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RESEARCH PAPER

Economic Feasibility and Break-Even Analysis of a Mini Tractor Operated Roto-Planter for Small Farms

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ABSTRACT

The present study evaluated the operational performance and economic feasibility of a mini tractor-operated roto-planter developed for small and marginal farmers. The implement integrates rotary tillage and seed sowing into a single field operation, thereby reducing labour requirements, fuel consumption, and cultivation costs. Field experiments were conducted under uniform operating conditions using paddy as the test crop. The developed machine achieved an effective field capacity of 0.15 ha h^{-1} with satisfactory operational performance. Economic analysis indicated a total operating cost of ₹ 265.76 h^{-1} (₹ 1,771.73 ha^{-1}), resulting in a cost saving of ₹ 1,228.27 ha^{-1} (40.9%) over conventional cultivation practices. Break-even analysis revealed that the machine becomes economically viable at an annual utilization of 615.93 h (92.38 ha), while the investment could be recovered within 1.46 years under the assumed utilization pattern. The findings demonstrate that the developed roto-planter provides a technically efficient and economically viable mechanization option for smallholder farming systems and has considerable potential for custom hiring services.

HIGHLIGHTS

- Integration of rotary tillage and sowing in a single-pass mini tractor–operated roto-planter improves field operational efficiency.
- The developed machine offers a cost-effective mechanization option for small and marginal farmers.
- Economic evaluation confirms financial feasibility through break-even and payback analysis.

Keywords: Cost economics, tractor, roto-planter, break-even point, payback period

Timely sowing is one of the most critical operations determining crop establishment and subsequent productivity. Delayed sowing not only reduces crop yield but also increases production costs due to repeated tillage operations and labour shortages. Small and marginal farmers in India continue to rely heavily on conventional tillage and manual sowing methods, which are labour-intensive, time-consuming, and often result in poor seed placement (Singh *et al.* 2019).

Mini tractors ranging from 11–25 hp have emerged as an economical power source for fragmented landholdings. However, the availability of compatible multifunctional implements remains limited. Integrating rotary tillage with precision seed placement in a single operation can substantially reduce field passes, fuel consumption, soil compaction, and labour requirements (FAO, 2018; Patil & Raheman, 2018).

Although several studies have reported the performance of tractor-operated seed drills and

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rotary tillage implements, limited information is available regarding the economic feasibility of mini tractor-operated roto-planters specifically designed for small farms. Therefore, besides evaluating field performance, the present study investigates the cost economics, break-even point, and payback period of the developed implement under realistic operating conditions.

MATERIALS AND METHODS

Experimental Design

Field experiments were conducted at the experimental farm of Dr. NTR College of Agricultural Engineering under uniform soil and moisture conditions. Paddy was selected as the test crop because of its widespread cultivation in the region.

The developed roto-planter was evaluated using an 11 hp Swaraj CODE mini tractor operating at forward speeds ranging from 1.5 to 2.5 km h^{-1} while maintaining a constant PTO speed. Three independent replications were conducted for each operating condition to minimize experimental error. The average values were used for economic analysis.

Development of Mini Tractor-operated Roto-planter

The mini tractor-operated roto-planter was developed to perform rotary tillage and seed sowing simultaneously in a single field operation. The integration of these two operations reduces the number of field passes, labour requirement, fuel consumption and overall operational cost compared with the conventional practice of separate tillage and sowing. The machine was designed specifically for small and marginal farmers to improve timeliness of field operations and reduce the cost of crop establishment.

The developed implement consists of a rotary tillage unit integrated with a three-row planter assembly mounted on a common frame. During operation, power from the tractor power take-off (PTO) is transmitted to the rotary tillage unit through a gear drive mechanism. The rotating blades pulverize the soil and prepare a fine seedbed, while the planter assembly simultaneously places the seeds at the required depth behind the rotary unit. Seed delivery is accomplished through seed hoppers, interchangeable seed metering mechanisms, seed tubes and furrow openers, ensuring uniform seed placement and adequate soil coverage in a single pass. The developed roto-planter was operated using an 11 hp Swaraj CODE mini tractor as shown in Fig. 1. The detailed specifications of the tractor, rotary tillage unit and planter components are presented in Table 1.

Table 1: Specifications of the mini tractor operated roto-planter

Component	Parameter	Specification
Prime mover	Make and model	Swaraj CODE mini tractor
	Engine power	11 hp (8.28 kW)
	PTO power	9.46 hp
	PTO speed	1000 rpm
	Forward speed range	1.9–16.76 km h^{-1}
Rotary tillage unit	Model	W85 roto weeder
	Working width	725 mm
	PTO power requirement	6.5 kW
	Number of blades	20 (C-type)
	Drive type	Gear drive
Planter unit	Frame	Mild steel square tube (1070 × 965 mm)
	Furrow opener	Single-point shovel type
	Number of seed hoppers	3
	Seed metering mechanism	Fluted roller and star wheel
	Seed tubes	PVC, 25 mm diameter

Performance Evaluation of the Developed Roto-planter

The performance of the developed roto-planter was evaluated under field conditions using paddy seeds to assess its operational suitability and economic feasibility. Two seed metering mechanisms, namely fluted roller and vertical cell (star wheel), were evaluated during field testing. The experiments were conducted at forward speeds ranging from 1.5 to 2.5 km h^{-1}, corresponding to theoretical field capacities of 0.135–0.225 ha h^{-1}.

The machine was operated under uniform field conditions while maintaining a constant PTO speed throughout the experiment. The effective field capacity was determined by measuring the actual area covered and the total time required to complete the operation, including turning and other field delays. Theoretical field capacity was calculated from the machine working width and forward speed, whereas field efficiency was determined from the ratio of effective field capacity to theoretical field capacity. The average effective field capacity of the developed roto-planter was 0.15 ha h^{-1}, demonstrating satisfactory field performance under operating conditions. The field performance data obtained from these experiments were subsequently used for estimating the operating cost, break-even point and payback period of the developed machine.

Fig. 1: Mini tractor drawn roto planter

Economics of the Roto Planter

The economic feasibility of the developed roto-planter was evaluated assuming its operation with an 11 hp Swaraj CODE mini tractor, considering 1000 annual tractor working hours and 300 annual implement working hours. The production cost of the developed roto-planter was considered as its purchase price for estimating ownership and operating costs. The economic analysis was carried out following standard farm machinery cost estimation procedures described by Singh (2017) and Mehta *et al.* (2019), together with recent methodologies adopted by Venkat *et al.* (2021) and Vinayak *et al.* (2025) for evaluating the economic feasibility of agricultural machinery.

The total operating cost was estimated on both an hourly (₹ h^{-1}) and area (₹ ha^{-1}) basis by considering all ownership and operating cost components. Ownership (fixed) costs included depreciation, interest on capital investment, housing, insurance and taxes, whereas operating (variable) costs comprised fuel consumption, lubrication, repair and maintenance, and operator wages. The ownership and operating costs of the tractor and the developed roto-planter were estimated separately and then combined to determine the total operating cost of the machine.

Depreciation was estimated using the straight-line method by considering the capital cost, salvage value and useful life of the machine. Interest on investment was calculated based on the average annual investment using the prescribed interest rate. Housing, insurance and taxes were estimated as a percentage of the initial capital cost. Fuel cost was estimated from the actual fuel consumption during field operation and the prevailing diesel price. Lubrication cost was calculated as 3% of the fuel cost, while repair and maintenance cost was estimated based on the annual utilization of the machine. Operator wages were calculated considering the prevailing local wage rate for agricultural machinery operation.

The total operating cost of the tractor and roto-planter combination was obtained by summing the ownership and operating costs of both units. The operating cost on an area basis was estimated using the effective field capacity obtained during field evaluation. The economic feasibility of the developed machine was further assessed using the break-even point and payback period. The break-even point represents the minimum annual machine utilization required to recover the annual ownership cost, whereas the payback period indicates the number of years required to recover the initial investment through annual savings obtained by using the developed roto-planter instead of conventional field operations. Similar economic indicators have been widely employed for evaluating newly developed agricultural machinery by Venkat *et al.* (2021) and Vinayak *et al.* (2025).

The mathematical equations used for estimating ownership costs, operating costs and economic indicators are presented in Table 2.

The economic analysis was performed following the standard cost estimation procedures suggested by Singh (2017) and Mehta *et al.* (2019). The following assumptions were adopted:

- Tractor useful life: 10 years
- Implement useful life: 10 years
- Salvage value: 10%

Table 2: Formulas Used for Fixed and Variable Cost Estimation

Cost Component	Formula	Description / Assumptions
Depreciation (₹/year)	$D = \frac{C - S}{L}$	C = Capital cost, S = Salvage value (10% of C), L = Useful life (years) (Mehta *et al.* 2019)
Interest (₹/year)	$I = \frac{C + S}{2} \times \frac{i}{100}$	i = Interest rate (12%) (Mehta *et al.* 2019)
Taxes, Housing & Insurance (₹/year)	$C \times \frac{M}{100}$	M = 3% of capital cost (Mehta *et al.* 2019)
Fuel Cost (₹/h)	Fuel consumption × Fuel price	Fuel consumption = 1.30 L/h; Fuel price = ₹ 70/L (Singh, 2017)
Lubrication (₹/h)	30% of fuel cost	(Singh, 2017)
Repair & Maintenance (₹/h)	$\frac{C}{H} \times \frac{R}{100}$	H = Annual hours; R = 5% of capital cost (Singh, 2017)
Operator Wages (₹/h)	₹ 500 per 8-hour day	Operator wage = ₹ 500/day

- Interest rate: 12%
- Annual tractor utilization: 1000 h
- Annual implement utilization: 300 h
- Diesel price: ₹ 70 L^{-1}
- Lubrication cost: 30% of fuel cost
- Repair and maintenance cost: 5% of purchase price
- Operator wage: ₹ 500 day^{-1}

Breakeven point

The break-even point (BEP) represents the minimum annual utilization of the developed roto-planter at which the total annual income generated from its operation equals the total annual ownership and operating costs. Beyond this utilization level, ownership of the machine becomes economically profitable, whereas below the break-even point, hiring the machine is economically more suitable. The break-even point was determined on both annual operating hours and annual area coverage basis using the following equations (Singh, 2017; Mehta *et al.* 2019; Venkat *et al.* 2021; Vinayak *et al.* 2025).

$$\text{BEP (h/year)} = \frac{\text{Annual Fixed Cost}}{\text{Custom hiring charge per hour} - \text{Operating cost per hour}}$$

$$\text{BEP (ha/year)} = \frac{\text{Annual Fixed Cost}}{\text{Custom hiring charge per ha} - \text{Operating cost per ha}}$$

where,

Annual fixed cost = Total annual ownership cost (₹ year^{-1})

Custom hiring charge = Hiring rate of the machine (₹ h^{-1} or ₹ ha^{-1})

Operating cost = Total operating cost of the machine (₹ h^{-1} or ₹ ha^{-1})

Payback period

The payback period represents the time required to recover the initial investment made in the development of the roto-planter through the annual net economic benefit obtained from its operation. A shorter payback period indicates faster recovery of investment and better economic feasibility of the developed machine. The payback period was calculated using the following equation (Mehta *et al.* 2019; Venkat *et al.* 2021; Vinayak *et al.* 2025).

$$\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Average Net Annual Benefit}}$$

Where,

Initial investment = Purchase price of the developed roto-planter (₹)

Custom hiring charge = Hiring charge of the machine (₹ h^{-1})

Operating cost = Total operating cost of the machine (₹ h^{-1})

Annual machine use = Annual operating hours of the machine (h year^{-1})

Average net annual benefit = Annual savings generated by the machine (₹ year^{-1})

Sensitivity Analysis

Since machinery economics are influenced by annual utilization and fuel prices, a sensitivity analysis was performed to examine the robustness of the economic results. The analysis indicated that increasing annual utilization substantially reduced the fixed cost per unit area and shortened the payback period. Conversely, a 10% increase in diesel price increased the operating cost by approximately 3–4%, but the developed roto-planter remained economically viable under all tested scenarios. These results suggest that annual machine utilization has a greater influence on profitability than moderate fluctuations in fuel price.

RESULTS AND DISCUSSION

The developed mini tractor-operated roto-planter was evaluated under field conditions to determine its operational and economic performance. The average effective field capacity of the machine was 0.15 ha h^{-1}, indicating that the implement was capable of performing seedbed preparation and planting simultaneously in a single pass, thereby reducing the time and labour requirements compared to conventional methods. Similar improvements in field efficiency and operational timeliness have been reported for combined tillage and planting implements developed for smallholder farming systems (Dihingia *et al.* 2024; Kumar *et al.* 2025). The integration of rotary tillage and planting into a single operation minimizes repeated field passes, resulting in reduced fuel consumption and improved machinery utilization.

The developed roto-planter successfully combined rotary tillage and seed placement in a single pass, reducing operational time and field traffic. The observed effective field capacity of 0.15 ha h^{-1} was comparable with similar low-horsepower planting implements reported by Dihingia *et al.* (2024) and Kumar *et al.* (2025).

The combined operating cost of ₹ 265.76 h^{-1} was considerably lower than the cumulative cost of separate tillage and sowing operations. Cost savings of approximately 41% indicate substantial economic benefits for smallholder farmers, particularly in regions experiencing labour shortages.

The estimated break-even point of 615.93 h year^{-1} suggests that the developed machine is most economically attractive for custom hiring entrepreneurs, farmer producer organizations (FPOs), and cooperative societies capable of achieving higher annual machine utilization.

The estimated payback period of only 1.46 years further confirms the financial feasibility of investing in the developed implement.

Cost economics of mini tractor

The economic analysis of the mini tractor was carried out by considering a useful life of 10 years and an annual utilization of 1000 hours. The fixed cost of the tractor, including depreciation, interest, insurance, taxes and housing, was estimated as ₹ 29.76 h^{-1}, while the variable cost, comprising fuel, lubrication, repair and maintenance, and operator wages, was ₹ 188.80 h^{-1}. Accordingly, the total operating cost of the mini tractor was calculated as ₹ 218.56 h^{-1} (Table 4). Among the variable cost components, fuel and labour charges contributed the major share of the operating cost, indicating that efficient fuel utilization and increased annual machine usage can substantially improve the economic performance of the tractor. These observations agree with the findings of Namdev *et al.* (2023), who reported that fuel and labour costs constitute the largest share of machinery operating costs in tractor-operated tillage and sowing implements.

Cost economics of the developed roto-planter

The developed roto-planter was analysed by assuming a useful life of 10 years with an annual utilization of 300 hours. The fixed cost of the implement was estimated as ₹ 37.20 h^{-1}, whereas the variable cost, consisting mainly of repair and maintenance expenses, was ₹ 10.00 h^{-1}. Consequently, the total operating cost of the developed roto-planter was calculated as ₹ 47.20 h^{-1} (Table 5). The relatively low operating cost of the implement demonstrates its suitability for small and medium-sized farms where minimizing machinery investment and operating expenses is essential. Similar economic performance has been reported for recently developed tractor-operated planters, where low maintenance requirements and improved machine design contributed to reduced operating costs and enhanced economic feasibility (Kumar *et al.* 2025).

Combined cost economics of mini tractor and roto-planter

The overall operating cost of the mini tractor-operated roto-planter was obtained by combining the costs of the tractor and the implement. The total fixed cost of the system was ₹ 66.96 h^{-1}, corresponding to an annual fixed cost of ₹ 40,920 year^{-1}. The total variable cost was estimated as ₹ 198.80 h^{-1}, resulting in a total operating cost of ₹ 265.76 h^{-1}. Considering a 25% profit margin, the custom hiring charge of the developed machine was calculated as ₹ 332.20 h^{-1}.

Based on the effective field capacity of 0.15 ha h^{-1}, the operational cost of the developed machine was estimated as ₹ 1,771.73 ha^{-1}, whereas the custom hiring charge was ₹ 2,214.67 ha^{-1}. In comparison, the conventional manual method of seedbed preparation and planting required approximately ₹ 3,000 ha^{-1}. Thus, the developed mini tractor-operated roto-planter reduced the operational cost by ₹ 1,228.27 ha^{-1}, representing a cost saving of approximately 40.9% over the conventional method. Similar reductions in cultivation cost have been reported for integrated planting machinery by Dihingia *et al.* (2024), who observed that mechanized transplanting substantially lowered labour and operational costs compared with conventional practices. Likewise, Beg and Chauhan (2025) reported that precision planting systems reduced production costs and improved economic returns through efficient seed placement and higher machinery utilization.

Breakeven point

Break-even analysis was carried out by plotting the total annual cost of operation and the annual custom hiring income against the annual hours of machine use, as shown in Fig. 2. The point at which the two cost lines intersect represents the minimum annual utilization required for the developed roto-planter to recover its annual ownership and operating costs. If the annual machine use exceeds the break-even point, ownership of the machine becomes economically profitable; otherwise, custom hiring is a more economical option. The total annual cost of operation was expressed as:

$$y = 265.76x + 40920$$

where, 265.76 is the total operating cost (₹ h^{-1}), 40920 is the annual fixed cost (₹ year^{-1}), and **x** is the annual machine use (h year^{-1}). Similarly, the annual custom hiring income was expressed as:

$$y = 332.20x$$

where, 332.20 represents the custom hiring charge (₹ h^{-1}).

The intersection of the two equations yielded a break-even point of 615.93 h year^{-1} (approximately 616 h year^{-1}). This indicates that the developed roto-planter becomes economically viable when it is operated for more than 616 hours annually. The fixed cost, variable cost and total operating cost of the mini tractor, developed roto-planter and their combination are presented in Tables 4 and 5 (Appendix-1).

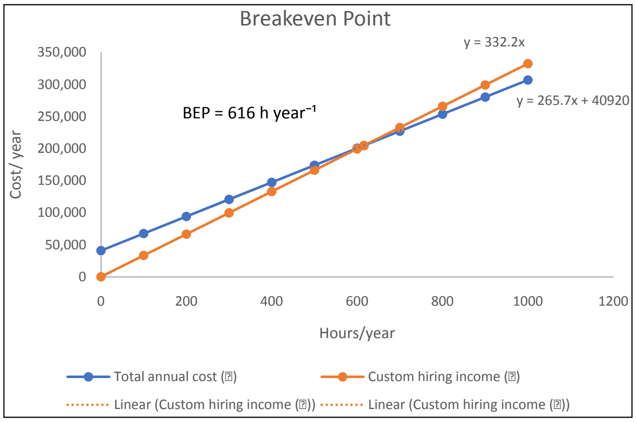

Fig. 2: Breakeven cost of owning the machine

Payback Period

The payback period of the developed mini tractor-operated roto-planter was estimated to evaluate the time required to recover the initial investment through annual net returns. Based on a custom hiring charge of ₹ 332.20 h^{-1}, an operating cost of ₹ 265.76 h^{-1}, and an annual utilization of 616 hours, the annual net benefit was calculated as ₹ 40,927.04. Considering the initial investment of ₹ 60,000 for the developed roto-planter, the payback period was estimated to be 1.46 years. This relatively short payback period indicates that the investment in the developed machine can be recovered within less than one and a half years under the assumed annual utilization. The results demonstrate the economic feasibility of the developed roto-planter for custom hiring services and suggest that higher annual machine utilization can further improve its profitability and financial viability for small and medium-scale farmers.

The economic performance of the developed mini tractor-operated roto-planter is summarized in Table 3. The table presents the estimated ownership and operating costs, field capacity, annual area coverage, cost savings, break-even point and payback period, demonstrating the economic viability of the developed machine under the assumed operating conditions.

Table 3: Mathematical calculations for cost estimation of mini tractor drawn roro planter

Sl. No.	Parameter	Value
1	Total fixed cost per hour (₹ h^{-1})	66.96
2	Total fixed cost per year (₹ $year^{-1}$)	40,920
3	Total variable cost (₹ h^{-1})	198.80
4	Cost of existing method of cultivation (₹ ha^{-1})	3,000.00
5	Total operating cost (₹ h^{-1})	265.76
6	Custom hiring charge (₹ h^{-1})	332.20
7	Total operating cost (₹ ha^{-1})	1,771.73
8	Field capacity (ha h^{-1})	0.15
9	Total area covered per year (ha $year^{-1}$)	92.40
10	Cost saving over existing method (₹ ha^{-1})	1,228.27
11	Break-even point (h $year^{-1}$)	615.93
12	Break-even point (ha $year^{-1}$)	92.38
13	Payback period (years)	1.46

Practical Implications

The developed roto-planter can significantly enhance mechanization among small and marginal farmers by reducing labour dependency, lowering cultivation costs, and improving timeliness of sowing operations. The machine is particularly suitable for custom hiring centres, Farmer Producer Organizations (FPOs), and rural entrepreneurship programmes under agricultural mechanization schemes.

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CONCLUSION

The developed mini tractor-operated roto-planter demonstrated satisfactory technical performance and excellent economic feasibility under field conditions. Integration of rotary tillage and seed sowing reduced operational costs by 40.9% compared with conventional practices while achieving an effective field capacity of 0.15 ha h^{-1}. Economic indicators, including a break-even utilization of 615.93 h $year^{-1}$ and a payback period of 1.46 years, confirm that the implement is financially viable, particularly under custom hiring conditions. Future research should evaluate the machine under different soil types, crops, and agro-climatic conditions and include comprehensive benefit–cost ratio and life-cycle cost analyses to support wider commercial adoption.

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Appendix-1

Table 4: Mathematical calculations for cost estimation of mini tractor

Fixed cost	Depreciation, ₹ per h	$D = \frac{C-S}{L\times H}$ $= \frac{1,60,000-16000}{10\times1000}$	14.4
	Interest, ₹ per h	$A = \frac{C+S}{2}\times\frac{i}{H}$ $= \frac{1,60,000+16000}{2}\times\frac{12}{100\times1000}$	10.56
	Insurance & Taxes, ₹ per h	$= \frac{2\%\ \text{of purchase value}}{\text{Annual use of machine}}$ $= \frac{2\times1,60,000}{100\times1000}$	3.2
	Housing, ₹ per h	$= \frac{1\%\ \text{of purchase value}}{\text{Annual use of machine}}$ $= \frac{1\times1,60,000}{100\times1000}$	1.6
	Total Fixed cost of mini tractor, ₹ per h		**29.76**
Variable cost	Fuel, ₹ per h	= 1.30 l/h × 70 ₹/l	91
	Lubrication oil, ₹ per h	0.30× 91	27.3
	Repair and maintenance, ₹ per h	= 5% of purchase value	8
	Wages and labor charge, ₹ per h	500 ₹ per for the operator and per day 8 hours	62.5
	Total variable cost, ₹ per h		188.8
Total Operating cost of Mini tractor, ₹ per h			218.56

Table 5: Mathematical calculations for cost estimation of developed roto-planter

Fixed cost	Depreciation, ₹ per h	$D = \frac{C-S}{L\times H}$ $= \frac{60,000-6,000}{10\times300}$	18
	Interest, ₹ per h	$A = \frac{C+S}{2}\times\frac{i}{L\times H}$ $= \frac{60,000+6,000}{2}\times\frac{12}{100\times300}$	18
	Insurance & Taxes, ₹ per h	$\frac{2\%\ \text{of purchase value}}{\text{Annual use of machine}}$ $= \frac{2\times60,000}{300\times100}$	4
	Housing, ₹ per h	$= \frac{1\%\ \text{of purchase value}}{\text{Annual use of machine}}$ $= \frac{1\times30,000}{100\times300}$	2
	Total Fixed cost of Roto-planter, ₹ per h		**37.2**
Variable cost	Repair and maintenance, ₹ per h	$= \frac{5\times60,000}{100\times300}$ = 5% of purchase value	10

	Total variable cost, ₹ per h	10
47 Total Operating cost of Roto-planter, ₹ per h		47.2

Total operating cost of mini tractor drawn roto-plnater

Total cost of machine (₹ per h) = 218.56 + 47.2 = 265.76

Total fixed cost of the machine is the sum of fixed costs of mini tractor and roto-planter

Total fixed cost (₹ per h) = 29.76 + 37.2 = 66.96

Total variable cost of the machine is the sum of variable costs of mini tractor and roto-planter

Total variable cost (₹ per h) = 188.8 + 10 = 198.8

Field capacity of developed machine = 0.15 hah^{-1}

For calculating breakeven point:

- **Total annual cost:** $y = 265.76x + 40920$
- **Custom hiring income:** $y = 332.20x$

Annual use (h/year)	Total annual cost (₹)	Custom hiring income (₹)
0	40,920	0
100	67,496	33,220
200	94,072	66,440
300	120,648	99,660
400	147,224	132,880
500	173,800	166,100
600	200,376	199,320
616	**204,628.16**	**204,635.20**
700	226,952	232,540
800	253,528	265,760
900	280,104	298,980
1000	306,680	332,200

Custom hiring charge, ₹/h = 25 *per cent over total cost of operation ₹/h*

= 1.25 265.76

= 332.2

Net Annual Benefit, ₹ = (Custom hiring charge – Operating cost) × Annual use

= (332.2 – 265.76) × 616

40,927.04 ₹

Payback period Calculation

$$\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Average Net Annual Benefit}}$$

$$\frac{60000}{40927.04}$$

$$1.46\,yrs$$