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# Prediction of Repair and Maintenance Costs of Massey Ferguson 285 Tractors

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**Abstract:** Prediction of repair and maintenance (R&M) costs of tractors and agricultural machinery in any mechanized farm is essential for owners and managers to achieve information on overall costs and to control financial balance and production economy. As Massey Ferguson 285 (MF-650) tractors are widely used by Iranian farmers and agro-industry companies, a study was conducted to model accumulated R&M costs of MF-285 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&M costs of MF-285 tractors with service life of 2275 h or less the power regression model $Y = 0.0187\ (X/100)^{1.6381}$ with $R^2 = 0.966$ and to predict accumulated R&M costs of MF-285 tractors with service life of 2275 h or more the polynomial regression model $Y = 0.0049\ (X/100)^2 - 0.2228\ (X/100) + 5.0759$ with $R^2 = 0.997$ can be properly suggested.

**Key words:** R&M costs · Tractor · MF-285 · Modeling · Prediction · 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&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&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&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&M costs data to develop models for predicting R&M costs. Fairbanks *et al.* [7] working in Kansas collected R&M costs data through investigation from 114 farm managers. At the end, accumulated R&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&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&M costs variation on tractors was so high as to preclude the use of an obtained model for predicting R&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&M costs data of 50 tractors in Weasenham Farm Company in Norfolk and used them to obtain R&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&M costs. Skill of operator, working conditions and maintenance standards were reported as

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important determinants of machinery R&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&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&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&M costs of tractors and farm machinery too. Almassi and Yeganeh [12] obtained an appropriate regression model for accurate prediction of accumulated R&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&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&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&M costs data, particularly for older machines. In addition, great variations in R&M costs between different tractor models, tractors and their operating conditions make it difficult to obtain general models. As Massey Ferguson 285 (MF-285) tractors are widely used by Iranian farmers and agro-industry companies, the purpose of this study was to model accumulated R&M costs (as percentage of initial purchase price) based on accumulated usage hours using farm records for 15 active MF-285 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&M costs including spare-parts, lubricants and labor costs. Labor charged at hourly rates includes all workshop related wages and overheads. Fifteen active MF-285 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 1162 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&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&M costs as percentage of initial purchase price which was considered to be dependent variable (Y) obtained through dividing the total accumulated R&M costs by initial purchase price of tractor. To acquire information (i.e. R&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&M costs trend.

## RESULTS AND DISCUSSION

Table 1 shows mean annual values and mean annual percent of R&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&M costs, average of annual usage hours and average of R&M costs per hour per unit of all tractors for different ages of them. Fig. 1 shows mean R&M costs fractions, i.e. spare-parts, wages and lubricants to be 68.0%, 24.1% and 7.9%, respectively, among which spare-parts costs are the highest.

Table 1: Mean annual values and mean annual percent of R&M costs fractions (spare-parts, wages and lubricants), average of whole annual R&M costs, average of annual usage hours and average of R&M costs per hour per unit of MF-285 tractors for different ages of them

| | Spare-parts | | Wages | | Lubricants | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age (years) | Value (Rials) | %* | Value (Rials) | % | Value (Rials) | % | Average of whole annual R&M costs (Rials) | Average of annual usage hours (h) | Average of R&M costs per hour (Rials) |
| 1 | 580421 | 63.3 | 253151 | 27.6 | 83476 | 9.10 | 917048 | 918.60 | 998.300 |
| 2 | 507319 | 61.3 | 220671 | 26.7 | 99542 | 12.0 | 827532 | 1015.3 | 815.100 |
| 3 | 996503 | 61.9 | 483430 | 30.0 | 130417 | 8.10 | 1610350 | 1280.7 | 1257.40 |
| 4 | 1325009 | 69.3 | 420860 | 22.0 | 166056 | 8.70 | 1911925 | 1345.0 | 1421.50 |
| 5 | 1895550 | 68.4 | 672000 | 24.2 | 204141 | 7.40 | 2771691 | 1307.6 | 2119.70 |
| 6 | 2236160 | 70.5 | 734189 | 23.2 | 199852 | 6.30 | 3170201 | 1320.2 | 2401.30 |
| 7 | 3674110 | 69.4 | 1353219 | 25.6 | 265308 | 5.00 | 5292637 | 1386.1 | 3818.40 |
| 8 | 3407707 | 61.5 | 1810216 | 32.6 | 327380 | 5.90 | 5545303 | 1373.2 | 4038.20 |
| 9 | 4380021 | 64.8 | 1959140 | 29.0 | 424000 | 6.30 | 6763161 | 1419.0 | 4766.10 |
| 10 | 6971618 | 69.6 | 2483491 | 24.8 | 557653 | 5.60 | 10012762 | 1171.0 | 8550.60 |
| 11 | 10389777 | 74.7 | 2752070 | 19.8 | 771000 | 5.50 | 13912847 | 1308.3 | 10634.3 |
| 12 | 6224183 | 69.9 | 1992018 | 22.4 | 689871 | 7.70 | 8906072 | 970.60 | 9175.80 |
| 13 | 5387651 | 68.4 | 1758194 | 22.3 | 734267 | 9.30 | 7880112 | 880.60 | 8948.60 |
| 14 | 5776146 | 76.4 | 983310 | 13.0 | 799810 | 10.6 | 7559266 | 900.00 | 8399.20 |
| 15 | 5288198 | 70.5 | 1347113 | 18.0 | 861770 | 11.5 | 7497081 | 832.20 | 9008.70 |
| Average | 3936025 | 68.0 | 1281538 | 24.1 | 420970 | 7.90 | 5638533 | 1162.0 | 5090.20 |

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

Table 2: Mean accumulated usage hours and mean accumulated R&M costs as percentage of initial purchase price per unit of MF-285 tractors for different ages of them

| Age (years) | Mean accumulated usage hours(h) | Mean accumulated R&M costs as percentage of initial purchase price(%) |
|---|---|---|
| 1 | 919 | 1.230 |
| 2 | 1934 | 2.340 |
| 3 | 3215 | 4.500 |
| 4 | 4560 | 7.070 |
| 5 | 5867 | 10.79 |
| 6 | 7187 | 15.05 |
| 7 | 8574 | 22.15 |
| 8 | 9947 | 29.59 |
| 9 | 11366 | 38.67 |
| 10 | 12537 | 52.11 |
| 11 | 13845 | 70.78 |
| 12 | 14816 | 82.73 |
| 13 | 15696 | 93.31 |
| 14 | 16596 | 103.5 |
| 15 | 17428 | 113.5 |

Table 3: Description, coefficients and coefficient of determination ($R^2$) of the four regression models obtained for MF-285 tractors under study

| Model | Description | a | b | c | $R^2$ |
|---|---|---|---|---|---|
| Linear | $Y = a\,(X/100) + b$ | 0.6889 | -23.200 | --- | 0.909 |
| Exponential | $Y = a\,e^{b(X/100)}$ | 1.8298 | 0.0258 | --- | 0.965 |
| Power | $Y = a\,(X/100)^{b}$ | 0.0187 | 1.6381 | --- | 0.966 |
| Polynomial | $Y = a\,(X/100)^2 + b\,(X/100) + c$ | 0.0049 | -0.2228 | 5.0759 | 0.997 |

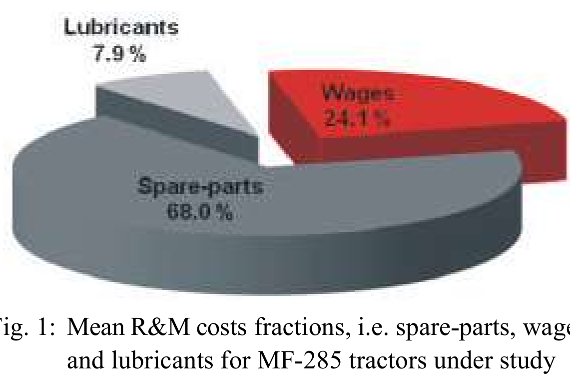


Fig. 1: Mean R&M costs fractions, i.e. spare-parts, wages and lubricants for MF-285 tractors under study

Table 2 provides information on mean accumulated usage hours and mean accumulated R&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

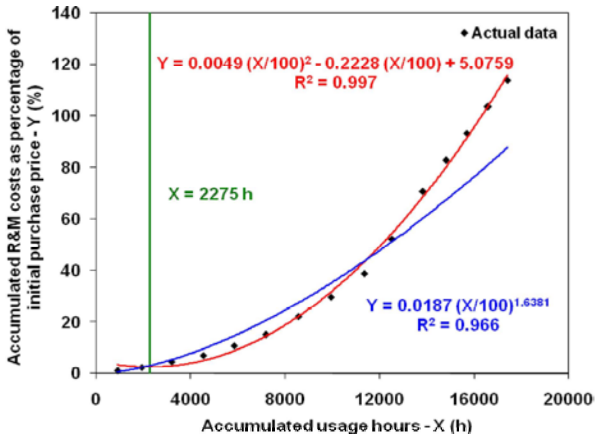


Fig. 2: Curves of predicted accumulated R&M costs as percentage of initial purchase price based on accumulated usage hours using the power and polynomial regression models for MF-285 tractors under study

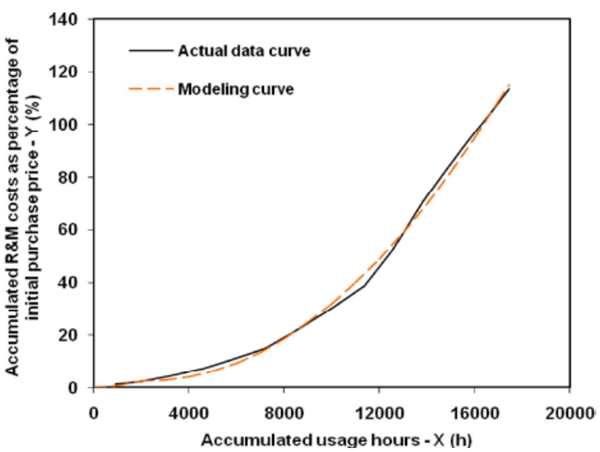


Fig. 3: Actual data curve and modeling curve of accumulated R&M costs based on accumulated usage hours for MF-285 tractors under study

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&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. Moreover, as the polynomial model shows accumulated R&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 2275 h as equation 1:

$$Y = 0.0187\ (X/100)^{1.6381}\ (X < 2275\ h) \qquad (1)$$

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 2275 h as equation 2:

$$Y = 0.0049\ (X/100)^2 - 0.2228\ (X/100) + 5.0759\ (X > 2275\ h) \qquad (2)$$

Figure 2 indicates the curves of predicted accumulated R&M costs based on accumulated usage hours using the power and polynomial models together with the actual data and the line of X = 2275 h.

Figure 3 shows the curve of predicted accumulated R&M costs based on accumulated usage hours using the power model for the first period of machine life and the polynomial model for the remaining service life of tractors (modeling curve) along with actual data curve. From comparison of two curves, it can be concluded that modeling curve and actual data curve give almost the same trend. It can also be observed that the rate of accumulated R&M costs at earlier life time of tractors was fairly low. However, trend of R&M costs was increasing thereafter and the rate of increase was moderately high. This increasing rate of R&M costs may be attributed to the facts like quality in design and manufacturing, scarcity and higher cost of some spare-parts and also much frequent need for repair in MF-285 tractors. This can also be related to more frequent break-downs, inferior production technology, inherent deficiencies and also incompatible field operations to their power and efficiencies.

## CONCLUSION

Results of this study indicated that average R&M costs per hour increased with tractor age. These results also indicated that in order to predict accumulated R&M costs of MF-285 tractors with service life of 2275 h or less the power regression model $Y = 0.0187\ (X/100)^{1.6381}$ with $R^2 = 0.966$ and to predict accumulated R&M costs of MF-285 tractors with service life of 2275 h or more the polynomial regression model $Y = 0.0049\ (X/100)^2 - 0.2228\ (X/100) + 5.0759$ with $R^2 = 0.997$ can be properly suggested.

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