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ECONOMIC EVALUATION OF TRACTOR USEFUL LIFE AS A DECISION-MAKING TOOL FOR AGRICULTURAL PRODUCTIVITY AND RURAL DEVELOPMENT IN SOUTH SUDAN

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Original research

ABSTRACT

The objective of this study was to develop the mathematical model that can be used to predict the useful life for Sonalika DI-90 farm tractors in Juba. Data that sought the costs for spare parts, repairs, oils, oils and fuel filters, grease, tire replacement, fuel, and tractor operator, in addition to the annual operating hours and the purchase or list price were collected using well-structured questionnaires. The Microsoft Excel 2010 was used to perform regression analysis on the accumulated total cost per hour which was considered as a dependent variable and thus, labelled on Y-axis and the age of operation that was regarded as an independent variable and thus, labelled on Y-axis. The five models of exponential, linear, logarithmic, polynomial, and power were tried and it was determined that the polynomial model was the suitable model for predicting the useful life for the Sonalika DI-90 farm tractors operated in the two areas of Mapel and Rajaf East South of the Capital City of South Sudan Juba. The useful life for Sonalika DI-90 farm tractors was determined to be 18 years, with an accumulated operating hours of 4096.10 hours of operation.

1. INTRODUCTION

The estimation of the economic useful life of farm tractors has important implications for rural development and agricultural productivity in developing regions. Efficient replacement timing of agricultural machinery can reduce operational costs, improve mechanization efficiency, and enhance farm output sustainability. In the context of South Sudan's agricultural sector, optimization of tractor economic life supports better capital allocation for farmers and agricultural enterprises, contributing to food security, improved farm management practices, and long-term rural economic stability. According to Kepner *et al*. (1982), the total cost for carrying a certain farming operation entails the repair and maintenance cost, the fuel cost, and the tractor operator cost. Kepner *et al*. (1982) also stated that the total cost of operation for the farm tractor or an implement per unit area or per unit time could be minimized by increasing the hours of operation in order to reduce the ownership cost per unit area or unit time. The costs for owning and operating farm tractors and implements approximate 35% to 50% of the total costs of farm production excluding the cost for land ownership (Anderson, 1988).

The costs for owning and operating farm tractors and implements are classified into two broader costs of ownership, fixed or overhead costs which included depreciation, interest on investment, and taxes, insurance and housing or shelter and the operating or variable costs which included repair and maintenance (R&M), fuel, and labor (tractor operator). The ownership costs are costs

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incurred due to the ownership of the farm tractor or an implement which means due to the farm tractor or farm implement not being operated and these costs are time-related. The costs for owning the agricultural equipment represent substantial part of the costs for crop and animal production (Cross, 1995).

The cost of depreciation for a farm tractor or an implement determines the lost in it's market value (price) over the period of ownership (Kaul & Egbo, 1985). It measures the quantity of lost in market value (price) of an agricultural equipment from one year of ownership to another regardless of whether that particular equipment has been used or not (Hunt, 1979).

The cost of the interest on the investment in a farm tractor or an implement is the cost that cannot be employed by another productive entity and it is estimated to be around 8% (Hunt, 1979). As it is the case with the cost of depreciation, the cost of the interest on the investment in an agricultural equipment is higher during it's early years of operation than it is during it's late years of operation. It is customary to use a fix rate to compute the annual and the accumulated interest on investment in an agricultural equipment (O'Callaghan., 1990) and (Witney, 1988; Witney & Saadoum; 1989). According to Hunt. (1979) the cost of taxes for one decade time is about 1% to 5% of the purchase price of a farm tractor or an implement. Hunt. (1979) also stated that the annual cost of insurance is about 0.25% of the purchase price. The farm tractor or an implement has to be insured or the owner will risk losing huge amount of money in case of an accident (Liljedhal *et al*., 1979). As for the cost of housing (shelter), Liljedhal *et al*. (1979) stated that it is about 1% of the purchase price. Whereas, ASAE. (1997) indicated that the housing (shelter) cost is approximately 0.75% of the purchase price. In case the actual data values for the costs of taxes, insurance and housing are unknown, then, the following percentages of 1%, 0.5%, and 0.75% of the purchase price should be used for them respectively (ASAE, 1983) or a total of 2% of the purchase price should be used to represent the three of them (ASAE., 1983; William, 2015).

The operating costs of a farm tractor or an implement is influenced by the following factors of purchase or list price, cost of fuel, cost of labour, terrain, etc to such an extent that each and every country within the same region or even each and every area within the same country has to establish their own numerical values and use the costs standards put forward by other countries or areas for the purpose of comparison only. Thus, it is harder to compute the operating costs for a certain entity or certain farming operation. The operating costs for a farm tractor or an implement are expenditures for spare parts, repair, lubricants and lubrication, grease and greasing, and labour. Operating costs are use-related costs, that is to say, they increase as the use of a farm tractor or an implement increases and vice versa. The cost parameter of repair and maintenance (R&M) belongs to both operating and ownership costs or in another words, it demonstrates both constant and variable characteristics (Singh, 1997; Singh, 2006a; Singh, 2006b). The cost of repair and maintenance (R&M) differs greatly from one farm tractor to another in accordance with the amount of care given to it by the farm power and machinery manager (Srivasava *et al*., 2006). The cost of repair and maintenance is positively impacted by it list price, the accumulated operating hours, and it's size (Rotz & Bowers, 1991). The costs for repair and maintenance (R&M) of a farm tractor increase with an increase in it's purchase price, it's size, and it's complexity. Generally speaking, the costs parameters pertinent to the operating costs of a farm tractor including repair and maintenance (R&M) cost or the operating or variable costs as a whole increase with an increase in it's operation. The cost of repair and maintenance for a farm tractor tends to be around 10% during the early years of it's operation, but as it ages, it increases until it becomes one of the important cost for owning and operating farm the tractor (Rotz and Bowers, 1991). The costs for lubricants (oils and grease) and lubrication (Maintenance) is usually estimated to be 5% to 15% of the fuel costs. According to the Nebraska Test Data, the lubrication (maintenance) costs for unpowered farm equipment is 5% of the purchase price, whereas, the lubrication costs for powered farm equipment is 15% of the fuel costs.

The costs for fuel is computed by multiplying the cost of fuel in gallon by the fuel consumption with an average diesel fuel consumption for tractors, combines, trucks, etc being 0.44 gallons per PTO horsepower-hour (Lazarus., 2009). The costs of fuel can be calculated per hectare or acre. The costs for the labour (tractor operator) should be included when it comes to the computation of the total cost of operation of a farm tractor or an implement and it should cover the benefits and taxes. According to Lazarus. (2009), the costs for labour (tractor operator) charged at a rate of an hourly wage include 30% as a rate of charged benefits per hour for both skilled and unskilled labors (tractors' operators). The costs for labors are usually computed using the labor's cost per hour. An adjustment factor is employed in order to compute the total hours of labor from the operation of a farm tractor or an implement excluding time for locating, hooking up, adjusting, and transporting machine. Some adjustments are added to the cost of labor to cover the downtime for such tasks as making adjustments, and filling sprayers and planters. These adjustments range from 2% for tilling operations to 33% for spraying operations.

The total cost of the farm tractor is the cost of owning and operating the farm tractor. In other words, it is the summation of the ownership cost and the operating cost of the farm tractor. The useful life of the farm tractor is the period of time during which the increase in the total cost of operating the farm tractor per unit time is still profitable for the agricultural business. Another way round, it is that specific year of operation after which continuing to operate or even own the farm tractor is no longer profitable for the farming business, and thus, replacing such a farm tractor or that fleet of farm tractors will definitely result into an agri-business saving thousands of dollars of production costs.

Several studies have been carried out concerning the useful life of farm tractors by so many researchers from around the world, few to mention of them are the ones of Ashtiani. (2005), conducted one more study at Dashte-Naz Agro-industry Co. of the Islamic Republic of Iran to determine the economic life for MF285 farm tractors operating in the study area at the time and the results concluded that the economic life for MF285 farm tractors in the study area is 8 years with an accumulated operating hours of 11554 hours. Another study that aimed at determining the appropriate replacement time for MF285 farm tractor was carried out in the Ahvaz area of Iran by Abbas Asakereh *et al*. (2012) and their result revealed that the appropriate replacement time for MF285 farm tractors operating in Ahvaz is 14 years at an accumulated operating hour of 6981 hours. One more Study was conducted by Pagare *et al*. (2019) carried out a study in the Indian Central Region of Madhya Pradesh to determine the economic life of farm tractors operating in the region and their study concluded that, the economic life of 60 HP farm tractors is 5 years.

This study set out to develop a mathematical model to predict the economic life for Sonalika DI-90 farm tractors operated in the study area of Mapel North of Juba City. Specifically, this study aimed at identifying the operating costs parameters, establish their numerically values, to determine the economic life for Sonalika DI-90 farm tractors operated in Juba City from the accumulated total cost per hour, to develop the mathematical model to predict the economic life for Sonalika DI-90 farm tractors, to compare the determined economic life for Sonalika DI-90 farm tractors with the determined economic life for other farm tractors operated in other areas around the world, and to compare the mathematical developed for the prediction of Sonalika DI-90 farm tractors with the mathematical models developed for the prediction of other farm tractors operated in other areas around the world.

2. MATERIALS AND METHODS

2.1 Study Area

This study was conducted in the Mapel Area of the Capital City of the Republic of South Sudan Juba which is also the Capital City of the Central Equatoria State, one of the ten states into which the Country is divided and that was in the two Months of September and October of the year 2016.

2.2 Tractor Material

The Sonalika DI-90 farm tractor has a water-cooled 4 cylinder diesel engine of 90 HP with a power take off (PTO) of 76.5 HP, an engine capacity of 4087 cc, a 2200 RPM, and with a dry type air filter with pre-cleaner and clog indicator. It has a synchromesh transmission system with a 4 WD and a 12-forward+12-reverse gearbox.

Figure 1. Sonalika DI-90 Farm Tractors Operated in the Mapel Area of the Capital City of South Sudan Juba

It also features a power steering type with an oil immersed brakes as well as a 3-point hitch category II hydraulic system with an automatic depth and draft control (ADDC).

2.3 Data Collection

The data collected for this study were the costs for repair and maintenance, fuel and the tractor operator, in addition to the purchase or list price and the annual hours of operation for Sonalika DI-90 farm tractors and they were collected using the questionnaires.

2.4 Calculation of the Accumulated Fixed Cost Parameters for the Sonalika DI-90 Farm Tractors

Calculation of the Accumulated Depreciation Cost for the Sonalika DI-90 Farm Tractors

Annual depreciation cost for each and every year of operation for Sonalika DI-90 farm tractors studied were computed using a straight line method for computation of depreciation presented in the below equation (1) (Hunt, 1983). The mean annual depreciation cost per each year of operation was computed, and the accumulated depreciation cost for every year of operation for Sonalika DI-90 farm tractors were computed by summing up the mean annual depreciation cost.

$$D = \frac{P - S}{L} \qquad [1]$$

Where:

D = Depreciation.
S = is the selling or salvage value.
P = list (Purchase) price.
L = Time between purchase (buying) and selling in years.

2.5 Calculation of the Accumulated Cost of the Interest on the Investment for the Sonalika DI-90 Farm Tractors

Annual cost of the interest on the investment were computed for each and every year of operation for the Sonalika DI-90 farm tractors studied and that is by employing an interest rate of 15% declared by the Central Bank of South Sudan for the fiscal year of 2016 using equation (3) below. Mean annual cost for the interest on the investment for each and every year of operation was then computed, and the accumulated cost for the interest on the investment for each year of operation were computed by summing up the mean annual cost. The interest rate can also be computed using the below equation (2) below (William Edwards., 2015).

$$I_r = \frac{Ip+Ig}{1+Ig} \quad [2]$$

Where: I_r = is the real interest rate.

I_p = is a nominal interest rate.

I_g = is the rate of inflation.

The cost of the interest on the investment for Sonalika DI-75 farm tractor was calculated by employing the below equation (3) (William Edwards., 2015).

$$I_n = V * I_r \quad [3]$$

Where:

I_r = is the rate of interest.

I_n = is the interest on investment in nth year ($).

V = is the remaining value at any time.

2.6 Calculation of the Accumulated Cost of Taxes, Insurance and Housing for the Sonalika DI-90 Farm Tractors

The three costs of taxes, insurance, and housing for the Sonalika DI-90 farm tractors studied were added together to be 2% of the purchase or list price, and then computed for each and every year of operation (William Edwards., 2015). Both the purchase or list price and the remaining values were employed for computing the annual cost of taxes, insurance, and housing for the Sonalika DI-90 farm tractors. The mean annual value for the costs of taxes, insurance, and housing were then computed per each year of operation, and the accumulated value for the costs of taxes, insurance, and housing were computed for per each year of operation for the Sonalika DI-90 farm tractors by summing up the mean annual value for the costs of taxes, insurance, and housing.

2.7 Calculation of the Accumulated Ownership Cost for the Sonalika DI-90 Farm Tractors

The accumulated ownership cost for each and every year of operation of Sonalika DI-90 farm tractors was computed by adding up the annual accumulated values for the costs of depreciation, interest on investment, taxes, insurance, and housing.

2.8 Calculation of the Accumulated Operating Cost Parameters for the Sonalika DI-90 Farm Tractors and Calculation of the Accumulated Repair and Maintenance (R&M) Cost for the Sonalika DI-90 Farm Tractors

The annual cost of repair and maintenance for each and every year of operation for the Sonalika DI-90 farm tractors was computed by adding up the annual values for the costs of spare parts, repairs, lubricants and lubrication, oil and fuel filters, grease and greasing, tire replacement. The mean annual cost of repair and maintenance was then computed for each year of operation, and the Accumulated cost of repair and maintenance was computed by adding up the mean annual cost of repair and maintenance (Ward *et al.*, 1985). The accumulated cost of repair and maintenance can also be computed using the below equation (4) (Hunt, 1983).

$$\frac{C_{rm}}{P_u} = RF1\left(\frac{t}{1000}\right)^{RF2} \quad [4]$$

Where:

RF1, RF2 = Repair factor.

P_u = Purchase price.

t = Accumulated use (h).

C_{rm} = Accumulated repair and maintenance cost.

2.9 Calculation of the Accumulated Fuel Cost for the Sonalika DI-90 Farm Tractors

Annual costs of fuel were computed for each and every year of operation for the Sonalika DI-90 farm tractors studied. Mean annual cost of fuel per each year of operation was then computed, and the accumulated cost of fuel per each year of operation was computed by adding up the mean annual cost of fuel (Ward *et al.*, 1985). On the annual basis, the average fuel consumption in gallons per hour for the agricultural tractor without referring to specific agricultural equipment can be computed using the two below mentioned equations of (5) for gasoline engine and (6) for diesel engine (William Edwards., 2015).

$$0.06 * maximum\ PTO \quad [5]$$

$$0.44 * maximum\ PTO \quad [6]$$

Where:

PTO = Power take off power.

2.10 Calculation of the Accumulated Tractor Operator (Labor) Cost for the Sonalika DI-90 Farm Tractors

The annual tractor operator cost was computed for each and every year of operation for the Sonalika DI-90 farm tractors studied. The mean annual tractor operator cost per each year of operation was then computed, and the accumulated tractor operator cost per each year of operation was computed by adding up the mean annual tractor operator cost (Ward *et al.*, 1985). The wages for all farming operations carried out by the Sonalika DI-90 farm tractors studied were multiplied by 1.1 or 1.2 and that is due to the fact that the actual hours of operation exceed the field hours of operation by 10% and 20% because of refilling the equipment, greasing (William Edwards, 2015).

2.11 Calculation of the Accumulated Operating Cost for the Sonalika DI-90 Farm Tractors

Annual operating cost per each and every year of operation was computed by adding up the annual values for the costs of repair and maintenance, fuel, and tractor operator. The mean annual operating cost per each year of operation was then computed, and the accumulated operating cost per each and every year of operation for the Sonalika DI-90 farm tractors studied was computed by adding up the mean annual values for the costs of repair and maintenance, fuel, and the tractor operators (Ward *et al.*, 1985).

2.12 Calculation of the Accumulated Total Cost for the Sonalika DI-90 Farm Tractors

The accumulated total cost per each and every year of operation for the Sonalika DI-90 farm tractors studied was computed by adding up the accumulated ownership cost per each year of operation for the Sonalika DI-90 farm tractors to the accumulated operating cost per each year of operation.

2.13 Calculation of the Accumulated Operating Hours for the Sonalika DI-90 Farm Tractors

The operating hours per each and every year of operation for the Sonalika DI-90 farm tractors studied was computed. The mean annual operating hours for each year of operation was then computed, and the accumulated operating hours per each and every year of operation for the Sonalika DI-90 farm tractors studied was computed by adding up the mean annual operating hours (Ward *et al.*, 1985).

2.14 Calculation of the Accumulated Total Cost per Hour for the Sonalika DI-90 Farm Tractors

The accumulated total cost per an hour of operation per each and every year of operation for the Sonalika DI-90 farm tractors studied was computed by dividing the values for the accumulated hours of operation for each year of operation for the Sonalika DI-90 farm tractors by the accumulated operating hours for each year of operation.

2.15 Determination of the Useful Life for the Sonalika DI-90 Farm Tractors

The useful life was determined to be the year of operation for the Sonalika DI-90 farm tractors studied in which the value for the accumulated total cost per an hour of operation is the minimum or in other words, the lowest point of the curve for the accumulated total cost per an hour of operation.

2.16 Development of the Mathematical Model for the Prediction of the Useful Life for the Sonalika DI-90 farm tractors

The mathematical model for the prediction of the useful life for the Sonalika DI-90 farm tractors studied was developed from the two variables of the accumulated total cost per an hour of operation, and the age of its operation in years. The accumulated total cost per hour was labeled on the Y-axis because it was considered as a dependent variable, whereas the age of operation for the Sonalika DI-90 farm tractors studied was labeled on the X-axis because it was considered as an independent variable (S. N. Wilba *et al.*, 2018).

2.17 Data Analysis

The Microsoft Excel 2010 was used to perform the regression analysis on the values for the accumulated total cost per an hour of operation for the Sonalika DI-90 farm tractors studied which was labelled on the Y-axis because it was considered as the dependent variable and the age of operation for Sonalika DI-90 farm tractors studied which was labelled on the X-axis because it was considered as an independent variable.

3. RESULTS AND DISCUSSIONS

3.1 The Accumulated Ownership Cost for the Sonalika DI-90 Farm Tractors

The accumulated values for the ownership cost parameters of depreciation, interest on the investment, taxes, insurance and housing as well as the values for the accumulated ownership cost per each and every year of operation are presented in the below table (1).

Table 1. Accumulated cost Values for Depreciation, Interest on Investment, Taxes, insurance and Housing and the Ownership Cost

Ac. Depreciation	Ac. Interest on Investment	Ac. TIH	Ac. Ownership Cost
792.54	95.11	15.85	903.50
1616.79	194.015	32.34	1843.14
2475.38	297.05	49.51	2821.93
3371.30	404.56	67.43	3843.28
4307.95	516.95	86.16	4911.06
5289.20	634.70	105.78	6029.69
6319.51	758.34	126.39	7204.24
7404.05	888.49	148.08	8440.62
8548.84	1025.86	170.98	9745.68
9760.97	1171.32	195.22	11127.51
11048.86	1325.86	220.98	12595.70
12422.61	1490.71	248.45	14161.78
13894.48	1667.34	277.89	15839.71
15479.57	1857.55	309.59	17646.71
17196.75	2063.61	343.94	19604.30
19070.04	2288.41	381.40	21739.85
21130.66	2535.68	422.61	24088.95
23420.24	2810.43	468.41	26699.07
25996.02	3119.52	519.92	29635.46
28939.76	3472.77	578.80	32991.33
32374.13	3884.90	647.48	36906.51
36495.37	4379.44	729.91	41604.72
41646.92	4997.63	832.94	47477.49
48515.66	5821.88	970.313	55307.85
58818.77	7058.25	1176.38	67053.40
77364.36	9283.72	1547.29	88195.37

3.2 The Accumulated Operating Cost for the Sonalika DI-90 Farm Tractors

The accumulated values for the operating cost parameters of the repair and maintenance (R&M), fuel and the tractor operator as well as the values for the accumulated operating cost per each and every year of operation are presented in the below table (2).

Table 2. Accumulated Cost Values for Repair and Maintenance, Fuel, Tractor Operator and the Operating Cost

Ac. R&M Cost	Ac. Fuel Cost	Ac. Tractor Operator Cost	Ac. Operating Cost
841	507	355	1703
1762	1034	730	3526
2693	1571	1115	5379

3634	2118	1510	7262
4585	2675	1915	9175
5546	3242	2330	11118
6517	3819	2755	13091
7498	4406	3190	15094
8489	5003	3635	17127
9490	5610	4090	19190
10501	6227	4555	21283
11522	6854	5030	23406
12553	7491	5515	25559
13594	8138	6010	27742
14645	8795	6515	29955
15706	9462	7030	32198
16777	10139	7555	34471
17858	10826	8090	36774
18949	11523	8635	39107
20050	12230	9190	41470
21161	12947	9755	43863
22282	13674	10330	46286
23413	14411	10915	48739
24554	15158	11510	51222
25705	15915	12115	53735
26866	16682	12730	56278
28037	17459	13355	58851

3.3 The Accumulated Total Cost for the Sonalika DI-90 Farm Tractors

The accumulated values for the operating cost, ownership cost as well as the total cost per each and every year of operation are presented in the below table (3).

Table 3. Accumulated Cost Values for the Operatin, Ownership and the Total Cost

Age	Accumulated Operating Cost	Accumulated Ownership Cost	Accumulated Total Cost
1	1703.00	903.50	2606.50
2	3526.00	1843.14	5369.14
3	5379.00	2821.93	8200.93
4	7262.00	3843.28	11105.28
5	9175.00	4911.06	14086.06
6	11118.00	6029.69	17147.69
7	13091.00	7204.24	20295.24
8	15094.00	8440.62	23534.62
9	17127.00	9745.68	26872.68
10	19190.00	11127.51	30317.51
11	21283.00	12595.70	33878.70
12	23406.00	14161.78	37567.78
13	25559.00	15839.71	41398.71
14	27742.00	17646.71	45388.71
15	29955.00	19604.30	49559.30
16	32198.00	21739.85	53937.85
17	34471.00	24088.95	58559.95
18	36774.00	26699.07	63473.07
19	39107.00	29635.46	68742.46
20	41470.00	32991.33	74461.33
21	43863.00	36906.51	80769.51
22	46286.00	41604.72	87890.72
23	48739.00	47477.49	96216.49
24	51222.00	55307.85	106529.85
25	53735.00	67053.40	120788.40
26	56278.00	88195.37	144473.37

3.4 The Accumulated Total Cost Per Hour for the Sonalika DI-90 Farm Tractors

The accumulated values for the total cost, operating hours as well as the total cost per hour per each and every year of operation are presented in the below table (4).

Table 4. Accumulated Values for the Total Cost, Operating Hours and the Total Cost per Hour

Age	Ac. Total Cost	Accumulated Operating Hours	Accumulated Total Cost Per Hour
1	2606.50	131.45	19.83
2	5369.14	282.90	18.98
3	8200.93	444.35	18.46
4	11105.28	615.80	18.03
5	14086.06	797.25	17.67
6	17147.69	988.70	17.34
7	20295.24	1190.15	17.05
8	23534.62	1401.60	16.79
9	26872.68	1623.05	16.56
10	30317.51	1854.50	16.35
11	33878.70	2095.95	16.16
12	37567.78	2347.40	16.00
13	41398.71	2608.85	15.87
14	45388.71	2880.30	15.76
15	49559.30	3161.75	15.68
16	53937.85	3463.20	15.58
17	58559.95	3774.65	15.514
18	63473.07	4096.10	15.50
19	68742.46	4427.55	15.53
20	74461.34	4769.00	15.61
21	80769.51	5120.45	15.77
22	87890.72	5481.90	16.03
23	96216.49	5853.35	16.44
24	106529.85	6224.80	17.11
25	120788.40	6606.25	18.28
26	144473.37	6997.70	20.65

3.5 Determination of the Useful Life for the Sonalika DI-90 Farm Tractors

The useful life for the Sonalika DI-90 farm tractors studied were determined from both the table and the curve for the accumulated total cost per hour to be the year of operation in which the value for the accumulated total cost per hour is the lowest as shown in the above table (4), or the age of operation in which the curve for the accumulated total cost per hour is at its lowest point as shown in figure (2) below. Therefore, the useful life for Sonalika DI-90 farm tractors operated in the Mapel area of the Capital City of the Republic of South Sudan Juba is 18 years with an accumulated operating hours of 4096.10 which corresponds to the lowest value for the accumulated total cost per hour of 10.70. Though the studies concerning either the ownership costs, the operating costs, the total costs, the economic life, or the mathematical model for predicting them are area specific and therefore should not be generalized, except that the finding of this study concerning the useful life for studied Sonalika DI-90 farm tractors operated in Mapel area of the Juba City differs from the results obtained by the following researchers of Ashtiani. (2005), V. Pagare *et al*. (2019), and Chenarbon *et al*. (2011) whose studies concluded that the useful life for MF285 farm tractors, 50HP farm tractors, and MF285 farm tractors operated in the Islamic Republic of Iran, India, and the Islamic Republic of Iran Respectively were 8 years, 6 years, and 9 years respectively.

3.6 Development of a Mathematical Model to Predict the Accumulated Total Cost Per Hour for each and every Year of Operation as well as to Predict the Economic Life for the Sonalika DI-90 Farm Tractors

The mathematical model meant for the prediction of the useful life for Sonalika DI-90 farm tractors operated in the Mapel Area of the Capital City of the Republic of South Sudan Juba was developed from the two variables of the accumulated total cost per hour and the age of operation for Sonalika DI-90 farm tractors as presented in the above table (4). The Y part of this mathematical model which is the accumulated total cost per hour was regarded as a dependent variable and thus, it was labeled on Y-axis, whereas, the X part of the mathematical model which is the age of operation was regarded as an independent variable and thus, it was labeled on the Y-axis.

3.7 The Mathematical Model Developed by this Study for the Prediction of the Useful Life for the Sonalika DI-90 Farm Tractors

The mathematical model developed by this study for predicting the useful life for Sonalika DI-90 farm tractors operated in the Mapel Area of Juba City is presented in figure (2) below:

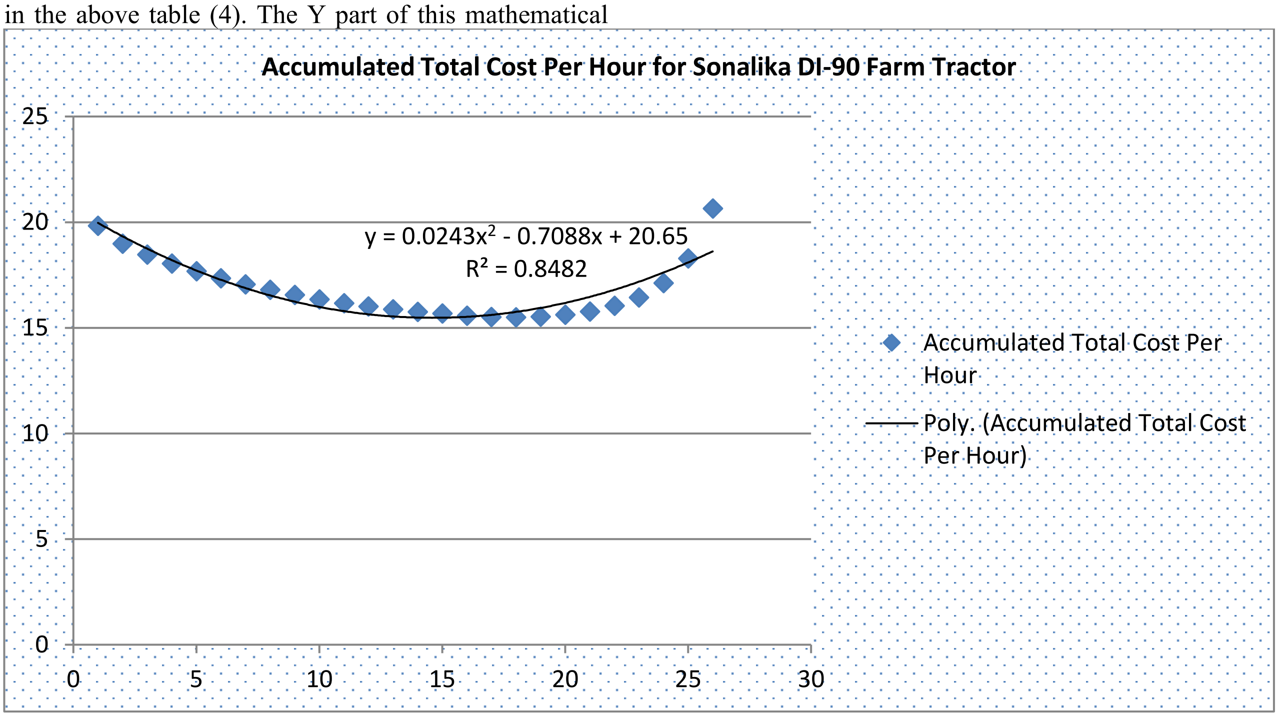

Figure 2. the Mathematical Model Developed for the Prediction of the Accumulated Total Cost per Every Year of Operation as well as the Useful Life for the Sonalika DI-90 Farm Tractors Operated in Juba City

The mathematical model presented in figure (2) above, which is a polynomial model was determined to be the suitable model among the five tried models of exponential, linear, logarithmic, and power for predicting the useful life which is also known as the economic life or the optimum life for the Sonalika DI-90 farm tractors operated in the Mapel Area of the Capital City of the Republic of South Sudan and that is because it predicted the useful life as well as the accumulated total cost per hour for each and every year or age of operation for Sonalika DI-90 farm tractors with an accuracy of 98.9%. The finding of the current study on the type of mathematical model appropriate for the prediction of the useful life for the Sonalika DI-90 farm tractors operated in the Mapel Area of the Capital City of the Republic of South Sudan which is the polynomial model is the same as the findings obtained by G. Khoub bakht *et al*. (2008) and Khoubbakht *et al*. (2010) which revealed that the polynomial model was an appropriate mathematical model for predicting the useful of MF285 farm tractors operated in the two areas of Khansar and Golpayegan of the Isfahan Province of the Islamic Republic of Iran. But this finding is different from the ones revealed by Abbas Asakereh *et al*. (2012), Chenarbon *et al*. (2014), and Buba Baba Shani and Aliyu Musa. (2018) which concluded that the quadratic model was an appropriate model for predicting the useful life for MF285 farm tractor, JD3140 farm tractor, and Mahindra605 farm tractor respectively, operated in Ahvaz of Iran, Varamin Pishva region of Iran, and the Kaduna State of Nigeria respectively.

3.7 Comparison of the Useful Life Determined By Studies from other Researchers with the Useful Life Determined by this Study.

The below table (5) shows the comparison between the economic life determined by this study for the Sonalika

DI-90 farm tractor with the economic life determined by the studies conducted by other researchers for farm tractors of different makes and models.

Table 5. Useful Life Determined by Studies Conducted by Other Researchers

Studies	Tractor Model	Economic Life	Study Area
(Khoub bakht *et al*., 2010)	MF285	20	Khansar and Golpayegan-Central Region of Iran
(Abbas Asakereh *et al*., 2012)	MF285	14	Ahvaz-Iran
(Chenarbon *et al*., 2014)	JD3140	8	Varamin Pishva-Iran

Comparison of the Mathematical Models Developed By Other Researchers around the Globe with the Mathematical Model Developed By this Study

The below table (6) shows the comparison between the mathematical Model developed by this study and the mathematical models developed by other studies for predicting the accumulated total cost per hour for each and every age of operation as well as the economic life for farm tractors of different makes and models.

Table 6. Mathematical Models Developed by the Studies Conducted by Other Researchers

Study	Tractor Model	Mathematical Model	Math Model Type
(G. Khoub bakht *et al*., 2008)	MF285	$Y=0.0013X^2-0.0525X+2.1381$	Polynomial
(Khoub bakht *et al*., 2010)	MF285	$Y=0.0013X^2-0.0525X+2.1381$	Polynomial
(Chenarbon *et al*., 2014)	JD3140	$Y=0.178X^2–2.182X+41.00$	Quadratic

4. CONCLUSIONS

The developed polynomial model should be interpreted as an economic decision-support tool rather than only a mechanical performance model. The model assists tractor owners and agricultural managers in determining the optimal replacement timing by minimizing accumulated cost per operating hour. Such analytical tools are valuable for investment planning and resource management in agricultural production systems in developing economies.

The economic life which is the age of replacement of Sonalika DI-90 farm tractor model which was operated in the study area of Mapel in Juba is 18 years with an accumulated operating hours of 4096.10.

The determined economic life is based on the total cost which is the summation of the operating cost and the ownership cost.

The major cost parameters that affected the economic life of Sonalika DI-90 tractors were the operating cost parameter of repair and maintenance and the two ownership cost parameters of depreciation and the interest on investment.

The polynomial model whose general formula is denoted by $Y=aX^2-bX+C$, where, Y= is the accumulated total cost per the operating hour, X= is the operating age, and C= is a constant, was determined to be an appropriate mathematical model for predicting the useful life for Sonalika DI-90 farm tractors operated in the Mapel area of the Juba City.

The result revealed by this study may serve the owners and the operators of the Sonalika DI-90 farm tractors operated in the Mapel area of the Juba City with an appropriate number for the years of operation before replacing their tractors.

The result of this study concerning the total cost of owning and operating the farm tractors may also serve both the Sonalika DI-90 farm tractor owners and operators to evaluate their tractors from the economical perspective.

5. RECOMMENDATIONS

The relevant institutions and personnel including both the farm power and machinery managers, tractor owners, tractor operators, and farmers within South Sudan are strongly encouraged to keep records for the ownership costs of their farm tractors

Further studies should be conducted to determine the appropriate age of operation at which the farm tractors operating within the border of South Sudan should be replaced.

Finally, more studies should be carried out with an objective of developing the mathematical model for predicting the economic life, the useful life, or the optimum life for the farm tractors operating within the border of South Sudan.

Statements and Declarations

This study is an original work that has not been submitted for publication at any other journal, nor is it under consideration for publication by any other journal.

Authors Contributions

The author would like to declare that all the works including conceptualization, Material Preparation, Data Collection and Analysis and drafting the manuscript are done by him alone.

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Competing Interest
The author has no financial or non-financial interest within or before the last three years to declare

Data Availability Statement
All the data concerning this study are presented in the above mentioned tables of (1, 2, 3, and 4) whose annual values data could be obtained by subtracting the value for the previous year of operation from the value for the operation year in question.

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