UNIT 5

Depreciation

The term depreciation refers to fall in the value or utility of fixed assets which are used in operations over the definite period of years. In other words, depreciation is the process of spreading the cost of fixed assets over the number of years it is useful. The fall in value or utility of fixed assets due to so many causes like wear and tear, decay, effluxion of time or obsolescence, replacement, breakdown, fall in market value etc.

According to the Institute of Chartered Accountant of India, "Depreciation is the measure of the wearing out, consumption or other loss of value of a depreciable asset arising from use, effluxion of time or obsolescence (outdated) through technology and market changes.

Methods of Depreciation:

There are several methods for calculating depreciation, generally based on either the passage of time or the level of activity (or use) of the asset.

Straight-line depreciation:

Straight-line depreciation is the simplest and most often used method. In this method, the company estimates the salvage value (scrap value) of the asset at the end of the period during which it will be used to generate revenues (useful life). (The salvage value is an estimate of the value of the asset at the time it will be sold or disposed of; it may be zero or even negative. Salvage value is also known as scrap value or residual value.) The company will then charge the same amount to depreciation each year over that period, until the value shown for the asset has reduced from the original cost to the salvage value.

The method is designed to reflect the consumption pattern of the asset, and is used when there is no particular pattern to the manner in which the asset is to be used over time. Use of the straight-line method is highly recommended, since it is the easiest depreciation method to calculate, and so results in few calculation errors.

Under the straight-line method of depreciation, recognize depreciation expense evenly over the estimated useful life of an asset. The straight-line calculation steps are:

1. Determine the initial cost of the asset that has been recognized as a fixed asset.
2. Subtract the estimated salvage value of the asset from the amount at which it is recorded on the books.
3. Determine the estimated useful life of the asset. It is easiest to use a standard useful life for each class of assets.
4. Divide the estimated useful life (in years) into 1 to arrive at the straight-line depreciation rate.
5. Multiply the depreciation rate by the asset cost (less salvage value).

$$annual\ depreciation\ expense = depreciable\ cost * rate\ of\ depreciation$$

Where;

$$depreciable\ cost = Cost\ of\ installation - Residual\ value$$

$$rate\ of\ depreciation = \frac{1}{Useful\ life\ of\ installation\ (years)}$$

Hence; $$annual\ depreciation\ expense = \frac{(Cost\ of\ installation - Residual\ value)}{Useful\ life\ of\ installation\ (years)}$$

For example, a vehicle that depreciates over 5 years is purchased at a cost of Rs17,000, and will have a salvage value of Rs2000. Then this vehicle will depreciate at Rs3,000 per year, i.e. (17-2)/5 = 3. This table illustrates the straight-line method of depreciation. Book value at the beginning of the first year of depreciation is the original cost of the asset. At any time book value equals original cost minus accumulated depreciation.

Book value = original cost − accumulated depreciation. Book value at the end of year becomes book value at the beginning of next year. The asset is depreciated until the book value equals scrap value.

Depreciation Expense	Accumulated Depreciation at year end	Book value at year end Original cost (17000Rs.)
3000	3000	14000
3000	6000	11000
3000	9000	8000
3000	12000	5000
3000	15000	2000= salvage value

Double Declining Balance Method:

As the depreciation in straight-line depreciation method is uniform over its life-time, which is not very appropriate, the double declining balance method calculates the annual depreciation based on the book value of the previous year.

Suppose a business has an asset with Rs1,000 original cost, Rs100 salvage value, and 5 years of useful life. First, the straight-line depreciation rate would be 1/5, i.e. 20% per year. Under the double-declining-balance method, double that rate, i.e. 40% depreciation rate would be used. The table below illustrates this:

Depreciation rate	**Depreciation expense**	**Accumulated depreciation**	**Book value at end of year**
			original cost Rs1,000.00

40%	400.00	400.00	600.00
40%	240.00	640.00	360.00
40%	144.00	784.00	216.00
40%	86.40	870.40	129.60
129.60 - 100.00	29.60	900.00	scrap value 100.00

When using the double-declining-balance method, the salvage value is not considered in determining the annual depreciation, but the book value of the asset being depreciated is never brought below its salvage value, irrespective of the method used. Depreciation stops when either the salvage value or the end of the asset's useful life is reached.

Since double-declining-balance depreciation does not always depreciate an asset fully by its end of life, some methods also compute a straight-line depreciation each year, and apply the greater of the two. This has the effect of converting from declining-balance depreciation to straight-line depreciation at a midpoint in the asset's life.

With the declining balance method, one can find the depreciation rate that would allow exactly for full depreciation by the end of the period, using the formula:

$$\text{Depreciation Rate} = \sqrt[N]{\frac{Residual\ value}{cost\ of\ installation}}$$

where N is the estimated life of the asset (for example, in years).

Annuity depreciation:

Annuity depreciation methods are not based on time, but on a level of Annuity. This could be miles driven for a vehicle, or a cycle count for a machine. When the asset is acquired, its life is estimated in terms of this level of activity. Assume the vehicle above is estimated to go 50,000 miles in its lifetime. The per-mile depreciation rate is calculated as: (Rs17,000 cost - Rs2,000 salvage) / 50,000 miles = Rs0.30 per mile. Each year, the depreciation expense is then calculated by multiplying the number of miles driven by the per-mile depreciation rate.

Units-of-production depreciation method:

Under the units-of-production method, useful life of the asset is expressed in terms of the total number of units expected to be produced:

$$Annual\ Depreciation\ Expense = \frac{depreciable\ cost}{Estimated\ total\ production} * Actual\ Production$$

Suppose, an asset has **original cost Rs70,000**, **salvage value Rs10,000**, and is expected to produce **6,000 units**.

Depreciation per unit = (Rs70,000−10,000) / 6,000 = Rs10

10 × actual production will give the depreciation cost of the current year.

The table below illustrates the **units-of-production** depreciation schedule of the asset.

Units of production	**Depreciation cost per unit**	**Depreciation expense**	**Accumulated depreciation**	**Book value at end of year**
				Rs70,000 (original cost)
1,000	10	10,000	10,000	60,000
1,100	10	11,000	21,000	49,000
1,200	10	12,000	33,000	37,000
1,300	10	13,000	46,000	24,000
1,400	10	14,000	**60,000**	**10,000 (scrap value)**

Depreciation stops when book value is equal to the scrap value of the asset. In the end, the sum of accumulated depreciation and scrap value equals the original cost.

Sum-of-years-digits method:

Sum-of-years-digits is a depreciation method that results in a more accelerated write-off than the straight line method, and typically also more accelerated than the declining balance method. Under this method the annual depreciation is determined by multiplying the depreciable cost by a schedule of fractions.

Sum of the years' digits method of depreciation is one of the accelerated depreciation techniques which are based on the assumption that assets are generally more productive when they are new and their productivity decreases as they become old. The formula to calculate depreciation under SYD method is:

Annual Depreciation cost= $depreciable\ cost$ x (Remaining Useful Life/Sum of the Years' Digits)

Depreciable Base = Cost - Salvage Value

The sum of the digits can also be determined by using the formula $(n^2+n)/2$ where n is equal to the useful life of the asset in years.

Example: If an asset has original cost of Rs1000, a useful life of 5 years and a salvage value of Rs100, compute its depreciation schedule.

First, determine years' digits. Since the asset has useful life of 5 years, the years' digits are: 5, 4, 3, 2, and 1.

Next, calculate the sum of the digits: 5+4+3+2+1=15

The example would be shown as $(5^2+5)/2=15$

Depreciation rates are as follows:

5/15 for the 1st year, 4/15 for the 2nd year, 3/15 for the 3rd year, 2/15 for the 4th year, and 1/15 for the 5th year.

Depreciable base	**Depreciation rate**	**Depreciation expense**	**Accumulated depreciation**	**Book value at end of year**
				Rs1,000 (original cost)
900	5/15	300 =(900 x 5/15)	300	700
900	4/15	240 =(900 x 4/15)	540	460
900	3/15	180 =(900 x 3/15)	720	280
900	2/15	120 =(900 x 2/15)	840	160
900	1/15	60 =(900 x 1/15)	**900**	**100 (scrap value)**

Sinking fund (SF) depreciation method:-

In this method it is assumed that money is deposited in a sinking fund over the useful life that will enable to replace the asset at the end of its useful life. For this purpose, a fixed amount is set aside every year/month from the revenue generated (profit obtained) and this fixed sum is considered to earn interest at an interest rate compounded annually over the useful life of the asset, so that the total amount accumulated at the end of useful life is equal to the total depreciation amount (initial cost less salvage value of the asset).

Thus the annual depreciation in any year has two components.

1. fixed sum that is deposited into the sinking fund
2. the interest earned on the amount accumulated in sinking fund till the beginning of that year.

For this purpose, first the uniform depreciation amount (i.e. fixed amount deposited in sinking fund) at the end of each year is calculated by multiplying the total depreciation amount (i.e. initial cost less salvage value) over the useful life by sinking fund factor.

$$Annual\ depreciation = (depreciable\ cost\ )\frac{i}{(1+i)^n}$$

Where i = interest rate per year

Depreciation amount for m_{th} year = $A(1+i)^m$

After that the interest earned on the accumulated amount is calculated. The calculations are shown below.

Book Value after m years = $P - A[\sum_{k=0}^{m}((1+i)^k]$

TIME VALUE OF MONEY

Time value of money quantifies the value of a rupee through time

Money has time value because of the following reasons:

1. **Risk and Uncertainty:** Future is always uncertain and risky. Outflow of cash is in our control as payments are made by us. There is no certainty for future cash inflows. Cash inflow is dependent on our Creditor, Bank etc. As an individual or firm is not certain about future cash receipts, it prefers receiving cash now.
2. **Inflation:** In an inflationary economy, the money received today, has more purchasing power than the money to be received in future. In other words, a rupee today represents a greater real purchasing power than a rupee a year hence.
3. **Consumption:** Individuals generally prefer current consumption to future consumption.
4. **Investment opportunities:** An investor can profitably employ a rupee received today, to give him a higher value to be received tomorrow or after a certain period of time.

A rupee received today is worth more than a rupee received tomorrow

- This is because a rupee received today can be invested to earn interest
- The amount of interest earned depends on the rate of return that can be earned on the investment

- The basic types to calculate time value of money are as follows:
    - Present value of a lump sum
    - Future value of a lump sum
    - Present value of cash flow streams
    - future value of cash flow streams
    - Present value of annuities
    - future value of annuities
- Keep in mind that these forms can, should, and will be used in combination to solve more complex TVM problems
- The following are simple rules that you should always use no matter what type of TVM problem you are trying to solve:
    - Stop and think: Make sure you understand what the problem is asking. You will get the wrong answer if you are answering the wrong question.
    - Draw a representative timeline and label the cash flows and time periods appropriately.
    - Write out the complete formula using symbols first and then substitute the actual numbers to solve.

1. Present value of a lump sum:

- Present value calculations determine what the value of a cash flow received in the future would be worth today (time 0)
- The process of finding a present value is called "discounting" (*hint: it gets smaller*)
- The interest rate used to discount cash flows is generally called the discount rate

$$PV = FV_t / (1+r)^t$$

Where PV=present value
FV=Future value
r = rate of return
t = time period

P) How much would Rs100 received five years from now be worth today if the current interest rate is 10%?

Draw a timeline

The arrow represents the flow of money and the numbers under the timeline represent the time period. Note that time period zero is today.

$PV = CF_t / (1+r)^t$

$PV = 100 / (1 + .1)^5$

PV = Rs62.09

2. Future value of a lump sum:

- The future value as the opposite of present value
- Future value determines the amount that a sum of money invested today will grow to in a given period of time
- The process of finding a future value is called "compounding" (*hint: it gets larger*)

$$FV_t = PV * (1+r)^t$$

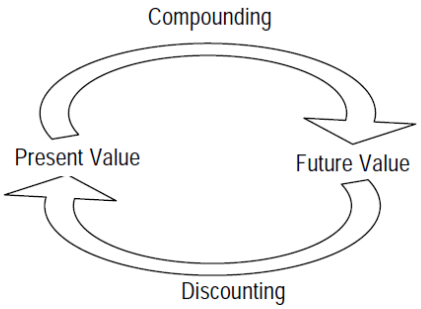
P) How much money will you have in 5 years if you invest Rs100 today at a 10% rate of return?

Draw a timeline

$FV_t = CF_0 * (1+r)^t$

$FV = Rs100 * (1+.1)^5$

FV = Rs161.05



3. Present value of a cash flow stream:

- A cash flow stream is a finite set of payments that an investor will receive or invest over time.
- The PV of the cash flow stream is equal to the sum of the present value of each of the individual cash flows in the stream.
- The PV of a cash flow stream can also be found by taking the FV of the cash flow stream and discounting the lump sum at the appropriate discount rate for the appropriate number of periods.

$$PV = \sum_{t=1}^{n} [CF_t / (1+r)^t]$$

Where CF = Cash flow (the subscripts t and 0 mean at time t and at time zero, respectively)

P) Joe made an investment that will pay Rs100 the first year, Rs300 the second year, Rs500 the third year and Rs1000 the fourth year. If the interest rate is ten percent, what is the present value of this cash flow stream? Draw a timeline:

$PV = [CF_1/(1+r)^1]+[CF_2/(1+r)^2]+[CF_3/(1+r)^3]+[CF_4/(1+r)^4]$

$PV = [100/(1+.1)^1]+[Rs300/(1+.1)^2]+[500/(1+.1)^3]+[1000/(1.1)^4]$

PV = Rs90.91 + Rs247.93 + Rs375.66 + Rs683.01

PV = Rs1397.51

4. Future value of a cash flow stream:
   - The future value of a cash flow stream is equal to the sum of the future values of the individual cash flows.
   - The FV of a cash flow stream can also be found by taking the PV of that same stream and finding the FV of that lump sum using the appropriate rate of return for the appropriate number of periods.

$$FV = \sum_{t=1}^{n} [CF_t * (1+r)^{n-t}]$$

Assume Joe has the same cash flow stream from his investment but wants to know what it will be worth at the end of the fourth year

Draw a timeline:

$FV = [CF_1*(1+r)^{n-1}]+[CF_2*(1+r)^{n-2}]+[CF_3*(1+r)^{n-3}]+[CF_4*(1+r)^{n-4}]$

$FV = [Rs100*(1+.1)^{4-1}]+[Rs300*(1+.1)^{4-2}]+[Rs500*(1+.1)^{4-3}] +[Rs1000*(1+.1)^{4-4}]$

FV = Rs133.10 + Rs363.00 + Rs550.00 + Rs1000

FV = Rs2046.10

5. Present value of an annuity: $PVA = payment * \{[1-(1+r)^{-t}]/r\}$
   - An annuity is a cash flow stream in which the cash flows are all equal and occur at regular intervals.

- Note that annuities can be a fixed amount, an amount that grows at a constant rate over time, or an amount that grows at various rates of growth over time. We will focus on fixed amounts.

P) Assume that Sally owns an investment that will pay her Rs100 each year for 20 years. The current interest rate is 15%. What is the PV of this annuity?

Draw a timeline

PVA_t = payment * $\{[1-(1+r)^{-t}]/r\}$

PVA = Rs100 * $\{[1-(1+.15)^{-20}]/.15\}$

PVA = Rs100 * 6.2593

PVA = Rs625.93

6. Future value of an annuity:

FVA_t = payment * $\{[(1+r)^t - 1]/r\}$

P) Assume that Sally owns an investment that will pay her Rs100 each year for 20 years. The current interest rate is 15%. What is the FV of this annuity?

Draw a timeline

FVA_t = PMT * $\{[(1+r)^t - 1]/r\}$

FVA_{20} = Rs100 * $\{[(1+.15)^{20} - 1]/.15$

FVA_{20} = Rs100 * 102.4436

FVA_{20} = Rs10,244.36

PRESENT WORTH ANALYSIS

One of the easiest ways to compare mutually exclusive alternatives is to resolve their consequences to the present time. Present worth analysis is most frequently used to determine the present value of future money receipts and disbursements. It would help us, for example to determine a present worth of income producing property, like an oil well or an apartment house. If the future income and cost are known, then using a suitable interest rate, the present worth of the property may be calculated. This should provide a good estimate of the price at which the property could be bought or sold.

In present worth analysis, careful consideration must be given to the time period covered by the analysis. Usually the task to be accomplished has a time period associated with it. In that case, the consequences of each alternative must be considered for this period of time which is usually called the analysis period.

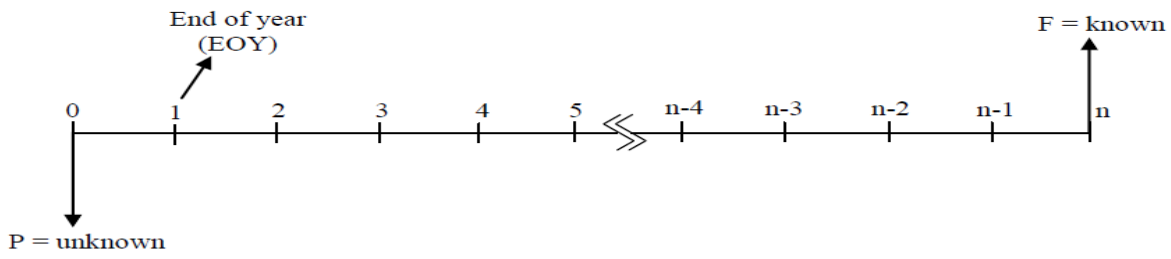
There are different analysis period situations that are encountered in economic analysis problems:

- Useful life of each alternative is same
- Useful lives of alternatives are different

Single payment present worth factor:

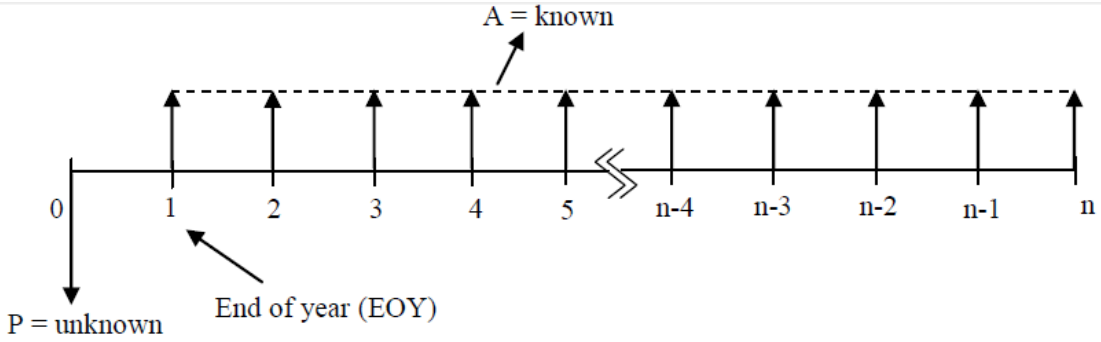
The single payment present worth factor is used to determine the present worth of a known future worth (F) at the end of "n" years at a given interest rate *'i'* per interest period. The present worth (P), future worth (F) and the total interest period „n" years are shown in Fig. The expression for the present worth (P) can be written as follows;

$$P = \frac{F}{(1+i)^n} \qquad (1)$$



Cash flow diagram for 'known F' and 'unknown P'

The uniform-series present worth factor is used to determine the present worth of a known uniform series. Let A be the uniform annual amount at the end of each year, beginning from end of year 1 till end of year n. The known A, unknown P, and the total interest period n years are shown in Fig. The present worth (P) of the uniform series can be calculated by considering each A of the uniform series as the future worth. Then by using the formula in equation (1), the present worth of these future worth can be calculated and finally taking the sum of these present worth values.



Cash flow diagram for 'known A' and 'unknown P'

The present worth (P) of the uniform series is given by;

$$P = \frac{A}{(1+i)} + \frac{A}{(1+i)^2} + \frac{A}{(1+i)^3} + \frac{A}{(1+i)^4} + \cdots\cdots\cdots + \frac{A}{(1+i)^{n-2}} + \frac{A}{(1+i)^{n-1}} + \frac{A}{(1+i)^n} \quad (2)$$

$$P = A\left\{(1+i)^{-1} + (1+i)^{-2} + (1+i)^{-3} + (1+i)^{-4} + \cdots\cdots\cdots + (1+i)^{-(n-2)} + (1+i)^{-(n-1)} + (1+i)^{-n}\right\} \quad (3)$$

The expression in the bracket is a geometric sequence with first term equal to $(1 + \mathrm{i})^{-1}$ and common ratio equal to$(1 + \mathrm{i})^{-1}$. Then the present worth (P) is calculated by taking the sum of the first n terms of the geometric sequence (at $i \neq 0$) and is given by;

$$P = A\left[(1+i)^{-1} \times \frac{1-(1+i)^{-n}}{1-(1+i)^{-1}}\right] \quad (4)$$

The simplification of equation (4) results in the following the expression;

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \quad (5)$$

Thus if the value of A in the uniform series is known, then the present worth P at interest rate of i(per year) can be calculated by equation (5).

Equal life span alternatives:

The comparison of mutually exclusive alternatives having equal life spans by present worth method is simpler than those having different life spans. In case of equal life span mutually exclusive alternatives, the future amounts are converted into the equivalent present worth values and are added to the present worth occurring at time zero. Then the alternative that exhibits maximum positive equivalent present worth or minimum negative equivalent present worth is selected from the available alternatives.

Different life span alternatives:

In case of mutually exclusive alternatives that have different life spans, the comparison is generally made over the same number of years i.e. a common study period. This is because; the comparison of the mutually exclusive alternatives over same period of time is required for

unbiased(impartial) economic evaluation of the alternatives. If the comparison of the alternatives is not made over the same life span, then the cost alternative having shorter life span will result in lower equivalent present worth i.e. lower cost than the cost alternative having longer life span.

RATE OF RETURN

The rate of return technique is one of the methods used in selecting an alternative for a project. In this method, the interest rate per interest period is determined, which equates the equivalent worth (either present worth, future worth or annual worth) of cash outflows (i.e. costs or expenditures) to that of cash inflows (i.e. incomes or revenues) of an alternative. The rate of return is also known by other names namely internal rate of return (IRR), profitability index etc. It is basically the interest rate on the unrecovered balance of an investment which becomes zero at the end of the useful life or the study period. In the following lectures, the rate of return is denoted by "*ir"*.

Using present worth, the equation for rate of return can be written as follows;

$$PW_o = PW_I \qquad (1)$$

PW_o = Present worth of cash outflows (cost or expenditure)

PW_I = Present worth of cash inflows (income or revenue)

- cost or expenditures are considered as negative cash flows
- income or revenues are considered as positive cash flows.

Above Equation can be rewritten as $0 = -PW_o + PW_I$

In the above equation the net present worth is zero. Now putting the expressions for present worth of cash outflows and that of cash inflows in equation (1) results in the following expression

$$P_0 + \sum_{t=0}^{n} \frac{A_{ot}}{(1+i)^t} = \sum_{t=0}^{n} \frac{A_{It}}{(1+i)^t} \qquad (2)$$

Po is the initial cost at time zero

A_{ok} is the expenditure occurring in k^{th} year.

A_{Ik} is the income or revenue (profit) occurring in k^{th} year.

The value of rate of return *ir* can be calculated by solving the above equation. Trial and error process for determination of the rate of return consumes more time but gives a clear understanding of the analysis of calculation for the rate of return.

The rate of return can also be determined by finding out the interest rate at which the net future worth or net annual worth is zero. After determination of the rate of return for a given alternative, it is compared with minimum attractive rate of return (MARR) to find out the acceptability of this alternative for the project.

If the rate of return i.e. *ir* is greater than or equal to MARR, then the alternative will be selected or else it will not be selected.

Example: A construction firm is planning to invest Rs.800000 for the purchase of a construction equipment which will generate a net profit of Rs.140000 per year after deducting the annual operating and maintenance cost. The useful life of the equipment is 10 years and the expected salvage value of the equipment at the end of 10 years is Rs.200000. Compute the rate of return using trial and error method based on present worth, if the construction firm‟s minimum attractive rate of return (MARR) is 10% per year.

Sol: Present worth= $-800000+140000\sum_{k=0}^{10}\frac{1}{(1+i)^{10}}+\frac{200000}{(1+i)^{10}}$

Now the above equation will be solved through trial and error process to find out the value of i.

Since MARR is 10%, first assume a value of i equal to 8% and compute the net present worth. Now putting the values of different compound interest factors in the expression for net present worth at i equal to 8% results in the following;

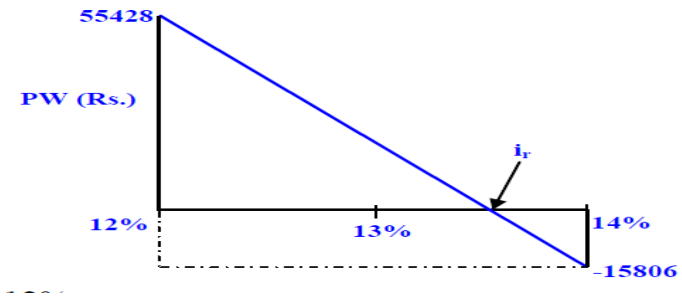
***PW* = Rs.232054**

The above calculated net present worth at i_r equal to 8% is greater than zero, now assume a higher value of ir i.e. 12% for the next trial and compute the net present worth.

***PW* = Rs.55428**

For 14% of i PW= -Rs.15806

PW = Rs.55428 at i_r = 12% PW = - Rs.15806 at i_r = 14%



$$\frac{55428-(-15806)}{14\%-12\%}=\frac{55428-0}{i_r-12\%}$$

On solving the above expression, the value of ir is found to be 13.55% per year which is greater than MARR (10%).

REPLACEMENT ANALYSIS

Replacement analysis is carried out when there is a need to replace or augment the currently owned equipment (or any asset). There are various reasons that result in replacement of a given equipment.

- One of the reasons is the **reduction in the productivity** of currently owned equipment. This occurs due to physical deterioration of its different parts and there is decrease in operating efficiency with age.
- **Increase in operating and maintenance cost** for the construction equipment due to physical deterioration. This necessitates the replacement of the existing one with the new alternative.
- If the production **demands a change in the desired output** from the equipment, then there is requirement of augmenting the existing equipment for meeting the required demand or replacing the equipment with the new one.
- Another reason for replacement of the existing equipment is **obsolescence**. Due to rapid change in the technology, the new model with latest technology is more productive than the currently owned equipment, although the currently owned equipment is still operational and functions acceptably. Thus continuing with the existing equipment may increase the production cost. The impact of rapid change in technology on productivity is more for the equipment with more automated facility than the equipment with lesser automation.

In replacement analysis, the existing (i.e. currently owned) asset is referred as **defender** whereas the new alternatives are referred as **challengers**.

In this analysis the 'outsider perspective' is taken to establish the first cost of the defender. This initial cost of the defender in replacement analysis is nothing but the estimated market value from perspective of a neutral party. The current market value represents the opportunity cost of keeping the defender i.e. if the defender is selected to continue in the service.

Sometimes, the defender is upgraded to make it competitive for comparison with the new alternatives. The additional cost required to upgrade the defender is added to its market value to establish the total investment for the defender. The revised annual operating and maintenance cost, salvage value and remaining service life of the defender, which are different from the original values, are estimated at the time of acquiring the asset.

The defender and challenger are compared over a study period. Generally the remaining life of the defender is less than or equal to the estimated life of the challenger. When the estimated lives of the defender and challenger are not equal, the duration of the study period has to be appropriately selected for the replacement analysis. When the estimated lives of defender and challenger are equal, annual worth method or present worth method may be used for comparison between defender and the challengers.

Example1: A construction company has purchased a piece of construction equipment 3 years ago at a cost of Rs.4000000. The estimated life and salvage value at the time of purchase were 12 years and Rs.850000 respectively. The annual operating and maintenance cost was Rs.150000. The construction company is now considering replacement of the existing equipment with a new model available in the market. Due to depreciation, the current book value of the existing

equipment is Rs.3055000. The current market value of the existing equipment is Rs.2950000. The revised estimate of salvage value and remaining life are Rs.650000 and 8 years respectively. The annual operating and maintenance cost is same as earlier i.e. Rs.150000. The initial cost of the new model is Rs.3500000. The estimated life, salvage value and annual operating and maintenance cost are 8 years, Rs.900000 and Rs.125000 respectively. Company's MARR is 10% per year. Find out whether the construction company should retain the ownership of the existing equipment or replace it with the new model, if study period is taken as 8 years (considering equal life of both defender and challenger).

Sol: For the replacement analysis the current revised estimates of the existing equipment will be used.

For existing equipment (defender),

Current market value (P) = Rs.2950000, Salvage value (F) = Rs.650000, Annual operating and maintenance cost (A) = Rs.150000, Study period (n) = 8 years.

For new model (challenger),

Initial cost (P) = Rs.3500000, Salvage value (F) = Rs.900000, Annual operating and maintenance cost (A) = Rs.125000, Study period (n) = 8 years.

Now the equivalent uniform annual worth of both defender (i.e. the existing equipment) and challenger (i.e. the new model) at MARR of 10% (i.e. i = 10%) are calculated as follows;

$$\boldsymbol{PW_{def}} = \mathbf{-2950000 - 150000}\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] + 650000\frac{1}{(1+i)^n}$$

$$\boldsymbol{PW_{def}} = \mathbf{-2950000 - 150000}\left[\frac{(1+i)^8 - 1}{i(1+i)^8}\right] + 650000\frac{1}{(1+i)^8}$$

$$\boldsymbol{PW_{def}} = \mathbf{-2950000 - 150000}[5.334] + 650000[0.4665]$$

$$\boldsymbol{PW_{def}} = \mathbf{-3446875}$$

$$\boldsymbol{PW_{chall}} = \mathbf{-3500000 - 125000}\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] + 900000\frac{1}{(1+i)^n}$$

$$\boldsymbol{PW_{chall}} = \mathbf{-3500000 - 125000}\left[\frac{(1+i)^8 - 1}{i(1+i)^8}\right] + 900000\left[\frac{1}{(1+i)^8}\right]$$

$$\boldsymbol{PW_{chall}} = \mathbf{-3500000 - 125000}[5.334] + 900000[0.4665]$$

$$PW_{chall} = -3746900$$

From the above calculations, it is observed that equivalent uniform annual cost of the defender is less than that of the challenger. Thus the construction company should continue in retaining the ownership of the defender against the challenger with above details.

LIFE CYCLE COSTING ANALYSIS

- Life cycle cost is equal to sum of all the estimated costs associated with a product, service or system over its life span starting from conceptual planning at the beginning to schematic design, detailed design, construction or production, operation and maintenance till its disposal at the end of the life span.
- The concept of life cycle costing lies in designing/producing the products, services or systems with systematic identification of both recurring and nonrecurring costs during various phases of their life cycle and estimating the cash flows during these phases over the life cycle.
- The economic evaluation of an alternative on the basis of life cycle cost results in a detailed analysis of the of both present and future costs and thus helps in taking the right decision regarding the selection of the most economical alternative.
- The life span of a product, service or system depends on the different phases starting from conceptual planning to its disposal. The end of life cycle may be governed by economic requirement or by functional requirement and depends on specific product.
- The economic life of a product/system is normally shorter than its physical life. The product/system may still be functional (over physical life) but may not be economical for the entire life period and may be replaced.
- The life cycle cost increases, if the design changes are made during later stages of the life cycle. The cost of design change increases with each stage of life cycle with lower cost during the early stages. The flexibility in design changes during the early stages is more as compared to that in the later stages of life cycle.
- Thus the potential for cost savings is more during the early stages of the life cycle and thus the selection of the most economical alternative and the effective design procedure during the design stage results in higher cost savings.
- Thus it is essential to have a detailed design of the product/system during the design stage of life cycle and to avoid or minimize the design changes during production and operation stages of life cycle to have a minimum impact on the life cycle cost of the product/system.

The life cycle cost analysis is more useful for selecting the alternatives for products, services or systems having longer life periods. The economic evaluation of alternatives using life cycle cost analysis can be carried out by finding out the equivalent worth of the each alternative by including all the cash flows occurring over various stages of life cycle by present worth analysis and selecting the most economical alternative that results in minimum life cycle cost.

ENERGY EFFICIENT MOTORS

An energy-efficient motor produces the same shaft output power (hp), but uses less electrical input power (kW) than a standard-efficiency motor. Energy-efficient motors must have nominal full-load efficiencies that exceed the minimum NEMA (National Electrical Manufacturers Association) standards.

Efficient use of energy enables to minimize production costs, increase profits, and stay competitive. The majority of electrical energy consumed in most industrial facilities is used to run electric motors. Energy-efficient motors now available are typically from 2 to 6 percent more efficient than their standard motor counterparts. This efficiency improvement translates into substantial energy and rupee savings.

The efficiency of an electric motor can only be improved through a reduction in motor losses. Improvement in the design, materials, and construction has resulted in efficiency gains of 2 to 6 percent which translates into a 25 percent reduction in losses. A small gain in efficiency can produce significant energy savings and lower operating costs over the life of the motor. Consequently, the higher purchase price of high-efficiency motors (15 to 30 percent) can be recovered in 2 years through cost savings in energy and operation. Because energy-efficient motors are a proven technology in terms of durability and reliability, their use should be considered for new installations, major modifications, replacement of failed motors or those that require rewinding, or extreme cases of oversized or under loaded motors.

Energy-efficient motors should be considered in the following instances.

- For new facilities or when modifications are made to existing installations or processes
- When procuring equipment packages
- Instead of rewinding failed motors
- To replace oversized and under loaded motors
- As part of an energy management or preventative maintenance program
- When utility rebates are offered that make high-efficiency motor retrofits (add new parts) even more cost effective

A motor's function is to convert electrical energy to mechanical energy to perform useful work. The only way to improve motor efficiency is to reduce motor losses. Even though standard motors operate efficiently, with typical efficiencies ranging between 83 and 92 percent, energy-efficient motors perform significantly better. An efficiency gain from only 92 to 94 percent results in a 25 percent reduction in losses. Since motor losses result in heat rejected into the atmosphere, reducing losses can significantly reduce cooling loads on an industrial facility's air conditioning system. Motor energy losses can be segregated into five major areas, each of which is influenced by design and construction decisions.

One design consideration, for example, is the size of the air gap between the rotor and the stator. Large air gaps tend to maximize efficiency at the expense of power factor, while small air gaps slightly compromise efficiency while significantly improving power factor. Motor losses may be categorized as those which are fixed, occurring whenever the motor is energized, and remaining

constant for a given voltage and speed, and those which are variable and increase with motor load.

These losses are described below.

1. **Core loss** represents energy required to magnetize the core material (hysteresis) and includes losses due to creation of eddy currents that flow in the core. Core losses are decreased through the use of improved permeability electromagnetic (silicon) steel and by lengthening the core to reduce magnetic flux densities. Eddy current losses are decreased by using thinner steel laminations.
2. **Windage and friction** losses occur due to bearing friction and air resistance. Improved bearing selection, air-flow, and fan design are employed to reduce these losses. In an energy-efficient motor, loss minimization results in reduced cooling requirements so a smaller fan can be used. Both core losses and windage and friction losses are independent of motor load.
3. **Stator Losses** appear as heating due to current flow through the resistance of the stator winding. This completely referred to as an I^2R loss. I^2R losses can be decreased by modifying the stator slot design or by decreasing insulation thickness to increase the volume of wire in the stator.
4. **Rotor loss** appears as I^2R heating in the rotor winding. Rotor losses can be reduced by increasing the size of the conductive bars and end rings to produce a lower resistance or by reducing the electrical current
5. **Stray load losses** are the result of leakage fluxes induced by load currents. Both stray load losses and stator, rotor I^2R losses increases with the motor load.

Besides reducing operating costs and extending winding and bearing service lives, additional benefits typically associated with using energy-efficient motors

- An extended warranty
- Extended lubrication cycles due to cooler operation
- Better tolerance to thermal stresses resulting from stalls or frequent starting
- The ability to operate in higher ambient temperatures
- Increased ability to handle overload conditions due to cooler operation and a 1.15 service factor
- Fewer failures under conditions of impaired ventilation
- More resistance to abnormal operating conditions, such as under and over voltage or phase unbalance.
- More tolerance to poorer voltage and current wave shapes.
- A slightly higher power factor in the 100 hp and lower size range, which reduces distribution system losses and utility power factor penalty changes