675	34845
5	204415	250514	154290	75000	57175
Mean	136679	171471.6	102070.6	243610.8	38700

Table 2b. Repair and Maintenance costs distribution for different tractor systems **(B)**75 hp tractor

1	39820	45465	34275	59706	17055
2	5465	64270	45710	46320	14983
3	78908	94745	53925	34270	18340
4	81825	100677	53890	25098	25636
5	75361	86410	48060	13755	17590
Mean	56275.8	78313.4	47172	35829.8	18720.8

Table 3. Regression analysis of the relation between the mean accumulated R&M cost as percent of purchase price and mean accumulated hours of use

Model	Equation	R square
Linear	Y= 0.0003x+22.181	0.732
Logarithmic	Y=23.598Ln (x)- 209.025	0.862
Polynomial	$Y=-E-091.568x^2+0.001x+7.04$	0.859
Exponential	$Y=20.017e^{7.467E-6x}$	0.617
Power	$Y=0.028x^{0.662}$	0.927

Table 4. The power relation of accumulated R&M cost with accumulated hours of use of the two tractors

Tractor type	Power model	R square	F
Tractor 75Hp	$Y= 0.011x^{0.763}$	0.994	501.813^{**}
Tractor 150Hp	$Y= 0.019x^{0.677}$	0.994	466.297^{**}
Mean	$Y=0.028x^{0.662}$	0.927	101.534^{**}

Table 5. The power relation of accumulated R&M cost with accumulated age (years) of the two tractors

Tractor type	Power model	R square	F
Tractor 75Hp	$Y= 14.14x^{1.14}$	0.994	465.008^{**}
Tractor 150Hp	$Y= 10.689x^{1.412}$	0.944	50.601^{**}
Mean	$Y=12.294x^{1.276}$	0.952	158.781^{**}

**=significant difference at P<0.01

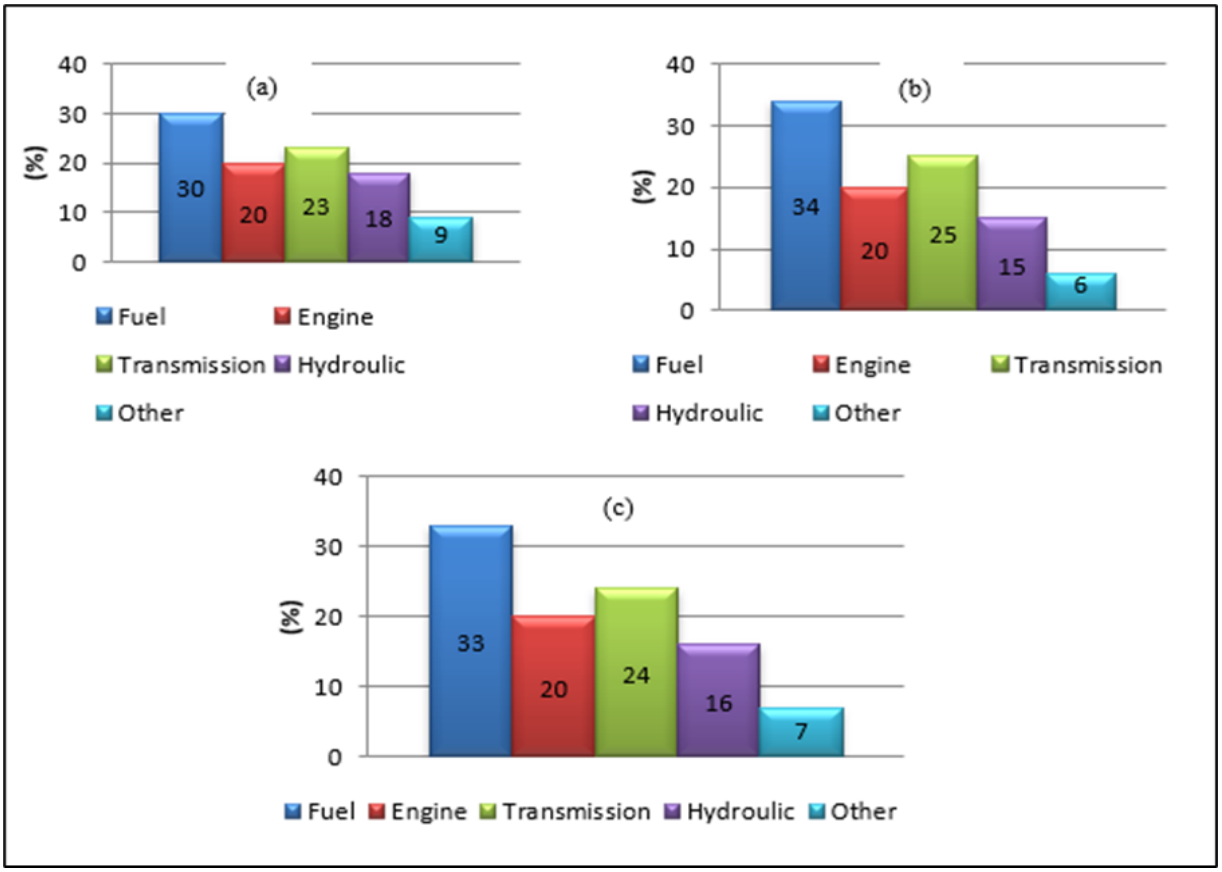

Figure 1. Distributions of accumulated repair and maintenance of agric tractor systems (a) 75hp tractor type (b) 150hp tractor type (c) mean of the two types

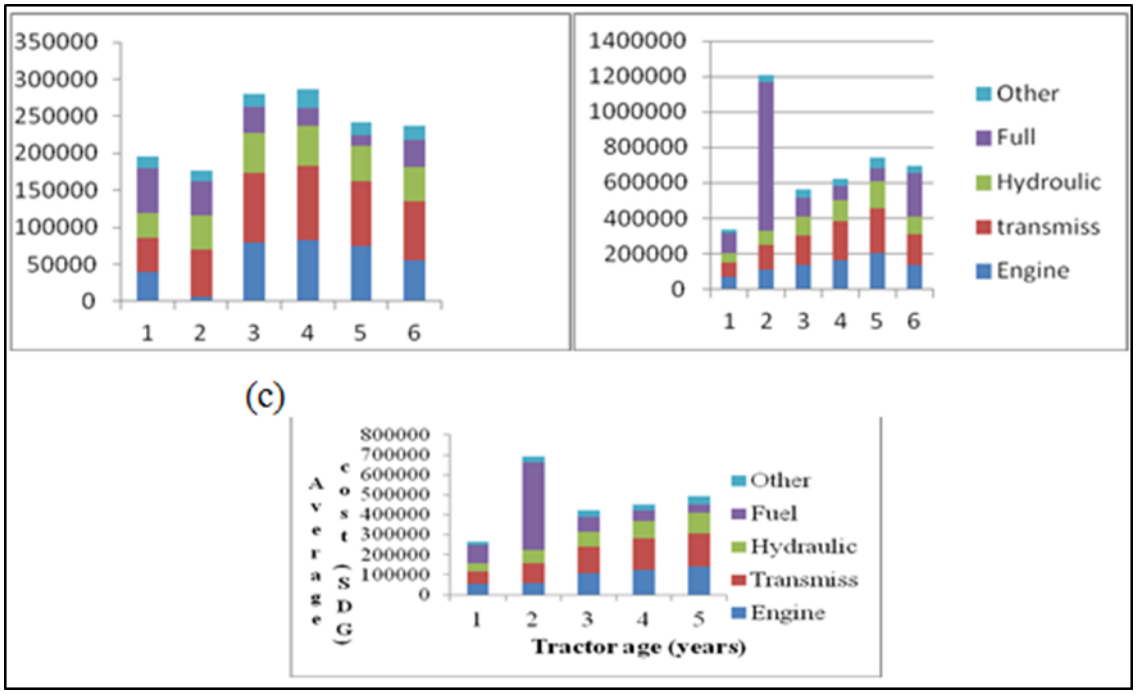

Figure 2. Distribution of repair and maintenance costs of agricultural tractor systems (a) 75 hp tractor (b) 150hp tractor (c) mean of two types

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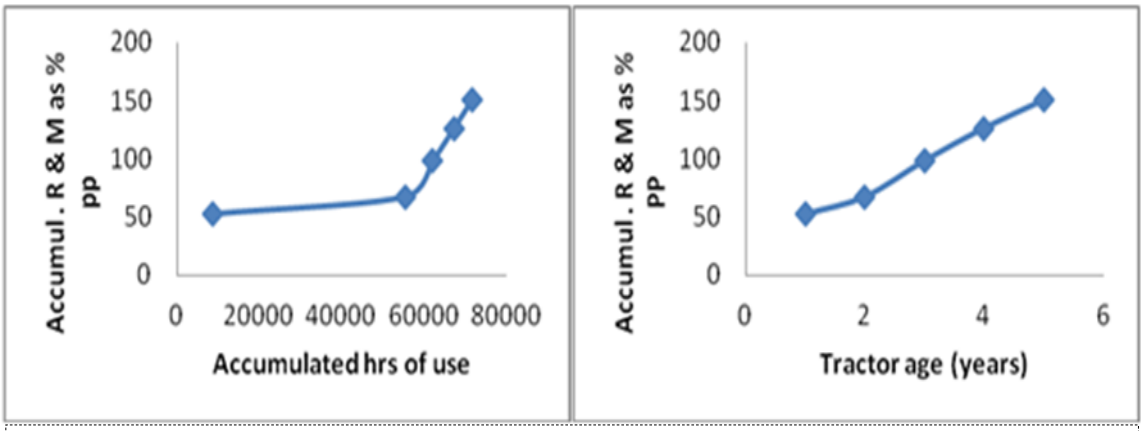

Figure 3a. Accumulated repair and maintenance costs as percent of purchase price as affected by hours of use and age (year) for the75Hp tractor

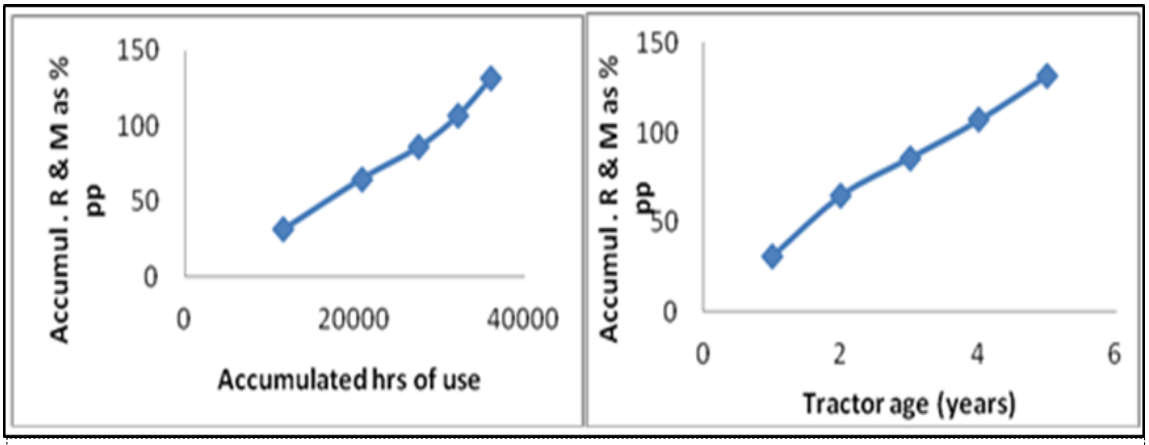

Figure 3b. Accumulated repair and maintenance costs as percent of purchase price as affected by hours of use and age (year) for the150 Hp tractor.

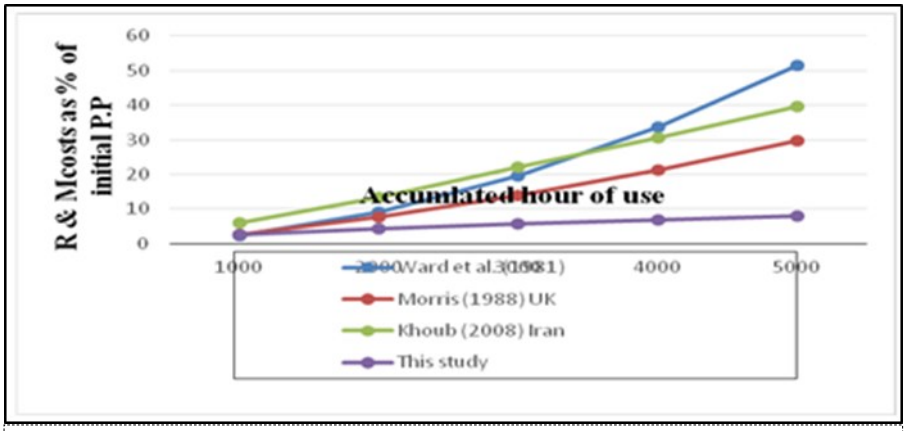

Figure 4. Comparison of the present study prediction models with other models in world

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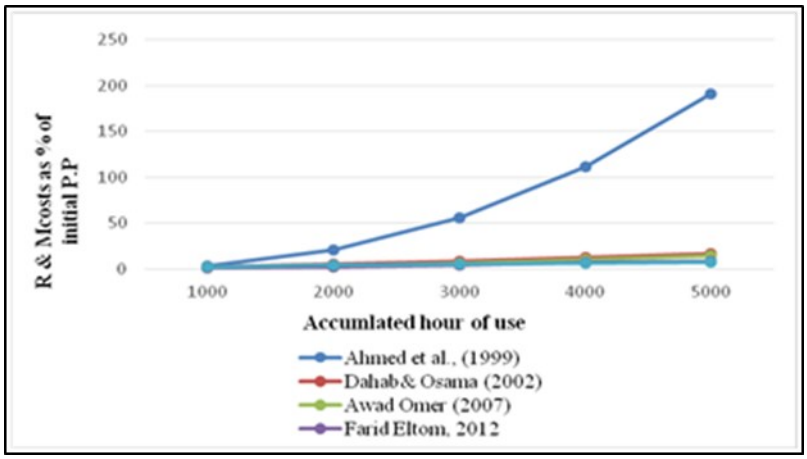

Figure 5. Comparison of the present study prediction models with other models in Sudan

models of linear, polynomial, logarithmic, power and exponential with correlation coefficient (Table 2). The value of correlation coefficient among the presented models was related to polynomial model with $R^2 = 0.86$ and the highest value of correlation was for power model with $R^2 = 0.93$ which is very close to the previous studies. In the most published studies in this field, power models were found easy in calculations and gave better cost predictions than the other models. Therefore, the small difference between the correlation coefficients of polynomial and power models and using of power model by other researchers, in the present study, power model was suggested as suitable form for repair and maintenance cost estimation. The power relations of accumulated R and M costs with accumulated hours of use and tractor age in years of study for the two tractor type and the average of the two types are given in Table 3 and Table 4, The average correlation coefficient was very high ($R^2 = 0.93$) indicating that the tractor age and accumulated hours of use could adequately explain variations in R&M costs.

Fig. 3, Fig 4, Fig 5 were predicted low accumulated R & M costs of the early stage tractor life, and then costs increased gradually with increasing age and accumulated hours of use in 75hp tractor type. The distribution of the accumulated repair and maintenance cost of different tractor system was increased gradually from fuel, transmission, engine hydraulic and other.

Comparison of the Present Study Prediction Models with Other Models in the World

The model of the average accumulated repair and maintenance costs predicted in this study was compared to the other similar models from USA, UK, and Ireland as shown in Table (5). It was clear that the present derived model accounted for relatively lower values of accumulated repair and maintenance costs compared to the world mentioned models. These variations 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 programmer 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 world countries.

Comparison of the Present Predictions Model with Other Models Developed in Sudan

When the predicted model in this study is compared to the other models from Sudan as shown in

Table 6. Comparison between the present study estimates of repair and maintenance costs as percentage of initial purchase price with other estimates from world

Source	Model	Repair and maintenance costs as % of initial purchase price				
		1000	2000	3000	4000	5000
Ward et al. (1981)	$y = (4.82x^{1.9}).10^{-6}$	2.4	9	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	30.7	39.7
This study	$Y=0.028x^{0.662}$	2.71	4.29	5.61	6.78	7.87

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

Table 7. 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 etal., (1999)	$y = (2.53x^{2.4}).10^{-7}$	4	21.2	56	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
Farid Eltom, (2012)	$y = (1.7x^{1.29}).10^{-4}$	1.3	3	5.2	7.5	9
This study	$Y=0.028x^{0.662}$	2.71	4.29	5.61	6.78	7.87

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

Table 6 it was observed that this model accounted for lower (1999) for all levels of accumulated hours of use, but after 2010 accumulated hours of use the rate of increase in accumulated repair and maintenance costs was gradual in this study while was very sharp[16] model. This may be attributed to differences in spare parts, oils and lubricants prices within the country also may be due to variations in repair rates, frequent breakdowns, labor charges for repairing and maintaining tractors and operators and mechanics skills. Table 7

When the model of this study was compared to Dahab and Osama (2002)[15] model for repair and maintenance costs, it was clear that the estimates of the present model accounted for lower values than[15] up to 2011 accumulated hours of use, after which this model accounted for higher values. This may be attributed to variations in tractors specifications, ages and makes.

The comparison between this model[17] prediction showed that the present model accounted for higher values of repair and maintenance costs [17] for all levels. This may be due to conditions of work, operators and mechanics skills, maintenance regime followed and labor charges for repairing and maintaining of tractors. The difference may also be attributed to differences in tractors technical specifications and cost computations methodology, however when the model of this study was compared[18], it was clear that the estimates of the present model accounted for larger values until 2025 accumulated hours of use, after which this model accounted for lower value. This may be attributed to variations in tractors specifications, condition of work and skills of mechanics and operators.

Conclusions

The following conclusion may be drawn from the present study

1. The relationship between accumulated repair and maintenance costs as percentage of the initial purchase price of the tractor and accumulated hours of use and age in years for the two tractors in Dongla area could better be described by the power function equation.
2. The accumulated repair and maintenance costs increase with tractor age and hours of use.
3. The predicted models for repair and maintenance costs of tractors in Sudan were lower than those of other countries; therefore, each area or country develops its own models of R&M costs to its operational and field conditions.

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