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Modeling of Repair and Maintenance Costs of Two-Wheel Drive Tractors

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Abstract: Estimating of repair and maintenance (R and M) costs of tractors and farm machinery in any mechanized farm is necessary for owners and managers to obtain information on overall costs and to control financial balance and production economy. For this reason, a study was conducted to model accumulated R and M costs (Y) of two-wheel drive (2WD) tractors based on accumulated usage hours (X). Recorded data of the Misagh-e-Sabz Agribusiness Company in Iran were used to determine regression model(s) for estimating accumulated R and M costs (as percentage of initial purchase price) based on accumulated usage hours. The statistical results of the study indicated that in order to estimate accumulated R and M costs of 2WD tractors with service life of 2260 h or less the power regression model $Y = 0.013 (X/100)^{1.677}$ with $R^2 = 0.976$ and to estimate accumulated R and M costs of 2WD tractors with service life of 2260 h or more the polynomial regression model $Y = 0.004 (X/100)^2 - 0.181 (X/100) + 4.373$ with $R^2 = 0.998$ can be strongly suggested.

Key words: R and M costs · 2WD tractors · Modeling · Estimating · Iran

INTRODUCTION

Machinery ownership (fixed) and operating (variable) costs represent substantial portion of total production expenses. Machinery ownership costs usually include charges for depreciation, interest of investment (opportunity cost), taxes, insurance and housing facilities. Operating costs include repair and maintenance, i.e. spare-parts, wages and lubricants [1, 2]. Repair and maintenance (R and M) costs of farm machinery are those expenditures necessary to restore or maintain technical soundness and reliability of the machine [3]. Accurate prediction of R and M costs trends is critical to determine optimum economical life of machine and to make appropriate decisions for machinery replacements and also for general farm management purposes [4]. Since variation in R and M costs depends on site and time specifications, a general relationship can not be suggested. But prediction of these costs at an acceptable level can be made by fitting a regression model based on the previous data [5].

Bower and Hunt [6] surveyed around 1800 farmers in Illinois and Indiana and used R and M costs data to develop models for predicting R and M costs. Fairbanks *et al.* [7] working in Kansas collected R and M costs data through investigation from 114 farm managers. At the end, accumulated R and M costs were predicted using a power regression model based on cumulative usage hours of tractors. Ward *et al.* [8] obtained a power regression model for predicting accumulated R and M costs based on accumulated usage hours for 63 forestry tractors in Ireland which gave very high cost estimates compared to other references. They concluded that the observed R and M costs variation on tractors was so high as to preclude the use of an obtained model for predicting R and M costs for a single tractor. They suggested this variation was most likely attributable to differences in tractor operation, maintenance services, operating practices and inherent tractor qualities, but they were not in a position to substantiate this claim. Morris [9] collected R and M costs data of 50 tractors in Weasenham Farm Company in Norfolk and used them to obtain R and M costs prediction model. His study showed that hours of use he could account for, shared no more than 16% of the observed variations in R and M costs. Skill of operator, working conditions and maintenance standards were reported as important determinants of machinery R and M costs. The models developed by Bower and Hunt [6] were revised by Rotz and Bower [10] based on expert opinion, but they did

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not do another survey. Obviously, machinery has changed a lot since the 1970 survey. The equations predict R and M costs as a percentage of the machine purchase price, so the equations should remain valid as long as the machine purchase price goes up at the same rate as the R and M costs. But, we do not know that for sure. Funding has just not been available to do much research in this area [11].

In Iran very limited studies have done on R and M costs of tractors and farm machinery too. Almassi and Yeganeh [12] obtained an appropriate regression model for accurate prediction of accumulated R and M costs based on accumulated usage hours for 213 tractors in Karoon Agro-Industrial Company in north of Khuzestan province. Also, Ashtiani-Eraghi *et al.* [13] conducted a study in order to derive a power regression model for predicting accumulated R and M costs based on cumulative usage hours for 27 active tractors of two different models in Dasht-e-Naz Agricultural Company in Mazandaran province. Moreover, Ajabshirchi *et al.* [14] obtained a polynomial regression model for predicting accumulated R and M costs based on accumulated usage hours for 42 tractors working actively at Astan-e-Ghods-e-Razavi farms in Khorasan province.

All researchers state that there is a little reliable recorded R and M costs data, particularly for older machines. In addition, great variations in R and M costs between tractors and their operating conditions make it difficult to obtain meaningful generalized models. Therefore, the purpose of this study was to model accumulated R and M costs (as percentage of initial purchase price) based on accumulated usage hours using farm records for 60 active two-wheel drive (2WD) tractors of four different models in the Misagh-e-Sabz Agribusiness Company in Ilam and Kermanshah provinces in the west of Iran.

MATERIALS AND METHODS

Required data were obtained from the Misagh-e-Sabz Agribusiness Company in Ilam and Kermanshah provinces which keep machinery records as part of a large management accounting system. For each tractor, separate records are kept as monthly hours of tractor's counter readings and R and M costs including spare-parts, lubricants and labor costs. Labor charged at hourly rates includes all workshop related wages and overheads. In this study, sixty active 2WD tractors on four different models including Universal 650 (U-650), Massey Ferguson 285 (MF-285), John Deere 3140 (JD-3140) and John Deere 4955 (JD-4955) with complete records were selected for analysis. Data over 15 years time period from 1991 to 2005 were collected. In order to adjust for inflation effect, all of the cost elements were adjusted to a common base year, i.e. 2005. The average annual operation hours for each tractor was about 1212 h. Majority of the tractors had worked much more than 12000 h, which is the normal service life of tractor as suggested by the American Society of Agricultural and Biological Engineers (ASABE). Some variations were apparent between individual tractors for the service hours. As hours of annual usage for each tractor were needed for the purpose of data analysis study, for the tractors which had no intact hour-meter, the engine oil change intervals were considered as 120 hours of service. To determine regression model(s) for predicting R and M costs of these tractors at any point of service life, accumulated hours of use for each year were added up to previous usage hours and the sum was considered to be independent variable (X) of the model(s). Then, R and M costs as percentage of initial purchase price which was considered to be dependent variable (Y) obtained through dividing the total accumulated R and M costs by initial purchase price of tractor. To acquire information (i.e. R and M costs, hours of service and also initial purchase price) for all tractors, weighted average of data was employed for analysis. Regression analysis of data for each individual type of tractor and, also as well on all tractors as whole was done using SPSS 12.0 (Version, 2003). Linear, exponential, power and polynomial regression types were tried. Accuracy of different regression models and significance of their coefficients were examined using analysis of variance and F statistical test. The regression model(s) having the highest coefficient of determination (R^2) was selected as the best model(s) for predicting actual R and M costs trend.

RESULTS AND DISCUSSION

Table 1 shows mean annual values and mean annual percent of R and M costs fractions, i.e. spare-parts, wages and lubricants per unit of all tractors for different ages of them. This table also indicates average of whole annual R and M costs, average of annual usage hours and average of R and M costs per hour per unit of all tractors for different ages of them. Fig. 1 shows mean R and M costs fractions, i.e. spare-parts, wages and lubricants to be 69.54%, 24.15% and 6.31%, respectively, among which spare-parts costs are the highest.

Table 1: Mean annual values and mean annual percent of R and M costs fractions (spare-parts, wages and lubricants), average of whole annual R and M costs, average of annual usage hours and average of R and M costs per hour per unit of all tractors for different ages of them

	Spare-parts		Wages		Lubricants		Average of whole annual R and M costs (Rials)	Average of annual usage hours (h)	Average of R and M costs per hour (Rials)
Age (years)	Value (Rials)	%*	Value (Rials)	%	Value (Rials)	%			
1	626572	59.85	258117	24.66	162138	15.49	1046827	987.50	1060
2	723558	61.75	278724	23.79	169447	14.46	1171729	1090.0	1075
3	1469455	68.38	479445	22.31	199940	9.30	2148840	1289.6	1666
4	1914256	69.89	591663	21.60	233138	8.51	2739057	1382.5	1981
5	2601489	69.45	881354	23.53	263247	7.03	3746090	1472.4	2730
6	3114299	69.80	1040751	23.33	306891	6.88	4461942	1404.4	3177
7	4223267	69.60	1502648	24.76	342248	5.64	6068163	1435.2	4228
8	4975056	67.66	1973164	26.84	404681	5.50	7352902	1408.7	5220
9	6377547	67.03	2655577	27.91	480783	5.05	9513907	1358.7	7002
10	8746043	71.68	2871566	23.54	583577	5.78	12201187	1241.3	9829
11	9586391	73.23	2806774	21.44	697104	5.33	13090269	1085.5	12060
12	7334245	69.18	2596409	24.49	670979	6.33	10601633	959.60	11048
13	7804522	68.64	2814729	24.76	751039	6.61	11370290	1011.7	11239
14	7636723	68.95	2639510	23.83	799355	7.22	11075589	1052.0	10528
15	9507604	69.77	3227558	23.69	891671	6.54	13626833	1002.6	13592
Average	5109402	69.54	1774533	24.15	462749	6.31	7347684	1212.0	6429

* As percentage of average of whole annual R and M costs

Table 2: Mean accumulated usage hours and mean accumulated R and M costs as percentage of initial purchase price per unit of all tractors for different ages of them

Age (years)	Mean accumulated usage hours (h)	Mean accumulated R and M costs as percentage of initial purchase price (%)
1	988	0.970
2	2078	2.050
3	3367	4.040
4	4750	6.580
5	6122	10.05
6	7526	14.18
7	8962	19.80
8	10370	26.61
9	11729	35.42
10	12970	46.72
11	14056	58.85
12	15015	68.67
13	16027	79.20
14	17079	89.45
15	18082	102.1

Table 3: Description, coefficients, coefficient of determination (R^2) and F test results of the four regression models obtained for all tractors

Model	Description	a	b	c	R^2	F	MS
Linear	$Y = a (X/100) + b$	-20.263597**	0.582489**	---	0.910	131**	114.45
Exponential	$Y = a\, e^{b(X/100)}$	1.580551**	0.025171**	---	0.957	291**	0.0970
Power	$Y = a (X/100)^{b}$	0.013043**	1.677382**	---	0.976	527**	0.0540
Polynomial	$Y = a (X/100)^2 + b (X/100) + c$	0.003990**	-0.180539**	4.373408**	0.998	3241**	2.5400

** = Significant at probability level of 1%

MS = Mean square of residuals

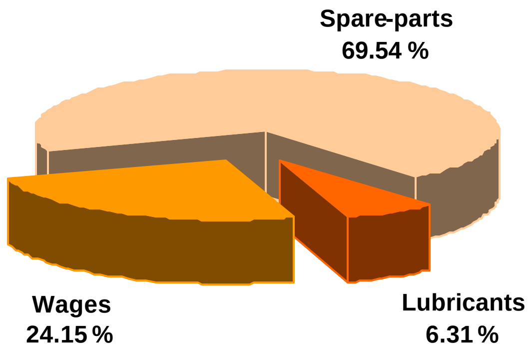

Fig. 1: Mean R&M costs fractions, i.e. spare-parts, wages and lubricants for all tractors under study.

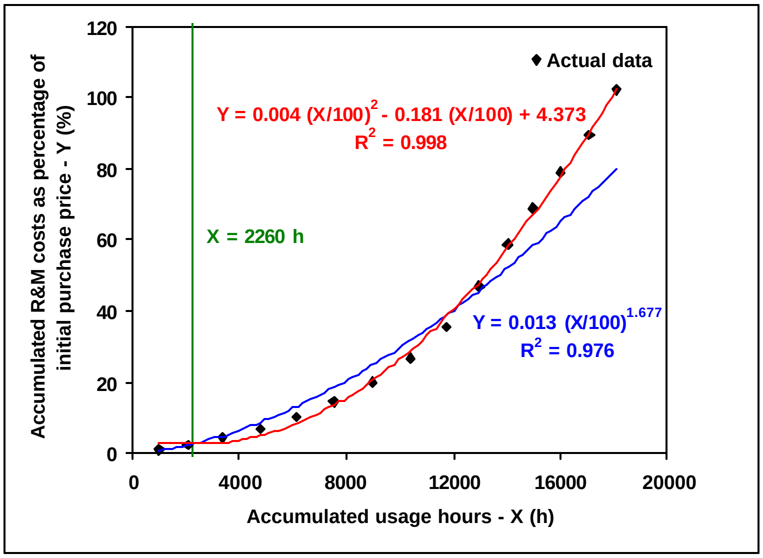

Fig. 2: Curves of predicted accumulated R&M costs as percentage of initial purchase price based on accumulated usage hours using the power and polynomial regression models for all tractors under study.

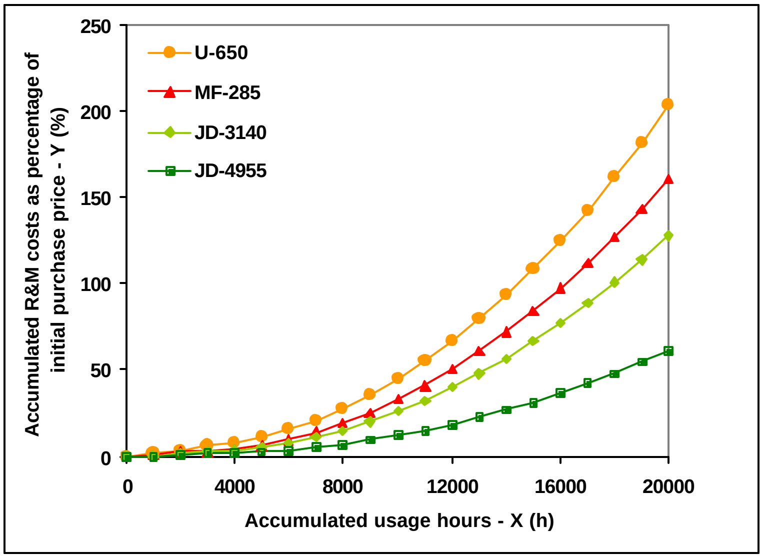

Fig. 3: Comparison of accumulated R&M costs as percentage of initial purchase price based on accumulated usage hours on four different tractor models under study

Table 2 provides information on mean accumulated usage hours and mean accumulated R and M costs as percentage of initial purchase price per unit of all tractors for different ages of them which were used as base data for regression analysis. In this study, tractors' initial purchase prices declared by the Misagh-e-Sabz Agribusiness Company were adjusted for mean annual inflation rate for a period of 15 years.

Table 3 shows linear, exponential, power and polynomial models. Considering F values, there is a significant correlation between X and Y variables in all four models. However, R^2 values indicate that the power and polynomial models have higher conformity with actual data trend in comparison with the linear and exponential models. For prediction of accumulated R and M costs, the power model can be applied because of its simple structure and easiness of calculating procedure, but this model has lower R^2 value than the polynomial model. But, as the polynomial model shows accumulated R and M costs to be lower than the actual data for the first period of machine life and also predicts some fixed amount of costs before binging service life of tractor, the power model can be suitably applied for the first period of machine life, i.e. accumulated usage hours up to 2260 h as equation 1:

$$Y = 0.013\,(X/100)^{1.677}\ (X < 2260\ h) \qquad (1)$$

On the other hand, as the polynomial model conforms well to actual data trend particularly at later life time of tractors, polynomial model is preferred to power one for the remaining service life of tractor, i.e. accumulated usage hours above 2260 h as equation 2:

$$Y = 0.004\,(X/100)^2 - 0.180\,(X/100) + 4.373\ (X > 2260\ h) \qquad (2)$$

Fig. 2 indicates the curves of predicted accumulated R and M costs based on accumulated usage hours using the power and polynomial models for all tractors together with the actual data and the line of X = 2260 h. Differences of repair factors on different types of tractors may be attributed to the nature of different farm operations, skill of operators, annual service hours of tractor, wage-rate of operator, spare-part costs and some other factors alike.

Fig. 3 shows the curves of predicted accumulated R and M costs based on accumulated usage hours for all types of tractors using the power model for the first period of machine life and the polynomial model for the remaining service life of tractors. It can be observed that the rate of accumulated R and M costs for all tractor types at earlier life time of them was low and fairly similar. However, trend of R and M costs was rapidly increasing thereafter. The rate of increase was lowest for JD-4955 tractor model and highest for U-650 tractor model. Differences in increasing rate of R and M costs may be attributed to the facts like quality in design and manufacturing, scarcity and higher cost of some spare-parts as compared to new price of tractor type and also much frequent need for repair in some models. Steepness of accumulated R and M costs curves for MF-285 and U-650 tractor models was higher than JD-3140 and JD-4955 tractor models. This can be related to more frequent break-downs, inferior production technology, inherent deficiencies and also incompatible field operations to their power and efficiencies.

CONCLUSION

The R and M costs prediction models and agricultural machinery repair coefficients values are generally dependent on factors such as research method performance and time spans, number and type of samples under study, type of operation and working conditions, repair and maintenance management, quality of materials used, weather conditions and skill of operator. Results of this study indicated that average R and M costs per hour increased with machine age. These results also confirmed that there are considerable variations in R and M costs among tractor models as well as individual ones.

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