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Prediction of Repair and Maintenance Costs of Universal 650 Tractors

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Abstract: As Universal 650 (U-650) tractors are widely used by Iranian farmers and agro-industry companies, a study was conducted to model accumulated R and M costs of U-650 tractors as percentage of initial purchase price (Y) based on accumulated usage hours (X). Recorded data of an Agribusiness Company in Iran were used to determine regression model(s). The statistical results of the study indicated that in order to predict accumulated R and M costs of U-650 tractors with service life of 1970 h or less the power regression model $Y = 0.0377\ (X/100)^{1.5451}$ with $R^2 = 0.982$ and to predict accumulated R and M costs of U-650 tractors with service life of 1970 h or more the polynomial regression model $Y = 0.0056\ (X/100)^2 - 0.2205\ (X/100) + 6.9088$ with $R^2 = 0.997$ can be suitably recommended.

Key words: R and M costs · Tractor · Universal 650 · Modeling · Prediction

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 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].

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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 different tractor models, tractors and their operating conditions make it difficult to obtain meaningful generalized models. As Universal 650 (U-650) tractors are extensively used by Iranian farmers and agro-industry companies, 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 15 active U-650 tractors in an Agribusiness Company in Ilam and Kermanshah provinces in the west of Iran.

MATERIALS AND METHODS

Required data were obtained from an 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. Fifteen active U-650 tractors 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 1165 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, average of data was employed for analysis. Regression analysis of data for all tractors was done using SPSS 12.0 (Version, 2003). Linear, exponential, power and polynomial regression types were tried. 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 tractors. 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 64.3%, 27.7% and 8.0%, respectively, among which spare-parts costs are the highest.

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 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 R^2 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,

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 U-650 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	491224	56.4	223259	25.6	156610	18.0	871093	920.00	946.800
2	549203	55.9	286000	29.1	147211	15.0	982414	985.20	997.200
3	1407168	66.5	542170	25.6	168173	7.90	2117511	1201.6	1762.20
4	1476050	67.8	528061	24.2	174130	8.00	2178241	1325.3	1643.60
5	1987172	65.3	854141	28.1	203018	6.70	3044331	1391.2	2188.30
6	2203478	68.8	713965	22.3	284019	8.90	3201462	1405.0	2278.60
7	2697068	72.8	734000	19.8	274160	7.40	3705228	1420.9	2607.70
8	2986610	68.9	1053262	24.3	296133	6.80	4336005	1295.1	3348.00
9	3840218	66.4	1610023	27.8	332051	5.70	5782292	1214.0	4763.00
10	6123098	66.0	2681304	28.9	467019	5.00	9271421	1424.0	6510.80
11	3624701	62.4	1720341	29.6	463291	8.00	5808333	845.80	6867.30
12	4832810	66.4	2001189	27.5	438912	6.00	7272911	1003.0	7251.20
13	5627730	65.5	2504431	29.1	459800	5.40	8591961	965.40	8899.90
14	5237030	57.8	3289180	36.3	537102	5.90	9063312	1107.3	8185.10
15	5476012	56.7	3621200	37.5	564100	5.80	9661312	964.80	10013.8
Average	3237305	64.3	1490835	27.7	331049	8.00	5059188	1164.6	4550.90

* 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 U-650 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	920	1.610
2	1905	3.430
3	3107	7.350
4	4432	11.38
5	5823	17.02
6	7228	22.95
7	8649	29.81
8	9944	37.84
9	11158	48.55
10	12482	65.72
11	13328	76.48
12	14331	89.95
13	15297	105.9
14	16404	122.6
15	17369	140.5

Table 3: Description, coefficients and coefficient of determination (R^2) of the four regression models obtained for U-650 tractors under study

Model	Description	a	b	c	R^2
Linear	$Y = a (X/100) + b$	0.8064	-24.469	---	0.912
Exponential	$Y = a e^{b(X/100)}$	2.8927	0.0242	---	0.946
Power	$Y = a (X/100)^b$	0.0377	1.5451	---	0.982
Polynomial	$Y = a (X/100)^2 + b (X/100) + c$	0.0056	-0.2205	6.9088	0.997

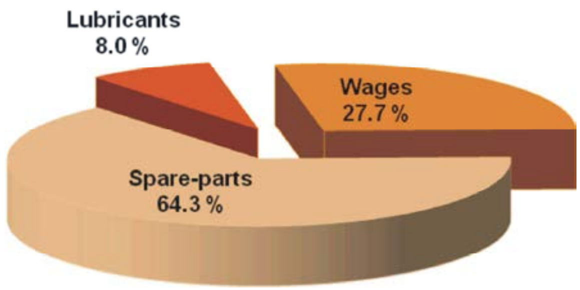

Fig. 1: Mean R and M costs fractions, i.e. spare-parts, wages and lubricants for U-650 tractors under study

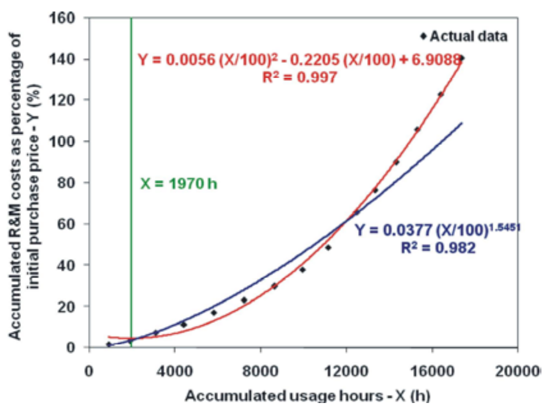

Fig. 2: Curves of predicted accumulated R and M costs as percentage of initial purchase price based on accumulated usage hours using the power and polynomial regression models for U-650 tractors under study

but this model has lower R^2 value than the polynomial model. Moreover, 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 1970 h as equation 1:

$$Y = 0.0377\ (X/100)^{1.5451}\ (X < 1970\ h) \quad (1)$$

On the other hand, as the polynomial model conforms well to actual data trend particularly at later life time of tractors, the polynomial model is preferred to the power one for the remaining service life of tractor, i.e. accumulated usage hours above 1970 h as equation 2:

$$Y = 0.0056\ (X/100)^2 - 0.2205\ (X/100) + 6.9088\ (X > 1970\ h) \quad (2)$$

Fig. 2 indicates the curves of predicted accumulated R and M costs based on accumulated usage hours using the power and polynomial models together with the actual data and the line of X = 1970 h.

CONCLUSION

Results of current study indicated that average R and M costs per hour increased with tractor age. These results also indicated that in order to predict accumulated R and M costs of U-650 tractors with service life of 1970 h or less the power regression model $Y = 0.0377\ (X/100)^{1.5451}$ with $R^2 = 0.982$ and to predict accumulated R and M costs of U-650 tractors with service life of 1970 h or more the polynomial regression model $Y = 0.0056\ (X/100)^2 - 0.2205\ (X/100) + 6.9088$ with $R^2 = 0.997$ can be suitably recommended.

REFERENCES

1. Bowers, W., 1981. Fundamentals of Machine Operation (FMO): Machinery Management. Second Edition. Deere and Company. Moline. IL. USA.
2. Morris, J., 1987. Tractor Depreciation, Repair and Holding Cost: A Case Study. Silso College. Silso. Bedford. UK.
3. Srivastava, A.K., C.E. Georing, R.P. Rohrbach and D.R. Buckmaster, 2006. Engineering Principles of Agricultural Machines. Second Edition. American Society of Agricultural and Biological Engineers, Niles Road, St. Joseph, MI, USA.
4. Hunt, D.R., 2001. Farm Power Machinery Management. Tenth Edition. Iowa State University Press. Ames. Iowa. USA.
5. Rotz, C.A., 1987. A standard model for repair costs of agricultural machinery. Applied Eng. Agric., 3: 3-9.
6. Bowers, W. and D.R. Hunt, 1970. Application of mathematical formulas to repair cost data. Transactions of ASAE, 13: 806-809.
7. Fairbanks, G.E., G.H. Larson and D.S. Chung, 1971. The cost of using farm machinery. Transactions of ASAE, 14: 98-101.
8. Ward, S.M., P.B. McNulty and M.B. Cunny, 1985. Repair costs of 2WD and 4WD tractors. Transactions of ASAE, 28: 1074-1076.
9. Morris, J., 1988. Estimation of tractor repair and maintenance costs. J. Agric. Eng. Res., 41: 191-200.
10. Rotz, C.A. and W. Bowers, 1991. Repair and maintenance cost data for agricultural equipment. In: Proc. of International Winter Meeting Sponsored by the American Society of Agricultural Engineers, Paper 911531.

11. Lazarus, W.F., 2008. Estimating farm machinery repair costs, http://www.apec.umn.edu/faculty/wlazarus/documents/mf2008.pdf 28/10/2008.
12. Almassi, M. and H.R. Yeganeh, 2002. Determination a suitable mathematical model to predict the repair and maintenance costs of farm tractors in Karoon Agro-industry Company. Iranian J. Agric. Sci., 33: 707-716.
13. Ashtiani-Eraghi, A.R., I. Ranjbar and M. Toorchi, 2006. Optimum mathematical model for predicting R and M costs of operation tractors in Mazandaran Dasht-e-Naz Farm Company. J. Agri. Sci., 15: 101-112.
14. Ajabshirchi, Y., I. Ranjbar, M.H. Abbaspour, M. Valizadeh and A. Rohani, 2006. Determination of a mathematical model for estimating tractor repair and maintenance costs. J. Agric. Sci., 16: 257-267.