NINE

Quantitative Techniques for Economic Performance

9.1 FEASIBILITY OF THE ROBOTIZATION PLAN

Investment in robotization needs careful study and analysis of the feasibility of the project. There are usually two basic situations of robotic installations. The first is a new application to meet production capacity and predicted production schedule. The second application is to introduce robots to replace the present method of manual production or it may be to replace hard automation. A feasibility study to select the best alternative is to be made. In general, a flexible automation in which robotics is one of the important technologies becomes cost effective in medium volume production. It is effective where production style, design and annual volume vary often due to demand levels of the customers and the market. Figure 9.1(a) indicates a general trend in the unit cost for varying production volume. While planning for the feasibility study, cycle time, quality level, reliability, safety, inventory, material handling systems, product design, product flow, routing, etc. are considered carefully and then a decision for robotization is taken.

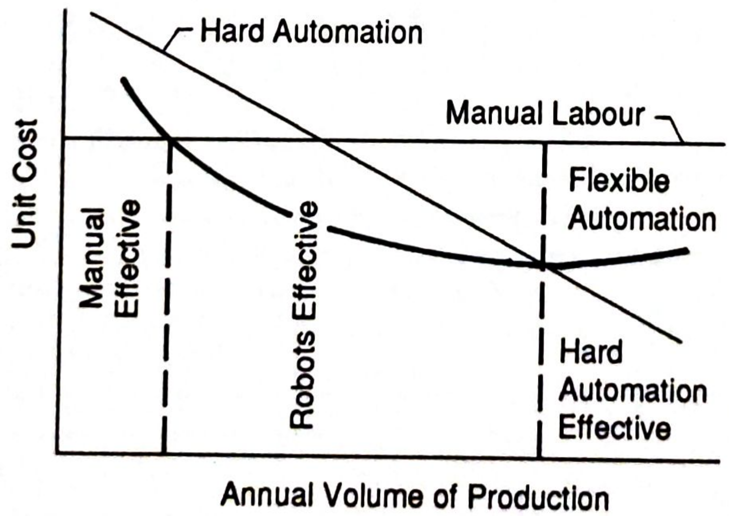

FIG. 9.1 (a) *General trend of cost for robotized and other production*

9.2 DATA ACQUISITION

In order to analyze the economy of robotization, data concerning production volume, production rate, daily production hour and various direct and indirect costs are required to be collected. Direct costs include robot investment costs and robot operating costs. The following are the direct costs associated with the robots.

Robot Investments Costs

1. Cost of robots (manipulator & controller)
2. Engineering cost (mainly the planning costs)
3. Programming cost
4. Installations cost
5. Tooling costs (costs for grippers, part positioners and special tools and fixtures)
6. Miscellaneous costs including costs of other related equipment for the work cell.

Robot Operating Expenses

1. Direct labour cost [Fig. 9.1 (b)] to operate the robot
2. Supervisory costs for other personnel engaged excluding maintenance staff
3. Maintenance costs—this includes labour costs for maintenance crew, spare parts, services; annual maintenance
4. Costs for utilities and servicing facilities
5. Training costs—frequent and regular training and refresher courses are necessary for the staff.

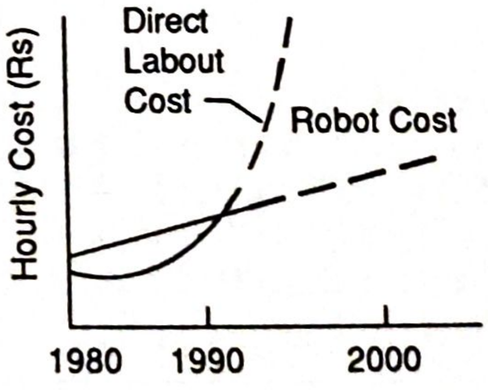

FIG. 9.1 (b) Labour and Robot Cost

However, indirect costs for robotization are indeed difficult to determine as they cannot be easily quantified. Indirect costs include:

1. Inventories carrying costs—both in-process and finished goods
2. Materials utilization and savings
3. Reduced scrap and rework
4. Space utilization
5. Improved management control
6. Improved workers participation

9.3 INVESTMENT AND EVALUATION STRATEGIES

Different organizations have different set-up, different product ranges and plant facilities. So they opt for different economic strategies for their investment on robots. However, there are basically four methods of economic evaluation. They are:

1. Method of pay-back period
2. Return on investment method
3. Discounted cash flow method
4. Equivalent uniform annual cost method

9.3.1 Method of Payback Period

This method determines the payback period during which time the net accumulated cash flow is equal to the total investment on the robot. Assuming that the net annual cash flows are equal every year, payback is determined from the following formula,

$$P = \frac{C}{L + V - R}$$

where, P = payback period in years
C = total capital (investment) cost, Rs.
L = cost of annual labour saved, Rs.
V = added value of increased output, Rs.
R = annual running costs of robot, Rs.

The term of capital recovery is calculated and decided by the length of return period. The major disadvantage is that the time value of money is ignored.

Example 9.1
Suppose the total investment on the robot is estimated to be Rs. 500,000. There is 1 shift operation of 2000 hours and 1 man replaced. Assuming labour rate inducing direct overheads to be Rs. 80 per hour, robot running costs including maintenance and depreciation to be Rs. 1,00,000 and added value of increased output be Rs. 1,20,000, determine the payback period.

$$\text{Payback period} = \frac{5,00,000}{(80 \times 2000) + 1,20,000 - 1,00,000}$$
$$= 2.77 \text{ years}$$

However double shifting will improve the payback period. It favours short term return and ignores long time returns.

Example 9.2

Suppose, capital cost on robot	=	Rs. 20,00,000
Total operating costs	=	Rs. 4,00,000
Total revenue out of robot installation	=	Rs. 14,00,000

Determine the payback period in years.

$$\text{Payback period} = \frac{20,00,000}{14,00,000 - 4,00,000} = 2 \text{ years}$$

9.3.2 Return on Investment

The robot is depreciated over its useful span of life. The approximate life span of a robot is between 5 and 8 years. Assuming straight line depreciation method, the total robot investment (capital) is depreciated evenly over the life of the robot. If C is the investment cost and n is the life of the robot, yearly depreciation is (C/n). If salvage value of robot is F, depreciation per year can be obtained from $(\overline{C - F}/n)$.

Example 9.3

Taking the previous example of 9.1,

Assume

Cost of robot and accessories : Rs. 5,00,000

Yearly depreciation (straight line method)

for robot with a life of 8 years : $\frac{\text{Rs. } 5,00,000}{8}$ or Rs. 62,500

Annual maintenance costs : Rs. 32,000

Annual value of increased output : Rs. 1,20,000

1 man has been replaced, i.e. 1 shift of operation = 2000 hours

Labour rate including direct overhead : Rs. 80/hour

Annual rate of return in percentage

$$= \frac{\text{Net savings (or income)} \times 100}{\text{Total investment on robot}}$$

$$= \frac{\begin{array}{l}\text{(Annual rate of increased output)} + \text{(Cost of labour savings)} \\ - \text{(Annual depreciation)} - \text{(Annual maintenance cost)}\end{array}}{\text{Total Capital (investment) costs}} \times 100\%$$

$$= \frac{120,000 + (80 \times 2,000) - 62,500 - 32,000}{500,000} \times 100\%$$

$$= 37.1\%$$

The rate of return is 37% which is quite good. Rate of return may be up to 50% or so. If the investor in this case borrows money with 20% annual interest, he will still get the benefit of net return on investment of about 17%.

If the robot is used for 2 shift operations, the annual rate of return (in percent)

$$= \frac{2,40,000 + (160 \times 2000) - 62,500 - 40,000}{5,00,000} \times 100\%$$

$$= 91.5\%$$

9.3.3 Discounted Cash Flow Method

Discounted cash flow method is the way to calculate the expected value today of the investment returned at some point of future time. For example, the present value of investment received after *n* years at the rate of 30 percent is given as a ratio of the amount received. For example, Rs. 10,000 in 5 years at the rate of 30% interest will have a present value of Rs. 2700. Table 9.1 gives the present value of money to be received in the future.

Table 9.1 *Present Value of Money to be Received in the Future*

Year	Interest Rate			
	10% ratio	15% ratio	20% ratio	30% ratio
0	1.000	1.000	1.000	1.000
1	.909	.870	.835	.770
2	.826	.757	.695	.590
3	.751	.660	.578	.455
4	.683	.572	.483	.362
5	.621	.498	.402	.270
6	.564	.433	.334	.208
7	.513	.376	.279	.160
8	.467	.327	.232	.123
9	.424	.284	.193	.094
10	.386	.247	.162	.072

The ratio $R = 1/(1 + r)^n$ where *r* is the yearly interest rate in percent and *n* is the number of years.

Present value may also be expressed in the form:

$$PV = \sum_{k=0}^{n} \frac{(-C_k + S_k - R_k)}{(1 + i)^k} + \frac{L}{(1 + i)^n}$$

where, PV = Present value
C_k = investment cost in year k
S_k = savings in year k
R_k = running costs in year k
L = forecasting of salvage value
i = interest rate
n = life in years

9.3.4 Equivalent Uniform Annual Cost Method (EUAC)

EUAC converts all the present and future investments into their equivalent uniform cash flows over the anticipated life of the project. So for all the investments and cash flows, the uniform annual cost is found from the theory and practice of engineering economy. If the EUAC of the project is greater than the minimum attractive rate of return (MARR), the project is viable.

Table 9.2 indicates the percent compound interest factors. If the EUAC is less than zero, the project is unattractive.

Table 9.2 *30 Percent Compound Interest Factors*

	Single Payment		Uniform Series Payment			
Year n	Compounded amount F/P	Present Worth P/F	Sinking Fund A/F	Compounded Amount F/A	Capital Recovery A/P	Present Worth
1	1.3000	0.7692	1.00000	1.000	1.30000	0.7692
2	1.6900	0.5917	0.43478	2.300	0.73478	1.3609
3	2.1970	0.4552	0.25063	3.990	0.55063	1.8161
4	2.8561	0.3501	0.16163	6.187	0.46163	2.1662
5	3.7129	0.2693	0.11058	9.043	0.41058	2.4356
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
10	13.7858	0.0725	0.02346	42.619	0.32346	3.0915

An example of equivalent uniform annual cost method is given. If the value of uniform annual cost method is negative, it is not advisable to invest money.

Example 9.4

Suppose, cost of robot : Rs 5,00,000
annual revenue : Rs. 3,25,000
annual running costs : Rs. 1,00,000

Assuming the robot has a service life of 5 years and a minimum rate of return 30%.

Equivalent uniform annual cost
= – 5,00,000 × 0.41058 + 3,25,000–1,00,000
[the ratio of capital recovery is 0.41058 from Table 9.2]
= – 205290 + 225 000
= + 19710

As the resulting uniform annual cost value is +ve, this is a good investment.

9.4 PLANNING FOR ROBOT INSTALLATION

The choice for applications depends on careful planning and evaluation of economy. A general guideline is to prepare a questionnaire form and an economic analysis form. The following are some of the considerations for robotics planning: