Construction Economics & Finance

Module 4
Lecture-1

Equipment costs:-

For construction firms, it is important to accurately estimate the equipment cost as part of the total cost of the construction project. Inaccurate estimation of construction equipment cost may adversely affect the profit margin of the firms especially engaged in projects with more involvement of different types of construction equipments. The total cost of a piece of construction equipment consists of two components namely ownership cost and operating cost. This is also referred as O&O cost of the construction equipment. The selection of a piece of equipment in a construction project depends on the total cost associated with that equipment. The details about equipment ownership cost and operating cost are presented below.

Ownership cost:-

Ownership cost is the total cost associated with the construction equipment for owning it irrespective of the equipment is employed or not in the project. The ownership cost consists of the following;

a) Initial cost, b) Salvage value, c) Interest cost or cost of capital investment, d) Taxes, e) Insurance cost, and f) Storage cost

a) Initial cost

Initial cost is the capital investment required to own the equipment. It includes purchase cost, sales tax, transportation cost (or freight charges) to bring the equipment to company's storage yard or construction site and cost of assembly and installation of the equipment. If the equipment is mounted on rubber tires (pneumatic tires), then the tire cost is deducted from the initial cost for calculating ownership cost. This is because the expected service life of pneumatic tires is less than that of the remaining of the equipment. Accordingly the rate of deprecation of tires is different from that of the equipment. Cost of tires is considered as a part of operating cost of the equipment. As the equipment is used in the project, there is depreciation in value of the equipment with time due to wear and tear and obsolescence. The total amount of depreciation for the construction equipment over the useful life is equal to the initial cost less the estimated salvage value. The details about different methods for calculation of depreciation of the asset are already presented in Module 3.

b) Salvage value

As already mentioned in Module 3, salvage value represents expected cash inflow that will be received by disposing of equipment at the end of its useful life. The estimation of expected salvage value of the equipment can be carried out by referring to the data obtained from past projects wherein same (or similar) equipment was used or information obtained from other relevant sources.

c) Interest cost or cost of capital investment

It is the annual cost of interest charged on the borrowed money or that of capital investment to acquire the ownership of the equipment. If the equipment is purchased by borrowing money from a lender, then interest cost is the interest charged (at interest rate charged by lender) on the borrowed amount. On the other hand if the equipment is purchased using construction firm’s own funds, then cost of capital investment is the interest charged on capital investment at interest rate equal to construction firm’s rate of return. Even though the construction firm uses its own funds to purchase the equipment, cost of capital investment is charged as part of the ownership cost because the construction firm could have invested the funds elsewhere to earn the return instead of purchasing the equipment.

The interest cost on borrowed money or cost of capital investment can be exactly calculated by considering time value of money and using appropriate compound interest factors. However the interest cost or cost of capital investment can also be calculated approximately as percentage of constant average annual investment (cost) over the useful life of the equipment. The annual interest rate or the rate of return is multiplied to the average annual investment to find out the annual interest cost or cost of capital investment. The average annual investment can be calculated by finding out the average value of the equipment over the useful life of the equipment. It may be noted here that the value of the equipment depreciates with time. By considering straight-line depreciation, the average annual investment can be found out by calculating average of the book value at the beginning of 1st year and that at beginning of last year of useful life i.e. at the beginning of ‘*n*’ year.

From module 3, the expression for constant annual depreciation from straight-line method (equation (3.1)) is given as follows;

$$D_m = \frac{P - SV}{n}$$

Where, *P* is the initial cost of equipment, *n* is the useful life and *SV* is the estimated salvage value of the equipment.

The book value at the beginning 1st year is equal to the initial cost i.e. ‘*P*’. Now the book value at beginning of last year (i.e. ‘*n*’), which is equal to book value at the end of ‘(*n*-1)’ year, can be calculated by using equation (3.7) from module 3.

$$BV_{n\text{-}1} = P - (n-1)D_m = P - (n-1)\left(\frac{P - SV}{n}\right)$$

Now the average annual investment (*AAI*) is calculated by taking the average of the book value at the beginning of 1st year and that at beginning of last year of useful life i.e. $BV_{n\text{-}1}$.

$$AAI = \frac{P + BV_{n-1}}{2} \qquad \text{……………………………………. (4.1)}$$

Putting the expressions of $BV_{n\text{-}1}$ in equation (4.1) results in;

$$AAI = \frac{P + P - (n-1)\left(\frac{P - SV}{n}\right)}{2} = \frac{2nP - (nP - n \times SV - P + SV)}{2n}$$

On simplifying the above expression;

$$AAI = \frac{P(n+1) + SV(n-1)}{2n} \qquad \text{………………………. (4.2)}$$

It may be noted here that while calculating average annual investment (*AAI*) for equipments mounted on pneumatic tires using the equation (4.2), cost of pneumatic tires is subtracted from initial cost of the equipment. The annual interest cost or cost of capital investment annual can be calculated by multiplying the average annual investment (*AAI*) as mentioned in equation (4.2) by the annual interest rate or rate of return.

d) Taxes

It represents the property taxes to be paid to the state or central government. It depends on the value of the equipment owned and the applicable tax rate for a given location. The property tax can be calculated as a percentage of the average annual investment or a percentage of the book value in a given year. Generally it ranges from 2 to 5% of the average annual investment or book value of equipment.

e) Insurance cost

It represents the annual premium to be paid to insurance companies to cover the cost incurred due to accident, fire, theft etc. for the construction equipment. In other words, it represents the cost that protects the owner of the equipment against these damages. Similar to taxes, the insurance cost can be calculated as a percentage of the average annual investment or the book value in a given year. It is generally about 1 to 3% of the average annual investment or book value of equipment.

f) Storage cost

It is the cost of keeping the equipment in storage yards when it is not operating at the work site. Storage cost includes the rental and maintenance charge for storage yards, wages of security guards and wages of workers employed for bringing in and out of the storage yards. It is around 0.5 to 1.5% of the average annual investment or book value of equipment. The annual storage cost can be calculated for the entire fleet of equipment and is then prorated to individual equipment requiring the storage facility.

Similar to storage cost, the tax and insurance cost can be calculated for the equipment fleet and then prorated to individual equipment. It may be noted here that the annual rates (%) mentioned above for taxes, insurance and storage costs are typical values. However the actual rates will vary depending on the type and size of equipment, place of purchase, location of project site etc.

After calculating the different components, the total annual ownership cost of the construction equipment is calculated by summing up depreciation cost, investment (or interest) cost, tax, insurance and storage costs. Then the hourly cost of ownership can be calculated by dividing the annual ownership cost by the number of operating hours the equipment will operate annually. The hourly ownership cost can also be calculated by first determining the components of ownership cost individually on hourly basis followed by adding these hourly costs to get the total hourly ownership cost.

Lecture-2

Operating cost:-

Operating cost is incurred only when the equipment is operated. The operating cost of the equipment is influenced by various parameters namely number of operating hours, location of job site, operating conditions, category of equipment etc. The operating cost consists of the following;

a) Repair and maintenance cost, b) Fuel cost, c) Cost of lubricating oil, filter and grease, d) Tire cost e) Equipment operator wages, f) Cost of replacing high-wear items and g) Cost of mobilization, demobilization and assembly.

a) Repair and maintenance cost

Repair and maintenance cost is incurred as the construction equipment is subjected to wear and tear due to the operations it performs. The repair and maintenance cost includes the cost of replacement parts, labor charges and the cost of setting up and operating facilities to carry out major repair and maintenance operations. The repair and maintenance cost varies from one year to another over the service life of the equipment, however it increases with age of the equipment. This cost contributes a substantial portion of the operating cost. The increase in service life and decrease in repair and maintenance cost of construction equipment can be achieved by carrying out timely recommended maintenance and repair operations. The minor repairs can be carried out at the job site where the equipment is operating, however the major repairs can be carried out in the facilities set up by the equipment owner or in the workshop of authorized dealers for the equipment. The annual repair and maintenance cost can be calculated as a percentage of the annual depreciation cost of the equipment. Past information available from company records or from other relevant sources for similar equipment under similar working conditions can be used for estimating the repair and maintenance cost. If this data is not available, equipment manufacturer's guidelines can be used for calculating this cost. The hourly repair and maintenance cost can be calculated by dividing the annual cost by the number of operating hours per year.

b) Fuel cost

The construction equipments are generally powered by internal combustion engines which use either gasoline (petrol) or diesel as the fuel. The fuel consumption depends on the rated flywheel horsepower (fwhp) of the engine and the nature of working conditions. The flywheel horsepower represents the power available for operating a piece of equipment. A gasoline engine consumes about 0.06 gal (gallon) of fuel per flywheel horsepower hour whereas a diesel engine consumes about 0.04 gal of fuel per flywheel horsepower hour when operating under standard conditions. Historical data about the quantity of fuel consumed by similar equipment under similar working conditions can be used to estimate the hourly fuel consumption by the equipment. If these records are not available, equipment manufacturer's fuel consumption data can be used to estimate the fuel cost. The hourly fuel cost can be calculated by multiplying the hourly fuel consumption by its unit price.

c) Cost of lubricating oil, filter and grease

The quantity of lubricating oil, filter and grease required depends on operating hours, frequency of changes, engine characteristics and working conditions at the job site. The equipment manufacturer guidelines or past data from experience of similar equipment in similar working conditions can be used to estimate of time period between the changes.

The quantity of lubricating oil required by an engine is equal to the amount added during complete change plus the small amount added between the changes. The quantity of lubricating oil required by engine can be calculated by using the following relationship.

$$q_l = \frac{hp \times f \times 0.006\, lb/hp-h}{7.4\, lb/gal} + c/t \qquad \ldots\ldots\ldots\ldots\ldots\ldots \text{(4.3)}$$

Where

q_l = quantity of oil required in gal/h

hp = rated horsepower of the engine

f = operating factor

c = capacity of crankcase in gallons

t = number of hours (i.e. duration) between the oil changes

The term 0.006 lb/hp-h in the above equation is based on the assumption that the quantity of lubricating oil required per rated horsepower hour between the changes is 0.006 lb and

7.4 lb/gal is the conversion factor. The operating factor (*f*) in the above equation depends on throttle load factor and the efficiency factor i.e. operating efficiency. Manufacturer's guidelines or past experience from similar equipment under similar working conditions can be used to calculate the cost of these items. The hourly cost of lubricating oil, filter and grease can be calculated from hourly consumption quantities. It may be noted here that the quantity of oil required in SI unit system can also be obtained by using the appropriate conversion factors in the above equation.

d) Tire cost

The cost of pneumatic tires (rubber tires) is considered as a part of operating cost. The tire cost includes the tire repair and replacement charges. The service life of tires is generally shorter than that of the equipment as the tires wear out at a faster rate than the equipment. The life of tires varies according to extent of wear it is subjected to, which depends on the job site conditions. Tire repair charges can be calculated as a certain percentage of tire depreciation cost. The past data from similar operating and project site conditions and tire and equipment manufacturer guidelines can be used to estimate the expected life of tires. The hourly tire repair and replacement cost can be calculated by dividing the sum of the cost of a set of tires and repair charges by the life of tires in hours.

e) Equipment operator wages

The operator cost includes the hourly wages and benefits paid by the company to the operators. It includes normal wages, workmen's compensation insurance premium, fringe benefits, bonus etc. The operator wages vary from project to project. The operator cost is normally calculated as a separate cost category and is added to other components of operating cost.

f) Cost of replacing high-wear items

It represents the cost of high-wears items and these items have a shorter life as compared to the service life of the equipment. The high-wear items include blades, cutting edges, drill bits, bucket teeth etc. The expected life of these items can be estimated from past records or from manufacture guidelines. The hourly cost can be calculated by dividing the unit cost by estimated life (in hours).

g) Cost of mobilization, assembly and demobilization

This cost includes transportation charges from one project site to another, cost required for getting road permits, unloading charges, cost of assembly at the project site etc. The hourly cost can be calculated by dividing the total cost by the number of operating hours.

In the following examples, the calculation of equipment ownership and operating costs is demonstrated.

Example -1

The initial cost of a piece of construction equipment (pneumatic tire mounted) is Rs.5500000. The estimated salvage value of the equipment is Rs.900000. The useful life of the equipment is 10 years. The equipment will operate 2000 hours per year. The cost of one set of tires is Rs.400000. A new set of tires will be replaced at the end of every 3 years of operation. In addition a repair work of cost Rs.450000 is expected at the end of year '6'. The interest rate is 8% per year. Find out the total cost per hour for the construction equipment considering time value of money.

Solution:

For calculating the hourly ownership and operating cost by considering time value of money, first the equivalent uniform annual cost is calculated at the given interest rate and is then divided by the number of operating hours per year.

As the initial cost includes cost of tires, tire cost is subtracted from initial cost of the equipment for calculating ownership cost, as cost of tires is considered as an element of operating cost.

Equivalent uniform annual worth of initial cost: A_1

Initial cost less cost of tires = Rs.5500000 – Rs.400000 = Rs.5100000

$$A_1 = Rs.5100000(A/P,i,n) = Rs.5100000(A/P,8\%,10)$$

$$A_1 = Rs.5100000 \times 0.1490$$

$$A_1 = Rs.759900$$

Equivalent uniform annual worth of salvage value: A_2

Salvage value = Rs.900000

$$A_2 = Rs.900000(A/F,i,n) = Rs.900000(A/F,8\%,10)$$

$$A_2 = Rs.900000 \times 0.0690$$

$$A_2 = Rs.62100$$

$$\text{Hourly ownership cost} = \frac{(A_1 - A_2)}{\text{Yearly operating hours}} = \frac{Rs.759900 - Rs.62100}{2000\,\text{hours}} = Rs.348.90/h$$

In the above expression, (A_1-A_2) is the equivalent uniform annual worth of the depreciation cost of the equipment considering time value of money.

Equivalent uniform annual worth of tire cost: A_3

The equipment will require 3 sets of replacement tires in addition to the original set. The first replacement set will be required at the end of 3rd year, second set at the end of 6th year and third set at the end of 9th year. In order to find out the equivalent uniform annual worth of tire cost, first the equivalent present worth of cost of replacement tires is calculated using the appropriate compound interest factor followed by adding it to the cost of original set (initial set) of tires and then converting the equivalent present worth to equivalent uniform annual cost over the entire useful life of 10 years using the appropriate compound interest factor.

$$A_3 = [400000 + 400000(P/F,8\%,3) + 400000(P/F,8\%,6) + 400000(P/F,8\%,9)](A/P,8\%,10)$$
$$A_3 = [400000 + 400000 \times 0.7938 + 400000 \times 0.6302 + 400000 \times 0.5002](0.1490)$$

$$A_3 = Rs.174282$$

Equivalent uniform annual worth of repair cost: A_4

Cost of repair work at the end of year '6' = Rs.450000.

$$A_4 = Rs.450000(P/F,8\%,6)(A/P,8\%,10)$$

$$A_4 = Rs.450000 \times 0.6302 \times 0.1490 = Rs.42255$$

$$\text{Hourly operating cost} = \frac{A_3 + A_4}{\text{Yearly operating hours}} = \frac{Rs.174282 + Rs.42255}{2000\,\text{hours}} = Rs.108.3/h$$

The total hourly cost for the construction equipment:

Hourly ownership cost + hourly operating cost = Rs.348.90/h + Rs.108.3/h

= **Rs.457.2/h**

Example -2

For a piece of construction equipment mounted on pneumatic tires, find out the hourly ownership cost using average annual investment method with straight line depreciation from the following data;

Initial cost = Rs.8000000, Estimated salvage value = Rs.1350000,

Useful life of the equipment = 11 years, Cost of a set of tires = Rs.600000.

The equipment will operate 1800 hours per year. The interest rate on investment is 7.5% per year. The annual rates for taxes, insurance and storage cost are 3%, 2.5% and 1% respectively. For this equipment, also calculate the hourly tire cost by not considering time value of money, if a new set of tires will be replaced at the end of every 4 years of operation and the estimated tire repair cost is 15% of straight-line depreciation.

Solution:

As the initial cost includes cost of tires, tire cost is subtracted from initial cost of the equipment for calculating ownership cost.

Initial cost less cost of tires (P) = Rs.8000000 – Rs.600000 = Rs.7400000

Salvage value (SV) = Rs.1350000, Useful life (n) = 11 years

The average annual investment (AAI) is calculated using equation (4.2) and is presented below.

$$AAI = \frac{P(n+1) + SV(n-1)}{2n}$$

$$AAI = \frac{Rs.7400000(11+1) + Rs.1350000(11-1)}{2 \times 11}$$

$$AAI = Rs.4650000$$

Annual interest or investment cost: A_1

The average annual interest or investment cost is calculated by multiplying average annual investment (AAI) by the annual interest rate (7.5%).

$$A_1 = AAI \times 0.075 = Rs.4650000 \times 0.075 = Rs.348750$$

Annual depreciation cost: A_2

The annual depreciation cost is calculated by straight-line depreciation method.

$$A_2 = \frac{P - SV}{n} = \frac{Rs.7400000 - Rs.1350000}{11} = Rs.550000$$

The annual expenses for taxes (A_3), insurance (A_4) and storage (A_5) are calculated by multiplying average annual investment (AAI) by the respective annual rates (%).

$$A_3 = AAI \times 0.03 = Rs.4650000 \times 0.03 = Rs.139500$$

$$A_4 = AAI \times 0.025 = Rs.4650000 \times 0.025 = Rs.116250$$

$$A_5 = AAI \times 0.01 = Rs.4650000 \times 0.01 = Rs.46500$$

Then the hourly ownership cost for the construction equipment is calculated as follows;

$$\text{Hourly ownership cost} = \frac{(A_1 + A_2 + A_3 + A_4 + A_5)}{\text{Annual operating hours}}$$

$$= \frac{Rs.348750 + Rs.550000 + Rs.139500 + Rs.116250 + Rs.46500}{1800\ \text{hours}} = Rs.667.2/h$$

Hourly tire cost (by not considering time value of money)

The hourly tire cost is equal to the sum of hourly tire use (replacement) cost and hourly tire repair cost. The hourly tire use cost is obtained by dividing the cost of a set of tires by the life of tires in hours. The hourly tire repair cost is equal to 15% of the hourly depreciation (straight-line) cost of tires. The total depreciation cost of a set of tires over its estimated life is equal to its initial cost as its salvage value is assumed as zero. As mentioned in the question, a new set of tires will be replaced at the end of every 4 years of operation and the equipment will operate 1800 hours per year. Thus the life of a set of tires is equal to 7200 hours (1800×4).

Hourly tire cost = hourly tire use cost + hourly tire repair cost

$$\text{Hourly tire cost} = \frac{Rs.600000}{7200\ \text{hours}} + \frac{Rs.600000 \times 0.15}{7200\ \text{hours}} = Rs.95.8/h$$

Thus for the construction equipment, the hourly ownership cost is Rs.667.2/h and the hourly tire cost (by not considering time value of money) is Rs.95.8/h.

Similar to the calculation of hourly cost of equipment as mentioned in above examples, other components of equipment operating cost can also be calculated by using already mentioned guidelines and equations.

Lecture-3

Buy, Rent and Lease Options

There are different methods of acquiring the construction equipment required for a project. These are namely buying, renting and leasing. There are advantages and disadvantages associated with each of these methods. Before acquiring the equipment, it is essential to explore all the options by considering various parameters namely company's cash flow, working capital, equipment utilization and its maintenance, obsolescence and replacement of equipment, operating conditions etc.

Buying

Buying results in direct ownership of the equipment. Acquisition of equipment by buying is done either through cash purchase by using company funds or through financing purchase. The outright cash purchasing is done when sufficient funds are available. However cash purchase can have an adverse effect on company's cash flow as it reduces the liquid asset thus affecting company's working capital. When sufficient funds are not available for outright cash purchase, the equipment can be acquired by finance purchasing wherein the purchasing is done through loan arrangements from lenders i.e. banks or other financial institutions that includes the payment of loan through installments along with an initial down payment. One of the main advantages of owning the equipment by outright cash purchase is that it may result in lowest cost per operating hour as compared to renting or leasing. Other advantages associated with buying include, complete control of the owner over use of the equipment and its maintenance and replacement of equipment when it is no more economical. In addition, there is also income tax benefit associated with depreciation of the equipment. Acquiring the equipment through buying is an economically attractive option when there is more work load leading to higher utilization rate of the equipment over its useful life. Otherwise it will lead to the risk of not getting the required return on the capital investment if there is not enough utilization of the equipment. This is one of the disadvantages associated with buying. If the equipment is purchased through finance purchasing, the equipment owner has to pay the required loan installment to the lender even when the equipment is not operational. Acquisition through buying may sometimes force the owner to use the obsolete equipment due to financial constraints.

Renting

Renting is a method of acquiring the equipment for a shorter duration. It is an alternative to direct ownership (i.e. through buying) of the equipment for a shorter period. Acquisition of equipment through renting is suitable when the contractor or the construction company requires the equipment for a project task of shorter duration. In addition through renting, the company can select the equipment that is exactly suited for the project task and it is possible to acquire the equipment based on latest technology which is more productive than older models. In these circumstances, renting of the equipment is more beneficial than direct ownership even though the rental charges are higher than the direct ownership charges. Since the equipment is not owned by the user, there is no tax benefit associated with depreciation of the equipment. However tax benefit is gained as the rental cost is considered as an expense that reduces the income of the company using the equipment. The capital that is tied up when the equipment is acquired through buying can be used in other investment if the equipment is rented. Among the three methods of acquiring the equipment, typically the hourly rental cost is higher as compared to that of lease or direct ownership. Rental period may a day, a week or a month and may go up to one year. The rental rates are generally established on daily basis, weekly basis or monthly basis. The daily rate on hourly basis is higher than the weekly rate on hourly basis and the weekly rate (on hourly basis) is higher than the monthly rate (on hourly basis). The repair and maintenance cost of the equipment to be paid either by the user or owner of the equipment (i.e. renting company) is stated in the rental contract. In case of major repair work, generally the cost is paid by the renting company whereas the cost of minor repair and maintenance that is incurred at the project site is usually paid by the user of the equipment. The cost fuel and lubricants is mostly paid by the user of the equipment. By renting, it is possible to reduce the downtime experienced due to breakdown of the equipment followed by repair as the equipment is replaced by the rental service. Further in order to check the suitability of specific equipment in actual job site conditions, the equipment can be rented and its performance can be tested before taking a decision to purchase the equipment that involves a major capital investment. In addition, the user of the equipment can get rid of the cost of transporting the equipment from one project site to another by renting it. However the user mostly pays the transportation charges for bringing the equipment from renting company's yard to the work site and also pays the cost of assembly, loading etc.

Leasing

Leasing is another method of acquiring the equipment, for a longer period of time as compared to renting. It is a long term alternative to direct ownership of the equipment. The leasing company (i.e. owner of the equipment) is known as lessor whereas the user of the equipment is known as lessee. Lease is a contract between the lessor and the lessee wherein the lessee uses the equipment owned by lessor by paying the rentals over the lease period. Mostly the lease period is more than six months and may run up to years. It is important for the lessee to know about the details of past and ongoing leases in which lessor is involved and also to check the terms and conditions of the lease agreement before entering into lease contract with lessor. Most of the equipment leases are noncancellable. During lease period the lessor retains the ownership of the equipment and also gets the tax benefits from depreciation of the equipment. Thus there is no tax benefit to lessee from depreciation of the equipment. However similar to renting, lessee gains tax benefits as the lease payments are considered as an expense. Due to leasing, the capital of lessee is not tied up in purchasing the equipment and lessee can use it for other investment. Even if the equipment is purchased through loan arrangement, the owner has to pay an initial down payment. However leasing can provide 100% financing, including the cost delivery and installation of the equipment. Lease payments can be made monthly, yearly or at other time intervals as agreed upon between the two parties. The lease payments need not necessarily be uniform over the lease period and there is flexibility of coordinating the schedule of payment (to be made by the lessee) to that of revenue generated from use of the equipment by the lessee. Generally, the cash inflow due to use of the equipment at the beginning may be low and thus the lessee prefers to pay less amount at the beginning of lease period. This type of payment arrangement may be accepted by the lessor from tax considerations as the lessor receives less payment at the beginning.

Two types of commonly offered leases through which construction equipments acquired are finance lease and operating lease. The finance lease is generally offered by a financial institution (usually a bank or a finance company) and the equipment is leased to the lessee. The lease period may extend up to the operating life of the equipment. The rental paid by the lessee over the lease period covers the cost of the equipment less the estimated residual value at the end of lease period, along with the profit margin of the lessor. The lessee has the option to purchase the equipment with a discounted price or a predetermined price at the end of the lease period. Usually the lease contract can not be cancelled till the lessor has recovered the investment cost at the end of the lease period. The finance lease is stated on lessee's balance sheet.

The operating lease is offered by the manufacturer or dealer of the equipment. In operating lease, payment charges are lower as compared to finance lease. In this type of lease, lessor (manufacturer or dealer of the equipment) provides the skilled service personnel required for carrying out the repair and maintenance operations and this type of arrangement is more suitable for sophisticated equipments requiring specialized repair and maintenance. Thus in this type of lease, lessee does not hire service personnel required for carrying out servicing and maintenance operations. Usually lessee returns the equipment to lessor at the end of lease period. Unlike finance lease, operating lease is not stated on lessee's balance sheet and is often referred to as off-balance-sheet financing.

Lecture-4

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. In addition to reduced productivity, there is also 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. Similarly 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. In other words this cost is the investment amount which is assigned to the currently owned asset (i.e. defender) in the replacement analysis. The current market value represents the opportunity cost of keeping the defender i.e. if the defender is selected to continue in the service. In other words, if the defender is selected, the opportunity to obtain its current market value is forgone. Sometimes the additional cost required to upgrade the defender to make it competitive for comparison with the new alternatives is added to its market value to establish the total investment for the defender.

Along with the market value, there will be revised estimates for annual operating and maintenance cost, salvage value and remaining service life of the defender, which are expected to be different from the original values those were estimated at the time of acquiring the asset. The past estimates of initial cost, annual operating and maintenance cost, salvage value and useful life of defender are not relevant in the replacement analysis and are thus neglected. The past estimates also incorporate a **sunk cost** which is considered irrelevant in replacement analysis. Sunk cost occurs when the book value (as determined using depreciation method) of an asset is greater than its current market value, when the asset (i.e. defender) is considered for replacement. In other words it represents the amount of past capital investment which can not be recovered for the existing asset under consideration for replacement. Sunk cost may occur due to incorrect estimates of different cost components and factors related productivity of the defender, those were made at the time of original estimates in the past with uncertain future conditions. Since sunk cost represents a loss in capital investment of the asset, the income tax calculations can be done accordingly by considering this capital loss. In replacement analysis the incorrect past estimates and decisions should not be considered and only the cash flows (both present and future) applicable to replacement analysis should be included in the economic analysis. For replacement analysis, it is important know about different lives of an asset, as this will assist in making the appropriate replacement decision. The different lives are physical life, economic life and useful life. **Physical life** of an asset is defined as the time period that is elapsed between initial purchase (i.e. original acquisition) and final disposal or abandonment of the asset. **Economic life** is defined as the time period that minimizes the total cost (i.e. ownership cost plus operating cost) of an asset. It is the time period that results in minimum equivalent uniform annual worth of the total cost of the asset. **Useful life** is defined as the time period during which the asset is productively used to generate profit. In replacement analysis the defender and challenger is 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 (new alternatives).

In the following example, replacement analysis involving equal lives of defender and challenger is discussed.

Example -3

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).

Solution:

For the replacement analysis, initial cost (Rs.4000000), initial estimate of salvage value (Rs.850000) and remaining life (12 – 3 = 9 years) and current book value (Rs.3055000) of the existing equipment (i.e. defender) are irrelevant. Similarly sunk cost of Rs.105000 (Rs.3055000 – Rs.2950000) is also not relevant for the replacement analysis. 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;

For defender;

$$AW_{def} = -2950000(A/P,i,n) - 150000 + 650000(A/F,i,n)$$

$$AW_{def} = -2950000(A/P,10\%,8) - 150000 + 650000(A/F,10\%,8)$$

$$AW_{def} = -2950000 \times 0.1874 - 150000 + 650000 \times 0.0874$$

$$AW_{def} = -646020$$

For challenger;

$$AW_{cha} = -3500000(A/P,i,n) - 125000 + 900000(A/F,i,n)$$

$$AW_{cha} = -3500000(A/P,10\%,8) - 125000 + 900000(A/F,10\%,8)$$

$$AW_{cha} = -3500000 \times 0.1874 - 125000 + 900000 \times 0.0874$$

$$AW_{cha} = -702240$$

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. Since the useful lives of defender and challenger are equal, the same conclusion will also be obtained by using present worth method for economic evaluation.

Lecture-5

Replacement Analysis

When useful lives of defender and challenger are not same i.e. remaining life of defender is not equal to useful life of the challenger (new alternative), mostly the duration of the longer life span alternative is selected as the study period. In other words the useful life of the challenger (which is generally greater than remaining life of defender) is taken as the study period. In this case it is assumed that the equivalent uniform annual cost of the defender (i.e. the shorter life span alternative) will be same after its remaining life and till the end of the study period. In other words the shorter life span alternative will function at the same equivalent annual cost throughout the study period. However if realistic estimate of the equivalent annual cost of the shorter life span alternative (i.e. defender) after its remaining life is available, the same can be used appropriately in the economic analysis over the study period.

Sometimes the use of longer study period may not be beneficial because of the fact that the rapid obsolescence may force the replacement of longer life span alternative, due to availability of new models with latest technology which are more productive. In addition inaccurate estimate of different cost components with uncertain future conditions for longer life span alternative is also another factor which may adversely affect the selection of longer study period. These reasons may force the management of the company to select a shorter study period for replacement analysis between defender and challenger. However the use of a shorter study period will force the recovery of initial capital investment of the longer life span alternative (i.e. challenger) at company's MARR in a shorter period of time which is less than its estimated useful life and this may affect the unbiased selection of the most economical alternative in the replacement analysis. When a shorter study period is used, the use of a realistic estimate of the salvage value or market value of the longer life span alternative (i.e. challenger) will result in an unbiased selection of the most economical alternative.

In the following example, the effect of longer and shorter study period on the selection of the most economical alternative between defender and challenger is discussed.

Example -4

For the replacement analysis of an asset of a construction company, the following information is available;

For defender (existing asset);

The original estimate includes, initial cost 4 years ago = Rs.5000000, Estimated salvage value and useful life at the time purchase = Rs.1200000 and 12 years respectively, Annual operating cost = Rs.115000.

The revised estimate includes, current market or trade-in value = Rs.3600000, remaining life = 7 years, Salvage value = Rs.780000, Annual operating cost = Rs.115000 (same as earlier).

For challenger (new alternative);

Initial cost = Rs.4500000, Estimated salvage value and useful life = Rs.1040000 and 14 years respectively, Annual operating cost = Rs.100000, Estimated value of the asset at the end of 7 years = Rs.2500000.

Carry out the replacement analysis using 14 year study period and 7 year study period at MARR of 8% per year.

Solution:

Replacement analysis using 14 year study period;

For defender (existing asset);

Current market or trade-in value = Rs.3600000, Salvage value = Rs.780000,

Annual operating cost = Rs.115000.

For challenger (new alternative);

Initial cost = Rs.4500000, Salvage value = Rs.1040000,

Annual operating cost = Rs.100000.

The equivalent uniform annual worth of defender is calculated at MARR of 8% over a period of 7 years (its remaining life) by using its revised estimates and it is assumed that, the calculated equivalent uniform annual worth of defender will be same after its remaining life and over the study period of 14 years. The equivalent uniform annual worth of challenger is calculated over the study period of 14 years (its estimated useful life) at MARR of 8%.

For defender;

$$AW_{def} = -3600000(A/P,i,n) - 115000 + 780000(A/F,i,n)$$

$$AW_{def} = -3600000(A/P,8\%,7) - 115000 + 780000(A/F,8\%,7)$$

$$AW_{def} = -3600000 \times 0.1921 - 115000 + 780000 \times 0.1121$$

$$AW_{def} = -719122$$

For challenger;

$$AW_{cha} = -4500000(A/P,i,n) - 100000 + 1040000(A/F,i,n)$$

$$AW_{cha} = -4500000(A/P,8\%,14) - 100000 + 1040000(A/F,8\%,14)$$

$$AW_{cha} = -4500000 \times 0.1213 - 100000 + 1040000 \times 0.0413$$

$$AW_{cha} = -602898$$

From the above calculation, it is observed that the new alternative is the most economical one over the study period of 14 years as it shows lower equivalent annual cost. Thus the construction company should replace the existing asset with the new one.

Replacement analysis using 7 year study period;

For defender (existing asset) the equivalent uniform annual cost will be same i.e. Rs.719122 as calculated above for the period of 7 years.

The equivalent uniform annual worth of challenger is calculated by considering its estimated value (i.e. Rs.2500000) at the end of 7 years.

For challenger;

$$AW_{cha} = -4500000(A/P,i,n) - 100000 + 2500000(A/F,i,n)$$

$$AW_{cha} = -4500000(A/P,8\%,7) - 100000 + 2500000(A/F,8\%,7)$$

$$AW_{cha} = -4500000 \times 0.1921 - 100000 + 2500000 \times 0.1121$$

$$AW_{cha} = -684200$$

The new alternative again shows lower equivalent annual cost as compared to the defender (existing asset) over the study period of 7 years.

If a study period of 6 years is considered and it is assumed the equivalent annual cost of the defender remains same i.e. Rs.719122 over the study period, then the equivalent annual cost of the challenger is calculated over this study period. Assuming the same estimated value of the challenger i.e. Rs.2500000 at the end of 6 years, its equivalent annual cost over the study period of 6 years is calculated as follows;

$$AW_{cha} = -4500000(A/P,i,n) - 100000 + 2500000(A/F,i,n)$$

$$AW_{cha} = -4500000(A/P,8\%,6) - 100000 + 2500000(A/F,8\%,6)$$

$$AW_{cha} = -4500000 \times 0.2163 - 100000 + 2500000 \times 0.1363$$

$$AW_{cha} = -732600$$

From this calculation it is observed the new alternative (challenger) is exhibiting higher equivalent annual cost as compared to the existing asset (defender) when the study period of 6 years is used. This is due to the fact that the challenger is allowed only 6 years to recover the same investment as compared to the study period of 7 or 14 years and thus resulting in an increased equivalent annual cost.

As already mentioned (in Lecture 4 of this module), if there is requirement of a change in the desired output from the existing equipment, then the enhanced production capacity can be achieved by augmenting the existing equipment or replacing it with a new one. In some cases construction firms plan for major overhaul or retrofitting of the existing equipment in order to met the required demand. In the following example replacement analysis involving the major overhaul of the currently owned asset i.e. defender and its comparison against challenger is presented.

Example -5

A construction firm has purchased an excavator 3 year ago at a cost of Rs.6000000 and the estimated life and salvage value at the time of purchase were 11 years and Rs.1600000 respectively. The annual operating cost was Rs.195000. The current market value of the equipment is Rs.4400000. The construction firm is planning for a major overhaul of the equipment now at a cost of Rs.1000000. After overhaul, the revised estimate of salvage value, annual operating cost and remaining life of the excavator are Rs.1250000, Rs.175000 and 9 years respectively.

However the construction firm has the option to replace the current excavator with a new model. The initial cost of the new model is Rs.6300000. The estimated life, annual operating cost and salvage value are 9 years, Rs.150000 and Rs.1800000 respectively. Determine whether the construction firm should continue with the existing excavator with the planned overhaul or replace it with the new model if the firm's MARR is 10% per year.

Solution:

For the replacement analysis the revised estimates of the existing excavator (defender) are as follows.

Current market value (P) = Rs.4400000, Salvage value (F) = Rs.1250000, Cost of major overhaul, now = Rs.1000000, Annual operating cost (A) = Rs.175000.

For new model (challenger),

Initial cost (P) = Rs.6300000, Salvage value (F) = Rs.1800000,

Annual operating cost (A) = Rs.150000.

The estimated lives of both defender and challenger are same i.e. 9 years. Now the equivalent uniform annual cost of both the existing excavator and the new model at MARR of 10% per year (i.e. i = 10%) are calculated over the study period of 9 years and are presented as follows;

For existing excavator (defender);

$$AW_{def} = -4400000(A/P,i,n) - 1000000(A/P,i,n) - 175000 + 1250000(A/F,i,n)$$

$$AW_{def} = -4400000(A/P,10\%,9) - 1000000(A/P,10\%,9) - 175000 + 1250000(A/F,10\%,9)$$

$$AW_{def} = -4400000 \times 0.1736 - 1000000 \times 0.1736 - 175000 + 1250000 \times 0.0736$$

$$AW_{def} = -1020440$$

For new model (challenger);

$$AW_{cha} = -6300000(A/P,i,n) - 150000 + 1800000(A/F,i,n)$$

$$AW_{cha} = -6300000(A/P,10\%,9) - 150000 + 1800000(A/F,10\%,9)$$

$$AW_{cha} = -6300000 \times 0.1736 - 150000 + 1800000 \times 0.0736$$

$$AW_{cha} = -1111200$$

From the above calculations, it is noted that equivalent uniform annual cost of the existing excavator with the planned overhaul is less than that of the new model. Thus the construction firm should continue with the existing excavator. Similarly the replacement analysis involving comparison of defender with augmentation against the challenger can also be carried out.

Further in replacement analysis, the remaining economic life of the defender can be found out by determining the number of years, which minimizes the total cost of owning and operating the asset. For this purpose, the equivalent uniform annual cost of the defender is determined year by year by considering the time value of money. The remaining economic life of the defender is taken as the year which results in the minimum equivalent uniform annual cost. Similarly the economic life of the challenger can also be determined in the same manner by considering the time value of money. Further replacement analysis involving the comparison of total cost of defender for retaining it for one additional year in service with the minimum equivalent uniform annual cost of challenger can also be carried out and accordingly the decision of retaining or replacing the defender can be taken.

It may be noted that the calculation of equipment cost and replacement analysis using the information from real life construction projects can be carried out in the same manner.