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Codifying a proper mathematical model for predicting the repair of the tractors used in Shahid Beheshti Cultivation Firm of Dezfoul.

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Abstract
This study tries to codify a proper mathematical model which can be predict the costs of repair and maintaining the tractors as precisely as possible for three common models of tractors in Shahid Beheshti cultivation firm in Andimeshk-Ahvaz road of Dezfoul. Studied tractors include: Newhland TM155 Tractor which is chosen from the most perfect file of 10 tractor machines and Jandier tractor-3140 of 35 machines. Then we calculated the cumulative values of the two sets of data was used for different years of tractors working fitted to the final performance of the mathematical model of the six (linear exponential reverse multiple, second and third degree) the by method of least squares and use of an computer software. With this operation, the most proper model of estimating maintenance cost for all three types of tractors is obtained as a multiplicative model and the corresponding parameters were calculated. In addition, the final model which is the best fit for a cumulative repair costs for operating hours of all tractors, was determined by multiplying. In order to determine the economic life (replacement age) 61 tractors in three different models based on price, the amount of interest rate and annual depreciation was calculated for each model and used along with the annual cost of maintenance for determining the economic life.

Key words: Harvester, Replacement age, Mathematical model, neural network

Introduction

Due to the seasonal nature of agricultural work, machines is used for a certain time of year and time loss in agriculture is very harmful. Thus, agricultural machines must have high reliability and work efficiency (Aghajani, 1390). The maintenance and repair have important role in keeping reliability, availability, product quality, reducing risk, increasing efficiency and security of equipment (Derakhshan, 1386). Maintenance coefficients of various agricultural machineries are listed in the table of coefficients and standard of agriculture in developing countries, but unfortunately these coefficients are not available in our country. Since the coefficient repairs of imported tractors are not available and determining the appropriate time to replace imported is of great importance, it was decided to perform a study for determining the mathematical model to predict the cost of repairs and maintenance coefficients and determine the useful life of the tractors in Shahid Beheshti firm.

Objectives

1. Developing a suitable mathematical model to predict the repair and maintenance cost of tractors.
2. Determining the appropriate placement age for tractors with regard to the situation in the region, using the model Math.
3. Determining the main causes of the increase in the cost of repairs by a cost separating important cost items and comparing them together.

Literature Review

In 1381, Almasi and colleagues in a study to determine the cost of maintenance, argued that maintenance cost is an important factor in determining the appropriate time to replace these machines and With predicting the amount of these costs by appropriate mathematical model and contrasting it with fixed costs and capital expenditures, the amount of usage and ownership of tractors in the function, can be calculated and then calculate the right replacement age of the old tractors that in fact at the minimum cost point.

Larson and Bowers 1965 gathered the data about 1,100 tractors repair costs in the West part of Central America in a broad program and from estimated repair costs in selected samples.

Ajabshiri and colleagues in 1385 argued that how to change the maintenance costs due to the randomness of them is heavily dependent on local conditions. So a standard relationship cannot be offered to estimate these costs but it can be estimated by a reasonably fitted model based on data from previous years. And by the mathematical model to estimate the cost of repair and maintenance of agricultural tractors, achieving an acceptable result with a good approximation in anticipating the costs of future maintenance of the tractor may be obtained, So that they can be used for all types and sizes of tractors and several hours of work.

Larson, and Gorman in their research of 1989, gathered a comprehensive information about 2500 Crawler tractors of American farms in the states of Arizona, California and Florida. They considered 18,400 hours during which they repair costs equal 78% of the list price of the car as a good value for the life of the sprocket wheel tractors.

Ruthz, in a research in 1987, suggested a comprehensive model to predict maintenance costs proposed. His goal was to determine the coefficients that in addition to predict acceptable values for maintenance, has good compatibility with various types of cars and also has vast amounts of working hours.

Hunt, in 1983, calculated the agricultural machinery repair costs by cost per one hour of machine performance based on pounds per hour. He also determined fixed costs per unit of pounds of farm in acres and the cost of one hour work of a machine in every time of its life is expressed in terms of a percentage of the purchase price. More research has been done on the costs associated with the repair of agricultural machines in America.

Findings

Investigating the maintenance costs for Harvester

Figure 1 shows the increased maintenance costs accompanied by Harvester aging. In addition, Figure 1 illustrates the share of each item in the total annual cost of Harvester. According to this

chart, the cost of spare parts for the 423/241 million Rials includes the average annual cost of a 07/57 percent of total costs and allocates the maximum amount.
Then maintenance payment fees associated with the 563/107 million Rials annual average and value of 55/25 percent of total costs is in second place. Lowest average cost of consumables costs is 132/74 million Rials a year and 38/17% of the total cost.

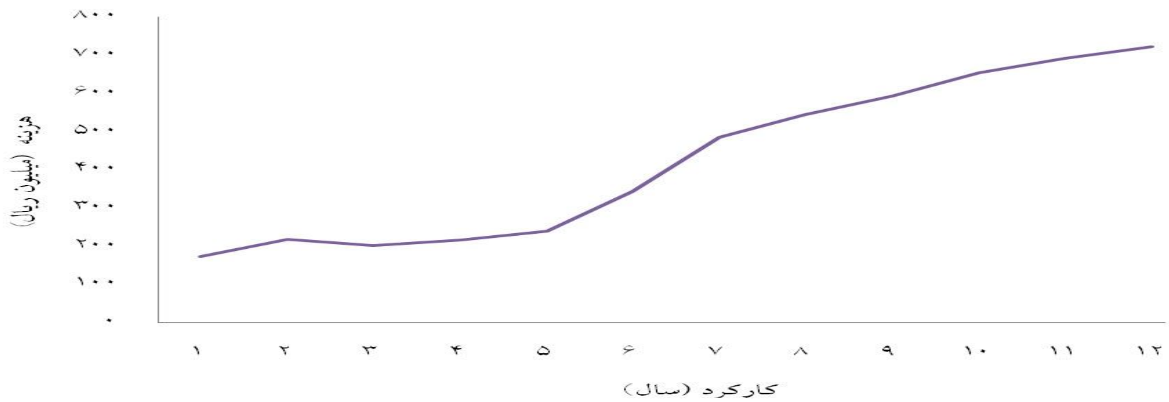


Figure 1: A graph showing the changes in maintenance costs versus the age of Harvester tractors

Determine the appropriate mathematical model to predict maintenance costs of John Deere Jundeer -4955 and -3350

Table 2: The values of cumulative operating hours and cumulative maintenance costs of Harvester

Cumulative maintenance cost percent)basic Price(	amount)Million Rials(	Cumulative costs percent)basic age(	amount)hour(	Harvest Age
5/09	172/033	10/96	1096/04	1
11/49	388/351	23/46	2346/16	2
17/41	588/618	35/11	3511/03	3
23/81	804/694	47/51	4751/18	4
30/87	1043/521	59/06	5905/60	5
41/04	1387/196	69/78	6978/02	6
55/38	1871/884	81/02	8102/14	7
71/50	2416/628	93/16	9316/33	8
89/06	3010/300	105/44	10544/47	9
108/39	3663/541	117/75	11774/65	10
128/85	4354/964	130/38	13037/79	11
150/22	5077/432	142/76	14275/95	12

Regression analysis was performed using the data in Table 2. The results of operations for the seven under-study mathematical models are given in Table 3.

Table 3: Regression analysis of data of Harvester

Equation Coefficients d	c	b	a	Mathematical construct	model
-	-	1/108**	-23/517*	$Y = a + b.X$	linear
-	-	53/807**	-160/771*	$Y = a + b.LnX$	log
-	-	-1294/796*	90/267**	$\frac{1}{Y} = a + b.X$	reverse
-	0/006**	0/113*	3/910*	$Y = a + b.X + c.X^2$	Degree 2
$-0/00001005^{n.s}$	0/009**	n.s-0/034	6/112*	$Y = a + b.X + c.X^2 + d.X^3$	Degree 3
-	-	1/342**	0/162*	$Y = a.X^b$	Square
-	-	0/024**	6/616**	$Y = a.e^{b.X}$	exponential

* Significant at the one percent level, * significant at the five percent level, n.s not significant

To determine the best model to fit the data Harvester data analysis operations was performed and the results were analyzed. The results are shown in Table 4.

Table 4

r	R^2	F	Average squres	Degree of freedom	Change source	Mathematical model	
/977 0	95/4 %	209/577**	/417 24724	1	Model	$Y = a + b.X$	linear
			117/973	10	error		
/855 0	73/1 %	27/110**	/791 18923	1	Model	$Y = a + b.LnX$	log
			698/035	10	error		
/640 0	%41	6/945*	/683 10616	1	Model	$\frac{1}{Y} = a + b.X$	reverse
			1528/746	10	error		
/000 1	99/9 %	/464** 5099	/653 12940	2	Model	$Y = a + b.X + c.X^2$	Degree 2
			2/538	9	error		
/000 1	99/9 %	/008** 3559	8628/250	3	Model	$Y = a + b.X + c.X^2 + d.X^3$	Degree 3
			2/424	8	error		
/990 0	97/9 %	475/671**	11/776	1	Model	$Y = a.X^b$	square
			0/025	10	error		
/978 0	95/6 %	219/082**	11/499	1	Model	$Y = a.e^{b.X}$	exponential
			0/052	10	error		

* Significant at the one percent level, * significant at the five percent level

Figure 3 displays the regression mathematical models of the study.

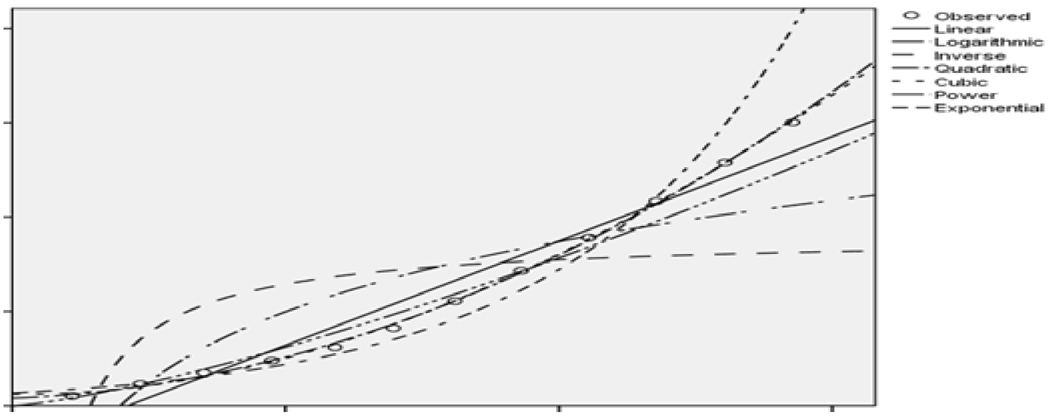


Figure 3: Different mathematical regression models

After drawing tables of estimating the coefficients, and ANOVA for all mathematical models, the significant of models and coefficients are tested with F statistics and t-test.

According to the F values obtained from the data analysis which are listed in Table 4 and comparison with the quantities of distribution table F, it was found that the value of F for all models except the inverse model (the model is statistically significant at the 5% level) is significant at the one percent level.

Therefore, it is concluded that all appropriate mathematical models and significant correlation with the corresponding data are established. Comparing the coefficients of determination (R^2) estimated for all mathematical models indicated that the quadratic, cubic, power, exponential, linear, respectively, are the highest determination coefficient. That is a good explanation of the observed variation between the independent and dependent variables are expressed. Mathematical models were determined by examining the constant obtained for the linear model was negative which cannot be accepted due to estimated amount of negative charge in the early years of life.

Exponential function in spite of significant coefficients at one percent level was much higher than estimated costs. The square function, in spite of significant coefficients at the five percent of the estimated costs, was underestimated.

The second and third coefficients had the lowest difference of predicted by the amount of actual costs compared to real annual costs.

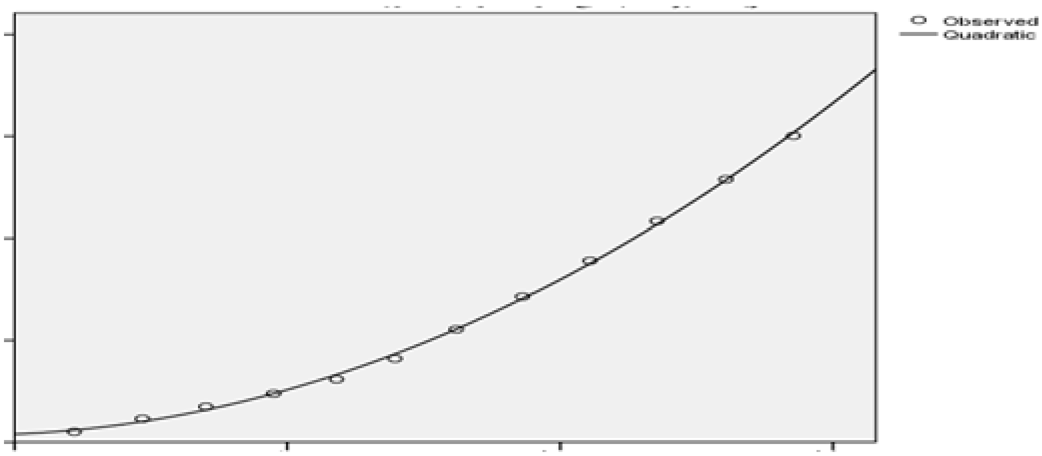
By examining the Coefficients, it was determined that third-function coefficients are significant at the five percent level and quadric function of the coefficients are significant at the five percent level. Thus the quadratic function with coefficient of 9/99% and a correlation coefficient of 000/1 was chosen as an appropriate model to predict maintenance costs in Harvesters of Cane Harvester Company of Imam Khomeini which is shown in following equation and the curve is shown in Figure 4.

$$Y = 3/910 + 0/113\left(\frac{X}{100}\right) + 0/006\left(\frac{X}{100}\right)^2$$

Where:

Y: Cumulative maintenance fee based on a percentage of the original price
X: Cumulative functions are GMT.

Figure 4: Curve fitted quadratic model for predicting maintenance costs of Harvester



Predicting the cumulative maintenance costs obtained by the mathematical model

In Table 5, the values of cumulative maintenance costs per operating hour of Harvester were obtained using the quadratic model.

Table 5: Predicted values and maintenance costs by using the quadratic model

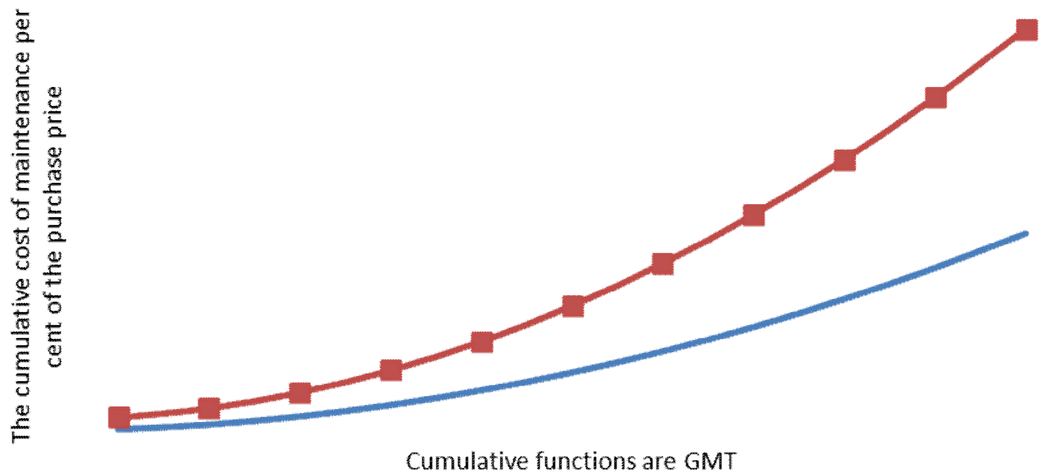
Costs of cumulative maintenance)million Rials(	**Costs of cumulative maintenance) percent of basic price(**	**Working hour**
190/632	5/65	1000
289/666	8/57	2000
429/260	12/70	3000
609/414	18/03	4000
830/128	24/56	5000
1091/402	32/29	6000
1393/236	41/22	7000
1735/63	51/35	8000
2118/584	62/68	9000
2542/098	75/21	10000
3006/172	88/94	11000
3510/806	103/87	12000
4056	120/00	13000
4641/754	137/33	14000
5268/068	155/86	15000

Comparing mathematical models obtained by the results of other researches

To compare the final model obtained in this study with the results of other research expenses curve predicted by the models Hours of operation from zero to 10,000 hours on one set was drawn. Figure 5 is a representative comparison.

As it is observed in Figure 5, the curve of the study estimated the costs less than previous studies.

Figure 5: Comparison of mathematical models with other studies



Appropriately designed neural network to predict maintenance costs of Harvester tractors

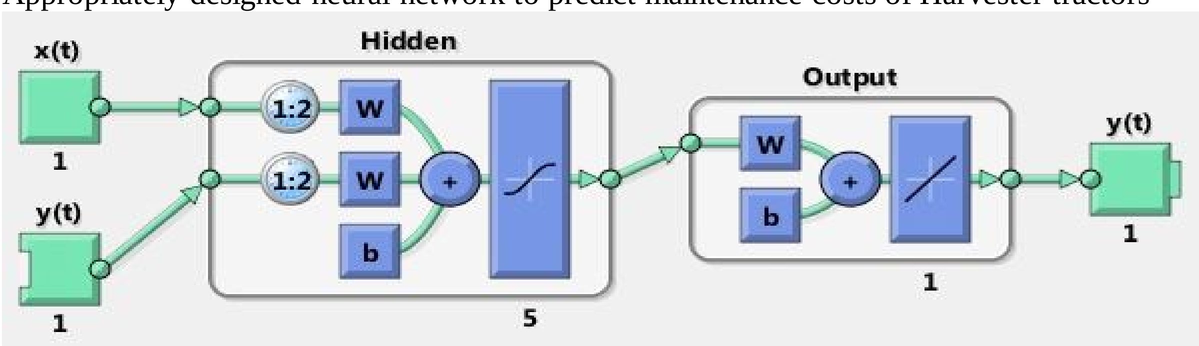


Figure 6: schema of neural networks designed

In the network above a neuron was placed in input and output layer of (with the number of inputs and outputs of the network). To select the best network structure, the number of hidden layer neurons, was considered from 1 to 10 respectively and by evaluating the performance of designed networks, the most appropriate structure was chosen to predict maintenance costs Harvesters performing cane harvest.The results of the evaluation of the performance of designed structures are listed in Table 6.

Table 6: Evaluation of the performance of designed structures

Coefficient od determination) R^2(	Mean square error)MSE(	Linear regression	Network structure
0/9924	0/314	$pv = 0/87dv + 5/7$	1-1-1
0/9999	0/033	$pv = 0/99dv + 0/94$	1-2-1
0/9998	0/856	$pv = 0/95dv + 2/8$	1-3-1
0/9993	0/578	$pv = 0/98dv + 1/6$	1-4-1
0/9998	$4/98 \times 10^{-7}$	$pv = 1dv + 0/2$	1-5-1

0/9987	15/230	$pv = 0/94dv + 2/5$	1-6-1
0/9995	0/0156	$pv = 1dv + 0/25$	1-7-1
0/9997	1/877	$pv = 0/98dv + 2/8$	1-8-1
0/9896	347/140	$pv = 0/73dv + 12$	1-9-1
0/9960	0/694	$pv = 0/99dv + 1/7$	1-10-1

Pv: predicted values by the network, dv: data values

Coefficient and linear regression between actual data and the values predicted by the network is shown in Table 6. Best results based on two criteria are achieved when linear equations between the actual and predicted values, in addition to having a high coefficient, intercept close to zero and the slope is close to one. By examining the designed structures, it is determined that 1-5-1 structure with coefficient of 9998/0 and y-intercept 2/0 and the slope has the best conditions among the designed structures. So the 1-5-1 structure was the most suitable designed structure. Table 7 shows cumulative maintenance costs and actual values predicted by the neural network. So, NARX neural network with learning algorithm Trainlm and 1-5-1 structure show that it is a proper tool for predicting repair and maintenance costs of Harvesters.

Table 7: Cumulative actual and projected maintenance costs by neural network (million rials)

Predicted Value of Network	Real value	year
5/37	5/09	1379
12/43	11/49	1380
17/81	17/41	1381
22/71	23/80	1382
30/98	30/87	1383
42/79	41/04	1384
55/22	55/38	1385
71/30	71/49	1386
91/89	89/06	1387
111/22	108/38	1388
130/09	128/84	1389
155/19	150/22	1390

Conclusions

The mathematical model for predicting maintenance costs

To determine the proper mathematical model to predict maintenance costs of Harvester, a seven-linear, exponential, square, logarithmic, inverse, quadratic, degree of fit and analysis of variance were used.

The quadratic model with coefficient of 9/99 percent was chosen as the appropriate model and its mathematical equation is as follows:

$$R^2 = \%99/9 ، \qquad Y = 3/910 + 0/113(\frac{X}{100}) + 0/006(\frac{X}{100})^2$$

Where:

X: Harvester cumulative operating hours

Y: The cumulative cost of maintenance per cent of the purchase price

Neural network designed to predict maintenance costs for predicting the maintenance costs, a neural network called Narx with learning algorithm Trainlm with different structures were designed and finally, the structure of the 1-5-1 was chosen as the appropriate structure prediction for Harvester maintenance costs.

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