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Determination of optimum life for MF285 tractor based on repair and maintenance costs: A case study in center region of Iran

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The use of tractor to do agricultural mechanized operations is responsible for a fundamental and important role to mechanize agricultural section. Decision making about replacement of used farm equipment with a new similar one is one of the important items in farm machinery management. Appraisal of repair and maintenance cost models for farm machinery is important to decide for replacement time and to decrease total costs. Proper performance in this case can lead to timely, high quality farm operations which in turns results in considerable decrease in product expenditures and also more income. Based on this the study was to determine optimum life or economic life for MF285 in west region of Isfahan province was performed. Repair and maintenance costs for the studied tractor were investigated to present an appropriate mathematical model in order to predict these costs. Listed price of tractor, annual depreciation and Internal Rate of Return (I.R.R) in the study period were calculated. These items accompanied by their repair and maintenance cost were used to determine their economic life. Finally replacement time for the study, tractor 18316 hours was predicted.

Key words: economic life, replacement time, Repair and maintenance costs, MF285 tractor

Introduction

Today, tractor is one of the most important power sources in agriculture. Effect of tractor power on agriculture is considerable (Singh, 2006). The use of modern technology during latter decades resulted in rapid growth of farm production. Tractors and farm machinery are important samples of this modern technology (Xinan *et al.,* 2005; Singh, 2000; Singh, 2000). The quality of

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inputs of mechanization, and consequently land and labor productivity in both situations, may differ considerably (Gifford *et al.*, 1980; Singh, 1997; Singh and Chandra, 2002).

Management of farm machinery is one of the important branches of farm management. Deciding considering replacement time of farm machinery noted to conditions of their economical and technological is one of the considered aims in management of farm machinery. A complete line of machinery is one of the largest investments that a farm business can make. Yet, unlike land or buildings, machinery must be constantly monitored, maintained, and eventually replaced. How and when equipment is replaced can mean a difference of thousands of dollars in annual production costs.

Deciding for replacing old machinery by new machinery is performed based on its economic life. Economic life, named as optimum life, has a direct relation with repair and maintenance costs. Costs of owning and operating of farm machinery represent 35 to 50% of the costs of agricultural production when excluding the land (Anderson, 1988). The R&M (repair and maintenance cost) is an important item in costs of owning and operation. 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 of farm machines (Rotz and Bowers, 1991). Agricultural engineers have done many studies regarding R&M of farm machines. Several studies were conducted in both developed and undeveloped 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 (Bowers and Hunt, 1970; Fairbanks *et al.*, 1971; Farrow *et al.*, 1980; Ward *et al.*, 1985; Rotz, 1987; Gliem *et al.*, 1986; Gliem *et al.,* 1989). Based on ASAE, replacement age for a machine that is placed on economic life arrives typically before fundamental breakdowns resulted worn-out and technological disabling (ASAE, 2000).

Some studies conducted in undeveloped countries regarding R&M of farm machines have been reported in the literature (Inns, 1978; Hendrson and Fanasb, 1984; Beppler and Hummeida, 1985; Konda and Larson, 1990; Abdelmotaleb, 1993). The operating costs of the farm machines in undeveloped countries were estimated using the models of developed countries (Inns, 1978). Henderson and Fanash (1984) conducted a study in Jordan on the cost of tractor use. This study showed that there was a proportional increase of repair costs with tractor use. They proposed a model to estimate the repair cost of the tractor/hour/acre based on the Jordanian currency. Economic or optimum life for a machine presents a time period based on constant and variable costs that using the machine is economical (ASAE, 2000b; Hunt, 2001). Each machine has a determined economical life that thereafter using the machine is not economical. It is known that repair and maintenance cost has a large share from machine ownership costs.

As it is shown in Fig. 1. while machine age is raised, constant costs is reduced, but repair and maintenance (variable) costs is raised. As it is seen, indication of total annual machine costs is obtained by sum total constant and variable costs. Minimum point of this curve, that is intersection point of constant and variable cost curves, is present as the most appropriate time for replacing machine (Ward *et al*., 1985).

The aim of this study is to provide a statically analysis on constant and variable costs for MF285 tractor in order to present an appropriate mathematical model and the best time for replacing tractor. Determining economical life for farm machinery provides planners and policy makers and also farmers an opportunity to evaluate the performance of machinery economic.

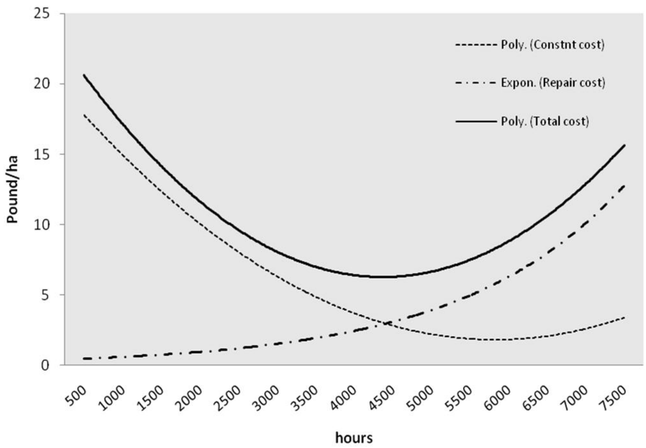

Fig. 1. Curves of total annual machine, constant and variable costs for two wheel drive tractor.

Materials and methods

Collecting and classifying data

This study was carried out in Khansar and Golpayegan townships in central region of Iran. Data were collected from 118 MF285 tractor operators in the study region by using a face-to-face questionnaire in the year 2008. Information was sought on tractor characteristics and economic costs such as use of tractor each year, lubrication cost, filter cost, repairman wage, etc.

Sample operators were randomly selected from the 32 Villages in the study area by using a stratified random sampling method. The tractors were classified according to their age in unit year into 26 groups from 1 to 26. Therefore, for example, class 4 includes the total tractors four-year-worked.

The mean working hours in per year was obtained, separately, for per class, after stratifying samples. Accumulated working hours for per class were calculated using Eq. 1.

$$X_n = \sum_{i=1}^{n} x_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where X is the accumulated working hours for the class n (h), n is the class number or age of the class tractors in unit year, x is the mean yearly working hours for per class (h/year).

Fixed and variable costs

Machinery costs are divided into two categories, fixed and variable costs. Variable costs increase proportionally with the amount of operational use given the machine, while fixed costs are independent of use.

It is not always clear as to which category some of the specific costs belong. The costs of interest on the machinery investment, taxes, housing, and insurance are dependent on calendar-year time and are clearly independent of use. The costs of fuel, lubrication, daily service and maintenance, power, and labor are clearly cost associated with use. The two remaining cost items, depreciation and the cost of repairing, seem to be functions of both use and time.

Estimations of yearly costs are adequate for determining crop production costs and for deciding if machine ownership is profitable; but the time of replacement decision depends on the accumulated costs over a period of years. Fig. 2 compares yearly costs and accumulated costs during the life of a machine. The costs in Fig. 2 need to include only depreciation, interest on investment and repair as all other costs are assumed to be independent of the time of replacement.

Depreciation

Declining-balance was used to calculate depreciation for the study tractor. A uniform rate is applied each year to the remaining value (includes salvage value) of the machine at the beginning of the year. The depreciation amount is different for each year of the machine´s life. Equations 2 to 4 express the relationships by formulas.

$$D = V_n - V_{n+1} \quad \text{...........................(2)}$$

$$V_n = P\left(1 - \frac{rr}{L}\right)^n \quad \text{..................(3)}$$

$$V_{n+1} = P\left(1 - \frac{rr}{L}\right)^{n+1} \quad \text{.......................(4)}$$

Where: Depreciation, is amount of depreciation charged for year n+1, n, is number representing age of the machine in years at beginning of year in question, V, is remaining value at any time and rr, is ratio of depreciation rate used to that of straight-line method (rr may have any value between 1 and 2). If rr = 2, the method is called a double-declining-balance method and is the maximum rate method permitted by the IRS. For used tractor the rate is rr = 1.5.

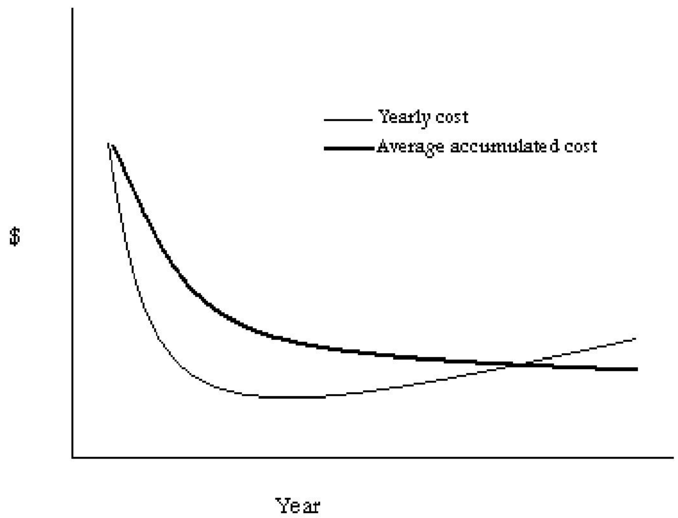

Fig. 2. Average annual and accumulated costs.

Interest on investment

The interest on investment in a farm machine is included in operational cost estimates. Even if the investment money is not actually borrowed, a charge is made since that money cannot be used for some other interest-paying enterprise. Nominal interest rates include expected inflation. In times of substantial monetary inflation, a machinery manager must include the effects of inflation on machinery planning. Inflation causes increased prices for goods and services in future years.

The real interest rate, i_r, is a function of the nominal interest rate, in, and the rate of inflation, i_i, as shown in Eq. (5).

$$i_r = \frac{i_n - i_i}{1 + i_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Therefore the interest on investment was calculated by using Eq.(6).

$$i_n = V_n \times i_r \quad \ldots\ldots\ldots\ldots\ldots\ldots..(6)$$

Where i_n is the interest on investment in n-th year ($), and i_r is the real interest rate.

Repair

Repair costs are the expenditures for parts and labor for, 1: installing replacement parts after a part failure and 2: reconditioning renewable parts as a result of wear. The anticipated annual cost of repair for any one machine is highly uncertain.

For per class, classified in section 2.1, the mean annual repair and maintenance costs were separately calculated. To calculate, accumulated repair and maintenance costs Eq. (7) was used.

$$Y_n = \sum_{i=1}^{n} y_i \ldots\ldots\ldots\ldots\ldots\ldots...(7)$$

Where Y is the accumulated repair and maintenance costs based on percent of list price, y is the mean annual repair and maintenance costs for per class based on percent of list price. Based on that, ratio of the cumulative costs to the list price was estimated as the dependent variable and the cumulative working hours was obtained as independent variable.

In order to determine mathematical model for the study tractor, regression analysis was performed on the data by using the computer software sppss13.0. Five models were used to perform regression analysis, which included the following:

$Y=a+bx$	*linear*
$Y=a+bx+cx^2$	*Polynomial*
$Y=ae^{bx}$	*Exponential*
$Y=a+\ln bx$	*logarithmic*
$Y=ax^b$	*Power*

Dependent and independent variables were used to obtain the best equations to estimate repair and maintenance costs. Other models in the reported studies were used to predict repair and maintenance costs of the study tractor and compared with obtained model in this study.

Finally, to determine time of replacement for the study tractor accumulated depreciation, interest on investment and repair costs were calculated and regression analysis was performed on the data by using the computer software SPSS 13.0.

Results and discussion

Separating costs of repair and maintenance for MF285 tractor

According to obtained data from the operators, repair and maintenance costs for MF285 tractor include tractor spare parts and repairman wage, consumption of oil, and fuel and oil filler replacement costs. The mean annual repair and maintenance costs related to the study tractor were separately shown in Table 1. According to this table, it is found that tractor spare parts cost with 66.7 percent have the most share compared to other costs. The large share of tractor spare parts cost can be due to numerous factors such as making use of substandard tractor spare parts, unsuitable use of tractor, novice driver, undesirable repairs, and making use of tractor more than its optimum life that can be seen as the most important factor.

In Table 1, also, it is found that the repairman wage with 18.95 percent of the total repair costs is the secondary importance. The large share of repairman wage cost can be chiefly due to high interest rate in country economic and subsequently to be increase rapidly wages. This causes that operators are encouraged to repair their tractors by themselves. Because, commonly, operators are not able to repair tractor, professionally, numerous breakdowns for tractor will be found. Accordingly referral of tractors to repair shop and also the total repair costs will be increased.

Table 1. The mean annual repair and maintenance costs for MF285 tractor.

Cost	Spare parts	Repairman wage	oil	Oil and fuel filter	Total
Price ($/h)	0.675	0.183	0.110	0.244	1011.31
Percent	66.72	18.54	12.01	2.73	100

Determination of appropriate mathematical model to predict repair and maintenance costs for MF285 tractor

The obtained data from 118 sample tractors including annual use and cost were used to calculate the accumulated repair and maintenance cost and working hours. The results are listed in Table 2. The presented data in this table were used to analysis and determine the repair and maintenance cost model.

Table 3 presents the relation between the accumulated repair and maintenance cost and the cumulative working hours on the models of linear, logarithmic, Polynomial, Power, and Exponential with correlation coefficient of related to itself. The highest value of correlation coefficient among presented models is related to Power model with R^2=0.996 and after that Polynomial model with R^2=0.995 has the most value of correlation coefficient.

In the most published studies in this field and also the present study, Power model gave better cost prediction with higher confidence and less variation than that of Polynomial Exponential and logarithmic models. Because of, easiness in calculations, the high correlation coefficients of Power model, and using of this model by other researchers, in the present study, Power model was suggested as final form of the repair and maintenance cost model. Therefore, the repair and maintenance model was developed following the ASAE (1993) standard by using the exponential form: $y=aX^b$, where the coefficients α and β were statistically predicted. The independent variable, X is related to the cumulative working hours, while the dependent variable, y referred to the accumulated repair and maintenance cost to list price ratio. For comparison, the accumulated repair and maintenance costs, predicted by ASAE model and models developed by others are shown in Table 4 and Fig. 3. These models gave higher costs by to 6 times higher than costs of the present study. Therefore, it is highly recommended that each area or country develop its own models according to its operational and field conditions.

Table 2. The accumulated repair and maintenance costs and working hours.

Age (year)	Accumulated working hours	Accumulated R&M costs (percent of list price)
1	796.23	4.44
2	1738.48	10.23
3	2753.78	15.76
4	3544.03	21.17
5	4681.4	27.35
6	5464	33.73
7	6457.88	40.48
8	7283.38	46.95
9	8187.04	54.81
10	9056.46	62.66
11	10106.14	70.57
12	10851.39	77.66
13	11788.13	85.61
14	12672.63	93.07
15	13640.17	100.29
16	14526.92	109.69
17	15389.42	119.60
18	16488.62	129.92
19	17414.37	139.68
20	18316.62	150.24
21	19181.98	162.10
22	20144.48	174.19
23	21111.68	188.10
24	21946.43	201.19
25	22856.68	213.28
26	23904.18	226.46

Table 3. The Model Summary and Parameter Estimates.

Model	Model Summary		Parameter Estimates		
	R Square	F	a	b	c
linear	0.983	1394.565**	-18.623	0.01	
logarithmic	0.754	73.592**	-525.727	68.101	
Polynomial	0.995	20482.692**	2.209	0.005	1.98×10^{-7}
Power	0.996	5387.905**	0.0015	1.1709	
Exponential	0.886	186.840**	13.147	0.00013	

Table 4. Presented different models by researchers.

models developed by others researcher	accumulated R&M costs based on percent of list price			references
	5000 hours	8000 hours	10000 hours	
$y = 0.042(\frac{x}{120})^{1.895}$	49	120	183	Ward (1985)
$y = 1.2(\frac{x}{1000})2$	30	77	120	ASAE. (1987)
$y = 0.00865x^{1}$	43	69	86	Culpin,C.P. (1975)
$y = 0.076(\frac{x}{120})1.6$	30	63	89	Bowers and Hunt (1970)
$y = (0.0996x^{1.4775})10^{-3}$	29	57	80	Morris (1987)
$y = /0015\ x^{1/1709}$	32	55	72	The present model

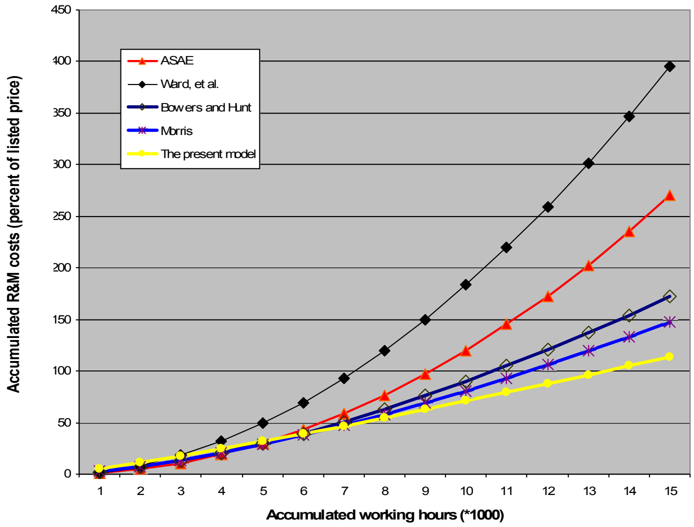

Fig. 3. Presented different models by researchers.

Accumulated costs for MF285 tractor

Accumulated depreciation, interest on investment, repair and total costs for the study tractor are presented in Table 5. One of the difficulties in analyzing machinery costs is that they change over time. Depreciation, often the largest cost of farm machinery, measures the amount by which the values of a machine decrease with the passage of time whether used or not. As it is seen in Table 5 depreciation tends to be great at first, especially for a machine purchased new, but declines over time. Likewise, interest expends is high initially but gradually diminishes. This is true whether the interest cost is cash interest paid on a loam, or an opportunity cost based on revenue foregone by continuing to own a machine year after year. On the other hand, repair costs may amount to little or nothing when a machine is still under warranty, but eventually increase as parts wear out and maintenance requirement rise.

Table 5. Accumulated costs for Mf285 tractor.

Age (year)	**Accumulated repair cost($)**	**Accumulated depreciatio cost($)**	**Accumulated interest on investment cost($)**	**Total accumulated cost($)**
1	464.085	783.75	522.5	1770.335
2	1069.121	1508.718	1005.813	3583.652
3	1647.098	2179.314	1452.877	5279.288
4	2212.387	2799.615	1866.411	6878.412
5	2857.565	3373.393	2248.93	8479.887
6	3524.459	3904.138	2602.76	10031.36
7	4229.831	4395.077	2930.053	11554.96
8	4906.758	4849.196	3232.799	12988.75
9	5727.207	5269.256	3512.839	14509.3
10	6548.354	5657.811	3771.876	15978.04
11	7375.043	6017.224	4011.485	17403.75
12	8115.893	6349.681	4233.124	18698.7
13	8946.061	6657.204	4438.14	20041.4
14	9725.721	6941.663	4627.779	21295.16
15	10480.17	7204.787	4803.196	22488.15
16	11462.86	7448.177	4965.456	23876.49
17	12498.6	7673.313	5115.547	25287.46
18	13576.43	7881.563	5265.637	26723.64
19	14596.43	8074.195	5404.471	28075.1
20	15700.13	8252.379	5532.893	29485.4
21	16939.54	8417.199	5651.683	31008.42
22	18203	8570.147	5761.563	32534.72
23	19656.96	8711.171	5863.227	34231.35
24	21024.03	8841.618	5957.244	35822.89
25	22288.17	8962.281	6044.209	37294.66
26	23665.33	9073.895	6113.038	38852.26

Determination of optimum life for MF285 tractor

Accumulate and annual operating hours and also average annual and total costs are presented in Table 6. As it is seen in the table, average accumulated costs in 20th year drop to their lowest value. Fig. 4. presents the accumulated costs through an equation of polynomial with a correlation coefficient $R^2 = 0.93$ and yearly costs through an equation of polynomial with a correlation coefficient $R^2 = 0.42$for MF 285 tractor.

As it is shown in the figure, the first year´s costs are high because of the very real marketplace depreciation obtained from the estimate value method. The yearly costs drop to their lowest value (20th year) and then begin to rise if the annual repair costs increase with age. The accumulate cost curve drops more gradually and levels out at the point where it crosses the yearly cost curve. The standard rule for minimizing the long-run cost of equipment is to make a change when the annualized total cost of owning and operating the machine begins to increase. In the study, this happens in about the 20th year of ownership. At this point repair costs begin to increase faster than depreciation and interest costs decrease. However, the rate at which total costs rise is often very gradual.

Thus, while the rule of increasing total cost can give a general picture of when to replace a particular machine, it cannot give a precise answer. Note that the estimates for repair costs project them to increase gradually over time. In reality, though, repair costs tend to be quite variable from year to year, ranging from only routine maintenance items to a complete overhaul. Being able to anticipate when large repair costs will be needed is a key consideration in deciding when to replace a machine.

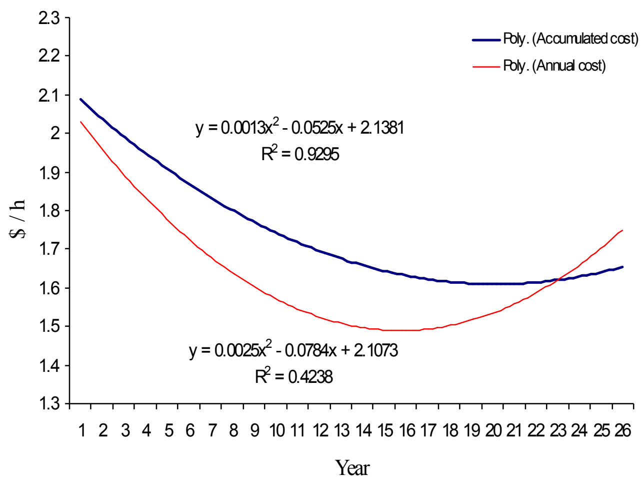

Fig. 4. Average annual and accumulated costs for MF285 tractor.

Table 6. Operating hours and cost for MF285 tractor.

Age(year)	Annual operating hours	Accumulate operating hours	Average accumulated cost ($/h)	Average annual cost ($/h)
1	796.23	796.23	2.223	2.223
2	942.25	1738.48	2.061	1.924
3	1015.32	2753.78	1.917	1.670
4	790.25	3544.03	1.941	2.024
5	1137.37	4681.41	1.811	1.408
6	762.6	5464.20	1.836	1.982
7	993.88	6457.88	1.789	1.533
8	825.5	7283.38	1.783	1.737
9	903.66	8187.04	1.772	1.683
10	869.44	9056.48	1.764	1.689
11	1049.25	10106.14	1.722	1.358
12	745.25	10851.39	1.723	1.738
13	936.74	11788.13	1.700	1.433
14	884.52	12674.63	1.680	1.417
15	967.54	13640.17	1.649	1.233
16	886.75	14526.92	1.644	1.566
17	862.52	15389.42	1.643	1.636
18	1099.20	16488.62	1.621	1.307
19	925.75	17414.37	1.612	1.460
20	902.25	18316.62	1.610	1.563
21	865.36	19181.98	1.617	1.760
22	962.52	20144.48	1.615	1.586
23	964.71	21111.48	1.621	1.754
24	834.25	21946.43	1.632	1.907
25	910.25	22856.68	1.632	1.617
26	1047.50	23904.18	1.625	1.487

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