

Repair and Maintenance Costs Estimation as Affected by Hours of Use and Age of Agricultural Tractor in New Halfa Area - Sudan

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Abstract – A field survey was carried out in the New Halfa irrigated agricultural scheme of Sudan to collect data on tractor repair and maintenance costs. Random samples representing three tractor makes were collected. Based on the data collected, mathematical models were derived to predict the accumulated repair and maintenance (R & M) costs as percent of purchase price in relation to accumulated hours of use and age (years) of each tractor make, and also for the three makes collectively. Five model forms (linear, logarithmic, polynomial, power and exponential) were analyzed and the power function was found the best to explain the relation. The accumulated R&M costs as percent of purchase price (Y) increased as the accumulated hrs of use (x) and age (g) of the tractor increased.

$$Y = 4E-05 x 1.527; Y = 1.883 g^{1.101}$$

High correlation was found between the accumulated R&M cost and both accumulated hours of use and tractor age in years (Average $R^2 = 0.99$).

Keywords – Repair, Maintenance, Hours of Use, Age, Tractor, New Halfa.

I. INTRODUCTION

Agricultural tractors generally represent an important item of power budget in agricultural farming systems. Now a days they are the main source of farm power which almost replaced the other sources for many heavy and time consuming operations [1] and [2]. 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. [3] reported that the tractor breakdowns and failures 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 they require regular care or maintenance to reduce failures and extra costs and to protect the machine from wearing down quickly [4]. [5] reported that poorer and irregular maintenance reduces tractor reliability, increases fuel consumption, decreases engine power and life and increase exhaust emission.

The repair and maintenance (R&M) costs are the most important parts of machine operating costs and they are dependent on the amount of usage and the age of the tractor. These costs are generally estimated to be 10 – 20% of the total costs [6] - [7] and [8].

Several studies were conducted in both developing and under developed countries to develop mathematical relations to estimate the cost of repair and maintenance [9] - [10].

It was possible to develop mathematical relationship between accumulated hours of use; tractor age and purchase price to predict accumulated R & M costs [11] - [12] – [13]. Most of these relations can best be described by a power function equation in the form; $y = ax^b$. Using of American and European mathematical relations to estimate R & M costs in under developed and, developing countries produced unrealistic and misleading results and therefore, these countries developed their own mathematical models (e.g., [14]; [15]; [16] and [17].

In the Sudan agricultural tractors were introduced in early nineteen's century and there are many tractor makes, models and sizes now distributed between irrigated and rain-fed agricultural farms. These tractors are owned by private and public sectors and even some are owned by individual farmers and they often work for more that 1200 hrs per year [18]. Many breakdowns and failures were recorded which cost the owners a lot of money for repairing and maintenance. 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 [18].

Some mathematical relations were developed in the Sudan for R & M costs estimation for agricultural tractors [15]; [19]; [20]. They are varied in structure components due to differences in tractors specifications and conditions and locations of work, therefore, it is difficult to depend on one model for proper repair and maintenance management decisions. The aims of this study are to (i) develop appropriate mathematical models relating accumulating R&M costs to age and hours of use for three tractor makes and (ii) compare the derived model with other models in other countries.

II. MATERIALS AND METHODS

A field survey was carried out in New Halfa irrigated agricultural scheme, in the central clay plain of eastern Sudan, to collect data on tractor repair and maintenance costs items. The soil of the scheme is vertisols containing about 60 – 65% montmorillonite clay particles, poor in nitrogen and organic matter [21].

A questionnaire was designed to collect the required data and information on tractor model, make, age, initial purchase price, annual hours of use, annual area covered, annual repairs and maintenance of different tractor systems and their costs (spare-parts and labour) and repair and maintenance times in hours. These data were collected by interviewing and direct contacting individuals in public and private workshops, agricultural engineers and mechanics, private tractor owners and operators.

The commonly used three tractor makes in the scheme were selected for this study and named as Make M, Make B and Make F. All of the tractors were 2-WD and their rated power range was 65 – 89 hp, and they were 1– 15 years old. The total number of surveyed tractors was 121 units (43 Make M, 45 Make B and 33 Make F).

The tractor systems studied were grouped as follows; engine, fuel systems, transmission system, hydraulic system and others. It was difficult to find all information and data required for individual tractor every year; therefore, for the same make the data for 1 – 3 years old tractors was averaged and used for the study. For each age group, the average annual hours of use, the average repair and maintenance costs were calculated. Finally, summations of the total means up to the last year in the age of the selected tractor make were determined [9].

Statistical analysis was performed using the computer statistical package (SPSS). Five models; linear, polynomial, exponential, logarithmic and power were used (Table 1) to perform the correlation regression relations and obtain the best fit equation to estimate repair and maintenance costs.

Table 1. Mathematical models for correlation regression relations

Models	Equation
Linear	$y = ax + b$
Logarithmic	$y = a \ln x + b$
Polynomial	$y = ax^2 + bx + c$
Exponential	$y = a^{expb}$
Power	$y = ax^b$

III. RESULTS AND DISCUSSION

It was observed the average repair and maintenance costs of different systems for the three tractor makes generally increased with age, but the rate of increase varies for the three makes (Table 2). However, the mean R&M cost of the three tractor makes showed relatively higher repair and maintenance costs occurred from year 10 and above (Fig. 1).

This is in line with the findings of [16]. The engine and transmission unit accounted for more than 58% of the total accumulated R & M costs of the three tractor makes when 15 years of ownership was considered (Fig. 2). The distribution of the accumulated R & M cost of different tractor systems was almost similar for the three makes, but the hydraulic system R & M cost of Make (B) was higher compared with the other two makes.

Table 2. Repair and maintenance costs distribution for the different tractor systems of the three makes

System Age(yrs)	Engine	Fuel	Transmission	Hydraulic	Others
<u>Make M</u>					
1-3	260	128	162	106	62
4-6	298	166	318	158	91
7-9	295	175	366	210	69
10-12	313	221	432	231	94
13-15	300	220	430	178	50
Mean	293	182	342	183	73
<u>Make B</u>					
1-3	245	146	185	182	97
4-6	298	178	396	247	97
7-9	308	186	432	268	83
10-12	308	197	468	289	95
13-15	318	186	472	288	25
Mean	295	179	391	255	79
<u>Make E</u>					
1-3	284	155	188	146	93
4-6	288	197	398	192	97
7-9	302	207	416	190	22
10-12	306	205	435	208	63
13-15	308	195	468	218	76
Mean	298	192	381	191	70

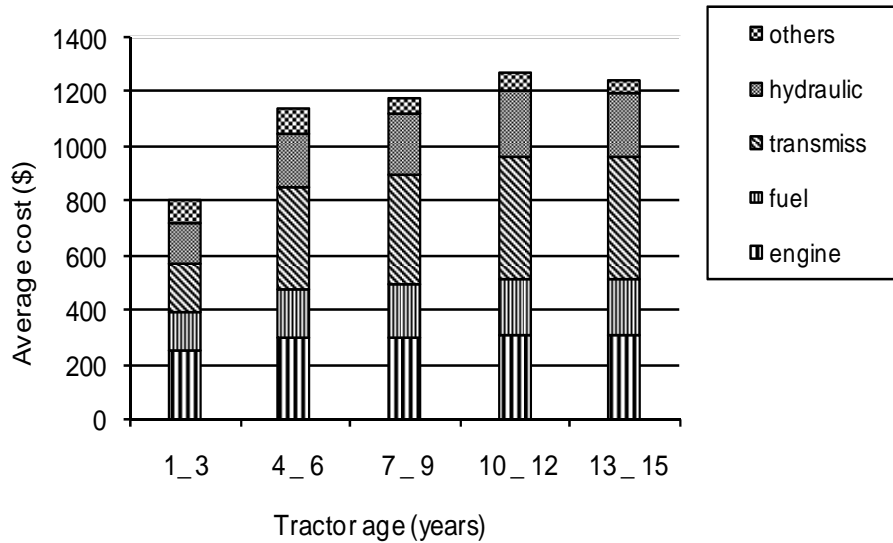


Fig. 1. Average repair and maintenance of different agric tractor systems (mean of three makes)

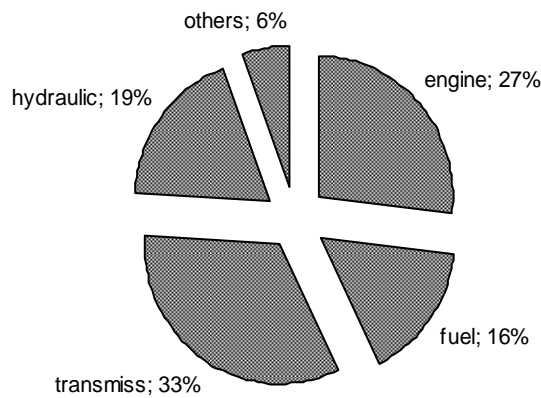


Fig. 2. distributions of accumulated repair and maintenance of t agric tractor systems (mean of three makes)

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 three tractor makes, on the models 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 $R^2 = 0.997$ and after that power model with $R^2 = 0.993$ 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. 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 the final form for repair and maintenance cost estimation. The power relations of accumulated R&M costs with accumulated hours of use and tractor age in years of the three make and the average of the makes are given in Table (4). The average correlation coefficient was very high ($R^2 = 0.99$) indicating that the tractor age and accumulated hours of use could adequately explain variations in R&M costs.

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

Model	Equation	R square
Linear	$Y = 0.0062x - 10.25$	0.962
Logarithmic	$Y = 23.03\text{Ln}(x) - 169.9$	0.771
Polynomial	$Y = 5E-07x^2 + 0.001x + 0.16$	0.993
Exponential	$Y = 2.144e^{0.0004x}$	0.942
Power	$Y = 4E-05x^{1.527}$	0.997

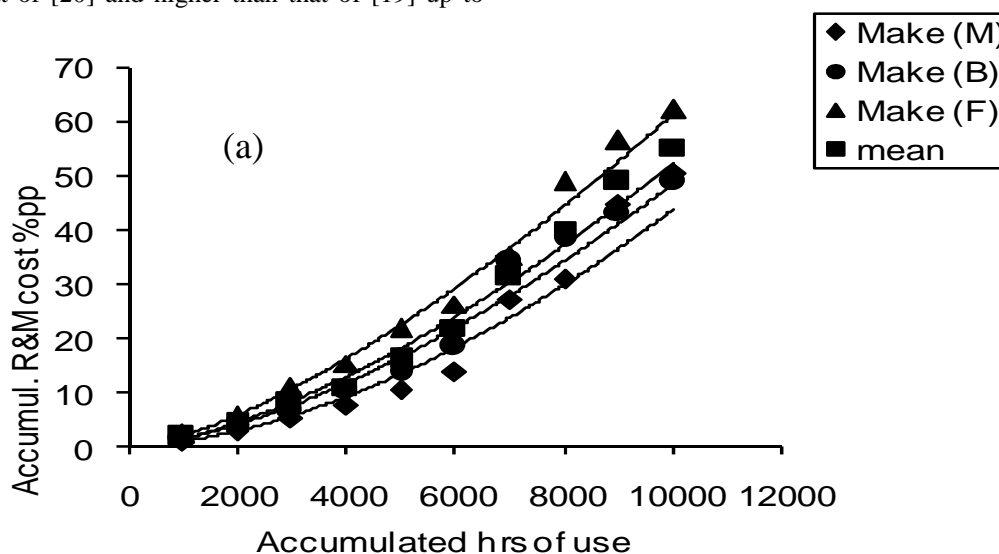
Table 4. The power relations of accumulated R&M costs with accumulated hours of use and tractor age (years) of the three makes

Tractor makes	Power model	R square	F
<u>Hours of use</u>			
Make M	$Y = 6E-06 x^{1.718}$	0.981	85.6 ^{ns}
Make B	$Y = 3E-05 x^{1.563}$	0.988	167.7 [*]
Make E	$Y = 0.0001 x^{1.439}$	0.996	266.0 [*]
Mean	$Y = 4E-05 x^{1.527}$	0.997	270.8 [*]
<u>Age (years)</u>			
Make M	$Y = 1.243 x^{1.182}$	0.995	168 [*]
Make B	$Y = 2.036 x^{1.114}$	0.997	325 [*]
Make E	$Y = 2.339 x^{1.049}$	0.964	110.7 [*]
Mean	$Y = 1.883 x^{1.101}$	0.989	182.8 [*]

The mathematical models predicted low accumulated R&M costs at the early stages of tractors life, and then costs increased gradually with increase in age and accumulated hours of use (Fig 3a, b). These findings are in line with those of [15]; [17]; [20] and [22].

Make (M) accounted for the lowest magnitude R & M costs at all levels of accumulated hours of use and tractor age while Make (F) accounted for the highest accumulated R&M cost as percent of purchase price. The variation in R&M costs between the three tractor makes may be attributed to spare -parts prices, technical know-how of operators and mechanics and maintenance management. The mathematical model developed from the mean accumulated R&M costs of the three makes was compared with other prediction models developed before in Sudan (Fig.4). The predictions of the present study model was similar to that of [20] and higher than that of [19] up to

4500 accumulated hours of use. Afterwards, it was higher than both of them. These variations may be attributed to differences in types and frequency of breakdowns, repair rates, spares-parts types and prices, labour charges and technical skills of operators and mechanics. The power model developed from mean accumulated R&M cost and accumulated hours of use of the three makes was also compared with similar models from different world countries (Fig.5). The mathematical model of the present study predicted the lowest accumulated R&M costs compared to the models from Africa, U.K. and U.S.A. This may be due to use of spurious and non-genuine spare-parts and also due to lower labour charges for repairing and maintaining of tractor systems in Sudan or may be attributed to differences in tractor specifications and condition of work.



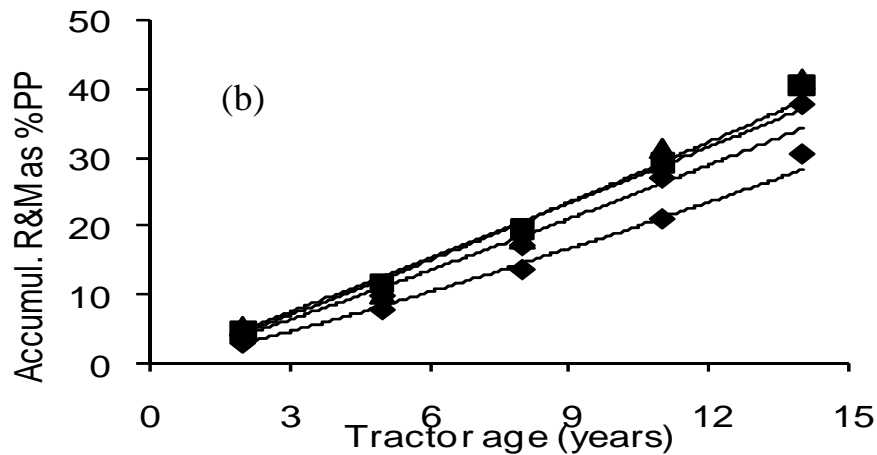


Fig. 3. Accumulated repair and maintenance costs as percent of purchase price as affected by (a) hours of use (b) tractor age (year) for the three tractor makes.

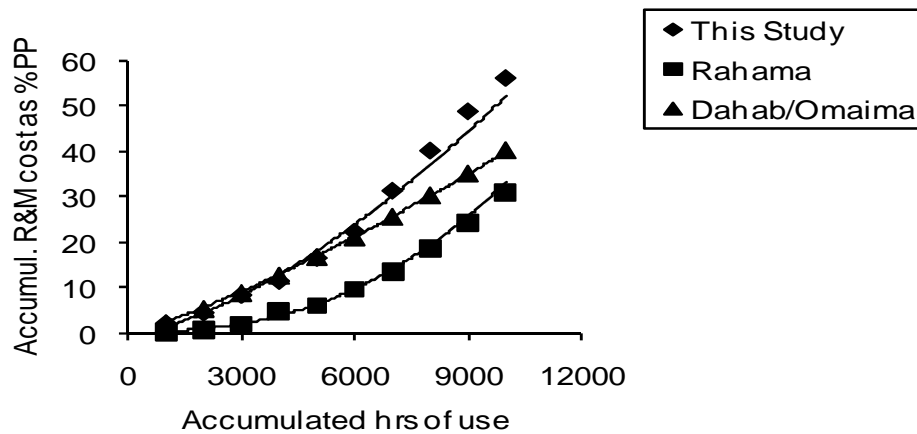


Fig. 4. Comparison of some repair and maintenance cost prediction models (Sudan)

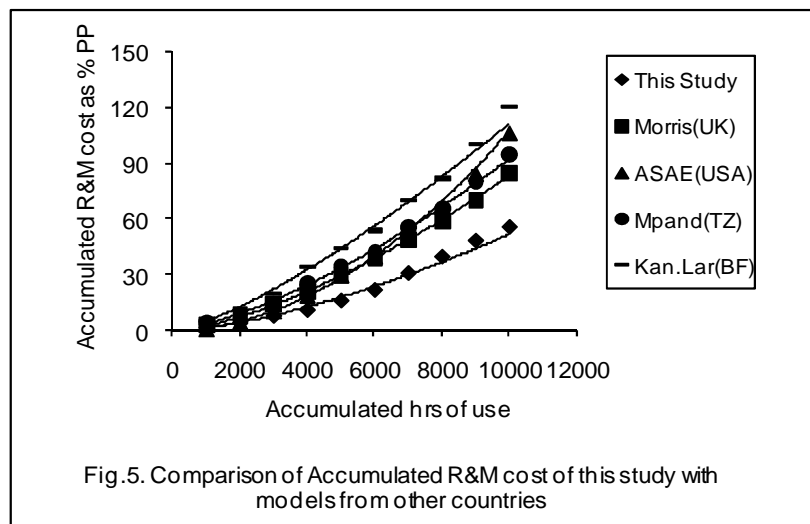


Fig.5. Comparison of Accumulated R&M cost of this study with models from other countries

IV. CONCLUSIONS

For 15 years of operations, engine and transmission system accounted for more than 58% of the total R&M costs of the tractor.

The accumulated repair and maintenance costs of the selected tractor makes as percent of purchase price in relation to accumulated hours of use and age of tractor in years, could best be described by the power function equations.

Each area or country develops its own models of R&M costs to its operational and field conditions.

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