CHAPTER VII

COMPARISON OF COSTS OF IRRIGATION BY DIFFERENT MODES

In previous chapters we have fitted cost functions for 3 sample modes of lift, viz., electric motors, oil engines and bullock-operated lifts. However, cost functions of these three modes cannot be directly compared due to non-comparability of their hours of irrigation because of different discharge capacities. It is, therefore, necessary to standardize their hours of irrigation in order to compare costs of irrigatiom by these modes at different levels of operation. Hours of operation of modes can be standardized either in terms of their hourly discharge capacities or in terms of their performance of acreage irrigated per hour. The performance of different modes has been standardized in terms of acreage irrigated per hour, since it was not possible to collect data on hourly discharge of water from all the sample modes of irrigation during field investigation.

Standard for Comparison

Performance of different modes of irrigation is expressed in terms of performance of electric motor of 5 HP. In other words, performance of electric motor of 5 HP in terms of acreage irrigated per hour is considered as 'standard' for comparing costs of irrigation by different modes at various levels of operation. Hours of irrigation of all sample modes are expressed in terms of hours of irrigation of electric motor of 5 HP, for the following reasons :

(a) Sample oil engines selected were mostly of the size of 5 HP. If these engines were to be replaced by electric motors, in most cases, it was expected that they would be substituted by 5 HP electric motors. Thus, the comparison of costs of both these modes at different levels of operation expressed in terms of levels of operation of 5 HP motor would show upto what level it was economical to use engine, and secondly, what were the economies effected by motor beyond this level.

(b) Secondly, practice followed by M.S.E.B. in certain cases where connections were granted, was also relevant in the selection of 5 HP motor as a standard. In some of the sample villages, group of cultivators were forced to install 5 HP motors even when 3 HP motors would have been sufficient to meet their purpose, just because 5 HP motors, with higher minimum annual consumption guarantee, could satisfy the criterion stipulated for extending line, i.e., 15 per cent revenue return on the investment. Such was the case of village Dawadi and Retawadi, where the cultivators reported that though the dealers in motors recommended 3 HP motor, the M.S.E.B. officials insisted that unless 5 HP motors were installed, the connections would not be granted. Under the circumstances, the conversion of even 3 HP motor-hours into 5 HP motor-hours would point out what economies could have been effected for the cultivators of the above category, if they were to install 3 HP motor instead of 5 HP motor.

We shall now proceed to describe the method of conversion of hours of operation of the different modes into hours of operation of electric motor of 5 HP.

<u>Methodology for Conversion</u>

As stated earlier, we had collected data in respect of cultivator using sample mode on (i) number of crops with area under each crop irrigated by his sample mode during the reference period; (ii) number of irrigations given to each crop; and (iii) average duration (in hours) of each irrigation. Thus for each sample mode of irrigation, per acre estimates of total hours of irrigation could be prepared crop-wise.

It may be recalled here that all the three modes of irrigation (viz., electric motor, oil engine and bullock-operated lift) could be had only in one set of sample villages, i.e., electrified villages having developed the use of electricity for irrigation purposes, while in the other set of sample villages, only two modes of irrigation (i.e., oil engine and bullock-lift) could be had as the use of electricity for irrigation purpose had not developed in these villages. As such, only the villages in the former set are considered for comparing hours of irrigation of different modes and reducing them to a common standard. Thus, while all the sample electric motors of 3 and 5 HP have been considered for comparing hours of operation of different modes, 31 out of 63 sample engines and 36 out of 59 sample bullock-lifts located in the villages having irrigational use of electricity have been considered.

Further, it is not possible to include all the crops irrigated by three modes of irrigation for purposes of comparing their hours of operation, for the following reasons :

(a) Crops grown in Kharif season (e.g. bajra, paddy, leafy vegetables, chillies, etc.), though irrigated sometimes when rains failed, were not necessarily irrigated by all the cultivators and, therefore, are not included for the purposes of comparison; and

(b) Such crops (e.g., sugarcane) whose full crop season was not covered by the reference period (June 1965 to May 1966), and therefore, all the irrigations normally given to crops were not included in the data, are also excluded for the purpose of comparison as their inclusion would have distorted the comparison of hours.

Thus, only five crops were selected for the purposes of comparison of hours of operation of three modes of irrigation. These crops are (i) Jowar, (ii) Wheat, (iii) Onion, (iv) Potato, and (v) Lucerne grass. It may be noted that Jowar and Wheat are Rabi crops irrigated during the period November to February, requiring 3 to 4 irrigations in all. Similarly, Potato and Onion are also Rabi crops requiring 10 to 11 irrigations in all, while Lucerne Grass is a perennial crop requiring about 33 to 36 irrigations during the year.

It may, further, be noted that if a particular mode of irrigation had not fully irrigated a particular crop (selected crop) till it was harvested, that mode was not considered under that particular crop. For instance, if particular electric motor (say of 3 HP) had fully irrigated onion but had not fully irrigated lucerne grass because of break-down, then that motor is included under onion but not under lucerne grass.

Table 7.1 depicts data on the number of units of each mode of irrigation included under each selected crop for the purpose of comparing the hours of operation of each mode with the hours of operation of 5 HP motor. It also presents information on total acreage irrigated under the crop and average number of hours of irrigation for one acre of the crop by sample modes during the reference period.

Table 7.1 : Details of sample modes considered for comparison of hours of operation.

Total number of sample modes in the villages	Electric Motor 5 HP	Electric Motor 3 HP	Oil engine 5 HP	Bullock lift One bullock-pair
Total No.of Sample modes	42	31	31	36
JOWAR				
Number of sample modes considered.	19	13	13	14
Total acreage irrigated by samplemodes considered.	22.375	10.625	36.500	13.600
Average hours of irrigation per acre.	12.40	21.86	13.59	75.37
Index of hours of irrigation per acre with 5 HP electric motor as base.	100.00	176.29	109.60	607.82
WHEAT				
Number of sample modes considered.	19	15	15	7
Total acreage irrigated by sample modes considered	28.900	9.725	20.250	2.975
Average hours of irrigation per acre.	25.78	46.30	25.90	147.90
Index of hours of irrigation per acre with 5 HP electric motor as base.	100.00	179.60	100.47	573.70
O N I O N				
Number of sample modes considered.	27	17	19	20
Total acreage irrigated by samplemodes considered	42.850	14.600	36.625	24.699
Average hours of irrigation per acre	85.50	138.60	79.59	328.88
Index of hours of irrigation per acre with 5 HP electric motor as base.	100.00	162.11	93.09	384.65

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Table 7.1 (contd.)

Total number of sample modes in the villages	Electric Motor 5 HP	Electric Motor 3 HP	Oil engine 5 HP	Bullock lift One bullock-pair
POTATO				
Number of sample modes considered.	10	10	4	9
Total acreage irrigated by sample modes considered.	19.950	10.000	4.500	8.625
Average hours of irrigation per acre.	65.50	103.16	74.67	245.45
Index of hours of irrigation per acre with 5 HP electric motor as base.	100.00	157.50	114.00	374.73
LUCERNE GRASS				
Number of sample modes considered.	6	9	6	6
Total acreage irrigated by sample modes considered.	2.575	3.050	2.650	2.200
Average hours of irrigation per acre.	333.60	463.85	299.43	1248.18
Index of hours of irrigation per acre with 5 HP electric motor as base.	100.00	139.04	89.76	374.15

It may be noted that for each mode (3 HP, 5 HP motors, oil engines and bullock-lift) of irrigation, the number of units included under each crop is not mutually exclusive. The number of units of the mode considered under each crop out of total units of sample modes in these villages varies from crop to crop and ranges between approximately 15 per cent to 60 per cent of the total units of the mode, except in the case of Potato, where only 12 per cent of total oil engines in these villages have been considered.

Table 7.1 brings out difference in the capacities of these four modes of irrigation in terms of their performance in irrigating one acre of a crop. The table reveals more or less, stable relationship between irrigational capacities of different modes as evident from indices of average hours of irrigation of selected crops based on average hours of irrigation of these crops by 5 HP electric motor. It is in this context that an attempt is made in the following pages to formalise the relationship of irrigational capacities of different modes by reducing them to a common standard. This exercise would facilitate comparison of hours of irrigation of different modes, and hence costs at different levels of their operation.

Underlying Assumptions

In the following, we state the assumptions underlying the comparison of hours of operation of each mode with those of

5 HP motor. The assumptions are :

(i) Irrigational requirements of the crops were fully met by the cultivators, whether the crop was irrigated by bullock-lift, engine or motor. In other words, excess water was not given than the total irrigational (water) requirement of the crop if it was irrigated by a mechanised device or less water was not given than the requirement if it was irrigated by bullock-lift.

(ii) The time taken for irrigating one acre of crop by any mode depends upon the discharge of water, which, in turn, depends upon the depth of the well. Since the depths of wells on which sample modes were operated varied from each other, the comparison is valid only for the sample of different modes of irrigation adopted for the study.

It may be noted in this context that for the purpose of comparing hours of irrigation of different modes, we have taken the total time (hours) taken by different modes to provide all irrigations to the crop and not the time taken for providing one isolated irrigation to the crop by different modes. This is because time taken for providing individual irrigation to the crop might vary, depending upon the stage of growth of the crop and as such, if only one irrigation among many provided to the crop were to be considered. to compare hours of operation of different modes, there would be distortion in the comparison.

<u>Model for Comparison of Hours of Operation</u>

Let us define :

H_{ijk} ≡ total hours of irrigation of farmer i, for crop k, by mode j,

Where i is a farmer selected under mode j irrigating crop k. Under our system, k ranges from 1 to 5, since we have chosen five crops, and j ranges from 1 to 4, since there are four modes of irrigation. Further, let mode j = 1 be electric motor of 5 HP.

A_{ijk} ≡ acres irrigated of farmer i of crop k by mode j

M_{jk} ≡ hours of irrigation per acre of crop k by mode j

Thus :

$$M_{jk} = \frac{\sum_{i=1}^{n} H_{ijk}}{\sum_{i=1}^{n} A_{ijk}} \quad \ldots\ldots (1)$$

It may be noted that corresponding to five crops and four modes of irrigation, we shall have 20 such M_{jk}s.

Let us further define :

R_{jk} ≡ per acre hours of irrigation by mode j(j=2,3,4) for crop k equivalent to per acre of hours of irrigation of mode j=1, i.e, 5 HP electric motor for the same crop.

Thus :

$$R_{jk} = \frac{M_{jk} \quad (j=2,3,4)}{M_{jk} \quad (j=1)} \qquad \text{..... (2)}$$

Thus for each mode (j=2,3,4) we will have 5 separate R_{jk}s (one for each crop) which would denote hours of irrigation of that mode to each of the crops equivalent to one hour of irrigation of electric motor of 5 HP for respective crops.

To make a composite index of hour equivalent of electric motor of 5 HP for each mode based on these five indices for five crops, the following weights are assigned to different R_{jk}s.

The ratio R_{jk} for each crop is weighted in proportion of total acreage under that crop irrigated by all modes of irrigation to total acreage under all five crops irrigated by all modes of irrigation. We will denote these weights as W_k

Thus :

$$W_k = \frac{\sum_{i=1}^{n} \sum_{j=1}^{4} A_{ijk}}{\sum_{i=1}^{n} \sum_{j=1}^{4} \sum_{k=1}^{5} A_{ijk}} \qquad \text{..... (3)}$$

Thus, the composite index (denoted as R_j) for hours of each mode (j=2,3,4) equivalent of hour of electric motor of 5 HP based on five indices (R_{jk}s) of hours equivalence corresponding to five crops would be :

$$R_j = \sum_{k=1}^{5} R_{jk} W_k \qquad \text{..... (4)}$$

The details of computation of "M_{jk}", "R_{jk}", "W_k" and "R_j" are presented in annexure 7A. As can be seen from annexure 7A, we have derived the following hour equivalent of 5 HP electric motor for the remaining three modes of irrigation.

Mode of irrigation	Hours of mode equivalent of one hour of operation of 5 HP electric motor
Electric Motor (3 HP)	1.679
Oil engine (5 HP)	1.017
Bullock lift	4.782 (pair hours)

Consequently, hours of irrigation of 3 HP electric motor, 5 HP oil engine and bullock lift shown in the graphs depicting cost functions of these modes of irrigation are modified based on hours of equivalence of 5 HP electric motor, so as to compare costs of irrigation of these modes at different levels of operation. The revised graph showing comparison of costs of irrigation by all the modes or irrigation is presented in Annexure 7B.

Comparison of costs of Irrigation by DifferentModes

From the graphical presentation of the cost functions, following observations may be made.

(i) At a low level of operation or irrigational requirement, it is economical to operate traditional device rather than sophisticated mechanised devices like oil engine or electric motor.

In fact, as can be observed from the graph, all other things remaining the same for a scale of operation lower than 300 hours equivalent of 5 HP electric motor, it is costliest to operate electric motor of 5 HP followed by oil engine and electric motor of 3 HP, while bullock operated mode is the cheapest to operate.

(ii) Cost function of bullock-operated lift cuts from below the cost function of 3 HP motor at around 300 hours of operation of 5 HP motor. Thus upto requirement of irrigation equivalent to 300 hours of 5 HP electric motor, it is economical to operate traditional mode than an electric motor. However, it may be noted that operation of bullock-lift for a period equivalent to 300 hours of 5 HP electric motor actually means deployment of a pair of bullocks for about 1435 hours or 180 days[1] for irrigation purposes alone. Hence, unless the cultivator can afford to maintain two pairs of bullocks and he can gainfully employ two pairs throughout the year, he may not opt for this mode even if the requirement is equivalent to 300 hours of 5 HP electric motor.

(iii) The graphical representation of cost function of 5 HP electric motor extends upto around 2,000 hours, that of oil engine upto 2350 hours, and those of 3 HP motor and bullock-lift

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1 In other words, under the assumption of 172 normal working days for a pair of bullocks in a year, it means reservation of one pair of bullocks exclusively for irrigation purposes.

upto 1200 hours and 490 hours, respectively, all in terms of 5 HP electric motor hours.

Although the graph depicting the functional relationship can be extended to any amount of hours in respect of these modes, the observed values of total hours operated in a year perhaps, indicate the limits (ceiling) of the total hours for which the modes could be operated in a year. This ceiling of total hours in respect of each mode is not only because of lack of availability of water in the well but also due to technicalities[1] involved in the operation of the modes themselves. Thus in respect of bullock-lift, it may not be possible to obtain total hours of irrigation beyond (say) 500 hours equivalent of 5 HP electric motor in a year. The same may be true in case of 3 HP motor, which could not be operated for more than 1250 5 H.P electric motor hours in a year.

(iv) Finally, an important observation on intersection of

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1 Technicalities may be described as a combination of the following factors :

(1) Cultivators preferring to operate the mode only during day time although it can be operated during night also.

(2) Mode cannot be operated continuously. For instance, bullock pair has to be rested after continuous operation for (say) 3 to 4 hours. Similarly, oil engine also gets heated after continuous operation and has to be switched off for some time. Also, in respect of motor, there is weekly shutdown of overhead lines by the Electricity Board for giving new connection/repairs etc., apart from fluctuations in the voltage prohibiting its use continuously.

(3) General efficiency of mode itself in terms of hours it takes to irrigate one acre of land which actually determines, inter alia, the net and gross area irrigated under the mode, the cropping pattern on irrigated plot (distribution of net area irrigated into acreage under crops requiring irrigation frequently and not-so-frequently), thus delimiting total hours of its operation in a year.

cost functions of 5 HP oil engine and 5 HP electric motor may be made, which has interpretative significance.

As stated earlier, in respect of electric motor, being an immobile mode of irrigation, total hours of irrigation shown on x-axis (total hours of irrigation by electric motor in a year) relate to hours for which the mode was operated on one plot of land coming under the command of one irrigational well. This is not necessarily true in case of other two modes of irrigation, viz., oil engine and bullock-operated lift, which are mobile units. In respect of these modes, total hours of irrigation, presented on x-axis, are the sum of hours of operation of the mode on different plots of land coming under the command of different wells on which the same mode (oil engine or bullock-operated lift) was operated.

However, the graphical presentation, prima facie, might create an impression that at certain levels of operation, substitution of other modes (either oil engine or bullock-operated lift, as the case may be) by electric motor would prove economical, which might not be so in reality, if the composition of irrigational holding of those using oil engine and bullock-operated lift is considered. For instance, where the irrigational requirement of the cultivator was (say) 400 hours in terms of 5 HP motor hours and where he was meeting the requirement by use of oil engine, the graph would indicate that it would be cheaper for the cultivator to switch over to 5 HP electric motor (if it was not feasible to operate 3 HP motor or bullock-operated lift for technical reasons), for irrigating his holding. However, if his total irrigational requirement of 400 hours was scattered, i.e., comprising of three parts, (say) 100 hours, 140 hours and 160 hours, coming under the command of three different wells, it would not be economical for him to switch over to electric motor since at these hours of operation, it was cheaper to use engine than motor as the graph indicates. Moreover, he would have had to raise finance to install three separate motors at these wells, while he could irrigate all these scattered holdings with one oil engine.

Up-dating the costs of Irrigation

So far, we have been analysing the costs of irrigation for the period 1965-66, when the survey was conducted for assessing the same by different modes of irrigation. Since the costs of irrigation by these modes are likely to witness rise in an inflationary situation with passage of time, it would be relevant to analyse the same so as to bring out the impact of such a change on relative costs of irrigation by different modes.

It may be pointed, at the outset, that such an analysis of the change in the costs of irrigation is confined to the costs of irrigation by electric motor and by oil engines only. The change in costs of irrigation by bullock-operated lift has not been attempted for the following two reasons :

(a) Data for latest years were not available to facilitate analysis of the extent of change in costs of bullock feed, human labour cost and the cost of lift equipment, etc.

(b) With the passage of time, it is expected that the traditional bullock-operated lift would give way to mechanical modes of irrigation, i.e., electric motor or oil engine. In fact, the study conducted in M.S. University of Baroda did observe that the process of mechanisation in respect of lift irrigation was almost complete in the State of Gujarat.[1]

Further, it may be noted that the analysis of change in the costs of irrigation by these two modes of irrigation is restricted to discerning the trend in different components of costs of irrigation of respective modes so that overall impact of the change on relative costs of irrigation of these modes can be gauged.

Sources of Data :

As regards, data on investment costs of irrigation by these two modes of irrigation for the latest period (i.e., 1979-80), the same was collected from local agents of electric motors and oil engines of different makes in Poona city. The

1 V.N. Kothari, & M.M. Dadi : op.cit., Chapter III, p.55.

data in respect of cost of operation of electric motor (electricity charges) for the latest period was obtained from the Head Office of MSEB from the rates of tariff structure published by it. The prices of fuel used by oil engines (i.e. diesel, lubricating oil, etc.) were likewise obtained from the petrol stations.

It may be mentioned here that since the objective of updating the costs of irrigation is to perceive the impact of change in prices on relative costs of irrigation, certain items of costs such as transportation charges, interest costs and cost of pump house, etc., which are common to both electric motor and oil engine, are not taken into consideration.

Initial Investment Costs

In table 4.3 and 4.4, (Chapter IV) we have given the break-up of initial investment costs of electric motors of 3 HP and 5 HP, respectively. Like-wise in Table 5.1 (Chapter V), we have presented initial investment cost for oil engines. With respect to break-up of investment presented in those tables for the year 1964-65, the investment costs obtaining during 1979-80 on the basis of prices of different items quoted by dealers of differentmakes are given in Table 7.2

As can be seen from table 7.2, initial investment costs of electric motor of 5 HP has evinced far more increase during the period 1964-65 to 1979-80, than that of 5 HP oil engine.

Table 7.2 : Comparative positions of initial investment costs - 3 HP and 5 HP electric motors and 5 HP oil engine: 1964-65 and 1979-80.

	Electric Motors					Oil Engines (5 HP)	
	3 HP		5 HP				
	1964-65	1979-80	1964-65	1979-80		1964-65	1979-80
(a) Average cost of motor, pump, pipe & other accessories	1495.14	4505.00	1790.15	5010.00	(a) Average cost of oil engine & Pump	2821.67	4438.00
(b) Average cost of installation charges	177.15	250.00	213.23	300.00	(b) Average cost of pipes	416.67	770.00
(c) Average cost of Other charges*	126.00	395.00	156.00	425.00	(c) Average cost of installation charges	128.33	400.00
Total (a+b+c)	1798.29	5150.00	2159.38	5735.00	Total(a+b+c)	3366.67	5608.00

*Relates to only service connection charges and refundable security deposit. For both the periods, the amount of refundable security deposit has remained the same, i.e., Rs.45 for 3HP motor and Rs.75 for 5 HP motor.

The cost of 5 HP electric motor increased by 165.6 per cent, whereas that of 5 HP oil engine increased only by 66.6 per cent. As a result, the gap in the initial investment costs of electric motor and oil engine as at 1964-65 is more than bridged. In fact, by 1979-80, the initial investment cost of 5 HP electric motor was more than that of 5 HP oil engine, though only marginally. Perhaps, substantial increase in investment costs of electric motor over the years is indicative of considerable increase in demand[1] for them, apart from the rise in the costs of raw material. The rise in demand for installation of electric motors is indeed corroborated by the disproportionate increase in service connection charges of MSEB which were only Rs.81 in 1964-65 and 1965-66 as reported by the farmers, mow going upto Rs.350 by 1979-80.[2] All other things remaining the same (i.e., interest costs and operation and maintenance charges), this increase in initial investment cost would push to the right the curve representing cost function of 5 HP electric motor in relationto curve representing 5 HP oil engine and intersection of these curves will be at much higher level of operation than indicated in the graph. However, the increase in the operation cost of the oil engine vis-a-vis that in operation cost of the electric motor, has more than offset the advantages to engines emerging from increase in their initial investment costs over the years, as described below :

1 The contributory factors for increase in demand are wide-scale implementation of rural electrification programme by State Electricity Boards, but more particularly, the shortage of diesel in recent months.

2 See page 15, table on Service Connection charges for agricultural consumers from 'Conditions and Miscellaneous Charges for Supply of Electrical Energy' effective from 1-1-1976, a booklet issued by MSEB.

Operation Costs

Table 7.3 depicts variations in the tariff for agricultural use of electricity over the years (year of enquiry and 1979-80) as also the prices of lubricating oil and diesel and kerosene used by oil engine during the same period.

As can be observed from Table 7.3, per hour operational cost has registered higher increase in respect of oil engine in comparison to that of electric motor, over the years. For instance, electricity charges in the highest size-group of operation of electric motor worked out as 11.75 paise per unit under the system of slab rate during the year of enquiry, which have now gone upto 20 paise per unit, i.e., a rise of 8.25 paise per unit or 70.2 per cent. With electric motor of 5 HP consuming 3.73 units during one hour of operation, the cost per hour of operation in the highest size-group of operation has gone up by 31 paise. On the other hand, the costs of diesel and crude, consumed by the oil engines in the range of 0.90 litre to 1.50 litres per hour, have registered an increase of 100 per cent over the years. Additionally, per hour cost of lubricating oil which worked out to be 16 paise in respect of sample oil engines during the year 1965-66 would also register over 100 per cent increase, as a result of 1.5 fold to over 2 fold rise in prices of lubricating oil, both fresh and reclaimed. Consequently, the gap in per hour operation

Table 7.3 : Variations in operation costs of electric motors and oil engines during 1965-66 and 1979-80.

Cost of Electricity	Electric Motor 3 HP 1965-66	Electric Motor 3 HP 1979-80	Electric Motor 5 HP 1965-66	Electric Motor 5 HP 1979-80	Cost of Oil/fuel	Oil Engine 5 HP 1965-66	Oil Engine 5 HP 1979-80
Electricity tariff	13 paise-10 paise per unit (slab rate)*	20 paise per unit flat rate	13 paise-10 paise per unit (slab rate)*	20 paise per unit - flat rate	Lubricating Oil		
					Fresh	Rs.3.10 to Rs.3.60 per litre	Rs.9/- per litre
Minimum Bill	Rs.120 per annum	Rs.120 per annum	Rs.200 per annum	Rs.200 per annum	Reclaimed	Rs.2 to Rs.2.70 per litre	Rs.6/- to Rs.7/- per litre
					Fuel		
Meter Rent	Re.1/- per month	Rs.2/- per month	Re.1/- per month	Rs.2/- per month			
					Diesel	77 paise to 90 paise per litre	Rs.1.55 to Rs.1.70 per litre
					Crude (Kerosene)	50 paise to 58 paise per litre	Rs.1.16 to Rs.1.30 per litre

* For details, see section on tariff structure in Chapter IV.

cost of electric motor and oil engine which was around 42 paise in 1965-66 would widen further, mainly on account of greater absolute increase in the hourly operational cost of oil engine in relation to that in per hour operational cost of electric motor. It may be noted here that though the meter rent in respect of electric motor has registered 100 per cent rise (from Re.1 to Rs.2) over the years, it is a fixed charge and not related to the scale of operation of motor.

Even at lower level of operation of electric motor, the gap in per hour cost of electric motor and oil engine would narrow down, thus implying intersection of curves of oil engine and electric motor at a lower level than indicated in the graph due to (a) minimum amount of bill in respect of electric motor remaining the same over the years and (b) the rise in per hour cost of oil engine, as mentioned above. However, due to higher increase in initial investment costs of electric motor and thus in its depreciation charges vis-a-vis oil engine, the intersection of the curves would perhaps take place at the same level as indicated in the graph.

On the whole, as a result of increase in initial investment cost and operational charges, the curves of both these mechanised modes of irrigation would shift to the right and the gap in the curves at higher level of operation of electric motor would widen further.

However, the cultivator would now be required to raise finance of the order of nearly Rs.6000/- as against Rs.2500 in the past to install an electric motor of 5 HP. A cultivator with scattered irrigated holding (i.e., having more than one well in the village) might perhaps find it difficult to install more than one electric motor. Despite operational economies in respect of electric motor, a cultivator with scattered irrigated holding might still opt for a mobile oil engine due to high initial investment costs of electric motor and its static nature (i.e., immobility of electric motors).

ANNEXURE 7A

Details of computation of M_{jk}, R_{jk}, W_k and R_j

Table I : Computation of 'M_{jk}'.

Mode of irrigation	JOWAR			WHEAT			ONION		
	Total acre-age	Total hrs.of irri-gation	Per acre hrs.	Total acre-age	Total hrs.of irri-gation	Per acre hrs.	Total acre-age	Total hrs.of irri-gation	Per acre hrs.
3 HP Electric Motor	10.625	232.22	21.86	9.725	450.32	46.30	14.600	2023.61	138.60
5 HP Oil engine	36.500	496.00	13.59	20.250	524.50	25.90	36.625	2915.00	79.59
Bullock lift	13.600	1025.00	75.37	2.975	440.00	147.90	24.699	8123.00	328.88
5 HP Electric Motor	22.375	277.34	12.40	28.900	745.07	25.78	42.850	3663.47	85.50

Mode of Irrigation	POTATO			LUCERNE GRASS		
	Total acre-age	Total hrs.of irri-gation	Per acre hrs.	Total acre-age	Total hrs.of irri-gation	Per acre hrs.
3 HP Electric motor	10.000	1031.60	103.16	3.050	1414.75	463.85
5 HP oil engine	4.500	336.00	74.67	2.650	793.50	299.43
Bullock lift	8.625	2117.00	245.45	2.200	2746.00	1248.18
5 HP Electric motor	19.950	1306.81	65.50	2.575	859.01	333.60

ANNEXURE 7A (contd.)

Table II : Computation of $'R_{jk} = \frac{M_{jk}}{M_{1k}}$

Mode of irrigation	Jowar	Wheat	Onion	Potato	Lucerne grass
3 HP Electric Motor	1.763	1.796	1.621	1.575	1.390
5 HP Oil engine	1.096	1.005	0.931	1.140	0.898
Bullock Lift	6.078	5.737	3.846	3.747	3.742

Note : This is derived by dividing per acre hours of irrigation by the respective mode for a given crop by per acre hours of irrigation of 5 HP Electric motor for the same crop.

Table III : Computation of $'W_k' = \frac{\sum_{i=1}^{n} \sum_{j=1}^{4} A_{ijk}}{\sum_{i=1}^{n} \sum_{j=1}^{4} \sum_{k=1}^{5} A_{ijk}}$

Mode of irrigation	Total Acreage Irrigated Under the Crop: Jowar	Wheat	Onion	Potato	Lucerne grass	Total
3 HP electric motor	10.625	9.725	14.600	10.000	3.050	48.000
5 HP oil engine	36.500	20.250	36.625	4.500	2.650	100.525
Bullock Lift	13.600	2.975	24.699	8.625	2.200	52.099
5 HP electric motor	22.375	28.900	42.850	19.950	2.575	116.650
Total	83.100	61.850	118.774	43.075	10.475	317.274
W_k	0.2619	0.1949	0.3744	0.1358	0.0330	

Computation of $'R_j'$

$'R_j'$ for 3 HP electric motor = (1.763x0.2619)+(1.796x0.1949)+(1.621x0.3744)+(1.575x0.1358)+(1.390x0.0330) = 1.679

$'R_j'$ for 5 HP Oil engine = (1.096x0.2619)+(1.005x0.1949)+(0.931x0.3744)+(1.140x0.1358)+(0.898x0.0330) = 1.017

$'R_j'$ for bullock lift = (6.078x0.2619)+(5.737x0.1949)+(3.846x0.3744)+(3.747x0.1358)+(3.742x0.0330) = 4.782