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Web and hybrid application based decision support system for farm machinery cost estimation

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Abstract
A web and hybrid application Decision Support System, namely Farm Machinery Decision Support System (FarMeD) for estimation of overall farm machinery costs was developed. The application can calculate the break-even units, custom hiring charges, net profit, and payback period in addition to the fixed and variable costs. The application is free with a user-friendly interface and can be accessed online from any computer or mobile phone with an internet connection. The application can also be deployed by using standalone packages for offline use on Windows-based PCs or as a standalone app on any Android device to work in the absence of internet connectivity. The user can make subsequent calculations by varying the various input parameters and compare the results to make decisions regarding whether to purchase a machine or to go for custom hiring and also to determine custom hiring rates in case he intends to offer his machine for custom hiring.

Keywords: Break-even points, custom hiring, decision support system, farm machinery, fixed cost, variable cost

1. Introduction
Agriculture witnessed a progressive shift from draught animal power to mechanization across the span of the 20th century [1]. An essential aspect of increasing profit is to reduce the unit cost of agricultural production [2]. This can be achieved by reducing the cost of every single factor contributing to the total expenditure. Strategies of agriculture thus need to be based upon reliable entrepreneurship and business management principles in order to make agriculture a profitable venture. After land and farm structures, the cost of farm equipment and machinery contributes to the single significant input in agricultural production. The cost of machinery ownership and operation represents a substantial share of the total expenses of production. Effective management of farm machinery is vital to maintain profitability in production [3].

For the capital invested in any farm machine to be utilized efficiently, the machine has to be operated over a suitable area or for a suitable duration to have the expenses comparable or less than the operation being carried out by a custom operator. Several economic, as well as engineering principles, are employed by economists and agricultural engineers to calculate the cost and use of machines [4].

Proper selection of farm machinery is essential for the economical production of agricultural products [5]. Producers need to assess the number of farm machinery they should own and what should be their power and capacity. Also, different alternatives for machine ownership, machine leasing, or custom hiring need to be considered. These issues have to be addressed before actual procurement or use of the machine [3]. The management decisions by the producers can be guided by proper calculation of operating and ownership costs of the farm machinery. The most reliable information to budget the costs of farm machinery are authentic farm-level records of the costs incurred. Calculation methods can be put to practice in the absence of these records.

Information and communications technology have progressively contributed to improving business forms and has led to ground-breaking establishments to address day to day problems. Nowadays, users need to be associated with valuable data progressively. This has led to the widespread use of technology related to the internet and computers. Mobile technologies and applications have also been distinguished as one amongst the top-ten strategic technology trends globally [6].

For the selection of tractor and farm machinery systems, several DSSs have been developed. The DSSs by Mehta *et al.* [7], Loghmanpour *et al.* [8] and Sopegno *et al.* [9] are a few of the studies. Many other scientists have developed computer and mathematical models which attempt to calculate the cost of farm machinery during the previous years. Beaton *et al.* [10]

developed a quick and adaptable method for calculating the per-unit cost to own and operate farm machinery. Abubakar *et al*. [11] presented a mathematical model for the calculation of repair and maintenance costs for the State of Nigeria. The model was, however, limited to the specific models of the tractor. Singh and Pandey [12] also developed a computer program that is developed in a Visual Basic environment to determine all types of machinery costs. Most of these DSS's were developed only for a single platform either for a computer using Visual Basic programming with MS Access database system for use on the computer with no online access or for the web providing no offline access in the absence of internet connectivity.

Keeping the above points in mind and to facilitate the farmers to use the application with ease, a hybrid application Decision Support System for estimation of overall farm machinery costs was developed. The application also calculates the custom hiring charges, net profit, payback period, and break-even points in addition to the fixed and variable costs. The interface is user-friendly and can be accessed online from any computer as well as a mobile phone with an internet connection. The application can also be deployed by using standalone packages for offline use on Windows-based PCs or as a standalone app on any Android device. The purpose is to aid producers in estimating the costs of ownership and operation of farm machinery and to assist in making machinery management decisions. The producers do not need to perform the tedious and extensive calculations, and the same would be done with a single click. The producers can determine the cost of the machines accurately and select the lowest cost machine that would be adequate for the required farm operation

2. Theoretical Considerations

2.1 Operating Cost of Farm Machinery

Farm machinery costs consist of expenditures for ownership, operation, and overhead charges. Costs that are independent of the actual machine use are fixed costs. Variable costs include those costs that are incurred as a result of the actual use of a machine. These costs vary with the use of the machine. Costs for supervision, establishment, and working capital interest are included in overhead charges. The sum of ownership, operation, and overhead charges gives the total cost of farm machinery operation. For the present study, the costs of operation of farm machinery were estimated using the following guidelines.

A. Fixed Costs

These costs are independent of the actual operation of the machine. These costs are also referred to as ownership costs. The fixed costs for farm machinery include depreciation, interest on investment, insurance and taxes, and housing.

i. **Depreciation:** Depreciation accounts for the recognized. Depreciation expense accounts for a decline in the price of machinery because of age or technological desuetude. Depreciation depends on the actual trade price of the machine after its usage. The straight-line method was used for the estimation of depreciation in the study [3, 13]:

$$D = \frac{(P - S)}{L}$$

where,
D = Cost of depreciation for the machine, Rs. per year
P = Purchasing price of the machine, Rs.
S = Residual value of the machine, Rs.
L = useful life of the machine, years

Hourly depreciation is calculated by dividing D by annual hours of use of the machine. Salvage value (S) can be taken as 5% of the purchase price of the machine.

ii. **Interest:** Capital investment is required for the purchase of farm machinery. If the money is on loan, the interest rate calculated should be in general adequate to cover the interest payable on the loan. The average yearly interest charge is calculated as [3].

$$I = \frac{(P - S)}{2} \times \frac{i}{100}$$

where,
I = interest cost, Rs. per year
i = rate of interest (%)

If the information about the actual rate of interest is not available, 12% of the average investment (A) is taken as interest. Average investment (A) for the machine over its life is calculated as [13]:

$$A = \frac{(P + S)}{2}$$

iii. **Insurance and Taxes:** Actual amount of insurance and taxes to be paid need to be acknowledged for estimating the total cost of farm machinery. In the absence of actual data, 2% of "A" is taken as the average cost of insurance and taxes per year [13].

B. Variable Costs

These are also called as operating costs of the machine. These costs vary with the use of a machine. These include fuel charges, lubricating oil, repair and maintenance charges, and wages and labor charges.

i. **Fuel Charges:** Fuel consumption is a function of the size of the power unit, load factor as well as the conditions under which the machine operates. The actual fuel consumption of a machine can be noted during the operation of the machine or from official testing centers. The formulae for estimating the average fuel consumption are [13].

$$A = 0 \cdot 15 \times B$$

where,
A = average diesel consumption in l/h
B = rated power in kW

$$C = 0 \cdot 25 \times B$$

where,
C = average petrol consumption in l/h,
B = rated power in kW

ii. **Lubricating Oil Charges:** The actual consumption of oil should be noted while operating the machine. Otherwise, it can be taken as 2.5 to 3.0% of the volume of fuel consumption [13]. For non-power equipment, the cost of lubricating oil can be taken as 5% of its purchase price [3].

iii. **Repair and Maintenance Charges:** In order to keep farm machinery in an operative condition, repair and maintenance expenses are essential. Some chief repairs, such as engine overhauls, may be considered as fixed costs if the owner knows in advance and plans for the

expenditure. Such costs may be included under depreciation among the fixed costs. Minor repairs such as belt replacement, replacement of chains, etc. are counted in operating costs because these are incurred as a result of actual usage of the machine. Repair and maintenance costs also include the cost of filters, replacement of oil, and other lubricants. The accumulated repair and maintenance costs (TAR) at any stage during the life of a machine were calculated following the guidelines laid in IS 9164-1979 [13].

iv. **Wages and Labor Charges:** An operator has to be engaged in order to perform any farm operation. An assistant may also be needed in some cases. The average cost per hour is calculated by dividing the total cost by the number of hours the operator did the work.

C. Total Cost Per Hour

The total cost per hour is the sum of fixed, variable, and overhead costs gives the total cost per hour.

D. Cost of Custom Hire Services

The farmers who cannot afford to purchase some or all farm machinery use custom hire services for obtaining the machinery services on their farms. Custom hire services refer to paying some other person for any farm machinery/implement. The fixed and variable costs of a machine are compared with the custom hire charges in order to determine the more economical option. The custom hire rates for different field operations are given in Table 1 [14].

Table 1: Custom hiring rates for different field operations [14]

Type of field operation	Risk condition	Proposed custom rate
Light tillage	Minimal risk	Cost + 20-30% of cost
Ploughing or chiseling	Average risk	Cost + 30-40% of cost
Medium to heavy	Heavy risk	Cost + 30-40% of cost
Hay and silage operation	Heavy risk	Cost + 30-40% of cost
Combining	Severe field condition	Cost + 40-50% of cost

E. Net Benefit

The net benefit is obtained as the difference of the custom hire cost and the variable (operating) cost as[14]:

$$\text{Net benefit} = \text{Custom hiring cost} - \text{Operating Cost}$$

F. Break-Even Points

The point where an investment generates a positive return is referred to as a break-even point. Analysis of Break-even points calculates the charge necessary at a particular level of production to encompass all charges. It is calculated using the following formula [15].

$$BE = \frac{F}{S - V}$$

where,

BE = break-even units, h or ha
F = annual fixed costs, Rs.
V = variable costs per unit, Rs./h or Rs./ha
S = custom charge per unit, Rs./h or Rs./ha

G. Payback Period

The payback period is defined as the period in years within which the total net benefit will cover the investment cost of the machine as is calculated as:

$$\text{Payback period (years)} = \frac{\text{Investment cost (Rs.)}}{\text{Net benefit (Rs./year)}}$$

3. Methodology

A Decision Support System was developed, which calculates the ownership and operating costs of farm machinery. The DSS is also able to calculate the Break-Even Units in case of custom hiring of farm machinery. The DSS is developed using HTML5, JavaScript, and CSS for online use on PC and mobile phones, and software, namely HTML Compiler and Website2Apk Builder, were used to convert the files into standalone applications for offline use on both PCs and Android phones. There are several sequential screens to complete the process and get the desired output. The developed screens are very intuitive, and it is very easy to select the parameters and enter the expected values wherever required. The data input selection screen follows the flash start screen of the DSS for the selection of farm implement/machinery or power source and to enter the desired input values for calculating the cost of farm machinery. The results were presented in terms of the total cost as well as relative percentages of ownership and operational cost. For visual comparisons, the results are also presented graphically through stacked bar charts.

3.1 Model Subsystem of the DSS

In this system, modules were developed for calculation of the operating cost of agricultural prime mover and farm machinery and for calculation of break-even units for custom hiring of farm machinery.

3.2 Operating cost of farm machinery

An algorithm developed for calculation of operating cost of farm machinery. The flow chart of the program for the calculation of the operating cost of farm machinery is shown in Figure 1. The considered variables for calculation are depreciation, interest, insurance, fuel cost, repair cost, labor, etc.

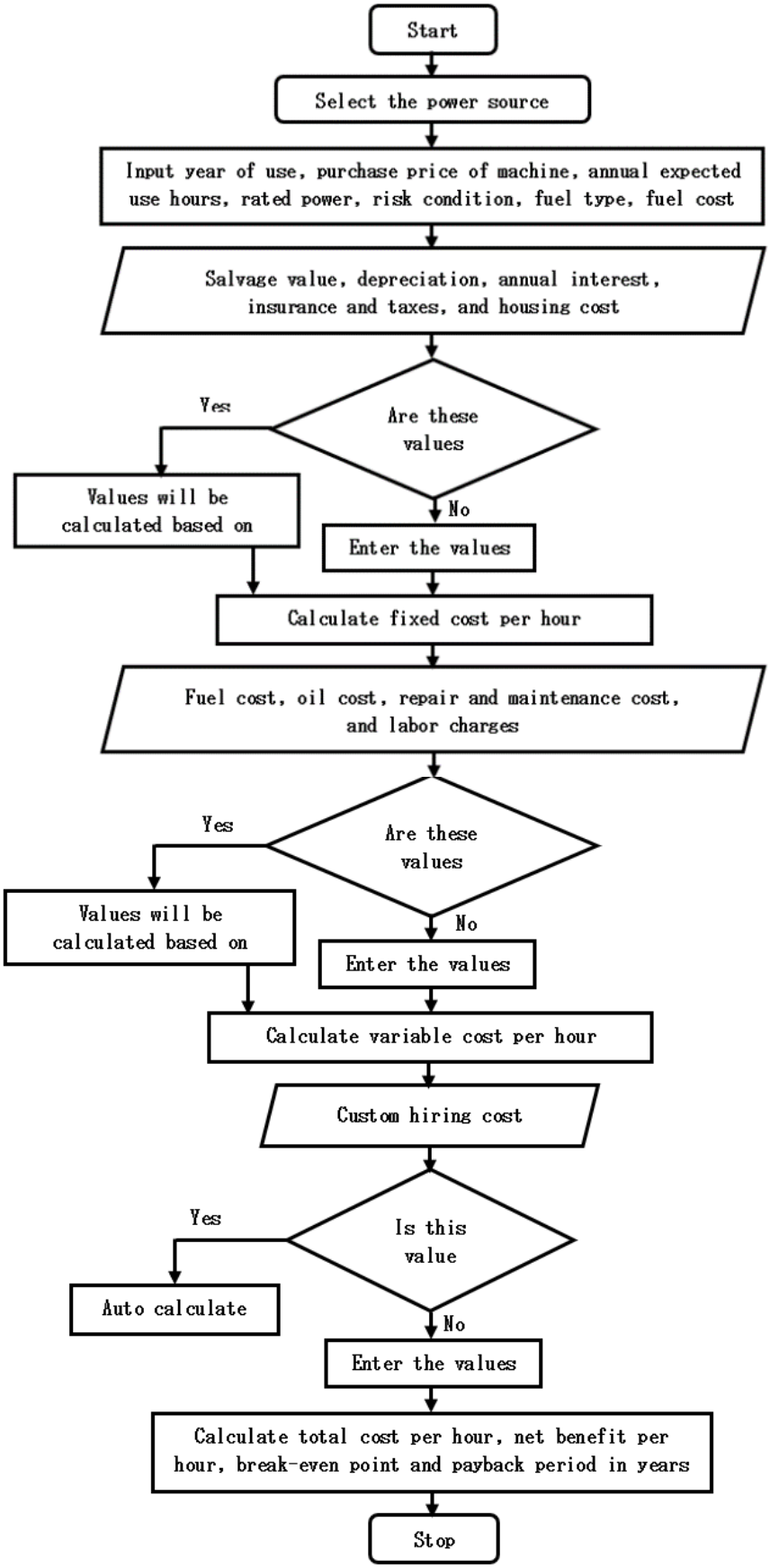

Fig 1: Flow chart for calculation of operating cost of farm machinery

The splash screen (Figure 2) of the DSS is followed by the page where the machine and its specifications are selected. Other parameters like the risk condition of the machine, type of fuel, purchase price, rated power of the machine, annual use hours, and others are entered (Figure 3). The DSS is then initialized by pressing the proceed button on the same page. This screen is followed by the screen for fixed cost calculation (Figure 4). The fixed cost includes depreciation, interest, insurance and taxes, and housing. The DSS auto-calculated the various fixed costs based on pre-defined standard formulae and also provides the user to enter the values manually if he wishes to.

The fixed cost screen is followed by the screen for calculating the variable costs (Figure 5). The variable cost for the selected implement/ machinery or power source included fuel cost, oil cost, repair and maintenance, and wages and labor charges. The variable costs can again be auto-calculated based on pre-defined standard formulae and or entered manually. The DSS calculated the repair cost as the percentage of purchased price for whole usable life of the machines based on the formula as per IS 9164 (1979). The variable costs screen in followed by the screen for calculation of custom hiring charges (Figure 6) based on standard formulae or user input. This screen is followed by the results screen (Figure 7), which presents various fixed and variable costs as stacked bar charts for visual comparison and also gives a comparison of the fixed vs. variable costs. The results page also displays the total cost, custom hiring cost, net benefit, break-even point, and the payback period for the selected machine.

The wages of the driver were taken as Rs. 500 ($ 7.79) per day (8 h). The DSS calculated the total operating cost of the tractor for varying purchase price of the tractor from Rs. 5 to 7 lakhs ($ 7744 to $ 10911) at an interval of 1 lakh ($ 1558.73) and annual hours of use from 450 to 650 h at an interval of 50 h.

Fig 2: Splash screen of the developed DSS

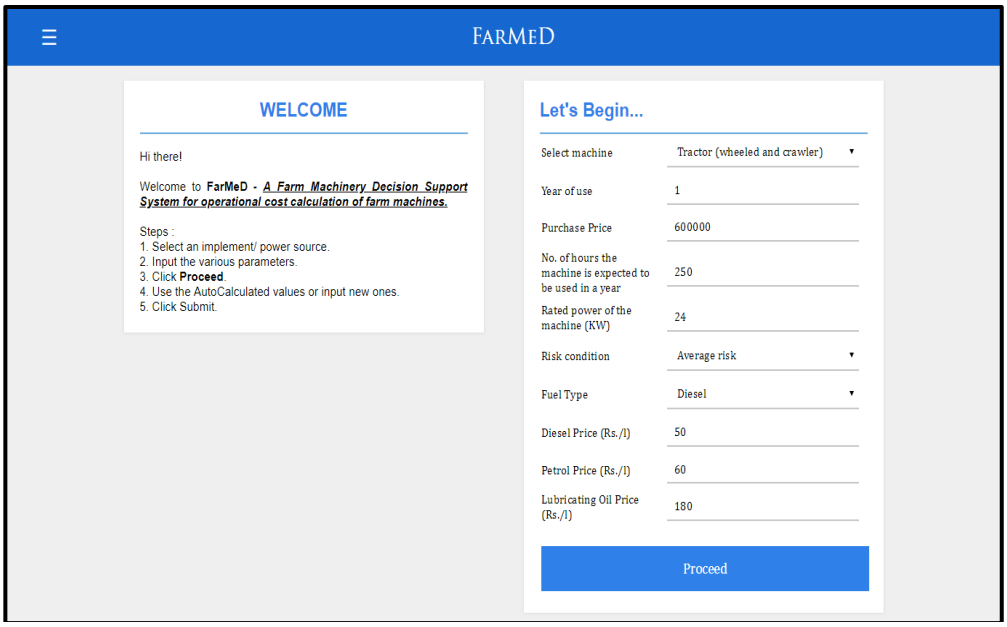

Fig 3: Screen for machine selection and parameter input

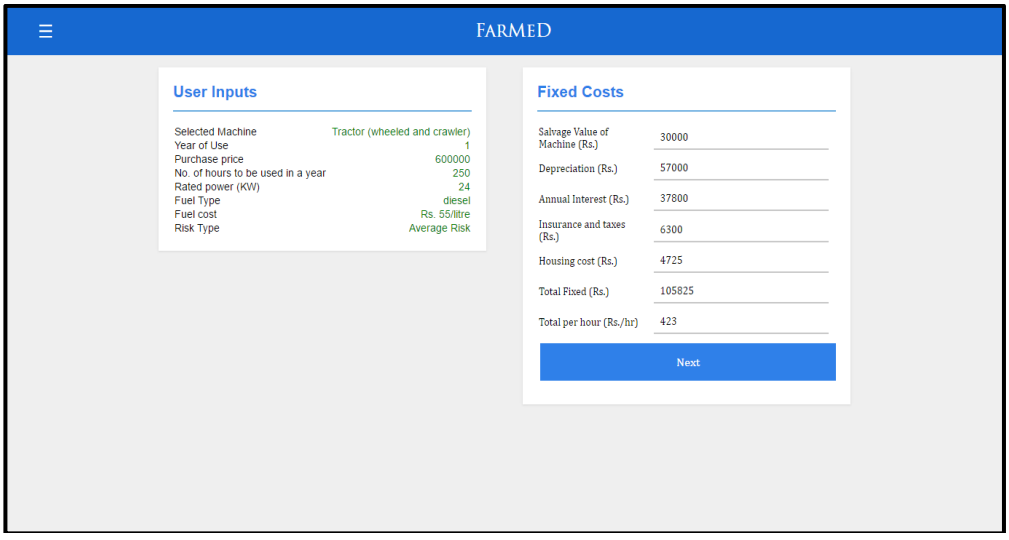

Fig 4: Calculation of fixed cost of a tractor using DSS

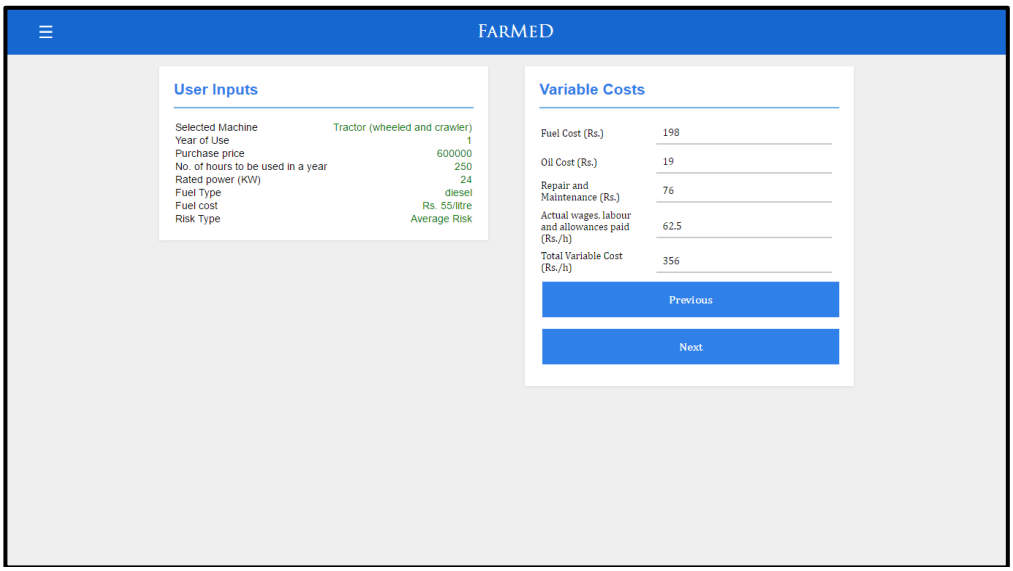

Fig 5: Calculation of variable cost of a tractor using DSS

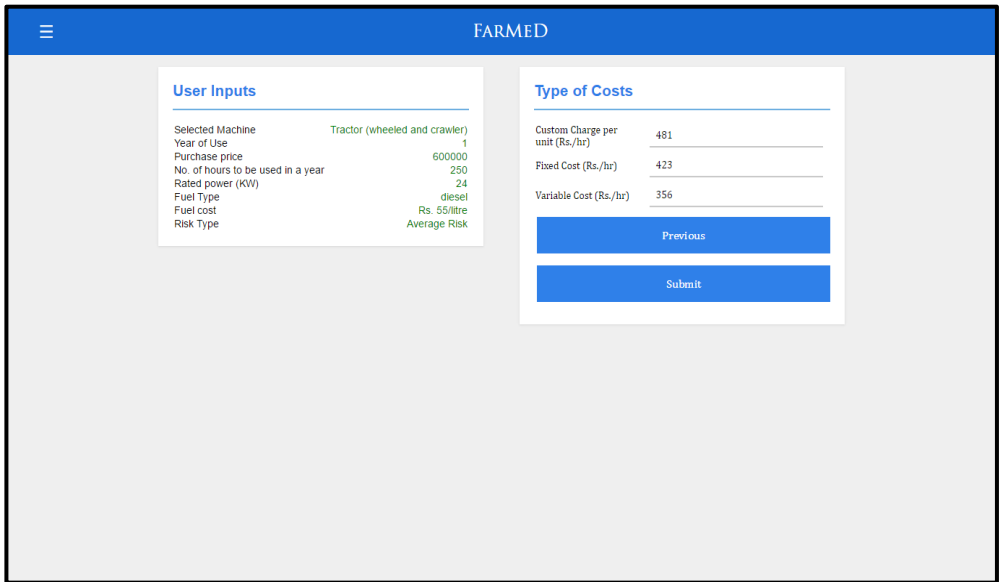

Fig 6: Calculation of custom hiring rate of a tractor using DSS

Fig 7: Results obtained from the DSS

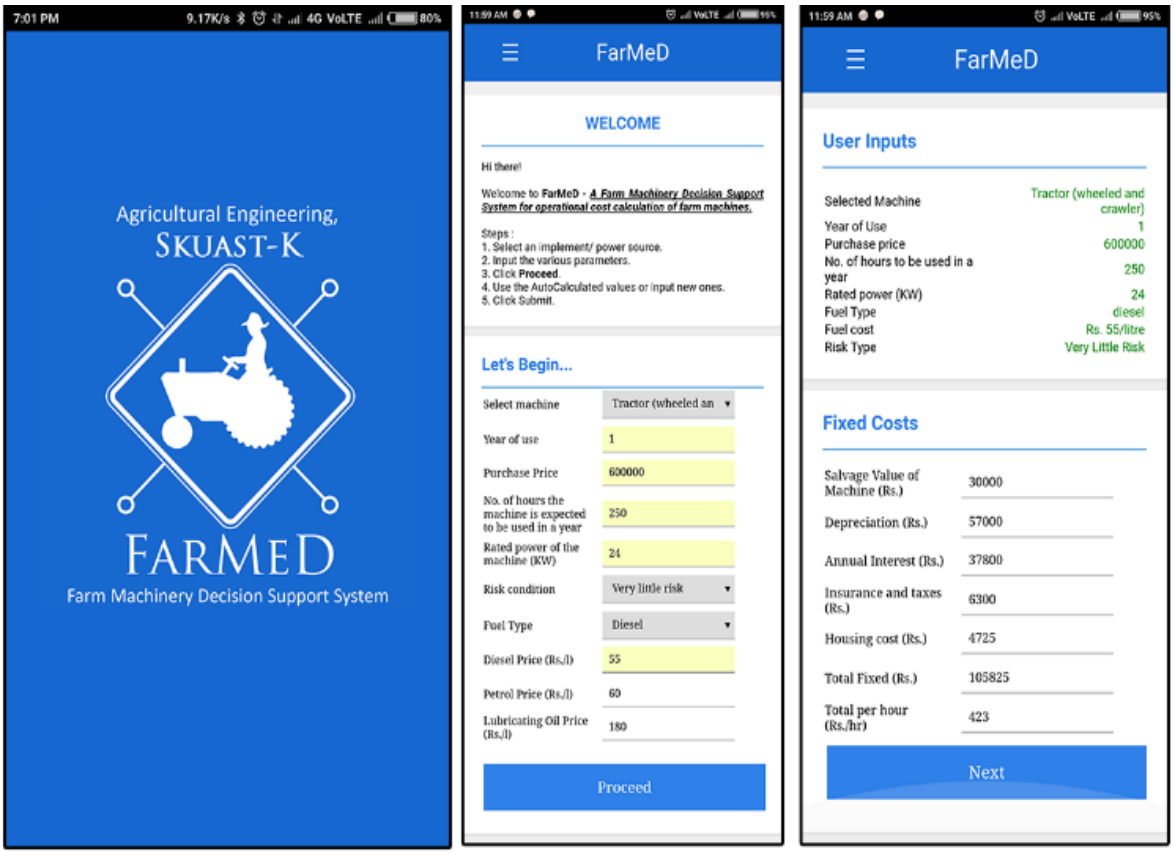

Fig 8: DSS splash, input and fixed cost screens rendered on a mobile phone

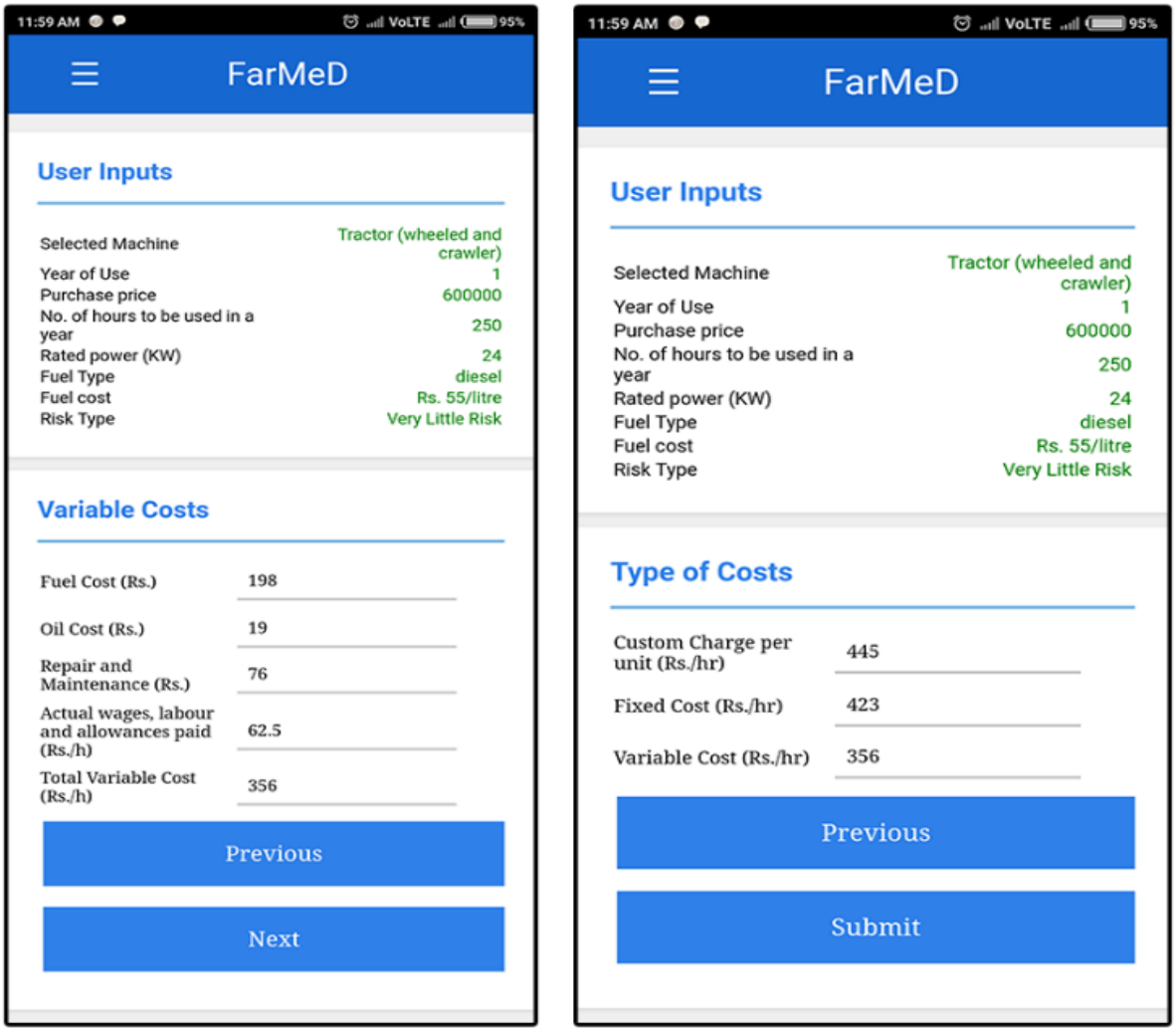

Fig 9: DSS variable cost and custom hiring cost screens rendered on a mobile phone

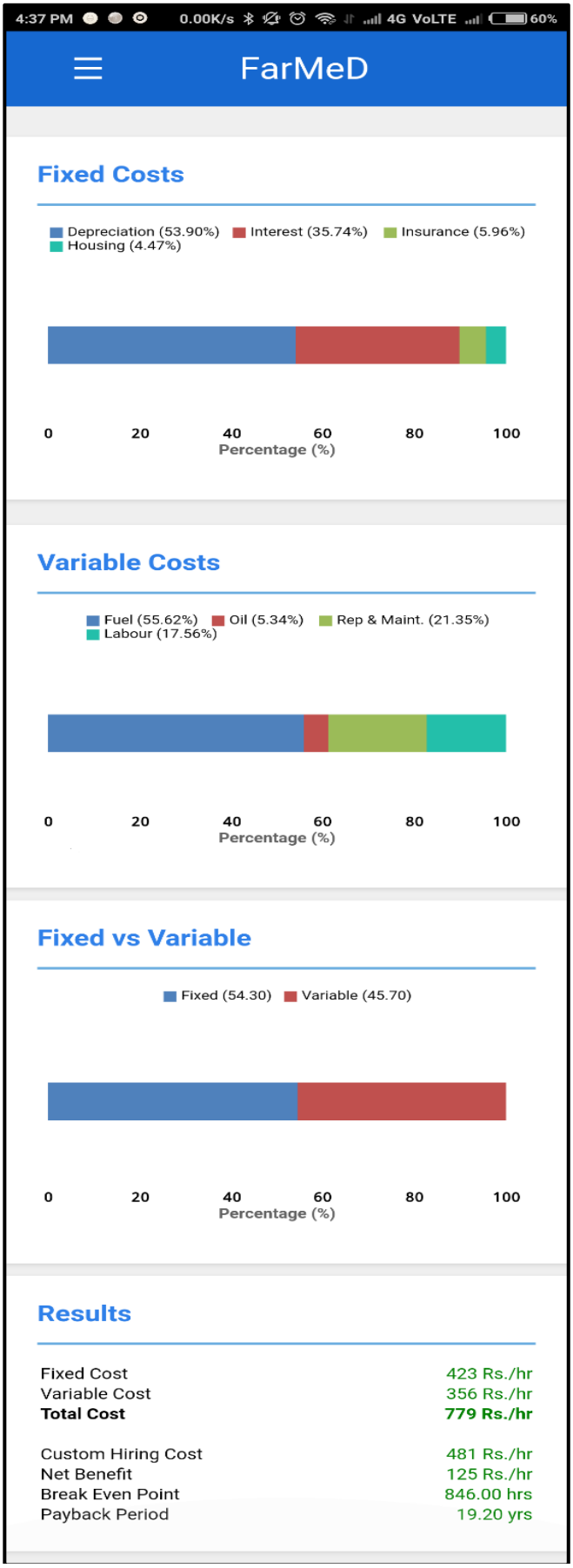

Fig 10: DSS results screen rendered on a mobile phone

4. Results and Discussions

Software Output: The developed DSS was operated for six different implements and machines; Stationary engine, Power chaff cutter, Power tiller, Rotavator, Tractor, and disc harrow. The input and output parameters for these farm machinery are given in Table 2. The output indicates that the developed DSS is capable of calculating all components of fixed and operating costs of the machines.

Table 2: The input and output parameters for selected farm machinery.

	Stationary engine	*Power chaff cutter*	*Power tiller*	*Rotavator*	*Tractor*	*Disc harrow*
Input Parameters						
Year of use	3	1	2	4	5	2
Purchase price	45000	15000	180000	80000	600000	50000
No. of hours the machine is expected to be used in a year	1000	200	900	150	1000	250
Rated power of the machine (KW)	1.5	2.3	6.7	26	31.3	0
Risk condition	Average	Average	Average	Heavy	Average	Heavy
Fuel Type	Petrol	Diesel	Diesel	Diesel	Diesel	Diesel
Diesel Price (Rs./l)	-	50	50	50	50	50
Petrol Price (Rs./l)	60	-	-	-	-	-
Lubricating Oil Price (Rs./l)	180	180	180	180	180	180
Output Parameters						
Fixed Costs						
Salvage Value of Machine (Rs.)	2250	750	9000	4000	30000	2500
Depreciation (Rs.)	4275	1781	17100	9500	57000	4750
Annual Interest (Rs.)	2835	945	11340	5040	37800	3150
Insurance and taxes (Rs.)	473	158	1890	840	6300	525
Housing cost (Rs.)	354	118	1418	630	4725	394
Total Fixed (Rs.)	7937	3002	31748	16010	105825	8819
Total per hour (Rs./hr)	8	15	35	107	106	35
Variable Costs						
Fuel Cost (Rs.)	23	17	50	195	235	225
Oil Cost (Rs.)	2	2	5	21	25	24
Repair and Maintenance (Rs.)	9	4	21	203	212	29
Actual wages, labour and allowances paid (Rs./h)	63	63	63	63	63	63
Total Variable Cost (Rs./h)	97	86	139	482	535	341
Custom Charge per unit (Rs./hr)	131	116	188	699	722	494
Final Output						
Fixed Cost (Rs./hr)	8	15	35	107	106	35
Variable Cost (Rs./hr)	97	86	139	482	535	341
Total cost (Rs./hr)	105	101	174	589	641	376
Net Benefit (Rs./hr)	34	30	49	217	187	153
Break-even point (hrs.)	233	100	648	74	566	58
Payback period (years)	1.3	2.46	4.04	2.45	3.2	1.3

4.1 Relationship among repair and maintenance costs versus age and use hours of tractors

The case considered to validate the developed DSS for calculating the total operating cost of farm machinery and for calculating the break-even points for a tractor (24 kW) is presented in this section. The costs of diesel and oil were taken as Rs. 55/*l*($ 0.86/*l*) and Rs. 180/*l*($ 2.86/*l*), respectively, for the calculation of the operating cost of the tractor.

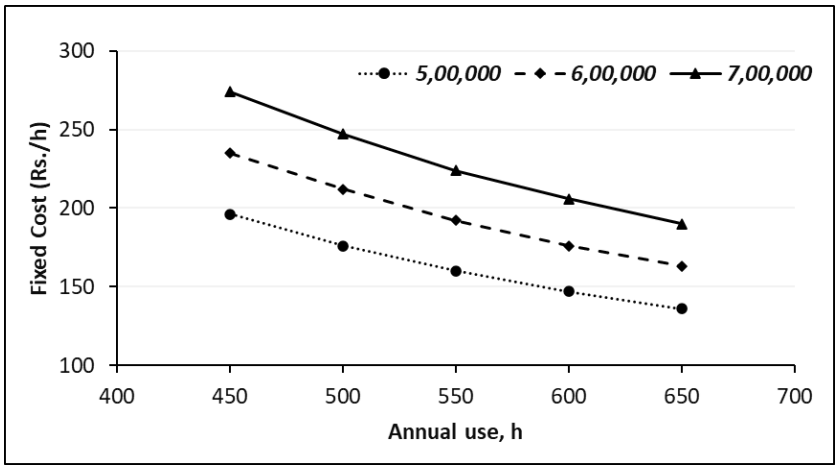

Fig 11: Variation of fixed cost of the tractor with annual use (h)

The variation in fixed costs and variable costs of the tractor is shown in Figure 11 and Figure12. It was observed that the fixed and variable cost of the tractor increased with an increase in the purchase price of the tractor and decreased with an increase in annual hours of use. The decrease in the fixed cost of the tractor was sharp, with an increase in annual hours of use from 450 to 650 h. A similar trend was observed for the total operating cost of the tractor (Figure 13). However, the decrease in the variable cost of the tractor was gradual, with the increase in annual hours of use from 450 to 650 h. Therefore, it may be concluded that the annual hours of use significantly affected the fixed and total operating costs of the tractor.

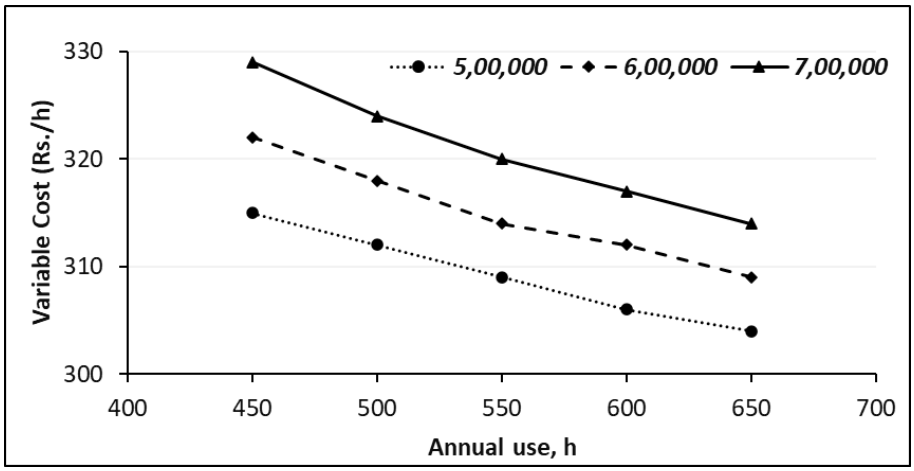

Fig 12: Variation of variable cost of the tractor with annual use (h)

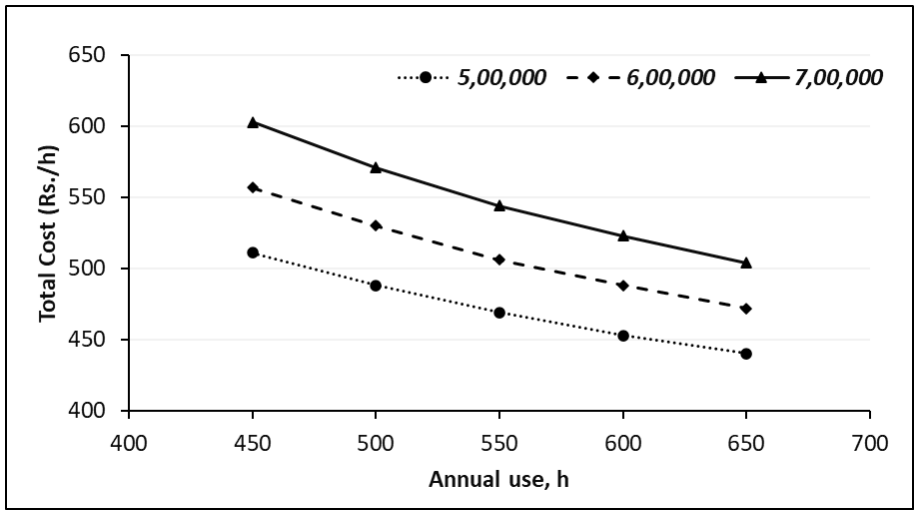

Fig 13: Variation of total cost of the tractor with annual use (h)

The break-even units in hour of the tractor were also calculated using DSS for varying custom hiring rates of Rs. 400, 450, and 500/h ($ 6.23, 7.01 and 7.79/h) for varying hours of use from 450 to 650 h, and results are shown in Figure 14.

It indicated that break-even units reduced with an increase in custom hiring rates from Rs. 400/h to Rs. 500/h ($ 6.23/h to $ 7.79/h) and with an increase in annual use of tractor from 450 to 650 h. Table 2 also shows that break-even units decreased from 594 to 555 h with the increase in annual use of tractor from 450 to 650 h for tractor costing Rs. 6 lakh ($ 9352.35) at custom hiring rate of Rs. 500/h ($ 7.79/h). A similar trend was observed for the purchase price of the tractor of Rs. 5 lakh ($ 7793.63) and 7 lakh ($ 10911.08) and custom hiring rates of Rs. 400 and Rs. 450/h ($ 6.23/h and $ 7.01/h)). Therefore, it may be concluded that custom hiring rates significantly affected the break-even units of the tractor.

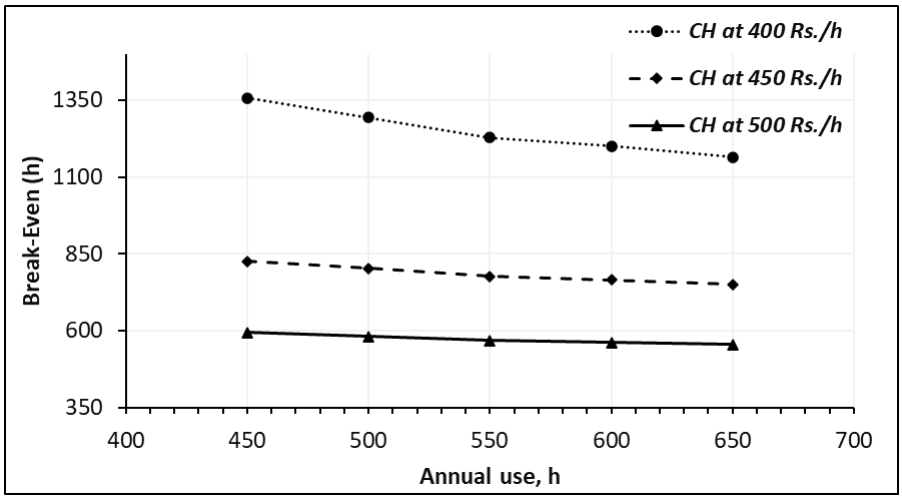

Fig 14: Variation of break-even point of the tractor with annual use (h)

5. Conclusions

The FarMeD app is available free of charge to the users. It is a hybrid DSS, meaning that it can be accessed both online with an internet connection or can be installed on the device for offline use in the absence of internet connectivity. The DSS was used to calculate the ownership, operating, and fixed costs of operation of farm machinery in addition to the break-even points. The cost was also calculated for varying hours of use for different farm operations and different power rated machinery. The DSS was validated using some examples, which showed that the developed DSS was effective in estimating the costs of operation of various farm machinery. The variation in costs with rated power, annual operation hours, and custom hire rates can be easily monitored with the developed DSS, which can thus be beneficial while acquiring any farm machinery.

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