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A MATHEMATICAL EXPRESSION FOR COST ANALYSIS OF FARM EQUIPMENTS

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Introduction

Recent mechanization of Indian agriculture has raised several methodological issues in working out the operation cost of tractors of varying horse power and also of other farm machineries. Problems which usually occur in these cost calculations are with respect to the depreciation rates and interest rates on the capital invested in purchasing farm machineries. Such cost calculations are not only important to the farmers for knowing the possibilities of reducing the operation costs but also to the policy-makers for fixing prices of farm produce and inputs in view of the conflicting views on the impact of farm mechanization with respect to labour employment (4).†

Existing Method of Calculating Cost of Operation

Machinery costs are divided into two categories, *viz.*, fixed and variable costs. Fixed costs are those which are independent of the level of production, whereas variable costs are those which vary with the level of production. Fixed cost includes depreciation, interest, shelter, maintenance, taxes and insurance, whereas the variable cost includes labour, fuel and lubricating oil, repairs and replacements.

Generally for calculating the depreciation of any farm machinery the straight line method is used. Other methods are more accurate but are difficult and complex to handle. The comparison of the straight line, declining balance, and sum of the digits methods for determining depreciation for a machine with a life expectancy of 10 years is given in Figure 1.

Table I describes the rate of depreciation of various farm machines but one's experience also be well utilized as the workmanship of the machine differs from manufacturer to manufacturer and usage of the machine. Figure 2 shows the relationship between hours of life, hours of use per year and depreciation cost per hour per Rs. 100 new cost at various salvage value factors. For finding depreciation cost per hour first locate the intersection of hours of use per year with hours of life and then locate the intersection of hours of use per year with years until obsolete and finally from upper point of these intersections move to right and read at required salvage value factor.

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† Figure in brackets denotes reference cited at the end of the paper.

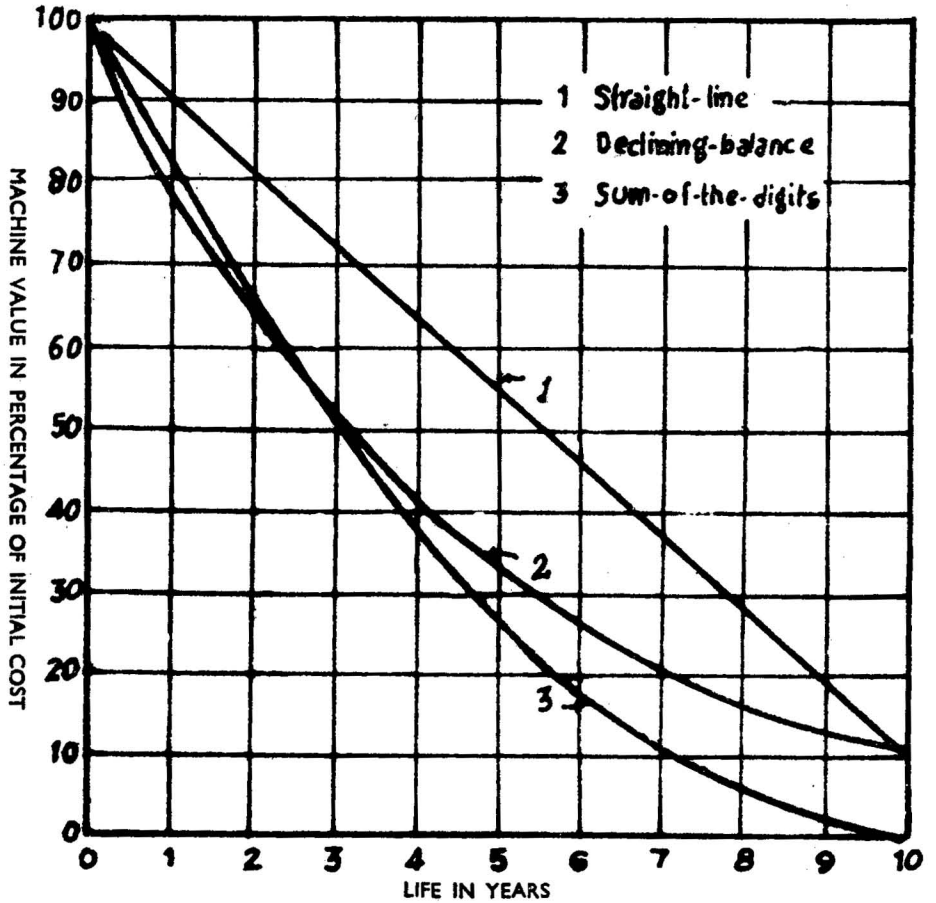

Figure 1—Comparison of the Straight Line, Declining Balance, and Sum of Digits Methods for Determining Depreciation for a Machine with a Life Expectancy of 10 Years (G. H. Larson, Kansas Agri. Expt. Sta. Bull. 417, 1960)

In the straight line method of depreciation, the annual interest is charged on the average investment of the machine. Figure 3 shows the relationship between annual hours of use, rate of interest and interest per hour per Rs. 100 new cost at various salvage value factors. For finding interest per hour, locate the intersection of annual hours of life with prevailing rate of interest and from this point of intersection move towards left horizontally and read at required salvage value factor.

TABLE I—SUGGESTED YEARLY RATES OF DEPRECIATION AND REPAIRS AND REPLACEMENT CHARGES FOR VARIOUS AGRICULTURAL MACHINERY

Sr. No.	Name of machine	Suggested rates in terms of initial costs	
		Depreciation (per cent)	Repairs and replacement (per cent)
1.	Tractor	10	10
2.	Plough	7	5.5
3.	Cultivator	9	3.8
4.	Harrow	7	3.5
5.	Seed drill	5	2.2
6.	Thresher	10	5
7.	Leveller	5	4

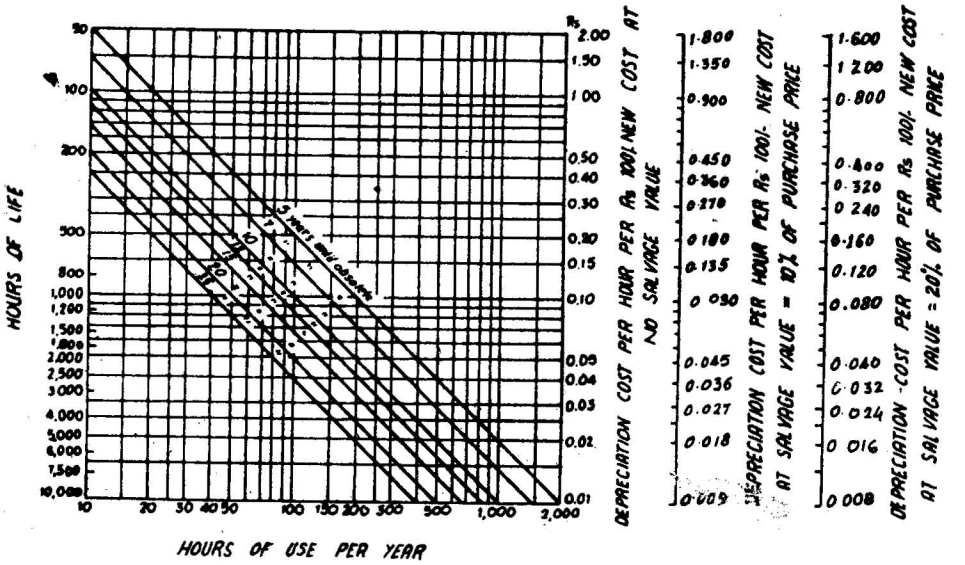

Figure 2—Relationship between Hours of Life, Hours of Use Per Year and Depreciation Cost Per Hour Per Rs. 100 New Cost at Various Salvage Value Factors

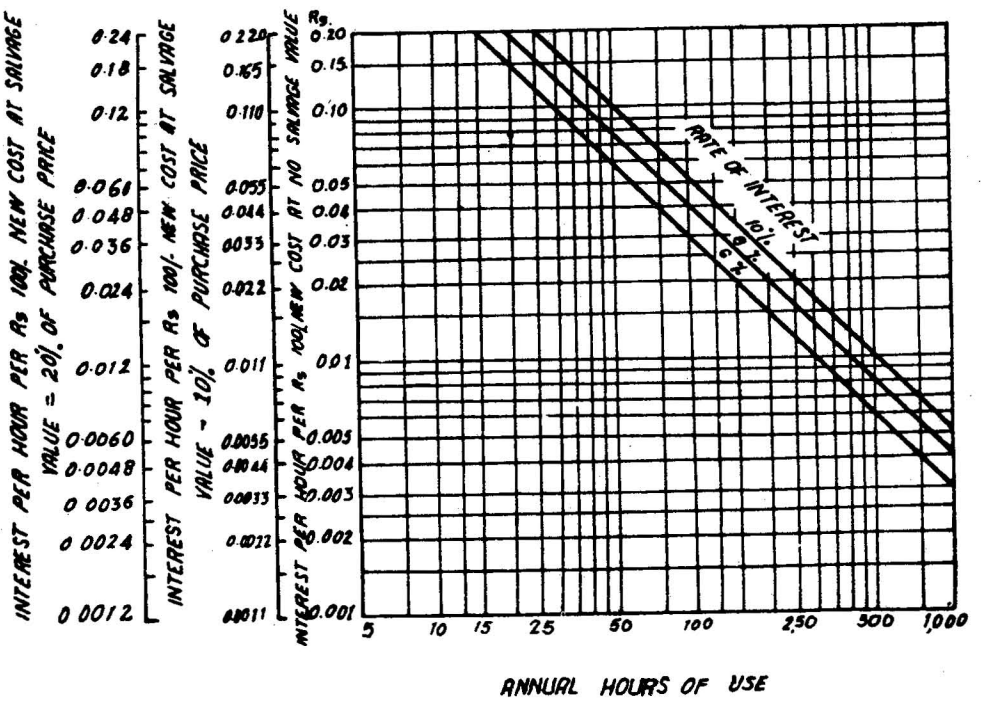

Figure 3—Relationship between Annual Hours of Use, Rate of Interest and Interest per Hour Per Rs. 100 New Cost at Various Salvage Value Factors

The cost of repairs and replacements has some percentage relationship with the purchase price of the machine as given in Table I. Figure 4 shows the relationship between hours of life and repair cost per hour per Rs. 100 new cost at various life repair costs. To find out the repair cost per hour per Rs. 100 new cost, first locate the intersection of hours of life with required life repair cost percentage, then move left horizontally and read. For calculating the cost of operation on hourly basis, the annual cost of operation is divided by the annual usage of machine.

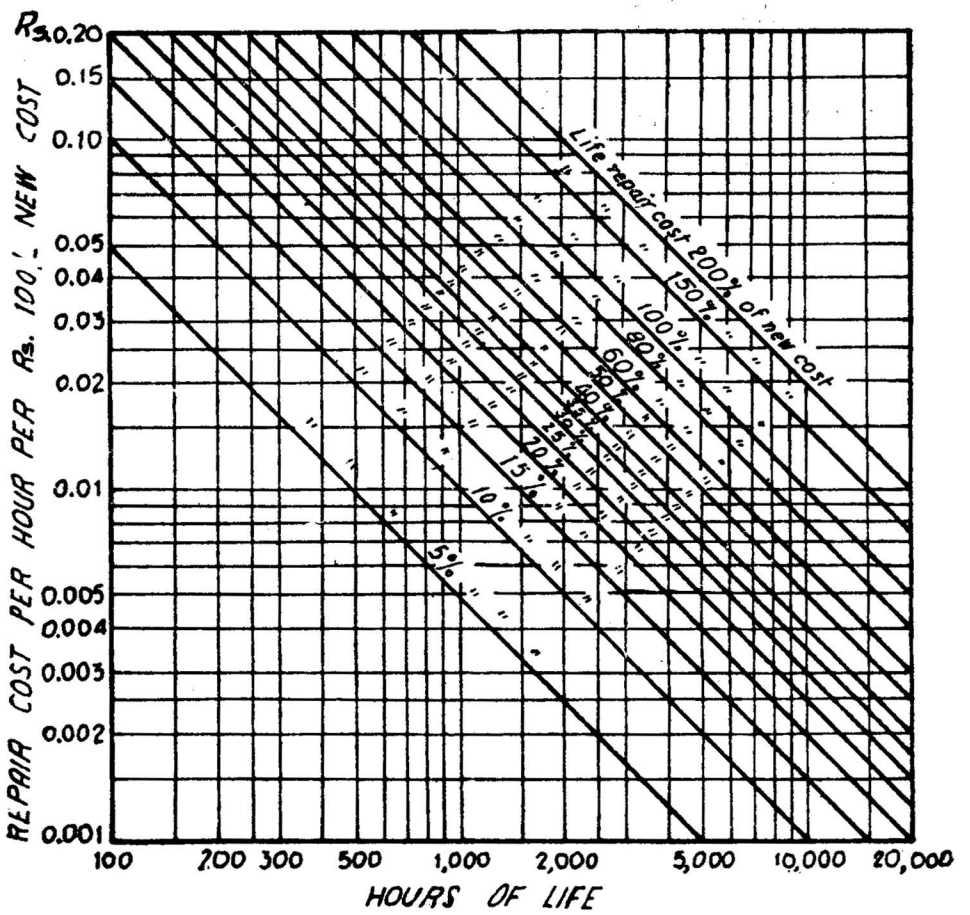

Figure 4—Relationship between Hours of Life and Repair Cost Per Hour Per Rs. 100 New Cost (Amer. Soc. Agrl. Engin. Year Book 1962)

Proposed Method of Calculating Cost of Operation

In the suggested method of calculating cost of operation, the fixed and variable cost items discussed above have been added and put in the following mathematical expression :

$$Ocy = P\ (\ d + 0.5i + S + M + R + T)\ +\ K\ (0.5i - d)\ +\ H(FC_1\ +\ LC_2)$$

$$+\ 12\ W\ +\ X \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

$$Och = \frac{P}{H}(d + 0.5i + S + M + R + T) + \frac{K}{H}(0.5i - d) + (FC_1 + LC_2)$$

$$+\left(12\,\frac{W}{H}\ +\frac{X}{H}\right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

where,

Ocy	=	annual operation costs (Rs.)
Och	=	hourly operating cost (Rs.)
S	=	shelter (%)
M	=	maintenance (%)
R	=	repairs and replacement (%)
H	=	annual use of machine (hours)
F	=	fuel consumption (litre/hour)
C_1	=	cost of fuel (Rs./litre)
L	=	lubricating oil consumption (Rs./litre)
C_2	=	cost of lubricating oil (Rs./litre)
W	=	monthly wages of operator (Rs.)
T	=	taxes and insurance rate (%)
X	=	other factor (if any) (Rs.)
d	=	rate of depreciation (%)
K	=	salvage value (%)
P	=	purchase price of machine (Rs.)
i	=	rate of interest (%)

Reduction Formula for Tractors

Various values for calculating the cost of operation for tractors are : d = 10%, i = 10%, S = 2%, M = 2%, R = 10%, T = 1%, K = 0.P (10% of the purchase price), H = 1000 hours and X = 0. Thus the equations (1) and (2) reduced to the following form by putting these values in decimals :

$$Ocyt = (0.295\ P + 12W) + (FC_1 + LC_2)\ \times 10^{-3} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$Ocht = (0.295\ P + 12W) \times 10 + (FC_1 + LC_2) \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where,

Ocyt = annual operating cost of tractor (Rs.)

Ocht = hourly operating cost of tractor (Rs.).

If the purchase price, cost incurred for taxes and insurance, monthly wages of the operator, hourly fuel consumption is known, one can calculate the cost of operation on yearly or hourly basis.

Empirical Findings

Tables II and III show the cost of operation on hour basis for various makes of the tractor based on the existing and proposed method of estimation. It may be seen from the tables that there is no difference in the total cost of operation of tractor except in the case of Byelarus, Rumanian U-650 and Zetor-2011 tractors. This difference is because approximation for various cost factors like depreciation, interest, repairs and maintenance has been done to the nearest decimal number. In the case of International and Massey Ferguson tractors, there is no variation in the total cost of operation calculated by the existing and the proposed mathematical expression as the approximation has been done in the purchase price itself. It is obvious that the proposed expression is less time consuming and is simple. It eliminates various cost factors and slight changes in purchase price, wages of operator, fuel consumption and its cost and lubricating oil consumption and its cost do not make the estimation process repetitive as in the existing method of calculating cost of operation.

Similarly, the cost of other agricultural implements can be found by generalised equation (2). Ploughing, harrowing and levelling charges, and custom charge can be worked out by calculating how much acres the implement covers in one hour with the aid of Figure 5 which shows the relationship between width of the machine, effective capacity, speed of travel and interrupted capacity of the machine. One can read the capacity of the farm equipment for various width, speed of travel and the percentage of time lost without making calculations. For example, if the width of the machine is four meters, travelling at speed of 5 km. per hour, the uninterrupted capacity of the machine would be 2 hectares per hour, whereas the effective capacity of the machine would be one hectare per hour at 50 per cent lost time (Figure 5).

Equations (1) and (2) are the generalised forms of the reduction formulae. These include all the variables and factors involved in calculating the cost of operations of any farm machinery equipment. The variable X can take any value as overhead charges or any extra value which is not being included in the above factors. For the farm machineries like ploughs, harrow or any other non-self propelled machine, the values of F, C_1, L, C_2 will be zero. If a farmer or any owner of the tractor is doing ploughing operation in the field,

TABLE II—BREAK-UP OF COST OF OPERATION FOR VARIOUS MAKES OF TRACTORS BASED ON THE EXISTING METHOD OF COST ANALYSIS

Assumptions : Salvage value = 10 per cent of purchase price
Hours of use per year = 1,000
Total life of tractor = 10,000 hours

Sr. No.	Make	Purchase price (Rs.)	Depreciation at 10 per cent (Rs./hr)	Interest at 10 per cent (Rs./hr)	Shelter at 2 per cent (Rs./hr)	Maintenance at 2 per cent (Rs./hr)	Taxes and insurance at 1 per cent (Rs./hr)	Total fixed cost (Rs./hr)	Fuel cost at Re. 0.90 per litre (Rs./hr)	Lubricating oil cost at Rs. 5.00 per litre (Rs./hr)	Repairs and replacement at 10 per cent (Rs./hr)	Wages at Rs. 250 per month (Rs./hr)	Total variable cost (Rs./hr)	Total cost of operation (Rs./hr)
1.	International B-275 ..	30,000.00	2.70	1.65	0.60	0.60	0.30	5.85	3.60	0.31	3.00	3.00	9.91	15.76
2.	Byelarus	21,322.13	1.93	1.19	0.43	0.43	0.21	4.19	5.40	0.48	2.13	3.00	11.01	15.20
3.	Rumanian—U-650 ..	27,230.06	2.46	1.50	0.55	0.55	0.27	5.33	5.40	0.48	2.72	3.00	11.60	16.93
4.	Massey Ferguson-1035 ..	31,000.00	2.79	1.70	0.62	0.62	0.31	6.04	2.70	0.31	3.10	3.00	9.11	15.15
5.	Zetor-2011	23,355.17	2.11	1.29	0.47	0.47	0.23	4.57	2.25	0.25	2.34	3.00	7.84	12.41

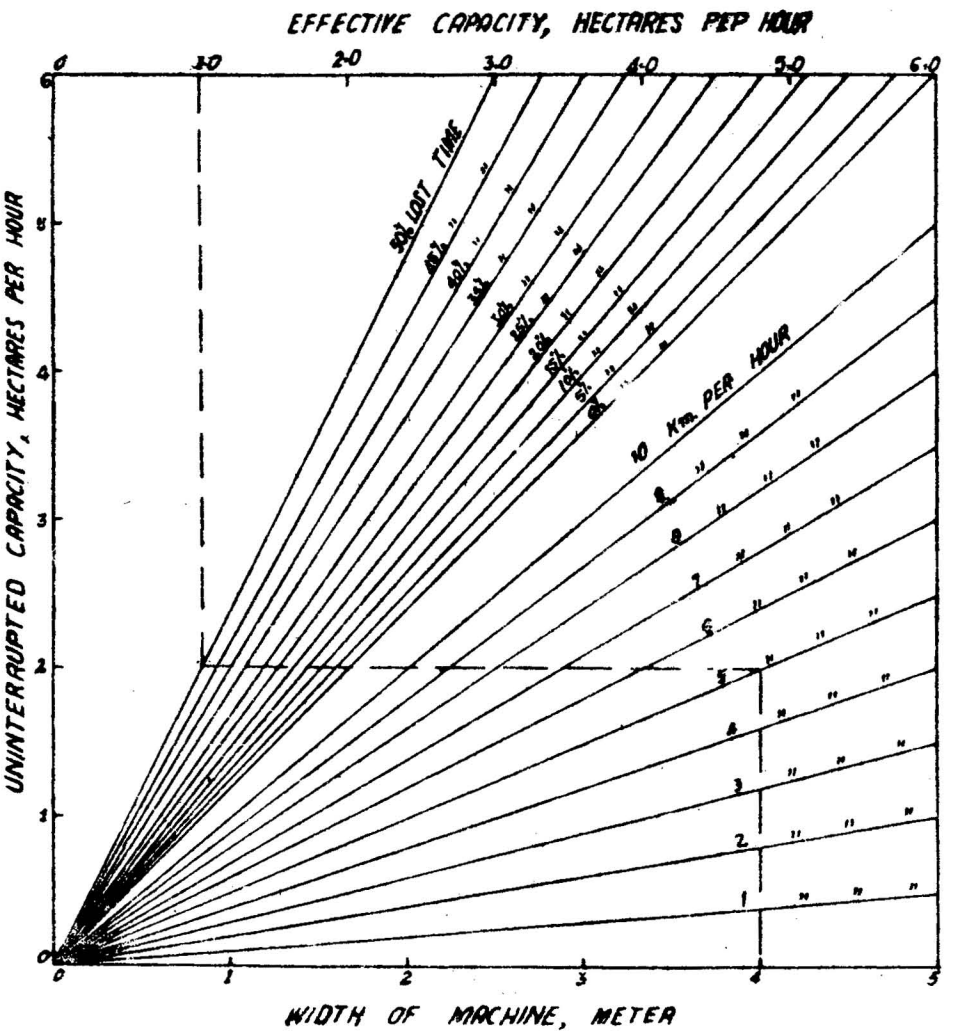

Figure 5—Relationship between Width, Speed of Travel, Effective Capacity and Uninterrupted Capacity of the Machine

the total cost of ploughing per hour could be calculated for plough and tractor separately by equations (2) and (4) respectively and added to obtain the total cost of operation for ploughing. Similarly, the cost can be calculated for harrowing, threshing and other farm operations with the help of the proposed formula.

Conclusion

In the existing method of calculating cost of operation various cost components like depreciation, interest, shelter, daily maintenance and repairs and replacements, etc., are calculated separately. The summation of such

TABLE III—COST OF OPERATION FOR VARIOUS MAKES OF TRACTORS BASED ON PROPOSED MATHEMATICAL EXPRESSION

Mathematical expression

$$\text{Ocht} = (0.295\ P + 12\ W) \times 10^{-3} + (FC_1 + LC_2)$$

Assumptions :

Wages (W) = Rs. 250 per month
Fuel cost (C_1) = Re. 0.90 per litre
Lubricating oil cost (C_2) = Rs. 5 per litre

Sr. No.	Make	Purchase price (Rs.)	Fuel consumption (Litre/hr)	Cost of fuel at Re. 0.90 per litre (Rs./hr)	Lubricating oil consumption (Litre/8 hrs)	Lubricating oil cost at Rs. 5 per litre (Rs./hr)	Total cost of operation by eq. Ocht = $(0.295\ P + 12\ W) \times 10^{-3} + (FC_1 + LC_2)$
1.	International B-275 ..	30,000.00	4.0	3.60	0.50	0.31	15.76
2.	Byelarus	21,322.13	6.0	5.40	0.74	0.48	15.17
3.	Rumanian U-650 ..	27,220.06	6.0	5.40	0.75	0.48	16.91
4.	Massey Ferguson-1035 ..	31,000.00	3.0	2.70	0.50	0.31	15.15
5.	Zetor-2011	23,355.17	2.5	2.25	0.40	0.25	12.39

individual cost items gives the total cost of operation. Since the cost of machines, fuel, lubricating oil and wages of operator vary with time and space, one has to repeat the whole process for finding the cost of operation with any change in an individual cost item. To avoid this repetition and to have quick and more accurate estimates of the total cost of operation, an approach has been made to find out a mathematical expression which holds good under revised costs of various variables. The mathematical expression enumerated is simple and estimates of the cost of operation of farm machineries could be obtained quickly irrespective of the change in the values of the variables.

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