UNIT 4 OPERATING COST OF CONSTRUCTION EQUIPMENT

Structure

4.1 INTRODUCTION

To manage an equipment fleet properly, it is necessary that accurate records be kept of all operating cost. This not only provides management information for bidding purposes, but indirectly assists in determining replacement. Supplemental records should be maintained at the job level to record downtime, availability and performance. Management should carefully analyse all related costs, including layout rates, sources of parts and transportation expenses.

Operating costs include operator's wages, cost of fuel, lubricants and other consumables, cost of transportation, erection, dismantling, insurance charges, etc. All these costs are to be accounted for in the case of all construction equipment and plant.

Objectives

By the end of this unit you should be able to explain how the operating cost of construction equipment is determined in respect of

- operating personnel,
- POL,
- electric power,
- fees, licences, insurance, etc.,
- erection, dismantling and shifting,
- downtime,
- non-availability of workfront,
- preventive maintenance, and
- mismatch of equipment, the desirable objectives and monitoring of equipment costs.

4.2 OPERATING PERSONNEL

The operating cost of a construction equipment will include the charges of the operating personnel. They include the salaries of workmen, such as operators, helpers, mechanics, greasers, etc. employed for operating the equipment. In addition, the wages of supervisory staff (foremen, chargemen, time-keeper, etc.) may also be added. Provision of leave reserves to the extent of about 10 to 20 % of the cost of operating personnel should be made under this head.

The salaries of staff vary from project to project and from one category to another on the same project. The pay scales of the staff are frequently revised, and all available information pertaining to the project area should be utilised in estimating the cost of operating personnel.

SAQ 1

How are the charges payable to operating personnel included in the operating cost of a construction equipment?

4.3 POL

Construction equipment commonly use diesel or petrol engines as prime movers. The actual consumption of fuel in working of an IC engine would depend upon the engine BHP, the load factor at which it is worked and the condition of the engine. The probable consumption for engines working at full load and at constant speed under favourable conditions can be computed by using the following rules:

Diesel Engine

Fuel consumption per BHP per hour	= 0.1814 litres
Fuel consumption per m HP per hour	= 0.15 litres
Fuel consumption per kwh	= 0.205 litres

Petrol Engine

Fuel consumption per BHP per hour	= 0.27276 litres
Fuel consumption per m HP per hour	= 0.225 litres
Fuel consumption per kwh	= 0.307 litres

In actual working the engine may not run over about 60% load factor. Therefore, necessary correction for load factor should be made to determine average probable consumption of fuel by an engine. Caterpillars have recommended the following load factors for cranes and excavators:

Cranes	30 - 50 %
Clamshells and draglines	40 - 60 %
Shovels and backhoes	50 - 70 %

For diesel powered equipment, in general, the fuel consumed per hour can be estimated from the following relationship.

$$\text{Fuel consumed in litres per hour} = 0.22 \times \text{FHP} \times C_1 \times C_2$$

where,

C_1 = factor for category of equipment, and

C_2 = factor for type of duty to which it is put in use,

Values of C_1 and C_2 are given in Table 4.1.

Table 4.1 : Multiplying Factors for Construction Equipment

Sl. No	Category of Equipment	C_1, Type Factor	C_2		
			Light Duty	Medium Duty	Heavy Duty
1)	Dump Truck	0.30	0.70	1.00	1.40
2)	Motor Grader	0.40	0.67	1.00	1.33
3)	Excavator	0.50	0.80	1.00	1.20
4)	Wheel Loader	0.58	0.70	1.00	1.30
5)	Motorised Scraper				
	a) Twin Engine	0.57	0.70	1.00	1.30
	b) Single Engine	0.62	0.70	1.00	1.30
6)	Bulldozer	0.57	0.75	1.00	1.25
7)	Dozer Shovel	0.61	0.75	1.00	1.25
8)	Diesel Generator Sets	1.00	0.75	1.00	1.25
9)	Air Compressors	1.00	0.75	1.00	1.25

The lubricants include engine oil, air filter oil, transmission oil, greases and hydraulic oil. The requirements can be assessed on the basis of information supplied by manufacturer of the equipment, who would also specify the type and grade of lubricant to be used. The actual consumption by a machine depends upon its condition and the need for topping, in addition to the periodic oil changes. A rule of thumb which may be used to estimate the cost of lubricants is to take about 30 % of the fuel cost in case of diesel engines and about 20 % of the fuel cost in case of petrol engines, as the cost for oils and lubricants.

SAQ 2

i) How are the fuel charges for construction equipment computed?

ii) How are the costs of lubricants considered in finding the operating cost of a construction equipment ?

4.4 ELECTRIC POWER

For construction equipment electric motors are commonly used as prime movers. For electric motors, energy charges may be calculated on the basis of motor rating and operating load factor. Estimated power consumption for electric shovels as given by Caterpillars is shown below:

Size of machine (cum)	4.6	6.1	7.6	99	11.4	13	19
Power consumption (kwh)	225	300	375	475	620	740	1250

In case of general electrically operated equipment, the energy charges can be obtained by estimating energy consumed in kwh and multiplying it by the energy rate.

$$\text{Energy consumed} = \text{BHP} \times 746 \times C_1 \times \frac{C_2}{1000}$$

where,

C_1 = factor for category of equipment, and

C_2 = factor for type of duty to which it is put to use.

The values of C_1 and C_2 are given in Table 4.1.

SAQ 3

How are the energy charges computed for equipment working on electricity?

4.5 COST, TAXES, INSURANCE AND STORAGE

The costs payable towards purchase, taxes, insurance and storage are termed as investment cost. How the investment costs are applicable is discussed below.

The investment cost is in the nature of a fixed cost which continues to be incurred whether the equipment is used or not. The cost comprises interest on the money invested in acquiring the equipment, taxes pertaining to ownership of the equipment, insurance and storage. The money spent in purchase of equipment, if invested in a bank of some other interest bearing asset instead, would bring a return of interest. The prospect of earning this interest is lost due to purchase of the equipment, and so the recovery of this amount should be made on the machine's account. The rate of interest may depend upon prevailing bank rate of the country. The amount of taxes, insurance charge and storage cost are usually considered, like interest, a percentage of average investment. For most estimates the combined investment cost including interest, taxes, insurance and storage may be taken as about 10 % to 15 % of the average investment.

The capital cost of the equipment does not remain the same as the initial investment for its entire life but continues to decrease with time. Since the investment is considered at the beginning of each year, the cost of the equipment at the beginning of the year of its life should be taken as the investment during that year.

It is, therefore, necessary to compute the annual investment cost on the basis of actual intrinsic worth of the equipment during each year of its life. In practice, however, it is more convenient to compute an average value of the equipment during its entire useful life. This average value may be found as a % of original cost by using the formula

$$\text{Average cost as \% of original} = \frac{[(1+n)\times 100]}{2n} \qquad \ldots(4.1)$$

where,

n = useful life of the equipment in years.

In order to find the average investment, the original cost of the equipment and its anticipated useful life must be known. The total capital cost of the equipment should include, beside the price paid to the manufacturer or supplier, all such other costs as are incurred in connection with locating the equipment at the site of work. Thus, the total cost may comprise :

1) price, fob with all attachments and accessories,
2) shipping and insurance charges,
3) expenses for loading, unloading and clearance, including custom duty,
4) cost of inland transportation, including loading into wagons and unloading,
5) transportation cost to the work site, and
6) erection and commissioning cost.

The fob price should include the cost of the equipment with all attachments and accessories. Shipping, transportation, loading and unloading, charges would depend upon the weight and size of the equipment, and erection and commissioning cost on the type and size.

SAQ 4

i) What is the investment cost of a machine?

ii) What charges or costs are included in total capital cost?

4.6 ERECTION, DISMANTLING AND SHIFTING

Charges towards erection, dismantling and shifting are to be included in the operating cost of construction equipment.

4.6.1 Erection

Certain equipment and plant are assembled after being received at the job site from the manufacturer's premises. These include equipment like batching and mixing plant, aggregate processing plant, etc. The facilities required to install the equipment may be cranes, winches, hoists besides others. The facilities may be available with the contractor or he may have to hire them for purposes of erecting the plant. The cost towards hiring these facilities, their transportation and return to the owner have to be included in the cost of the construction plant.

4.6.2 Dismantling

After the project has been completed and there is no need for the plant or equipment, the same has to be dismantled before it can be shifted to some other project or location. Again facilities like cranes, winches and hoists may be acquired from some hiring agency for dismantling the equipment. Cost of such facilities are to be considered while working out the cost of the construction equipment or plant.

4.6.3 Shifting

The charges for transportation of equipment from the manufacturers premises on the first shipment is capitalised with the cost of the machine. The cost of further shifting of equipment on the project is payable by the receiving job. If the equipment is not shifted to another job, the last using job would normally pay for the return of equipment to the owner's store or yard.

In the case of rail transportation, it is important to investigate the possibility of "Storage in transit" particularly in regard to the home office or yard. "Storage in transit" is a term used when commodities including equipment, are shipped from one point to another point of storage and after storage are shipped on to a third point. The railways normally offer special rates under these circumstances that result in substantial savings.

SAQ 5

i) What are erection charges?

ii) Why are dismantling costs included?

iii) How are charges for shifting an equipment accounted for in the operating cost?

4.7 DOWNTIME

The modern trend is toward faster, more productive–and more expensive–machines. As productivity increases, the cost of lost time due to machine breakdown also rises.

Downtime is the time that an equipment is not working because it is undergoing repairs or adjustments. Downtime increases with usage. Equipment availability is a term that indicates the portion of the time that a machine is in actual production or is available for production, expressed as a percent. For example, if a machine is down 5% of the time, its availability is 95%. Downtime should not be considered if productivity of the machine is not actually required. The equipment must have been scheduled to operate, and conditions such that it could have been operated.

Although it is desirable to have 100% machine availability, usage generally results in increased downtime as a machine grows older. This loss of machine availability can vary greatly with the make, age and especially the service provided. Actual records should be used in computing downtime expense.

To be complete, an evaluation of an acceptable level of downtime must take into account the economics of field repairs versus home shop repairs versus dealer repairs. It must consider the level of parts a dealer may consign to a job as opposed to a purchased inventory. For the more complex assemblies, the specialised training of the dealer must be weighed against the training of the equipment owner's mechanic.

4.7.1 Downtime Analysis

The maintenance records must provide for an acceptable level of downtime analysis, from the records themselves. Table 4.2 shows a typical record.

Table 4.2 : Record of Downtime of Dozer

Date	Item	Fault	Downtime, hrs
1	Main panel	Fuse blown	0.1
2	Blade	Main arm came off	1.3
6	Gear box	Gear box shaft broken (spare gearbox fitted)	0.5
10	Radiator	Burst pipe (guard fitted)	0.3
11	Tracks	One link snapped (replaced)	0.4
19	Diesel tank	Punctured (welded)	3.0
22	Gear stick	Knob broken (replaced)	0.3
26	Radiator	Burst pipe (repaired and refitted)	0.5

Information produced in this way includes :

1) An indication of downtime per structure of work, per equipment, or if necessary per operator.

2) The time taken for fault diagnosis and repair on various types of fault, or on specific equipment, or by various personnel.

3) Indications of the cause of breakdown.

Among the useful points made clear by Analysis A may be:

1) The true ratio of downtime to use time (to answer rumours or inaccuracies being quoted against the maintenance department).

2) The need for further investigation, by the operation and maintenance managements, of high downtime.

3) The relationships between operator performance and the downtime on individual equipment.

Analysis B may help to define:

1) High downtime areas where permanent standby repair staff or field workshops might be beneficial.

2) Suppliers to be avoided on future procurement.

3) A requirement for specific training for maintenance crew (e.g. electronic fault finding).

4) The most efficient members of the maintenance staff for the various types of work (fault-diagnosis, repairs, renewals, etc.).

Analysis C will define:

1) The spare parts and materials requirements for the various equipment.

2) Any requirement for increased operator training.

3) Problems caused by variations in the product materials used in the construction processes.

It will be seen that downtime analysis is complementary to any cost analysis work. However, downtime recording in detail is relatively expensive and, may be applied only in certain areas rather than generally. The areas chosen may be high risk area containing plant which is vital to a high production rate, or may be areas of rising maintenance cost as defined by the normal cost summary, or areas in which large consequential losses could occur.

Equipment downtime should never exceed 7 percent of the available working hours and should average less than 5 percent. The concept of downtime control is extremely important in terms of total capital investment in the equipment fleet. Assuming a 200 unit fleet, a 7 percent downtime factor would result in 14 units out of service for maintenance or repair on any given day. If this could be reduced to 5 percent by application of management effort in the maintenance function, the out-of-service unit would be 10 per day. This would provide 4 more units per day for operational requirements, or conversely avoid the purchase of 4 additional units.

SAQ 6

i) Explain what is downtime of a machine?

ii) How are downtime costs computed?

iii) How is downtime control exercised?

4.8 NON-AVAILABILITY OF WORKFRONT

Due to non-availability of workfront, the equipment will not be productive. However, some expenses will be incurred on the idle equipment by way of security, watch and ward, etc. Thus, the unproductive machine will have to be charged when no workfront is available. Since the security and other expenditure will be covering a number of equipment kept in the storage yard, their cost should be divided equally amongst all the equipment for the period of retention in the yard. Thus, when an equipment is idle some charges are to be levied on this account.

SAQ 7

How are charges levied for non-availability of workfront?

4.9 PREVENTIVE MAINTENANCE

Maintenance cost includes cost of materials and spare parts, labour and overheads of maintenance organisation. As against these costs, the benefits achieved through a proper maintenance programme include: efficient operation of machines and prevention of downtime. A judicious maintenance programme should balance the costs against the benefits.

Each element of cost and benefits varies with the degree of maintenance effort expended in the programme. The degree of maintenance effort may be defined as the frequency of lubrication, inspections, repairs, replacements, adjustments and cleaning, and the amount of supervision and planning involved in it. A high degree of maintenance would cause very frequent inspection and servicing, and would exclude chances of any breakdowns and emergencies. A low degree of maintenance, would, on the other hand, comprise maintenance at long intervals or upon breakdown. The relationship between the cost of each component and the degree of maintenance needs to ascertain the optimum level of maintenance for an equipment.

The elements of total cost of maintenance are :

a) cost of labour and overheads of maintenance department,

b) cost of materials including spare parts,

c) loss in production due to inefficient operation, and

d) loss due to downtime.

As the degree of maintenance effort is increased, the costs of labour and overheads tend to increase, slowly at first but sharply later. The higher degree of maintenance increases effective life of machine parts resulting in a lower rate of material and spare parts consumption. However, if the degree of maintenance increases very much it would mean very frequent replacement of parts thereby increasing the cost of materials and spare parts. The losses due to inefficient operation reduce as the degree of maintenance effort is increased; and can, in the extreme case, be reduced to zero. These losses are difficult to estimate. However, a comparison of standard expected output of the machine with the output attained could be used as a measure of this loss. Downtime costs are incurred when the machine is rendered unproductive by being stopped for inspection and repairs or while under a breakdown. These costs reduce, sharply in the beginning as the degree of maintenance increases. After reaching a minimum level they start increasing due to over-maintenance. Figure 4.1 shows the variation of the different costs with the degree of maintenance effort.

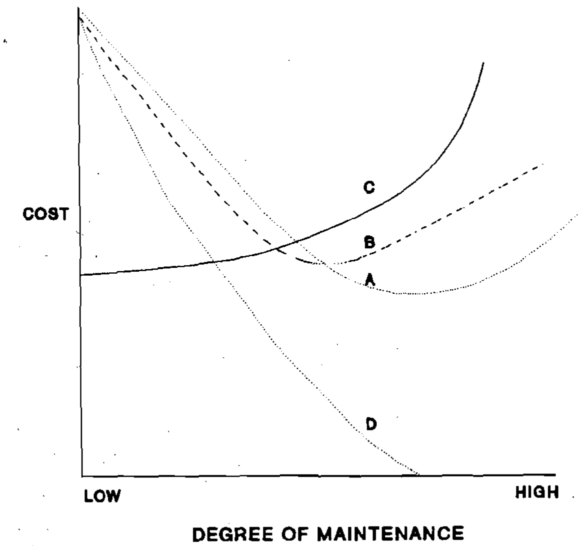

Figure 4.1 : Variation of Elements of Cost with Degree of Maintenance
A - Downtime Cost
B - Material and Spare Parts Cost
C - Labour and Overhead Cost
D - Loss due to Inefficient Operation

An optimal plan of maintenance is one that gives the lowest total cost. The different costs are summed up for each degree of maintenance effort and a curve of total cost vs degree of maintenance is plotted. From this curve the point of minimum cost is found which gives the optimum level of maintenance for the equipment under study. Such a curve is shown in Figure 4.2.

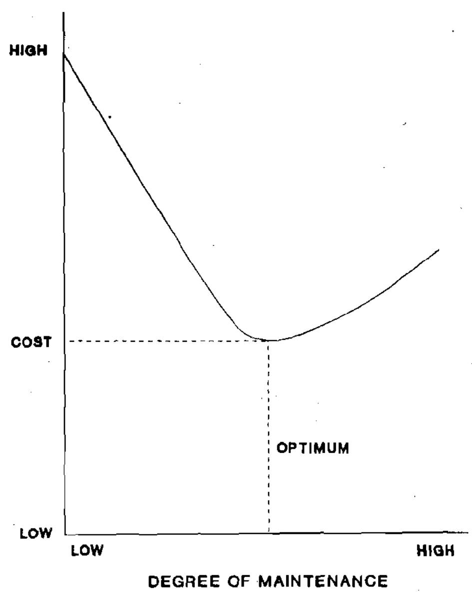

Figure 4.2 : Relation between Total Cost of Maintenance and Degree of Maintenance

The principles in optimizing preventive maintenance costs is illustrated by the following example.

Example 4.1

A screening plant has to be stopped for adjustments, cleaning and other maintenance work periodically. The plant works for 24 hours every day, and for 7 days every week. The following information about cost is available:

a) Downtime cost for idle staff, overhead, etc. is Rs. 10 per hour.

b) Cleaning and servicing require 12 hours and cost Rs. 130.

c) The fall in production, cost of material and spares, cost of labour and overhead for repairs, and breakdown hours are as given in Table 4.3.

Table 4.3 : Cost of Screening Plant

Frequency of Servicing (Weeks)	Value of Production per Week (Rs.)	Cost of Material and Spares/Week (Rs.)	Cost of Labour and Overheads per Week (Rs.)	Downtime (hrs.)
1	2200	75	80	0
2	2200	60	57	4
3	2100	66	42	10
4	1900	96	32	20
5	1600	132	25	35
6	1000	180	20	60

Solution

The different elements of cost are calculated in Table 4.4.

Table 4.4

Frequency of Servicing (Weeks)	Downtime Cost (Rs/Week)	Cleaning & Servicing Cost (Rs/Week)	Cost of Material and Spares/Week (Rs/Week)	Cost of Labour and Overheads per Week (Rs/Week)	Loss of Production (Rs/Week)	Total Cost (Rs/Week)
1	(12+ 0) × 10 = 120.00	130	75	80	0	405.00
2	(12 + 0 + 4) × 10/2 = 80.00	130/2 = 65.00	60	57	0	262.00
3	(12 + 0 + 4 +10) × 10/3 = 86.77	130/3 = 43.33	66	42	(2200 – 2100)/3 = 33.33	271.33
4	(12+0+4+10+20) × 10/4 = 115.00	130/4 = 32.50	96	32	[(33.33 × 4)+ (2200 – 1900)]/4 = 100.00	375.50
5	(12+0+4+10+20+35) × 10/5 = 162.00	130/6 = 26.00	132	25	[(100 × 4)+ (2200 – 1600)]/5 = 200.00	545.00
6	(12 + 0 + 4+10 +20+ 35+60) × 10/6 = 235.00	130/7 = 21.67	180	20	[(200 × 5)+ (2200 – 1000)]/6 = 366.67	823.34

The above results show that the lowest cost would be achieved when the frequency is between 2 and 3 weeks. The exact value can be found by plotting the curve of total cost vs frequency of maintenance, and reading the frequency for minimum total cost.

SAQ 8

i) What is meant by maintenance cost?

ii) How are maintenance cost and benefit related?

iii) What are the elements of cost of maintenance?

iv) How do you define an optimal plan of maintenance?

4.10 MISMATCH OF EQUIPMENT

When two pieces of equipment are to work as a team, the two should be properly matched. By proper matching, the production of one equipment will be received by the second equipment without loss of time. An example often quoted is that of a power shovel loading material into a dump truck. One power shovel may serve a number of dump trucks. If the number of trucks are less than the production of the shovel, the shovel is underworked. Similarly, if the number of trucks are more than the production of the shovel, the trucks remain idle and underworked. Both situations will increase the cost of material handled in terms of loading and transport, and the two types of equipment are mismatched. The better of the two combinations is one in which the total cost of loading and carriage is the lesser.

SAQ 9

When two machines working as a team are mismatched, how will the cost of a unit item of work be affected?

4.11 DESIRABLE OBJECTIVES

The objectives of the equipment owner are to be fulfilled through proper costing records. A maintenance cost system is necessary to protect an agency's high capital investment in construction equipment. It permits the control of good service procedures and the prevention of excessive operating costs due to overmaintenance or inadequate maintenance. It should enable the owner to price his work more intelligently. The fulfillment of these objectives should govern efforts to develop effective information systems. So long as construction projects are of shorter duration than the life of equipment, the control of equipment costs will be a major challenge.

SAQ 10

How do costing records help an equipment owner in his objectives?

4.12 MONITORING EQUIPMENT COSTS

Equipment cost estimates should continuously be monitored and maintained to provide a measure of performance for project managers and to permit budgetary control over equipment cost. The level at which budgetary control of maintenance is attempted varies significantly between constructing agencies. Most agencies record their cost to the individual piece of equipment by type of expenditure. A typical breakdown of the types of expenditure used is

1) labour,

2) parts,

3) tyres and tubes,
4) lubrication and preventive maintenance,
5) accident repairs, and
6) special modifications.

Along with the maintenance expenditures, depreciation and other ownership costs are normally charged to the individual equipment numbers.

SAQ 11

Why is monitoring of equipment costs necessary?

4.13 SUMMARY

In this unit you learnt how the operating cost of a construction equipment is to be computed. The various components of cost, which include operating personnel, POL, electric power, actual cost, taxes, insurance and storage, erection, dismantling and shifting are to be considered to arrive at a proper cost figure. How downtime is analysed and equipment costs are monitored are discussed.

4.14 ANSWERS TO SAQs

Check answers of all SAQs with respective preceding text.