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Repair and Maintenance Cost Models for MF285 Tractor: A Case Study in Central Region of Iran

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Abstract: Appraisal of repair and maintenance cost models for farm machinery is important to decide for replacement time and to decrease total costs. In this study repair and maintenance costs for MF285 tractor were investigated to present an appropriate mathematical model in order to predict these costs. To present the model, the stratified random sampling method on the basis of tractor age per year was used. The mean accumulated repair and maintenance costs and also the mean working hours (h/year) were calculated for per class separately. Calculated data was analyzed on the five models, linear, logarithmic, polynomial, power and exponential. Finally, it was found that power model gave better cost prediction with higher confidence and less variation than other models.

Key words: Repair % Maintenance % Cost models % Iran % MF285

INTRODUCTION

Today, tractor is one of the most important power sources in agriculture. Effect of tractor power on agriculture is considerable [1]. 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 [2-4]. The quality of inputs of mechanization and consequently land and labor productivity in both situations, may differ considerably [5-7].

Costs of owning and operating of farm machinery represent 35 to 50% of the costs of agricultural production when excluding the land [8]. The repair and maintenance cost (R&M) is an important item in costs of owning and operation. In general, the costs other than those for repair and maintenance cost 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 [9]. 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 [10-16].

Bowers and Hunt [10] collected information from several farms in Illinois and Indiana in the United States as part of their study. Fairbanks *et al*. [11] made an extensive survey on 114 farms in Kansas and two models were derived. One model to calculate the cost of repairing diesel tractors and the other model calculated the cost of repair for combines. These models had the same format as given by ASAE [17], but differed in their parameters. The accumulated cost of R&M was estimated to be 30% of the list price by the end of the economic age. Farrow *et al*. [12] tested the performance of prediction equations and estimated the required changes needed for seven farm machines including trucks. The study concluded with emphasis to improve the existing models for obtaining better accuracy. Ward *et al*. [13] made an extensive study of 10 years of government records for repair costs of 4-wheel and 2-wheel drive tractors and derived a cost model for each type of tractor. This study agreed with other studies regarding the difference existing between the two types of tractors. Rotz [14] derived a model based on equipment price and operating hours. The testing of the model showed that the costs were more realistic when the area worked was considered instead of the operating hours. Rotz and Bowers [9] made an attempt to collect information from companies and experts, but limited response was received. They revised the models published by ASAE regarding R&M costs. They noticed that the R&M costs varied with operating conditions.

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Some studies conducted in undeveloped countries regarding R&M of farm machines were reported in the literature [18-22]. The operating costs of the farm machines in undeveloped countries were estimated using the models of developed countries [18]. Henderson and Fanash [19] 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.

The aim of this study is to provide a statistical analysis for the repair and maintenance costs of MF285 tractor in order to present an appropriate mathematical model. Display of appropriate models for the repair and maintenance costs of farm machineries provide planners and policy makers and also farmers an opportunity to evaluate the performance of machinery economic.

MATERIALS AND METHODS

This study was carried out in Khansar and Golpayegan townships in central region of Iran. Data were collected from 102 MF285 tractor operators in the study region by using a face-to-face questionnaire in the year 2007. 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. Also, for per class, the mean annual repair and maintenance costs were separately calculated. Accumulated working hours for per class were calculated using Eq. 1.

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

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). Also, for calculated of accumulated repair and maintenance costs Eq. (2) was used.

$$Y_n = \sum_{i=1}^{n} y_i \qquad (2)$$

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 were obtained as independent variable. Classified tractors on the basis of their age and also other data related to per class were prepared as intermediate tables. In order to determine mathematical model for the study tractor, regression analysis was performed on the data by using the computer software sppss12.0 (version, 2003). 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.

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.

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

Cost	Spare parts	Repairman wage	oil	Oil and fuel filter	Total
Price ($)	687.2	185.87	113.56	24.68	1011.31
Percent	66.72	18.54	12.01	2.73	100

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	7.9623	4.4400
2	17.3848	10.2300
3	27.5378	15.7600
4	35.4403	21.1700
5	46.8140	27.3500
6	54.6400	33.7300
7	66.5788	40.4800
8	74.8338	46.9500
9	83.8704	54.8100
10	91.5646	62.6600
11	102.0614	70.5700
12	109.5139	77.6600
13	118.8813	85.6100
14	127.7263	93.0700
15	137.4017	100.2900
16	146.2692	109.6900
17	154.8942	119.6000
18	165.8862	129.9200
19	176.1437	139.6800
20	185.1662	150.2400
21	196.8198	162.1000
22	206.4448	174.1900
23	217.1168	188.1000
24	225.4643	201.1900
25	236.5668	213.2800
26	247.0418	226.4600

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.

Determination of appropriate mathematical model to predict repair and maintenance costs for MF285 tractor: The obtained data from 102 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: The Model Summary and Parameter Estimates

Model	Model Summary: R Square	Model Summary: F	Parameter Estimates: a	Parameter Estimates: b	Parameter Estimates: c
linear	0.987	1788.412**	-17.549	0.009	
logarithmic	0.758	75.020**	-523.049	67.709	
Polynomial	100	42519.021**	0.677	0.005	164×10-7
Power	0.996	5911.822**	0.002	1.162	
Exponential	0.880	176.545**	12.462	0.000	

Table 4: Presented different models by researchers

models developed by others researcher	accumulated R&M costs based on percent of list price: 5000 hours	8000 hours	10000 hours	refrence
$y = 0.042(\frac{x}{120})^{1.895}$	49	120	183	[13]
$y = 1.2(\frac{x}{1000})2$	30	77	120	[23]
$y = 0.00865x^{1}$	43	69	86	[24]
$y = 0.076(\frac{x}{120})1.6$	30	63	89	[10]
$y = (0.0996x^{1.4775})10^{-3}$	29	57	80	[25]
$y = 0.002x^{1.162}$	39	68	88	The present 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 Polynomial model with R^2=1 and after that Power model with R^2=0.99 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 Exponential and logarithmic models. Because of, easiness in calculations, the small difference between the correlation coefficients of Polynomial and Power models and using of Power model by other researchers, in the present study, Power model was suggested as final form of the repair and maintenance cost model. Therefore, the repair and maintenance model was developed following the ASAE [17] standard by using the exponential form:

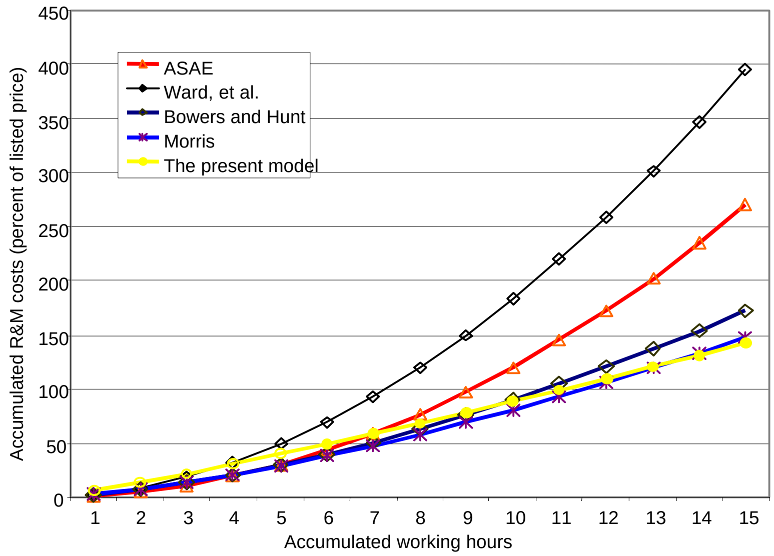

Fig. 1: Presented different models by researchers

$y=aX^b$, where the coefficients " and $ 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 Figure 1. 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.

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