Engineering Costs
Engineering Costs and Cost Estimating

Engineering Costs

An engineering economic analysis may involve many types of costs. Here is a list of cost types, including definitions and examples.

A **fixed cost** is constant, independent of the output or activity level. The annual cost of property taxes for a production facility is a fixed cost, independent of the production level and number of employees.

A **variable cost** does depend on the output or activity level. The raw material cost for a production facility is a variable cost because it varies directly with the level of production.

The **total cost** to provide a product or service over some period of time or production volume is the total fixed cost plus the total variable cost, where:

Total variable cost = (Variable cost per unit) (Total number of units)

A **marginal cost** is the variable cost associated with one additional unit of output or activity. A direct labor marginal cost of $2.50 to produce one additional production unit is an example marginal cost.

The **average cost** is the total cost of an output or activity divided by the total output or activity in units. If the total direct cost of producing 400,000 is $3.2 million, then the average total direct cost per unit is $8.00.

The **breakeven point** is the output level at which total revenue is equal to total cost. It can be calculated as follows:

BEP = FC/(SP - VC)

where
BEP = breakeven point
FC = fixed costs
SP = selling price per unit
VC = variable cost per unit

A **sunk cost** is a past cost that cannot be changed and is therefore irrelevant in engineering economic analysis. One exception is that the cost basis of an asset installed in the past will likely affect the depreciation schedule that is part of an after-tax economic analysis. Although depreciation is not a cash flow, it does affect income tax cash flow. Three years ago, an engineering student purchased a notebook PC for $2,800. The student now wishes to sell the computer. The $2,800 initial cost is an irrelevant, sunk cost that should play no part in how the student establishes the minimum selling price for the PC.

An **opportunity cost** is the cost associated with an opportunity that is declined. It represents the benefit that would have been received if the opportunity were accepted. Suppose a product distributor decides to construct a new distribution center instead of leasing a building. Leasing a building immediately would have resulted in a $12,000 product distribution cost savings during the next 6 months while the new warehouse is being constructed. By forgoing the warehouse leasing alternative, the distributor experiences an opportunity cost of $12,000.

A **recurring cost** is one that occurs at regular intervals and is anticipated. The cost to provide electricity to a production facility is a recurring cost.

A **nonrecurring cost** is one that occurs at irregular intervals and is not generally anticipated. The cost to replace a company vehicle damaged beyond repair in an accident is a nonrecurring cost.

An **incremental cost** represents the difference between some type of cost for two alternatives. Suppose that A and B are mutually exclusive investment alternatives. If A has an initial cost of $10,000 while B has an initial cost of $12,000, the incremental initial cost of (B - A) is $2,000. In engineering economic analysis we focus on the differences among alternatives, thus incremental costs play a significant role in such analyses.

A **cash cost** is a cash transaction, or cash flow. If a company purchases an asset, it realizes a cash cost.

A **book cost** is not a cash flow, but it is an accounting entry that represents some change in value. When a company records a depreciation charge of $4 million in a tax year, no money changes hands. However, the company is saying in effect that the market value of its physical, depreciable assets has decreased by $4 million during the year.

Life-cycle costs refer to costs that occur over the various phases of a product or service life cycle, from needs assessment through design, production, and operation to decline and retirement.

Question 1.

A company produces a single, high-volume product. One year its production volume was 780,000 units, its fixed costs were $3.2 million and its variable costs were $16 per unit. What was the company's total cost for the year?

A $3,200,000

B $3,200,016

C $12,480,000

D $15,680,000

Cost Estimating and Estimating Models

Engineering Costs and Cost Estimating

Cost Estimating and Estimating Models

Engineering economic analysis involves present and future economic factors; thus, it is critical to obtain reliable estimates of future costs, benefits and other economic parameters. Several methods to do so are discussed here.

Estimates can be rough estimates, semi detailed estimates, or detailed estimates, depending on the needs for the estimates.

A characteristic of cost estimates is that errors in estimating are typically nonsymmetric because costs are more likely to be underestimated than overestimated.

Difficulties in developing cost estimates arise from such conditions as one-of-a-kind estimates, resource availability, and estimator expertise. Generally the quality of a cost estimate increases as the resources allocated to developing the estimate increase. The benefits expected from improving a cost estimate should outweigh the cost of devoting additional resources to the estimate improvement.

Several models are available for developing cost (or benefit) estimates.

The **per-unit model** is a simple but useful model in which a cost estimate is made for a single unit, then the total cost estimate results from multiplying the estimated cost per unit times the number of units.

The **segmenting model** partitions the total estimation task into segments. Each segment is estimated, then the segment estimates are combined for the total cost estimate.

Cost indexes can be used to account for historical changes in costs. The widely reported Consumer Price Index (CPI) is an example. Cost index data are available from a variety of sources. Suppose A is a time point in the past and B is the current time. Let IV_A denote the index value at time A and IV_B denote the current index value for the cost estimate of interest. To estimate the current cost based on the cost at time A, use the equation:

Cost at time B = (Cost at time A) (IV_B / IV_A).

The **power-sizing model** accounts explicitly for economies of scale. For example, the cost of constructing a six-story building will typically be less than double the construction cost of a comparable three-story building. To estimate the cost of B based on the cost of comparable item A, use the equation

Cost of B = (Cost of A) [("Size" of B) / ("Size" of A)] ^{x}

where x is the appropriate power-sizing exponent, available from a variety of sources. An economy of scale is indicated by an exponent less than 1.0 An exponent of 1.0 indicates no economy of scale, and an exponent greater than 1.0 indicates a diseconomy of scale.

"Size" is used here in a general sense to indicate physical size, capacity, or some other appropriate comparison unit.

Learning curve cost estimating is based on the assumption that as a particular task is repeated, the operator systematically becomes quicker at performing the task. In particular, the model is based on the assumption that the time required to complete the task for production unit 2x is a fixed percentage of the time required for production unit x for all positive, integer x. The learning curve slope indicates "how fast" learning occurs. For example, a learning curve rate of 70% represents much faster learning than a rate of 90%. If an operator exhibits learning on a certain task at a rate of 70%, the time required to complete production unit 50, for example, is only 70% of the time required to complete unit 25.

Let b = learning curve exponent
= log (learning curve rate in decimal form) / log 2.0

Then T_N = time estimate for unit N (N = 1, 2, ...)
= (T_1) $(N)^b$

where T_1 is the time required for unit 1.

As an example: A learning curve rate is 70%, the operator’s time for the first^t unit is 65 seconds. What is the operator’s time for the 50th unit?

b = log (0.70) / log 2.0 = -0.5145

$T_{100} = T_1 * (50)$ ^ b = 65 * (50) ^ -0.5145 = 8.68 min

Question 1.

The cost to provide workplace safety training to a new employee is estimated at $600 for a particular manufacturer. Use the per-unit cost estimating model to estimate the annual workplace safety training cost if an estimated 30 new employees are hired annually.

A $600

B $1,800

C $6,000

D $18,000

You multiplied the per-unit cost, $600 per new employee, by the number of new employees, 30.

Choose an option below.

Cash Flow Diagrams

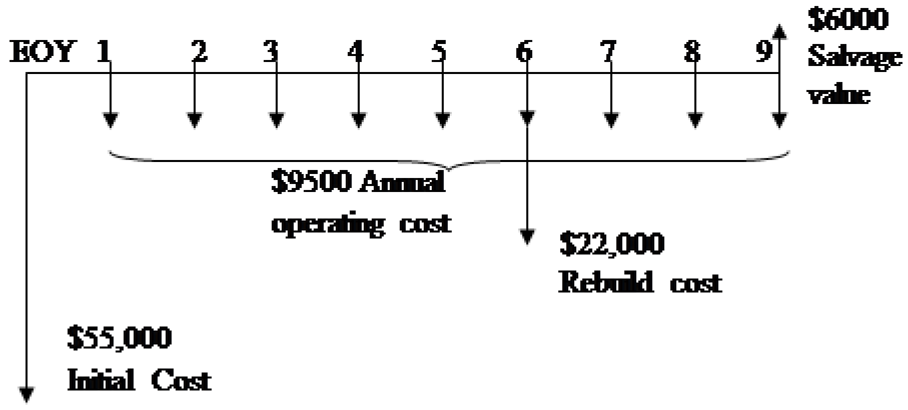
Engineering Costs and Cost Estimating

Cash Flow Diagrams

Cash flow diagrams visually represent income and expenses over some time interval. The diagram consists of a horizontal line with markers at a series of time intervals. At appropriate times, expenses and costs are shown.

Note that it is customary to take cash flows during a year at the end of the year, or EOY (end-of-year). There are certain cash flows for which this is not appropriate and must be handled differently. The most common would be rent, which is normally taken at the beginning of a cash period. There are other pre-paid flows which are handled similarly.

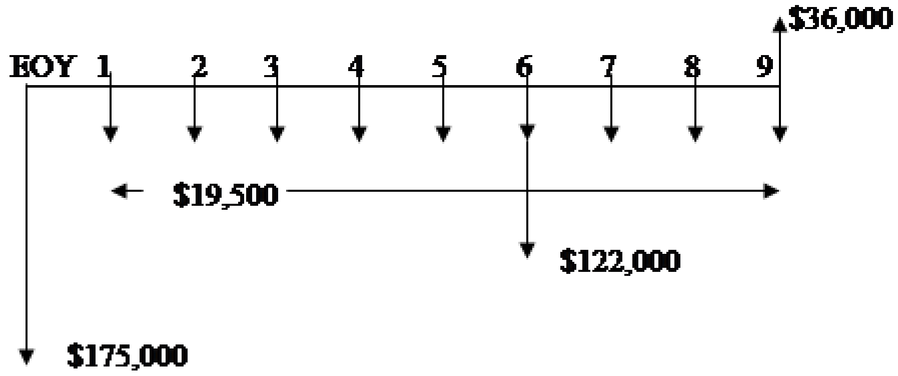
For example, consider a truck that is going to be purchased for $55,000. It will cost $9,500 each year to operate including fuel and maintenance. It will need to have its engine rebuilt in 6 years for a cost of $22,000 and it will be sold at year 9 for $6,000. Here is the cash flow diagram:



Note that the initial cost, the purchase price, is recorded at the beginning of Year 1, sometimes referred to as end-of-year 0, or EOY 0. Also, operating and maintenance costs actually will occur during a year, but they are recorded at EOY, and so forth.

Question 1.

Given the cash flow diagram below, answer the questions by clicking on the correct answer. Note that there are several questions; as you correctly answer each, you go to the next question. (Note that these questions will take more time than previous questions did.)



1.What is the initial cost of this new machine?

1.A $122,000

1.B $19,500

1.C $175,000

1.D $36,000

Computing Cash Flows

Interest and Equivalence

Computing Cash Flows

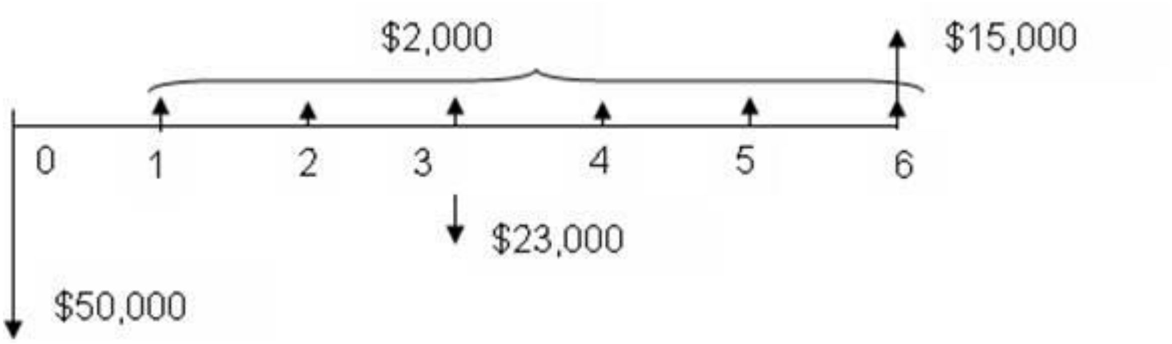
One way we model financial processes is with cash flow diagrams.

These are horizontal lines that represent time. At various points we place arrows pointing up or down to represent cash going out (payments) or coming in (revenues). Usually, payments are represented as negative, down-pointing, and revenues as positive, up-pointing. However, you will see other representations; within a single financial process you must be consistent. (Remember that EOY means End-Of-Year.)

Consider several cash flows; do not be concerned with why they are occurring:

At time 0 (beginning of the first year)	$50,000 is paid out
At EOY 3	$23,000 is paid out
At EOY 6	$15,000 is received
Every year starting at EOY 1	$2,000 is received

Here is the way the Cash Flow Diagram will look:



We can see that in some years the cash flow is simple: At EOY 1 the cash flow is positive — that is, revenue — and equals $2,000. In other years, there may be more than one contributor to the cash flow: At EPY 3, the cash flow is composed of the $2,000 annual amount minus the $23,000 one-time expense. Thus, the total cash flow at EOY 3 is $21,000 negative.

What is the cash flow at EOY 6?

Scroll down to check your answer.

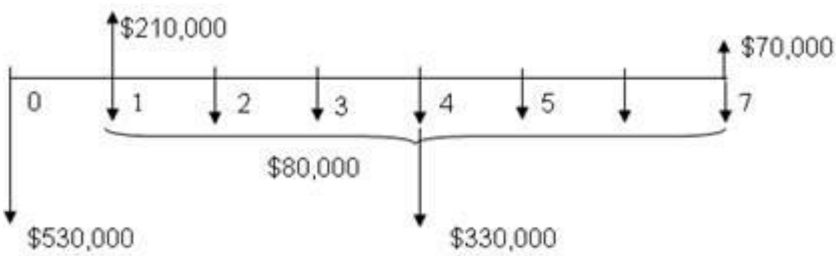
Did you get $17,000? Note that at EOY 6, there is the annual received amount of $2000 plus the one-time receipt of $15,000.

Question 1.

The Huge Sheet Printing Company is considering purchasing a new web printing press, and they have determined the following cash items:

Initial Cost:	$530,000
Annual Revenue	210,000
Annual Maintenance	80,000
Rebuild Expenses EOY 4	330,000
Salvage Value EOY 7	70,000

Here is a possible cash-flow diagram. Select the answer below that describes this diagram.



A The $210,000 is shown in the wrong year.

B The $70,000 should be pointing down.

C The $210,000 must be shown for years 1 through 7.

D The $80,000 arrows must point up.

Effective interest rate is the one which caters the compounding periods during a payment plan. ... The **nominal interest rate** is the periodic **interest rate** times the number of periods per year. For example, a **nominal** annual **interest rate** of 12% based on monthly compounding means a 1% **interest rate** per month (compounded)

Single Payment Compound Interest Formulas (other periods)

Interest and Equivalence

Single payment compound interest formulas (other periods)

If the interest period and compounding period are not stated, then the interest rate is understood to be annual with annual compounding. Examples:

"12% interest" means that the interest rate is 12% per year, compounded annually.

"12% interest compounded monthly" means that the interest rate is 12% per year (not 12% per month), compounded monthly. Thus, the interest rate is 1% (12% / 12) per month.

"1% interest per month compounded monthly" is unambiguous.

When the compounding period is not annual, problems must be solved in terms of the compounding period, not years.

Example: If $100 is invested at 6% interest, compounded monthly, then the future value of this investment after 4 years is:

$F = P (1 + i)^{n} = \$100 (1 + 0.005)^{48}$

$= \$100 (1.005)^{48} = \$100 (1.2705) = \$127.05$

Note that the interest rate used above is (6% / 12) = 0.5% per month = 0.005 per month, and that the number of periods used is 48 (months), not 4 (years).

Question 1.

Use interest tables. Suppose that $1,000 is invested for 4 years at an interest rate of 12%, compounded quarterly. How much will be in the account at the end of 4 years?

Choose an answer by clicking on one of the letters below, or click on "Review topic" if needed.

A F = $1,000 (F/P,12%,4) = $1,000 (1.574) = $1,574

B F = $1,000 (F/P,12%,16) = $1,000 (6.130) = $6,130

C F = $1,000 (F/P,3%,4) = $1,000 (1.126) = $1,126

D F = $1,000 (F/P,3%,16) = $1,000 (1.605) = $1,605

Single Payment Compound Interest (solving for i or n)

Interest and Equivalence

Single payment compound interest (solving for i or n)

The single payment compound interest formula

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

or single payment interest table factors can be used to solve for unknown i or n.

Example: A $100 investment now in an account that pays compound interest annually will be worth $250 at a point exactly 31 years from now. What annual interest rate does this account pay?

Solving the equation for i:

$$250 = 100 (1 + i)^{31}$$

$$1 + i = (250/100)^{1/31} = 1.0299$$

yields an answer of 3%.

Or, using interest tables, note that i = 3%, because (F/P,3%,31) = 2.500.

Salvage value is the book **value** of an asset after all depreciation has been fully expensed. The **salvage value** of an asset is based on what a company expects to receive in exchange for selling or parting out the asset at the end of its useful life

Useful Lives Different from the Analysis Period and Multiple Alternatives

Present Worth Analysis

Useful Lives Different from the Analysis Period and Multiple Alternatives

Go to questions covering topic below

When alternatives under consideration have unequal lives, one approach is to use an analysis period that is the least common multiple of the alternative lives. For example, if X has a 3-year life and Y has a 4-year life, then a 12-year analysis period is used. In such cases, we assume that each alternative can be identically replaced at the end of its service life.

When there are more than two alternatives, the analysis techniques are unchanged. Calculate the PW or NPW, taking into account possible different time horizons and compare the values. Here is a situation with three alternatives having different useful lives.

Example: A company with a MARR of 10% plans to install one of three production machines (X, Y or Z) that provide equivalent service (same benefits). Doing nothing is not an option. The machines have zero salvage values at the end of their lives. The machines are expected to have the same annual operating and maintenance (O&M) costs, although their initial costs and service lives differ, as follows:

Machine:	X	Y	Z
Initial cost ($)	25,000	30,000	50,000
Service life (years)	3	4	6

Select a 12-year analysis period, the least common multiple of 3, 4 and 6. The appropriate criterion is to select the machine with the lowest PW (cost) over the 12-year analysis period, assuming that X is identically replaced at EOY 3, EOY 6 and EOY 9; that Y is identically replaced at EOY 4 and EOY 8; and Z is identically replaced EOY 6.

X: PW (cost) = \$25k + \$25k (P/F,10%,3)
+ \$25k (P/F,10%,6) + \$25k (P/F,10%,9)

PW (cost) = \$25k [1 + (P/F,10%,3) + (P/F,10%,6) + (P/F,10%,9)]

PW (cost) = \$25k [1 + 0.7513 + 0.5645 + 0.4241]
= \$25k (2.7399) = <u>\$68,498</u>

Y: PW (cost) = \$30k [1 + (P/F,10%,4) + (P/F,10%,8)]
= \$30k [1 + 0.6830 + 0.4665]

PW (cost) = \$30k (2.1495) = <u>\$64,485</u>

Z: PW (cost) = \$50k [1 + (P/F,10%,6)]
= \$50k [1 + 0.5645] = \$50k (1.5645) = <u>\$78,225</u>

Select machine Y because it has the lowest PW (cost).

Another case of multiple alternatives is where there is a fixed horizon and the alternative may not have lives that match that horizon.

Consider the case where alternative X has a 6-year life and alternative Y has a 4-year life. You need the capability for 6 years. MARR is 10%.

To compare these two cases, use a 6 year horizon and plan on replacing Y at the end of 4 years. However, since the replacement Y will be used for only 2 years, it is necessary to also know the 2-year salvage value for Y.

The data for the two alternatives are as follows (just including initial cost and salvage values:

	Alternative X	Alternative Y
Initial cost	\$15,000	\$22,000
Life	4 years	6 years
Salvage Value at Life	\$2,000	\$1,000
Salvage value at 2 years	\$4,000	N/A

In this case, Alternative X will be replaced at 4 years and the replacement sold 2 years later. Alternative Y will be sold at 6 years. The PWs for the two cases are:

X: PW (cost) = \$16k + (\$16k - \$2k)(P/F,10%,4) - \$4k (P/F,10%,6)
= \$16k + (\$14k)(.6830) - \$4k (.5645) = -\$23.3k

Y: PW (cost) = \$22k - \$1k (P/F,10%,6)
= \$22k - \$1k (.5645) = -\$21.4k

Question 1.

A company with a MARR of 15% must install one of two production machines that provide equivalent service (same benefits).

Machine X has an initial cost of $40,000 with an annual operating and maintenance (O&M) cost of $30,000 and a salvage value of $5,000 after its 5-year life.

Machine Y has an initial cost of $60,000 with an annual O&M cost of $20,000 and a salvage value of $12,000 after its 10-year life.

Which choice below gives the correct PW (costs) equation for machine X over the comparative analysis period?

A PW (costs) = $40k + $30k (P/A,15%,5) - $5k (P/F,15%,5)

B PW (costs) = $40k + $40k (P/F,15%,5) + $30k (P/A,15%,10) - $5k (P/F,15%,5)

C PW (costs) = $40k + $40k (P/F,15%,5) - $5k (P/F,15%,5) -$5k (P/F,15%,10)

D PW (costs) = $40k + $40k (P/F,15%,5) + $30k (P/A,15%,10) - $5k (P/F,15%,5) - $5k (P/F,15%,10)