CHAPTER 6

Evaluation of Engineering Alternatives

6.1 INTRODUCTION

In all engineering problems, engineers encounter one important question, i.e. which project to select. To select among the different alternatives, various methods have been evolved. There are several bases for comparing the worthiness of projects which as follows:

1. Present worth method
2. Future worth method
3. Annual equivalent method
4. Rate of return method
5. Cost-benefit analysis.

6.2 PRESENT WORTH METHOD

Many economists prefer the present worth method because it reveals the sum in today's rupee that is equivalent to a future cash flow stream. For example, Rs. 110 expected one year hence is worth only Rs. 100 today, if the rate of interest is 10 per cent, compounded annually. This means that Rs. 100 is the present value of Rs. 110 to be earned one year hence.

In the present worth method, the present worth of all cash inflows (revenues) is compared against the present worth of all cash outflows (costs) associated with an investment project. In this method of comparison, the cash flow of each alternative will be reduced to time zero by assuming an interest rate *i*. Then, depending on the type of decision, the best alternative will be selected by comparing the present worth amounts of the alternatives. The difference between the present worth of the cash flows (inflows – outflows) is referred to as the Net Present Worth (NPW) which determines whether or not the project is a feasible investment.

6.2.1 Steps Needed for Present Worth Comparison

The following are the steps involved in present worth comparison:

1. Estimate the interest rate that the firm wishes to earn on its investment.
2. Determine the service life of the project.

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3. Ascertain the cash inflows over each service life.
4. Find out the cash overflows over each service period.
5. Calculate the net cash flows (inflows – outflows).

If there is a single investment proposal, then the decision whether a project will be selected or rejected can be made accordingly.

- If $PW > 0$, then the proposal will be selected. A positive NPW means that the equivalent worth of the inflows is greater than the equivalent worth of the outflows. So, the project will make profit.
- If $PW < 0$, then the investment project should be rejected. A negative NPW means the equivalent worth of the inflows is less than the equivalent worth of the outflows.
- If $PW = 0$, then one should remain indifferent to the investment.

In case there are mutually exclusive alternatives, then the present worth cash flows can be calculated by two prominent methods:

- Revenue-based present worth
- Cost-based present worth

In a revenue/profit-based cash flow diagram, the profit, revenue, salvage value (all inflows to an organization) will be assigned with a positive sign. The costs (outflows) will be assigned with a negative sign. In a cost-based cash flow diagram, on the other hand, the costs (outflows) will be assigned a positive sign and the profit, revenue, salvage value (all inflows), etc. will be assigned a negative sign. In revenue-based cases, the decision is to select the alternative with the maximum profit. Thus, the alternative with the maximum present worth will be selected. In cost bases cases, if the decision is to select the alternative with the minimum cost, then the alternative with the least present worth amount will be selected.

6.2.2 Revenue-based Cash Flow Diagram

See Figure 6.1.

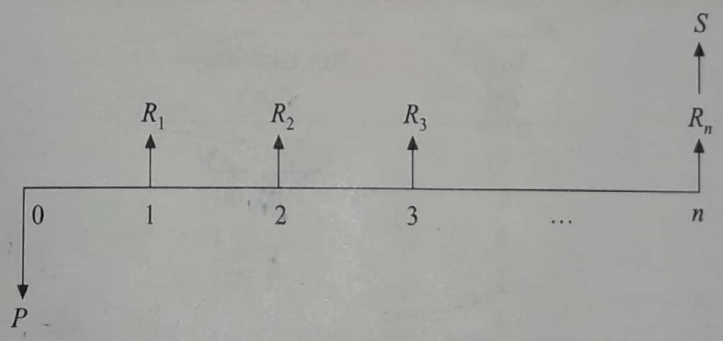

Figure 6.1 Revenue-based cash flow diagram.

Here, P is the initial investment, R_n is the net revenue at the end of nth year, i is the interest rate compounded annually, and S is the salvage value at the end of nth year.

To find the present worth of the cash flow from Figure 6.1 for a given interest rate, the required formula is

$$PW(i) = -P + \frac{R_1}{(1+i)^1} + \frac{R_2}{(1+i)^2} + \cdots + \frac{R_n}{(1+i)^n} + \frac{S}{(1+i)^n}$$

or

$$PW(i) = -P + R_1(P/F, i, 1) + R_2(P/F, i, 2) + \cdots + R_n(P/F, i, n) + S(P/F, i, n)$$

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If it is a uniform series or equal-payment series, then the formula will be

$$PW(i) = -P + R(P/A, i, n) + S(P/F, i, n)$$

6.2.3 Cost-based Cash Flow Diagram

See Figure 6.2.

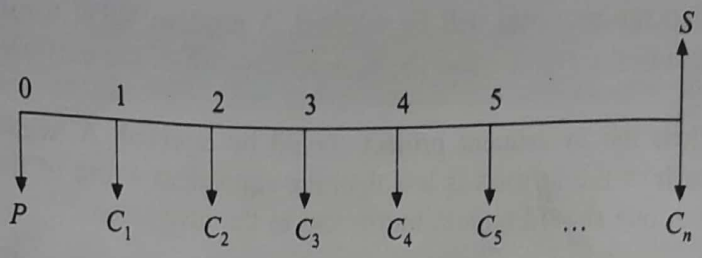

Figure 6.2 Cost-based cash flow diagram.

Here P is the initial investment, C_n is the net cost of operation and maintenance at the end of nth year, S is the salvage value at the end of nth year, and C_i is the discounted rate of interest.

Thus, the present worth expression is

$$PW(i) = P + \frac{C_1}{(1+i)^1} + \frac{C_2}{(1+i)^2} + \cdots + \frac{C_n}{(1+i)^n} - \frac{S}{(1+i)^n}$$

or

$$PW(i) = P + C_1(P/F, i,1) + C_2(P/F, i, 2) + \cdots + C_n(P/F, i, n) - S(P/F, i, n)$$

If it is a uniform series or equal-payment series, then the formula will be

$$PW(i) = P + C(P/A, i, n) - S(P/F, i, n)$$

EXAMPLE 6.1

The following table summarizes a cash flow stream of an investment project:

Year (n)	Net cash flow (Rs.)
0	−650,000
1	162,500
2	162,500
3	162,500
4	
5	
6	
7	
8	162,500

If the firm's rate of interest is 15 per cent, compute the NPW of this project. Moreover, this project acceptable?

Solution

The cash flow diagram for the given project is shown in Figure E6.1.1.

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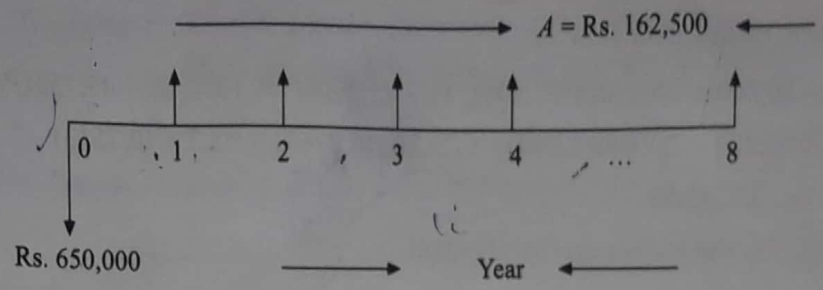

Figure E6.1.1

This is a uniform cash flow stream. Since the project requires an initial investment of Rs. 650,000 at present ($n = 0$) followed by eight equal annual receipts of Rs. 162,500, we can easily determine the NPW as follows:

$$\begin{aligned} NPW &= -P + R(P/A, i, n) \\ &= -\text{Rs. } 650{,}000 + \text{Rs. } 162{,}500(P/A, 15\%, 8) \\ &= -\text{Rs. } 650{,}000 + \text{Rs. } 162{,}500(4.4873) \\ &= -\text{Rs. } 650{,}000 + \text{Rs. } 729{,}186 \\ &= \text{Rs. } 79{,}186 \end{aligned}$$

Since $PW(15\%) > 0$, the project can be accepted.

EXAMPLE 6.2

The project cash flows of an investment proposal is given here

End of year (n)	Net cash flow (Rs.)
0	– 50,000
1	20,400
2	25,200
3	45,750

Evaluate the economic desirability of this project for $i = 10\%$.

Solution

The cash flow diagram for the given project is shown in Figure E6.2.1.

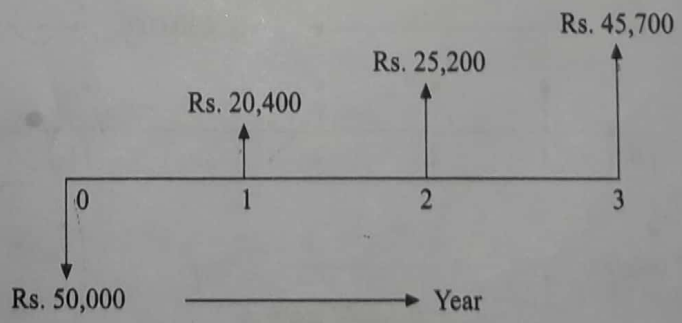

Figure E6.2.1

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The present worth of this cash flow is

$$PW(10\%) = -50{,}000 + 20{,}400(P/F, 10\%, 1) + 25{,}200(P/F, 10\%, 2) + 45{,}750(P/F, 10\%, 3)$$
$$= -50{,}000 + 20{,}400(0.9091) + 25{,}200(0.8264) + 45{,}750(0.7513)$$
$$= \text{Rs. } 23{,}742.89$$

Since $PW(10\%) > 0$, the project can be accepted.

EXAMPLE 6.3

Given the following information, suggest the best alternative which is to be implemented based on the present worth method, assuming 20 per cent interest rate, compounded annually:

Alternative	Initial cost	Annual revenue	Life
A	Rs. 1,500,000	Rs. 800,000	15 years
B	Rs. 2,000,000	Rs. 600,000	15 years
C	Rs. 1,600,000	Rs. 400,000	15 years

Solution

The cash flow diagram for alternative A is given in Figure E6.3.1.

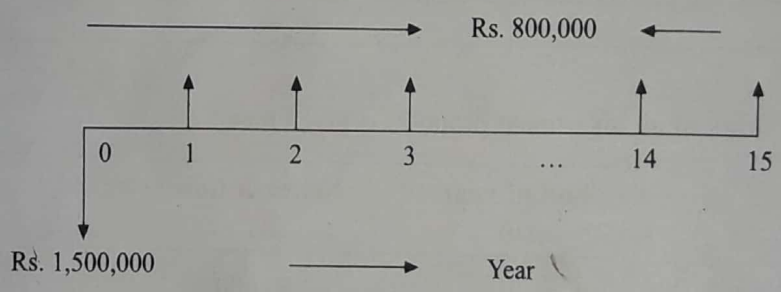

Figure E6.3.1

The present worth for this cash flow is

$$PW(20\%)_A = -\text{Rs. } 1{,}500{,}000 + \text{Rs. } 800{,}000(P/A, 20\%, 15)$$
$$= -\text{Rs. } 1{,}500{,}000 + \text{Rs. } 800{,}000(4.6755)$$
$$= \text{Rs. } 2{,}240{,}400$$

The cash flow diagram for alternative B is given in Figure E6.3.2.

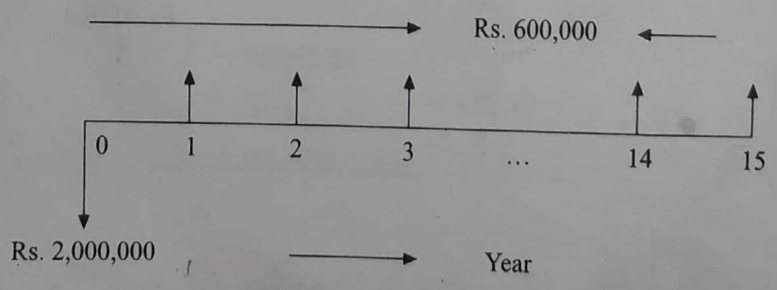

Figure E6.3.2

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$$PW(20\%)_B = -\text{Rs. } 2{,}000{,}000 + \text{Rs. } 600{,}000(P/A, 20\%, 15)$$
$$= -\text{Rs. } 2{,}000{,}000 + \text{Rs. } 600{,}000(4.6755)$$
$$= \text{Rs. } 805{,}300$$

The cash flow diagram for alternative C is given in Figure E6.3.3.

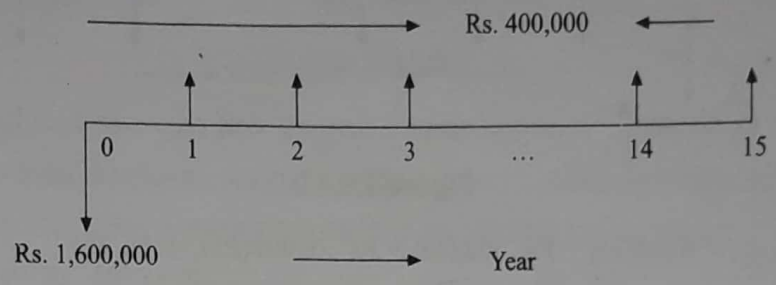

Figure E6.3.3

$$PW(20\%)_C = -\text{Rs. } 1{,}600{,}000 + \text{Rs. } 400{,}000(P/A, 20\%, 15)$$
$$= -\text{Rs. } 1{,}600{,}000 + \text{Rs. } 400{,}000(4.6755)$$
$$= \text{Rs. } 270{,}200$$

Since the present worth of alternative A is the highest among all the alternatives, so it is recommended for implementation.

EXAMPLE 6.4

Given the following information, suggest which technology should be selected based on the present worth method, assuming 15 per cent interest rate compounded annually.

Technology	Initial cost (Rs.)	Service life	Annual operational and management cost
A	400,000	15 years	25,000
B	500,000	15 years	29,000

Solution

The cash flow diagram for technology A is given in Figure E6.4.1.

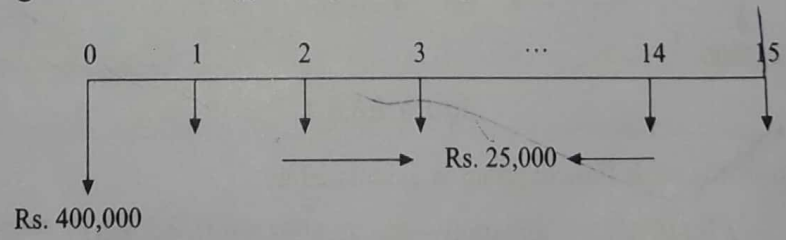

Figure E6.4.1

The present worth amount of this cash flow stream is

$$PW(15\%)_A = \text{Rs. } 400{,}000 + \text{Rs. } 25{,}000(P/A, 15\%, 15)$$
$$= \text{Rs. } 400{,}000 + \text{Rs. } 25{,}000(5.8474)$$

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$$= \text{Rs. } 400{,}000 + \text{Rs. } 146{,}185$$
$$= \text{Rs. } 546{,}185$$

The cash flow diagram for technology B is given in Figure E6.4.2.

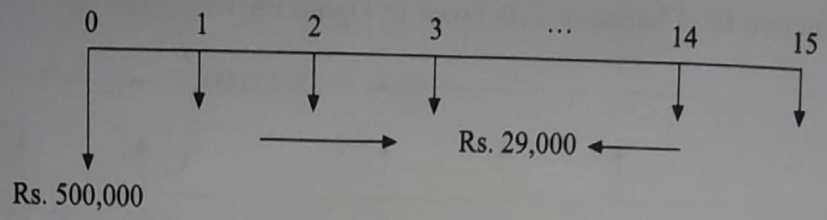

Figure E6.4.2

$$PW(15\%)_B = \text{Rs. } 500{,}000 + \text{Rs. } 29{,}000(P/A, 15\%, 15)$$
$$= \text{Rs. } 500{,}000 + \text{Rs. } 29{,}000(5.8474)$$
$$= \text{Rs. } 500{,}000 + \text{Rs. } 169{,}574.6$$
$$= \text{Rs. } 669{,}574.6$$

Since PW amount of technology A is lower, it should be selected.

EXAMPLE 6.5

A finance company advertises two investment plans. In plan 1, the company pays Rs. 22,000 after 15 years for every Rs. 1000 invested now. In plan 2, for every Rs. 1000 invested the company pays Rs. 4000 at the end of the tenth year and Rs. 4000 at the end of the fifteenth year. Select the best investment plan at i = 10 per cent compounded annually.

Solution

The cash flow diagram for plan 1 is given in Figure E6.5.1.

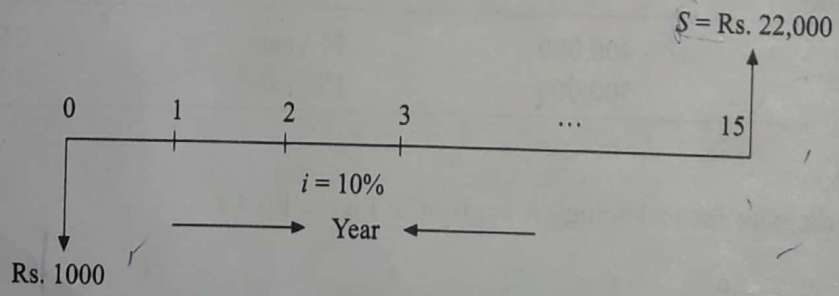

Figure E6.5.1

The present worth of the cash flow diagram is calculated as

$$PW(10\%)_1 = -\text{Rs. } 1000 + \text{Rs. } 22{,}000(P/F, 10\%, 15)$$
$$= -\text{Rs. } 1000 + \text{Rs. } 22{,}000(0.2394)$$
$$= \text{Rs. } 4266.8$$

The cash flow diagram for plan 2 is given in Figure E6.5.2.

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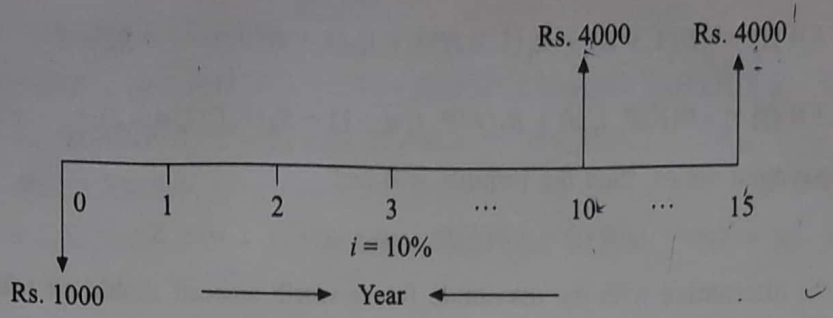

Figure E6.5.2

The present worth of the above cash flow diagram is computed as

$$\begin{aligned} PW(10\%)_2 &= -\text{Rs. } 1000 + \text{Rs. } 4000(P/F, 10\%, 10) + \text{Rs. } 4000(P/F, 10\%, 15) \\ &= -\text{Rs. } 1000 + \text{Rs. } 4000(0.3855) + \text{Rs. } 4000(0.2394) \\ &= -\text{Rs. } 1000 + \text{Rs. } 11{,}118 \\ &= \text{Rs. } 10{,}118 \end{aligned}$$

The present worth of plan 1 is more than that of plan 2. So, plan 1 is the best plan from the investors' point of view.

6.3 FUTURE WORTH METHOD

Future worth method is particularly useful in an investment situation where we need to compute the equivalent worth of a project at the end of its investment period rather than at its beginning.

6.3.1 Steps for Computing Future Worth Method

The following are the steps for computing future worth method.

1. Determine the interest rate.
2. Estimate the service life of the project.
3. Calculate the cash inflows for each period over the service life.
4. Ascertain the cash outflows over each service period.
5. Find out the net cash flows (inflows – outflows).

For a single project evaluation, if

1. $FW > 0$, then the project will be accepted;
2. $FW < 0$, then the investment proposal will be rejected; and
3. $FW = 0$, then one will remain indifferent to the investment.

For a mutually exclusive alternative, the future worth cash flows can be calculated by the following:

1. Revenue-based future worth
2. Cost-based future worth

In revenue-based future worth, the alternative with the maximum future worth amount will be selected. In cost-based future worth, the alternative with the least future worth amount will be accepted. The formula for the future worth for a given interest rate i is

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$$FW(i) = -P(1+i)^n + R_1(1+i)^{n-1} + R_2(1+i)^{n-2} + \dots + R_n + S$$

or

$$FW(i) = -P(F/P, i, n) + R_1(F/P, i, n-1) + R_2(F/P, i, n-2) + \dots + R_n + S$$

If it is equal-payment series, then the formula will be

$$FW(i) = -P(F/P, i, n) + R(F/A, i, n) + S$$

In this case, the alternative with the maximum future worth amount should be selected as the best alternative.

If the cash flow stream is cost based, then the future worth is given by

$$FW(i) = P(1+i)^n + C_1(1+i)^{n-1} + C_2(1+i)^{n-2} + \dots + C_n - S$$

or

$$FW(i) = P(F/P, i, n) + C_1(F/P, i, n-1) + C_2(F/P, i, n-2) + \dots + C_n - S$$

In equal-payment series, the formula will be

$$FW(i) = P(F/P, i, n) + C(F/A, i, n) - S$$

In this case, the alternative with the minimum future worth amount should be selected as the best alternative.

EXAMPLE 6.6

The project cash flow of an investment proposal is given in the following tabular form

Year (n)	Net cash flow (Rs.)
0	– 50,000
1	20,400
2	25,200
3	52,740

Compute the NFW at the end of year 3 at i = 15 per cent. Is this project acceptable?

Solution

The cash flow diagram for the project is given in Figure E6.6.1.

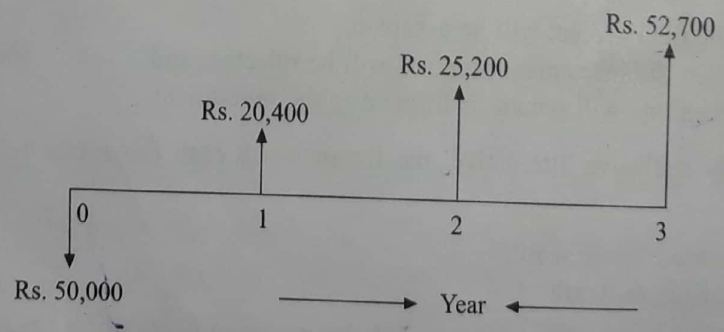

Figure E6.6.1

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The future worth of the project is

$$FW(15\%) = -P(F/P, i, n) + R_1(F/P, i, n-1) + R_2(F/P, i, n-2) + R_3(F/P, i, n-3)$$
$$= -\text{Rs. } 50{,}000(F/P, 15\%, 3) + \text{Rs. } 20{,}400(F/P, 15\%, 2)$$
$$+ \text{Rs. } 25{,}200(F/P, 15\%, 1) + \text{Rs. } 52{,}740$$
$$= -\text{Rs. } 50{,}000(1.521) + \text{Rs. } 20{,}400(1.323) + \text{Rs. } 25{,}200(1.150) + \text{Rs. } 52{,}740$$
$$= \text{Rs. } 32{,}659.2$$

Since $FW(15\%) > 0$, the project is acceptable.

EXAMPLE 6.7

Given the following two mutually exclusive alternatives, select the best one based on future worth method of comparison assuming $i = 12$ per cent.

Alternative	Cash flow at the end of year (Rs.)				
	0	1	2	3	4
A	−4,000,000	1,000,000	1,000,000	1,000,000	1,000,000
B	−4,500,000	800,000	800,000	800,000	800,000

Solution

The cash flow diagram for alternative A is given in Figure E6.7.1.

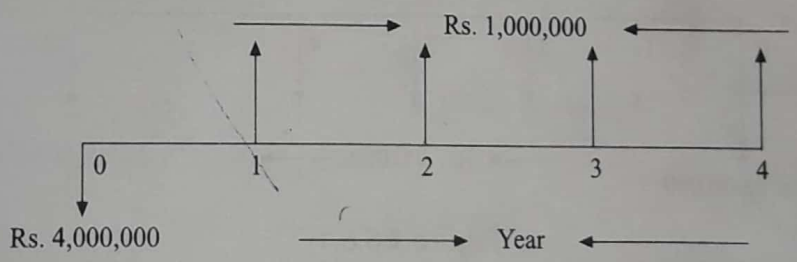

Figure E6.7.1

$$FW(12\%)_A = -\text{Rs. } 4{,}000{,}000(F/P, 12\%, 4) + \text{Rs. } 1{,}000{,}000(F/A, 12\%, 4)$$
$$= -\text{Rs. } 4{,}000{,}000(1.574) + \text{Rs. } 1{,}000{,}000(4.779)$$
$$= -\text{Rs. } 15{,}17{,}000$$

The cash flow diagram for alternative B is given in Figure E6.7.2.

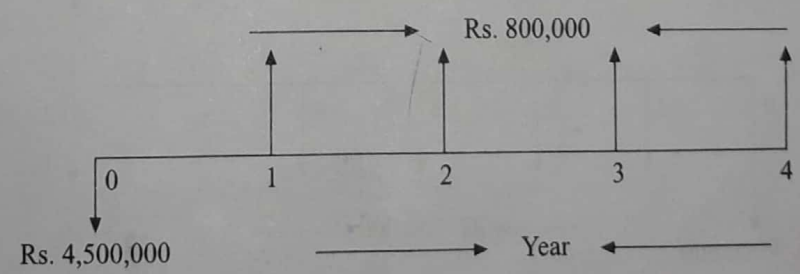

Figure E6.7.2

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$$FW(12\%)_B = -\text{Rs. } 4{,}500{,}000(F/P, 12\%, 4) + \text{Rs. } 800{,}000(F/A, 12\%, 4)$$
$$= -\text{Rs. } 4{,}500{,}000(1.574) + \text{Rs. } 800{,}000(4.779)$$
$$= -\text{Rs. } 3{,}259{,}800$$

Since $FW(A) > FW(B)$, alternative A should be selected.

EXAMPLE 6.8

Given the following particulars, which machine should be selected based on future worth method, assuming 20 per cent interest rate, compounded annually.

Particulars	Machine A	Machine B
Initial cost (Rs.)	8,000,000	7,000,000
Life (years)	12	12
Annual operational and maintenance cost (Rs.)	800,000	900,000
Salvage value (Rs.)	500,000	400,000

Solution

The cash flow diagram for machine A is given in Figure E6.8.1.

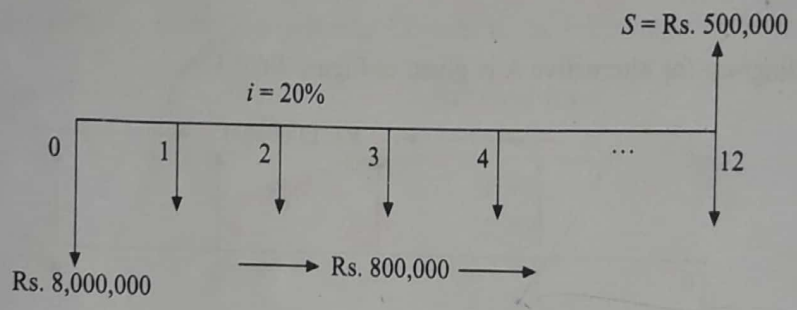

Figure E6.8.1

The future worth amount of machine A is computed as

$$FW(20\%)_A = \text{Rs. } 8{,}000{,}000(F/P, 20\%, 12) + \text{Rs. } 800{,}000(F/A, 20\%, 12) - \text{Rs. } 500{,}000$$
$$= \text{Rs. } 102{,}492{,}800$$

The cash flow diagram for machine B is given in Figure E6.8.2.

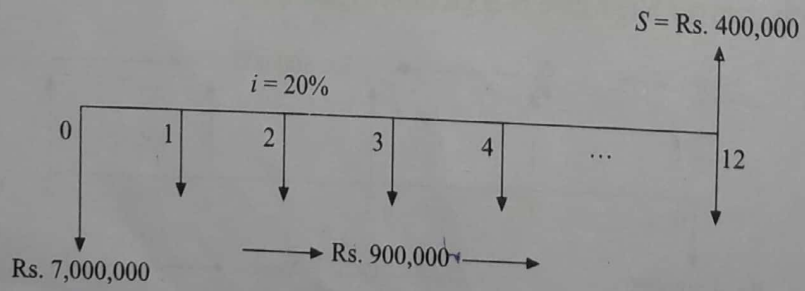

Figure E6.8.2

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The future worth amount of machine B is computed as

$$FW(20\%)_B = \text{Rs. } 7{,}000{,}000(F/P, 20\%, 12) + \text{Rs. } 900{,}000(F/A, 20\%, 12) - \text{Rs. } 400{,}000$$
$$= \text{Rs. } 97{,}634{,}900$$

The future worth cost of machine B is less than that of machine A. So, machine B should be selected.

EXAMPLE 6.9

Which alternative from the following should be selected based on the future worth method of comparison assuming 12 per cent interest rate, compounded annually.

Particulars	Alternative A	Alternative B
Initial cost (Rs.)	400,000	800,000
Useful life (year)	4	4
Salvage value (Rs.)	200,000	550,000
Annual cost (Rs.)	40,000	Nil

Solution

The cash flow diagram of alternative A is shown in Figure E6.9.1.

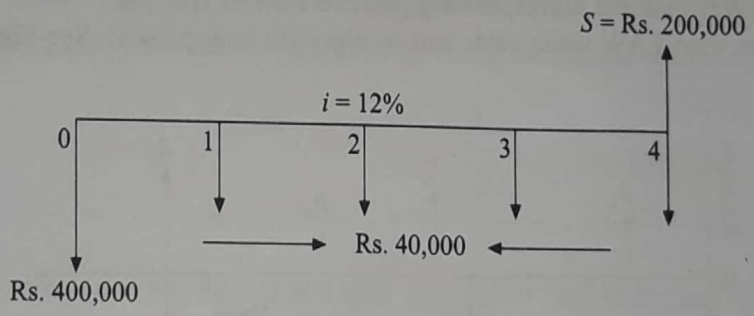

Figure E6.9.1

The future worth amount of alternative A is computed as

$$FW(12\%)_A = \text{Rs. } 400{,}000(F/P, 12\%, 4) + \text{Rs. } 40{,}000(F/A, 12\%, 4) - \text{Rs. } 200{,}000$$
$$= \text{Rs. } 620{,}760$$

The cash flow diagram for alternative B is given in Figure E6.9.2.

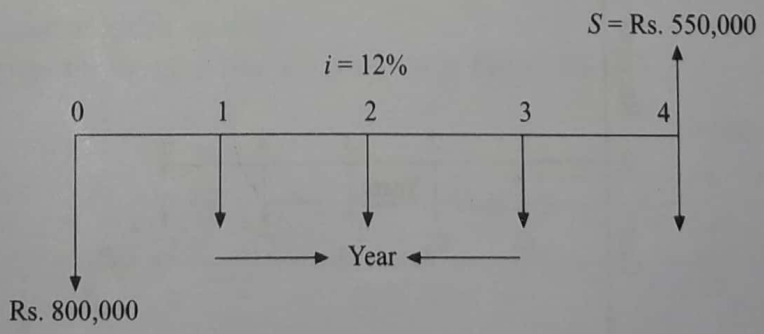

Figure E6.9.2

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The future worth amount of alternative B is computed as

$$FW(12\%)_B = \text{Rs. } 800{,}000(F/P, 12\%, 4) - \text{Rs. } 550{,}000$$
$$= \text{Rs. } 800{,}000(1.574) - \text{Rs. } 550{,}000$$
$$= \text{Rs. } 709{,}200$$

The future worth cost of alternative A is less than that of alternative B. Therefore, alternative A should be selected.

6.4 EQUIVALENT ANNUAL WORTH COMPARISON

There are various alternatives for comparing the worthiness of a project. Equivalent Annual Worth (EAW) is one important method for comparing engineering alternatives. In an annual worth method, all the receipts and disbursements occurring over a period are converted to an equivalent uniform yearly amount. EAW is a popular method because a year's profit and loss are taken into account. A large number of engineering economic decisions are based on annual comparison and hence the term 'equivalent uniform yearly amount' is often used. For example, cost accounting procedures, depreciation charges, tax calculations. These yearly cost tabulations generally make the annual worth method easier.

Equivalent Annual Cost (EAC) indicates that the equivalent value of negative cash flow for disbursement is greater than the corresponding positive flow of receipts.

We will use the term EAW when costs and receipts are both present. See Figure 6.3.

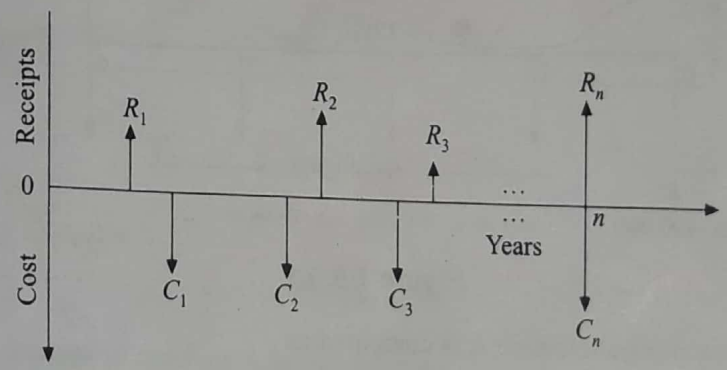

Figure 6.3 Equivalent annual worth diagram.

We will use the term EAC to designate comparison involving only costs. See Figure 6.4.

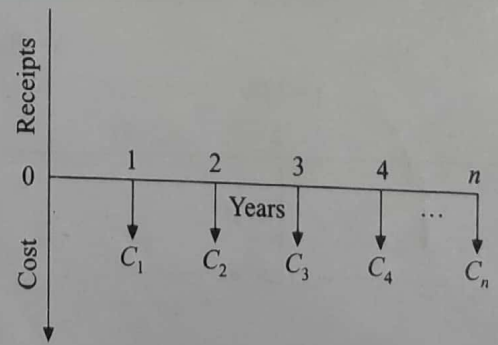

Figure 6.4 Equivalent annual cost diagram.

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6.4.1 Steps for Computing EAW

The following are the steps for computing EAW.

1. Estimate the cash flows (inflows, outflows) over each service period.
2. Calculate the service life of the project.
3. Determine the interest rate.
4. Compare with before tax cash flows.
5. Do not include intangible considerations for EAW comparisons.

For single alternatives, if

1. $EAW > 0$, then the investment proposal will be accepted;
2. $EAW < 0$, then the investment proposal will be rejected; and
3. $EAW = 0$, then one should remain indifferent to the investment.

For multiple alternatives or mutually exclusive alternatives, if all the alternatives are revenue dominated, then the alternative with the higher EAW will be selected. If all the alternatives are cost based, then the alternative with the least EAW will be accepted.

Equivalent annual worth consists of the following steps:

1. Compute the net present worth.
2. Multiply the amount of present worth by the capital recovery factor, i.e. $EAW = PW(i)$ $(A/P, i, n)$, where $(A/P, i, n)$ is called *equal-payment series capital recovery factor.*

The annual equivalent worth can be computed by using the general formula,

$$EAW = PW(i)\frac{i(1+i)^n}{(1+i)^n - 1}$$

EXAMPLE 6.10

Consider a machine that costs Rs. 40,000 and a 10 year useful life. At the end of tenth year, it can be sold for Rs. 5,000 after tax adjustment. If the firm could earn an after tax revenue of Rs. 10,000 per year with this machine, should it be purchased at an interest rate of 15 per cent, compounded annually.

Solution

Initial cost (P) = Rs. 40,000
Useful life (n) = 10 years
Salvage value (S) = Rs. 5,000
Revenue = Rs. 10,000
i = 15 per cent, compounded annually

The cash flow diagram for the given project is shown in Figure E6.10.1.

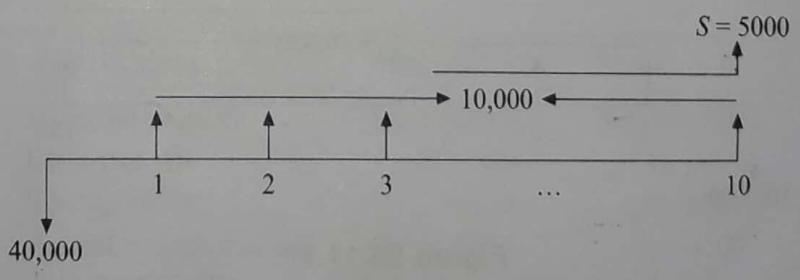

Figure E6.10.1

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Step 1: To find $NPW(15\%)$

$$NPW(15\%) = -P + R(P/A, \text{i}, n) + S(P/F, i, n)$$
$$= -40{,}000 + 10{,}000(5.0188) + 5000(0.2472)$$
$$= \text{Rs. } 11{,}424$$

Step 2: To find $EAW(15\%)$

$$EAW(15\%) = PW(i)\,(A/P, i, n)$$
$$= \text{Rs. } 11{,}424\,(A/P, 15\%, 10)$$
$$= \text{Rs. } 11{,}424\,(0.1993)$$
$$= \text{Rs. } 2276.80$$

Since $EAW(15\%) > 0$, so the project can be accepted.

There will be an equivalent profit of Rs. 2276.8 per year over the machine life.

EXAMPLE 6.11

A company invests in one of the two mutually exclusive alternatives. The life period of both the alternatives is estimated to be 15 years with the following investments, annual equal returns and salvage values:

Particulars	Alternative 1	Alternative 2
First cost	Rs. 100,000	Rs. 110,000
Annual equal returns	Rs. 70,000	Rs. 80,000
Salvage value	Rs. 10,000	Rs. 20,000

Determine the better alternative based on the annual equivalent method by assuming $i = 20$ per cent, compounded annually.

Solution

Alternative 1

First cost (P) = Rs. 100,000
Annual equal return = Rs. 70,000
Salvage value (S) = Rs. 10,000
Interest rate, (i) = 20%

The cash flow diagram for alternative 1 is given in Figure E6.11.1.

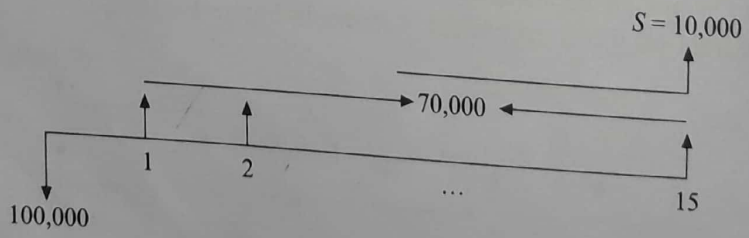

Figure E6.11.1

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$$NPW(20\%) = -P + R(P/A, i, n) + S(P/F, i, n)$$
$$= -100{,}000 + 70{,}000\,(4.6755) + 10{,}000\,(0.0649)$$
$$= \text{Rs. } 227{,}934$$

$$EAW(20\%)_1 = NPW(A/P, i, n)$$
$$= \text{Rs. } 227{,}934(A/P, 20\%, 15)$$
$$= \text{Rs. } 227{,}934(0.2139)$$
$$= \text{Rs. } 48{,}755{,}082$$

Alternative 2

First cost (P) = Rs. 110,000
Annual equal return = Rs. 80,000
Salvage value (S) = Rs. 20,000
Interest rate (i) = 20%

The cash flow diagram for alternative 2 is given in Figure E6.11.2.

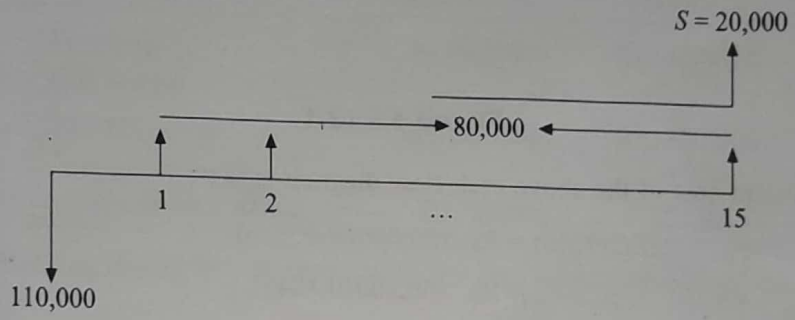

Figure E6.11.2

$$NPW(20\%)_2 = -P + R(P/A, i, n) + S(P/F, i, n)$$
$$= \text{Rs. } 110{,}000 + \text{Rs. } 80{,}000\,(4.6755) + \text{Rs. } 20{,}000\,(0.0649)$$
$$= \text{Rs. } 485{,}338$$

$$EAW(20\%)_2 = NPW(A/P, i, n)$$
$$= \text{Rs. } 485{,}338(A/P, 20\%, 15)$$
$$= \text{Rs. } 485{,}338(0.2139)$$
$$= \text{Rs. } 103{,}813.79$$

Since EAW of alternative 2 is higher than that of alternative 1, the former should be accepted.

EXAMPLE 6.12

Particulars	Machine A	Machine B
Initial investment	Rs. 150,000	Rs. 240,000
Estimated life	12 years	12 years
Salvage value	Rs. 0	Rs. 6000
Annual operational and maintenance cost	Rs. 0	Rs. 4500

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Suggest which machine should be selected based on annual equivalent cost by assuming 15 per cent, interest rate, compounded annually.

Solution

Machine A

Initial investment (P)	= Rs. 150,000
Life period (n)	= 12 years
Salvage value (S)	= Rs. 0
Annual operational and management cost (A)	= Rs. 0
Interest (i)	= 15 per cent compounded annually

The cash flow diagram for machine A is given in Figure E6.12.1.

Figure E6.12.1

The annual equivalent cost of the above cash flow diagram is

$$AEC(15\%) = \text{Rs. } 150{,}000(A/P, i, n)$$
$$= \text{Rs. } 150{,}000(0.1845)$$
$$= \text{Rs. } 27{,}675$$

Machine B

Initial investment (P)	= Rs. 240,000
Life period (n)	= 12 years
Salvage value (S)	= Rs. 6000
Annual operational and management cost (A)	= Rs. 4500
Interest rate (i)	= 15%

The cash flow diagram for machine B is given in Figure E6.12.2.

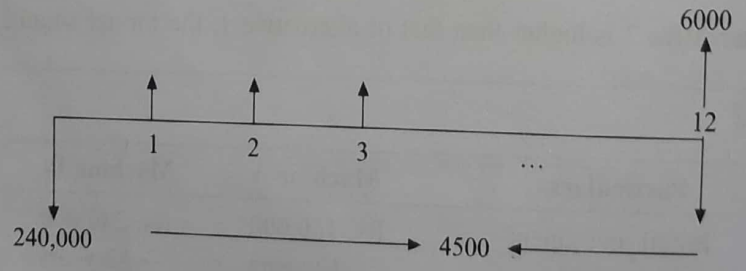

Figure E6.12.2

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$$NPW_B(15\%) = P + C(P/A, i, n) - S(P/F, i, n)$$
$$= 240{,}000 + 4500\ (5.4206) - 6000\ (0.1869)$$
$$= \text{Rs. } 263{,}271.3$$
$$= EAC_B(15\%)$$
$$= NPW(A/P, i, n)$$
$$= NPW(A/P, 15\%, 12)$$
$$= \text{Rs. } 263{,}271.3\ (0.1845)$$
$$= \text{Rs. } 48{,}573.55$$

The annual equivalent cost of machine A is less than that of machine B. So machine A is a more cost-effective machine.

EXAMPLE 6.13

Particulars	Machine A	Machine B
First cost	Rs. 300,000	Rs. 600,000
Life period	4	4
Salvage value	Rs. 200,000	Rs. 300,000
Operational and management cost	Rs. 30,000	Rs. 0

Suggest which machine should be purchased at 15 per cent interest rate based on annual equivalent worth method.

Solution

Machine A

First cost (P) = Rs. 300,000
Life period (n) = 4 years
Salvage value (S) = Rs. 200,000
Operational and management cost (A) = Rs. 30,000
Interest rate (i) = 15 per cent, compounded annually.

The cash flow diagram for machine A is shown in Figure E6.13.1.

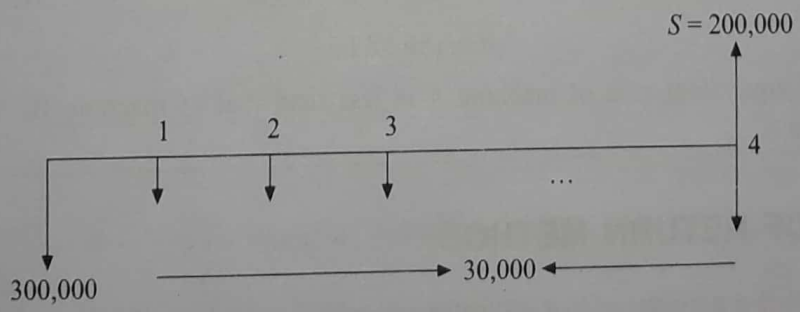

Figure E6.13.1

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$$NPW(15\%)_A = P + C(P/A, i, n) - S(P/F, i, n)$$
$$= 300{,}000 + 30{,}000(P/A, i, n) - 200{,}000(P/F, i, n)$$
$$= 300{,}000 + 30{,}000(2.8550) - 200{,}000(0.5718)$$
$$= \text{Rs. } 271{,}290$$

$$EAW(15\%)_A = NPW \times A/P, i, n$$
$$= \text{Rs. } 271{,}290(A/P, 15\%, 4)$$
$$= \text{Rs. } 271{,}290(0.3503)$$
$$= \text{Rs. } 95{,}032.887$$

Machine B

First cost(P)	= Rs.6,00,000
Life period(n)	= 4 years
Salvage value(S)	= Rs. 300,000
Operational and management cost(A)	= Rs. 0
Interest rate(i)	= 15 per cent, compounded annually.

The cash flow diagram for machine B is shown in Figure E6.13.2.

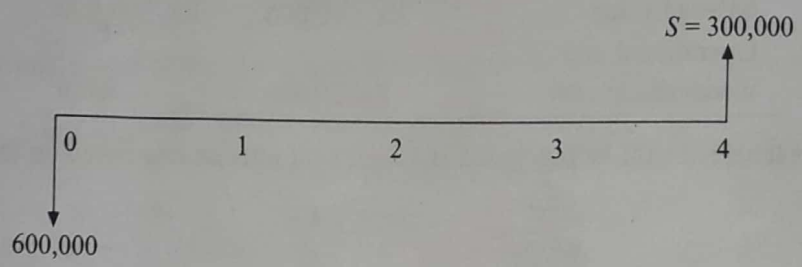

Figure E6.13.2

$$NPW(15\%)_B = P - S(P/F, i, n)$$
$$= 600{,}000 - 300{,}000(0.5718)$$
$$= \text{Rs. } 600{,}000 - 171{,}540$$
$$= \text{Rs. } 428{,}460.$$

$$EAW(15\%)_B = NPW \times A/P, i, n$$
$$= \text{Rs. } 428{,}460 \times 0.3503$$
$$= \text{Rs. } 150{,}089.53$$

Since the annual equivalent cost of machine A is less than that of machine B, it is advisable to purchase machine A.

6.5 RATE OF RETURN METHOD

The rate of return is a percentage that indicates the relative yield on different uses of capital. The following three rates of return appear frequently in engineering economics studies:

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1. The **Minimum Acceptable Rate of Return (MARR)** is the rate set by an organization to designate the lowest level of return that makes an investment acceptable.
2. The **Internal Rate of Return (IRR)** is the rate on the unrecovered balance of the investment in a situation where the terminal balance is zero. It is a discount rate at which NPW equals to zero.
3. The **External Rate of Return (ERR)** is the rate of return that is possible to obtain for an investment under the current economic conditions. For example, suppose the analysis of an investment shows that it will realize an IRR of 50 per cent. Rationally, it is not reasonable to expect that we can invest in the external market and get that high a rate. In engineering economics studies, the external interest rate most often will be set to the MARR.

6.5.1 Minimum Acceptable Rate of Return

The (MARR) also known as minimum attractive rate of return, is a lower limit for investment acceptability set by organizations or individuals. It is a method designed to make the best possible use of a limited resource, i.e. money. Rates vary widely according to the type of organization. They even vary within the organization. Historically, government agencies and regulated public utilities have utilized lower required rates of return than have competitive industrial enterprises. Within a given enterprise, the required rate may be different for various divisions or activities. These variations usually reflect the risks involved. For instance, the rate of return required for cost reduction proposals may be lower than that required for research and development projects where there are less certainty about the prospective cash flows.

6.5.2 Internal Rate of Return (IRR)

The internal rate return (IRR) method is a modern technique in evaluating the capital project. It is also known as **discounted cash flow technique, time adjusted rate of return, yield method, and trial and error yield method**. Under this method, the cash flows of a project are discounted at a suitable rate by trial and error method which equates the net present value. The internal rate of return can be defined as that rate of discount at which the present value of cash inflows is equal to the present value of cash outflows. Mathematically,

The present worth of cash inflows = present worth of cash outflows

The following steps are required to practise the IRR method.

1. Determine the future net cash flows during the entire economic life of the project.
2. Determine the rate of discount by hit and trial method at which the value of cash inflows is equal to the present value of cash outflows.
3. Accept the proposal if the internal rate of return is higher than or equal to the minimum acceptable rate of return (MARR) and reject the proposal if the internal rate of return is lower than the MARR.
4. In the case of alternative proposals, select the proposal with the highest rate of returns.

In the case of IRR method, one has to find out the discount rate by trial and error basis at which net present value will be equal to zero. So one has to take a particular discount rate and find out the net present value. If the net present value is positive, then go in for a higher discount rate and, if the net present value is negative, go in for a lower discount rate. This process is continued till we get a net present value which is equal to zero.

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The IRR is the best known and most widely used rate of return method. It is also known as the **true rate of return method** and the **discounted cash flow method**. The IRR represented by i in the traditional interpretation of interest rates, is the rate of interest earned by an alternative investment on the unrecovered balance of an investment.

The IRR can be calculated by equating the annual, present, or future worth of cash flow to zero, and solving for the interest rate (IRR) that allows equality. It should be added that solving for the interest rate in this manner results in a polynomial equation, a function of i, which may result in multiple roots of the equation. In such cases, the IRR may or may not be one of the equation roots.

Although both the EAW and the FW approaches are legitimate, the rate of return is often defined in terms of present worth, under the constraints of possible i^* roots, where IRR is

- the interest rate at which the present worth of the cash flow of a project is zero, or,
- to restate this in another way the rate which when employed in computing the present worth of all costs and present worths of all returns will make both equal.

As the rate of return computations usually begin with a problem expressed in terms of present worth or annual worth, it is necessary to pay attention to the guidelines for EAW and PW methods. In particular, mutually exclusive alternatives (where selection of one precludes the selection of another) must be compared on the basis of equivalent outcomes. In the case of independent alternatives (the choice of one does not affect the choice of another, except for limited capital availability), all costs and benefits must be explicitly stated.

Calculation of IRR

The IRR should be determined based on the type of investment (simple, pure, and mixed) and the characteristics of the alternatives (mutually exclusive or independent). If we have independent projects, we may fund combinations of the projects since an independent project does not affect the funding of another project (except for capital availability limitations which are very real in most situations analysed by the engineering economist). The cash flows of several independent alternatives that are being considered as a group may be summed to form the group's composite cash flow. The analysis can then be performed on this composite cash flow. Where capital limitations are apparent in a department and several independent alternatives are competing for funding, the combinations of alternatives may be formed where each combinations first cost has to be equal to or less than the capital available. In this case, mutually exclusive combination's will usually be realized, where selection of one group of independent alternatives will preclude the selection of another. This can be due to alternatives being in more than one group and/or capital limitations.

We will see that the ranking alternatives according to their IRR values are not consistent with PW, FW, or AW rankings. Mutually exclusive alternatives may be analysed by incremental IRR analysis, and the results will be found to be completely consistent with PW, FW, and AW methods. Incremental analysis assumes that we start with a satisfactory low investment alternative. Analysis of a higher investment alternative is then based on the differences between the cash flows of the second alternative and the acceptable alternative. These differences in cash flows are incremental cash flows. The cash flow of the second alternative is equal to the cash flow of the first alternative plus the incremental cash flow. Thus, if the incremental cash flow is acceptable when compared to MARR, then the higher investment has to be a better investment than the first alternative, which was also acceptable. Otherwise, do not consider the higher investment. This type of evaluation is continued until all alternatives have been evaluated; one of the mutually exclusive alternatives is then determined to be the best investment. As mentioned earlier, there is a possibility that the PW

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equation may be a polynomial in terms of i such that multiple roots i^* of polynomial PW(i') may result. Often, multiple i^*s are assumed to be multiple IRR values. This is misleading since there is really only one true IRR for an investment, and so we will need to determine which i^*, if any, is the investment IRR. Classifying investments into simple and non-simple investments will tell us if just one i^* exists. Thus, in turn, tells us that we have found the IRR when we have found i^*. An investment is simple if there is only one cash flow sign change (minus to plus) from period to period. A simple investment is given in Table 6.1.

Table 6.1 Simple Investment

Time period	Cash flow (Rs.)	Sign change
0	−2000	
1	−200	
2	500	Yes (− to +)
3	500	
4	500	

There will only be one i^* if the investment is simple. A non-simple investment will have more than one sign change in the cash flow sequence, as given in Table 6.2.

Table 6.2 Non-simple Investment

Time period	Cash flow (Rs.)	Sign change
0	−2000	Yes (− to +)
1	200	Yes (+ to −)
2	−500	Yes (− to +)
3	500	
4	500	

There may be multiple i^* values if the investment is non-simple.

Finally, if we have multiple i^* values (non-simple investment), we will need to determine the true IRR. First, we determine whether the investment is pure or mixed. A pure investment occurs if the project cash flow balances, evaluated at i^*, are all less than or equal to zero. We should now realize that a simple investment has to be a pure investment as exemplified in the following paragraph. If any of the project cash balances are positive (and some are negative), then we have a need to use an external interest rate for reinvestment. This is called a **mixed investment** since we will 'externally' reinvest at the external rate (MARR) when balances are positive and 'internally' invest at the IRR rate when balances are negative or zero.

Single, simple investment

The rate of return for a single, simple investment is determined by setting the present worth (or EAW) of receipts equal to the present worth (or EAW) of disbursements. Then an interest rate is sought that makes the discounted cash flows conform to equality.
Find i so that

$$PW(\text{receipts}) = PW(\text{disbursements})$$

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The same relation obviously occurs when the discounted flows are subtracted from each other to equal zero.

Find i so that

$$PW(\text{receipts}) - PW(\text{disbursements}) = \text{Net } PW = 0$$

For either PW formulation, the manual calculation of i is usually a trial and error procedure. When a single proposal is for a cost reduction project, the receipts take the form of net savings from the method of operation used before the cost reduction investment. In effect, we get an incremental investment that is the difference between do-nothing case and single investment.

The rate of return of a cash flow pattern is the interest rate at which the present worth of that cash flow pattern reduces to zero. In this method of comparison, the rate of return for each alternative is computed. Then the alternative which has the highest rate of return is selected as the best alternative.

EXAMPLE 6.14

A person is planning a new business. The initial outlay and cash flow pattern for the new business are as given in the tabular representation.

Period	Cash flow (Rs.)
0	–100,000
1	30,000
2	30,000
3	30,000
4	30,000
5	30,000

The expected life of the business is five years. Find the rate of return for the new business.

Solution

Initial investment = Rs. 100,000
Annual equal revenue = Rs. 30,000
Life = 5 years

The cash flow diagram for this situation is given in Figure E6.14.1.

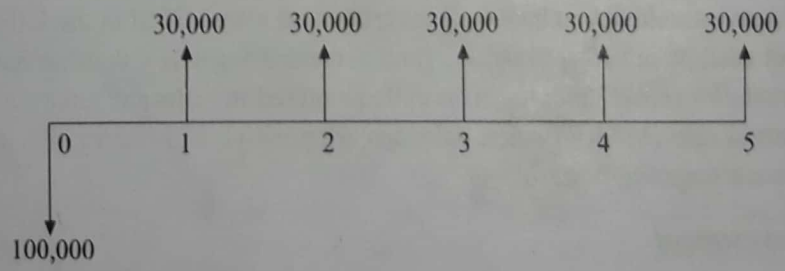

Figure E6.14.1

The present worth function for the business is

$$PW(i) = -100{,}000 + 30{,}000(P/A, i, 5)$$

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When $i = 10\%$

$$PW(10\%) = -100{,}000 + 30{,}000(P/A, 10\%, 5)$$
$$= -100{,}000 + 30{,}000(3.7908)$$
$$= \text{Rs. } 13{,}724$$

When $i = 15\%$

$$PW(15\%) = -100{,}000 + 30{,}000(P/A, 15\%, 5)$$
$$= -100{,}000 + 30{,}000(3.3522)$$
$$= \text{Rs. } 566$$

When $i = 18\%$

$$PW(18\%) = -100{,}000 + 30{,}000(P/A, 18\%, 5)$$
$$= -100{,}000 + 30{,}000(3.1272)$$
$$= \text{Rs. } -6{,}184$$

$$IRR = 15\% + \frac{566 - 0}{566 - (-6184)} \times (3\%)$$
$$= 15\% + 0.252\%$$
$$= 15.252\%$$

Therefore, the rate of return for the new business is 15.252 per cent.

EXAMPLE 6.15

A company is trying to diversify its business in a new product line. The life of the project is 10 years with no salvage value at the end of its life. The initial outlay of the project is Rs. 2,000,000. The annual net profit is Rs. 350,000. Find the rate of return for the new business.

Solution

Life of the product line(n)	= 10 years
Initial outlay	= Rs. 2,000,000
Annual net profit	= Rs. 350,000
Scrap value after 10 years	= 0

The cash flow diagram for this situation is shown in Figure E6.15.1.

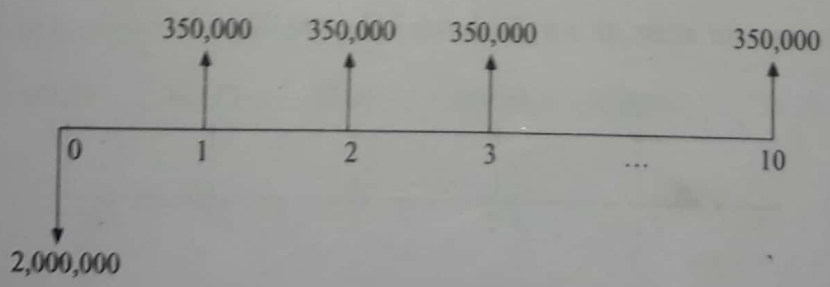

Figure E6.15.1

The formula for the net present worth function of the situation is

$$PW(i) = -2{,}000{,}000 + 350{,}000(P/A, i, 10)$$

When $i = 10\%$,

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$$PW(10\%) = -2{,}000{,}000 + 350{,}000(P/A, 10\%, 10)$$
$$= -2{,}000{,}000 + 350{,}000(6.1446)$$
$$= \text{Rs. } 150{,}610.$$

When $i = 12\%$

$$PW(12\%) = -2{,}000{,}000 + 350{,}000(P/A, 12\%, 10)$$
$$= -2{,}000{,}000 + 350{,}000(5.6502)$$
$$= \text{Rs. } -22{,}430$$

$$i = 10\% + \frac{150{,}610 - 0}{150{,}610 - (-22{,}430)} \times (2\%)$$
$$= 11.74\%$$

Therefore, the rate of return of the new product line is 11.74 per cent.

EXAMPLE 6.16

A firm has identified three mutually exclusive investment proposals whose details are given below. The life of all the three alternatives is estimated to be five years with negligible salvage value. The minimum attractive rate of return for the firm is 12 per cent.

	Alternative		
	A_1	A_2	A_3
Investment	Rs. 150,000	Rs. 210,000	Rs. 255,000
Annual net income	Rs. 45,570	Rs. 58,260	Rs. 69,000

Find the best alternative based on the rate of return method of comparison.

Solution

Calculation of rate of return for alternative A_1:

Initial outlay = Rs. 150,000
Annual profit = Rs. 45,570
Life = 5 years

The cash flow diagram for alternative A_1 is shown in Figure E6.16.1.

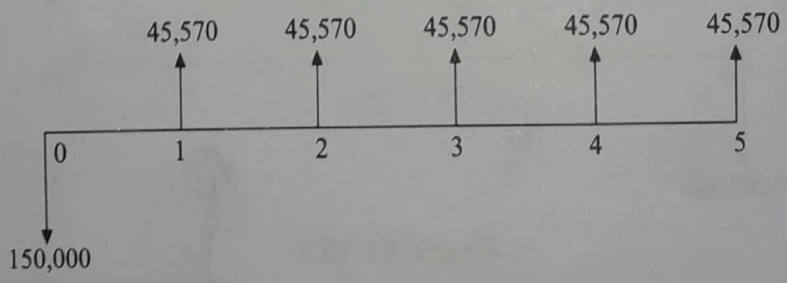

Figure E6.16.1

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The formula for the net present worth for alternative A_1 is given as

$$PW(i) = -150{,}000 + 45{,}570(P/A, i, 5)$$

When $i = 10\%$

$$PW(10\%) = -150{,}000 + 45{,}570(P/A, 10\%, 5)$$
$$= -150{,}000 + 45{,}570(3.7908)$$
$$= \text{Rs. } 22{,}746.76$$

When $i = 12\%$

$$PW(12\%) = -150{,}000 + 45{,}570(P/A, 12\%, 5)$$
$$= -150{,}000 + 45{,}570(3.6048)$$
$$= \text{Rs. } 14{,}270.74$$

When $i = 15\%$

$$PW(15\%) = -150{,}000 + 45{,}570(P/A, 15\%, 5)$$
$$= -150{,}000 + 45{,}570(3.3522)$$
$$= \text{Rs. } 2759.75$$

When $i = 18\%$

$$PW(18\%) = -150{,}000 + 45{,}570(P/A, 18\%, 5)$$
$$= -150{,}000 + 45{,}570(3.1272)$$
$$= \text{Rs. } -7493.50$$

Therefore, the rate of return for alternative A_1 is

$$i = 15\% + \frac{2759.75 - 0}{2759.75 - (-7493.50)} \times (3\%)$$
$$= 15\% + 0.81\%$$
$$= 15.81\%$$

Calculation of the rate of return for alternative A_2:

Initial outlay = Rs. 210,000
Annual profit = Rs. 58,260
Life of alternative A_2 = 5 years

The cash flow diagram for alternative A_2 is shown in Figure E6.16.2.

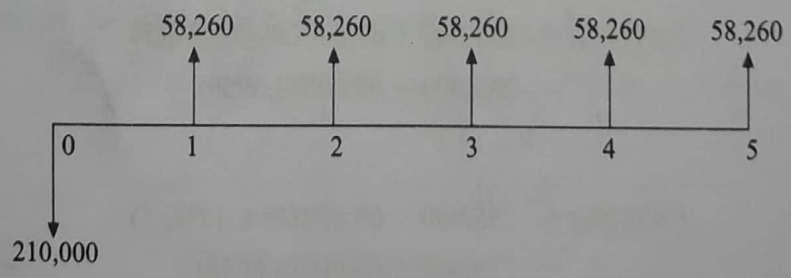

Figure E6.16.2

The formula for the net present worth of this alternative is

$$PW(i) = -210{,}000 + 58{,}260(P/A, i, 5)$$

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When $i = 12\%$

$$PW(12\%) = -210{,}000 + 58{,}260(P/A, 12\%, 5)$$
$$= -210{,}000 + 58{,}260(3.6048)$$
$$= \text{Rs. } 15.65$$

When $i = 13\%$

$$PW(13\%) = -210{,}000 + 58{,}260(P/A, 13\%, 5)$$
$$= -210{,}000 + 58{,}260(3.5172)$$
$$= \text{Rs. } -5087.93$$

Therefore, the rate of return for alternative A_2 is

$$i = 12\% + \frac{15.65 - 0}{15.65 - (-5087.93)} \times (1\%)$$
$$= 12\% + 0\%$$
$$= 12\%$$

Calculation of the rate of return for alternative A_3:

Initial outlay = Rs. 255,000
Annual profit = Rs. 69,000
Life of alternative A_3 = 5 years

The cash flow diagram for alternative A_3 is depicted in Figure E6.16.3.

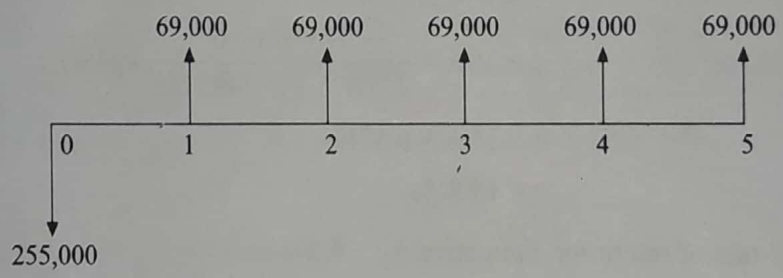

Figure E6.16.3

The formula for the net present worth for this alternative A_3 is

$$PW(i) = -255{,}000 + 69{,}000(P/A, i, 5)$$

When $i = 11\%$

$$PW(11\%) = -255{,}000 + 69{,}000(P/A, 11\%, 5)$$
$$= -255{,}000 + 69{,}000(3.6959)$$
$$= \text{Rs. } 17.1$$

When $i = 12\%$

$$PW(12\%) = -255{,}000 + 69{,}000(P/A, 12\%, 5)$$
$$= -255{,}000 + 69{,}000(3.6048)$$
$$= \text{Rs. } -6268.80$$

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Therefore, the rate of return for alternative A_3 is

$$i = 11\% + \frac{17.1 - 0}{17.1 - (-6268.80)} \times (1\%)$$
$$= 11\%$$

The rates of returns for the three alternatives are tabulated here.

Alternative	Rate of return
A_1	15.81%
A_2	12%
A_3	11%

From the data, it is clear that the rate of return for alternative A_3 is less than the minimum attractive rate of return of 12 per cent. So, it should not be considered for comparison. The remaining two alternatives qualify for consideration. Among alternatives A_1 and A_2, the rate of return of alternative A_1 is greater than that of alternative A_2. Hence, alternative A_1 should be selected.

EXAMPLE 6.17

A company is planning to expand its present business activity. It has two alternatives for the expansion programme and the corresponding cash flows are tabulated below. Each alternative has a life of five years and a negligible salvage value. The minimum attractive rate of return for the company is 12 per cent. Suggest the best alternative to the company.

	Initial investment (Rs.)	Yearly revenue (Rs.)
Alternative 1	500,000	170,000
Alternative 2	800,000	270,000

Solution

Alternative 1

Initial outlay = Rs. 500,000
Annual revenue = Rs. 170,000
Life of alternative 1 = 5 years

The cash flow diagram for alternative 1 is illustrated in Figure E6.17.1.

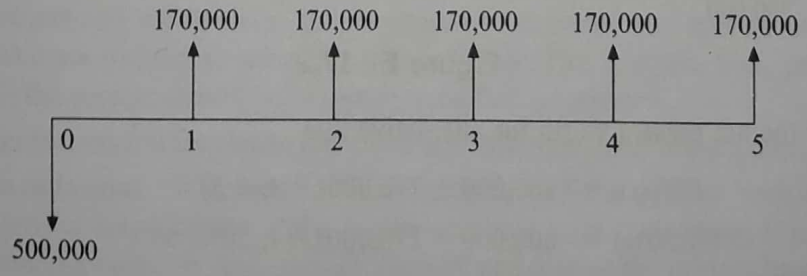

Figure E6.17.1

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The formulas for the net present worth for alternative 1 are as follows:

$$PW_1(i) = -500{,}000 + 170{,}000(P/A, i, 5)$$

$$PW_1(15\%) = -500{,}000 + 170{,}000(P/A, 15\%, 5)$$
$$= -500{,}000 + 170{,}000(3.3522)$$
$$= \text{Rs. } 69{,}874$$

$$PW_1(17\%) = -500{,}000 + 170{,}000(P/A, 17\%, 5)$$
$$= -500{,}000 + 170{,}000(3.1993)$$
$$= \text{Rs. } 43{,}881$$

$$PW_1(20\%) = -500{,}000 + 170{,}000(P/A, 20\%, 5)$$
$$= -500{,}000 + 170{,}000(2.9906)$$
$$= \text{Rs. } 8402$$

$$PW_1(22\%) = -500{,}000 + 170{,}000(P/A, 22\%, 5)$$
$$= -500{,}000 + 170{,}000(2.8636)$$
$$= \text{Rs. } -13{,}188$$

Therefore, the rate of return for alternative 1 is

$$i = 20\% + \frac{8402 - 0}{8402 - (-13{,}188)} \times (2\%)$$
$$= 20.78\%$$

Alternative 2

Initial outlay = Rs. 800,000
Annual revenue = Rs. 270,000
Life = 5 years

The cash flow diagram for alternative 2 is depicted in Figure E6.17.2.

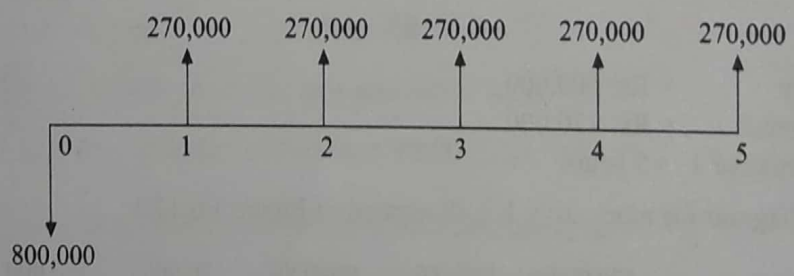

Figure E6.17.2

The formula for the net present worth for alternative 2 is

$$PW_2(i) = -800{,}000 + 270{,}000(P/A, i, 5)$$

$$PW_2(20\%) = -800{,}000 + 270{,}000(P/A, 20\%, 5)$$
$$= -800{,}000 + 270{,}000(2.9906)$$
$$= \text{Rs. } 7462$$

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$$PW_2(22\%) = -800{,}000 + 270{,}000(P/A, 22\%, 5)$$
$$= -800{,}000 + 270{,}000(2.8636)$$
$$= \text{Rs. } -26{,}828$$

Thus, the rate of return for alternative 2 is

$$i = 20\% + \frac{7462 - 0}{7462 - (-26{,}828)} \times (2\%)$$
$$= 20.435\%$$

Since the rate of return of alternative 1 is greater than that of select it.

6.6 PROJECT EVALUATION AND COST–BENEFIT ANALYSIS

Project evaluation, as a technique of development planning, has grown rapidly in application in recent years. In fact, it has on its own become a method of economic planning. The public investment analysis involves the treatment of a number of important aspects of which appraisal of the economic costs and benefits of the project are perhaps the most important.

The preparation of a report on a project is a complex task which requires the services of both engineers and economists. Prior to the preparation of a project report, a 'pre-feasibility study' is carried out by the appropriate authority. The pre-feasibility study states, in broad terms, the objectives, and defines the alternative means (sizes, designs, location, etc.) which the report appraisal team is expected to examine. The project report is generally known as 'feasibility report'. It has now become the main basis on which authorities decide whether a particular project is to be accepted, modified or rejected. Project reports are not prepared on uniform lines and often differ considerably in their presentation. However, one can identify the following six main components of these reports:

1. **Terms of reference:** They are based on the pre-feasibility study and provide guidelines for the project appraisal team. These include the definition of the objectives of the study, outline of the project alternatives, etc.
2. **Engineering study:** Its purpose is to determine the technical feasibility of the project. Engineering study covers the physical characteristics of the project, the design of construction and plant, the technical aspect of output, time schedule for the project execution, etc.
3. **Financial study:** It provides cost estimates of the project in budgetary terms. Financial study examines the direct costs of construction of a plant at market prices and presents financial evaluation on an accounting basis.
4. **Cost-benefit analysis:** This analysis includes appraisal of the economic costs and benefits of the project and alternatives, and its impact on the economy and on the welfare of the people who are directly or indirectly affected by it. This analysis, thus, provides the basis on which the project should be accepted, modified or rejected.
5. **Implementation:** It examines the social and environmental implications of the project.
6. **Recommendation:** It presents a brief summary of the project with specific recommendations for consideration at the decision-making level. This report is usually submitted to the planning authority, the relevant ministry and also to the project financing agency. If the project is accepted, it may be undertaken. It will usually pass through the three main stages: viz. the *design stage*, the *construction* and the *entry into the operation*.

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6.6.1 Cost–Benefit Analysis

The question to which cost-benefit analysis addresses itself is whether it is socially desirable to undertake a number of investment projects A, B, C, D, etc. and if investible funds are limited, then how many of these should be selected. Since the choice involves maximization, we have to discuss what it is that investment planners wish to maximize. In general terms, an investment planner wants to maximize the present value of all benefits less that of all costs, subject to specific constraints. This general formulation raises the following specific questions, the answers to which provide the general principles of cost-benefit analysis:

- In project appraisal which costs and which benefits are to be considered?
- How are these costs and benefits to be valued?
- How can profitability of a project be measured?
- What is the relevance of uncertainty in project appraisal?
- What are the relevant constraints?

There is certainly some arbitrariness in the choice of these questions. In evaluating alternatives of private organizations, the criterion is to select the alternative with the maximum profit. Profit maximization is the main goal of private organizations besides providing goods/services as per specifications to their customers. But the same criterion cannot be used while evaluating public alternatives. Examples of some public alternatives are: constructing bridges, roads, dams, establishing public utilities.

The main objective of any public alternative is to provide goods/services to the public at the minimum cost. In this process, one should see whether the benefits of the public activity are at least equal to its costs. If yes, then the public activity can be undertaken for implementation. Otherwise, it can be cancelled. This is nothing but making a decision based on Benefit-Cost ratio (BC) given by

$$\text{BC ratio} = \frac{\text{Equivalent benefits}}{\text{Equivalent costs}}$$

The benefits may occur at different time periods of the public activity. For the purpose of comparison, these are to be converted into a common time base (present worth, future worth or annual equivalent). Similarly, the costs consist of initial investment, yearly operation and maintenance cost. These are to be converted to a common time base as done in the equivalent benefits. Now, the ratio between the equivalent benefits and the equivalent costs is known as the'benefit-cost ratio'. If this ratio is at least one, the public activity is justified; otherwise, it is not justified. Let

B_P = Present worth of the total benefits
B_F = Future worth of the total benefits
B_A = Annual equivalent of the total benefits
P = Initial investment
P_F = Future worth of the initial investment
P_A = Annual equivalent of the initial investment
C = Yearly cost of operation and maintenance
C_P = Present worth of yearly cost of operation and maintenance
C_F = Future worth of yearly cost of operation and maintenance

$$\text{BC ratio} = \frac{B_P}{P + C_P} + \frac{B_F}{P_F + C_F} + \frac{B_A}{P_A + C}$$

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EXAMPLE 6.18

In a particular locality of a state, the vehicle users take a roundabout route to reach certain places because of the presence of a river. This results in excessive travel time and increased fuel cost. So, the state government is planning to construct a bridge across the river. The estimated initial investment for constructing the bridge is Rs. 4,000,000. The estimated life of the bridge is 15 years. The annual operation and maintenance cost is Rs. 150,000. The value of fuel savings due to construction of the bridge is Rs. 600,000 in the first year and it increases by Rs. 50,000 every year thereafter till the end of the life of the bridge. Check whether the project is justified based on BC ratio by assuming an interest rate of 12 per cent, compounded annually.

Solution

Initial investment	= Rs. 4,000,000
Annual operation and maintenance	= Rs. 150,000
Annual fuel savings during the first year	= Rs. 600,000
Equal increment in fuel savings in the following years	= Rs. 50,000
Life of the project	= 15 years
Interest rate	= 12%

The cash flow diagram for the project is shown in Figure E6.18.1.

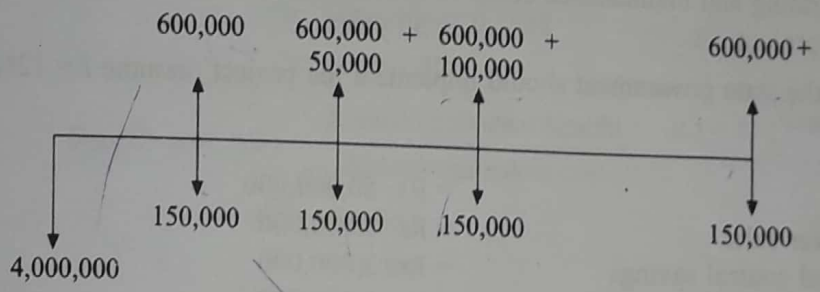

Figure E6.18.1

Total present worth of costs = Initial investment (P)
+ Present worth of annual operating and maintenance cost (C_P)

$= P + C_P$

$= \text{Rs. } 4{,}000{,}000 + 150{,}000 \times (P/A, 12\%, 15)$

$= \text{Rs. } 4{,}000{,}000 + 150{,}000 \times 6.8109$

$= \text{Rs. } 5{,}021{,}635$

Total present worth of fuel savings (B_P):

$A_1 = \text{Rs. } 600{,}000$
$G = \text{Rs. } 50{,}000$
$N = 15$ years
$i = 12$ per cent

Annual equivalent fuel savings (A) $= A_1 + G(A/G, 12\%, 15)$

$= 600{,}000 + 50{,}000\ (4.9803)$

$= \text{Rs. } 849{,}015$

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Present worth of the fuel savings (B_P) = $A(P/A, 12\%, 15)$

= 849,015 (6.8109)

= Rs. 5,782,556

$$\text{BC ratio} = \frac{B_P}{P + C_P} = \frac{5,782,556}{5,021,635} = 1.1515$$

Since the BC ratio is more than 1, the construction of the bridge across the river is justified.

EXAMPLE 6.19

A state government is planning a hydroelectric project for a river basin. In addition to the production of electric power, this project will provide flood control, irrigation and recreation benefits. The estimated benefits and costs that are expected to be derived from this project are as follows:

Initial cost	= Rs. 80,000,000
Annual power sales	= Rs. 6,000,000
Annual flood control savings	= Rs. 3,000,000
Annual irrigation benefits	= Rs. 5,000,000
Annual recreation benefits	= Rs. 2,000,000
Annual operating and maintenance costs	= Rs. 3,000,000
Life of the project	= 50 years

Check whether the state government should implement the project (assume i = 12%).

Solution

Initial cost	= Rs. 80,000,000
Annual power sales	= Rs. 6,000,000
Annual flood control savings	= Rs. 3,000,000
Annual irrigation benefits	= Rs. 5,000,000
Annual recreation benefits	= Rs. 2,000,000
Annual operating and maintenance costs	= Rs. 3,000,000
Life of the project = 50 years, and i	= 12%

Total annual benefits

= Flood control savings + Irrigation benefits + Recreation benefits

= Rs. 3,000,000 + Rs. 5,000,000 + Rs. 2,000,000

= Rs. 10,000,000

Present worth of the benefits = Total annual benefits × $(P/A, 12\%, 50)$

= 10,000,000 × (8.3045)

= Rs. 83,045,000

Present worth of costs = Initial cost + Present worth of annual operation and maintenance cost – Present worth of power sales

= Rs. 80,000,000 + 3,000,000 × $(P/A, 12\%, 50)$ – 6,000,000 $(P/A, 12\%, 50)$

= Rs. 80,000,000 + 3,000,000 × 8.3045 – 6,000,000 × 8.3045

= Rs. 55,086,500

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$$\text{BC ratio} = \frac{\text{Present worth of benefits}}{\text{Present worth of costs}} = \frac{83{,}045{,}000}{55{,}086{,}500} = 1.508$$

Since the BC ratio is more than 1, the state government can implement the hydroelectric project.

EXAMPLE 6.20

Two mutually exclusive projects are being considered for investment. Project A_1 requires an initial outlay of Rs. 3,000,000 with the net receipts estimated as Rs. 900,000 per year for the next five years. The initial outlay for project A_2 is Rs. 6,000,000, and the net receipts have been estimated at Rs. 1,500,000 per year for the next seven years. There is no salvage value associated with either of the projects. Using the benefit-cost ratio, which project would you select? Assume an interest rate of 10 per cent.

Solution

Alternative A_1

Initial cost (P) = Rs. 3,000,000
Net benefits/year (B) = Rs. 900,000
Life (n) = 5 years

Annual equivalent of initial cost $= P \times (A/P, 10\%, 5)$
$= 3{,}000{,}000 \times 0.2638$
$=$ Rs. 791,400

$$\text{Benefit-cost ratio} = \frac{\text{Annual equivalent benefit}}{\text{Annual equivalent cost}}$$

$$= \frac{900{,}000}{791{,}400}$$

$$= 1.137$$

Alternative A_2

Initial cost (P) = Rs. 6,000,000
Net benefits/year (B) = Rs. 1,500,000
Life (n) = 7 years

Annual equivalent of initial cost $= P \times (A/P, 10\%, 7)$
$= 6{,}000{,}000 \times 0.2054$
$=$ Rs. 1,232,400

$$\text{BC ratio} = \frac{\text{Annual equivalent benefit}}{\text{Annual equivalent cost}}$$

$$= \frac{1{,}500{,}000}{1{,}232{,}400}$$

$$= 1.217$$

The benefit-cost ratio of alternative A_1 is more than that of alternative A_2. Hence, alternative A_1 is to be selected. The comparison is made on a 35-year period which is the minimum common multiple of the lives of alternatives 1 and 2.

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REVIEW QUESTIONS

1. A project involves an initial outlay of Rs. 2,000,000, with the following transactions for the next five years.

End of the year (n)	Maintenance and operating expense (Rs.)	Revenue (Rs.)
1	200,000	900,000
2	250,000	1,000,000
3	300,000	1,200,000
4	300,000	1,300,000
5	400,000	1,200,000

The salvage value at the end of the life of the project after five years is Rs. 300,000. Draw a cash flow diagram of the project and find its present worth by assuming i = 15 per cent, compounded annually.

2. Find the present worth of the following cash flow series, assuming i = 15 per cent, compounded annually:

End of the year (n)	Cash flow (Rs.)
0	–20,000
1	40,000
2	40,000
3	40,000
4	40,000
5	40,000

3. Consider the following cash flow series over a 20-year period. Assuming the interest rate as 18 per cent compounded annually, compute the present worth of the series. Give your comments.

End of the year (n)	Cash flow (Rs.)
0	–4,000,000
1	600,000
2	600,000
.	.
.	.
.	.
20	600,000

4. The cost of erecting an oil well is Rs. 250,000. The annual equivalent yield from the oil well is Rs. 3,000,000. The salvage value after its useful life of 10 years is Rs. 300,000. Assuming an interest rate of 18 per cent, compounded annually, find out whether the erection of the oil well is financially feasible, based on the present worth method.

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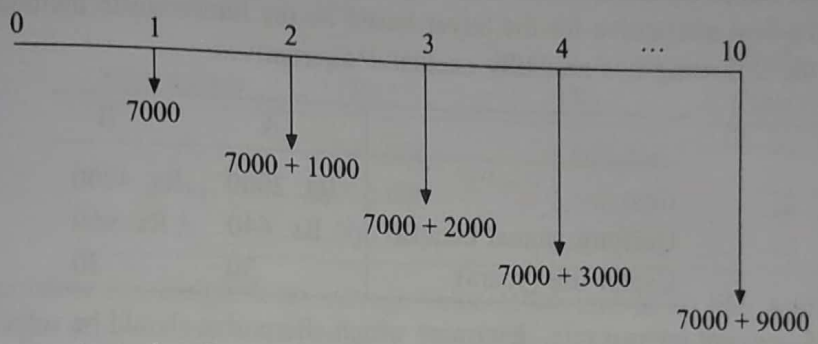
5. The details of the feasibility report of a project are given here. Check the feasibility of the project based on the present worth method, using $i = 20\%$.

Initial outlay	= Rs. 3,000,000
Life of the project	= 20 years
Annual equivalent revenue	= Rs. 2,500,000
Modernizing cost at the end of the tenth year	= Rs. 400,000
Salvage value at the end of the project life	= Rs. 400,000.

6. Consider the following cash flow diagram.



Find the present worth using an interest rate of 15%, compounded annually.

7. An automobile company recently advertised its car for a down payment of Rs. 450,000. Alternatively, the car can be taken home by customers without making any payment, but they have to pay an equal yearly amount of Rs. 20,000 for 15 years at an interest rate of 18 per cent, compounded annually. You are asked to advise the best alternative for the customers based on the present worth method of comparison.

8. The cash flows of two project proposals are given in the tabular representation. Each of the project has an expected life of 10 years. Select the best project based on the present worth method of comparison using an interest rate of 18 per cent, compounded annually.

	Initial outlay (Rs.)	**Annual equivalent revenue** (Rs.)	**Salvage value after 10 years** (Rs.)
Project 1	–750,000	400,000	50,000
Project 2	–950,000	325,000	200,000

9. A suburban taxi company is considering buying taxis with diesel engines instead of petrol engines. The cars average 30,000 km a year, with a useful life of three years for the taxi running on petrol and four years for the taxi running on diesel. Other comparative information are as follows:

	Diesel	**Petrol**
Vehicle cost	Rs. 300,000	Rs. 200,000
Fuel cost per litre	Rs. 9.00	Rs. 24.00
Mileage (km/litre)	30	20
Annual insurance premium	Rs. 300	Rs. 300
Salvage value at the end of vehicle life	Rs. 70,000	Rs. 100,000

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Determine the more economical choice based on the future worth method of comparison if the interest rate is 15 per cent, compounded annually.

10. A motor cycle is sold for Rs. 40,000. The motor cycle dealer is willing to sell the motorcycle on the following terms:

(a) Make no down payments but pay Rs. 2,500 at the end of each of the first four months and Rs. 2,000 at the end of each month. After that for 18 continuous months.

(b) Make no down payment but pay a total amount of Rs. 50,000 at the end of the twenty second month; till that time the buyer should mortgage property worth Rs. 20,000 at present. Based on these terms and a 12 per cent annual interest rate compounded monthly, find the best alternative for the buyer based on the future worth method of comparison.

11. Consider the following two mutually exclusive alternatives.

	A	B
Cost	Rs. 2000	Rs. 4000
Uniform annual benefit	Rs. 640	Rs. 960
Useful life (years)	30	30

Using a 15 per cent interest rate, determine which alternative should be selected based on the future worth method of comparison.

12. A company must decide whether to buy machine A or machine B :

	Machine A	Machine B
Initial cost	Rs. 300,000	Rs. 500,000
Useful life (years)	5.0	5.0
Salvage value at the end of machine life	Rs. 100,000	Rs. 250,000
Annula maintenance cost	Rs. 20,000	Rs. 0

At 15 per cent interest rate, which machine should be selected? (Use the future worth method of comparison.)

13. Due to increasing awareness of customers, two different television manufacturing companies started a marketing war. The details of the advertisements of the companies are as follows:

	Brand X	Brand Y
Selling price of a television set	Rs. 25,000	Rs. 20,000
Amount returned to buyer after five years	Rs. 18,000	...

Select the most economical brand from the customers' point of view using the future worth method of comparison, assuming an interest rate of 15 per cent, compounded annually.

14. Alpha finance company is coming with an option of accepting Rs. 20,000 now and paying a sum of Rs. 260,000 after 20 years. Beta finance company is coming with a similar option of accepting Rs. 20,000 now and paying a sum of Rs. 300,000 after 25 years. Compare and select the best alternative based on the future worth method of comparison with 15 per cent interest rate, compounded annually.

15. An insurance company gives an endowment policy for a person aged 40 years. The yearly premium for an insured sum of Rs. 200,000 is Rs. 8,000. The policy will mature after

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20 years. Also the person is entitled for a bonus of Rs. 70 per thousand per year at the end of the policy. If a person survives till the end of the twentieth year:

(a) What will be the total sum that he will get from the insurance company at that time?

(b) Instead of paying the premium for the insurance policy, if the person invests an equal sum of Rs. 8,000 at the end of each year for the next 20 years in some other scheme which is having similar tax benefit, find the future worth of the investment at 15 per cent interest rate, compounded annually.

(c) Rate the above alternatives assuming that the person is sure of living for the next 20 years.

16. A company has three proposals for expanding its business operations. The details are as follows:

Alternative	Initial cost (Rs.)	Annual revenue (Rs.)	Life (Years)
A_1	2,000,000	1,800,000	10
A_2	2,000,000	1,600,000	10
A_3	4,000,000	1,000,000	10

Each alternative has insignificant salvage value at the end of its life. Assuming an interest rate of 15 per cent, compounded annually, find the best alternative for expanding the business operations of the company using the annual equivalent method.

17. An automobile dealer has recently advertised for its new car. There are three alternatives for purchasing the car which are explained here.

Alternative 1: The customer can take delivery of a car after making a down payment of Rs. 35,000. The remaining money should be paid in 30 equal monthly instalments of Rs. 10,000 each.

Alternative 2: The customer can take delivery of the car after making a down payment of Rs. 100,000. The remaining money should be paid in 30 equal monthly instalments of Rs. 7,000 each.

Alternative 3: The customer can take delivery of the car by making full payment of Rs. 300,000.

Suggest the best alternative of buying cars for customers by assuming an interest rate of 30 per cent, compounded annually. Use the annual equivalent method.

18. A small-scale industry is in the process of buying a milling machine. The purchase value of the milling machine is Rs. 50,000. It has identified two banks for loan to purchase the milling machine. The banks can give only 80 per cent of the purchase value of the milling machine as loan. In Urban Bank, the loan is to be repaid in 50 equal monthly instalments of Rs. 2500 each. In State Bank, the loan is to be repaid in 40 equal monthly instalments of Rs. 4500 each. Suggest the most economical loan scheme for the company, based on the annual equivalent method of comparison. Assume a nominal rate of 20 per cent, compounded monthly.

19. There are two alternatives of replacing a machine. The details of the alternatives are as follows:

Alternative 1

Purchase value of the new machine = Rs. 300,000
Life of the machine = 10 years

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Salvage value of the new machine at the end of its life = Rs. 10,000
Annual operation and maintenance cost = Rs. 40,000
Buyback price of the existing machine = Rs. 20,000

Alternative 2

Purchase value of the new machine = Rs. 300,000
Life of the machine = 10 years
Salvage value of the new machine at the end of its life = Rs. 15,000
Annual operation and maintenance cost = Rs. 35,000
Buyback price of the existing machine = Rs. 8,000

Suggest the best replacement option for the company using the annual equivalent cost method of comparison by assuming 10 per cent interest rate, compounded annually.

20. A company receives two options for purchasing a copier machine for its office.

Option 1: Make a down payment of Rs. 30,000 and take delivery of the copier machine. The remaining money is to be paid in 24 equal monthly instalments of Rs. 4500 each.

Option 2: Make a full payment of Rs. 100,000 and take delivery of the copier machine.

Suggest the best option for the company to buy the copier machine based on the annual equivalent method of comparison by assuming 15 per cent interest rate, compounded annually.

21. Find the best alternative using the annual equivalent method of comparison. Assume an interest rate of 10 per cent compounded annually.

Alternative	A	B	C
Initial cost (Rs.)	500,000	800,000	600,000
Annual receipt (Rs.)	200,000	150,000	120,000
Life (years)	10	10	10
Salvage value (Rs.)	100,000	50,000	30,000

22. Consider the following cash flow of a project:

Year	Cash flow
0	−10,000
1	3000
2	4500
3	6000
4	8500
5	5000

Find the rate of return of the project.

23. A person invests a sum of Rs. 200,000 in a business and receives equal net revenue of Rs. 50,000 for the next 10 years. At the end of the tenth year, the salvage value of the business is Rs. 25,000. Find the rate of return of the business.

24. A company is in the process of selecting the best alternative among the following three mutually exclusive alternatives:

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Alternative	Initial investment (Rs.)	Annual revenue (Rs.)	Life (Years)
A_1	Rs. 500,000	100,000	10
A_2	Rs. 800,000	140,000	10
A_3	Rs. 300,000	70,000	10

Find the best alternative based on the rate of return method of comparison.

25. A shipping firm is considering the purchase of a materials handling system for unloading ships at a dock. The firm has reduced its choice to three different systems, all of which are expected to provide the same unloading speed. The initial costs and the operating costs estimated for each system are tabulated here.

System	Initial cost	Annual operating expenses
S_1	Rs. 650,000	Rs. 91,810
S_2	Rs. 780,000	Rs. 52,600
S_3	Rs. 750,000	Rs. 68,417

The life of each system is estimated to be five years and the firm's minimum attractive rate of return is 15 per cent. If the firm must select one of the materials handling systems, which one is the most desirable?

26. A firm has identified three mutually exclusive alternatives. The life of all three alternatives is estimated to be five years. The minimum attractive rate of return is 12 per cent. Find the best alternative based on the rate of return method.

Alternative	Initial investment (Rs.)	Annual income (Rs.)
A_1	300,000	50,000
A_2	380,000	70,000
A_3	360,000	100,000

27. An automobile company is planning to buy a robot for its forging unit. It has identified two different companies for the supply of the robot. The details of cost and incremental revenue of using robots are summarized in the following tabular representation.

	Brand	
	Speedex	Giant
Initial cost (Rs.)	500,000	900,000
Annual incremental revenue (Rs.)	80,000	250,000
Life (years)	4	4
Life-end slavage value (Rs.)	40,000	60,000

The minimum attractive return for the company is 10 per cent. Suggest the best brand of robot to the company based on the rate of return method.

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28. A bank introduces two different investment schemes whose details are as follows:

	Alpha bank	Beta bank
Deposit amount (Rs.)	100,000	200,000
Period of deposit (years)	5 years	3 years
Maturity amount (Rs.)	300,000	450,000

Find the best investment alternative from the investor's point of view.

29. A company is planning for its expansion programme which will take place after five years. The expansion requires an equal sum of Rs. 500,000 for consecutive three years. Gamma bank has recently introduced a scheme in this line. If the company invests Rs. 700,000 now with this bank, it will make equal repayments of Rs. 500,000 for three consecutive years starting from the end of the fifth year from now. The minimum attractive rate of return for the company is 12 per cent. Suggest whether the company should invest with Gamma Bank for its expansion programme.

30. Consider the following table which summarizes the data of two alternatives:

	First cost	Annual return	Life
Alternative 1	Rs. 500,000	Rs. 150,000	10 years
Alternative 2	Rs. 800,000	Rs. 250,000	10 years

Find the best alternative based on the rate of return method of comparison.

31. A company is planning to expand its present business activity. It has two alternatives for the expansion programme and the corresponding cash flows are given in the tabular representation below. Each alternative has a life of five years and a negligible salvage value. The minimum attractive rate of return for the company is 15 per cent. Suggest the best alternative to the company.

	Initial investment (Rs.)	Yearly revenue (Rs.)
Alternative 1	450,000	150,000
Alternative 2	750,000	250,000

32. A governmental agency is considering four independent projects, each having 30-year projected useful lives. The current budget for this agency allows not more than 35,000,000 to be spent, in terms of initial investment, and the nominal interest rate 10 per cent per year. Using the BC ratio method, which of the projects shown below should be selected?

Project	Initial investment (Rs.)	Annual cost (Rs.)	Annual benefit (Rs.)
A	10,000,000	1,250,000	2,250,000
B	30,000,000	4,500,000	7,000,000
C	20,000,000	750,000	2,250,000
D	15,000,000	1,450,000	5,050,000

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33. Five independent projects are available to funding by a certain public agency. The following tabulation shows the equivalent annual benefits and cost for each.

Project	Annual benefit (Rs.)	Annual cost (Rs.)
A	2,800,000	3,000,000
B	8,600,000	6,200,000
C	7,400,000	4,800,000
D	3,600,000	3,800,000
E	6,600,000	5,400,000

(a) Assume that the projects are of the types of which the benefits can be determined with considerable certainty and that the agency is willing to invest money as long as the BC ratio is least. Which alternative should be selected?
(b) What is the rank ordering of projects from best to worst?
(c) If the projects involved have intangible benefits that require considerable judgement in assigning their values, would your recommendation be affected?

34. Two projects from each of the four departments have been submitted for evaluation and they are mutually exclusive. Associated data are as follows.

Department	Project	Benefit (Rs.)	Cost (Rs.)
A	A1	200,000	80,000
	A2	110,000	90,000
B	B1	80,000	50,000
	B2	70,000	60,000
C	C1	260,000	200,000
	C2	284,000	220,000
D	D1	120,000	70,000
	D2	1,022,000	80,000

(a) Which project should be funded according to the BC ratio criterion if one project must be selected from each department?
(b) Which project should be funded if only Rs. 300,000 is available?

35. The Orissa government is planning a hydro-electric project for a river basin. In addition to the production of electric power, this project will provide flood control, irrigation and recreation benefits. The estimated benefits and costs that are expected to considerations are as follows:

	A (Rs.)	B (Rs.)	C (Rs.)
Initial cost	20,000,000	30,000,000	50,000,000
Annual benefits and costs power sales	2,000,000	1,200,000	1,800,000
Flood cost savings	200,000	350,000	400,000

(Contd.)

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(*Contd.*)

	A (Rs.)	B (Rs.)	C (Rs.)
Irrigation benefits	350,000	450,000	800,000
Revision benefits	100,000	200,000	950,000
Operating and maintenance costs	200,000	250,000	850,000

The interest rate is 5 per cent and the life of each project is estimated at 50 years.

(a) Using incremental benefit-cost analysis, determine which project should be selected.
(b) Calculate the benefit-cost ratio for each alternative. Is the best alternative selected of the alternative with the maximum benefit-cost ratio?
(c) If the interest rate is 8 per cent, which alternative will be chosen?

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