# 17

# Construction Economics

## 17–1 INTRODUCTION

As has been noted on a number of occasions, construction contracting is a highly competitive business. Therefore, the financial management of a construction company is equally as important to company success as is its technical management. As a matter of fact, many successful constructors have evolved from a background of business and finance rather than from construction itself. However, there is little doubt that a strong technical base supported by business skills and management ability provides the best foundation for success as a construction professional.

A complete discussion of the many facets of construction economics is beyond the scope of this book. Rather, the purpose of this chapter is to introduce the reader to the terminology and basic principles involved in determining the owning and operating costs of construction plant and equipment, analyzing the feasibility of renting or leasing rather than purchasing equipment, and the financial management of construction projects.

## 17–2 TIME VALUE OF MONEY

Everyone is aware that the amount of money held in a savings account will increase with time if interest payments are allowed to remain on deposit (compound) in the account. The value of a sum of money left on deposit after any period of time may be calculated using Equation 17–1.

$$F = P(1 + i)^n \qquad \textbf{(17–1)}$$

where $F$ = value at end of $n$ periods (future value)
$P$ = present value
$i$ = interest rate per period
$n$ = number of periods

The expression $(1 + i)^n$ is often called the *single-payment compound interest factor.* Equation 17–1 can be solved to find the present value (present worth) of some future amount, resulting in Equation 17–2.

$$P = \frac{F}{(1 + i)^n} \tag{17–2}$$

The expression $1/(1 + i)^n$ is called the *single-payment present worth factor.* Expressions have also been developed that yield the value of a series of equal periodic payments at the end of any number of periods *(uniform series compound amount factor),* the present worth of such a series *(uniform series present worth factor),* the periodic payment required to accumulate a desired amount at some future date *(sinking fund factor),* and the annual cost to recover an investment, including the payment of interest, over a given period of time *(capital recovery factor).* Other expressions have been developed to find the present and future worth of gradient (nonuniform) series of payments.

These equations form the basis of a type of economic analysis commonly called *engineering economy.* The methods of engineering economy are widely used to analyze the economic feasibility of proposed projects, to compare alternative investments, and to determine the rate of return on an investment. However, because of their complexity and the difficulty of accounting for the effects of inflation and taxes, these techniques have not been widely used within the construction industry. Construction equipment owning costs, for example, are usually determined by the methods described in the following section rather than by employing engineering economy techniques. A present worth analysis, however, is very helpful when comparing the cost of different alternatives. This is illustrated by the rent–lease–buy analysis described in Section 17–4.

## 17–3 EQUIPMENT COST

### Elements of Equipment Cost

In earlier chapters, we have discussed the proper application of the major items of construction equipment and some methods for estimating equipment's hourly production. We then divided the equipment's hourly cost by its hourly production to obtain the cost per unit of production. However, up to this point we have simply assumed that we knew the hourly cost of operation of the equipment. In this section we consider methods for determining the hourly cost of operation of an item of equipment. Although the procedures explained in this section are those commonly employed in the construction industry, they are not the only possible methods.

In following the procedures of this section, you will note that it is necessary to estimate many factors, such as fuel consumption, tire life, and so on. The best basis for estimating such factors is the use of historical data, preferably those recorded by your construction company operating similar equipment under similar conditions. If such data are not available, consult the equipment manufacturer for recommendations.

Equipment *owning and operating costs* (frequently referred to as *O & O costs*), as the name implies, are composed of owning costs and operating costs. Owning costs are fixed costs that are incurred each year whether the equipment is operated or not. Operating costs, however, are incurred only when the equipment is used.

## Owning Costs

*Owning costs* are made up of the following principal elements:

- Depreciation.
- Investment (or interest) cost.
- Insurance cost.
- Taxes.
- Storage cost.

Methods for calculating each of these items are described next.

### Depreciation

*Depreciation* represents the decline in market value of an item of equipment due to age, wear, deterioration, and obsolescence. In accounting for equipment costs, however, depreciation is used for two separate purposes: (1) evaluating tax liability, and (2) determining the depreciation component of the hourly equipment cost. Note that it is possible (and legal) to use different depreciation schedules for these two purposes. For tax purposes many equipment owners depreciate equipment as rapidly as possible to obtain the maximum reduction in tax liability during the first few years of equipment life. However, the result is simply the shifting of tax liability between tax years, because current tax rules of the U.S. Internal Revenue Service (IRS) treat any gain (amount received in excess of the equipment's depreciated or book value) on the sale of equipment as ordinary income. The depreciation methods explained in the following pages are those commonly used in the construction equipment industry. Readers familiar with the subject of engineering economics should recognize that the methods of engineering economy may also be employed. When the methods of engineering economics are used, the depreciation and investment components of equipment owning costs will be calculated together as a single cost factor.

In calculating depreciation, the initial cost of an item of equipment should be the full delivered price, including transportation, taxes, and initial assembly and servicing. For rubber-tired equipment, the value of tires should be subtracted from the amount to be depreciated because tire cost will be computed separately as an element of operating cost. Equipment salvage value should be estimated as realistically as possible based on historical data.

The equipment life used in calculating depreciation should correspond to the equipment's expected economic or useful life. The IRS guideline life for general construction equipment is currently 5 years, so this depreciation period is widely used by the construction industry.

The most commonly used depreciation methods are the straight-line method, the sum-of-the-years'-digits method, the double-declining balance method, and IRS-prescribed methods. Procedures for applying each of these methods are explained below.

**Straight-Line Method.** The *straight-line method* of depreciation produces a uniform depreciation for each year of equipment life. Annual depreciation is thus calculated as the amount to be depreciated divided by the equipment life in years (Equation 17–3). The amount to be depreciated consists of the equipment's initial cost less salvage value (and less tire cost for rubber-tired equipment).

$$D_n = \frac{\text{Cost} - \text{Salvage}\ (-\text{tires})}{N} \qquad \textbf{(17–3)}$$

where $N$ = equipment life (years)
$n$ = year of life (1, 2, 3, etc.)

## EXAMPLE 17–1

Using the straight-line method of depreciation, find the annual depreciation and book value at the end of each year for a track loader having an initial cost of $50,000, a salvage value of $5000, and an expected life of 5 years.

### *SOLUTION*

$$D_{1,2,3,4,5} = \frac{50{,}000 - 5000}{5} = \$9000$$

| Year | Depreciation | Book Value (End of Period) |
|---|---|---|
| 0 | 0 | $50,000 |
| 1 | $9,000 | 41,000 |
| 2 | 9,000 | 32,000 |
| 3 | 9,000 | 23,000 |
| 4 | 9,000 | 14,000 |
| 5 | 9,000 | 5,000 |

**Sum-of-the-Years'-Digits Method.** The *sum-of-the-years'-digits method* of depreciation produces a nonuniform depreciation which is the highest in the first year of life and gradually decreases thereafter. The amount to be depreciated is the same as that used in the straight-line method. The depreciation for a particular year is calculated by multiplying the amount to be depreciated by a depreciation factor (Equation 17–4). The denominator of the depreciation factor is the sum of the years' digits for the depreciation period (or $1 + 2 + 3 + 4 + 5 = 15$ for a 5-year life). The numerator of the depreciation factor is simply the particular year digit taken in *inverse* order (i.e., $5 - 4 - 3 - 2 - 1$). Thus for the first year of a 5-year life, 5 would be used as the numerator.

$$D_n = \frac{\text{Year digit}}{\text{Sum of years' digits}} \times \text{Amount to be depreciated} \qquad \textbf{(17–4)}$$

The procedure is illustrated in Example 17–2.

## EXAMPLE 17–2

For the loader of Example 17–1, find the annual depreciation and book value at the end of each year using the sum-of-the-years'-digits method.

### *SOLUTION*

Using Equation 17–4:

$$D_1 = \frac{5}{15} \times (50{,}000 - 5000) = 15{,}000$$

$$D_2 = \frac{4}{15} \times (50{,}000 - 5000) = 12{,}000$$

$$D_3 = \frac{3}{15} \times (50{,}000 - 5000) = 9{,}000$$

$$D_4 = \frac{2}{15} \times (50{,}000 - 5000) = 6{,}000$$

$$D_5 = \frac{1}{15} \times (50{,}000 - 5000) = 3{,}000$$

| Year | Depreciation | Book Value (End of Period) |
|---|---|---|
| 0 | 0 | $50,000 |
| 1 | $15,000 | 35,000 |
| 2 | 12,000 | 23,000 |
| 3 | 9,000 | 14,000 |
| 4 | 6,000 | 8,000 |
| 5 | 3,000 | 5,000 |

**Double-Declining-Balance Method.** The *double-declining-balance method* of depreciation, like the sum-of-the-years'-digits method, produces its maximum depreciation in the first year of life. However, in using the double-declining-balance method, the depreciation for a particular year is found by multiplying a depreciation factor by the equipment's *book value at the beginning of the year* (Equation 17–5). The annual depreciation factor is found by dividing 2 (or 200%) by the equipment life in years. Thus for a 5-year life, the annual depreciation factor is 0.40 (or 40%). Unlike the other two depreciation methods, the double-declining-balance method does not automatically reduce the equipment's book value to its salvage value at the end of the depreciation period. Since the book value of equipment is not permitted to go below the equipment's salvage value, care must be taken when performing the depreciation calculations to stop depreciation when the salvage value is reached. The correct procedure is as follows:

$$D_n = \frac{2}{N} \times \text{Book value at beginning of year} \qquad \textbf{(17–5)}$$

## EXAMPLE 17–3

For the loader of Example 17–1, find the annual depreciation and book value at the end of each year using the double-declining-balance method.

### *SOLUTION*

Using Equation 17–5:

$$\text{Annual depreciation factor} = \frac{2.00}{5} = 0.40$$

$$D_1 = 0.40 \times 50{,}000 = 20{,}000$$
$$D_2 = 0.40 \times 30{,}000 = 12{,}000$$
$$D_3 = 0.40 \times 18{,}000 = 7{,}200$$
$$D_4 = 0.40 \times 10{,}800 = 4{,}320$$
$$D_5 = 0.40 \times \ 6{,}480 = 2{,}592 \text{ use } \$1{,}480^*$$

| Year | Depreciation | Book Value (End of Period) |
|---|---|---|
| 0 | 0 | $50,000 |
| 1 | $20,000 | 30,000 |
| 2 | 12,000 | 18,000 |
| 3 | 7,200 | 10,800 |
| 4 | 4,320 | 6,480 |
| 5 | 1,480* | 5,000 |

*Because a depreciation of $2592 in the fifth year would reduce the book value to less than $5000, only $1480 ($6480 − $5000) may be taken as depreciation.

**IRS-Prescribed Methods.** Since the Internal Revenue Service tax rules change frequently, always consult the latest IRS regulations for the current method of calculating depreciation for tax purposes. The Modified Accelerated Cost Recovery System (MACRS) has been adopted by the Internal Revenue Service for the depreciation of most equipment placed in service after 1986. Although several different depreciation methods are permitted under MACRS, the depreciation method most commonly used is the General Depreciation System (GDS) with a modified double-declining-balance schedule (200% DB) and the half-year convention.

Under the MACRS system, depreciation for all property except real property is spread over a 3-year, 5-year, 7-year, or 10-year period. Most vehicles and equipment, including automobiles, trucks, and general construction equipment, are classified as 5-year property. The yearly deduction for depreciation is calculated as a prescribed percentage of initial cost (cost basis) for each year of tax life without considering salvage value. The "half-year convention" considers all property placed in service or disposed of during a year as having been acquired or disposed of at midyear. Using the 200% DB method and the half-year convention, the annual depreciation percentages are 20%, 32%, 19.2%, 11.52%, 11.52%, and 5.76% of years 1 through 6 respectively. Notice that regardless of the month of purchase, only one-half of the normal double-declining-balance depreciation is taken in the year of purchase. The remaining cost basis is spread over a period extending through the year following the recovery life. Thus, depreciation for 5-year property actually extends over a 6-year period as illustrated in Example 17–4.

### EXAMPLE 17–4

For the loader of Example 17–1, find the annual depreciation and book value at the end of each year using the MACRS method.

#### *SOLUTION*

$$D_1 = 0.20 \times 50{,}000 = 10{,}000$$
$$D_2 = 0.32 \times 50{,}000 = 16{,}000$$
$$D_3 = 0.192 \times 50{,}000 = 9{,}600$$
$$D_4 = 0.1152 \times 50{,}000 = 5{,}760$$
$$D_5 = 0.1152 \times 50{,}000 = 5{,}760$$
$$D_6 = 0.0576 \times 50{,}000 = 2{,}880$$

| Year | Depreciation | Book Value (End of Period) |
|---|---|---|
| 0 | 0 | $50,000 |
| 1 | 10,000 | 40,000 |
| 2 | 16,000 | 24,000 |
| 3 | 9,600 | 14,400 |
| 4 | 5,760 | 8,640 |
| 5 | 5,760 | 2,880 |
| 6 | 2,880 | 0 |

### Investment Cost

*Investment cost* (or interest) represents the annual cost (converted to an hourly cost) of the capital invested in a machine. If borrowed funds are utilized, it is simply the interest charge on these funds. However, if the item of equipment is purchased from company assets, an interest rate should be charged equal to the rate of return on company investments. Thus investment cost is computed as the product of an interest rate multiplied by the value of the equipment, then converted to cost per hour. The true investment cost for a specific year of ownership is properly calculated using the average value of the equipment during that year. However, the average hourly investment cost may be more easily calculated using the value of the average investment over the life of the equipment given by Equation 17–6.

$$\text{Average investment} = \frac{\text{Initial cost} + \text{Salvage}}{2} \qquad \textbf{(17–6)}$$

The results obtained using Equation 17–6 should be sufficiently accurate for calculating average hourly owning costs over the life of the equipment. However, the reader is cautioned that the investment cost calculated in this manner is not the actual cost for a specific year. It will be too low in the early years of equipment life and too high in later years. Thus this method should not be used for making replacement decisions or for other purposes requiring precise investment cost for a particular year.

## Insurance, Tax, and Storage

*Insurance cost* represents the cost of fire, theft, accident, and liability insurance for the equipment. *Tax cost* represents the cost of property tax and licenses for the equipment. *Storage cost* represents the cost of rent and maintenance for equipment storage yards and facilities, the wages of guards and employees involved in handling equipment in and out of storage, and associated direct overhead.

The cost of insurance and taxes for each item of equipment may be known on an annual basis. In this case, these costs are simply divided by the hours of operation during the year to yield the cost per hour for these items. Storage costs are usually obtained on an annual basis for the entire equipment fleet. Insurance and tax cost may also be known on a fleet basis. It is then necessary to prorate these costs to each item. This is usually done by converting total annual cost to a percentage rate by dividing these costs by the total value of the equipment fleet. When this is done, the rate for insurance, tax, and storage may simply be added to the investment cost rate to calculate the annual cost of investment, tax, insurance, and storage.

## Total Owning Cost

Total equipment owning cost is found as the sum of depreciation, investment, insurance, tax, and storage. As mentioned earlier, the elements of owning cost are often known on an annual cost basis. However, whether the individual elements of owning cost are calculated on an annual-cost basis or on an hourly basis, total owning cost should be expressed as an hourly cost.

## Depreciation Bonus and Investment Credit

In order to stimulate the economy and encourage businesses to purchase new equipment, the U.S. government has sometimes created a *depreciation bonus* for equipment purchases. When in effect, such laws provide an immediate depreciation equal to a designated percentage of the cost of new equipment for the year in which the equipment is placed in service. The remaining portion of equipment cost is then depreciated according to normal depreciation procedures.

There are two major tax implications of equipment ownership. The first, depreciation, including the depreciation bonus, has already been discussed. The second is investment credit. *Investment credit* is another mechanism sometimes used by the U.S. government to encourage industry to modernize production facilities by providing a tax credit for the purchase of new equipment. When in effect, investment credit provides a direct credit against tax due, not merely a reduction in taxable income. The investment credit last authorized allowed a tax credit equal to 10% of the investment for the purchase of equipment classified as 5-year property and 6% for equipment classified as 3-year property. However, when investment credit is taken, the cost basis (amount used for cost recovery calculations) must be reduced or a smaller investment credit used. Current IRS regulations should always be consulted for up-to-date tax information, including investment credit procedures.

## Operating Costs

*Operating costs* are incurred only when equipment is operated. Therefore, costs vary with the amount of equipment use and job operating conditions. Operating costs include operators' wages, which are usually added as a separate item after other operating costs have been calculated.

The major elements of operating cost include:

- Fuel cost.
- Service cost.
- Repair cost.
- Tire cost.
- Cost of special items.
- Operators' wages.

### Fuel Cost

The *hourly cost of fuel* is simply fuel consumption per hour multiplied by the cost per unit of fuel (gallon or liter). Actual measurement of fuel consumption under similar job conditions provides the best estimate of fuel consumption. However, when historical data are not available, fuel consumption may be estimated from manufacturer's data or by the use of Table 17–1. Table 17–1 provides approximate fuel consumption factors in gallons per hour per horsepower for major types of equipment under light, average, and severe load conditions.

### Service Cost

*Service cost* represents the cost of oil, hydraulic fluids, grease, and filters as well as the labor required to perform routine maintenance service. Equipment manufacturers publish consumption data or average cost factors for oil, lubricants, and filters for their equipment under average conditions. Using such consumption data, multiply hourly consumption (adjusted for operating conditions) by cost per unit to obtain the hourly cost of consumable items. Service labor cost may be estimated based on prevailing wage rates and the planned maintenance program.

Since service cost is related to equipment size and severity of operating conditions, a rough estimate of service cost may be made based on the equipment's fuel cost (Table 17–2). For example, using Table 17–2 the hourly service cost of a scraper operated under severe conditions would be estimated at 50% of the hourly fuel cost.

**Table 17–1** Fuel consumption factors (gal/h/hp)

| Type of Equipment | Load Conditions* | | |
|---|---|---|---|
| | *Low* | *Average* | *Severe* |
| Clamshell and dragline | 0.024 | 0.030 | 0.036 |
| Compactor, self-propelled | 0.038 | 0.052 | 0.060 |
| Crane | 0.018 | 0.024 | 0.030 |
| Excavator, hoe, or shovel | 0.035 | 0.040 | 0.048 |
| Loader | | | |
| Track | 0.030 | 0.042 | 0.051 |
| Wheel | 0.024 | 0.036 | 0.047 |
| Motor grader | 0.025 | 0.035 | 0.047 |
| Scraper | 0.026 | 0.035 | 0.044 |
| Tractor | | | |
| Crawler | 0.028 | 0.037 | 0.046 |
| Wheel | 0.028 | 0.038 | 0.052 |
| Truck, off-highway | 0.014 | 0.020 | 0.029 |
| Wagon | 0.029 | 0.037 | 0.046 |

*Low, light work or considerable idling; average, normal load and operating conditions; severe, heavy work, little idling.

**Table 17–2** Service cost factors (% of hourly fuel cost)

| Operating Conditions | Service Cost Factor |
|---|---|
| Favorable | 20 |
| Average | 33 |
| Severe | 50 |

## Repair Cost

*Repair cost* represents the cost of all equipment repair and maintenance except for tire repair and replacement, routine service, and the replacement of high-wear items, such as ripper teeth. It should be noted that repair cost usually constitutes the largest item of operating expense for construction equipment. (See Section 19–6 for a discussion of equipment maintenance and repair procedures.)

*Lifetime repair cost* is usually estimated as a percentage of the equipment's initial cost less tires (Table 17–3). It is then necessary to convert lifetime repair cost to an hourly repair cost. This may be done simply by dividing lifetime repair cost by the expected equipment life in hours to yield an average hourly repair cost. Although this method is adequate for lifetime cost estimates, it is *not* valid for a particular year of equipment life. As you might expect, repair costs are typically low for new machines and rise as the equipment

**Table 17–3** Typical lifetime repair cost (% of initial cost less tires)

| Type of Equipment | Operating Conditions | | |
|---|---|---|---|
| | *Favorable* | *Average* | *Severe* |
| Clamshell and dragline | 40 | 60 | 80 |
| Compactor, self-propelled | 60 | 70 | 90 |
| Crane | 40 | 50 | 60 |
| Excavator, hoe, or shovel | 50 | 70 | 90 |
| Loader | | | |
| Track | 85 | 90 | 105 |
| Wheel | 50 | 60 | 75 |
| Motor grader | 45 | 50 | 55 |
| Scraper | 85 | 90 | 105 |
| Tractor | | | |
| Crawler | 85 | 90 | 95 |
| Wheel | 50 | 60 | 75 |
| Truck, off-highway | 70 | 80 | 90 |
| Wagon | 45 | 50 | 55 |

ages. Thus it is suggested that Equation 17–7 be used to obtain a more accurate estimate of repair cost during a particular year of equipment life.

$$\text{Hourly repair cost} = \frac{\text{Year digit}}{\text{Sum of years' digits}} \times \frac{\text{Lifetime repair cost}}{\text{Hours operated}} \quad \textbf{(17–7)}$$

This method of prorating repair costs is essentially the reverse of the sum-of-the-years'-digits method of depreciation explained earlier, because the year digit used in the numerator of the equation is now used in a normal sequence (i.e., 1 for the first year, 2 for the second year, etc.).

## EXAMPLE 17–5

Estimate the hourly repair cost for the first year of operation of a crawler tractor costing \$136,000 and having a 5-year life. Assume average operating conditions and 2000 hours of operation during the year.

### *SOLUTION*

$$\text{Lifetime repair cost factor} = 0.90 \qquad \text{(Table 17–3)}$$

$$\text{Lifetime repair cost} = 0.90 \times 136{,}000 = \$122{,}400$$

$$\text{Hourly repair cost} = \frac{1}{15} \times \frac{122{,}400}{2000} = \$4.08$$

**Table 17–4** Typical tire life (hours)

| | Operating Conditions | | |
|---|---|---|---|
| **Type of Equipment** | ***Favorable*** | ***Average*** | ***Severe*** |
| Dozers and loaders | 3,200 | 2,100 | 1,300 |
| Motor graders | 5,000 | 3,200 | 1,900 |
| Scrapers | | | |
| Conventional | 4,600 | 3,300 | 2,500 |
| Twin engine | 4,000 | 3,000 | 2,300 |
| Push-pull and elevating | 3,600 | 2,700 | 2,100 |
| Trucks and wagons | 3,500 | 2,100 | 1,100 |

### Tire Cost

Tire cost represents the cost of tire repair and replacement. Among operating costs for rubber-tired equipment, tire cost is usually exceeded only by repair cost. Tire cost is difficult to estimate because of the difficulty in estimating tire life. As always, historical data obtained under similar operating conditions provide the best basis for estimating tire life. However, Table 17–4 may be used as a guide to approximate tire life. Tire repair will add about 15% to tire replacement cost. Thus Equation 17–8 may be used to estimate tire repair and replacement cost.

$$\text{Tire cost} = 1.15 \times \frac{\text{Cost of a set of tires (\$)}}{\text{Expected tire life (h)}} \tag{17–8}$$

### Special Items

The cost of replacing high-wear items such as dozer, grader, and scraper blade cutting edges and end bits, as well as ripper tips, shanks, and shank protectors, should be calculated as a separate item of operating expense. As usual, unit cost is divided by expected life to yield cost per hour.

### Operator

The final item making up equipment operating cost is the operator's wage. Care must be taken to include all costs, such as worker's compensation insurance, Social Security taxes, overtime or premium pay, and fringe benefits, in the hourly wage figure.

## Total Owning and Operating Costs

After owning cost and operating cost have been calculated, these are totaled to yield total owning and operating cost per hour of operation. Although this cost may be used for estimating and for charging equipment costs to projects, notice that it does not include overhead or profit. Hence overhead and profit must be added to obtain an hourly rental rate if the equipment is to be rented to others.

## EXAMPLE 17–6

Calculate the expected hourly owning and operating cost for the second year of operation of the twin-engine scraper described below.

Cost delivered = $152,000
Tire cost = $12,000
Estimated life = 5 years
Salvage value = $16,000
Depreciation method = sum-of-the-years'-digits
Investment (interest) rate = 10%
Tax, insurance, and storage rate = 8%
Operating conditions = average
Rated power = 465 hp
Fuel price = $1.30/gal
Operator's wages = $32.00/h

### *SOLUTION*

**Owning Cost**

Depreciation cost:

$$D_2 = \frac{4}{15} \times (152{,}000 - 16{,}000 - 12{,}000) = \$33{,}067 \qquad \text{(Eq. 17–4)}$$

$$\text{Depreciation} = \frac{33{,}067}{2000} = \$16.53/\text{h}$$

Investment, tax, insurance, and storage cost:

Cost rate = Investment + tax, insurance, and storage = 10 + 8 = 18%

$$\text{Average investment} = \frac{152{,}000 + 16{,}000}{2} = \$84{,}000 \qquad \text{(Eq. 17–6)}$$

$$\text{Investment, tax, insurance, and storage} = \frac{84{,}000 \times 0.18}{2000} = \$7.56/\text{h}$$

Total owning cost = 16.53 + 7.56 = $24.09/h

**Operating Cost**

Fuel cost:

Estimated consumption = 0.035 × 465 = 16.3 gal/h (Table 17–1)

Fuel cost = 16.3 × 1.30 = $21.19/h

Service cost:

Service cost = 0.33 × 21.19 = \$7.06/h (Table 17–2)

Repair cost:

Lifetime repair cost = 0.90 × (152,000 − 12,000) = \$126,000 (Table 17–3)

$$\text{Repair cost} = \frac{2}{15} \times \frac{126{,}000}{2{,}000} = \$8.40/\text{h} \qquad \text{(Eq. 17–7)}$$

Tire cost:

Estimated tire life = 3000 h (Table 17–4)

$$\text{Tire cost} = 1.15 \times \frac{12{,}000}{3000} = \$4.60/\text{h}$$

Special item cost: None

Operator wages = \$32.00/h

Total operating cost = 21.19 + 7.06 + 8.40 + 4.60 + 32.00 = \$73.25/h

**Total O & O Cost**

Owning and operating cost = 24.09 + 73.25 = \$97.34/h

## 17–4 EQUIPMENT RENTAL

Historically there has been a growing use of rental equipment by contractors and subcontrators. For example, in a recent year the value of new equipment purchases totaled some \$20 to 25 billion while a like amount was spent on equipment rental. Over the same period, the value of used equipment purchases amounted to about \$15 billion. With the growing demand for rental equipment, several national equipment rental chains have been formed along with increased rental of equipment by major equipment manufacturers.

Since a rental agreement is a short-term arrangement (usually having a duration of less than 1 year) and no advance payment is normally required, rental equipment provides the contractor with great flexibility in meeting project requirements. In addition, the rental dealer commonly provides all equipment maintenance except for high-wear items. A rental-purchase option (RPO), which credits a portion of the rental payments to the purchase price if the option is exercised, may also be available.

A discussion of the rent-lease-buy decision process is contained in the following section.

## 17–5 THE RENT-LEASE-BUY DECISION

The question of whether it is better to purchase a piece of construction equipment rather than renting or leasing the item is difficult to answer. Leasing involves a commitment for a fixed period and may include a purchase option in which a portion of the lease payments is credited toward the purchase price if the option is exercised. In recent years, there has been a trend toward increased leasing and renting of construction equipment. Some of the reasons for this trend include the rising cost of equipment, rapid changes in equipment technology, and the wide fluctuation in the rate of demand for construction services. Some construction companies make it a policy to rent or lease all major items of equipment.

Advantages of equipment ownership include governmental tax incentives (investment credit and depreciation), full control of equipment resources, and availability of equipment when needed. However, leasing and renting require little initial capital (usually none for renting) and equipment costs are fully tax deductible as project expenses. A rational analysis of these alternatives for obtaining equipment is complex and must include cost under the expected conditions, as well as equipment availability and productivity. In general, purchasing equipment will result in the lowest hourly equipment cost if the equipment is properly maintained and fully utilized. However, as we noted earlier, equipment owning costs continue whether equipment is being utilized or sitting idle. Therefore, renting is usually least expensive for equipment with low utilization. Leasing is intermediate between the two and may be the best solution when capital is limited and equipment utilization is high. The lease-with-purchase option may provide an attractive opportunity to purchase the equipment at low cost after lease costs have been paid under a cost-type contract.

One approach to comparing the cost of buying, leasing, and renting an item of equipment is illustrated in Example 17–7. The analysis considers net after-tax cash flow, and its present value (present worth). The example is based on a method suggested by David J. Everhart of Caterpillar Inc. In making the calculations for present value, the present worth factors for midyear were used for yearly costs. To ensure that alternatives were compared under equal conditions, maintenance and repair costs were excluded from all calculations, although maintenance and repair is often included in rental rates. Notice that such an analysis depends on the specific tax rules applied (in this case, ACRS depreciation and 10% investment credit).

Under the particular circumstances of Example 17–7, buying is significantly less expensive than either leasing or renting if the equipment is fully utilized for the planned 5 years or 10,000 hours. However, notice that the cost difference is considerably smaller when considered on a present worth basis. Figure 17–1 illustrates the effect on hourly cost (present value) when equipment utilization declines. Since total capital cost is constant over the 5-year period for both leasing and buying, hourly capital cost increases as utilization declines for both of these alternatives. Since the 5-year cost of leasing is fixed, leasing is always more expensive than owning in these circumstances. Since the hourly cost for renting is constant, the hourly cost for renting and buying become equal at 42% utilization, or 4200 h of use. As utilization continues to decline, renting becomes even more advantageous.

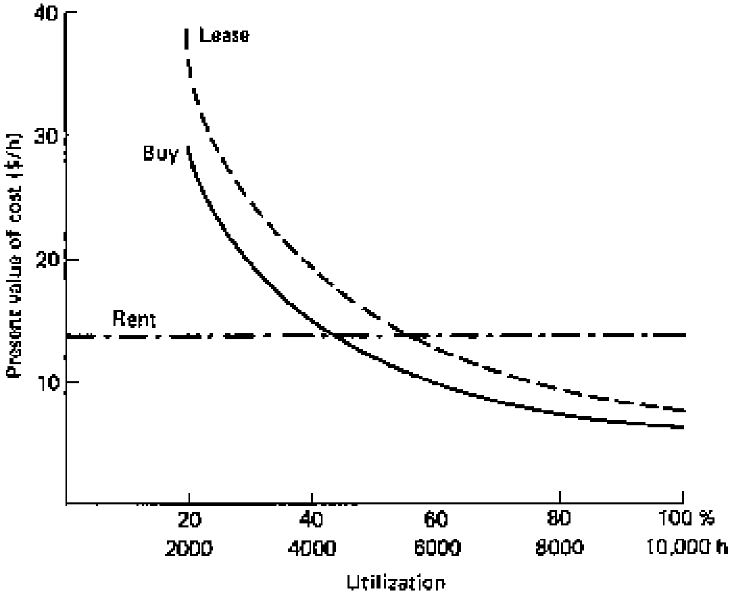



**Figure 17–1** Hourly cost of buying, leasing, and renting for Example 17–7.

## EXAMPLE 17–7

Analyze the cost of renting, leasing, and purchasing an item of construction equipment under the conditions described. Evaluate total net after-tax cash flow and its present value.

Basic assumptions:

Company's marginal tax rate = 46%

Company's after-tax rate of return = 8%

Planned equipment use = 2000 h/year for 5 years

Purchase assumptions:

Equipment cost = $150,000

Estimated resale value after 5 years = $60,000

Cost recovery method = 5-year ACRS (yearly depreciation of 15%, 22%, 21%, 21%, and 21%)

Investment credit (10%) = $15,000

Cost basis = $142,500 (cost less 1/2 investment credit)

Down payment (20%) = $30,000

Loan period = 36 months

Loan interest rate = 12%

Monthly payment = $3,985.72

Loan amortization:

| Year | Payments | To Principal | Interest |
|---|---|---|---|
| 1 | $47,828.64 | $35,329.91 | $12,498.73 |
| 2 | $47,828.64 | $39,810.61 | $ 8,018.03 |
| 3 | $47,828.64 | $44,859.48 | $ 2,969.16 |

Lease assumptions:

Term of lease = 5 years

Lease payment = $2,800 per month

Initial payment = 3 months in advance

Rental assumptions:

Rental period = 5 years, month to month

Rental rate = $5150 per month

Mid-year present worth factors (average of start-of-year and end-of-year values) for $i = 8\%$:

Initial (year 0) = 1.00000

Year 1 = 0.96297

Year 2 = 0.89164

Year 3 = 0.82559

Year 4 = 0.76443

Year 5 = 0.70781

Final (end of Year 5) = 0.68058

### *SOLUTION*

Values are rounded to nearest whole dollar.

***Purchase Cost ($)***

| | Initial | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Final | Total |
|---|---|---|---|---|---|---|---|---|
| Payments | 30,000 | 47,829 | 47,829 | 47,829 | 0 | 0 | 0 | 173,487 |
| Resale | 0 | 0 | 0 | 0 | 0 | 0 | (60,000) | (60,000) |
| Tax at resale | 0 | 0 | 0 | 0 | 0 | 0 | 27,600 | 27,600 |
| Tax savings—depreciation | 0 | (9,832) | (14,421) | (13,766) | (13,766) | (13,766) | 0 | (65,551) |
| Tax savings—interest | 0 | (5,749) | (3,688) | (1,366) | 0 | 0 | 0 | (10,803) |
| Investment credit | 0 | (15,000) | 0 | 0 | 0 | 0 | 0 | (15,000) |
| Net cost | 30,000 | 17,248 | 29,720 | 32,697 | (13,766) | (13,766) | (32,400) | 49,733 |
| Present value of net cost | 30,000 | 16,609 | 26,500 | 26,994 | (10,523) | (9,744) | (22,051) | 57,785 |

**Lease Cost ($)**

| | Initial | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Final | Total |
|---|---|---|---|---|---|---|---|---|
| Payments | 8,400 | 33,600 | 33,600 | 33,600 | 33,600 | 25,200 | 0 | 168,000 |
| Tax savings—payments | (3,864) | (15,456) | (15,456) | (15,456) | (15,456) | (11,592) | 0 | (77,280) |
| Net cost | 4,536 | 18,144 | 18,144 | 18,144 | 18,144 | 13,608 | 0 | 90,720 |
| Present value of net cost | 4,536 | 17,472 | 16,178 | 14,980 | 13,870 | 9,632 | 0 | 76,668 |

**Rental Cost ($)**

| | Initial | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Final | Total |
|---|---|---|---|---|---|---|---|---|
| Payments | 0 | 61,800 | 61,800 | 61,800 | 61,800 | 61,800 | 0 | 309,000 |
| Tax savings—payments | 0 | (28,428) | (28,428) | (28,428) | (28,428) | (28,428) | 0 | (142,140) |
| Net cost | 0 | 33,372 | 33,372 | 33,372 | 33,372 | 33,372 | 0 | 166,860 |
| Present value of net cost | 0 | 32,136 | 29,756 | 27,552 | 25,511 | 23,621 | 0 | 138,576 |

# 17–6 FINANCIAL MANAGEMENT OF CONSTRUCTION

The high rate of bankruptcy in the construction industry was pointed out in Chapter 1. Statistics compiled by Dun & Bradstreet on construction company failure in the United States indicate that the four major factors of inadequate financing, underestimating costs, inadequate cost accounting, and poor management account for over 80% of all failures. Thus the basis for the statement earlier in this chapter that "the financial management of a construction company is equally as important to company success as is its technical management" is apparent. In this section, we shall consider the basic principles of financial planning and cost control for construction projects.

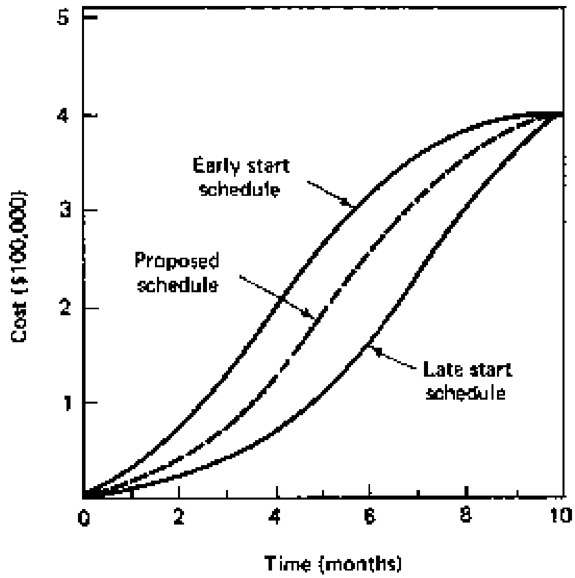
## Financial Planning

Financial planning for a construction project includes cost estimating prior to bidding or negotiating a contract, forecasting project income and expenditure (or cash flow), and determining the amount of work that a construction firm can safely undertake at one time.

Cost estimating for a project, as the name implies, involves estimating the total cost to carry out a construction project in accordance with the plans and specifications. Costs that must be considered include labor, equipment, materials, subcontracts and services, indirect (or job management) costs, and general overhead (off-site management and administration costs). Cost estimating for bidding purposes is discussed further in Chapter 18.

A finance schedule or cash flow schedule shows the planned rate of project expenditure and project income. It is common practice in the construction industry (as discussed in Chapter 18) for the owner to withhold payment for a percentage of the value of completed work (referred to as "retainage") as a guarantee until acceptance of the entire project. Even when periodic progress payments are made for the value of completed work, such payments (less retainage)

**Figure 17–2** Project cost versus time.




are not received until some time after the end of each accounting period. Hence project income will almost always lag behind project expenditure. The difference must be provided in cash from company assets or borrowed funds. The construction industry relies heavily on the use of borrowed funds for this purpose. Therefore, the finance charges associated with the use of such funds, as well as the maximum amount of funds available, are important considerations in the financial planning for a construction project. While a financial schedule may be developed manually from any type of project schedule, the use of CPM methods will facilitate preparation of a financial schedule. The use of CPM procedures also makes it easy to determine the effect on cash flow of different project schedules. Figure 17–2 shows a graph of project cost versus time for three different schedules: an early start schedule, a late start schedule, and a proposed schedule which is between these limits. Figure 17–3 illustrates a financial schedule showing project expenditures, value of completed work, and receipts for a particular project schedule.

Another important consideration in financial planning is the capacity of a firm to undertake additional projects. It has been found that most construction contracts require a minimum working capital of about 10% of the contract value. This working capital is needed to cover the difference between project income and project expenditures described above. The availability of working capital also affects the type of construction contract that might be appropriate for any additional work to be undertaken. When working capital is marginal, any additional work should be limited to low-risk projects such as cost-reimbursable contracts.

## Project Cost Control

Project cost control involves the measurement and recording of project costs and progress and a comparison between actual and planned performance. The principal objective of project cost control is to maximize profit while completing the project on time at a satisfactory level of quality. Proper cost control procedures will also result in the accumulation of historical cost data, which are invaluable in estimating and controlling future project costs.

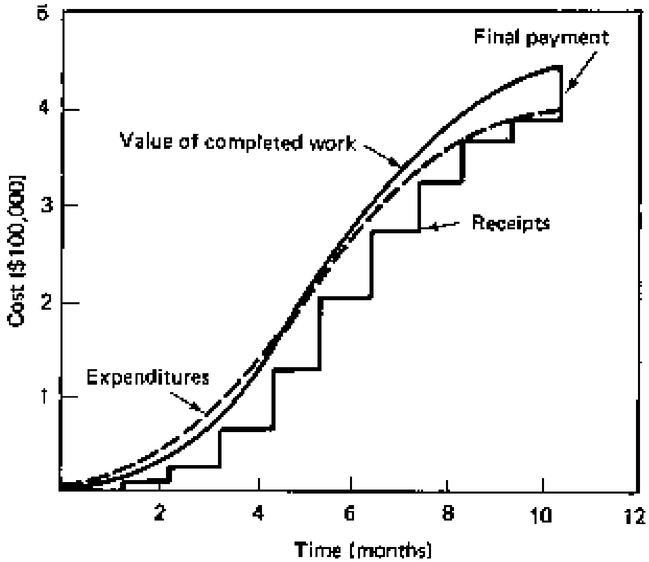



**Figure 17–3** Project financial schedule.

To carry out project cost control it is necessary to have a method for identifying cost and progress by project work element. The use of CPM procedures greatly simplifies this process, because major work items have already been identified as activities when preparing the project network diagram. A cost code system is usually combined with activity numbering to yield a complete system of project cost accounts. It is essential that the coding system permit charging all labor, material, equipment, and subcontract costs to the appropriate work item. Indirect and overhead costs for the project are usually assigned a separate cost code. Record-keeping requirements for foremen and other supervisors should be kept to a minimum consistent with meeting the objectives of accurate and timely reporting. Labor costs may be easily computed if time sheets are coded to identify the activity on which the time is expended. Plant and equipment costs may be similarly computed if a record is kept of the time spent on each activity by each machine. The cost of materials used may be based on priced delivery invoices coded to the appropriate activity. Since subcontract and service work may not be billed at the same interval at which costs are recorded, it may be necessary to apportion such costs to the appropriate activity at each costing interval.

To permit a comparison of project progress versus cost, it is necessary that progress reporting intervals coincide with cost reporting intervals. The interval between reports will depend on the nature and importance of the project. Monthly intervals are commonly used as the basis for requesting progress payments. However, construction management may desire weekly or even daily cost and performance reports for the control of critical construction projects.

A number of systems have been developed for relating project cost and progress and for forecasting time and cost to project completion. One such system, called PERT/Cost, has been developed by the U.S. government and has been extensively used by government agencies for project control. Figure 17–4 illustrates a PERT/Cost report for a project. Note that

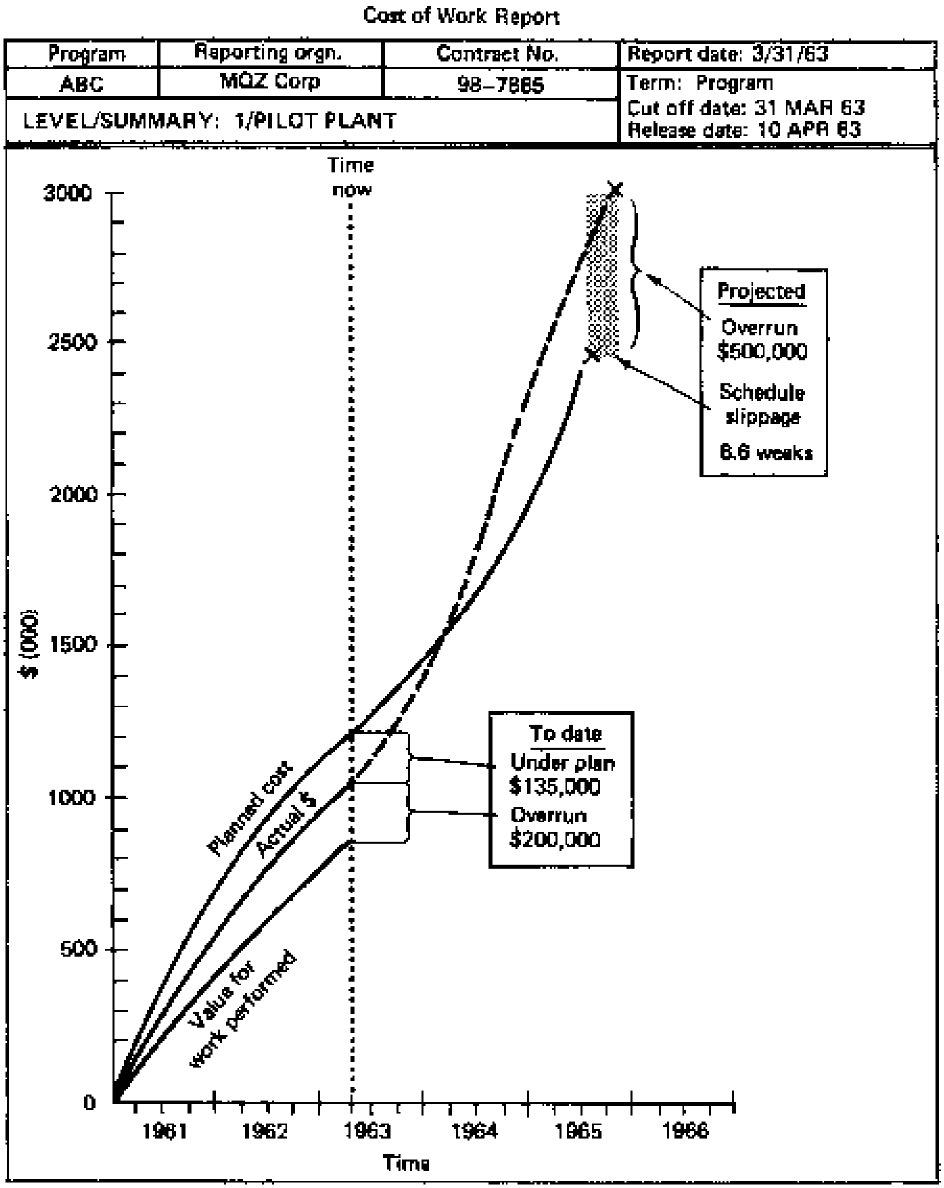



**Figure 17-4** PERT/Cost progress and cost report. (PERT Coordinating Group, U.S. Government)

project progress and cost to date are graphed, together with the value of the work completed to date and projections of final completion time and cost. While PERT/Cost itself has not been widely used in the construction industry, systems have been developed within the construction industry which offer similar capabilities tailored to the construction environment.

## PROBLEMS

1. For the project whose data are shown here, plot the cumulative project expenditures, value of work, and progress payments received versus time. What is the contractor's maximum negative cash flow and when does it occur? Progress payments are calculated at the end of each month and received the middle of the following month. Retainage is 10% until project completion. Assume that final project payment, including released retainage, is received the middle of the month following project completion.

| Month | End-of-Month Cumulative Expenditures | Value of Work |
|---|---|---|
| 1 | $14,400 | $9,600 |
| 2 | 28,800 | 24,000 |
| 3 | 49,200 | 45,000 |
| 4 | 72,000 | 69,000 |
| 5 | 102,000 | 76,800 |
| 6 | 144,000 | 144,000 |
| 7 | 210,000 | 216,000 |
| 8 | 276,000 | 288,000 |
| 9 | 288,000 | 300,000 |
| 10 | 294,000 | 312,000 |
| 11 | 295,200 | 321,600 |
| 12 | 296,400 | 330,000 |

2. Analyze the cost of renting, leasing, and purchasing a backhoe loader using the data given here. Evaluate after-tax cash flow and its present value.

Basic assumptions:

Marginal tax rate = 46%

After-tax rate of return = 7%

Planned equipment use = 2000 h/year for 5 years

Present value factors ($i$ = 7%)

| Year | P/F |
|---|---|
| 1 | 0.967 |
| 2 | 0.904 |
| 3 | 0.845 |
| 4 | 0.790 |
| 5 | 0.738 |
| End of 5 | 0.713 |

Purchase assumptions:

Cost = $ 100,000

Estimated resale value after 5 years = $40,000

Cost recovery method = 5-year MACRS

Down payment = $20,000

Loan terms = $80,000, 12%, 36 months = $2657.20/month

Interest payments:

| Year | Interest |
|---|---|
| 1 | $8333 |
| 2 | 5346 |
| 3 | 1979 |

Lease assumptions:

Term of lease = 5 years

Lease payments = $1850/month

Initial payment = 3 months in advance

Rental assumptions:

Rental period = 5 years, month to month

Rental rate = $3375/month

3. Find the hourly operating cost for the first year of life of the tractor of Problem 6. Use the following additional data.

Rated power = 300 hp (224 kW)

Fuel price = $1.50/gal ($0.396/ℓ)

Load conditions = average

Operating conditions = average

Hours operated = 2000 h/year

Operator cost = $20.00/h

4. Determine the probable average cost per hour over the life of the equipment for owning and operating a wheel loader under the conditions listed below. Use the straight-line method of depreciation.

Operator cost = $20.00/h

Operating conditions = average

Delivered price = $70,000

Cost of a set of tires = $4000

Expected loader life = 5 years

Hours operated = 2000 h/year

Estimated salvage value = $32,000

Fuel cost = \$1.00/gal (\$0.26/ℓ)

Loader horsepower = 120 hp (89.5 kW)

Rate for interest, tax, insurance, and storage = 15%

5. What are the advantages and disadvantages of equipment rental compared with equipment purchase?
6. A crawler tractor costs \$250,000, has an estimated salvage value of \$50,000, and has a 5-year life. Find the annual depreciation and book value at the end of each year using the double-declining-balance method of depreciation.
7. For the tractor of Problem 6, find the annual depreciation and book value at the end of each year using the sum-of-the-years'-digits method of depreciation.
8. Calculate the average hourly owning cost for the first year of life of the tractor of Problem 6 if the tractor is operated 2000 hours during the year. The rate for interest, taxes, and insurance is 12%, and the rate for storage and miscellaneous costs is 2%. Use the sum-of-the-years'-digits method of depreciation.
9. What factors have been identified as the major causes of construction company failure?
10. Develop a computer program to determine the probable average hourly owning and operating cost of a piece of construction equipment over the life of the equipment. Use the straight-line method of depreciation. Solve Problem 4 using your program.

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