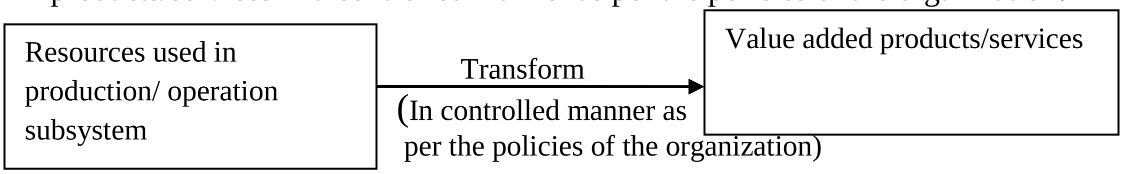
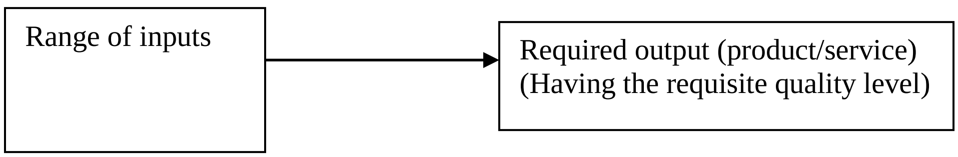
CHAPTER-I
PRODUCTIVITY

1.1 Introduction

Production/Operation management is the process which combines and transforms various resources used in the production/operation subsystem of the organization into value added products/services in a controlled manner as per the policies of the organization.



Production/Operation function:

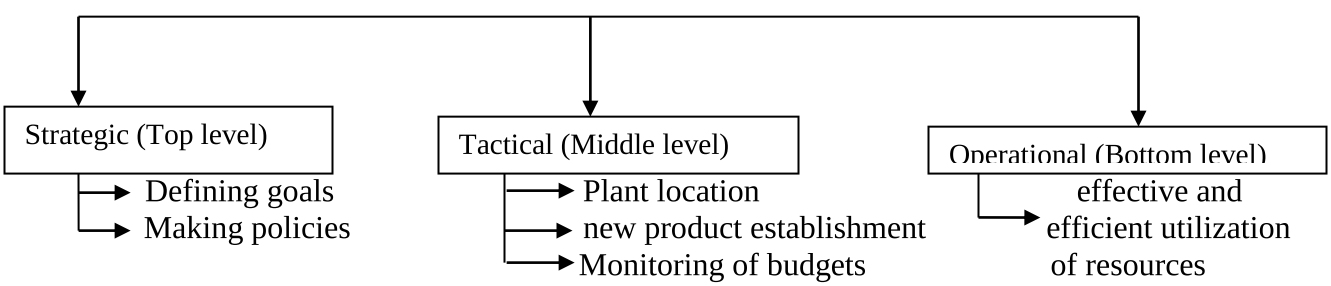


The set of interrelated management activities which are involved in manufacturing certain products is called production management and for service management, then corresponding set of management activities is called as operation management.

Examples: (Products/goods)
Boiler with a specific capacity,
Constructing flats,
Car, bus, radio, television.

Examples: (Services)
Medical facilities,
Travel booking services.

In the process of managing various subsystems of the organization executives at different levels of the organization need to track several management decisions. The management decisions are Strategic, tactical and operational.



Corrections from feedback information:

- ❖ Tight quality check on the incoming raw-material.
- ❖ Adjustment of machine settings.
- ❖ Change of tools.
- ❖ Proper allocation of operations to machines with matching skills.
- ❖ Change in the production plans.

1.2 Productivity:

Productivity is a relationship between the output (product/service) and input (resources consumed in providing them) of a business system. The ratio of aggregate output to the aggregate input is called productivity.

Productivity = output/Input

- ❖ For survival of any organization, this productivity ratio must be at least 1.If it is more than 1, the organization is in a comfortable position. The ratio of output produced to the input resources utilized in the production.

1.3 Importance:

Benefits derived from higher productivity are as follows:

- ✓ It helps to cut down cost per unit and thereby improve the profits.
- ✓ Gains from productivity can be transferred to the consumers in form of lower priced Products or better quality products.
- ✓ These gains can also be shared with workers or employees by paying them at higher rate.
- ✓ A more productive entrepreneur can have better chances to exploit expert opportunities.
- ✓ It would generate more employment opportunity.
- ✓ Overall productivity reflects the efficiency of production system.
- ✓ More output is produced with same or less input.
- ✓ The same output is produced with lesser input.
- ✓ More output is produced with more input.
- ✓ The proportional increase in output being more than the proportional increase in input.

1.4 Productivity Measurement:

Productivity may be measured either on aggregate basis or on individual basis, which are called total and partial measure.

Total productivity Index/measure = Total output/ Total input

$$= \frac{\text{Total production of goods and services}}{\text{Labour+material+capital+Energy+management}}$$

Partial productivity indices, depending upon factors used, it measures the efficiency of individual factor of production.

$$\text{Labour productivity Index/Measure} = \frac{\text{Output in unit}}{\text{Man hours worked}}$$

$$\text{Management productivity Index/Measure} = \frac{\text{Output}}{\text{Total cost of management}}$$

$$\text{Machine productivity Index/Measure} = \frac{\text{Total output}}{\text{Machine hours worked}}$$

$$\text{Land productivity Index/Measure} = \frac{\text{Total output}}{\text{Area of Land used}}$$

$$\text{Partial Measure} = \frac{\text{Output}}{\text{Labour}} \text{ or } \frac{\text{Output}}{\text{Capital}} \text{ or } \frac{\text{Output}}{\text{Materials}} \text{ or } \frac{\text{Output}}{\text{Energy}}$$

PROBLEMS:

Example-1

The input and output data for an industry given in the table. Find out various productivity measures like total, multifactor and partial measure.

<u>Output and Input production data in dollar ($)</u>

<u>Output</u>

1.	Finished units	10,000
2.	Work in progress	2,500
3.	Dividends	1,000
4.	Bonds	-------
5.	Other income	--------

<u>Input</u>

1.	Human	3,000
2.	Material	153
3.	Capital	10,000
4.	Energy	540
5.	Other Expenses	1,500

Solution:

$$\text{Total measure} = \frac{\text{Total Output}}{\text{Total Input}} = \frac{13{,}500}{15{,}193} = 0.89$$

$$\text{Multi factor measure} = \frac{\text{Total Output}}{\text{Human+Material}} = \frac{13{,}500}{3{,}153} = 4.28$$

$$\text{Multi factor measure} = \frac{\text{Finished units}}{\text{Human+Material}} = \frac{10{,}000}{3{,}153} = 3.17$$

$$\text{Partial Measure}_1 = \frac{\text{Total Output}}{\text{Energy}} = \frac{13{,}500}{540} = 25$$

$$\text{Partial Measure}_2 = \frac{\text{Finished units}}{\text{Energy}} = \frac{10{,}000}{540} = 18.52$$

Note: For multifactor and partial measures it is not necessary to use total output as numerator. Often, it is describe to create measures that represent productivity as it relates to some particular output of interest.

Other fields for the measurement of partial measures of productivity are:

Business	**Productivity Measure**
Restaurant	Customers (Meals) per labour hour
Retail Store	Sales per square foot
Utility plant	Kilowatts per ton of coal
Paper mill	Tons of paper per cord of wood

Example-2

A furniture manufacturing company has provided the following data. Compare the labour, raw materials and supplies and total productivity of 1996 and 1997.

Output: Sales value of production in dollar ($)
22,000 (in 1996) and 35,000 (in 1997)

	1996	**1997**
Inputs: Labour	**10,000**	**15,000**
Raw materials and Supplies	**8,000**	**12,500**
Capital equipment depreciation	**700**	**1,200**
Other	**2,200**	**4,800**

Solution:

	1996	1997
a. Partial productivities		
Labour	2.20	2.33
Raw materials and Supplies	2.75	2.80
b. Total Productivity	1.05	1.04

1.5 Productivity measurement approaches at the enterprises level:

As stated above total productivity is expressed as the ratio of aggregate output to the aggregate input. That the total overall performance is captured in this ratio, becomes apparent, if we examine the relationship between this ratio and the age-old performance measure of profit.

If the outputs and input for the period for which productivity is measured, are expressed in rupees, then under such restrictive assumptions one can write:

Aggregate output =Gross Sales=G (Say)

Aggregate input=Cost =C (Say)

Total Productivity=P(Say)= $\frac{G}{C}$ ………………..(1)

From the definition of profit, we have;

Profit= π = G-C ………………….(2)

By dividing eq^n (2) by C, $\frac{\pi}{C} = \frac{G}{C} - 1$

So from (1), $\Rightarrow \frac{\pi}{C}$ =P-1

For Zero profit (π =0), $P = 1$

For a Loss, (π $\langle$ 0), $P \langle 1$

For a profit, $\pi \rangle 0, P \rangle 1$

Zero profit will give a productivity value of 1, while a loss will give productivity value less than 1.The profit to cost ratio will determine the increase in productivity.

The above relationship that demonstrates that increased profit to cost ratio will lead to increased overall productivity, is constituent with our expectation on how an overall performance measure should behave. However it suffers from a number of drawbacks. Some of which are listed here,

a) Given that our objective in productivity measurement is to capture the efficiency of utilization of resources, the effect of price variations over time need to be corrected. Thus aggregate output should be equal to gross sales suitably inflated or deflated with respect to a base year.
b) Equating output to sales implies, whatever is produced in the particular period is sold. Possibility of inventory, material manufactured for own use, etc. are n't taken in to consideration.
c) Equating aggregate input to cost raises a host of problems and involves several restrictive assumptions. How to account for the fixed investment and working capital, whether to take the fringe benefits in to account etc. are some of the problems.

The different approaches to measurement have arisen mainly in the context of correcting the above drawbacks.

1.6 Techniques for Productivity Improvement:

Higher productivity in organization leads to national prosperity and better standard of living for the whole community. The methods contribute to the improvement of productivity are method study and work measurement by reducing work content and Ineffective time.

Work content means the amount of work “contained in” a given product or process measured in man-hour or machine-hour. Except in some cases like in processing industries, actual operation times are far in excess of the theoretical minimum.

Ineffective time is the time for which the worker or machine or both are idle due to the shortcomings of the management or the worker.

CHAPTER-II
PRODUCTION SYSTEM

2.1 Introduction

A "Production System" is a system whose function is to transform an input into a desired output by means of a process (the production process) and of resources. The definition of a production system is thus based on four main elements: the input, the resources, the production process and the output.

Resources
Input-Production Process-Output

Most of the organizations (including non-profit organization) can be described as production systems.These organizations transform (or convert) a set of inputs (such as materials, labour, equipment, energy etc.) in to one or useful outputs. The outputs of a production system are normally called products. These products may be:

(a)Tangible goods	(b)Intangible services	(c)combination of (a) and (b)
(Steels,chemicals etc.)	(Teaching,health care etc.)	(fast food,tailoring etc.)

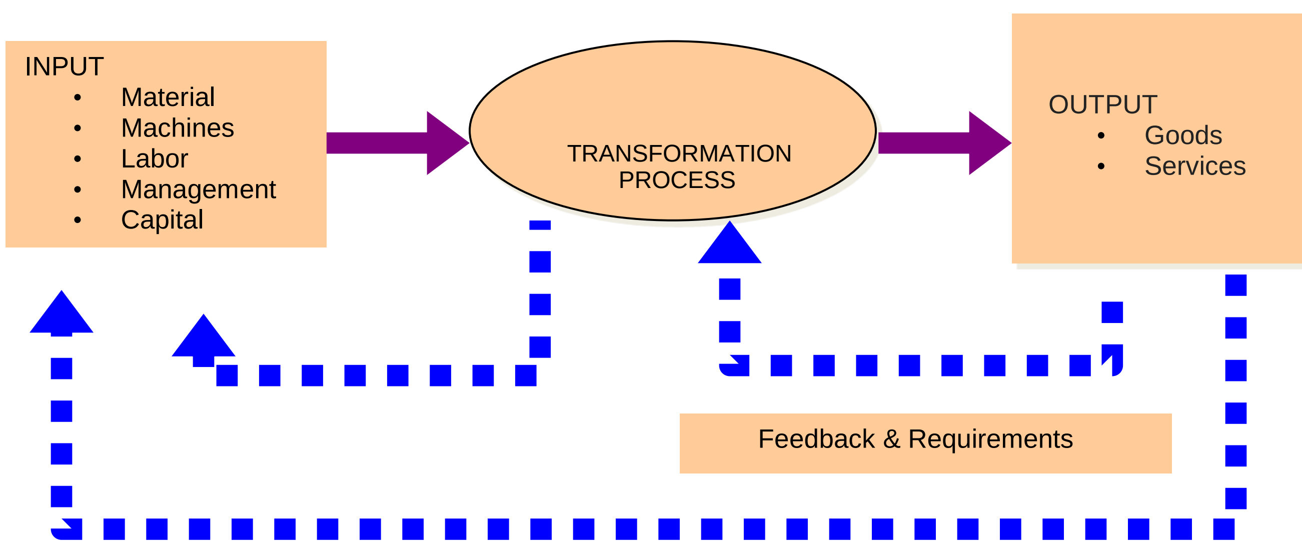


Fig 2.1 A simple block diagram of a production system

Production system refers to manufacturing subsystem that includes all functions required to design, produce, distribute and service a manufactured product. So this system produces goods and/or services on a continuous and/or batch basis with or without profit as a primary objective.

Production is the basic activity of all organizations and all other activities revolve around production activity. The output of production is the creation of goods and services which satisfy the needs of the customers. In some organization the product is physical (tangible) good. For example, refrigerators, motor cars, television, toothpaste etc., while in others it is a service (insurance, healthcare etc.).The production system has the following characteristics:

- Production is an organized activity, so every production system has an objective.
- The system transforms the various inputs (men, material, machines,information,energy) to useful outputs (goods and/or services).
- Production system doesn't oppose in isolation from the other organization system such as marketing, finance etc.
- There exists a feedback about the activities which is essential to control and improve system performance.

  The transformation process involves many activities and operation necessary to change inputs to output. These operations and activities can be mechanical, chemical, inspection and control, material handling operation etc.

2.2 Models of Production system:

A model is a representation of reality that captures the essential features of an object/system/process. Three types of models are there such as physical, schematic and mathematical.

I. *Physical model:* Replica of a physical object with a change of scale.
   a. For big/huge structure of physical object: small scale (Ex. solar system)
   b. For microscopic objects: magnified scale(Ex. Atomic model)
II. *Schematic model:* These are 2-D models which represents
   - Price fluctuations with year.
   - Symbolic chart of activities in sequence for a job.
   - Maps of routings
   - Networks of timed events.

   The pictorial aspects are useful for good demonstration purposes.

III. *Mathematical model:*
   Formulas and equations have long being the servants of physical sciences. One can represent the important aspect of a system/problem in mathematical form using variables, parameters and functions. This is called mathematical model .by analyzing and manipulating the mathematical model, we can learn how the real system will behave under various conditions.

2.3 Product vs. services

Product	Services
1-tangible, durable products. 2- Output can be inventoried. 3-consumption/use takes more time. 4-low costumer's involvement. 5-long response time. 6-available at regional, national and international market. 7-Reqire large facilities. 8-Capital intensive. 9-Quality easily measured. 10-Demand variable on weekly, monthly, seasonally.	1- Intangible, perishable products. 2- Output can't be inventoried. 3-Immidiate consumption. 4- High costumer's involvement. 5- Short response time. 6-local market. 7- Require small facilities. 8-Labour intensive. 9- Quality not easily measured. 10- Demand variable on hourly, daily, weekly basis.

Explanations

Manufacturing organization generally transfer tangible inputs or raw materials into some tangible output (ex: steel, refrigerator, toothpaste, soap etc.) Other inputs such as labour skills, management skills, capitals are used as well. Manufacturing organizations perform some chemical /physical processes (such as blending refining, welding, grinding.etc) to transfer their raw material into tangible products. Service providing organization though transform a set of input into set of output, they don't produce a tangible output.(ex: mail service, library service, restaurant etc.).or provide service(ex: health care, hair care, watch and automobile repair etc.). The service of service providing organization is intangible.

A 2nd distinction is based on inventories .durable goods can be kept for longer time these goods can be stored for longer time and can be transported in anticipation in future demand .Thus with durable goods ,operation manager can co up with the peaks and valleys in demand by creating inventories and smoothing out output levels. Whereas service can't be pre produced. For example: getting fast food from a fast food center, getting treatment from hospital etc.

A 3rd distinction is based on consumption/use of output. The products (goods) generally take longer period for its use, for ex refrigerator, T.V. automobile etc. can be used at least for 10 years. On the other hand, the output produced from a service operation (i.e. service) is consumed within a small time. Ex. consumption of fastfood,taking hair care, enjoying journey by a bus/train/aero plane enjoying entertainment program.

A 4th distinction is based on customer contact. Most of the consumers/customers have little or no contact with production system/organization. Whereas, in many service providing organization consumers/customers are directly involved. For example: students in an educational institution, patients in hospital.

The 5^{th} distinction is based on lead time/response time to customers demand. Manufacturers take generally some lead time (i.e. time period from placing the order to get the product) in terms of days/week. Whereas the services are offered within few minutes of customers arrival. For ex: ATM Service, getting postal stamps, getting grocery from a retail shop and getting examined by a doctor etc.

The 6^{th} distinction is on availability. Products can be available from regional, national or international markets due to availability of transportations and distribution facilities whereas, service can't shipped to distant locations. Thus service organization requiring direct customer contact must locate very near to the customers.

The 7^{th} distinction is based on liabilities/facilities. Manufacturing unit/organization producing products generally require larger facilities, more automation and greater capital investment than service providing organization.

The 8^{th} distinction is based on capital/labour priority. Generally manufacturing firm producing goods/products require more capital than a service provider. Ex. An automobile firm requires more capital than a post office/Nursing home. The 9^{th} and 10^{th} distinction is based on quality and demand variation.

2.4 Various types of Layout:

Plant layout means the disposition of the various facilities (equipment, material, manpower etc.) and services of the plant within the area of site located.

Objectives

- Material handling and transportation is minimized and effectively controlled.
- Bottlenecks and points of congestions are eliminated (by line balancing) so that the raw-material and semi-finished goods move fast from one workstation to other.
- Workstations are designed suitable and properly.
- Suitable spaces are allocated to production centers and service centers.
- The movements made by the workers minimized.

Layout can be classified into the following four categories:

a. process layout
b. product layout
c. Group layout(combination layout)
d. Fixed position layout

a. process layout:

- It is also known as functional layout.
- Here similar machines and services located together Ex. All the lathe machines will be at one place and all milling machines at another place and so on.
- This type of layout generally employed for industries engaged in job-shop production and non-repetitive kind of production.
- When there variety of products manufactured at low volume we prefer this type of layout.
- Ex. furniture manufacturer company, restaurant etc.

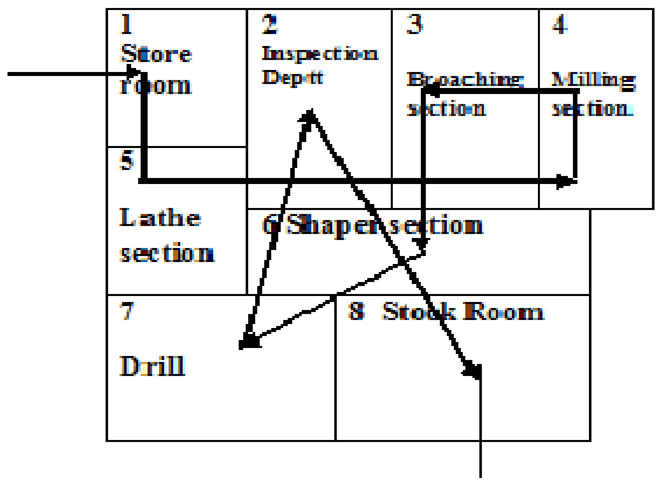


Fig 2.2 process layout

b. Product layout

- It is also known as line (type) layout.
- The flow of product will smooth and logical.
- When the machines and auxiliary services are located according to the processing sequence we prefer this layout.
- It implies that various operations raw material are performed in a sequence and the machines are placed along the product flow line.
- The product layout is selected when the volume of production of a product is high such that separate production line to manufacture it can be justified.
- Assembly line production or mass production prefer this type layout. Ex. Assembly of television sets assembly of computer key-board etc.

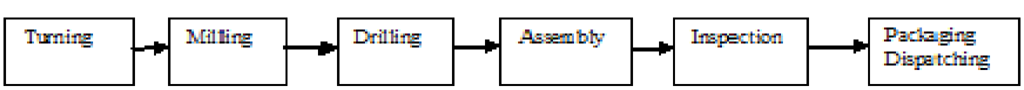


Fig 2.3 product layout

c. *Group layout:*

- It is the combination of both process and product layout.
- In this type of layout a set of machinery or equipment is grouped together in a section so that each group of machines or equipment is used to perform similar operations to produce a family of components. These machines grouped in to cells.
- It minimizes the sum of cost of transport and the cost of equipment.

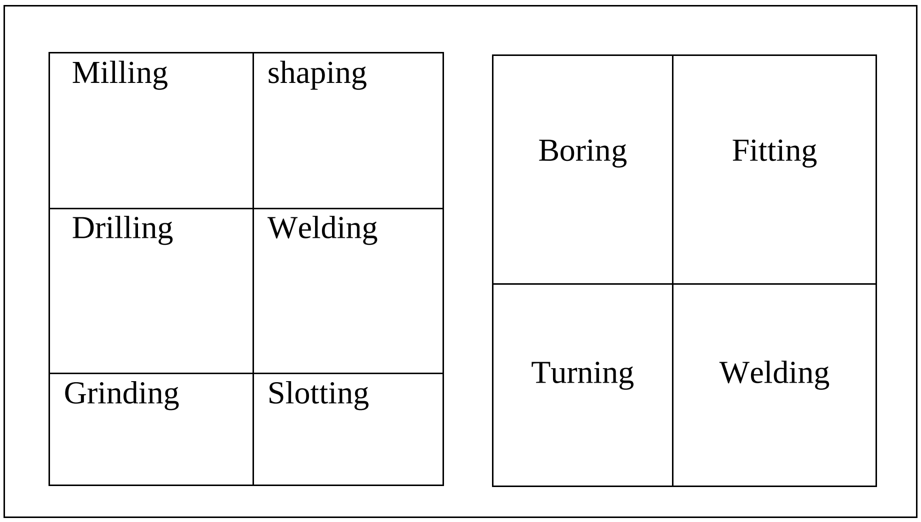


Fig 2.4 Group layout

d. *Fixed position layout*

- It is also called static product layoutin which the physical characterstics of the product dictate as to which type of machine and men are brought to the product.
- This type layout is inherent in ship building,aircraft manufacture and big pressure vessels fabrication.
- In other type layout the product moves past stationary production equipment where as in this case men and equipment are moved to the material at one place and the product is completed at the place where the material lies.

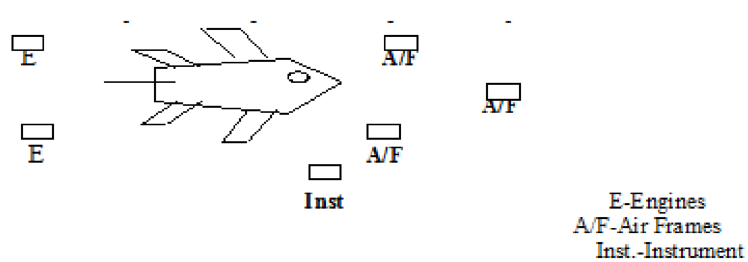


Fig 2.5 Fixed position layout

2.5 Process-focused and product-focused system:

In process-focused system the arrangement of facilities is made according to the process layout and in product-focused system the arrangement of facilities is made according to the product layout.

Comparison of process oriented layout and product oriented layout

Sl No.	Different Aspects	Process oriented	Product oriented
1	Product	Diversified products using operations, varying rate of output or small batches of many different products	Standardized product, large volume,stable rate of output
2	Workflow	Variable flow depending on nature of job	Identical flow and same sequence of operations for each unit.
3	Human skills	Semiskilled craftsman and able to do various/different categories of work	Highly specialized and able to perform repetitive tasks at fixed place
4	Supporting staffs	Less;scheduling,material handeling,production and inventory control	Large; schedule materials and people, monitor and maintain works
5	Material handling	Material handling cost high,handeling sometimes duplicated	Less dectble , flow systematized and often automated.
6	Inventory	In process inventory less	In process inventory high
7	Space utilization	Space and capital are tied up by work in process	Less space is occupied by work in transit and for temporary storage.
8	Capital requirement	Comparatively low investment in machines required	Large investment in specialized equipment and processes
9	Production cost	Relatively low fixed cost, high variable cost(for direct labour,material and material handling)	Relatively high fixed cost, low variable cost (for labour and materials)
10	Production time	Through time is larger.	Throughput time is lesser.
11	Flexibility of design change	high	low
12	Effect of breakdown	Break down of any machine doesn’t effect much on the final output	Seriously affected; as all are interrelated system.

2.6 Product life cycle

A product life cycle consist of 5 stages through which a product passes that is *introduction *growth*maturity*decline. the figure shown previously represent sales and profit associated with each stage and some practical example of products are also shown on it.

1. Introduction

At this stage, sales begin and profit goes from –ve to +ve. In this stage ,the demand is low .because the costumer don't know much about the product. The organization has to invest heavily in advertisement to make the product familiar to the costumers. the volume sales are low,and if proper care is not taken, there is chances to product failure.

2.Growth

The product next enters a stage at rapid growth. Early in this stage (due to acceptability of the product by the costumer) there is drastic jump in sales and profit rise. It is because of limited or no competition. During this stage the mandate for operation is somehow to keep up with demand; efficiency is less of concern.

3.Maturity

During this stage, sales level off and profit begins to decline. New competition create to cut costs and ultimately on unit profit margin. Now operation must stress on efficiency, although marketing can ease the pressure by intensifying to differentiate the product.

4.Decline

At last the existing product enters to a declining stage and becomes obsolete. Either demand despisers or a better less expensive product.

Life cycle suggest when to eliminate the existing product and introduce a new one. This life cycle varies greatly from product to product. For example it took 15 years for "Xerox" to introduce electrostatic copy m/c .in contrast and computer and microchip industry, products become obsolete in months.

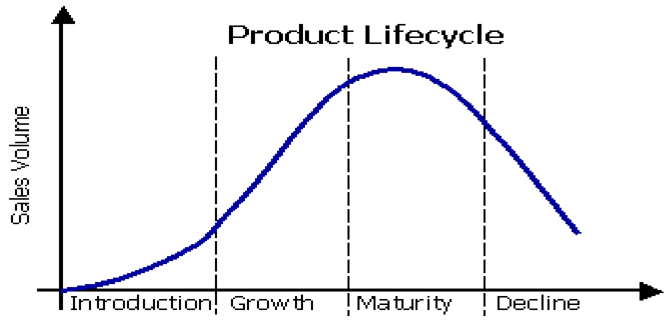


Fig 2.6. product life cycle

2.7 Production function

(a) Functions of industrial enterprise

(b) Functions of process

(a)Functions of industrial enterprise

The major functions of a relatively large industrial firm is represented by the following figure

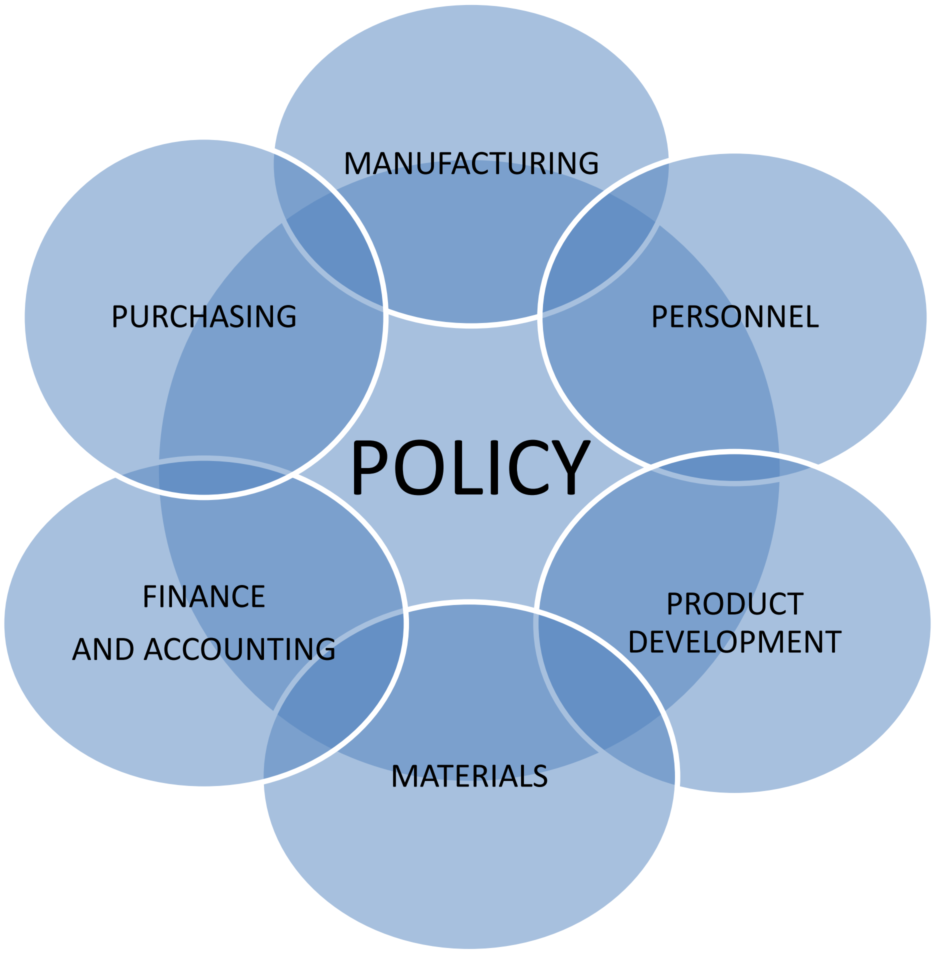


Fig 2.6 of production function a enterprise

The core area of the diagram represents the organization’s policy making group. In a hierarchic triangle, this group would occupy the apex. The overlapping portions of the circle denote the co-operation needed from the two groups in order to establish overall policy. The slope of each function and its relationship to the production process are briefly discussed in the following.

(i)Manufacturing

A fundamental function of much production system is to produce a physical output. Manufacturing includes the operations and direct support services for making the product operation management is concerned with production scheduling, performance standards, method improvement, quality control, plant layout and material handling. A plant service section handles shipping receiving, storing and transporting raw material parts and tools. The plant engineering group is usually responsible for in-plant construction, maintenance, design of tools and equipment and other problems of mechanical, hydraulic or electrical nature.

(ii) personnel

The recruitment and training of the personnel needed to operate the production system are the traditional responsibilities of the personnel function. Along with it, this department takes care health, safety, wage administration of the employees. Labour relation and employee services and benefits are increasingly important.

(iii) Product development

Many organizations give major emphasis on product development because the ultimate profit of any organization depends primarily on the nature/quality of product. The product must be customized. A separate section is responsible for this task.

(iv)Marketing

Many ideas of product development comes through the marketing function. Selling is the primary interest of marketing. Sales forecasts and estimate of the nature of future demands is also performed by this department. Contact with customers provide feedback about the quality expected from the firm and opinion on how well the products meet quality standard.

(v) Finance and accounting

Internal financing includes reviewing the budgets for operating sections, evaluating of proposed investments for production facilities and preparing balance sheet. Besides these the other responsibilities is to see how well the firm is scoring in the business competition game.

In this business game analogy the accounting functions are collection of cost data for materials direct labour and overhead. Special reports are prepared regarding scarp, parts and finished goods inventories, pattern of labour hours and similar data applicable to production activities.

(vi) Purchasing

In a narrow sense, purchasing is limited to accounting materials from outside sources. But while carrying out this activity, it requires to investigate the reliability of vendors, type of materials needed, co-ordinating material purchase volume with the requirement as per schedule, discovering new material and process. The purchasing function serves the other functional areas, overlap sometimes with inventory control, material inspection, shipping and receiving, sub-contracting and internal transportation.

(b)Functions of production process

Another was to group functions is according to their relative position in a production process. the sequential arrangement is shown in the following

Fig 2.7 functions of production process

2.8 Types of production system:

The production system of a company mainly uses facilities, equipments and operating methods(called the production system) to produce goods that satisfy customers' demand.The above requirements of a production system depend on the type of product that the company offers and the strategy that it employs to serve its customers. The classification of production system is explained in the table.

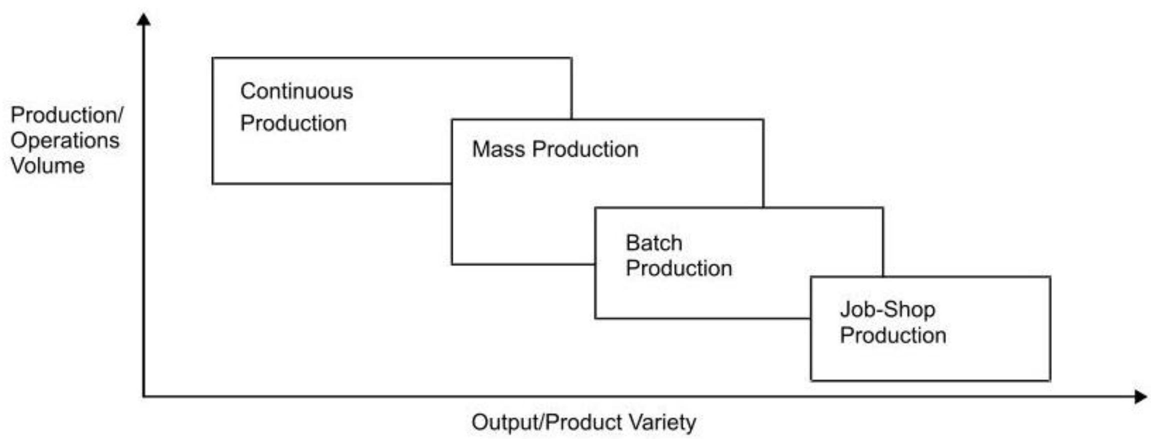


Fig 2.6 Classification of production systems

Job shop production

- Job shop is appropriate for manufactures of small batches of many different products, each of which is custom designed and requires its own unique set of processing steps or routing through production process.
- The production system in which different types of product follow different sequences through different shops. Ex. Furniture manufacturing company, restaurant, prototype industry.
- Much time is spent waiting for access to equipment. Some equipment overloaded.
- A process technology suitable for a variety of custom designed products in some volume.
- This production system adopts process layout as by this production system we manufacture more variety of products at low product volume.

Batch production

- A process technology suitable for variety of products in varying volumes.
- Here limited product variety which is fixed for one batch of product. Ex. Bakery shop, medicine shop.

- Within the wide range of products in the facility, several are demanded repeatedly and in large volume.
- This type of production system should be preferred when there is wide variety of products in wide variety of volumes.

Assembly line (mass) Production

- A process technology suitable for a narrow range of standardized products in high volumes.
- The successive units of output undergo the same sequence of operation using specialized equipment usually positioned along a production line.
- The product variety is fixed here. Ex. Assembly of television sets, assembly of auto, assembly of computer keyboard, cold drinks factory etc.

Continuous production

- A process technology suitable for producing a continuous flow of products.
- The product is highly standardized.
- Material and products are produced in continuous, endless flows, rather than in batches or discrete units.
- Continuous flow technology affords high volume, around-the clock operation with capital intensive, specialized automation.

2.9 Dimensions of Product Strategies:

- **Product-Positioning.**
- **Product-Repositioning.**
- **Product-Overlap.**
- **Product Scope.**
- **Product-Design.**
- **Product Elimination.**
- **New Product.**
- **Diversification.**
- **Value-Marketing.**

Product Positioning: The Procedure

1. **Analyze** product attributes that are salient to Customers.
2. **Examine** the distribution of these attributes among different segments.

3. **Determine** the optimal position for the product in regard to each attribute, taking into consideration the position occupied by existing brands.
4. Choose an overall position for the product (based on overall match between product attributes and their distribution in the population and the position of existing brands)

Product Positioning Strategy

- **Definition**: Placing a brand in that part of the market where it will have a favorable reception compared with competing brands.
- For Ex The marketers of “Liril” soap wants the people to think “Liril” when they think soap. The marketers of “Colgate” want the consumers to think “Colgate” when they think toothpaste etc.
- **Objective**
  - To position the product in the market so that it stands apart from competing brands. (b) To position the product so that it tells customers what you stand for, what you are, and how you would like customers to evaluate you. In the case of positioning multiple brands:
    - (a) To seek growth by offering varied products in differing segments of the market.
    - (b) To avoid competitive threats to a single brand
- **Requirements**: Use of marketing mix variables, especially design and communication efforts.
  - Successful management of a single brand requires positioning the brand in the market so that it can stand competition from the toughest rival and maintaining its unique position by creating the aura of a distinctive product.
  - Successful management of multiple brands requires careful positioning in the market so that multiple brands do not compete with nor cannibalize each other. Thus it is important to be careful in segmenting the market and to position an individual product as uniquely suited to a particular segment through design and promotion.
  - Expected Results:
  - Short term success
  - Meet as much as possible the needs of specific segments of the market

- Limit sudden changes in sales.
- Make customers faithful to the brands.

Product Re-positioning Strategy

- **Definition**: Reviewing the current positioning of the product and its marketing mix and seeking a new position for it that seems more appropriate.
- **Objectives**: (a) To increase the life of the product. (b) To correct an original positioning mistake.
- **Requirements:**
  - If this strategy is directed toward existing customers, repositioning is sought through promotion of more varied uses of the product.
  - If the business unit wants to reach new users, this strategy requires that the product be presented with a different twist to the people who have not been favorably inclined toward it. In doing so, care should be taken to see that, in the process of enticing new customers, current ones are not alienated.
  - If this strategy aims at presenting new uses of the product, it requires searching for latent uses of the product, if any. Although all products may not have latent uses, there are products that may be used for purposes not originally intended.
- **Expected Results:**
  - Among existing customers: increase in sales growth and profitability.
  - Among new users: enlargement of the overall market, thus putting the product on a growth route, and increased profitability.
  - New product uses: increased sales, market share, and profitability.

Product Overlap Strategy

- **Definition**: Competing against one's own brand through introduction of competing products, use of private labeling, and selling to original-equipment manufacturers.
- **Objectives:** Product overlap strategies can include selling similar goods in different markets, regions or international countries. For example, a company may sell widgets and cogs; both offer extremely similar consumer benefits. However, the company may sell widgets in the United States and cogs in Canada.
-

- **(a)** To attract more customers to the product and thereby increase the overall market.
- (b) To work at full capacity and spread overhead.
- (c) To sell to competitors; to realize economies of scale and cost reduction.

- **Requirements:**
  - (a) Each competing product must have its own marketing organization to compete in the market.
  - (b) Private brands should not become profit drains.
  - (c) Each brand should find its special niche in the market. If that doesn't happen, it will create confusion among customers and sales will be hurt.
  - (d) In the long run, one of the brands may be withdrawn, yielding its position to the other brand
- **Expected Results:**
  - Increased market share.
  - Increased growth.

Product Scope Strategy

- **Definition**: The product-scope strategy deals with the perspectives of the product mix of a company. The product-scope strategy is determined by taking into account the overall mission of the business unit. The company may adopt a single-product strategy, a multiple-product strategy, or a system-of-products strategy.
- **Objectives:**
  - Single product: to increase economies of scale by developing specialization.
  - Multiple products: to cover the risk of potential obsolescence of the single product by adding additional products.
  - System of products: to increase the dependence of the customer on the company's products as well as to prevent competitors from moving into the market.
- **Requirements:**
  - (a) Single product: company must stay up-to-date on the product and even become the technology leader to avoid obsolescence.
  - (b) Multiple products: products must complement one another in a portfolio of products.

- (c) System of products: company must have a close understanding of customer needs and uses of the products.

- **Expected Results:** Increased growth, market share, and profits with all three strategies. With system-of-products strategy, the company achieves monopolistic control over the market, which may lead to some problems with the Justice Department, and enlarges the concept of its product/market opportunities.

Product Design Strategy

- **Definition**: The product-design strategy deals with the degree of standardization of a product. The company has a choice among the following strategic options: standard product, customized product, and standard product with modifications.
- **Objectives:**
  - Standard product: to increase economies of scale of the company.
  - Customized product: to compete against mass producers of standardized products through product-design flexibility.
  - Standard product with modifications: to combine the benefits of the two previous strategies.
  - Requirements:
  - Close analysis of product/market perspectives and environmental
  - Changes, especially technological changes.
- **Expected Results:**
  - Increase in growth, market share, and profits. In addition, the
  - third strategy allows the company to keep close contacts with the market and
  - Gain experience in developing new standard products.

Product Elimination Strategy

- **Definition**: Cuts in the composition of a company's business unit product portfolio by pruning the number of products within a line or by totally divesting a division or business.
- **Objectives:**
  - To eliminate undesirable products because their contribution to fixed cost and profit is too low,

- Eliminate Products that its future performance looks grim, or because they do not fit in the business's overall strategy.
- The product elimination strategy aims at shaping the best possible mix of products and balancing the total business.
- Requirements:
- No special resources are required to eliminate a product or a division.
- However, because it is impossible to reverse the decision once the elimination

- **Requirements:**
  - No special resources are required to eliminate a product or a division.
  - An in-depth analysis must be done to determine
    - (a) the causes of current problems;
    - (b) The possible alternatives, other than elimination, that may solve problems (e.g., Are any improvements in the marketing mix possible?);
    - (c) The repercussions that elimination may have on remaining products or units.
    - Expected Results:
  - In the short run, cost savings from production runs, reduced
  - inventories, and in some cases an improved return on investment can be
  - Expected. In the long run, the sales of the remaining products may increase because more efforts are now concentrated on them.

New Product Strategy

- **Definition:** A set of operations that introduces (a) within the business, a product new to its previous line of products; (b) on the market, a product that provides a new type of satisfaction. Three alternatives emerge from the above: product improvement/modification, product imitation, and product innovation.
- **Objectives**: To meet new needs and to sustain competitive pressures on existing products. In the first case, the new-product strategy is an offensive one; in the second case, it is a defensive one.
- **Requirements:** A new-product strategy is difficult to implement if a "new product development system" does not exist within a company. Five components of this system should be assessed:

- Corporate aspirations toward new products,
- Organizational openness to creativity.

- **Requirements:** A new-product strategy is difficult to implement if a “new product development system” does not exist within a company. Five components of this system should be assessed:
  - Environmental favor toward creativity
  - Screening method for new ideas, and Evaluation process
- **Expected Results:** Increased market share and profitability.
  - are now concentrated on them.

Diversification Strategy

- **Definition**: Developing unfamiliar products and markets through:
  - Concentric diversification (products introduced are related to existing ones in terms of marketing or technology),
  - Horizontal diversification (new products are unrelated to existing ones but are sold to the same customers)
  - Conglomerate diversification (products are entirely new).
- **Objectives:** Diversification strategies respond to the desire for:
  - Growth when current products/markets have reached maturity,
  - Stability by spreading the risks of fluctuations in earnings,
  - Security when the company may fear backward integration from one of its major customers,
  - Credibility to have more weight in capital markets.
- **Requirements:** In order to reduce the risks inherent in a diversification strategy, a business unit should:
  - Diversify its activities only if current product/market opportunities are limited.
  - Have good knowledge of the area in which it diversifies.
  - Provide the products introduced with adequate support.
  - Forecast the effects of diversification on existing lines of products.
  - Expected Results:
  - Increase in sales.
  - Greater profitability and flexibility

Value Marketing Strategy

- **Definition**: The value-marketing strategy concerns delivering on promises made for the product or service. These promises involve product quality, customer service, and meeting time commitments.
- **Objectives:** Value-marketing strategies are directed toward seeking total customer satisfaction. It means striving for excellence to meet customer expectations.
- **Requirements:**
  - (a) Examine customer value perspectives.
  - (b) Design programs to meet customer quality, service, and time requirements.
  - (c) Train employees and distributors to deliver on promises.
  - Expected Results: This strategy enhances customer satisfaction, which leads to customer loyalty, and, hence, to higher market share. This strategy makes the firm less vulnerable to price wars, permitting the firm to charge higher prices and, thus, earn higher profits.

CHAPTER-III
FORECASTING

Casting data forward is called forecasting. It is a projection based upon past data or it is an estimate of an event which will happen in future.

Need of forecasting:

- When there is a time lag between awareness of an impending event or need and occurrence of that event. This lead time is the main reason of planning and forecasting.
- Planning is the fundamental activity of management. Forecasting forms the basis of planning.
- It is essential for the organization to know for what level of activities one is planning before investments in input.

Types of Forecasting:

→ **Short Term Forecasting**

→ **Long Term Forecasting**

Short Term forecasting is the forecasting that made for short term objectives covering less than one year. Ex. Material Requirement Planning (MRP), scheduling, sequencing, budgeting etc.

Long Term Forecasting is the forecasting that made for that made for long term objectives covering more than five years. Ex. Product diversification, sales and advertisement.

Elements of Forecasting:

Forecasting consists basically of analysis of the following elements.

a) Internal factors
b) External factors
   i. Controllable
   ii. Non-Controllable (Organizing with national economy,governments,customers and Competitors)

Basic categories of forecasting methods:

Forecasting methods can be divided in to three main categories.

A. Extrapolative or Time-series Methods
B. Casual or explanatory methods
C. Qualitative or judgmental methods

   Time-series Methods and explanatory methods are quantitative methods and judgmental methods are qualitative methods. Quantitative methods will be adopted when sufficient quantitative information available and when little or no qualitative information available but sufficient qualitative knowledge available qualitative methods will be preferable.

A. Extrapolative or Time-series Methods

- Time series forecasting models try to predict the future based on past data.
- Relate the forecast to only one factor – time.
- Include
  - ✓ Moving average
  - ✓ Exponential smoothing

Moving Average

- **Naive forecast:** demand in current period is used as next period's forecast
- **Simple moving average**
  - ♦ Uses average demand for a fixed sequence of periods.
  - ♦ Stable demand with no pronounced behavioral patterns.
- **Weighted moving average**
  - ♦ *Weights are assigned to most recent data.*

Moving Average: Naïve Approach

Example: Forecast the order for the month of November by Naïve approach.

MONTH	ORDERS PER MONTH	FORECAST
Jan	120	-
Feb	90	120
Mar	100	90
Apr	75	100
May	110	75
June	50	110
July	75	50
Aug	130	75
Sept	110	130
Oct	90	110
Nov	-	90

Solution: Forecast order for the month of November,

$$(F)_{Nov} = 90 \text{ units}$$

Simple Moving Average

n = number of periods taken to evaluate the moving average

D_t or D_i = Actual demand in that period

SMA_t = simple moving average at the end of the period t or estimated demand at the end of that period.

$$SMA_t = \frac{D_{t-(n-1)} + D_{t-(n-2)} + \ldots + D_{t-1} + D_t}{n}$$

3-month Simple Moving Average

MONTH	ORDERS MONTH PER MONTH	*MOVING AVERAGE*
Jan	120	–
Feb	90	–
Mar	100	–
Apr	75	103.3
May	110	88.3
June	50	95.0
July	75	78.3
Aug	130	78.3
Sept	110	85.0
Oct	90	105.0
Nov	-	110.0

$MA_3 =$

$$\frac{\sum_{i=1}^{3} D_i}{3} = \frac{90+110+130}{3} = 110$$

orders for Nov

5-month Simple Moving Average

MONTH	ORDERS MONTH PER MONTH	*MOVING AVERAGE*
Jan	120	–
Feb	90	–
Mar	100	–
Apr	75	–
May	110	–
June	50	99.0
July	75	85.0
Aug	130	82.0
Sept	110	88.0
Oct	90	95.0
Nov	-	91.0

$MA_5 =$

$$\frac{\sum_{i=1}^{5} D_i}{3} = \frac{90+110+130+75+50}{5} = 91$$

orders for Nov

Smoothing effects

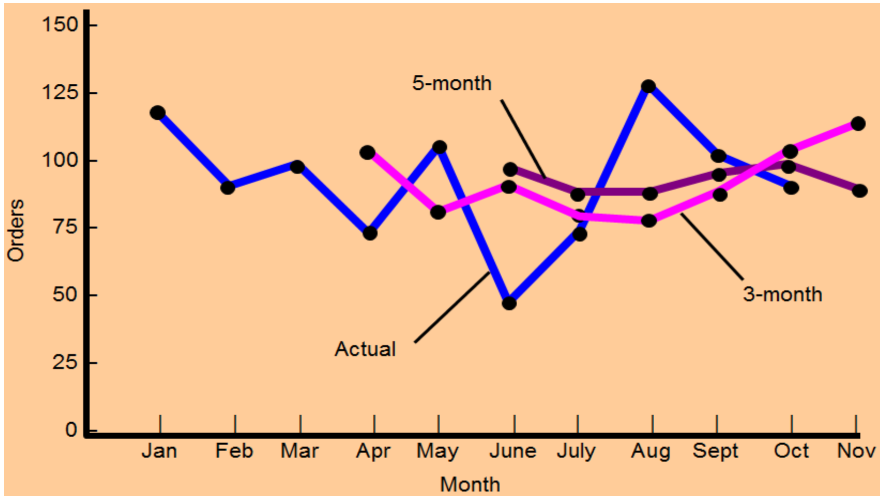


Fig 3.1 Classification of production systems

Note: ⅄ It gives equal weight to the demand in each of the most n periods.

⅄ Small value of n can capture data pattern more closely compared to high value of n Because high value of n averages out more to the data or a greater smoothing effect on random fluctuations.

Weighted Moving Average

While the moving average formula implies an equal weight being placed on each value that is being averaged, the weighted moving average permits an unequal weighting on prior time periods

$$WMA_t = \sum_{i=1}^{n} W_i D_i \qquad \sum_{i=1}^{n} w_i = 1$$

w_t = weight given to time period “t” occurrence (weights must add to one)

Question: Given the weekly demand and weights, what is the forecast for the 4^{th} period or Week 4?

Week	Demand
1	650
2	678
3	720
4	

Weights:
t-1
t-2
t-3

Note that the weights place more emphasis on the most recent data, that is time period “t-1”

Week	Demand	Forecast
1	650	
2	678	
3	720	
4		693.4

INPUT

- Material
- Machines
- Labor

Exponential Smoothing

$$F_{t+1} = \alpha D_t + (1 - \alpha) F_t$$

where:

F_{t+1} =forecast for next period

D_t =actual demand for present period

F_t = previously determined forecast for present period

α =weighting factor, smoothing constant

Effect of Smoothing Constant

$0.0 \leq a \leq 1.0$

If a = 0.20, then $F_{t+1} = 0.20\, D_t + 0.80\, F_t$

If a = 0, then $F_{t+1} = 0\, D_t + 1\, F_t = F_t$

Forecast does not reflect recent data

If a = 1, then $F_{t+1} = 1\, D_t + 0\, F_t = D_t$

Forecast based only on most recent data

Question: Given the weekly demand data, what are the exponential smoothing forecasts for periods 10^{th} using a=0.10 and a=0.60?

Assume $F_1 = D_1$

Week	Demand
1	820
2	775
3	680
4	655
5	750
6	802
7	798
8	689
9	775
10	

Solution: The respective alphas columns denote the forecast values. Note that you can only forecast one time period into the future.

Week	Demand	*0.1*	*0.6*
1	820	820.00	820.00
2	775	820.00	820.00
3	680	815.50	793.00
4	655	801.95	725.20
5	750	787.26	683.08
6	802	783.53	723.23
7	798	785.38	770.49
8	689	786.64	787.00
9	775	776.88	728.20
10		776.69	756.28

Note how that the smaller alpha results in a smoother line in this example

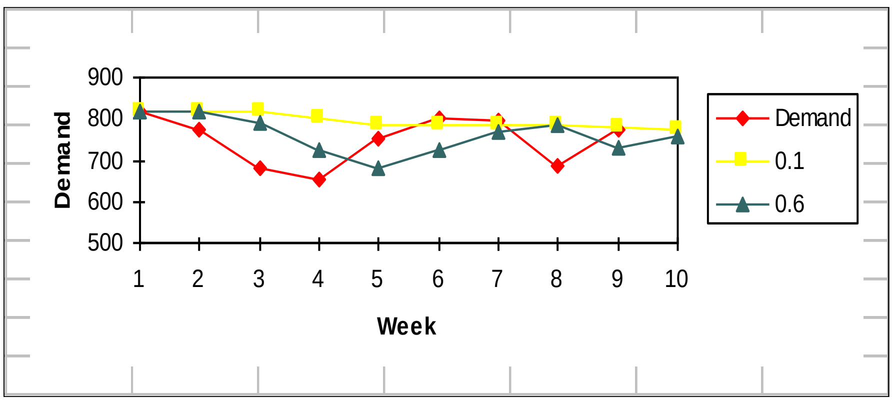


Fig 3.2 Effect of Smoothing Constant

Adjusted Exponential Smoothing

$$AF_{t+1} = F_{t+1} + T_{t+1}$$

where

T = an exponentially smoothed trend factor

$$T_{t+1} = \beta(F_{t+1} - F_t) + (1 - \beta)\ T_t$$

where

T_t = the last period trend factor

β = a smoothing constant for trend

$0 \le \beta \le 1$

$F_{t+1} = A_t + T_t$

Where,

$A_t = \alpha D_t + (1 - \alpha)(A_{t-1} + T_{t-1})$ and

T = an exponentially smoothed trend factor

$T_t = \beta(A_t - A_{t-1}) + (1 - \beta)T_{t-1}$

T = an exponentially smoothed trend factor

T_{t-1} = the last period trend factor

β = a smoothing constant for trend

$0 \le \beta \le 1$

Question

PM Computer Services assembles customized personal computers from generic parts. they need a good forecast of demand for their computers so that they will know how many parts to purchase and stock. They have compiled demand data for the last 12months. There is an upward trend in the demand. Use trend-adjusted exponential smoothing with smoothing parameter α= 0.5 and trend parameter β= 0.3 to compute the demand forecast for January (Period 13).

Period	Month	Demand	Period	Month	Demand
1	January	37	7	July	43
2	February	40	8	August	47
3	March	41	9	September	56
4	April	37	10	October	52
5	May	45	11	November	55
6	June	50	12	December	54

Solution:

For Period 2,

we have $F_2 = A_1 + T_1$, so to get the process started, let $A_0 = 37$ and $T_0 = 0$.

$A_1 = \alpha D_1 + (1 - \alpha)(A_0 + T_0) = 0.5(37) + (1 - 0.5)(37 + 0) = 37$,

and $T_1 = \beta(A_1 - A_0) + (1 - \beta)T_0 = 0.3(37 - 37) + (1 - 0.3)(0) = 0$

$F_2 = A_1 + T_1 = 37 + 0 = 37$

For Period 3,

$A2 = \alpha D2 + (1-\alpha)(A1+T1) = 0.5(40)+(1-0.5)(37+0) = 38.5$, and

$T2 = \beta(A2 - A1)+(1-\beta)T1 = 0.3(38.5 - 37) + (1 - 0.3)(0) = 0.45$.

$F3 = A2 + T2 = 38.5 + 0.45 = 38.95$.

			Expon. Smooth..	Trend-Adjusted Expon. Smooth. (α= 0.5, β = 0.3)		
Period	Month	Demand	α = 0.5	At	Tt	Ft
1	Jan	37	37.00	37.00	0.00	37.00
2	Feb	40	37.00	38.50	0.45	37.00
3	Mar	41	38.50	39.98	0.76	38.95
4	Apr.	37	39.75	38.87	0.20	40.73
5	May	45	38.38	42.03	1.09	39.06
6	Jun.	50	41.69	46.56	2.12	43.12
7	Jul.	43	45.84	45.84	1.27	48.68
8	Aug.	47	44.42	47.05	1.25	47.11
9	Sep.	56	45.71	52.15	2.41	48.31
10	Oct.	52	50.86	53.28	2.02	54.56
11	Nov.	55	51.43	55.15	1.98	55.30
12	Dec.	54	53.21	55.56	1.51	57.13
13	Jan	?	53.61			57.07

B. Casual or explanatory methods

Simple Linear Regression Model

$y = a + bx$

where

a = intercept

b = slope of the line

x = time period

y = forecast for demand for period x

$Nov_4 = WMA_3$ 0.5(720)+0.3(678)+0.2(650)=693.4

$$a = \bar{y} - b\bar{x}$$

$$b = \frac{\sum xy - n(\bar{y})(\bar{x})}{\sum x^2 - n(\bar{x})^2}$$

Question: Given the data below, what is the simple linear regression model that can be used to predict sales in future weeks?

Week	Sales
1	150
2	157
3	162
4	166
5	177

Solution: First, using the linear regression formulas, we can compute "a" and "b".

Week	Week*Week	Sales	Week*Sales
1	1	150	150
2	4	157	314
3	9	162	486
4	16	166	664
5	25	177	885
3	*55*	*162.4*	*2499*
Average	Sum	Average	Sum

$$b = \frac{\sum xy - n(\bar{y})(\bar{x})}{\sum x^2 - n(\bar{x})^2} = \frac{2499 - 5(162.4)(3)}{55 - 5(9)} = \frac{63}{10} = \mathbf{6.3}$$

$$a = \bar{y} - b\bar{x} = 162.4 - (6.3)(3) = \mathbf{143.5}$$

The resulting regression model is:

$$Y_t = 143.5 + 6.3x$$

Correlation Coefficient, *r*

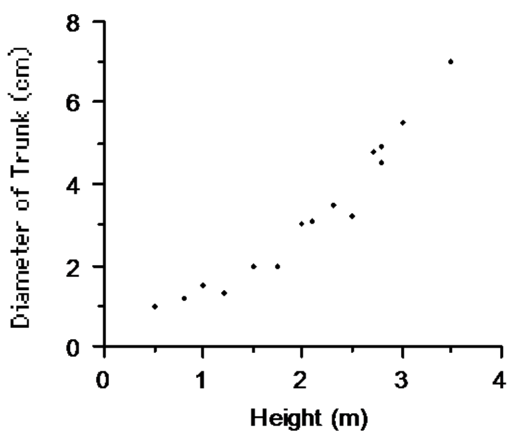
- ✓ The quantity *r*, called the *linear correlation coefficient*, measures the strength and the direction of a linear relationship between two variables. The linear correlation coefficient is sometimes referred to as the *Pearson product moment correlation coefficient* in honor of its developer Karl Pearson.
- ✓ The value of r is such that $-1 < r < +1$. The + and – signs are used for positive linear correlations and negative linear correlations, respectively.
- ✓ Positive correlation: If x and y have a strong positive linear correlation, r is close

to +1. An r value of exactly +1 indicates a perfect positive fit.   Positive values indicate a relationship between x and y variables such that as values for x increases, values for y also increase.

- ✓ Negative correlation: If x and y have a strong negative linear correlation, r is close to -1. An r value of exactly -1 indicates a perfect negative fit.   Negative values indicate a relationship between x and y such that as values for x increase, values for y decrease.
- ✓ No correlation: If there is no linear correlation or a weak linear correlation, r is Close to 0. A value near zero means that there is a random, nonlinear relationship between the two variables
- ✓ Note that r is a dimensionless quantity; that is, it does not depend on the units employed.
- ✓ A perfect correlation of ± 1 occurs only when the data points all lie exactly on a straight line. If r = +1, the slope of this line is positive. If r = -1, the slope of this line is negative.

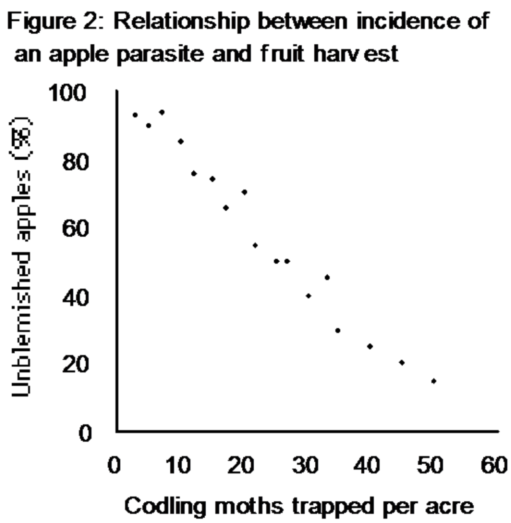
Positive Correlation

Figure 1: Relationship between height and trunk diameter in Eastern White Pines



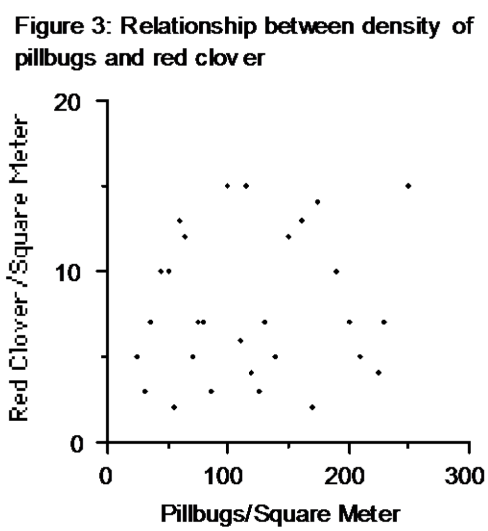
Notice that in this example as the heights increase, the diameters of the trunks also tend to increase. If this were a perfect positive correlation all of the points would fall on a straight line. The more linear the data points, the closer the relationship between the two variables.

Negative Correlation



Notice that in this example as the number of parasites increases, the harvest of unblemished apples decreases. If this were a perfect negative correlation all of the points would fall on a line with a negative slope. The more linear the data points, the more negatively correlated are the two variables.

No Correlation



Notice that in this example there seems to be no relationship between the two variables. Perhaps pillbugs and clover do not interact with one another.

The mathematical formula for computing ***r*** is:

$$r = \frac{n\sum xy - \left(\sum x\right)\left(\sum y\right)}{\sqrt{n\left(\sum x^2\right) - \left(\sum x\right)^2}\sqrt{n\left(\sum y^2\right) - \left(\sum y\right)^2}}$$

Where n is the number of pairs of data.

A correlation greater than .8 is generally described as strong , whereas a correlation less than .5 is generally described as weak.

Coefficient of Determination, r 2 or R2 :

- ✓ The *coefficient of determination*, r^2, is useful because it gives the proportion of the variance (fluctuation) of one variable that is predictable from the other variable. It is a measure that allows us to determine how certain one can be in making predictions from a certain model/graph.
- ✓ The *coefficient of determination* is the ratio of the explained variation to the total variation.
- ✓ The *coefficient of determination* is such that $0 \leq r^2 \leq 1$, and denotes the strength of the linear association between *x* and *y*.
- ✓ The coefficient of determination represents the percent of the data that is the closest to the line of best fit. For example, if r = 0.922, then r 2 = 0.850, which means that 85% of the total variation in y can be explained by the linear relationship between x and y (as described by the regression equation). The other 15% of the total variation in y remains unexplained.
- ✓ The coefficient of determination is a measure of how well the regression line represents the data. If the regression line passes exactly through every point on the scatter plot, it would be able to explain all of the variation. The further the line is away from the points, the less it is able to explain.

C. Qualitative or judgmental methods

- **Delphi Method**
- **Market Research**

Delphi Method

- The Delphi method is a process of gaining consensus from a group of experts While maintaining their anonymity.
- It is forecasting techniques applied to subjective nature demand values.
- It is useful when there is no historical data from which to develop statistical models and when managers inside the firm have no experience.
- Several knowledgeable persons are asked to provide estimates of demand or forecasts of possible advances of technology.
- A coordinator sends questions to each member of the panel of outside experts, and they are unknown to each other. Anonymity is important when some members of the tend to dominate discussion or command a high degree of respect in their field. The members tend to respond to the questions and support their responses freely. The coordinator prepares a statistical summary of the responses along with a summary of arguments for a particular response. If the variation

among the opinions too much the report is sent to the same group for another round and the participants may choose to modify their previous responses. This process will be continuing until consensus is obtained. So Delphi method is a iterative process.

Market Research

- It is systematic approach to determine external consumer interest in a service or product by creating and testing hypothesis through data-gathering surveys.
- It includes all research activities in marketing problem:
    - Gathering, recording and analyzing the utility and marketability of the product
    - The nature of the demand
    - The nature of competition
    - The methods of marketing
    - Other aspects of movements of product from the stage of to the point where they get consumed.
- Market research gathers records and analysis all facts about problems relating to the transfer and sale of goods and services from producer to consumer.
- Market Research procedure
  Define the problem clearly
  Develop a clear set of research objectives.
  Supervise the task of collecting the data from the existing consumers.
  Extract meaningful information from the collected data.
  Prepares a report presenting the major findings and recommendations coming from the study.
- It may be used to forecast demand for the short, medium and long-term. Accuracy is excellent for the short term, good for the medium term and only fair for the long term.

Forecast Error:

Forecast error
Difference between forecast and actual demand.

MAD (mean absolute deviation):

$$MAD = \frac{\sum_{t=1}^{n} \left| D_t - F_t \right|}{n}$$

where

t = period number
D_t = demand in period t
F_t = forecast for period t

n = total number of periods

Question: What is the MAD value given the forecast values in the table below?

Month	**Sales**	**Forecast**
1	220	
2	250	255
3	210	205
4	300	320
5	325	315

Solution

Month	**Sales**	**Forecast**	**Abs Error**
1	220		
2	250	255	5
3	210	205	5
4	300	320	20
5	325	315	10
			40

$$MAD = \frac{\sum_{t=1}^{n} |D_t - F_t|}{n} = \frac{40}{4} = 10$$

Note that by itself, the MAD only lets us know the mean error in a set of forecasts

Mean absolute percent deviation (MAPE)

$$MAPE = \frac{1}{n} \frac{\sum_{t=1}^{n} |D_t - F_t|}{D_t} * 100$$

Demand Behavior:

- Trend
    - a gradual, long-term up or down movement of demand
- Random variations
    - movements in demand that do not follow a pattern
- Cycle

- an up-and-down repetitive movement in demand

- Seasonal pattern
  - an up-and-down repetitive movement in demand occurring periodically

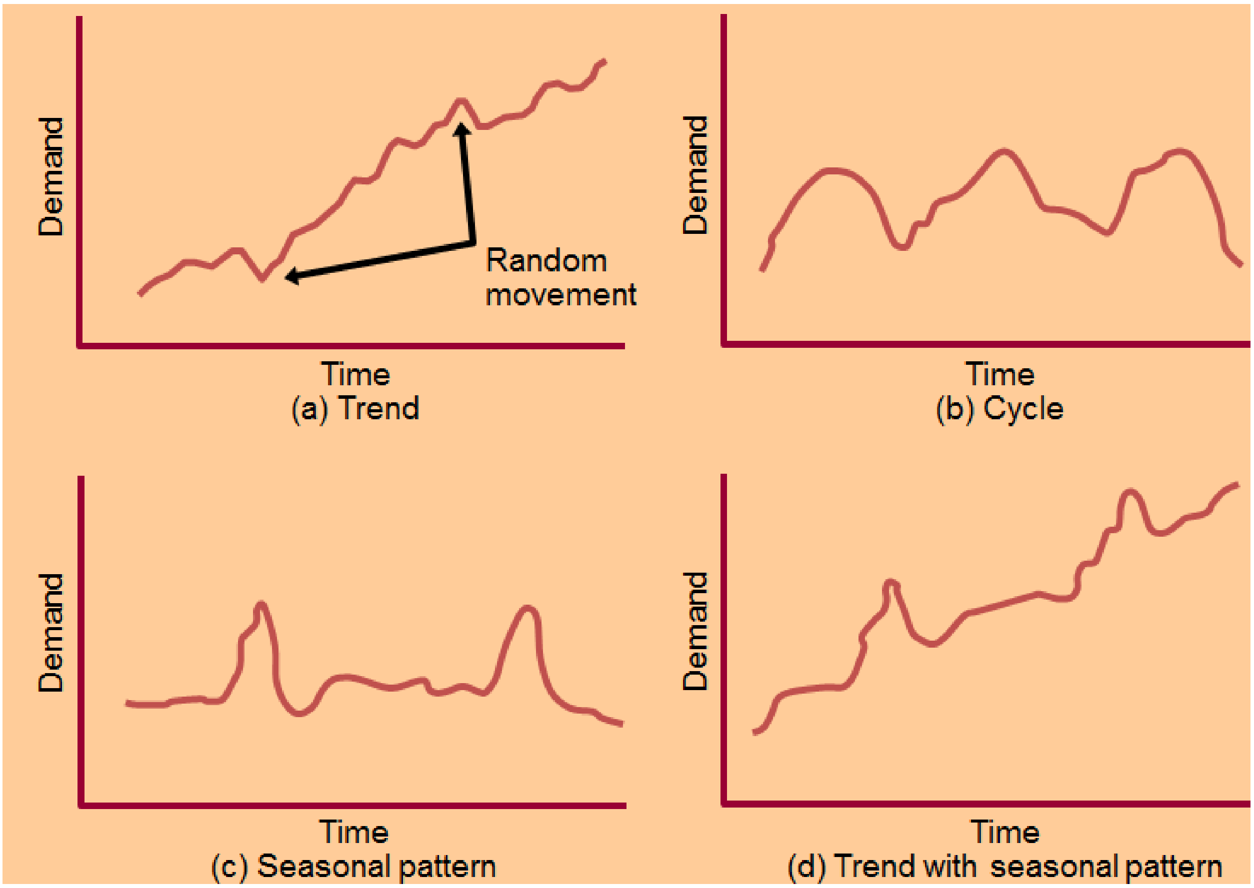


Fig 3.3 Forms of Forecast Movement

CHAPTER-IV
FACILITY PLANNING

To produce products or services business systems utilize various facilities like plant and machineries, ware houses etc.

Facilities can be broadly defined as buildings where people, material, and machines come together for a stated purpose – typically to make a tangible product or provide a service.

The facility must be properly managed to achieve its stated purpose while satisfying several objectives. Such objectives include producing a product or producing a service

- at lower cost,
- at higher quality,
- or using the least amount of resources.

4.1 Definition of Facilities Planning

Importance of Facilities Planning & Design Manufacturing and Service companies spend a significant amount of time and money to design or redesign their facilities. This is an extremely important issue and must be addressed before products are produced or services are rendered.

A poor facility design can be costly and may result in:

- poor quality products,
- low employee morale,
- customer dissatisfaction.

4.2 Disciplines involved in Facilities Planning (FP)

Facilities Planning (FP) has been very popular. It is a complex and a broad subject. Within the engineering profession:

- civil engineers,
- electrical engineers,
- industrial engineers,
- mechanical engineers are involved in FP.

Additionally,

- architects,
- consultants,
- general contractors,
- managers,
- real estate brokers, and
- urban planners are involved in FP.

4.3 Applications of Facilities Planning (FP)

Facilities Planning (FP) can be applied to planning of:

- a new hospital,
- an assembly department,

• an existing warehouse,
• the baggage department in an airport,
• department building of IE in EMU,
• a production plant, • a retail store,
• a dormitory,
• a bank,
• an office,
• a cinema,
• a parking lot,
• or any portion of these activities etc.

4.4 Factors affecting Facility Layout

Facility layout designing and implementation is influenced by various factors. These factors vary from industry to industry but influence facility layout. These factors are as follows:

- The design of the facility layout should consider overall objectives set by the organization.
- Optimum space needs to be allocated for process and technology.
- A proper safety measure as to avoid mishaps.
- Overall management policies and future direction of the organization.

4.5.1 Break-Even Analysis

The objective is to maximize profit. On economic basis only revenues and cost need to be considered for comparing various locations.

The steps for locational break-even analysis are :

- Determine all relevant costs for each location.
- Classify the location for each location in to annual fixed cost and variable cost per unit.
- Plot the total costs associated with each location on a single chart of annual cost versus annual volume.
- Selwct the location with the lowest total annual cost(TC) at the expected production volume.

Question:

Potential locations A,B and C have the cost structures shown below for manufacturing a product expected to sell for Rs 2700 per unit. Find the most economical location for an expected volume of 2000 units per year.

Site	Fixed Cost/year	Variable Cost/Unit
A	6,000,000	1500
B	7,000,000	500
C	5,000,000	4000

Solution:

For each plant find the total cost using the formula

TC=Fixed cost+ Variable cost/unit (volume)

= FC+VC(v)

Site	Total Cost
A	6,000,000+1500*2000=9,000,000
B	7,000,000+500*2000=8,000,000
C	5,000,000+4000*2000+13,000,000

From the above table, the cost of for the location B, is minimum. Hence it is to be selected for locating the plant.

Production Volume	Site A	Site B	Site C
500	6750000	7250000	7000000
1000	7500000	7500000	9000000
1500	8250000	7750000	11000000
2000	9000000	8000000	13000000
2500	9750000	8250000	15000000
3000	10500 000	8500000	17000000

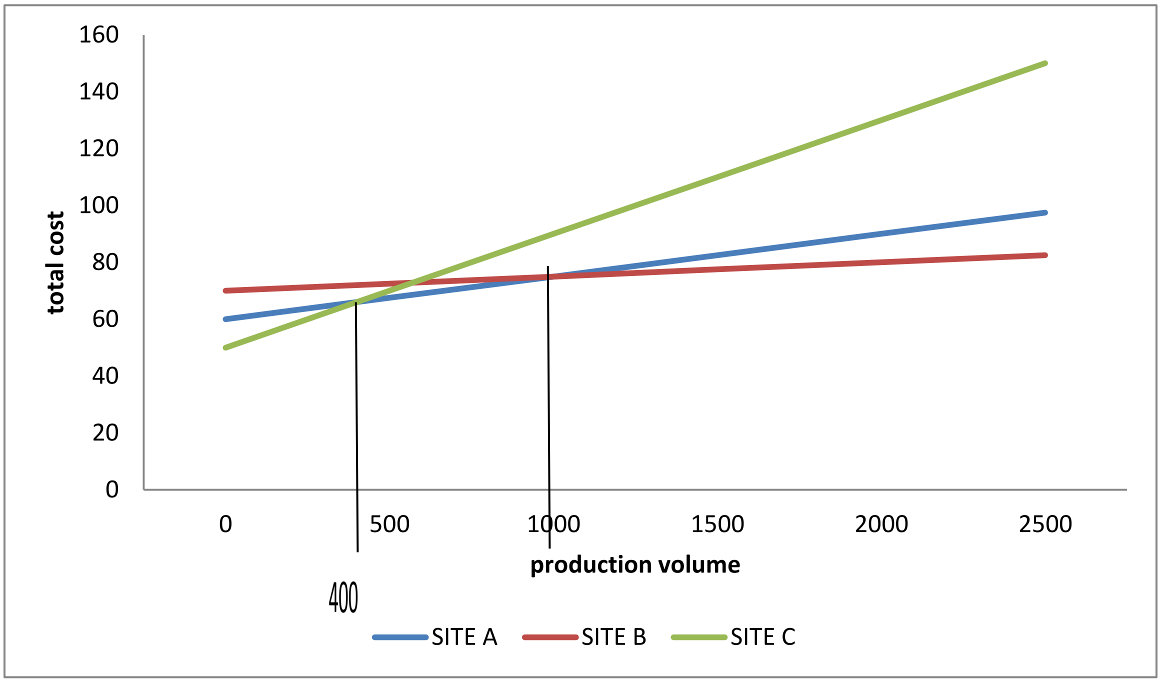


Fig 3.1 Break even analysis

From the graph, the different ranges of production volumes over which the best location to be selected are summarized.

Range of production volume	Best plant selected
0≤Q≤400 400≤Q≤1000 1000≤Q	A B C

The same details can be worked out using a graph

From the graph one can visualize that the site c is desirable for lower volume of production. For higher volume production site B is desirable For moderate volumes of production site nA is desirable. In the increasing order of production volume the switch over from one site to another takes place as per the order below

Site C to site A to site B

Let Q be the volume at which we switch the site C to site A

Total cost of site C ≥ Total cost site A

$5000000+4000Q \geq 6000000+1500*Q$

$2500Q \geq 1000000$

$Q \geq 400$ Units

Similarly the switch from site A to site B

Total cost of site A ≥ total cost of site B

$6000000+1500Q \geq 7000000+500Q$

$1000Q \geq 1000000$

$Q \geq 1000$ Units

The cutoff production volume for different ranges of production may be obtained by using similar procedure.

4.5.2 GRAVITY LOCATION PROBLEM

Objective- The objective of the gravity location problem, the total material handling cost based on the squared Euclidian distance is minimized

Assumption:- If the same type of material handling equipment / vehicle is used for all the movements, then it is equivalent to minimize the total weighted squared Euclidian distance, since the cost per unit distance is minimized

a_i = x-co-ordinate of the existing facilities i

b_i = y- co-ordinate of the existing facilities i

x = x-co-ordinate of the new facilities

y= y-co-ordinate of the new facilities

w_i= weight associated with the existing facilities i. This is the quantum of materials moved between the new facility and existing facilities I per unit period

m= total no of existing facilities

the formula for the sum of the weighted squared Euclidian distance is given as:

$$f(x,y) = \sum_{i=1}^{m} w\,i[(x-ai)^2 + (y-bi)^2]$$

The objective is to minimize f(x,y)

This is quadratic in nature the optimal values for the x and y may be obtained by equating partial derivatives to zero

$$\frac{\delta f(x,y)}{\delta x} = o \ , \quad \frac{\delta f(x,y)}{\delta y} = 0$$

$$x* = \frac{\sum_{i=1}^{m} wiai}{\sum_{i=1}^{m} wi} \quad ,y* = \frac{\sum_{i=1}^{m} wibi}{\sum_{i=1}^{m} wi}$$

Optimal location (x*,y*)=($\frac{\sum_{i=1}^{m} wiai}{\sum_{i=1}^{m} wi}$, $\frac{\sum_{i=1}^{m} wibi}{\sum_{i=1}^{m} wi}$)

These are weighted averages of the x-coordinate and y-co ordinates of the existing facilities.

Problem

There are five Existing facilities which are to be served by single new facilities are shown below in the table

Existing facility (i)	1	2	3	4	5
Co-ordinates (ai,bi)	(5,10) (15,20)	(20,5) (30,35)	(15,20) (25,40)	(30,25) (28,30)	(25,5) (32,40)
No of trips of loads/years (wi)	100 200	300 300	200 400	300 500	100 600

Find the optimal location of the new facilities based on giving location concept

SOLUTION

$$X^* = \frac{\sum_{i=1}^{5} wiai}{\sum_{i=1}^{5} wi} = \frac{(100*5+300*20+200*15+300*30+100*25)}{(100+300+200+300+100)} = 21$$

$$Y^* = \frac{\sum_{i=1}^{5} wibi}{\sum_{i=1}^{5} wi} = \frac{(100*10+300*5+200*20+300*25+100*5)}{(100+300+200+300+100)} = 14.5$$

4.5.3 SINGLE FACILITY LOCATION PROBLEM

Objective – To determine the optimal location for the new facility by using the given set of existing facilities co-ordinates on X-Y plane and movement of materials from a new facility to all existing facilities.

Generally we follow rectilinear distance for such decision. The rectilinear distance between any two points whose co-ordinates are (X1,Y1)and(X2,Y2) is given by the following formula

$d_{12} = |X1 - X2| + |Y1 - Y2|$

some properties of an optimum solution to the rectilinear distance location problems are as follows:

1. The X-coordinate of the new facility will be same as the X-co-ordinate of some existing facility. Similarly the Y co-ordinate of the new facility will coincide with the Y coordinate of some existing facility. It is not necessary that both coordinates of the new facility
2. The optimum X or Y-co-ordinate location for new facility is a median location. A median location is defined to be a location such that no more than one half the item movement is to the left/below of the new facility location and no more than one half the item movement is to the right /above of the new facility location.

EXAMPLE

Consider the location of a new plant which will supply raw materials to a set of existing plants in a group of companies, let there are 5 existing plants which have a materials movement relationship with the new plant. Let the existing plants have locations of (400,200),(800,500),(1100,800),(200,900)and(1300,300). Furthermore suppose that the number of tons of materials transported per year from the new plant to various existing plants are 450,1200,300,800 and 1500, respectively the objective is to determine optimum location for the new plant such that the distance moved(cost)is minimized

SOLUTION

Let (X,Y) be the coordinate of the new plant

The optimum X-coordinate for the new plant is determined as follows

Existing plant	X coordinate	weight	Cumulative Weight
4	200	800	800
1	400	450	1250
2	800	1200	2450
3	1100	300	2750
5	1300	1500	4250
		Total	4250 tons

Thus the median location corresponds to a cumulative weight of 4250/2=2125 from above the table, the corresponding X-coordinate value is 800, since the cumulative weight first exceeds 2125 at X=800

Similarly, the determination of Y coordinate is shown below

Existing plant	Y coordinate	weight	Cumulative Weight
1	200	450	450
5	300	1500	1950
2	500	1200	3150
3	800	300	3450
4	900	800	4250
		Total	4250 tons

Thus the median location corresponds to a cumulative weight of 4250/2=2125 from above the table, the corresponding Y-coordinate value is 500, since the cumulative weight first exceeds 2125 at X=500

The optimal (X*,Y*)=(800,500)

4.5.4 MINIMAX LOCATION PROBLEM

Objective- To locate the new emergency facility (X,Y) such that the maximum distance from the new emergency facility to any of the existing facilities is minimized

Fi(X,Y)= Distance between the new facilities and the existing facilities

Fi(X,Y)=|X-ai|+|Y-bi|

Fmax (X,Y)=maximum of the distance between the new facility and various existing facilities

Fmax(X,Y)= $\underbrace{max}_{1\le i\le m}$ {|X-a_i|+|Y-b_i|}

The distance between new facility and existing facility may be rectilinear or Euclidean

m=different shops in an industry

in the event of fire in any one of these shops a costly firefighting equipment showed reach the spot as soon as possible from its base location. Movements within any industry are rectilinear in nature. Our objective is to locate the new fire fighting equipment within the industry such that maximum distance it has to travel from its base location to any of the existing shops is minimized.

Step 1

Find c_1, c_2, c_3, c_4 and c_5,using following formula

$c_1 = \underbrace{min}_{1\le i\le m} (a_i + b_i)$ $c_2 = \underbrace{max}_{1\le i\le m} (a_i + b_i)$ $c_3 = \underbrace{min}_{1\le i\le m} (-a_i + b_i)$ $c_4 = \underbrace{max}_{1\le i\le m} (-a_i + b_i)$

$c_5 = \underbrace{max}_{1\le i\le m} (c_2 - c_1, c_4 - c_3)$

Step 2

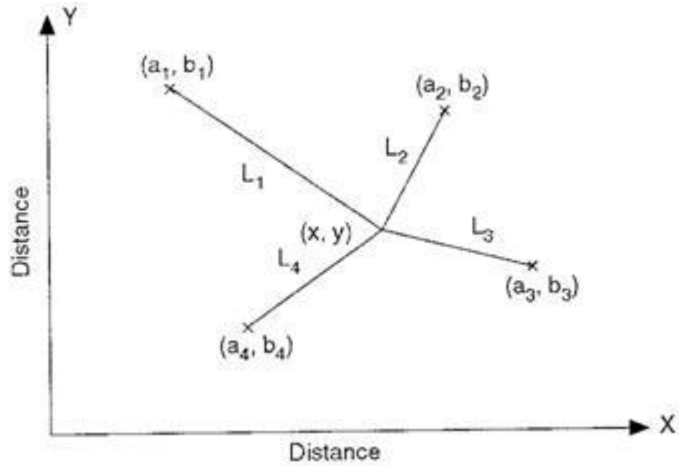
Find the points P_1 and P2 using the following formula

P1=[1/2($c_1 - c_3$), ½($c_1 + c_3 + c_5$)]

P2=[1/2($c_2 - c_4$), ½($c_2 + c_4 - c_5$)]

Step 3

Any pt(X*,Y*) on the line segment joining points P1 and P2 is a minimax location that minimize fmax(X,Y)



GRAPH OF MINIMAX LOCATION PROBLEM

EXAMPLE

In a foundry there are seven shops whose coordinates are summarized in the following table. The company is interested in locating a new costly fire fighting equipment in the foundry determine the minimax location of the new equipment

SL NO	EXISTING FACILITIES	CO-ORDINATE OF CENTROID
1	Sand plant	10,20
2	Molding shop	30,40
3	Pattern shop	10,120
4	Melting shop	10,60
5	Felting shop	30,100
6	Fabrication shop	30,140
7	Annealing shop	20,190

SOLUTION

The movement of new equipment is constrained within in the foundry the assumption of rectilinear distance more appropriate

The co ordinate of the centroid of the existing shops are

(a1,b1)=(10,20) (a2,b2)=(30,40) (a3,b3)=(10,120) (a4,b4)=(10,60) (a5,b5)=(30,100) (a6,b6)=(30,140) (a7,b7)=(20,140)

Step 1

$c_1 = \underbrace{min}_{1\le i\le m}(a_i + b_i)$ = min [(10+20),(30+40),(10+120),(10+60),(30+100),(30+140),(20+190)]

=min[30,70,130,70,130,170,210]=30

$c_2 = \underbrace{max}_{1\le i\le m}(a_i + b_i)$ = max[30,70,130,70,130,170,210]=210

$c_3 = \underbrace{min}_{1\le i\le m}(-a_i + b_i)$=min[(-10+20),(-30+40),(-10+120),(-10+60),(-30+100),(-30+140),

(-20+190)]=min[10,10,110,50,70,110,170]=10

$c_4 = \underbrace{max}_{1\le i\le m}(-a_i + b_i)$ =max[10,10,110,50,70,110,170]=170

$c_5 = \underbrace{max}_{1\le i\le m}(c_2 - c_1, c_4 - c_3)$=max[(210-30),(170-10)]=max[180,160]=180

P1=[1/2$(c_1 - c_3)$, ½$(c_1 + c_3 + c_5)$]=[1/2(30-10),1/2(30+10+180)]=(10,110)

P2=[1/2$(c_2 - c_4)$, ½$(c_2 + c_4 - c_5)$]= [1/2(210-170),1/2(210+170-180)]=(20,100)

Any point X*,Y* on the line segment joining pts (10,110),(20,100) is a minimax location for the firefighting equipment.

4.6 Layout Design Procedure

Layout design procedures can be classified into manual methods and computerized methods.

Manual methods. Under this category, there are some conventional methods like travel chart and Systematic Layout Planning (SLP).

Computerized methods

Under this method, again the layout design procedures can be classified in to constructive type algorithm and improvement type algorithms.

Construction type algorithms

Automated Layout Design program (ALDEP)

Computerized Relationship Layout Planning (CORELAP)

Improvement type Algorithm

Computerized Relative Allocation of Facilities Technique (CRAFT)

4.6.1 Computerized Relative Allocation of Facilities Technique (CRAFT)

CRAFT algorithm was originally developed by Armour and Buffa. CRAFT is more widely used than ALDEP and CORELAP. It is an improvement algorithim.It starts with an initial layout and improves the layout by interchanging the departments pairwise so that transportation cost is minimized.

CRAFT requirements

1. Initial layout
2. Flow data
3. Cost per unit distance
4. Total number of departments
5. Fixed departments
   Number of such departments
   Location of those departments
6. Area of departments

4.7 Algorithms and models for Group Technology

In this section Rank Order Clustering (ROC) and Bond Energy Algorithms are the methods can be applied to Group Technology (GT).

4.7.1 Rank Order Clustering Algorithm (ROC)

This algorithm was developed by J.R King(1980).This algorithm considers the following data**.**

- Number of Components
- Component Sequence

Based on the component sequences, a machine-component incidence matrix is developed. The rows of the machine-component incidence matrix represent the machines which are required to processes the components. The columns of the matrix represent the component numbers.

STEPS IN ROC LOGARITHM

Step 0 : Input : Total no of components and component sequences

Step 1. From the machine component incidence matrix using the component sequences

Step 2. Compute binary equivalent of each row.

Step 3. Re arrange the rows of the matrix in rank wise (high to low from top to bottom)

Step 4. Compute binary equivalent of each column and check whether the column of the matrix are arranged in rank wise (high to low from left to right)? If not go to step 5 otherwise go to step 7

step 5. Rearrange the columns of the matrix rank wise and compute the binary equivalent of each row

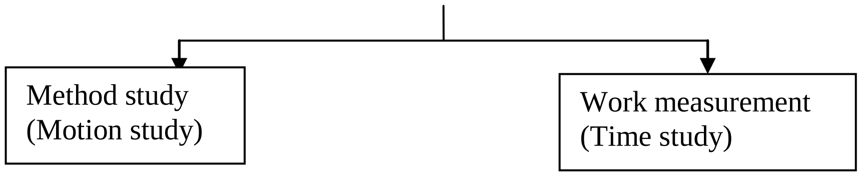
Step 6. Check whether the rows of the matrix are arranged rank wise? If not go to step 3; Otherwise, go to step 7

Step 7. Print the final machine component incidence matrix.

By following this steps the problems can be solved.

Chapter 5: Motion Study

- Work study is a technique which is employed to ensure the best possible use of men, machine, materials and energy in carrying out a specific activity. It deals with the techniques of method study and work measurement.



- Work study is based on the principle that for every job, there is:
  - a) One best way of doing it.
  - b) A scientific method is the best and surest way of finding this best way.

  } Motion study
  - c) The time taken for doing the job by the best way can be measured and set as standards.

  } Time study

5.1 Motion study:

- ➢ It is defined as a systematic and critical study of existing method of doing a task with a view to evolve the most efficient and economic method of doing it.
- ➢ It is a method for setting up employee productivity standards in which:
  - A complex job is broken down into small or simple steps.
  - The sequence of movements taken by the employee in performing those steps is carefully observed to detect and eliminate wasteful motion.
  - Precise time taken for each correct movement is measured.

From these measurements, production and delivery times and prices are computed and incentive schemes are devised. Generally it is appropriate only for repetitive tasks. Time and motion studies were pioneered by the US industrial engineer Frederick Winslow Taylor (1856-1915) and developed by the husband and wife team of Frank Gilbreth (1868-1924) and Dr. Lillian Gilbreth (1878-1972).

Objectives of motion study

The objectives of motion study are:

- To improve the procedure of doing a work.
- To improve the workplace layout (ultimately plant layout).
- To minimize the human motion for minimum fatigue of operators.
- To maximize the utility of resources (men, m/c, materials).
- To improve the overall working environment.

5.2 Principles of motion economy

- Analysis of an operation when carried out in terms of individual motion of a worker is known as Motion analysis.
- The purpose of motion analysis is to design an improved method which would eliminate unnecessary motion and employs human effort more productively. In doing so, the Principle of motion economy is very much helpful.
- It consists of a set of rules designed by Gilbreth and later rearranged and amplified by others (Branes Lowry et al) to develop better methods.

(i) It is classified into following 04 categories: Rules concerning human body, workplace layout and material handling, Tools and Equipment Design and time conservation.

(ii)Rules concerning human body

1. Both hands should be used for productive work.
2. Both hands should start and finish their motion at the same time.
3. Except for the rest period, the two hands should not be idle at one time.
4. Motion of both the hands and arms are symmetrical, simultaneous and opposite to each other.
5. Motions should be simple and involve minimum number of limbs. (The purpose-shortest duration and minimum fatigue)
6. Motion should be smooth and continuous. There should not be sharp direction change and frequent stop.
7. It is desirable for a worker to employ momentum to assist him.
8. A worker may use mechanical aids to assist him to overcome muscular effort.

(iii) Rules concerning workplace layout and material handling

1. There should be a definite, fixed and easy accessible location for materials and tools.
2. As far as possible, materials, tools and other mechanical devices should be kept close to work place.
3. Gravity should preferably be employed wherever feasible with a conveyor for transportation and delivering materials at the workplace between various workstations and departments.
4. An assembled and final product should preferably be dropped on a conveyor near the workplace so that gravity delivers the job at the required place.
5. Tools and materials should preferably be located in the order/sequence in which they will be required for use.
6. Good illumination is required for proper seeing, fast operating and reducing the accidents.
7. In order to impart rest to some of the limbs, an operator may sometimes sit or stand while working. This necessitates a relationship between his chair, height of table or workpiece.
8. In order to reduce fatigue, the sitting arrangement of the worker should be comfortable and adjustable.
9. All heavy parts should be lifted by mechanical devices.

(iv) Rules concerning Tools and Equipment Design

1. Jigs, fixtures and foot operated devices should be employed to reduce the work load on hand.
2. Tools should be multipurpose and easy to handle.
3. Foot-operated switches and controls should be designed as far as possible to reduce the workload on the hands.
4. Tools and materials should be properly arranged and located near the workpiece.
5. Tools and materials should be located in the order of their use.
6. There should be maximum surface contact between the tool handle and hand. It helps proper application of hand force and minimizes fatigue.
7. Gravity should be used for delivery of materials and finished goods.
8. Where the work is supposed to be carried out by fingers, the load distribution on each finger should be as per normal capacity of finger.
9. A worker should have the flexibility to stand or sit comfortably while working.
10. A worker should be able to operate levers and handles without changing the body position.
11. The workplace should have proper ergonomics in terms of illumination, proper conditions of heat, cold and humidity, reduced dust and noise, etc.

(v) Rules concerning time conservation

1. Even temporary ceasing of work by a man or m/c should not be encouraged.
2. Machine should not run idle as it leads to loss of production and power.
3. Two or more jobs should be done at the same time, or two or more operations should be carried out on a job simultaneously.
4. Number of motions involved in completing a job should be minimized.
5. The loading and unloading of the job and the cycle time should be synchronized in such a manner that one operator can be multi-functional or can simultaneously operate a number of machines.

6 Procedure in Motion Analysis

The steps in motion analysis are as follows:

a) Select: Select the work to be studied.
b) Record: Record all the relevant facts of the proposed work by direct observation.
c) Examine: Examine the facts critically in sequence, using special critical examination sheet.
d) Develop: Develop the best method i.e. the most practical, economic and effective method under prevailing circumstances using the principle of motion economy.
e) Install: install that method as standard practice.
f) Maintain: maintain that standard practice by regular routine check.

Recording

The recording may trace the movements of men, material or details of various processes. The principle is to use the simplest technique which will contain all relevant information needed for investigation.

The different recording techniques are charts, diagrams, models and photographic aids. The most commonly used recording techniques to cover most of the activities are shown in Table 5.1. The different symbols which are used in process charts are shown in Table 5.2.

Table 5.1 Recording Techniques

Recording Technique	**Information Recorded**
(a) Charts	
1. Outline process chart	Principle operations and inspection of the processes.
2. Flow process chart	Activities of men, material or equipment are analyzed into five events viz., operation, transport, inspection, delay and storage.
3. Two-handed process chart	Movements of two hands or limbs of the operator.
4. Multiple activity chart	Simultaneous/interrelated activities of operators and/or machines on a common time scale.
5. Simultaneous Motion Cycle Chart (SIMO)	Movement of body members of the operator, expressed in terms of therbligs on a common time scale.
(b) Diagrams and Models	
1. Flow diagram	Path of men, materials and equipments on a scale model.
2. String diagram	Same as above except for the variation that it uses string to trace the path.
(c) Photographic aids	
1. Cyclegraph	Movement of hand obtained by exposing a photographic plate to the light emitted from small bulbs attached to the operator's fingers.
2. Chrono-cyclegraphs	Modification of cyclegraph in which recording is made using flash light.

Table 5.2 Symbols used in Process Chart

Symbol	Activity	Purpose for which it is used
◯	Operation	Indicates the main steps in a process, method of procedure, usually the part, material or product concerned which is modified or changed during the operation.
→	Transport	Indicates movement of workers, material or equipment from place to place.
□	Inspection	Indicates any type of inspection, check, measurement, visual scrutiny for quality and/or quantity.
D	Temporary storage or delay	Indicates a delay in the sequence of events.
▽	Storage	Indicates a controlled storage in which material is received into or issued from stores under some form of authorization or an item is retained for reference purposes.

5.3Time study

- It was proposed by Frederick Taylor and later modified to include a performance rating (PR) adjustment.
- Once the method is established, the next objective is to set the standard time for the work. This aspect of work study is called Time study (or Work measurement).
- The main objectives of time study are:

1) To determine the standard time for various operations which helps in fixing wage rates and incentives.
2) To estimate the cost of product accurately.
3) To predict accurately the duration for a particular work and customer is promised accordingly.
4) To determine the number of machines an operator can run.
5) To determine the optimum number of men and machine.
6) To provide information for planning and scheduling.
7) To balance the work of all workers working in a group.
8) To compare the work efficiency of different workers/operators.

Work measurement techniques

1. Time study using stop watch.
2. Predetermined motion time system (PMTS).
3. Work sampling.
4. Analytical estimating.

The following table shows the application of each technique and unit of measurement.

Technique	Application	Unit of measurement
Time study using stop watch	Short cycle repetitive jobs	Centiminute (0.01 min)
PMTS	Manual operations confined to one work centre	TMU (I TMU = 0.006 min)
Work sampling	Long cycle jobs/ Heterogeneous operation	Minute
Analytical estimating	Short cycle non-repetitive job	Minute

Time study using stop watch is the most popular technique for determining standard time. The first task of the analyst is to divide the work/job into smaller work elements in such a way that the time for each element should not be less than 3 seconds because for such elements, recording time is difficult. The steps of time study are as follows:

Step 1: First select the job to be studied. Breakdown the work content of the job into smallest possible elements. Then, inform the worker and define the best method.

Step 2: Observe the time for appropriate number of cycles (such as 25 to 50).
Step 3: Determine the average cycle time (CT)

$$CT = \frac{\sum \text{Times}}{\text{No. of cycles}}$$

Step 4: Determine the normal time (NT)

NT = CT (PR)

Where, PR is the performance rating.

Step 5: Determine the standard time using the following formula.

$$ST = NT\ (AF) \text{ where } AF = \frac{1}{1 - \%\ Allowance}$$

AF being the allowance factor.

5.4 Selection of job for Time Study

Time Study is conducted on a job

- which has not been previously time-studied.
- for which method change has taken place recently.
- for which worker(s) might have complained as having tight time standards.

5.5 Selection of Worker for Time Study

The worker on which time study should be conducted must

- have necessary skill for the job.
- have sufficient experience with the given method on the job (that is, he should have crossed the learning stage).
- be an ‘average' worker as regards the speed of working.
- be temperamentally suited to the study (those who can't work in normal fashion when watched, are not suitable for the study).
- have knowledge about the purpose of study.

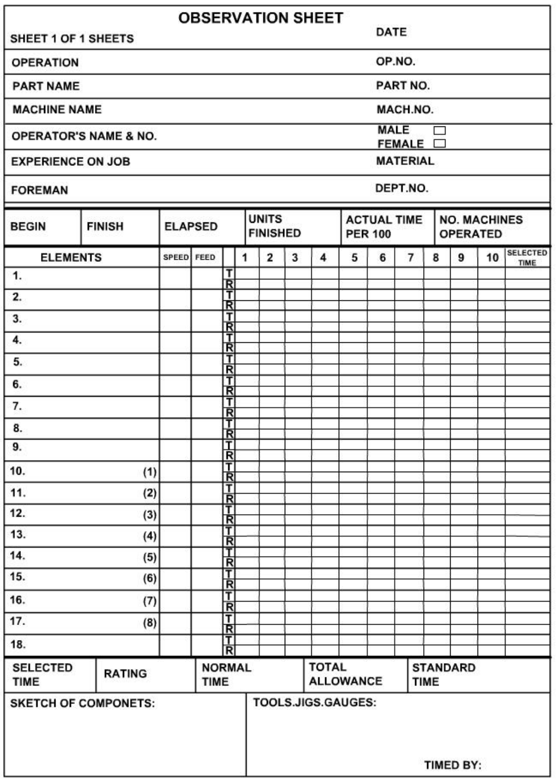
5.6Time Study Equipment

The following equipment is needed for time study work.

- Timing device
- Time study observation sheet
- Time study observation board
- Other equipment

Timing Device. The stop watch is the most widely used timing device used for time study, although electronic timer is also sometimes used. The two perform the same function with the difference that electronic timer can measure time to the second or third decimal of a second and can keep a large volume of time data in memory.

Time Study Observation Sheet. It is a printed form with spaces provided for noting down the necessary information about the operation being studied, like name of operation, drawing number, and name of the worker, name of time study person, and the date and place of study. Spaces are provided in the form for writing detailed description of the process (element-wise), recorded time or stop-watch readings for each element of the process, performance rating(s) of operator, and computation. Fig. 5.1 shows a typical time study observation sheet.


OBSERVATION SHEET
SHEET 1 OF 1 SHEETS DATE
OPERATION OP.NO.
PART NAME PART NO.
MACHINE NAME MACH.NO.
OPERATOR'S NAME & NO. MALE ☐ FEMALE ☐
EXPERIENCE ON JOB MATERIAL
FOREMAN DEPT.NO.

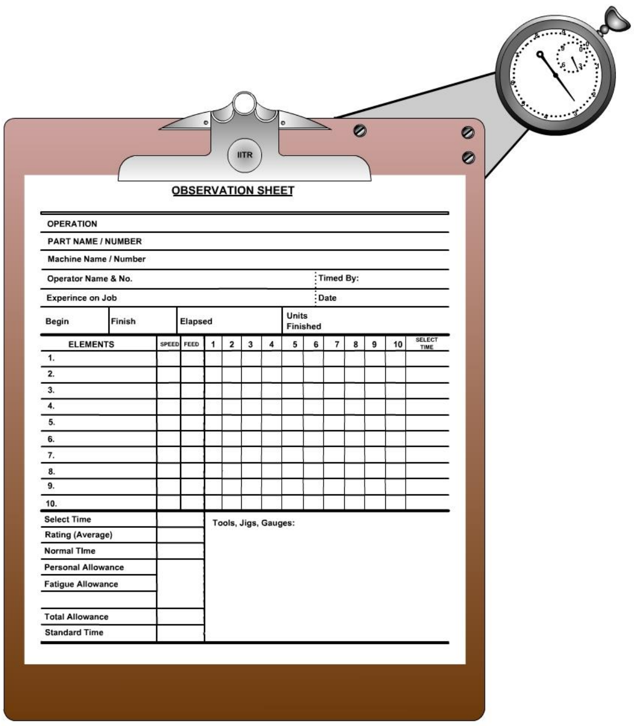
BEGIN	FINISH	ELAPSED	UNITS FINISHED	ACTUAL TIME PER 100	NO. MACHINES OPERATED

ELEMENTS	SPEED	FEED		1	2	3	4	5	6	7	8	9	10	SELECTED TIME
1.			T R											
2.			T R											
3.			T R											
4.			T R											
5.			T R											
6.			T R											
7.			T R											
8.			T R											
9.			T R											
10. (1)			T R											
11. (2)			T R											
12. (3)			T R											
13. (4)			T R											
14. (5)			T R											
15. (6)			T R											
16. (7)			T R											
17. (8)			T R											
18.			T R											

SELECTED TIME	RATING	NORMAL TIME	TOTAL ALLOWANCE	STANDARD TIME

SKETCH OF COMPONETS: TOOLS.JIGS.GAUGES:
TIMED BY:

Time Study Board. It is a light -weight board used for holding the observation sheet and stopwatch in position. It is of size slightly larger than that of observation sheet used. Generally, the watch is mounted at the center of the top edge or as shown in Figure near the upper right-hand corner of the board. The board has a clamp to hold the observation sheet. During the time study, the board is held against the body and the upper left arm by the time study person in such a way that the watch could be operated by the thumb/index finger of the left hand. Watch readings are recorded on the observation sheet by the right hand.



Other Equipment. This includes pencil, eraser, device like tachometer for checking the speed, etc.

5.7 Why Dividing Work into Short Elements is essential?

For the purpose of time study, the task is normally broken into short elements and each element is timed separately for the following reasons:

- To separate unproductive part of task from the productive one.
- To improve accuracy in rating. The worker may not work at the same speed throughout the cycle. He may perform some elements faster and some slower. Breaking of task into short elements permits rating of each element separately which is more realistic than just rating once for the complete cycle.
- To identify elements causing high fatigue. Breaking of task into short elements permits giving appropriate rest allowances to different elements.
- To have detailed job specifications. This helps in detection of any variation in the method that may occur after the time standard is established.
- To prepare standard data for repeatedly occurring elements.

The following guidelines should be kept in mind while dividing a task into elements.

(1) The elements should be of as short duration as can be accurately timed.

(This in turn, depends on the skill of the time study man, method of timing and recording, and many other factors. Generally, with the stop watch, elements of duration less than 0.03 to 0.05 minute are difficult to time accurately. The elements should not normally be longer than 0.40 min.).

(2) Manually performed elements should be separated from machine paced elements.

(Time for machine paced elements can be determined by calculation). Machine elements are not rated against a normal. This rule also helps in recognition of delays.

(3)Constant elements should be separated from variable elements.

(Constant elements are those elements which are independent of the size, weight, length, or shape of the workpiece. For example, the time to pick screw driver from its place and bring it to the head of a screw is constant, whereas the time to tighten or loosen the screw is a variable, depending upon the length and size of the screw).

(4) The beginnings and endings of elements should be easily distinguishable. These should preferably be associated with some kind of sound.

(5) Irregular elements, those not repeated in every cycle, should be separated from regular elements. For example, if the jig is cleaned off after every ten parts produced, "cleaning" is an irregular element, and its time should be spread over ten cycles.

(6) Unnecessary motions and activities should be separated from those considered essential.

(7) Foreign or accidental elements should be listed separately. Such elements are generally of non-repetitive type.

5.8 Number of cycles to be timed.

The following general principles govern the number of cycles to get the representative average cycle time.

(1) Greater the accuracy desired in the results, larger should be the number of cycles observed.

(2) The study should be continued through sufficient number of cycles so that occasional elements such as setting-up machine, cleaning of machine or sharpening of tool are observed for a good number of times.

(3) Where more than one operator is doing the same job, short study (say 10 to 15 cycles) should be conducted on each of the several operators than one long study on a single operator.

It is important that enough cycles are timed so that reliable average is obtained.

5.9 Following techniques are used to determine the number of cycles to be timed.

(i) Use of Tables: On the consideration of the cost of obtaining the data and the desired accuracy in results, most companies have prepared their own tables for the use of time study, which indicate the number of cycles to be timed as a function of the cycle time and the frequency of occurrence of the job in the company.

(ii) Statistical methods: On the basis of the requirements of the particular situation involved, *accuracy* and *confidence level* are decided (An accuracy of a confidence level of 95% is considered reasonable in most cases). A preliminary study is conducted in which some (say *N)* cycles are timed. Standard deviation o of these *(N)* observations is calculated as

$$\sigma = \sqrt{\left[\frac{1}{N}(t-T)^2\right]} = \frac{1}{N}\sqrt{N(\Sigma t^2) - (\Sigma t^2)}$$

Where t = each watch reading

T = average of N watch reading

n = number of watch readings in the preliminary study.

Now, to find M.the number of cycles to time. the following statistical method can be used.

calculated standard error of mean ε from the equation

$$X.\varepsilon = A.T$$

Where A = accuracy desired

t = average of N watch reading

X = a factor corresponding to confidence level desired. Its values is 1 for 68%, 2 for 95%, and 3 for 99% confidence level.

Determine the required sample size M from the equation

$$\varepsilon = \frac{\sigma}{\sqrt{M}}$$

5.10 Performance Rating

It is a process of comparing the performance rate of a worker against standard performance. The standard performance is different for different jobs. Te rating factor is used to convert the observed time into normal time.

$$\text{Normal time} = \text{Observed time} \times \frac{\text{Performance level of worker}}{\text{Standard performance level}}$$

5.11 Allowances

Allowances are added to normal time in order to arrive at standard time. The various allowances are:

1. **Process allowance:** This is an allowance provided to compensate for enforced idleness during a process. This includes loss of time due to (i) no work (ii) power failure (iii) faculty material (iv) faculty tool or equipment.

2. **Personal and Rest allowance**: This is allowed to compensate for the time spent by worker in meeting the physical needs, for instance a periodic break in the production routine. The amount of personal time required by operator varies with the individual more than with the kind of work, though it is seen that workers need more personal time when the work is heavy and done under unfavorable conditions.

   The amount of this allowance can be determined by making all-day time study or work sampling. Mostly, a 5 % allowance for personal time (nearly 24 minutes in 8 hours) is considered appropriate.

   Rest allowance is a relaxation allowance to a worker to overcome fatigue incurred during working. Excessive fatigue badly affects the performance of worker. This rest/relaxation may vary from 12% to 20% of normal time from light to heavy.

3. **Special Allowances**: These allowances are given under certain special circumstances. Some of these allowances and the conditions under which they are given are:

   Policy Allowance: Some companies, as a policy, give an allowance to provide a satisfactory level of earnings for a specified level of performance under exceptional circumstance. This may be allowed to new employees, handicap employees, workers on night shift, etc. The value of the allowance is typically decided by management.

   Small Lot Allowance: This allowance is given when the actual production period is too short to allow the worker to come out of the initial learning period. When an operator completes several small-lot jobs on different setups during the day, an allowance as high as 15 percent may be given to allow the operator to make normal earnings.

   Training Allowance: This allowance is provided when work is done by trainee to allow him to make reasonable earnings. It may be a sliding allowance, which progressively decreases to zero over certain length of time. If the effect of learning on the job is known, the rate of decrease of the training allowance can be set accordingly.

   Rework Allowance: This allowance is provided on certain operation when it is known that some percent of parts made are spoiled due to factors beyond the operator's control. The time in which these spoiled parts may be reworked is converted into allowance.

4. **Policy allowance:** It depends on the policy of an organization controlled by workers union.

Problem 1: In a welding shop, a direct time study was done on a welding operation. One inexperienced industrial engineer and one experienced industrial engineer conducted the study simultaneously. They agreed precisely on cycle time but their opinion on rating the worker differed. The experienced engineer rated the worker 100% and the other engineer rated the worker 120%. They used a 10% allowance.

Cycle time (in minutes)	Number of times observed
20	2
24	1
29	1
32	1

From the above statement,

(a) Determine the standard time using the experienced industrial engineer's worker rating.
(b) Find the standard time using the worker rating of inexperienced industrial engineer.

Solution:

(a) Rating of worker at 100% by the experienced industrial engineer

Cycle time (CT) = (20×2+24×1+29×1+32×1)/5 = 25 min

Normal time (NT) = CT×PR = 25×100% = 25 min

Standard time (ST) = NT/(1-%A) = 25/(1-0.10) = 27.78 min

(b) Rating of worker at 120% by the inexperienced industrial engineer

Cycle time (CT) = (20×2+24×1+29×1+32×1)/5 = 25 min

Normal time (NT) = CT×PR = 25×120% = 30 min

Standard time (ST) = NT/(1-%A) = 30/(1-0.10) = 33.33 min

Chapter 6: Production Planning and Control

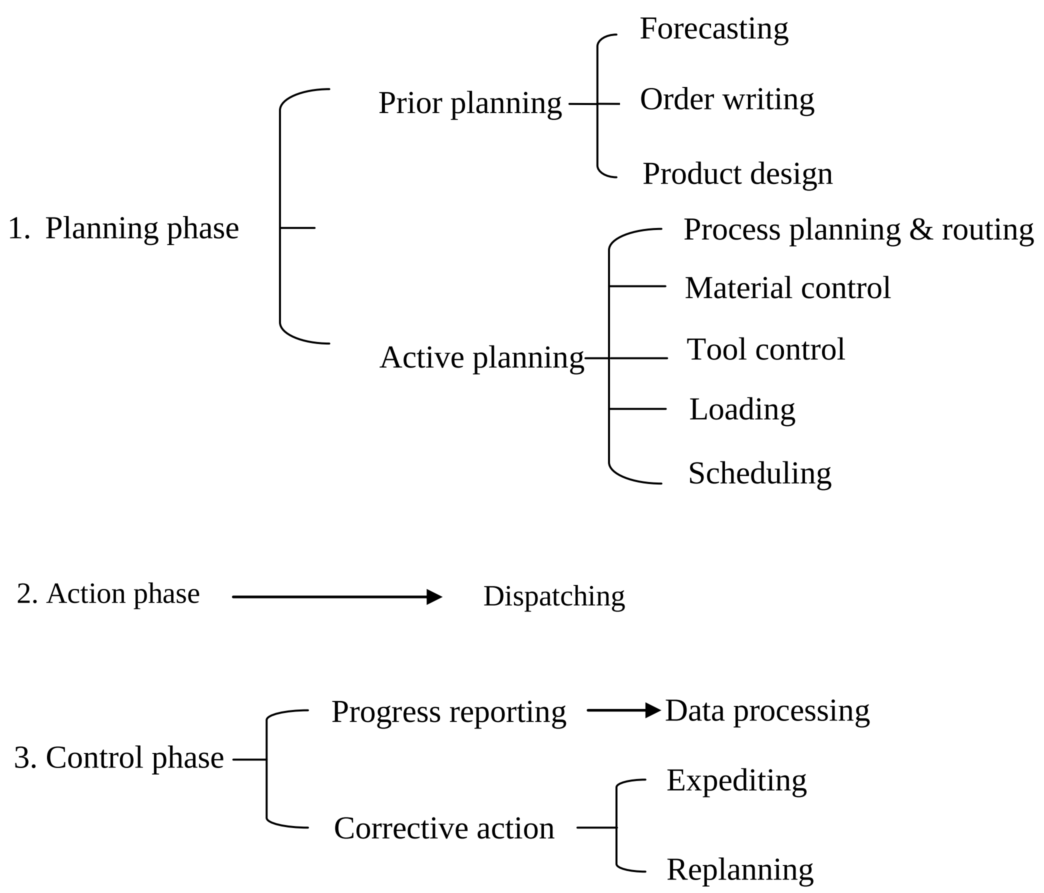
6.1 Production:

It is an organized activity of converting raw materials into useful products. But before starting the actual production, production planning is done to anticipate possible difficulties and to decide in advance as to how the production process should be carried out in a best and economical way to satisfy customers. Since only planning of production is not sufficient, hence management takes all possible steps to see that plans chalked out by planning department are properly adhered to and the standard set are attained. In order to achieve it, control over production is exercised. The ultimate aim of production planning and control (PPC) is to produce the products of right quality in right quantity at the right time by using the best and least expensive methods.

Production planning and control can thus be defined as:

- The process of planning the production in advance.
- Setting the exact route of each item.
- Fixing the starting and finishing date for each item.
- To give production orders to different shops.
- To see the progress of products according to order.

The various functions of PPC department can also be systematically written as:



Explanation on each term

1. Forecasting: Estimation of type, quantity and quality of future work.

2. Order writing: Giving authority to one or more persons to undertake a particular job.

3. Product design: Collection of information regarding specification, bill of materials, drawing, etc.

4. Process planning and routing: Finding the most economical process of doing work and then deciding how and where the work will be done.

5. Material control: It involves determining the material requirement and control of materials.

6. Tool control: It involves determining the requirement and control of tools used.

7. Loading: Assignment of work to man power and machining etc.

8. Scheduling: It determines when and in what sequence the work will be carried out. It fixes the starting and finishing time for the job.

9. Dispatching: It is the transition from planning to action phase. In this phase the worker is ordered to start the actual work.

10. Progress reporting: Data regarding the job progress is collected. It is interpreted by comparison with the preset level of performance.

11. Corrective action: (i) Expediting means taking action if the progress reporting indicates a deviation of the plan from the original set target. (ii) Replanning of the whole affair becomes essential, in case expediting fails to bring the deviation plan to its right path.

Objectives of PPC

1. To determine the sequence of operations to continue production.
2. To issue co-ordinated work schedule of production to the supervisor/foreman of various shops.
3. To plan out the plant capacity to provide sufficient facilities for future production programme.
4. To maintain sufficient raw materials for continuous production.
5. To follow up production schedule to ensure delivery promises.
6. To evaluate the performance of various shops and individuals.
7. To give authority to right person to do right job.

PPC and related functions

The Fig. 6.1 shows the relation of PPC with other functional departments.

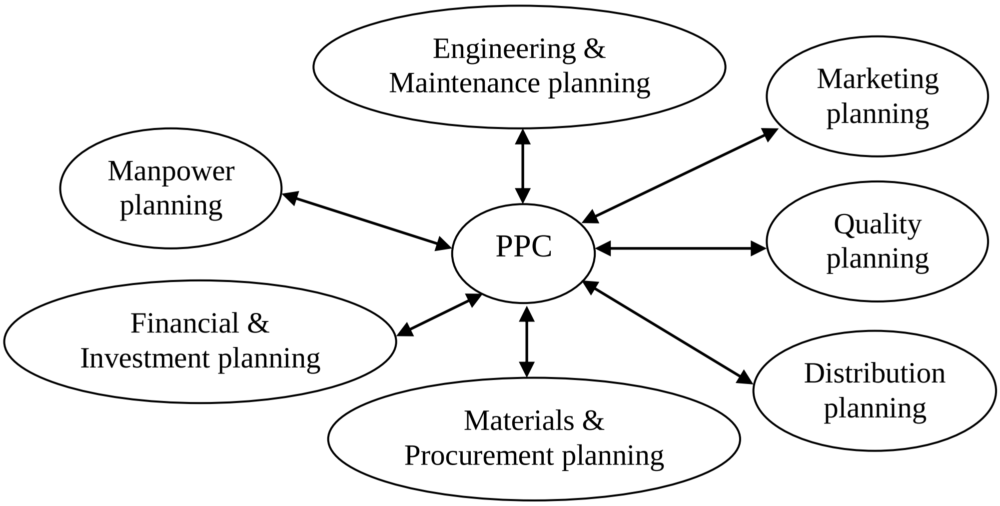
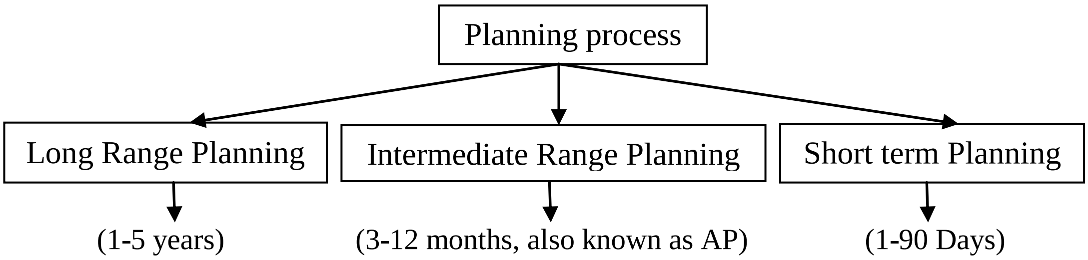
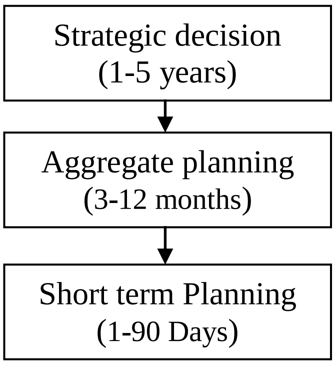


Fig. 6.1 Relation of PPC with other functional departments

6.2 Aggregate planning (AP)



Planning hierarchy



AP: Production planning in the intermediate range of time is termed as Aggregate planning.

Explanation of AP

The aggregate planning concentrates on scheduling production, personnel and inventory levels during intermediate term planning horizon such as 3-12 months. Aggregate plans act as an interface between strategic decision (which fixes the operating environment) and short term scheduling and control decision which guides firm's day-to-day operations. Aggregate planning typically focuses on manipulating several aspects of operations-aggregate production, inventory and personnel levels to minimize costs over some planning horizon while satisfying demand and policy requirements. In brief the objectives of AP are to develop plans that are feasible and optimal.

Aggregate planning

Aggregate Production Planning | Aggregate Capacity Planning

Aggregate Production Planning indicates the level of output.
Aggregate Capacity Planning keep capacity utilization at desired level and test the feasibility of planned output.

6.3 Decision options in Aggregate Planning

Decision options are basically of 2 types:

(i) Modification of demand for a product.
(ii) Modification of supply of a product.

(i) Modification of demand

Demand can be modified in several ways:

(a) Differential pricing: It is often used to reduce the peak demand or to increase the off period demand. Some examples are: reducing off season fan/woollen item rate, reducing the hotel rate in off season.
(b) Advertising and promotion: These methods are used to stimulate/smooth out demand. Advertising is generally so timed as to increase demand during off period and to shift demand from peak period to he off period.
(c) Backlogs: Through the creation of backlogs, the manufacturers ask customers to wait for the delivery of products, thereby shifting the demand from peak period to off period.
(d) Development of complementary products: Producer, who produces products which are highly seasonal in nature, applies this technique. Ex: Refrigerator company produce room heater, TV Company produces DVD, etc.

(ii) Modification of supply

There are various methods of modification of supply.

(a) Hiring and lay off employees: The policy varies from company to company. The man power/work force varies from peak period to slack/off period. Accordingly, firing/lay off employee is followed without affecting employee morale.
(b) Overtime and undertime: Overtime and undertime are common options used in cases of temporary change of demand.
(c) Use of part time or temporary labour: This method is attractive as the payment of part time/temporary labour is less.
(d) Subcontracting: The subcontractor may supply the entire product/some of the components needed for the product.
(e) Carrying inventories: It is used by manufacturers who produces items in a particular season and sell them throughout the year.

Aggregate planning strategies

Pure strategy | Mixed strategy

Pure strategy:

If the demand and supply is regulated by any one of the following strategy, i.e.

(a) Utilizing inventory through constant work force.
(b) Varying the size of workforce.
(c) Subcontracting.
(d) Making changes in demand pattern.

Mixed strategy:

If the demand and supply is regulated by mixture of the strategies as mentioned, it is called mixed strategy.

6.4 Sequencing

The order in which jobs pass through the machines or work stations is called sequencing. The relative priorities are based on certain rules as discussed in the following:

1. First Come, First Served (FCFS) rule: This is a fair approach particularly applicable to people. In case of inventory management, it is First In First Out (FIFO). That means the 1^{st} piece of inventory at a storage area is the 1^{st} one to be used.
2. The shortest processing time (SPT) rule: SPT rule sequences jobs in increasing order of their processing times (including set up).
3. The Earliest Due Date (EDD) rule: Sequences jobs in order of their due dates, earliest first.
4. The critical ratio (CR) rule: Sequences jobs in increasing order of their critical ratio.

   $$CR = \frac{\text{Due date- Today's date}}{\text{Remaining processing time}}$$

   If CR>1 The job is ahead of schedule.
   If CR<1 The job is behind schedule.
   If CR=1 The job is exactly on schedule.
5. The Slack Time Remaining (STR) rule: It employs that the next job processed is the one that has the least amount of slack time.
   Slack = (Due date – Today's date) – Remaining processing time

6.5 Sequencing of n jobs through 2 machines (Johnson's rule)

Considering 2 machines and 'n' jobs as shown in Table 6.1.

Table 6.1 Job sequencing for n jobs

1	t_{11}	t_{12}
2	t_{21}	t_{22}
3	t_{31}	t_{32}
4	t_{11}	t_{42}
.	.	.
.	.	.
i	t_{i1}	t_{i2}
.	.	.
n	t_{n1}	t_{n2}

Step 1: Find the minimum among t_{i1} and t_{i2}.

Step 2(a): If the minimum processing time requires m/c-1, place the associated job in the 1st available position in sequence.

Step 2(b): If the minimum processing time requires machine-2, place the associated job in the last available position in sequence.

Step 3: Remove the assigned job from the table and return to Step 1 until all positions in sequence are filled. (Ties may be considered randomly)

The above algorithm is illustrated with the following example.

Ex.1 Consider two machines and six jobs flow shop scheduling problem. Using Johnson's algorithm, obtain the optimal sequence which will minimize the makespan.

Job	Time taken by machines	
	1	2
1	5	4
2	2	3
3	13	14
4	10	1
5	8	9
6	12	11
Sum	50	42

Solution: The working of the algorithm is summarized in the form of a table which is shown below.

Stage	Unscheduled job	Min	Assignment	Partial sequence/ Full sequence
1	1 2 3 4 5 6	t_{42}	Job 4-[6]	× × × × × 4
2	1 2 3 5 6	t_{21}	Job 2-[1]	2 × × × × 4
3	1 3 5 6	t_{12}	Job 1-[5]	2 × × × 1 4
4	3 5 6	t_{51}	Job 5-[2]	2 5 × × 1 4
5	3 6	t_{62}	Job 6-[4]	2 5 × 6 1 4
6	3	t_{31}	Job 3-[3]	2 5 3 6 1 4

Now the optimal sequence is 2-5-3-6-1-4.

The makespan is determined as shown below.

Job	M/C-1		M/C-1		Idle time on m/c-2
	Time in	Time out	Time in	Time out	
2	0	2	2	5	2
5	2	10	10	19	5
3	10	23	23	37	4
6	23	35	37	48	0
1	35	40	48	52	0
4	40	50	52	53	0

The makespan for this schedule is 53.

6.6 Line balancing

Plants having continuous flow process and producing large volume of standardized components prefer conveyor assembly line. Here the work centres are sequenced in such a way that at each stage a certain amount of total work is carried out so that at the end of conveyor line, the final product comes out. This requires careful preplanning to balance the timing between each work centres so that idle/waiting time is minimized. This process of internal balancing is called Assembly line balancing.

Line balancing is defined as the procedure for creating work stations and assigning tasks to them according to a predetermined technological sequence such that the idle time at each work station is minimized.

In perfect line balancing, each work centre completes its assigned work within a fixed time duration so that output from all operations are equal on the line. Such a perfect balancing is difficult to achieve. Certain work station/centre take more operation time causing subsequent work centre to become idle.

Balancing may be achieved by

- Rearrangement of work stations
- Adding m/c and or workers at some work stations.

So that all work centres take about the same amount of time.

Some terminologies used in line balancing:

1. Work station: It is a location on the assembly line where specified work is performed.
2. Cycle time: It is the amount of average time a product spends at one work station

$$\text{Cycle time (CT)} = \frac{\text{Available time period}}{\text{Total no. of products/output}}$$

3. Task : The smallest grouping of work that can be assigned to a work station.
4. Task time: Standard time to perform task.
5. Station time: Total standard time at a particular work station.

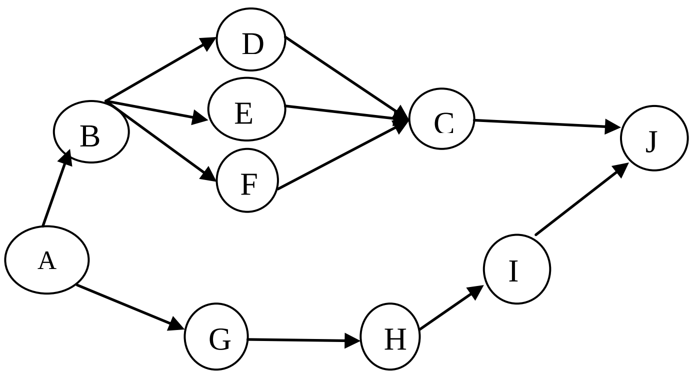
A typical example will clarify the procedure of line balancing.

Ex: A company is setting an assembly line to produce 192 units per 8 hour shift. The information regarding work elements in terms of times and intermediate predecessors are given below:

Work element	Time (Sec)	Immediate predecessor
A	40	None
B	80	A
C	30	D,E,F
D	25	B
E	20	B
F	15	B
G	120	A
H	145	G
I	130	H
J	115	C,I
Total	720	

1. What is the desired cycle time?
2. What are the theoretical numbers of stations?
3. Use largest work element time rule to work out a solution on a precedence diagram.
4. What are efficiency and balance delay of the solution obtained?

Solution: The precedence diagram is represented as shown below:



(a) Cycle time: 8hours/192 units = 150 sec/unit.
(b) Sum of the time of all work elements = 720 secs
So, minimum number of work station = 720/150 = 4.8 = 5 stations.

(c) Assignment of work element to stations:

Station/ stations	Elements	Work element time (Sec)	Cumulative time (Sec)	Idle time for station (Sec)
S1	A	40	40	05
	B	80	120	
	D	25	145	
S2	G	120	120	10
	E	20	140	
S3	H	145	145	05
S4	I	130	130	05
	F	15	145	
S5	C	30	30	05
	J	115	145	

(d) Efficiency: $\sum t \times 100 / n \times CT = 720 \times 100 / 5 \times 150 = 96\%$.
(e) Balance delay = 100-96 = 4%.

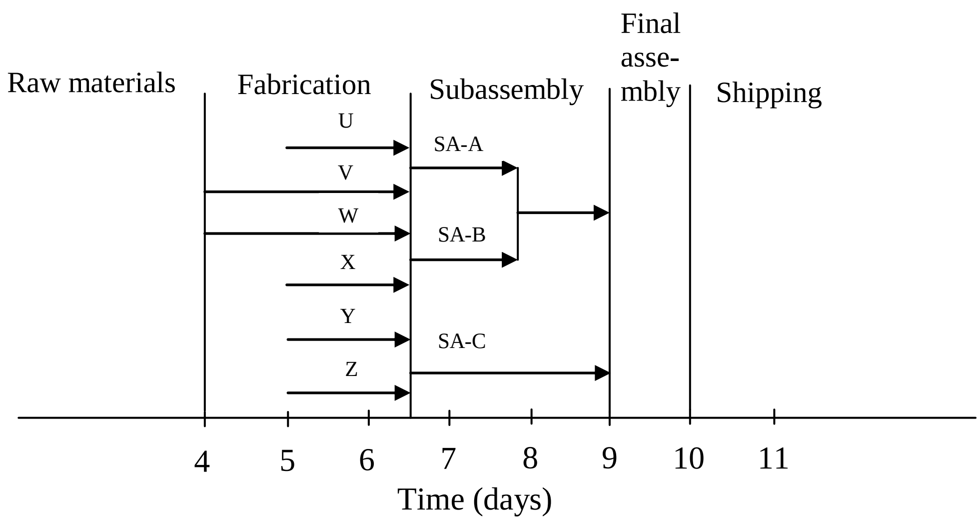
6.6 Flow control

Flow control applies to the control of continuous production as found in oil refineries, bottling works, cigarette making factories, paper making mills and other mass manufacturing plants.

The function of flow control is to match up the rates of flow of parts, subassemblies and final assemblies. Each part should be ready before the time of subassembling and each subassembly should be made available at the time and place of assembly in order to make the final product.

Flow control can be performed through the following:

(a) **Operation time**: It amounts the time required to manufacture each part, to make one subassembly and to execute one assembly. This information is available from the operation sheet.
(b) **Line balancing**: the assembly line should be balanced. Each work station should have the more or less same operating time and the various operations should be sequenced properly.
(c) **Routing and scheduling**: A combination route and schedule chart showing the fabrication of parts, subassemblies and final assembly is shown below.



The chart shows that part V & W started on 4^{th} day and the other parts on 5^{th} day such that all the components become ready for subassembly on 6.5^{th} day and all the subassembly become ready on 9^{th} day for final assembly. The assembly is over on 10^{th} day.

(d) **Control of parts subassemblies and Assembly**: A supervisory function coupled with an appropriate information feedback system keeps a check whether the small parts arriving in lots and big parts coming continuously are available at right time, in proper quantities for making subassemblies as per scheduled plan.

(e) Dispatching: Dispatching is nothing but issuing orders and instructions to start a particular work which has already been planned under routing and scheduling.

Functions of Dispatching

(i) Assignment of work to individual man, m/c or work place.
(ii) Release necessary order and production firm.
(iii) Authorize for issue of materials, tools, jigs, fixtures, gauges, dies for various jobs.
(iv) Required materials are authorized to move from stores or from operation to operation.
(v) Issue m/c loading and schedule chart, route sheet, etc.
(vi) To fix up the responsibilities of guiding and controlling the materials and operation processes.
(vii) To issue inspection order.
(viii) Issue of time tickets, drawing, instruction cards.

Dispatch procedure

The product is broken into different components. For each component, operations are mentioned in order as shown in Figure aside.

Route sheet for component C
Material-
Operation 1-
Operation 2-

The various steps of dispatch procedure for each operation are listed below:

(a) Store issue order: Authorise store department to deliver required material.
(b) Tool order: Authorise tool store to release the necessary tools. The tools can be collected by the tool room attendant.
(c) Job order: Instruct the worker to proceed with operation.
(d) Time tickets: It records the beginning and ending time of the operation and forms the basis for workers pay.
(e) Inspection order: Notify the inspectors to carry out necessary inspections and report the quality of the component.
(f) Move order: Authorise the movement of materials and components for one facility to another for further operation.

In addition, there are certain dispatch aspects such as:
(1) All production information should be available beforehand.
(2) Various order cards and drawing with specification should be ready.
(3) Equipment should be ready for use.
(4) Progress of various orders should be recorded.
(5) All production records should be on Gantt chart.

Centralized and decentralized dispatching

(a) Centralized Dispatching:

In centralized dispatching system, a central dispatching department orders directly to the work stations. It maintains a full record of the characteristics and capacity of each equipment and work load against each m/c. The orders are given to the shop supervisor who runs his machine accordingly. In most of the cases, the supervisor can also give suggestions as regards to loading of m/cs under him. A centralized system has the following advantages:

1. A greater degree of overall control can be achieved.
2. Effective coordination between different facilities is possible.
3. It has greater flexibility.
4. Because of urgency of orders, changes in the schedule can be made easily without upsetting the whole system.
5. Progress of orders can be readily assessed at any time because all the information is available is available at a central place.
6. There is effective and better utilization of manpower and machines.

(b) Decentralized Dispatching:

In decentralized dispatching system, the shop supervisor performs the dispatch function. He/she decides the sequence of handling different orders. He/she dispatches the orders and materials to each equipment and worker, and is required to complete the work within the prescribed duration. In case he/she suspects delay, he/she informs the production control department. A centralized dispatching system has the following advantages:

(i) Much of red tape (excessive adherence to official rules) is minimized.
(ii) Shop supervisor knows the best about his shop.
(iii) Communication gap is reduced.
(iv) It is easy to solve day to day problem.

Levels of Dispatch office: At plant manager's level.
At shop superintendent level.
At shop supervisor's level.
At specialist level.

6.7 Expediting

Expediting and dispatching are frequently performed under the same agency, particularly in special project control. An expeditor follows the development of an order from the raw material stage to the finished product. He/she is often given the authority and facilities to move materials or semi-finished products to relieve congestion in production flow.

6.8 Gantt chart

HL Gantt has developed a simplified graph which represents/displays the planned starting and finishing time of each task on a time scale. But it does not show the interrelationship among the tasks. On the left of the chart is a list of the activities and along the top is a suitable time scale. Each activity is represented by a bar; the position and length of the bar reflects the start date, duration and end date of the activity. This allows you to see at a glance:

- What the various activities are
- When each activity begins and ends
- How long each activity is scheduled to last
- Where activities overlap with other activities, and by how much
- The start and end date of the whole project

6.8 Line of balance (LOB)

LOB is a graphical technique used to find out the state of completion of various processes at a given time for a product. This technique is economical when the production volume is limited and applied to the production of aircrafts, missiles, heavy machines, etc.

For drawing the LOB, the following information are required:

- Contracted schedule of delivery
- Key operations in making the product.
- The sequence of key events.
- The expected/observed lead time w.r.t. delivery of final product.

Based on above information, a diagram is drawn which compares pictorically the planned verses actual progress. This is called line of balance (LOB).

6.9 Learning curve

From our everyday experience, we know that the first time we perform a skilled job, it takes much longer time than an experienced worker. But the next time if we perform the same job, we can perform it not only at faster rate but also with higher quality. Each additional time we do the same job, we become faster and better in performing. This improvement in productivity and quality of work as a job is repeated is called quality of work, as a job is repeated is called learning effect.

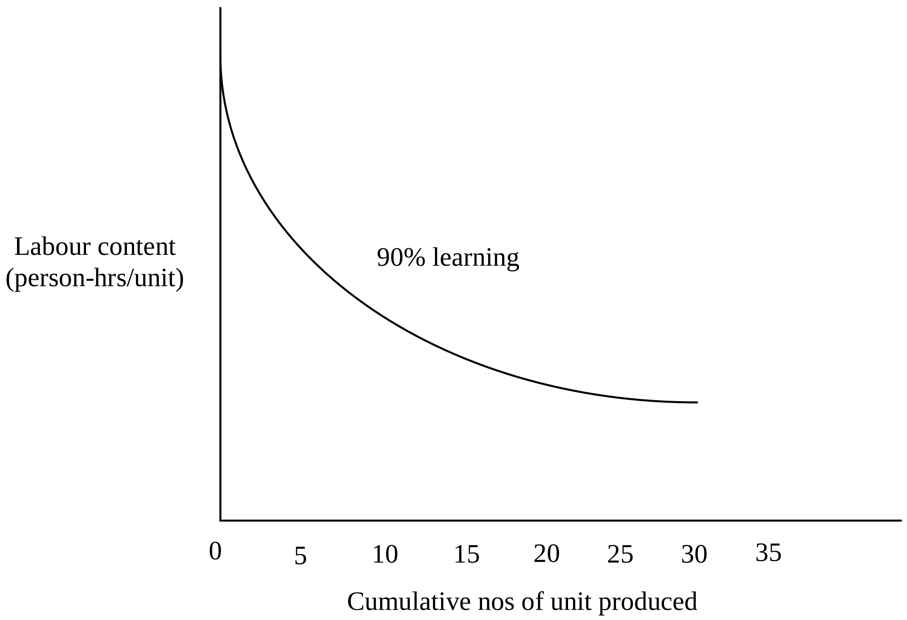
Similarly, when the number of units produced increases, the direct labour hours required per unit decreases for a variety of reasons such as:

(i) Workers become more and more skilled for a particular set of task.
(ii) Improvement in production methods and tooling takes place.
(iii) Improvement in layout and flow takes place and many other reasons.

While designing jobs, estimating work standards, scheduling production and planning capacity, it is important to know at what rate workers productivity will increase through learning. For example, if it takes a worker 10 hours to make the first 50 units of product, we don't want to plan on it taking 10 hours for every additional 50 units. Otherwise we will underestimate our production capacity and overstaff our operations. The role of worker learning in production, its effect on production costs and ways to measure it were popularized long ago.

The rate of learning and learning curve

The labour content (in person-hrs per unit) requires to make a product, expressed as a function of the cumulative number of units made is called Learning Curve. A typical learning curve is shown below.



We normally express the rate of leraning in terms of how quickly the labour requirement decrease as we double the cumulative amount of output. We say that an activity exhibits an x% learning rate or has an x% learning curve, if the amounts of labour required to make the 2nth units of the product is x% of that required to make the nth unit. More generally, the amount of time required to make the nth unit of the product will be

$T_n = T_1 \times n^a$

where T_n = Time to make the nth unit.
T_1 = Time to make 1st unit.
a = (ln x/ln 2)
x = learning rate (expressed as decimal)

This learning data can also be represented in tabular form.

Chapter 7: Project Management

Project

A project is an interrelated set of activities that has a definite starting and ending point and those results in a unique product. That means projects are not repetitive. Few examples of projects are:

1. Constructing a bridge, dam, highway or building.
2. Producing an airplane, missile or large machine.
3. Introducing a new product.
4. Installing a large computer system.
5. Redesigning the layout of plant or office.
6. Construction of a ship.
7. Fabrication of a steam boiler.
8. Maintenance of major equipments/Plants.
9. Commissioning of a power plant/factory.
10. Conducting National Election.

Basic steps in project management

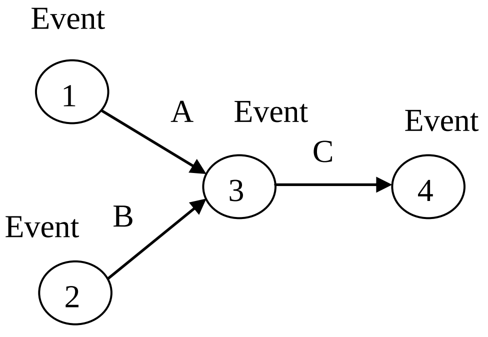
Managing a project, regardless of its size and complexity, requires identifying every activity to be undertaken and planning when each activity must begin and end in order to complete the overall project on time. Typically, all projects involve the following steps:

1. Describe the project.
2. Develop a network model.
3. Insert time estimates.
4. Analyze the model.
5. Develop the project plan.
6. Periodically assess the progress of the project and repeat steps 2-6 as needed.

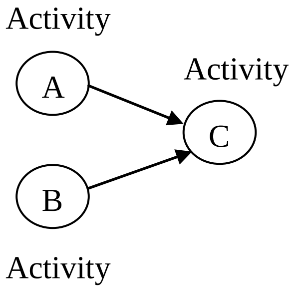
Network: A network is the graphical representation of the project activities arranged in a logical sequence and depicting all the interrelationships among them.

Terminologies used in Network diagram:

1. Activity: An activity means work/job. It is a time consuming process. It is represented by an arrow in the network diagram (AOA system).



Activity-on-arc (AOA) network



Activity on node (AON)

2. Event: An event is a specific instant of time marks the start and end of an activity.
3. Critical path: It is the sequence of activities which decides the total project duration.
4. Duration (d): Duration is the estimated or actual time required to complete a task or an activity.
5. Total project time: Time to complete the project. In other words, it is the duration of critical path.
6. Earliest start time (E): It is the earliest possible time at which an activity can start. It is calculated by moving from 1^{st} to last event in the network diagram.
7. Latest start time (L_i): It is the latest possible time by which an activity can start.
8. Earliest finish time (E_j): It is the last event time of the head event. It is calculated by moving backward in the network diagram.
9. Latest finish time (L_j): It is the last event time of the head event. It is calculated by moving backward in the network diagram.
10. Float/Slack: Slack is with reference to an event and Float is with reference to an activity.
11. Free float: (Latest Finish Time – Earliest Start Time) – Activity duration.

Rules for Network Construction:

The following are the primary needs for constructing Activity on Arc (AOA) network diagram.

1. The starting event and ending event of an activity are called tail and head event respectively.
2. The network should have a unique starting node. (tail event)
3. The network should have a unique completion node. (head event)
4. No activity should be represented by more than one are ($\longrightarrow$) in the network.
5. No two activities should have the same starting node and same ending node.
6. Dummy activity is an imaginary activity indicating precedence relationship only. Duration of dummy activity is zero.
7. The length of the arrow bears no relationship to the activity time.
8. The arrow in a network identifies the logical condition of dependence.
9. The direction of arrow indicates the direction of workflow.
10. All networks are constructed logically or based on the principle of dependency.
11. No event can be reached in a project before the completion of precedence activity.
12. Every activity in the network should be completed to reach the objective.
13. No set of activities should form a circular loop.

Time estimation of an activity

If t_0 = Optimistic time (i.e. time estimate for fast activity completion).
t_p = Pessimistic time (maximum time duration an activity can take).
t_m = Most likely time
t_e = The expected time of an activity = $(t_0 + 4t_m + t_p)/6$

Variance of an activity time $\sigma_e^2 = \left[\frac{t_p - t_o}{6}\right]^2$

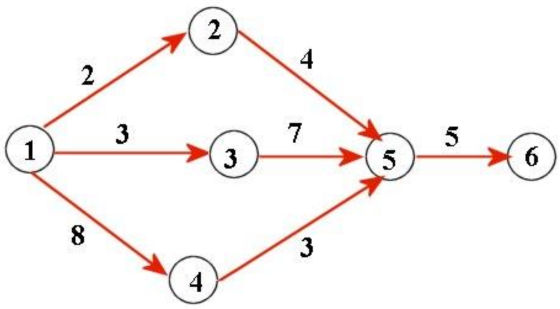
(c) Network scheduling

The biggest advance in project scheduling since the development of the Gantt chart in 1917 was made between1956-58. During this period, two new scheduling techniques were developed. These techniques are

(i) Program evaluation and review technique (PERT)
(ii) Critical path method (CPM)

Both are based on the use of a network/graphical model to depict the work tasks being scheduled. The popularity of network based scheduling can be attributed to its many benefits, especially its ease use. Other benefits include the following.

1. It provides a visual display of needed task and their temporal ordering, which makes it easy to see how tasks should be sequenced as shown below. This assists communication and co-operation among task teams because each team can see how its work affects other team.



2. It provides a relatively accurate estimate of the time required to complete the project at the proposed resource level.
3. It identified and highlights the tasks that are critical to keep the project on schedule.
4. It provides a method for evaluating the time-cost tradeoffs resulting from reallocating resources among tasks.
5. It provides a method for monitoring the project throughout its life cycle. As the project progresses, PERT/CPM easily identifies change in which tasks are critical and how the expected completion date is affected.
6. It provides a convenient method for incorporating uncertainty regarding task times into the schedule and it helps to evaluate the effect of this uncertainty on project completion time.

Difference between PERT and CPM

Sl. No.	PERT	CPM
1	PERT is a probabilistic model with uncertainty in activity duration. Activity duration is calculated from t_0, t_p and $t_{m.}$	CPM is a deterministic model with well known activity duration.
2	It is an event oriented approach.	It is an activity oriented approach.
3	PERT terminology uses word like network diagram, event and slack.	CPM terminology employs word like arrow diagram, nodes and float.
4	The use of dummy activity is required for representing the proper sequencing.	No dummy activity required.
5	PERT basically does not demarcate between critical and non-critical activities.	CPM marks the critical activities.
6	PERT is applied in projects where resources are always made available.	CPM is applied to projects where minimum overall cost is the prime importance.
7	PERT is suitable in Defence project and R&D where activity time can't be readily predicted.	Suitable for plant maintenance, civil construction projects etc. where activity duration is known.

Steps in using network techniques

1. Plan of project

(a) The project is analyzed by determining all the individual activities (sometimes called tasks/jobs/operation) that must be performed to complete it.
(b) A planned sequence of these activities are shown on a network (a graph where arrow and circles represent the relationship among project activities)

2. Schedule of project

(a) How long it will take to perform each activity is estimated.
(b) In order to locate the critical path, calculation is performed (the longest time chain of sequential activities which determines the duration of project). This step also provides other information that is useful in scheduling.
(c) The above information are used to develop a more economical and efficient schedule.

3. Project monitoring

(a) The plan and schedule started above are used to monitor the progress.
(b) Throughout the execution of project, the schedule is revised and updated so that the schedule represents the current plan and status of progress.
(c) PERT, Critical path, Most likely time estimates.

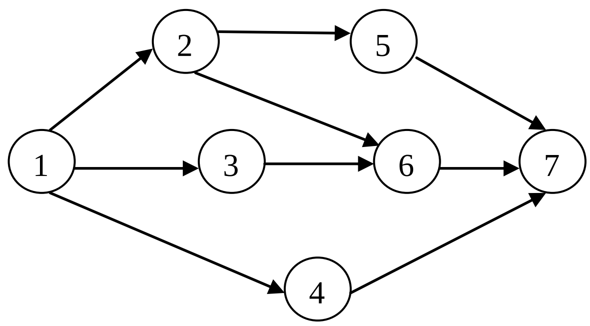
The above points can be explained with the following examples.

Ex: 1 A project consists of the following activities and time estimates.

Activity	Least time (t_0) in days	Greatest time (t_p) in days	Most likely time (t_m) in days
1-2	3	15	6
1-3	2	14	5
1-4	6	30	12
2-5	2	8	5
2-6	5	17	11
3-6	3	15	6
4-7	3	27	9
5-7	1	7	4
6-7	2	8	5

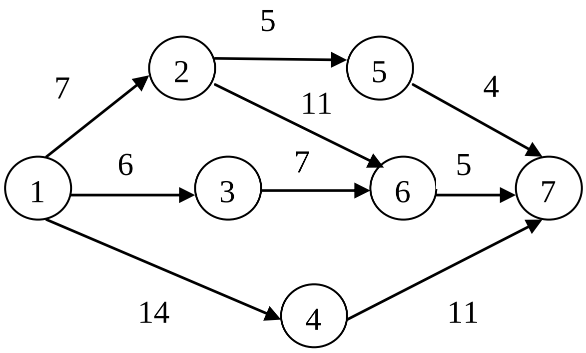
Construct the network. Determine the expected task time and the critical path.

Solution: The network diagram is shown below:



Expected task time (t_e) = $(t_0 + 4t_m + t_p)/6$
Using this formula, t_e for different activities are shown below.

Activity	t_e value
1-2	7
1-3	6
1-4	14
2-5	5
2-6	11
3-6	7
4-7	11
5-7	4
6-7	5



From the above figure, 1-4-7 is the critical path. The project duration is 14+11 = 25 days.

Resource levelling

There are two types of resource problem

(i) Resource smoothing
(ii) Resource levelling

(i) Resource smoothing:

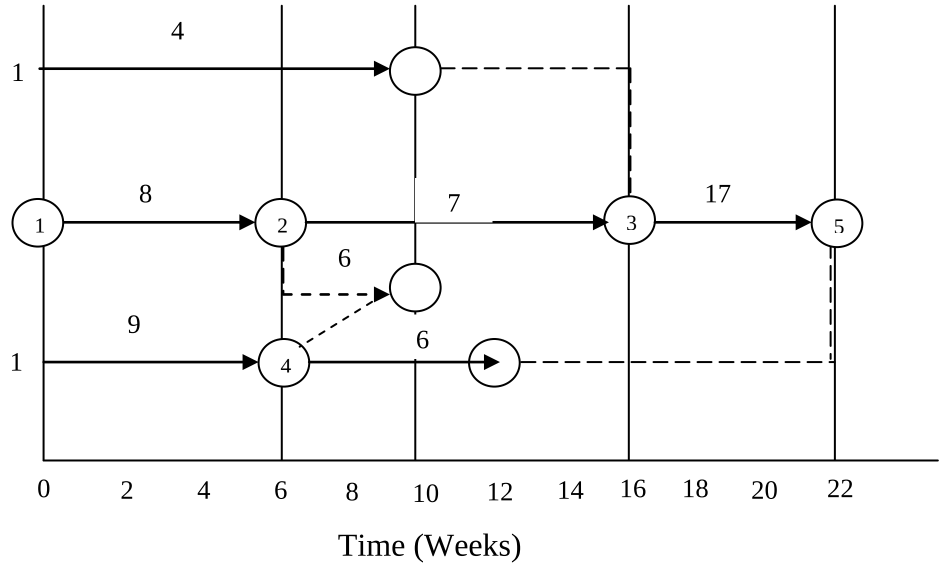
There may be a ceiling on the availability of resources in a particular period of time. For instance, only Rs 125 lakh per annum may be available to the project and if unutilized during the year, the remaining amount lapses. The resource analysis used for this type of case is called Resource smoothing.

(ii) Resource levelling:

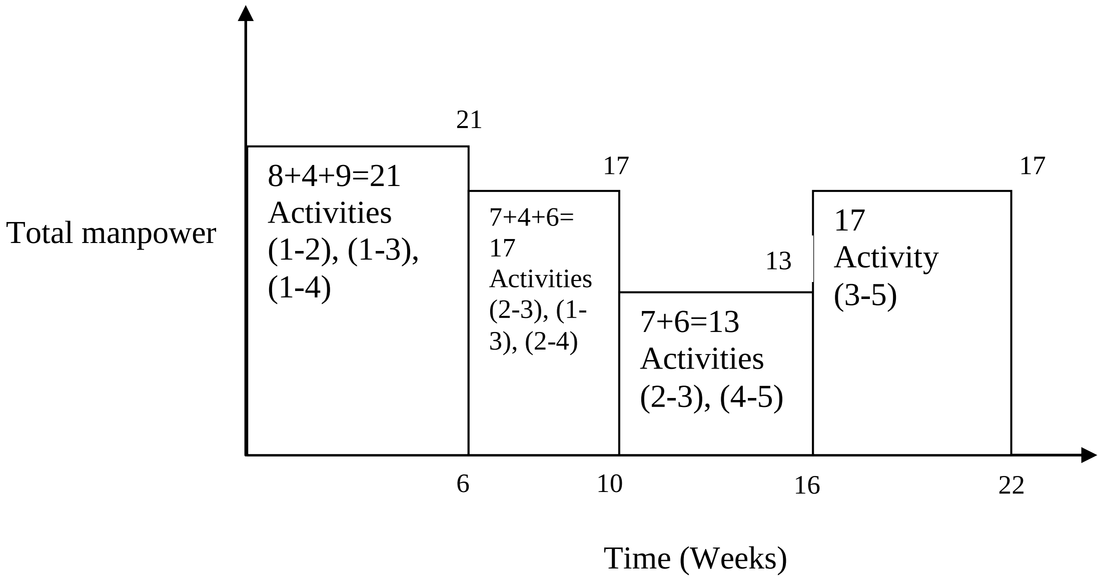
A resource may be required to be used in a uniform manner. For instance, in the present day labour situation one cannt have 100 labourers yesterday, 30 today and 80 tomorrow. Once a labour is hired, it is difficult to hire him. The rate of usage of labour has to be uniform. Resource analysis used for this category of problems is called Resource levelling.

Example: Consider the following problem of project scheduling. Obtain a schedule which will minimize the peak manpower requirement and smooth out period to period variation of manpower requirement.

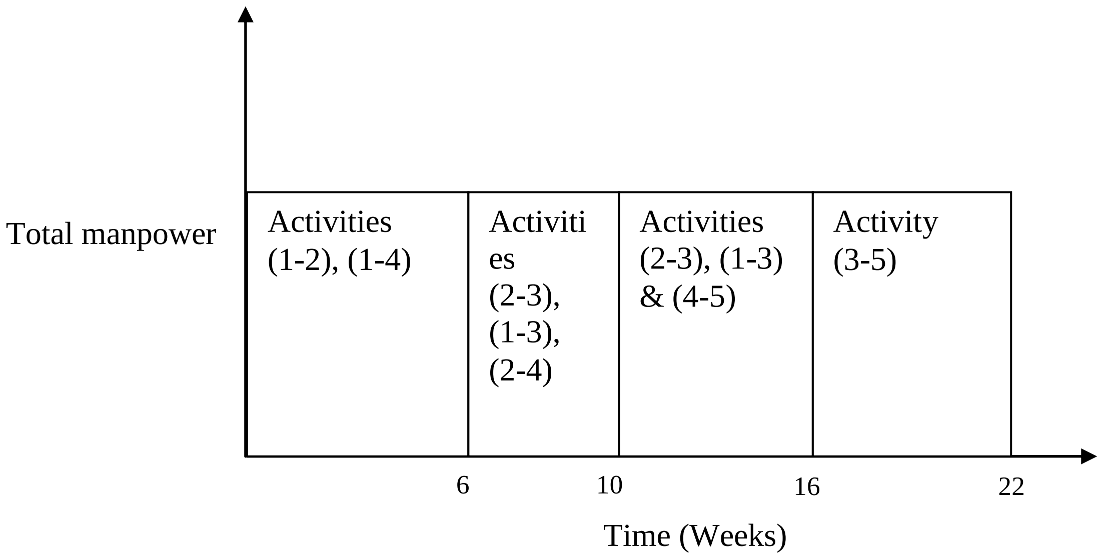
Activity	Duration in Weeks	Manpower requirements
1-2	6	8
1-3	10	4
1-4	6	9
2-3	10	7
2-4	4	6
3-5	6	17
4-5	6	6



The corresponding manpower requirement histogram is shown below.



From this figure, it is observed that the peak manpower requirement is 21 and it occurs from 0 to 6 weeks. The activities which are scheduled during the period are: (1-2), (1-3) and (1-4). The activity 1-2 is critical activity. So it should not be disturbed. Between activities (1-3) and (1-4), the activity (1-3) has high slack value of 6 weeks (whereas its only 4 weeks for (1-4)). Hence, it can be started at the end of 6 weeks. The corresponding modification is shown by the following histogram.



The manpower requirement is now smooth throughout the project duration.

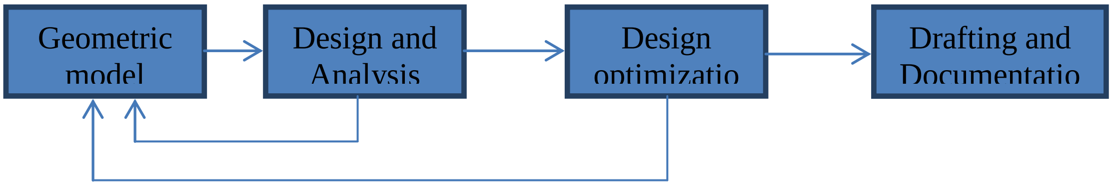
Chapter 8: Modern Trends in Mabufacturing

Basic concepts of CAD

Computer Aided Design (CAD) involves the use of computer in

- Creating
- Analyzing
- Modifying
- Optimizing
- Drafting/ Documenting

A product data so as to achieve its design goal efficiently and effectively. The various phases of CAD section are presented in the following form:



As per the above figure, there are four phases of CAD process. A geometric model is generated first. It is analyzed for the desired design conditions and is optimized before finally getting documented and drafted.

CAD tool includes the following three elements.

(i) Computer modelling and computer graphics

Geometric modelling and computer graphics help to generate and visualize models on which the analysis is done subsequently. Modelling and designing are being used as synonyms now a day's. The kind of analysis which can be done on a model is controlled by the type of model used. Hence the computer aided model must be made only after confirming the kind of analysis which is to be performed on the model. Eg. Some model may not work for fluid dynamics and vibration analysis.

(ii) Analysis and optimization tools

These are the algorithms and programs for exclusive application which are applied on to the virtual product already modelled. This section can predict the behaviour of the model under the loading condition when all constraints are simulated using boundary conditions. The analysis process is iterated number of times with varying attributes to optimize the results. The results so obtained from the model can be anticipated from the behavior of actual model in real situation.

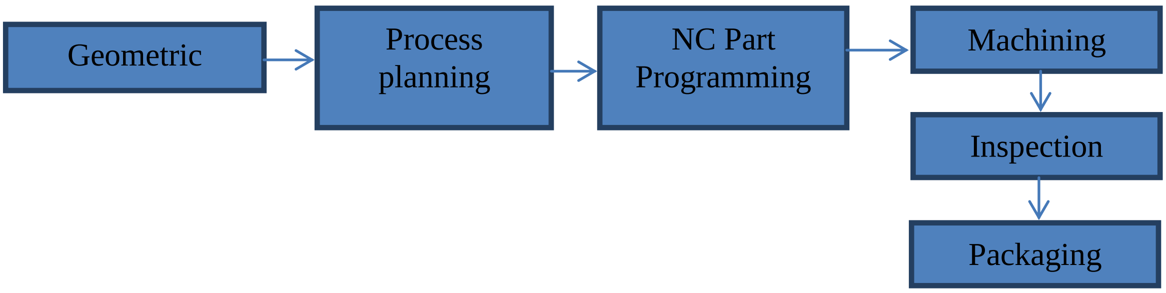
(iii) Drafting and documentation

The model already created, analysed and optimized guarantees a safe model under the real conditions. This safe model drawing is to be communicated to production floor with technical illustrations. The tool used for this application is called Computer Aided Drafting orcalled Computer Aided Design and Drafting (CADD). Computer Aided Modelling/Designing and Computer Aided Drafting represent two different concepts. Their differences are presented in the following:

Sl.No.	Computer Aided Modelling/Designing	Computer Aided Drafting
1.	This is done before analysis is performed on the geometric model.	This is done after analysis is performed on the geometric model.
2.	This provides dimension which may/maynot be safe.	The dimensions are safe since these are obtained after the analysis.
3.	This is 2D drawing/3D model	This is generally 2D drawing.
4.	This model is used for design analysis	These are made basically for conveying the production design.

Basic concepts of CAM (Computer Aided Manufacturing)

CAM is defined as a process of use of computers in planning, manufacturing, inspecting and controlling the manufacturing operation directly or indirectly. CAM includes those activities which manufacture the product with the product drawing and technical illustration as a input from the CAD and then make the product ready for shipment after inspection and packaging. The various phases of CAM section are shown below.



CAM Processes

In CAM, the basic information required is actually geometrical information which is supplied to the CAM processes through the CAD model already generated and analyzed. Interface algorithm extract that necessary geometrical information from the CAD model and feed it for process planning, part programming, machining, inspection and packaging.

CAM tool includes the following three elements:

(i) **CAD Tool**: The basic geometric information of the model is extracted from the geometric model created in the CAD phase of the product cycle. From the model necessary information regarding the shape, contour and sizes is extracted so as to implement in the manufacturing tool.

(ii) **Manufacturing tool**: The fundamental of manufacturing process which are used defines the manufacturing tool. It describes the method in which the product can be manufactured. This includes generation of part programming and manufacturing and computer aided process planning (CAPP) and tool and cutter design, etc.

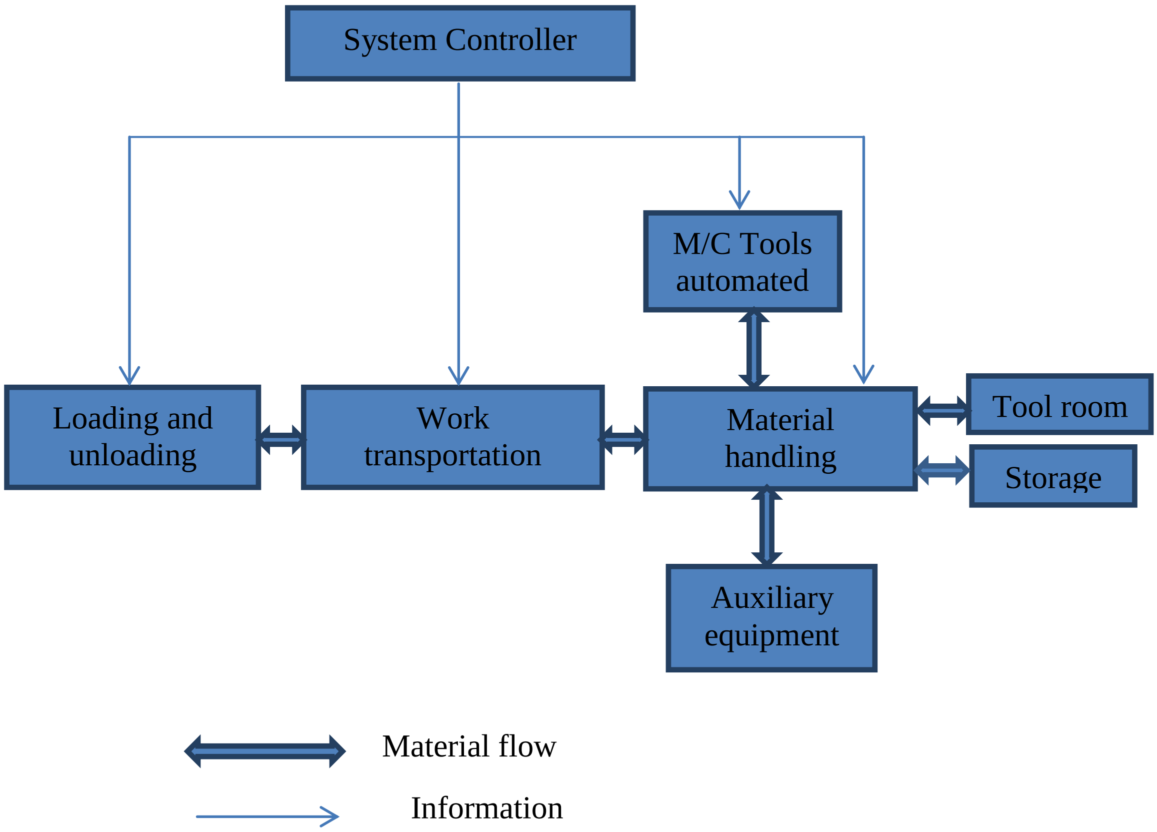
(iii) **Networking tools**: The knowledge of networking and interfaces is required for communication capability between various machines and computers. e.g. transferring a part program from one computer to 04 different machines, controlling a robot from a computer etc. a communication or networking tool is a must for CAM to be operational effectively.

CAM employs computers for 02 basic purposes:

(a) **Computer monitoring and control:** Where computers are used to control and monitor the applications. The major applications include in this category are: controlling machines and robots.

(b) **Manufacturing support application**: It includes those applications which are not controlled directly by computer but are used to support the primary and direct operation. Such applications include numeric part programming, CAPP, generating computer aided schedules and all other kinds of planning.

(c) **Flexible Manufacturing System (FMS)**: A FMA integrates all major elements of manufacturing into a highly automated system. FMS has born in the latter half of 1960's as a means to improve productivity of small and medium volume production.



Structure of FMS

The major components are:

(a) **Automated m/c tools**: In order to achieve the system flexibility, NC/Computer controlled general purpose m/c tools are normally used.

(b) **Work transportation device**: These devices are used to carry parts between loading area and machining station. Individual conveyors are used for high degree of flexibility.

(c) **Material handling device**: These devices transport work in process or tolls to assigned positions.

(d) **Loading and unloading station**: The raw materials and/or finished parts are loaded/unloaded in this area by robot.

(e) **Tool room and storage**: All the tools used in this system are stored in the tool room and transported to machining centers when required.

(f) **Auxiliary equipments**: Besides m/c tools, an FMS can also include cleaning online inspection, automated measurement and gauging equipments.

(g) **System controller**: The system controller oversees the operation of entire FMS. It coordinates the operation of variety of equipments in the system.

Advantages of FMS

1. There is a greater potential to make changes in terms of product, technology.
2. It reduces both direct and indirect labour cost because of automatic handling, gauging and inspection facilities.
3. It provides reduced manufacturing lead time, reduced inventory of parts (both stock and work in progress).
4. It improves the utilization of equipments. In this case, utilization is 85% compared to 50% in conventional method.
5. It provides a better management control by integration of computers.
6. It provides better and more consistent products.

Computer Integrated Manufacturing (CIM)

- CIM is defined as a process of integration of CAD, CAM and business aspects of a factory and it attempts to describe complete automation with all processes functioning under computer control.
- CIM includes Management Information System (MIS), sales marketing, finance, database management system, design, manufacturing, monitor and control and bar code software etc., which helps to manage and control the overall factory environment. CAD, CAM and CIM basically involve fundamental principles of these underlying branches with hardware and software to operate and utilize them effectively.

Just In Time (JIT)

The Just-in-time production concept was first implemented in Japan around 1970's to eliminate waste of

- Materials
- M/C
- Capital
- Manpower
- Inventory

through out the manufacturing system. The JIT concept has the following objectives:

- Receive supplies just in time to be used.
- Produce parts just in time to be made into subassembly.
- Produce subassemblies just in time to be assembled into finished products.
- Produce and deliver finished products just in time to be sold.

In order to achieve these objectives, every point in the organization where buffer stocks normally occur is identified. Then, critical examinations of reasons for such stocks are made. A set of possible reasons for maintaining high stock is listed below:

- Unreliable/unpredictable deliveries
- Poor qualities from supplier
- Increased variety of materials
- Machine break down
- Labourabsentism
- Frequent machine setting
- Variations in operators capabilities
- Schedule charges
- Changing product priorities
- Product modification

In traditional manufacturing, the parts are made in batches, placed in inventory and used whenever necessary. This approach is known as 'Push system' which means that parts is produced in accordance with the order. That means the rate at which the products come out at the end of final assembly matches with the order quantity for that product. There are no stockpiles within the production process. It is also called zero inventory, stockless production, demand scheduling. Moreover, parts are inspected by the workers as they are manufactured. This process of inspection takes a very short period. As a result of which workers can maintain continuous production control immediately identifying defective parts and reducing process variation. This JIT system ensures quality products. Extra work involved in stockpiling parts is eliminated.

Advantages of JIT

1. Exact delivery schedule is possible with JIT practices.
2. Quality of product is improved.
3. Lower defect rates i.e. lower inspection cost.
4. Lower raw material inventory, in process inventory and finished product inventory resulting lower product cost.
5. Satisfying market demand without delay in delivery.
6. Flexibility in utilizing manpower as workers is trained to do many jobs.
7. JIT helps in effective communication and reduce waste.
8. Less shop floor space is required.
9. Employee morale is high in an efficient working environment.
10. JIT reduces scrap and need for rework.

ISO 9000

ISO stands for International organization for standardization. It is an international body consists of representatives from more than 90 countries. The national standard bodies of these countries are the member of this organization. These are non-governmental

organizations and can provide common standards of goods and services on international trades.
ISO9000 series has 5 numbers of international standards on quality management which are listed below with different objectives.
ISO 9000: Provides guide lines on selection and use of quality management and quality assurance standards.
ISO 9001: This is applicable for industries doing their own design and development, production, installation and servicing. It has 20 elements.
ISO 9002: It has 18 elements. It is same as ISO 9001 without the 1sttwo tasks i.e. design and development.
ISO 9003: It has 12 elements covering final inspection and testing for laboratories and warehouses.
ISO 9004: This provides guidelines to interpret the quality management and quality assurance. It also has suggestions which are not mandatory.

Benefits of ISO 9000 Series

1. This gives competitive advantage in the global market.
2. Consistency in quality, as ISO helps in detecting non-conforming early which makes it possible to rectify.
3. Documentation of quality procedure adds clarity to quality system.
4. It ensures adequate and regular quality training for all members of the organization.
5. It helps in customers to have cost effective purchase procedure.
6. The customers during purchase from firm holding ISO certificate need not spend much on inspection and testing. This will reduce quality cost and lead time.
7. This will aid to improved morale and involvement of workers.
8. The level of job satisfaction will be more.
9. This will help in increasing productivity.

Steps in ISO 9000 Registration

1. Selection of appropriate standard from ISO 9001/9002/9003 using guidelines given in ISO 9000.
2. Preparation of quality manual to cover all the elements in the selected model.
3. Preparation of procedure and shop floor instruction which are used at the time of implementing the system. Also document these items.
4. Self-auditing to check compliance of the selected module.
5. Selection of a registrar (an independent body with knowledge and experience to evaluate any one of the three quality systems i.e. ISO 9001/ 9002/ 9003) and the application is to be submitted to obtain certificate for the selected quality system/ model.

Sl.No.	System requirement	ISO 9001	ISO 9002
1	Management responsibility	✓	✓
2	Quality system	✓	✓
3	Product identification & traceability	✓	✓
4	Inspection status	✓	✓
5	Inspection & Testing	✓	✓
6	Inspection, measuring & test equipment	✓	✓
7	Control of non-conforming products	✓	✓
8	Handling, storage, packaging & delivery	✓	✓
9	Document control	✓	✓
10	Quality record	✓	✓
11	Training	✓	✓
12	Statistical technique	✓	✓
13	Internal auditing	✓	✓
14	Contract review	✓	✓
15	Purchasing	✓	✓
16	Process control	✓	✓
17	Purchaser's supplied product	✓	✓
18	Corrective action		✗
19	Design control	✓	✗
20	Servicing	✓	

✓ Present

✗ Not Present

Quality circle (QC)

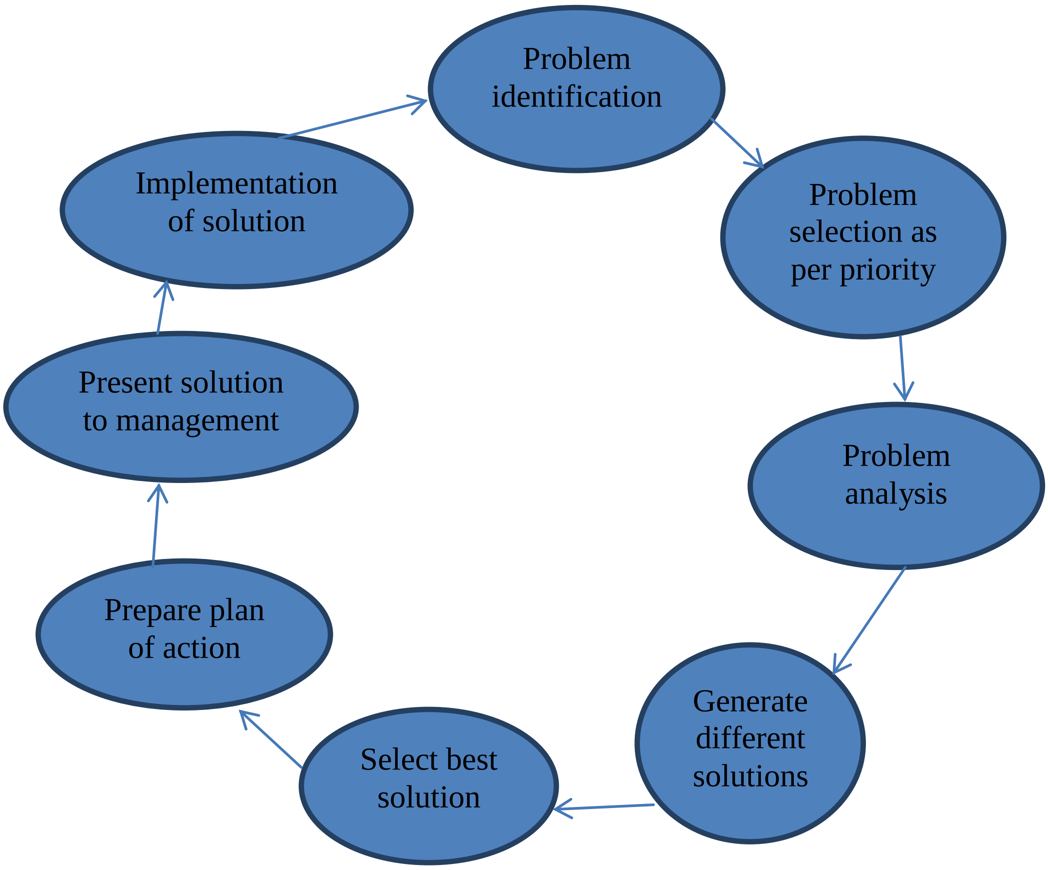
Quality circle may be defined as a small group of workers (5 to 10) who do the same work voluntarily meeting together regularly during their normal working time usually under the leadership of their own supervisor to identify, analyze and solve work related problems.

This group presents the solution to the management and wherever possible implement the solution themselves. The QC concept was first originated in Japan in 1960. The basic cycle of a quality circle starts from identification of problem.

Philosophical basis of QC

1. A belief that people will take pride and interest in their work if they get autonomy and take part in decision making.
2. It develops a sense of belongingness in the employees towards a particular organization.
3. A belief that each employee desires to participate in making the organization a better place.
4. It is a mean/method for the development of human resources through the process of training, work experience and participation in problem solving.

5. A willingness to allow people to volunteer their time and effort for improvement of performance of organization.
6. The importance of each member's role in meeting organizational goal.



Quality Circle

Characteristics of quality circle

1. QCs are small primary groups of employees/workers whose lower limit is 3 and upper limit is 12.
2. Membership is voluntary. The interested employees in some areas may come together to form a quality circle.
3. Each quality circle is led by area supervisor.
4. The members meet regularly every week/ as per agreeable schedule.
5. The QC members are specially trained in technique of analysis and problem solving in order to play their role efficiently.
6. The basic role of quality circle is to identify work related problems for improving quality and productivity.
7. QC enables the members to exercise their hidden talents, creative skills, etc.
8. It promotes the mutual development of their member through cooperative participation.

9. It gives job satisfaction because of identifying and solving challenging problems while performing the job.
10. It provides their member with opportunities for receiving public recognition from the company's management.
11. The members also receive recognition in the form of memento, certificate and privileges.
12. It also contributes to their self-esteem and self-confidence through acceptance of their recommendation by the management.

Objectives of QC

1. To improve the quality and productivity.
2. To reduce the cost of products/ services by waste reduction, effective utilization of resources eliminating error/ defects.
3. To utilize the hidden creative intelligence of the employees.
4. To identify and solve work related problems.
5. To motivate people for solving challenging tasks.
6. To improve communication within the organization.
7. To increase employee's loyalty and commitment to organizational goals.
8. To enrich human capability, confidence, morale, attitude and relationship.
9. To pay respect to humanity and create a happy bright workplace.
10. To satisfy the human needs of recognition and self development.

Kaizan

Kaizen means change (Kai) to become good (Zen). In other words, it means continuous improvement. In fact, continuous improvement is required in all activities of the organization such as:

- Productivity improvement
- New product development
- Labor management relation
- Total productive maintenance
- Just in time production & delivery system
- Customer orientation etc.

The various activities of an organization where continuous improvement is required is presented under the kaizen umbrells. This continuous improvement in all areas are taken through small step by step process. Because various behavioural, cultural and philosophical changes are better brought about through small step by step improvement than through radical changes.