

# MATHEMATICAL MODEL FOR REPAIR AND MAINTENANCE COSTS OF AGRICULTURAL MACHINERY

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A standard model for repair and maintenance costs of agriculture machinery is proposed alongwith model parameters for tractor, thresher, trailer and cultivator. The model predicts the total accumulated repair cost in percent of initial cost as a power function of machine age with age measured in percent of intended wear out life of a machine.

## INTRODUCTION

Repair and maintenance costs are a small but relatively important portion of total cost of owning and operating farm machinery. Repair costs are generally 10 to 15% of the total cost, but because they tend to increase with machine age, repair costs become important in influencing the optimal time for machinery replacement. The repair costs are difficult to estimate because accurate records of repair costs over the life time of machines are not readily available and the wide differences in these costs exist due to variation in operating conditions, management of machinery, maintenance programme, labour charges etc. (Kepner *et al*, 1978).

As the future course of farm mechanization would largely depend on how efficiently the problem of maintenance and repair is tackled, there is an imperative need to investigate the existing situation with regard

to assessing the repair and maintenance costs of farm machinery. In order to obtain a uniform procedure for machinery cost analysis, a standard model for repair and maintenance costs is desirable. This study was, therefore, designed to develop a mathematical model describing relationship between accumulated use of agricultural machines and their accumulated repair cost.

## METHODOLOGY

**Selection of study area and farmers:** The study area comprised 24 villages in 12 tehsils of Punjab. One hundred and twenty farmers were selected for interview and consequently collection of the required data. These tehsils were selected on the basis of prevailing four cropping patterns. In each tehsil two villages were selected and in each village five farmers were chosen, four on the basis of farm size and one farmer having machines on share basis. The selected cropping patterns and their respective tehsils were as follows:

Cropping pattern	Tehsils		
Wheat/cotton	i) Jhang	ii) Shorkot	iii) Kahirwala
Rice/wheat	i) Ferozwala	ii) Sheikhupura	iii) Nankana
Sugarcane/wheat	i) Bahawal	ii) Shahpur	iii) Sargodha
Wheat/sugarcane	i) Faisalabad	ii) Chiniot	iii) Samundari

**Data acquisition:** A survey was conducted to gather information for accumulated use of farm machines and their respective repair costs. In case accumulated use hours of a

machine were not known, particularly for older machines, the following technique was adopted to overcome this difficulty: Each machine was grouped by age and the

mean annual use for each group, together with the mean annual repair costs for that group were calculated. The total accumulated use in hours (TAUH) was calculated for each group by summation of the mean annual usage for all years up to and including that year. The same technique was used to obtain the total accumulated repair (TAR) for group (Ward *et al* ,1985). In the study area one hundred and twenty farmers were interviewed. Of these, only 84 farmers could furnish information about repair and maintenance costs of agricultural machines and their annual use, while 36 farmers did not respond. The data were recorded for 93 tractors (some of the farmers had more than one tractor) ,57 cultivators, 39 threshers and 28 trailers.

With the help of the regression analysis technique an appropriate equation was evolved to determine the relationship between the accumulated repair costs and the accumulated use, in hours, of the agricultural machines.

#### RESULTS AND DISCUSSION

**Model development:** The data were collected and arranged in the tabulated form for analysis purpose. From repair cost data for tractors, the power regression equation line was found the best fit, having coefficient of determination ( $R^2$ ) as 0.996. This equation was selected as a representative equation (1) for all agricultural machines.

$$TAR = A (TAUH)^B \quad (1)$$

Where:

TAR = Total accumulated repair cost, in percent of initial cost of tractor,

TAUH = Accumulated hours, in percent of lifetime hours,

A,B = Model parameters, function of machine type; parameter 'B' describes the distribution of repair and maintenance costs throughout the machine's life, while 'A' indicates the magnitude of the cost.

The first order power model predicts very low costs in the initial stage of machine life and an increase in later life. This model also predicts a nearly constant rate of increase in the accumulated cost toward the end of the machine's life. Although other models may provide a slightly better fit to actual data (Bowers and Hunt, 1970), the increase in the complexity of the model is unjustified, due to large variation in repair cost data. More important is the need for a model which accurately predicts the cost trend, because this trend will affect the optimal life of the machine. The analysis of repair and maintenance costs data for 93 tractors, 57 cultivators, 39 threshers and 28 trailers yielded the model parameters A and B shown in Table 1.

Table 1. Estimated life and repair parameters for agricultural machinery

Machine	Estimated life (hours)	Total life (repair in % of initial cost)	Model parameters	
			A	B
Tractor (2WD)	12000	100	0.0669	1.595
Cultivator	3000	80	0.3840	1.164
Thresher	6000	80	0.0936	1.465
Trailer	3000	88	0.0927	1.488

**Model accuracy:** A better understanding of the accuracy of a model can be obtained by observing the sensitivity of the model to the changes made in the model parameters. A change in the value of 'A' will cause a proportional change in the total accumulated repair and maintenance costs over the machine's life or during any year of the machine's life. The magnitude of the cost predicted by the model, therefore, can be varied through a change in the value of 'A'.

The value of 'B' controls the distribution of costs throughout the life of the machine. A decrease in 'B' will cause a shift of cost toward the early life of the machine. As an example, a 10 % decrease in the value of 'B' for a tractor use of 1000-hour will cause a 0.56% decrease in the predicted repair costs during the first year of operation. As 'A' was calculated based upon a value set for 'B' the

value of 'B' should not be adjusted without a corresponding change in 'A' to maintain the same repair and maintenance costs. For example, when the value of 'B' is decreased 10% the value of 'A' must be increased by 39.76% to maintain the same repair costs for the 1000-hour of use in first year. Only with an increase of 10% in value of 'B' the accumulated repair and maintenance costs increase about 0.78% in the first year and 29.3% in the mid life with no change in the machine's life and parameter 'A'.

A small change in the value of 'B' therefore, can have a significant impact on repair costs predicted. As an example the repair and maintenance costs of a tractor for third year of its life by employing the model developed in this study can be calculated as follows:

The purchase price of a tractor	=	Rs.1,56,000
Annual use of tractor	=	500 hours
The accumulated use of tractor at the end of 2nd year	=	1000 hours
The accumulated use of tractor at the end of 3rd year	=	1500 hours
The accumulated repair and maintenance costs at the end of 2nd year	$= 0.0669 ((1500 / 12000) \times 100)^{1.592} = 1.956\%$	
The accumulated repair and maintenance costs at the end of 3rd year	$= 0.0669 ((1500 / 12000) \times 100)^{1.592} = 3.729\%$	
Repair and maintenance costs for 3rd year	$= (3.729 - 1.956) / 100 \times 1,56,000$	
	$= \text{Rs. } 2765.88 / 500 \text{ hours}$	
	$= \text{Rs. } 5.53 / \text{hour.}$	

### CONCLUSIONS

The following conclusions were drawn.

1. The optimum replacement age for a given machine was dependent on repair costs rate and the replacement age for tractor, thresher, trailer and cultivator was found to be 12000, 6000, 3000 and 3000 hours respec-

tively.

2. Cultivator, trailer and thresher are generally replaced before reaching a total accumulated repair and maintenance cost less than 100 % of their initial prices
3. It was observed that the repair and maintenance costs of tractor, trailer, thresher and cultivator were very low

during the early hours of their use and increased rapidly with the increase in the machine life.

4. The power regression equations evolved in this study are suitable for calculating the expected repair costs of farm machinery for any specific farm.

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