

KNOWLEDGE INSTITUTE OF TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

Engineering Economics

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MG6863 ENGINEERING ECONOMICS

UNIT I INTRODUCTION TO ECONOMICS

Introduction to Economics- Flow in an economy, Law of supply and demand, Concept of Engineering Economics – Engineering efficiency, Economic efficiency, Scope of engineering economics- Element of costs, Marginal cost, Marginal Revenue, Sunk cost, Opportunity cost, Break-even analysis- V ratio, Elementary economic Analysis – Material selection for product Design selection for a product, Process planning.

INTRODUCTION TO ECONOMICS

- Efficient functioning of any business organization would enable it to provide goods/services at a lower price.
- In the process of managing organizations, the managers at different levels should take appropriate economic decisions which will help in minimizing investment, operating and maintenance expenditures besides increasing the revenue, savings and such other gains of the organization.

Economics

Economics is the science that deals with the production and consumption of goods and services and the distribution and rendering of these for human welfare.

The following are the economic goals.

- A high level of employment
- Price stability
- Efficiency
- An equitable distribution of income
- Growth

Flow in economy

The flow of goods, services, resources and money payments in a simple economy

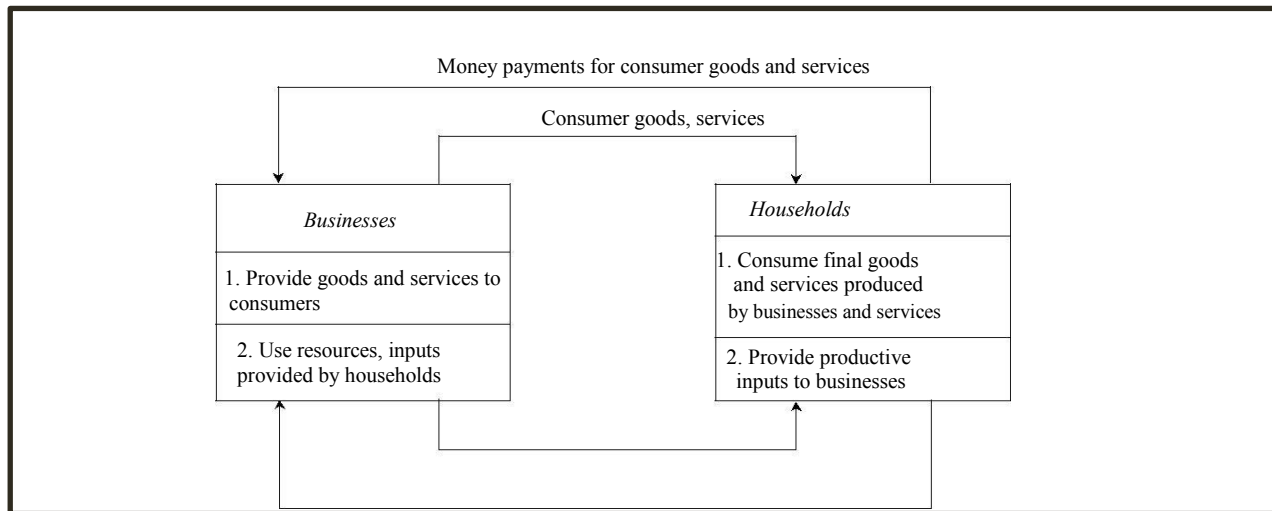
Households and businesses are the two major entities in a simple economy.

Business organizations use various economic resources like land, labour and capital which are provided by households to produce consumer goods and services which will be used by them.

Business organizations make payment of money to the households for receiving various resources.

The households in turn make payment of money to business organizations for receiving consumer goods and services.

This cycle shows the interdependence between the two major entities in a simple economy.



Laws of supply and demand

Laws of supply

states that the quantity of a commodity supplied varies directly with the price, other determinants of supply remaining constant.

If the cost of inputs increases, then naturally, the cost of the product will go up. In such a situation, at the prevailing price of the product the profit margin per unit will be less.

The producers will then reduce the production quantity, which in turn will affect the supply of the product.

Examples: Seasonal products

Factors influencing supply

The shape of the supply curve is affected by the following factors:

- ✓ Cost of the inputs
- ✓ Technology
- ✓ Weather
- ✓ Prices of related goods

Law of demand

states that other things being equal demand when price falls and contracts when price rises.

Market demand is the total quantity demanded by all the purchasers together.

Elasticity of Demand - Elasticity of demand may be defined as the degree of responsiveness of quantity demanded to a Change in price.

Price

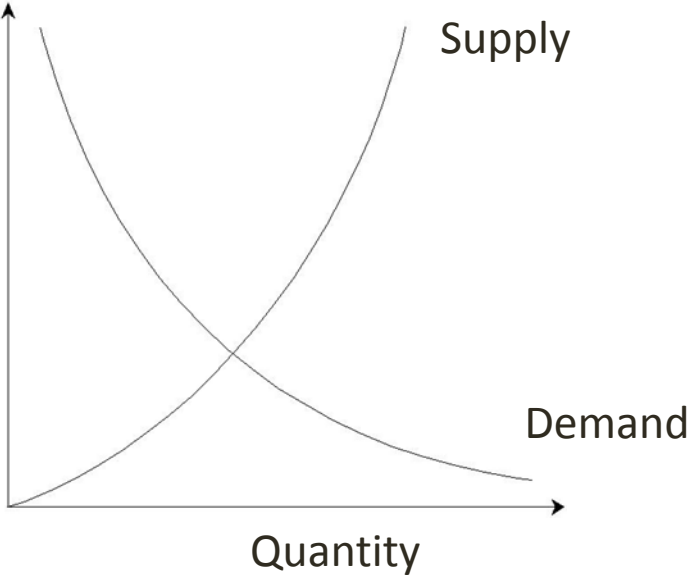


Fig. Demand and supply curve

From Fig. it is clear that when there is a decrease in the price of a product, the demand for the product increases and its supply decreases.

Also, the product is more in demand and hence the demand of the product increases.

At the same time, lowering of the price of the product makes the producers restrain from releasing more quantities of the product in the market.

Hence, the supply of the product is decreased. The point of intersection of the supply curve and the demand curve is known as the equilibrium point.

At the price corresponding to this point, the quantity of supply is equal to the quantity of demand. Hence, this point is called the equilibrium point.

Factors influencing demand

The shape of the demand curve is influenced by the following factors:

- ✓ Income of the people
- ✓ Prices of related goods
- ✓ Tastes of consumers

Concept of Engineering Economics

- ✓ Science is a field of study where the basic principles of different physical systems are formulated and tested.
- ✓ Engineering is the application of science. It establishes varied application systems based on different scientific principles.
- ✓ From the discussions in the previous section, it is clear that price has a major role in deciding the demand and supply of a product.
- ✓ Hence, from the organization's point of view, efficient and effective functioning of the organization would certainly help it to provide goods/services at a lower cost which in turn will enable it to fix a lower price for its goods or services.
- ✓ **The following section discusses the different types of efficiency and their impact on the operation of businesses and the definition and scope of engineering economics.**

Types of Efficiency

Efficiency of a system is generally defined as the ratio of its output to input. The efficiency can be classified into technical efficiency and economic efficiency.

1. Technical efficiency

It is the ratio of the output to input of a physical system. The physical system may be a diesel engine, a machine working in a shop floor, a furnace (heating system), etc.

$$\text{Technical efficiency (\%)} = \frac{\text{Output}}{\text{Input}} \times 100$$

The technical efficiency of a diesel engine is as follows:

$$\text{Technical efficiency (\%)} = \frac{\text{Heat equivalent of mechanical energy produced}}{\text{Heat equivalent of fuel used}} \times 100$$

In practice, technical efficiency can never be more than 100%.

2. Economic efficiency

Economic efficiency is the ratio of output to input of a business system.

$$\text{Economic efficiency (\%)} = \frac{\text{Output} \times 100}{\text{Input}} = \frac{\text{Worth} \times 100}{\text{Cost}}$$

‘Worth’ is the annual revenue generated by way of operating the business and ‘cost’ is the total annual expenses incurred in carrying out the business.

For the survival and growth of any business, the economic efficiency should be more than 100%.

Economic efficiency is also called 'productivity'. There are several ways of improving productivity.

- ✓ Increased output for the same input
- ✓ Decreased input for the same output
- ✓ By a proportionate increase in the output which is more than the proportionate increase in the input
- ✓ By a proportionate decrease in the input which is more than the proportionate decrease in the output
- ✓ Through simultaneous increase in the output with decrease in the input.

Scope of Engineering Economics

As stated earlier, efficient functioning of any business organization would enable it to provide goods/services at a lower price.

Definition

Engineering economics deals with the methods that enable one to take economic decisions towards minimizing costs and/or maximizing benefits to business organizations.

Scope

Elementary economic analysis,

Interest formulae,

Bases for comparing alternatives,

Present worth method,

Future worth method,

Annual equivalent method,

Rate of return method,

Replacement analysis,

Depreciation,

Evaluation of public alternatives,

Inflation adjusted investment decisions,

Make or buy decisions, Inventory control, project management, Value engineering, and linear programming.

Elements of Costs

Cost can be broadly classified into *variable cost* and *overhead cost*. Variable cost varies with the volume of production while overhead cost is fixed, irrespective of the production volume.

- ✓ Variable cost

direct material cost, direct labour cost, and direct expenses.

- ✓ overhead cost

factory overhead, administration overhead, selling overhead, and distribution overhead.

The selling price of a product is derived as shown below:

(a) Direct material costs + Direct labour costs + Direct expenses =
Prime cost

(b) Prime cost + Factory overhead = Factory cost

(c) Factory cost + Office and administrative overhead
Costs of production

(d) Cost of production + Opening finished stock – Closing finished
stock

Cost of goods sold

(e) $\text{Cost of goods sold} + \text{Selling and distribution overhead} = \text{Cost of sales}$

(f) $\text{Cost of sales} + \text{Profit} = \text{Sales}$

(g) $\text{Sales} / \text{Quantity sold} = \text{Selling price per unit}$

In the above calculations, if the opening finished stock is equal to the closing finished stock, then the cost of production is equal to the cost of goods sold.

(e) $\text{Cost of goods sold} + \text{Selling and distribution overhead} = \text{Cost of sales}$

(f) $\text{Cost of sales} + \text{Profit} = \text{Sales}$

(g) $\text{Sales} / \text{Quantity sold} = \text{Selling price per unit}$

In the above calculations, if the opening finished stock is equal to the closing finished stock, then the cost of production is equal to the cost of goods sold.

Other Costs/Revenues

The following are the costs/revenues other than the costs which are presented in the previous section:

- ✓ Marginal cost
- ✓ Marginal revenue
- ✓ Sunk cost
- ✓ Opportunity cost
- ✓ Average Cost
- ✓ Recurring cost
- ✓ Non-Recurring cost
- ✓ Incremental cost

1. Marginal Cost

Marginal cost of a product is the cost of producing an additional unit of that product.

2. Marginal Revenue

Marginal revenue of a product is the incremental revenue of selling an additional unit of that product.

3. Sunk Cost

This is known as the past cost of an equipment/asset.

4. Opportunity Cost

In practice, if an alternative (X) is selected from a set of competing alternatives (X, Y), then the corresponding investment in the selected alternative is not available for any other purpose. If the same money is invested in some other alternative (Y), it may fetch some return. Since the money is invested in the selected alternative (X), one has to forego the return from the other alternative (Y).

5.Average Cost

The average cost is the average obtained by dividing the total cost of producing a given volume of a product by the volume of production of that product.

6.Recurring cost

Recurring cost are those costs which are incurred for goods and services used in a business during a financial year.

Examples:

- 1.Monthly salary amount of employees in an organisation
- 2.Rent paid for building
- 3.Electricity bill of the company
- 4.Travelling expenses of marketing executives
- 5.Annual maintenance cost of machinery and building

7.Non-recurring cost

The costs which are incurred one time in a business are called non-recurring cost.

8.Incremental cost

The incremental cost is the cost of increasing the production volume by one unit. The total cost consists of fixed cost and variable cost.so,the cost of producing one unit extra will be equal to the average cost per unit. The incremental cost includes all variable costs.

The main objective of break-even analysis is to find the cut-off production volume from where a firm will make profit.

Let,

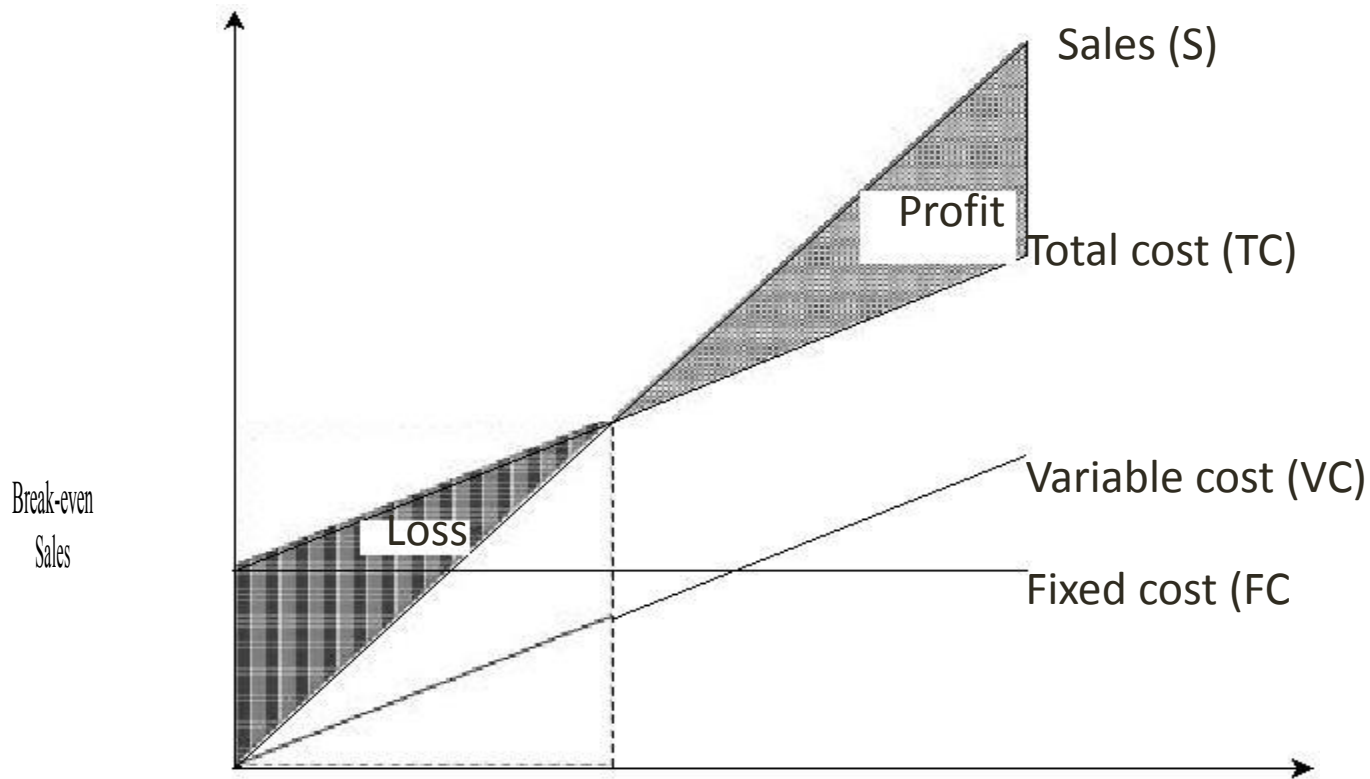
S = selling price per unit v = variable cost per unit FC = fixed cost per period

Q = volume of production .

The linear plots of the above two equations are shown in Fig. .

- ✓ The **intersection point** of the **total sales revenue line** and the **total cost line** is called the **break-even point**.
- ✓ The corresponding volume of production on the X -axis is known as the break-even sales quantity.
- ✓ At the **intersection point**, the **total cost is equal to the total revenue**. This point is also called the **no-loss or no-gain situation**.
- ✓ For any production quantity which is less than the break-even quantity, the total cost is more than the total revenue.

Hence, the firm will be making loss.



BEP(Q*) Production quantity

Fig. Break-even chart.

For any production quantity which is more than the break-even quantity, the total revenue will be more than the total cost. Hence, the firm will be making profit.

$$\text{Profit} = \text{Sales} - (\text{Fixed cost} + \text{Variable costs})$$

The contribution is the difference between the sales and the variable costs. The margin of safety (M.S.) is the sales over and above the break-even sales. The formulae to compute these values are

$$\text{Contribution} = \text{Sales} - \text{Variable costs}$$

$$\text{Contribution/unit} = \text{Selling price/unit} - \text{Variable cost/unit}$$

$$\text{M.S.} = \text{Actual sales} - \text{Break-even sales}$$

$$= \frac{\text{Profit}}{\text{Contribution}} \times \text{sales}$$

$$\text{M.S. as a per cent of sales} = (\text{M.S./Sales}) \times 100$$

Profit/Volume Ratio (P/V Ratio)

P/V ratio is a valid ratio which is useful for further analysis.

The different formulae for the *P/V* ratio are as follows:

$$P/V \text{ ratio} = \frac{\text{Contribution Sales} - \text{Variable costs}}{\text{Sales}} = \frac{\text{Sales}}{\text{Sales}}$$

The relationship between BEP and *P/V* ratio is as follows:

$$\text{BEP} = \frac{\text{Fixed cost}}{\text{Sales}}$$

- *P/V* ratio

Elementary Economic Analysis

Whether it is a business situation or a day-to-day event in somebody's personal life, there are a large number of economic decision making involved.

The following factors will affect the decision:

- ✓ Price of the raw material
- ✓ Transportation cost of the raw material
- ✓ Availability of the raw material
- ✓ Quality of the raw material

Consider the alternative of sourcing raw materials from a nearby place with the following characteristics:

- ✓ The raw material is more costly in the nearby area.
- ✓ The availability of the raw material is not sufficient enough to support the operation of the industry throughout the year.
- ✓ The raw material requires pre-processing before it is used in the production process. This would certainly add cost to the product.
- ✓ The cost of transportation is minimal under this alternative.

consider another alternative of sourcing the raw materials from a far-off place with the following characteristics:

- ✓ The raw material is less costly at the far off place.
- ✓ The cost of transportation is very high.
- ✓ The availability of the raw material at this site is abundant and it can support the plant throughout the year.
- ✓ The raw material from this site does not require any pre-
- ✓ processing before using it for production

Material Selection for A Product/Substitution of Raw Material

To find a suitable raw material will bring a reduction in the total cost in any one or combinations of the following ways:

- ✓ Reduced machining/process time
- ✓ Enhanced durability of the product
- ✓ Cheaper raw material price

Example (Sum)

In the design of a jet engine part, the designer has a choice of specifying either an aluminium alloy casting or a steel casting. Either material will provide equal service, but the aluminium casting will weigh 1.2 kg as compared with 1.35 kg for the steel casting.

The aluminium can be cast for Rs. 80.00 per kg. and the steel one for Rs. 35.00 per kg. The cost of machining per unit is Rs. 150.00 for aluminium and Rs. 170.00 for steel. Every kilogram of excess weight is associated with a penalty of Rs. 1,300 due to increased fuel consumption. Which material should be specified and what is the economic advantage of the selection per unit?

Solution

(a) Cost of using aluminum metal for the jet engine part:

Weight of aluminum casting/unit = 1.2 kg

Cost of making aluminium casting = Rs. 80.00 per kg

Cost of machining aluminium casting per unit = Rs. 150.00

Total cost of jet engine part made of aluminium/unit

= Cost of making aluminium casting/unit + Cost of machining aluminium casting/unit

$$80 \times 1.2 + 150 = 96 + 150$$

Rs. 246

(b) Cost of jet engine part made of steel/unit:

Weight of steel casting/unit = 1.35 kg

Cost of making steel casting = Rs. 35.00 per kg

Process Planning /Process Modification

While planning for a new component, a feasible sequence of operations with the least cost of processing is to be considered.

The process sequence of a component which has been planned in the past is not static.

The steps in process planning are as follows:

- ✓ Analyze the part drawing to get an overall picture of what is required.
- ✓ Make recommendations to or consult with product engineers on product design changes.
- ✓ List the basic operations required to produce the part to the drawing or specifications.

- ✓ Determine the most practical and economical manufacturing method and the form or tooling required for each operation.
- ✓ Devise the best way to combine the operations and put them in sequence.
- ✓ Specify the gauging required for the process.

BEP Example (sums)

Formulas:

1. Break even quantity

Fixed cost

Sales-Variable cost

2. Break even sales

Fixed cost

X sales

Sales-Variable costs

3. Contribution

Sales-Variable cost

4. Margin of safety all methods formulas given

Method-1

MS=sales-Break –even sales

Method-2

$$MS = \frac{\text{Profit}}{\text{Contribution}} \times \text{Sales}$$

Profit=Sales –(Fixed cost+ Variable x Quantity)

Profit /Volume Ratio(P/V ratio)

$$\frac{\text{Contribution}}{\text{Sales}} \times 100$$
$$\frac{\text{Sales-Variable Costs}}{\text{Sales}}$$

The relationship between BEP and P/V ratio is as follows:

BEP=

$$\frac{\text{Fixed cost}}{\text{P/V ratio}} \times 100$$

P/V ratio

The following formula helps us find the Margin of safety:

$$\frac{\text{Profit}}{\text{P/V ratio}} \times 100$$

P/V ratio

UNIT II VALUE ENGINEERING

Make or buy decision, Value engineering – Function, aims, Value engineering procedure. Interest formulae and their applications –Time value of money, Single payment compound amount factor, Single payment present worth factor, Equal payment series sinking fund factor, Equal payment series payment Present worth factor- equal payment series capital recovery factor-Uniform gradient series annual equivalent factor, Effective interest rate, Examples in all the methods.

INTRODUCTION

Value analysis is one of the major techniques of **cost reduction and cost prevention**. It is a disciplined approach that ensures necessary functions for **minimum cost without sacrificing quality, reliability, performance, and appearance**. According to the Society of American Value Engineers (SAVE),

Value Analysis is the systematic application of recognized techniques which identify the function of a product or service, establish a monetary value for the function and provide the necessary function reliably at the lowest overall cost.

Value

The term 'value' is used in different ways and, consequently, has different meanings. The designer equates the value with reliability; a purchase person with price paid for the item; a production person with what it costs to manufacture, and a sales person with what the customer is willing to pay.

Example

Cost value. It is the summation of the labour, material, overhead and all other elements of cost required to produce an item or provide a service compared to a base.

Exchange value. It is the measure of all the properties, qualities and features of the product, which make the product possible of being traded for another product or for money.

Value analysis/value engineering

It is a special type of cost reduction technique. It critically investigates and analyses the different aspects of materials, design, cost and production of each and every component of the product in produce it economically without decreasing its utility, function or reliability.

Applications

The various application areas of value engineering are machine tool industries, industries making accessories for machine tools, auto industries, import substitutes, etc.

Make or Buy Decisions - is a determination whether to produce a component part internally or to buy it from an outside supplier. The Organization should evaluate the costs and benefits of manufacturing a product or product component against purchasing it and then select the alternative which results in the lower cost.

CRITERIA FOR MAKE OR BUY

In this section the criteria for make or buy are discussed.

Criteria for make

The following are the criteria for make:

The finished product can be made cheaper by the firm than by outside suppliers.

The finished product is being manufactured only by a limited number of outside firms which are unable to meet the demand.

The part has an importance for the firm and requires extremely close quality control.

The part can be manufactured with the firm's existing facilities and similar to other items in which the company has manufacturing experience.

Criteria for buy

The following are the criteria for buy:

- ✓ Requires high investments on facilities which are already available at suppliers plant.
- ✓ The company does not have facilities to make it and there are more profitable opportunities for investing company's capital.

- ✓ Existing facilities of the company can be used more economically to make other parts.
- ✓ The skill of personnel employed by the company is not readily adaptable to make the part.
- ✓ Patent or other legal barriers prevent the company for making the part.
- ✓ Demand for the part is either temporary or seasonal.

APPROACHES FOR MAKE OR BUY DECISION

Types of analysis followed in make or buy decision are as follows:

- ✓ Simple cost analysis
 - ✓ Economic analysis
- Purchase model
- Manufacturing model

The formulae for EOQ and total cost (TC) for each model are given in the following table:

<i>Purchase model</i>	<i>Manufacturing model</i>
$Q_1 = \sqrt{\frac{2C_o D}{C_c}}$ $TC = D \left[P + \frac{DC_o}{Q_1} + \frac{Q_1 \times C_c}{2} \right]$	$Q_2 = \sqrt{\frac{2CD}{C_c(1-r/k)}}$ $TC = D \left[P + \frac{DC_o}{Q_2} + C_c(k-r) \frac{Q_2}{2 * k} \right]$

where

D = demand/year

P = purchase price/unit

C_c = carrying cost/unit/year

C_o = ordering cost/order or set-up cost/set-up

k = production rate (No. of units/year)

r = demand/year

Q_1 = economic order size

Q_2 = economic production size

TC = total cost per year

Break-even analysis

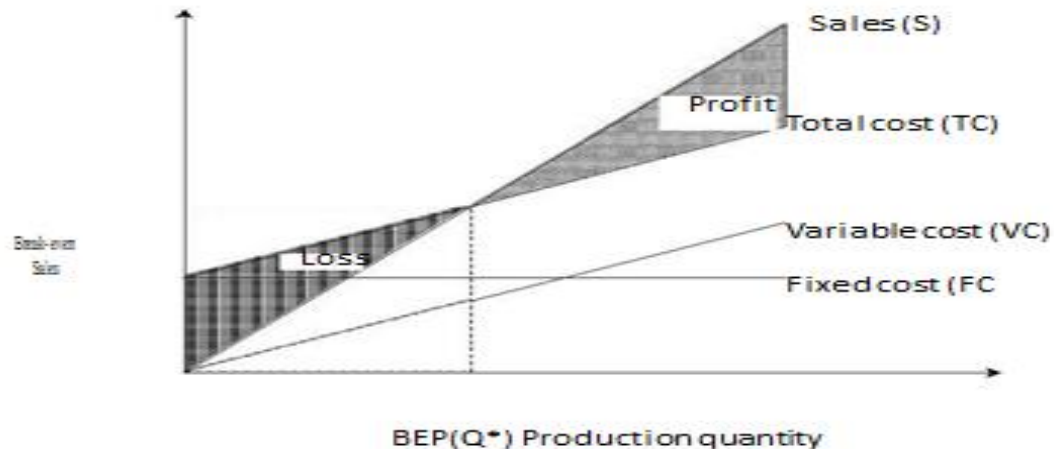


Fig. Break-even chart.

$TC = \text{total cost}$ $FC = \text{fixed cost}$

$TC = FC + \text{variable cost}$

$B = \text{the intersection of } TC \text{ and sales (no loss or no gain situation)}$

$A = \text{break-even sales}$

$c = \text{break-even quantity/break-even point (BEP)}$

The formula for the break-even point (BEP) is

FC

Selling price / unit - Variable cost per unit

Function

Function is the purpose for which the product is made. Identification of the basic functions and determination of the cost currently being spent on them are the two major considerations of value analysis.

Function identifies the characteristics which make the product/component/ part/item/device to work or sell. “Work functions” lend performance value while “sell functions” provide esteem value.

Classification of the functions

Rarely do all functions assume equal importance. Usually, some functions are more important than others. Functions can be classified into the following three categories:

✓ Primary function

Primary functions are the basic functions for which the product is specially designed to achieve.

✓ Secondary function

Secondary functions are usually related to convenience. The product can still work and fulfill its intended objective even if these functions are not in-built and yet they may be necessary to sell the product.

✓ Tertiary function

Tertiary functions are usually related to esteem appearance.

Aims

The aims of value engineering are as follows:

- ✓ Simplify the product.
- ✓ Use (new) cheaper and better materials.
- ✓ Modify and improve product design.
- ✓ Use efficient processes.
- ✓ Reduce the product cost.
- ✓ Increase the utility of the product by economical means.
- ✓ Save money or increase the profits.

Value Engineering Procedure

The basic steps of value engineering are as follows:

- (a) Blast
 - (i) Identify the product.
 - ii)Collect relevant information.
 - iii)Define different functions.
- (b)Create
 - (iv) Different alternatives.
 - V)Critically evaluate the alternatives.
- (C)Refine
 - (vi) Develop the best alternative.
 - Vii)Implement the alternative.

Step 1: Identify the product. First, identify the component for study. In future, any design change should add value and it should not make the product as obsolete one. Value engineering can be applied to a product as a whole or to sub-units.

Step 2: Collect relevant information. Information relevant to the following must be collected:

Technical specifications with drawings

Production processes, machine layout and instruction sheet

Time study details and manufacturing capacity

Complete cost data and marketing details

Latest development in related products

Step 3: Define different functions. Identify and define the primary, secondary and tertiary functions of the product or parts of interest. Also, specify the value content of each function and identify the high cost areas.

Step 4: Different alternatives. Knowing the functions of each component part and its manufacturing details, generate the ideas and create different alternatives so as to increase the value of the product. Value engineering should be done after a brain storming session. All feasible or non-feasible suggestions are recorded without any criticism; rather, persons are encouraged to express their views freely.

Interest Formulas Interest rate can be classified into simple interest rate and compound interest rate.

In simple interest, the interest is calculated, based on the initial deposit for every interest period. In this case, calculation of interest on interest is not applicable.

In compound interest, the interest for the current period is computed based on the amount (principal plus interest up to the end of the previous period) at the beginning of the current period.

The notations which are used in various interest formulae are as follows: P = principal amount

n = No. of interest periods

i = interest rate (It may be compounded monthly, quarterly, semiannually or annually)

F = future amount at the end of year n

A = equal amount deposited at the end of every interest period

G = uniform amount which will be added/subtracted period after period to/from the amount of deposit A_1 at the end of period 1

- **Single-Payment Compound Amount**

$$F = P(1 + i)^n = P(F/P, i, n)$$

- **Single-Payment Present Worth Amount**

- **Equal-Payment Series Sinking Fund**

The formula to get F is

- $$A = F = F(A/F, i, n) (1 + i)^n - 1$$

Equal-Payment Series Present Worth Amount

The formula to compute P is

$$P = A \frac{(1+i)^n - 1}{i} = \frac{1}{A(P/A, i, n)}$$

Where

$(P/A, i, n)$ is called *equal-payment series present worth factor*

Equal-Payment Series capital recovery

$$A = P \frac{i(1+i)^n}{(1+i)^n - 1} = P(A/P, i, n)$$

Uniform Gradient series annual equivalent

$$\frac{(1+i)^n - in - 1}{i^2}$$

$$A = A_1 + G$$

$$i(1+i)^n - i$$

$$= A_1 + G (A/G, i, n)$$

UNIT III CASH FLOW

Methods of comparison of alternatives – present worth method (Revenue dominated cash flow diagram), Future worth method (Revenue dominated cash flow diagram, cost dominated cash flow diagram), Annual equivalent method (Revenue dominated cash flow diagram, cost dominated cash flow diagram), rate of return method, Examples in all the methods.

INTRODUCTION

In this method of comparison, the cash flows of each alternative will be reduced to time zero by assuming an interest rate i . Then, depending on the type of decision, the best alternative will be selected by comparing the present worth amounts of the alternatives.

The sign of various amounts at different points in time in a cash flow diagram is to be decided based on the type of the decision problem.

In a cost dominated cash flow diagram, the costs (outflows) will be assigned with positive sign and the profit, revenue, salvage value (all inflows), etc. will be assigned with negative sign.-

In a revenue/profit-dominated cash flow diagram, the profit, revenue, salvage value (all inflows to an organization) will be assigned with positive sign. The costs (outflows) will be assigned with negative sign.

BASES FOR COMPARISON OF ALTERNATIVES

In most of the practical decision environments, executives will be forced to select the best alternative from a set of competing alternatives.

There are several bases for comparing the worthiness of the projects. These bases are:

- ✓ Present worth method
- ✓ Future worth method
- ✓ Annual equivalent method
- ✓ Rate of return method

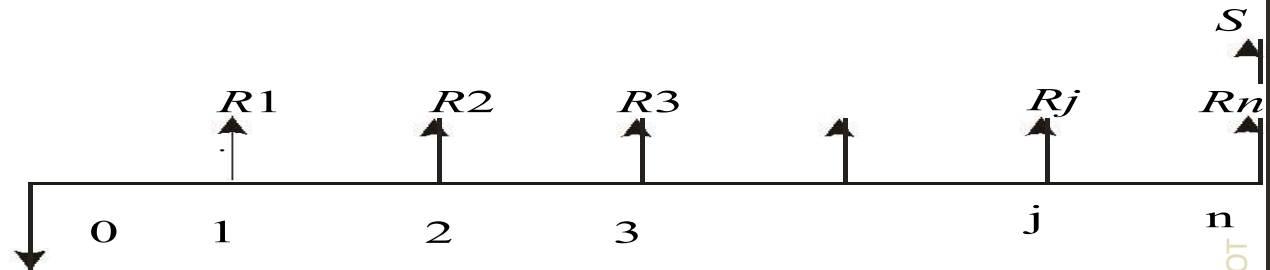
- ✓ Present worth method
- ✓ In this method of comparison, the cash flows of each alternative will be reduced to time zero by assuming an interest rate i .
- ✓ Then, depending on the type of decision, the best alternative will be selected by comparing the present worth amounts of the alternatives.

1.Revenue-Dominated Cash Flow Diagram

2.Cost-Dominated Cash Flow Diagram

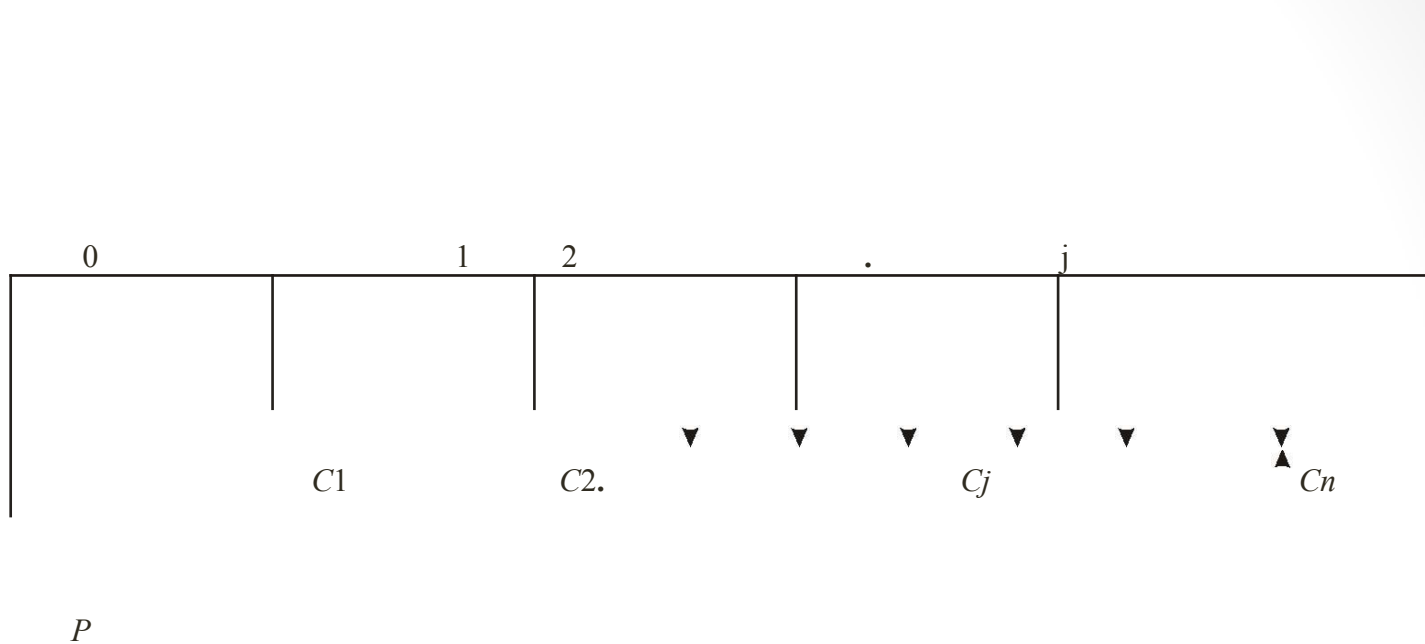
3.1.1.0 Revenue-Dominated Cash Flow Diagram

A generalized revenue-dominated cash flow diagram to demonstrate the present worth method of comparison is presented in Fig.



To find the present worth of the above cash flow diagram for a given interest rate, the formula is

$$\begin{aligned}
 PW(i) = & -P + R1\left[\frac{1}{(1+i)^1}\right] + R2\left[\frac{1}{(1+i)^2}\right] + \dots \\
 & + Rj\left[\frac{1}{(1+i)^j}\right] \\
 & + Rn\left[\frac{1}{(1+i)^n}\right] + S\left[\frac{1}{(1+i)^n}\right]
 \end{aligned}$$

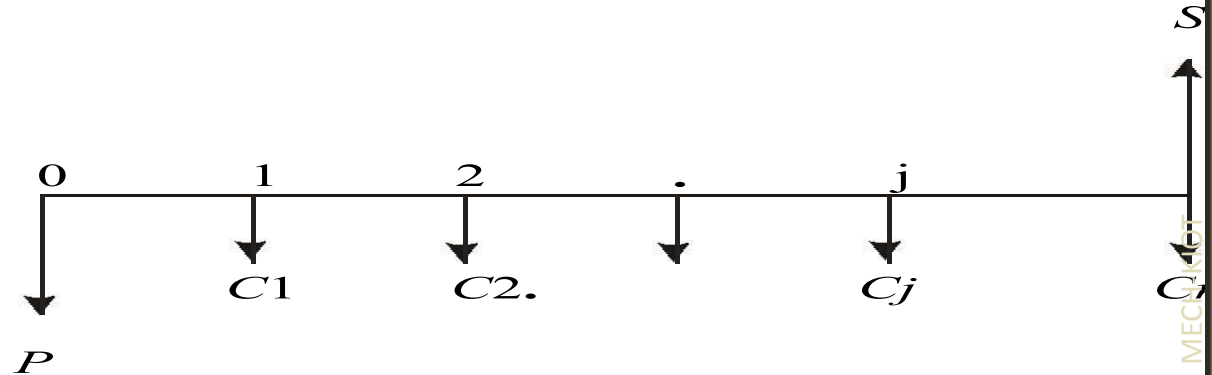


To compute the present worth amount of the above cash flow diagram for a given interest rate i , we have the formula

$$PW(i) = P + C_1[1/(1+i)^1] + C_2[1/(1+i)^2] + \dots + C_j[1/(1+i)^j] + C_n[1/(1+i)^n] - S[1/(1+i)^n]$$

3.1.1.1 Cost-Dominated Cash Flow Diagram

A generalized cost-dominated cash flow diagram to demonstrate the present worth method of comparison is presented in Fig.



To compute the present worth amount of the above cash flow diagram for a given interest rate i , we have the formula

$$\begin{aligned}
 PW(i) = & P + C_1 \left[\frac{1}{(1+i)^1} \right] \\
 & + C_2 \left[\frac{1}{(1+i)^2} \right] + \dots + \\
 & C_j \left[\frac{1}{(1+i)^j} \right] \\
 & + C_n \left[\frac{1}{(1+i)^n} \right] - \\
 & S \left[\frac{1}{(1+i)^n} \right]
 \end{aligned}$$

3.1.2 FUTURE WORTH METHOD

- ✓ In the future worth method of comparison of alternatives, the future worth of various alternatives will be computed.
- ✓ Then, the alternative with the maximum future worth of net revenue or with the minimum future worth of net cost will be selected as the best alternative for implementation.

3.1.2.1 Revenue-Dominated Cash Flow Diagram

A generalized revenue-dominated cash flow diagram to demonstrate the future worth method of comparison is presented in Fig.

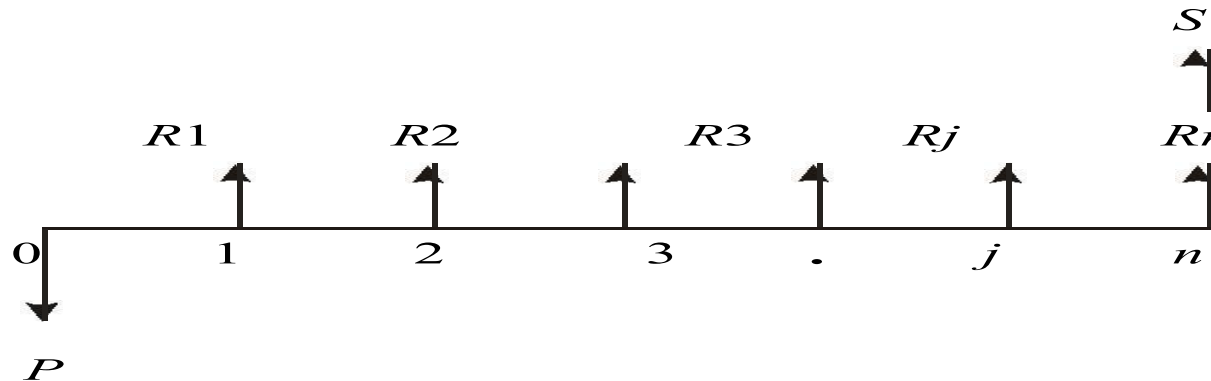


Fig Revenue-dominated cash flow diagram.

In Fig. P represents an initial investment, R_j the net-revenue at the end of the j th year, and S the salvage value at the end of the n th year.

The formula for the future worth of the above cash flow diagram for a given interest rate, i is

$$\begin{aligned}
 FW(i) = & -P(1+i)^n \\
 & + R_1(1+i)^{n-1} \\
 & + R_2(1+i)^{n-2} + \dots \\
 & + R_j(1+i)^{n-j} + \dots + \\
 & R_n + S
 \end{aligned}$$

In the above formula, the expenditure is assigned with negative sign and the revenues are assigned with positive sign.

3.1.2.2 Cost-Dominated Cash Flow Diagram

A generalized cost-dominated cash flow diagram to demonstrate the future worth method of comparison is given in Fig.

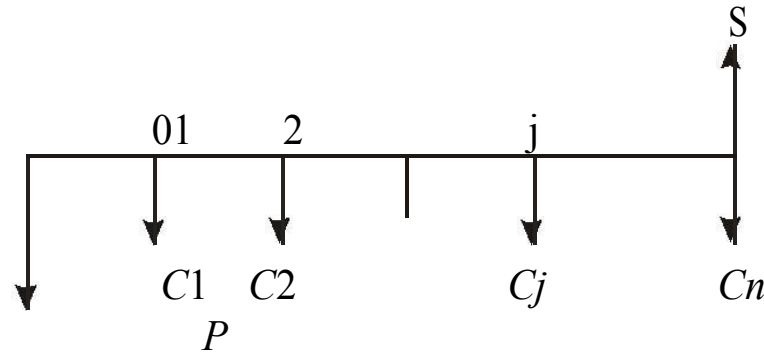


Fig. Cost-dominated cash flow diagram.

In Fig. 5.2, P represents an initial investment, C_j the net cost of operation and maintenance at the end of the j th year, and S the salvage value at the end of the n th year.

The formula for the future worth of the above cash flow diagram for a given interest rate, i is

$$FW(i) = P(1+i)^n + C_1(1+i)^{n-1} + C_2(1+i)^{n-2} + \dots + C_j(1+i)^{n-j} + \dots + C_n - S$$

3.1.3 ANNUAL METHOD

EQUIVALENT

- ✓ In the annual equivalent method of comparison, first the annual equivalent cost or the revenue of each alternative will be computed.
- ✓ Then the alternative with the maximum annual equivalent revenue in the case of revenue-based comparison or with the minimum annual equivalent cost in the case of cost-based comparison will be selected as the best alternative.

3.1.3.1 Revenue-Dominated Cash Flow Diagram

A generalized revenue-dominated cash flow diagram to demonstrate the annual equivalent method of comparison is presented in Fig.

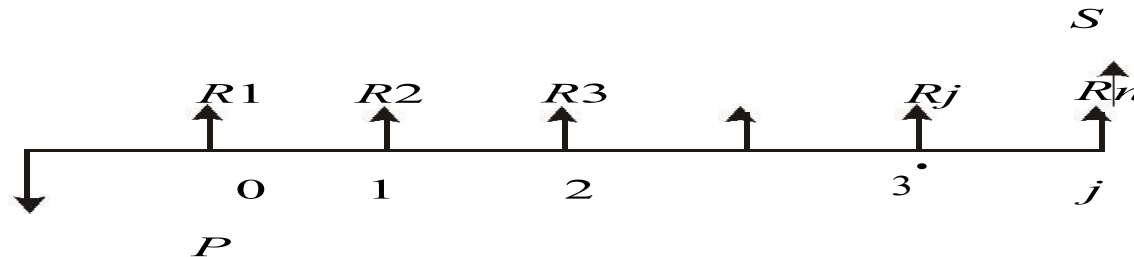


Fig. Revenue-dominated cash flow diagram.

In Fig. P represents an initial investment, R_j the net revenue at the end of the j th year, and S the salvage value at the end of the n th year.

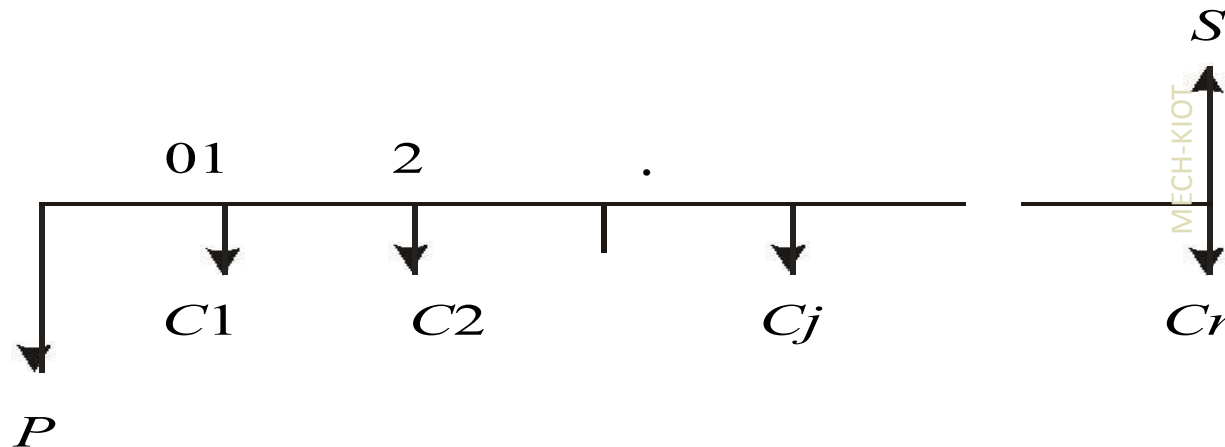
The first step is to find the net present worth of the cash flow diagram using the following expression for a given interest rate, i :

$$\begin{aligned}
 PW(i) = & -P + \\
 & R_1/(1+i)^1 + \\
 & R_2/(1+i)^2 + \dots \\
 & + R_j/(1+i)^j + \\
 & \dots + \\
 & R_n/(1+i)^n + \\
 & S/(1+i)^n
 \end{aligned}$$

In the above formula, the expenditure is assigned with a negative sign and the revenues are assigned with a positive sign.

Cost-Dominated Cash Flow Diagram

A generalized cost-dominated cash flow diagram to demonstrate the annual equivalent method of comparison is illustrated in Fig.



In Fig, P represents an initial investment, C_j the net cost of operation and maintenance at the end of the j th year, and S the salvage value at the end of the n th year.

The first step is to find the net present worth of the cash flow diagram using the following relation for a given interest rate, i .

$$\begin{aligned}
 PW(i) = & P + C_1/(1+i)^1 + C_2/(1+i)^2 + \\
 & \dots \\
 & + C_j/(1+i)^j \\
 & + \dots + C_n/(1+i)^n \\
 & - S/(1+i)^n
 \end{aligned}$$

3.1.4 RATE OF RETURN METHOD

- ✓ The rate of return of a cash flow pattern is the interest rate at which the present worth of that cash flow pattern reduces to zero.
- ✓ In this method of comparison, the rate of return for each alternative is computed. Then the alternative which has the highest rate of return is selected as the best alternative.
- ✓ A generalized cash flow diagram to demonstrate the rate of return method of comparison is presented in Fig

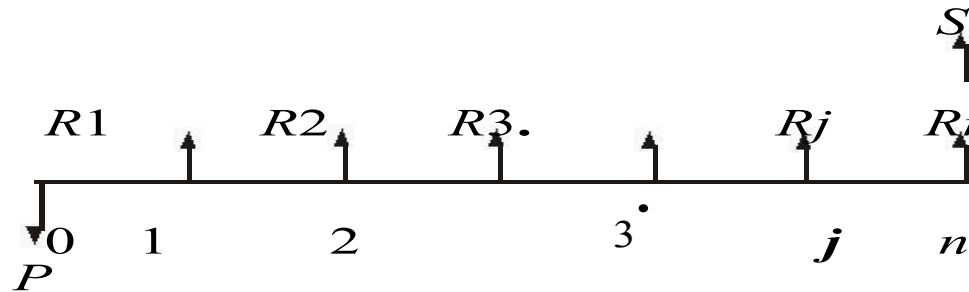


Fig. Generalized cash flow diagram.

In the above cash flow diagram, P represents an initial investment, R_j the net revenue at the end of the j th year, and S the salvage value at the end of the n th year.

The first step is to find the net present worth of the cash flow diagram using the following expression at a given interest rate, i .

$$\begin{aligned}
 PW(i) = & -P \\
 & + R_1/(1+i)^1 \\
 & + R_2/(1+i)^2 \\
 & + \dots \\
 & + R_j/(1+i)^j \\
 & + \dots \\
 & + R_n/(1+i)^n \\
 & + S/(1+i)^n
 \end{aligned}$$

UNIT IV REPLACEMENT AND MAINTENANCE ANALYSIS

Replacement and Maintenance analysis – Types of maintenance, types of replacement problem, determination of economic life of an asset, Replacement of an asset with a new asset – capital recovery with return and concept of challenger and defender, Simple probabilistic model for items which fail completely.

Introduction

Organizations providing goods/services use several facilities like equipment and machinery which are directly required in their operations. In addition to these facilities, there are several other items which are necessary to facilitate the functioning of organizations.

All such facilities should be continuously monitored for their efficient functioning; otherwise, the quality of service will be poor. Besides the quality of service of the facilities, the cost of their operation and maintenance would increase with the passage of time.

Types of Maintenance

Maintenance activity can be classified into two types:

- ✓ Preventive maintenance and
- ✓ Breakdown maintenance.

Preventive maintenance (PM) is the periodical inspection and service activities which are aimed to detect potential failures and perform minor adjustments or repairs which will prevent major operating problems in future.

Breakdown maintenance is the repair which is generally done after the equipment has attained down state. It is often of an emergency nature which will have associated penalty in terms of expediting cost of maintenance and down time cost of equipment.

Preventive maintenance will reduce such cost up to a point. Beyond that point, the cost of preventive maintenance will be more when compared to the breakdown maintenance cost.

The total cost, which is the sum of the preventive maintenance cost and the breakdown maintenance cost, will go on decreasing with an increase in the level of maintenance up to a point.

Beyond that point, the total cost will start increasing. The level of maintenance corresponding to the minimum total cost is the optimal level of maintenance. The concepts are demonstrated in Fig.

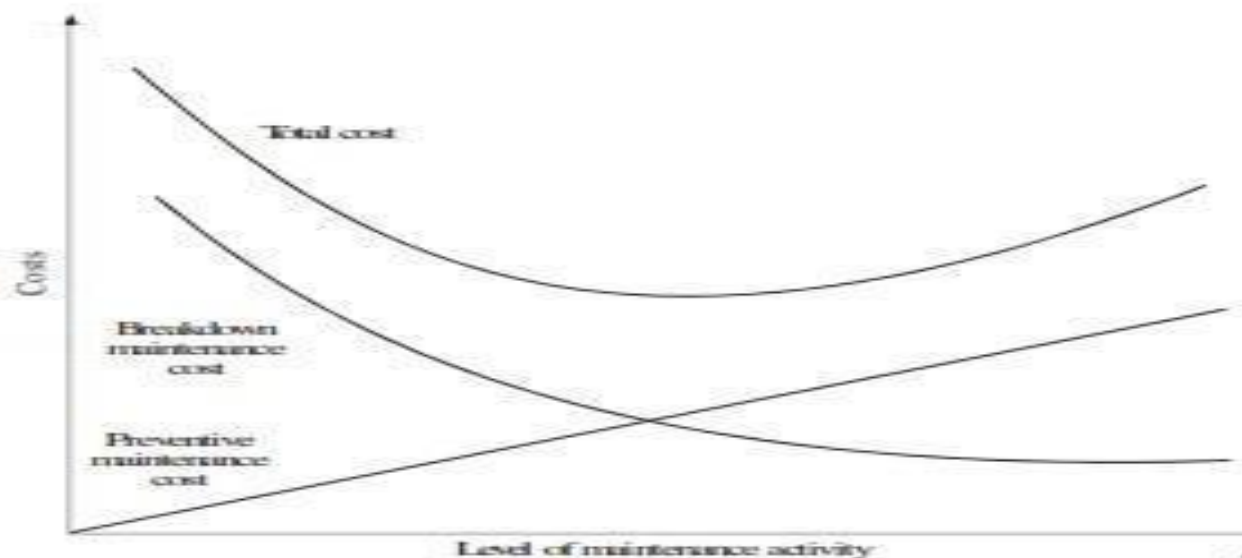


Fig. Maintenance costs.

Types of Replacement Problem

Replacement study can be classified into two categories:

- (a) Replacement of assets that deteriorate gradually (Replacement due to gradual failure, or wear and tear of components of the machines).

This can be further classified into the following types:

- (i) Determination of economic life of an asset.
 - (ii) Replacement of an existing asset with a new asset.
- (b) Simple probabilistic model for assets which fail completely (replacement due to sudden failure).

Determination of Economic Life of an Asset

Any asset will have the following cost components:

- ✓ Capital recovery cost (average first cost), computed from the first cost (purchase price) of the machine.
- ✓ Average operating and maintenance cost (O & M cost)
- ✓ Total cost which is the sum of capital recovery cost (average first cost) and average maintenance cost.

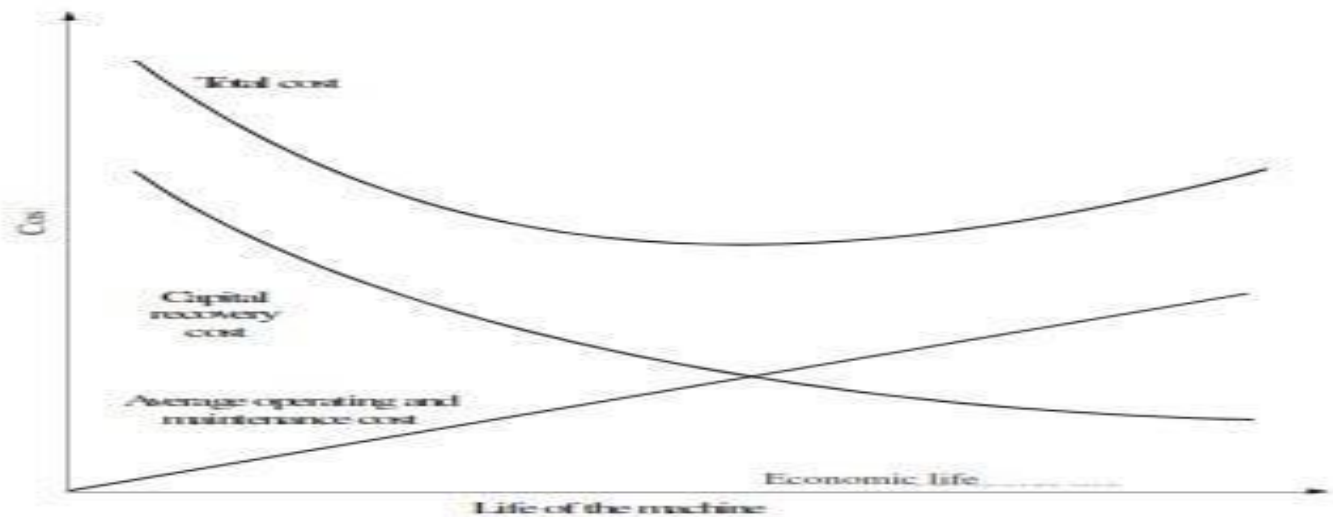


Fig. Chart showing economic life.

REPLACEMENT OF EXISTING ASSET WITH A NEW ASSET

In this section, the concept of comparison of replacement of an existing asset with a new asset is presented. In this analysis, the annual equivalent cost of each alternative should be computed first.

Then the alternative which has the least cost should be selected as the best alternative. Before discussing details, some preliminary concepts which are essential for this type of replacement analysis are presented.

Capital Recovery with Return

Consider the following data of a machine.

Let

P = purchase price of the machine,

F = salvage value of the machine at the end of machine life,

n = life of the machine in years, and

i = interest rate, compounded annually

The corresponding cash flow diagram is shown in Fig



Fig. Cash flow diagram of machine.

- The equation for the annual equivalent amount for the above cash flow diagram is
- $AE(i) = (P - F) (A/P, i, n) + F i$
- This equation represents the capital recovery with return.

Concept of Challenger and Defender

- If an existing equipment is considered for replacement with a new equipment, then the existing equipment is known as the defender and the new equipment is known as challenger.
- Assume that an equipment has been purchased about three years back for Rs. 5,00,000 and it is considered for replacement with a new equipment. The supplier of the new equipment will take the old one for some money, say, Rs. 3,00,000.
- This should be treated as the present value of the existing equipment and it should be considered for all further economic analysis.
- The purchase value of the existing equipment before three years is now known as sunk cost, and it should not be considered for further analysis.

Simple Probabilistic Model For Items Which Fail Completely

- Electronic items like transistors, resistors, tubelights, bulbs, etc. could fail all of a sudden, instead of gradual deterioration. The failure of the item may result in complete breakdown of the system. The system may contain a collection of such items or just one item, say a tubelight.
- Therefore, we use some replacement policy for such items which would avoid the possibility of a complete breakdown.
- The following are the replacement policies which are applicable for this situation.
- (i) Individual replacement policy. Under this policy, an item is replaced immediately after its failure.
- (ii) Group replacement policy. Under this policy, the following decision is
- made:

- At what equal intervals are all the items to be replaced simultaneously with a provision to replace the items individually which fail during a fixed group replacement period?
- There is a trade-off between the individual replacement policy and the group replacement policy. Hence, for a given problem, each of the replacement policies is evaluated and the most economical policy is selected for implementation. This is explained with two numerical problems.

UNIT V

DEPRECIATION

Depreciation- Introduction, Straight line method of depreciation, declining balance method of depreciation- Sum of the years digits method of depreciation, sinking fund method of depreciation/ Annuity method of depreciation, service output method of depreciation- Evaluation of public alternatives- introduction, Examples, Inflation adjusted decisions – procedure to adjust inflation, Examples on comparison of alternatives and determination of economic life of asset.

Introduction

- Any equipment which is purchased today will not work for ever. This may be due to wear and tear of the equipment or obsolescence of technology.
- Hence, it is to be replaced at the proper time for continuance of any business.
- The replacement of the equipment at the end of its life involves money. This must be internally generated from the earnings of the equipment.
- The recovery of money from the earnings of an equipment for its replacement
- purpose is called depreciation fund since we make an assumption that the value of the equipment decreases with the passage of time.
- Thus the word “depreciation” means decrease in value of any physical asset with the passage of time.

Methods of Depreciation

There are several methods of accounting depreciation fund. These are as follows:

1. Straight line method of depreciation
2. Declining balance method of depreciation
3. Sum of the years—digits method of depreciation
4. Sinking-fund method of depreciation
5. Service output method of depreciation

1. Straight Line Method of Depreciation

In this method of depreciation, a fixed sum is charged as the depreciation amount throughout the lifetime of an asset such that the accumulated sum at the end of the life of the asset is exactly equal to the purchase value of the asset.

Here, we make an important assumption that inflation is absent.

Let

P = first cost of the asset,

F = salvage value of the asset

n = life of the asset,

B_t = book value of the asset at the end of

t = depreciation amount for the period t

The formulae for depreciation and book value are as follows:

$$D_t = (P - F)/n$$

$$B_t = B_{t-1}$$

$$- D_t = P - t [(P - F)/n]$$

2. Declining Balance Method of Depreciation

- In this method of depreciation, a constant percentage of the book value of the previous period of the asset will be charged as the depreciation amount for the current period.
- This approach is a more realistic approach, since the depreciation charge decreases with the life of the asset which matches with the earning potential of the asset.
- The book value at the end of the life of the asset may not be exactly equal to the salvage value of the asset. This is a major limitation of this approach

Let

P = first cost of the asset,

F = salvage value of the asset,

n = life of the asset,

B_t = book value of the asset at the end of the period t ,

K = a fixed percentage, and

D_t = depreciation amount at the end of the period t .

The formulae for depreciation and book value are as follows:

$$D_t = K$$

$$B_t = B_{t-1} - D_t = B_{t-1} - K = (1 - K) B_{t-1}$$

- The formulae for depreciation and book value in terms of P are as follows:
- $D_t = K(1 - K)^{t-1} P$ $B_t = (1 - K)^t P$
- While availing income-tax exception for the depreciation amount paid in each year, the rate K is limited to at the most $2/n$. If this rate is used, then the corresponding approach is called the double declining balance method of depreciation.

3. Sum-of-the-Years-Digits Method of Depreciation

In this method of depreciation also, it is assumed that the book value of the asset decreases at a decreasing rate. If the asset has a life of eight years, first the sum of the years is computed as

$$\text{Sum of the years} = 1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 = 36 = n(n + 1)/2$$

The rate of depreciation charge for the first year is assumed as the highest and then it decreases. The rates of depreciation for the years 1–8, respectively are as follows: $8/36$, $7/36$, $6/36$, $5/36$, $4/36$, $3/36$, $2/36$, and $1/36$.

For any year, the depreciation is calculated by multiplying the corresponding rate of depreciation with $(P - F)$.

$$D_t = \text{Rate} (P - F)$$

$$B_t = B_{t-1} - D_t$$

The formulae for D_t and B_t for a specific year t are as follows:

$$D_t = \frac{n - t + 1}{n(n + 1)} (P - F)$$

$$B_t = (P - F) \left[\frac{n + 1 - t}{n + 1} \right]$$

4. Sinking Fund Method of Depreciation

In this method of depreciation, the book value decreases at increasing rates with respect to the life of the asset

Let

P = first cost of the asset,

F = salvage value of the asset, n = life of the asset,

i = rate of return compounded annually,

A = the annual equivalent amount,

B_t = the book value of the asset at the end of the period t , and

D_t = the depreciation amount at the end of the period t .

The loss in value of the asset ($P - F$) is made available in the form of cumulative depreciation amount at the end of the life of the asset by setting up an equal depreciation amount (A) at the end of each period during the lifetime of the asset.

$$A = (P - F) [A/F, i, n]$$

The fixed sum depreciated at the end of every time period earns an interest at the rate of $i\%$ compounded annually, and hence the actual depreciation amount will be in the increasing manner with respect to the time period. A generalized formula for D_t is

$$D_t = (P - F) (A/F, i, n) (F/P, i, t - 1)$$

The formula to calculate the book value at the end of period t is

$$B_t = P - (P - F) (A/F, i, n) (F/A, i, t)$$

The above two formulae are very useful if we have to calculate D_t and B_t for any specific period.

If we calculate D_t and B_t for all the periods, then the tabular approach would be better.

5. Service Output Method of Depreciation

In some situations, it may not be realistic to compute depreciation based on time period. In such cases, the depreciation is computed based on service rendered by an asset. Let

P = first cost of the asset

F = salvage value of the asset

X = maximum capacity of service of the asset during its lifetime

x = quantity of service rendered in a period.

Then, the depreciation is defined per unit of service

rendered: Depreciation/unit of service = $(P - F)/X$

Depreciation for x units of service in a period = $\frac{P - F}{X}(x)$

Evaluation Of Public Alternatives

In evaluating alternatives of private organizations, the criterion is to select the alternative with the maximum profit.

The profit maximization is the main goal of private organizations while providing goods/services as per specifications to their customers.

But the same criterion cannot be used while evaluating public alternatives. Examples of some public alternatives are

- constructing bridges,
- roads, dams,
- establishing public utilities, etc.

- The main objective of any public alternative is to provide goods/services to the public at the minimum cost. In this process, one should see whether the benefits of the public activity are at least equal to its costs.

Inflation Adjusted Decisions

Inflation is the rate of increase in the prices of goods per period. So, it has a compounding effect. Thus, prices that are inflated at a rate of 7% per year will increase 7% in the first year, and for the next year the expected increase will be 7% of these new prices.

If economic decisions are taken without considering the effect of inflation into account, most of them would become meaningless and as a result the organizations would end up with unpredictable return.

5 Procedure To Adjust Inflation

A procedure to deal with this situation is summarized now.

1. Estimate all the costs/returns associated with an investment proposal in terms of today's rupees.
2. Modify the costs/returns estimated in step 1 using an assumed inflation rate so that at each future date they represent the costs/returns at that date in terms of the rupees that must be expended/received at that time, respectively.
3. As per our requirement, calculate either the annual equivalent amount or future amount or present amount of the cash flow resulting from step 2 by considering the time value of money.

- Single-Payment Compound Amount

$$F = P(1 + i)^n = P(F/P, i, n)$$

- Single-Payment Present Worth Amount

- Equal-Payment Series Sinking Fund

$$P = F/(1 + i)^n = F(P/F, i, n)$$

- Equal-Payment Series Present Worth Amount

The formula to compute P is

$$i(1 + i)^n$$

$$P = A \frac{(1 + i)^n - 1}{i}$$

- **Equal-Payment Series Capital Recovery Amount**

- **Uniform Gradient Series Annual Equivalent Amount**
= $P(A/P, i, n)$

$$\frac{i(1+i)^n}{(1+i)^n - 1} \quad (1+i)^n - in - 1$$

$$A = A1 + G$$

$$i(1+i)^n - i$$

- $= A1 + G(A/G, i, n)$

Effective Interest Rate

METHOD 1

$$= P(1 + r)^N$$

METHOD 2

$$\text{Effective interest rate, } R = (1 + i/C)^C - 1$$

Thank You