Advances in Environmental Biology, 8(12) July 2014, Pages: 646-651

AENSI Journals

Advances in Environmental Biology

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/AEB/

Using Mathematics Modeling to Estimate Repair Costs of Tractors

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ARTICLE INFO

Article history:
Received 25 June 2014
Received in revised form
8 July 2014
Accepted 14 September 2014
Available online 27 September 2014

Keywords:
repair and maintenance, mathematical model, estimating the cost of tractor.

ABSTRACT

Costs of repair and maintenance of agricultural machines and estimating it led to more accurately determine the extent of profit rates which has been received and it is important in determining the optimal economic life of cars. This research is done in order to determine the relation between the hours of cumulative operation and cumulative repair and maintenance costs and determining the estimated coefficients of mathematic equations in order to calculate these costs for the three customary tractors in Iran's Fars province that involves: 1- John Deere 4955 2- John Deere 3350 3- Massey Ferguson 285. Required information was prepared with at least 100 tractors from each model in order to complete the questionnaire in 1390. The fit regression is done for final data by using the method of least squares and F tests. Six mathematical models including linear, exponential, inverse, multiplicative and quadratic and third degree for preparation of optimization models and estimating the costs to breakdown the tractor models were estimated. The results showed that multiplicative model provides the best fit and performance in predicting the costs even for different tractor model and also for all series tractors. Then constants of mathematic models to estimate the repairing cost of any kinds of tractor and for all series of tractors were calculated. Mathematic models were obtained that, between three selected tractor models, amount of repairing and maintenance of John Deere 4955 tractors costs compared with its initial costs has the lowest price, but process of repairing and maintenance costs increase by functions with higher speeds than the other two kinds of tractors. Downturn rate in effect of repairing for three tractor models are obtained respectively 18, 15 and 11 days per year.

To Cite This Article: Syamak Pishbin, Using Mathematics Modeling to Estimate Repair Costs of Tractors. ***Adv. Environ. Biol., 8(12)**, 646-651, 2014*

INTRODUCTION

The tractor is the most common and the most important source of power production in mechanized agriculture of the current era and developing agricultural mechanization largely the function of amount and it is how to use this source of power production. In view of the above, evaluation and the estimated costs of implementing the tractor, from inevitable priorities of economical management is the agricultural units, especially production units in vast, like many acres of farmland and cultivation and industries because of the multiplicity of these cars and therefore they are more pronounced impact on the production process and related costs, need to this measure and estimated increases. Assessment and anticipated of use of tractors costs in addition that in order to accurate estimation of production units and then to define the proceeds is necessary and inevitable, can be a criterion to identify the best time to replace these equipment and evaluation of technical management quality. Studies indicate that repairing and maintenance involves approximately from 20 to 25 of total annual costs of using the tractors [10]. Repair and maintenance costs which have direct relation from tractor life and using times and usage of it, so in determining the optimal time to replace the machine, play major roles. Another importance of these items will be happened in their controllable effects on productions costs, in other words, by increasing repair costs, the total cost of the machine is increased and this problem will raise the cost of agricultural production. So in order to prevent this increasing as possible can be improved and stem off the factors that cause to increase the repair and maintenance costs [5]. Repair and maintenance costs involve the important part in costs of using from agricultural machines. Because of tendency to increase them by increasing the machine using age can be happened, major importance in assessing these costs in their effects on optimal time to replace the machines. Studies have shown that the best and most comprehensive unit in this field is repair cost rate on hours of using the machine. If such a unit is expressed in terms of a percentage of the initial

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price can minimize the result changes of machine size and if while collecting the basic data, the increase in tractor prices is equal to the current inflation in the region, the effects of inflation will be minimize as well as. The best time to replace the machine is that costs of total machine are minimized and again start to increase. Mathematical model should be such that repair and maintenance costs predict carefully as possible in order to estimate, even though exact determining of these costs are impossible because of their great influence of the changing the conditions [7].

The goal of this current study involves presented a mathematical model to predict repair and maintenance costs and the recession rank because of repairing on common agriculture tractors of Fars province.

Rotz was presented by using the information in Annual of Agricultural Engineering and some other sources and analysis of these data, measure parameters such ragtime mathematical model in order to estimate the cost of repair and maintenance of different types of machines and agricultural equipment, including two wheel tractors and scooters machines [8].

In that time the same research was done in the England by Morris and by collecting information that related to repair and maintenance costs of 50 agricultural tractors and analysis of these information in terms of cumulative costs associated with cumulative hours of operation and the different models of best mathematical function that can describe these relationship has been determined [9].

Ziadi researched in order to estimate the repair costs by mathematical model. I this research, the statistics of repair costs and other needed information for 93 tractors were collected and finally the appropriate model in multiplicative way was proposed [12].

Rotz model structure is properly estimated common process of repair and maintenance costs, a power function is equivalent to equation 1.

$$AR = RC_1(X)^{RC_2} \quad (1)$$

In this equation:

AR= Accumulated Repair Costs

X = Accumulated working hours (multiple of cumulative hours)

RC_1, RC_2 (Repair Cost factors) = Model parameters, function of the machine

This basic model, costs are estimated that during the machine life is too low and slowly increasing in later years. Also this model by going to end of machine life estimates the fix percentage of increase in the cumulative cost of running the machine. Although other models may show stronger the value of actual data, but the increasing complexity of the other models due to the range of changes in values of undesirable cost. Rotz model based on different machine in burnout, amount of RC2 can change. Whatever amount of RC2 is close to 1, repair annual rate is closer to a fixed value or a linear relationship with respect to time. Whatever amount of RC2 increase, repair costs impact in end of machine life may be higher. Amount of RC2 show the distribution of repair and maintenance costs over the machine life while RC1 express the magnitude of repair and maintenance costs [4].

MATERIALS AND METHODS

Investigate places in Fars Province is as one of the most important manufactures of strategic agricultural productions and holds first place in grain production of country in recent years. Tractors of this province have different brands and widely distributed. By referring to mechanization Technical Center and receiving the statistics, three models include John Deere 4955 and John Deere 3350 and Massey Ferguson 285 has the highest amount in province, selection and authentic maintenance centers that repair and consumables documents and forms were completed, required information was collected.

It was necessary to determine the appropriate mathematical models that cumulative operating hours based on percentage of original price, eliminating other influences by different mathematical models are fitted and regression analysis that this operation was carried out separately for each of the three types of tractors. About operating hours of tractors, lifetime basis for the calculation of cumulative operating hours based on that, according to the values which presented in other researches [9, 11] and recommended by the country 's agricultural, was considered equivalent to 12000 hours. In order to fit the data with mathematical models and regression analysis, the four simple models and two models will be used. Regression analysis for each model by using the data values, appropriate mathematical model was obtained by comparing the coefficient of determination (r), correlation coefficients (R2) and F for each model. In order to information analysis with experimental data and analysis the regression data with the least squares method used from Minitab software.

RESULT AND DISCUSSION

The results showed that annual average of functional for Massey Ferguson 285 tractors is equal to 1713.04 hours and average of costs amounts is equal to 4838.3 thousand rails. Thus, the average amount of repair cost per hour is equal to 2833 rails. John Deere 3350 tractors, average of annually operation during the eight-year equal to 1610.61 hours per year and average of costs amount equal to 7564.28 thousand rails was estimated. Thus average value of cost of repair equal to 4525.76 rails per hour was achieved. The average of John Deere tractors operation equal to 1275.75 hours per year and the average of costs and maintenance equal to 10710.83 thousand rails and the cost is equal to 8395.75 rails per hours for repair and maintenance.

After determining the average time and hours of required average during the eight years period in order to complete overhaul and non overhaul, theoretically determined that each Massey Ferguson tractor the average annual 146.67 hours equal to 18 working days, John Deere 3350 tractor equal to 118.27 hours to 15 working days and John Deere 9455 tractor equal 88.70 hours to 11 working days face with recession. It is necessary to mentioned that actually because of absence and or waiting time for spare parts or repairman in repairing time are added to recession days. In order to the proper mathematical model to predict maintenance costs at first model of each tractor then total tractors were evaluated. In Massey Ferguson 285 according to the values in Table 1 F amount in comparing with Ft of distribution F Table, for all studied tractor models, is significant at the 5% level. About R2 (correlation coefficient) and r (correlation coefficient) is considered those third degree exponential functions and quadratic and multiplicative functions show the highest correlation values. Table 2 shows the obtained values for exponential functions are not significant at 1% and the value of this parameter is very close to zero. Constant calculated is negative that due to negative estimate of amount of the costs to operate tractors in the initial few years, cannot be appropriate models for predicting the repair and maintenance costs.

Thus, the multiplicative model with R2 values that equal to 99.7% established goodness of fit with the relevant data and values of parameters are significant at the 5 and 1 percent, is selected as an appropriate mathematical model.

Table 1: Analysis of variance of the data to Tractors MF-285.

Model	Ref.	D.F	M.S	F	R^2(%)	r
$Y = a + bx$	model	1	22658	4084.79	99.7	0.9983
	error	11	6			
$Y = Exp(a + bx)$	model	1	11.076	69.15	86.3	0.9290
	error	11	0.16			
$1/Y = a + bx$	model	1	0.0224	11.02	50.1	0.7078
	error	1	0.002018			
$Y = ax^b$	model	1	12.802	3855.33	99.7	0.9986
	error	11	0.003			
$Y = a + bx + cx^2$	model	2	11340	2893.94	99.8	0.9991
	error	10	4			
$Y = ax + bx^2 + cx^3$	model	3	7565.7	3092.21	99.9	0.9995
	error	9	2.4			

Table 2: Regression analysis of data relating to Tractors MF-285

	Model	a	b	c
	$Y = a + bx$	-10.78844**	0.76225**	-
	$Y = Exp(a + bx)$	2.14411**	0.01685**	-
	$1/Y = a + bx$	0.11675**	0.00075*	-
	$Y = ax^b$	0.14939**	1.30834**	-
	$Y = a + bx + cx^2$	-7.24022*	0.66363*	0.00048*
	$Y = ax + bx^2 + cx^3$	0.42944*	0.00332**	0.00001*

Non-significant, significant at the 5% and 1% probability levels, respectively **and* ns,

In order to determine the best model for estimating the costs associated with the operation of tractors JD-3350, analysis of variance was done. Except F that obtained for the inverse model, which is significant only at the 5% probability level, for other models, F value compared with the distribution of Table F, is significant at 1% and normally at 5%, which is implies the relevance of these models to fit the experimental data. The model F has greater amount and also higher correlation coefficients, two power models and correlation multiplicative models have the highest coefficients of determine and show the correlation. As can be seen in Table 4, the coefficient that obtained for the independent variables X2, X3 in second and third degree equations moreover that is near to zero, in none of the probably levels are not significant. So they cannot be a good fit for analysis the experimental data, in order to estimate the maintenance and repair costs of this kind of tractors the multiplicative model which according to variance analysis table amount of R2 is 97.8% and indicating an almost it’s perfect correlation with the data in Table 3, is selected as appropriate mathematical model.

Table 3: Analysis of variance of the data to Tractors JD-3350.

Model	Ref.	D.F	M.S	F	R^2(%)	r
$Y = a + bx$	model	1	6162.3	145.38	96	0.9798
	error	6	42.4			
$Y = Exp(a + bx)$	model	1	9.453	130.29	95.6	0.9777
	error	6	0.0726			
$1/Y = a + bx$	model	1	0.0578	13.15	68.7	-0.8288
	error	6	0.00439			
$Y = ax^b$	model	1	9.674	270.93	97.8	0.9889
	error	6	0.0357			
$Y = a + bx + cx^2$	model	2	3206.5	4284.3	99.9	0.9994
	error	5	0.7			
$Y = ax + bx^2 + cx^3$	model	3	2138.2	4297.23	100	1
	error	4	0.5			

Analysis of variance and regression were done in order to determine the appropriate mathematical model for estimating the repair and maintenance costs of power JD-4955 model tractors that results of this operation are shown in Table 5 and 6. As can be seen in Table 5, amount of F was very low for the inverse function and compared with the existing in distribution Table F in any of the two levels is not significant probability.

Table 4: Regression analysis of data relating to Tractors JD-3350

	Model	a	b	c
	$Y = a + bx$	-15.123**	0.87071**	-
	$Y = Exp(a + bx)$	1.1106**	0.03411**	-
	$1/Y = a + bx$	0.24094**	0.00266*	-
	$Y = ax^b$	0.07211**	1.48771**	-
	$Y = a + bx + cx^2$	0.309 n.s	0.12631*	0.00063 n.s
	$Y = ax + bx^2 + cx^3$	-0.0516 n.s	0.00999**	0.00002 ns

Non-significant, significant at the 5% and 1% probability levels, respectively ** and * ns

This function cannot be correlated with data table. Of the five other models, is similar what was observed in two other tractor, power and multiplicative functions show the amount of higher correlation that represent a strong fit of these models with the data. Table 6 shows that none of the coefficient obtained for the third degree model even in 5% probable level are not significant and so what about the two other tractor noted, its selection will be negative. For quadratic function of the parameters as specified in Table 6 is the coefficient obtained is very small and close to zero، as well as the constant of equation is negative , in addition of only 5% level of significance, therefore, its application such as this, is not suitable for the estimate of repair and maintenance costs. But besides that multiplicative function does not have faults of exponential function while its amount of the R2 is so close to power function and can be suggested as suitable model for estimating the repair and maintenance costs.

Table 5: Analysis of variance of the data to Tractors JD-4955.

Model	Ref.	D.F	M.S	F	R^2(%)	r
$Y = a + bx$	model	1	3164.7	271.33	97.8	0.9889
	error	6	11.7			
$Y = Exp(a + bx)$	model	1	11.121	45	88.2	0.9391
	error	6	0.247			
$1/Y = a + bx$	model	1	0.2788	5.49	47.8	-0.6914
	error	6	0.05082			
$Y = ax^b$	model	1	12.558	1657.6	99.6	0.9980
	error	6	0.008			
$Y = a + bx + cx^2$	model	2	1615.9	2825.4	99.9	0.9995
	error	5	0.6			
$Y = ax + bx^2 + cx^3$	model	3	1077.5	2022.24	99.9	0.9997
	error	4	0.5			

In order to determine the proper mathematical model to predict repair and maintenance costs for all tractors of results of variance decomposition analysis shows in Table 7 that all functions having a significant F value at the 5% and 1% are an acceptable fit functions. Among these functions, multiplicative model with equal to 94.9%, and the highest correlation coefficient equal to 0.974 gives a strong fit. Table 8 shows the coefficient obtained for the multiplicative model, is also significant at the 1% level.

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Table 6: Regression analysis of data relating to Tractors JD-4955.

Model		a	b	c
	$Y = a + bx$	-11.165**	0.80477**	-
	$Y = Exp(a + bx)$	0.5330 n.s	0.04771**	-
	$1/Y = a + bx$	0.5090**	-0.00755 n.s	-
	$Y = ax^b$	0.0211**	1.81187**	-
	$Y = a + bx + cx^2$	-2.5553*	0.29445*	0.00554*
	$Y = ax + bx^2 + cx^3$	0.1321 n.s	0.00952 n.s	-0.00003 n.s

Non-significant, significant at the 5% and 1% probability levels, respectively ** and* ns ,

Table 7: Analysis of variance of the data to all tractors.

Model	Ref.	D.F	M.S	F	R^2(%)	r
$Y = a + bx$	model	1	15397	134.05	85.9	0.9268
	error	22	115			
$Y = Exp(a + bx)$	model	1	25.877	97.3	81.6	0.9033
	error	22	0.266			
$1/Y = a + bx$	model	1	0.26959	12.3	35.9	0.5992
	error	22	0.02192			
$Y = ax^b$	model	1	30.119	412.1	94.93	0.9742
	error	22	0.073			
$Y = a + bx + cx^2$	model	2	7697.3	63.98	85.9	0.9286
	error	21	120.3			
$Y = ax + bx^2 + cx^3$	model	3	5179.2	43.42	86.7	0.9311
	error	20	2385.9			

Table 8: Regression analysis of data relating to all tractors.

Model		a	b	c
	$Y = a + bx$	-9.808*	0.80836**	-
	$Y = Exp(a + bx)$	1.2417*	0.03313**	-
	$1/Y = a + bx$	0.29128*	- 0.00338**	-
	$Y = ax^b$	0.05188**	1.58649**	-
	$Y = a + bx + cx^2$	-9.721 n.s	0.8043*	0.989 n.s
	$Y = ax + bx^2 + cx^3$	- 0.1080 n.s	0.01808 n.s	-0.000009 n.s

: Non-significant, significant at the 5% and 1% probability levels, respectively ** and* ns ,

So it can be concluded that multiplicative function is the most appropriate and it is final form to estimate the cost of repair and maintenance of each three types of tractors for per working hours. After calculation of regression and analysis of variance by using the data, the appropriate mathematical model to estimate repair costs were obtained as follows. For Massey Ferguson 285 tractors equal to:

$Y=0.149394(X.120)^{1.30834}$ (2)

R^2= % 99.7

For John Deere 3350 tractors equal to:

$Y=0.0721179(X.120)^{1.48771}$ (3)

R^2= % 97.8

For John Deere 4955 tractors equal to:

$Y=0.0211184(X.120)^{1.81187}$ (4)

R^2= % 99.6

By examining obtained equations, is determined that multiplicative parameters values in process of cost increase have significant impact. Multiplicative factors (a) are obtained from the ratio between costs and original price, it means that by increasing the difference between the maintenance costs and the initial purchase price are reduced amount of this parameter. So this factor alone cannot express the magnitude of spending on comparisons between different machines. In fact, this parameter indicates the magnitude repair and maintenance costs in compared to original price of the machine. But about power factor should be said that this factor represent the upward velocity cost increase operating tractor. That means that whatever the amount of (b) for the obtained model is more, increasing repair and maintenance costs for the relevant tractors, was more precipitous and by additional hours worked on the tractor, increasing amount is more expensive for them that it causes greater curvature of the cost curve and get closer to the vertical axis. According to the results, the best model to estimate the cost of repair and maintenance for all tractors were extracted as follows:

$Y=0.051886(X.120)^{1.58649}$ (5)

R^2= % 94.93

This model is also due to the multiplicative nature, like other models obtained for the three types of tractor, tractor repair and maintenance costs in the early stages of life, is low and in the later step is predicted with the upward.

As can be seen in the final multiplicative parameter values (a) is low and about 0.052. It can be related to the significant different between maintenance costs and original price of tractors, especially John Deere tractors. It means that according to the high original price of these tractors and in other hand low repair costs than that, the coefficient has fallen. The results of this study, can determine the multiplicative model as best mathematical model to estimate the cost of repair and maintenance of agricultural tractors that is adapted with Zaidi results (1992) and Morris (1988) and Rotz (1987).

Conclusion:

The annual average function and working regression of MF 285 tractors, John Deere 3350 and John Deere 4955 tractors respectively are 1713.04, 1610.61 and 1275.75 hours and 18, 15 and 11 days had regression that it represented that Massey Ferguson tractors have the most working hours in the farms. One of the reasons for this can consider being low average value of repair cost in hours of this brand other models as a research. But this brand had the most regression in the year because of more operating and accordingly high repairmen and maintenance. Due to different climate conditions in the country and different technical and managerial aspects in continued similar studies in different regions of the country, amended and revised of coefficient model values in different timeframe that prices and inflation are changed, is necessary. Interference and making quantity important factors like driving skill and tractor repairmen and taking other cost items such as fuel, chains, batteries, payroll driver, antifreeze, filters and tools with the machine can be examined. Especially in the current situation has increased the cost of some items such as fuel.

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