INDUSTRIAL ENGINEERING

&

MANAGEMENT

6TH SEMESTER, MECHANICAL ENGG.

GOVT. POLYTECHNIC, NAYAGARH

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Plant location and Plant layout

SECTION-A

1. **Define plant**.
   A Plant is a place where men, materials, money, equipments and machinery are brought together for manufacturing products.
2. **Define plant location.**
   Plant location means deciding a suitable location, area, place where the plant or factory will start functioning.
3. **Define plant layout.**
   a) Plant layout may also be defined as:"Plant layout means placing the right equipment coupled with right method in right place to permit the processing of products in most effective manner through shortest move in shortest time''.

   b) Plant layout means effective arrangement of various facilities of plant like arrangement of machines, material handling equipments, storage space, operating equipments and other supporting services.

4. **What are the functions of plant layout?**

a) The term plant layout does not necessarily mean planning a layout for a new plant only. It may involve

   i) Expansion of existing plant.
   ii) Minor improvements in existing plant.
   iii) Re-layout of the existing plant.

b) Plant lay out begins with the design of factory building and goes up to the location and movement of work table.

5. **What are the types of plant layout generally used in an organisation?**

According to type of industry and volume of production following are the types of layouts used in an organisation:

   a) Process layout or functional layout.
   b) Product layout or line layout.
   c) Combination layout or group layout.
   d) Fixed position layout.
   e) Cellular layout or group technology layout.

6. **Explain why plant location decisions are important to the organization?**

a) Plant location means deciding a suitable location, area, place where the plant or factory will start functioning.

b) Plant location decisions are important to the organization setup because it depends on following factors :

- Nearness to raw materials
- Transport facilities
- Nearness to markets
- Availability of labour
- Availability of fuel and power
- Availability of water
- The following factors should also be considered for plant location.
  - i) Climatic conditions.
  - ii) Financial and other aids.
  - iii) Land.
  - iv) Community attitude.
  - v) Presence of related industries.
  - vi) Existence of hospitals, marketing centres, schools, banks, post offices, clubs, etc.
  - vii) Housing facilities.
  - viii) Security.

SECTION-B

1. **State the objectives of good plant layout.**
   - Material handling and transportation is minimized and efficiently controlled.
   - Work stations are designed suitably and properly.
   - Suitable spaces are allocated to production centres and service centres.
   - The movements made by the workers are minimized.
   - Waiting time of the semi-finished products is minimized.
   - Working conditions are safer, better and improved.
   - There is increased flexibility for changes in product design and future expansion.
   - There is utilization of cubic space (length, width and height).
   - There are improved work methods and reduced production cycle times.
   - There is increased productivity and better product quality with reduced capital cost.
2. **Describe the principles of plant layout.**

- **Integration.** It means the combination of production centres facilities like workers, machinery, raw material, etc in a logical and balanced manner.
- **Minimum movements and material handling.** The number of movements of workers and materials should be minimized. it is better to transport materials in optimum bulk rather than in small amounts.
- **Smooth and continuous flow.** Bottlenecks, congestion point and back tracking should be removed by proper line balancing techniques.
- **Cubic space utilization.** Besides using the floor space of a room, if the ceiling height is also utilized. More materials can be accommodated in the same room. Boxes or bags containing raw material or goods can stocked one above the other to store more items in the same room
- **Flexibility.** In automotive and other industries where models of products change after some time, it is better to permit all possible flexibility in the layout. The machinery is arranged in such a way that the changes of the production process can be achieved at the minimum cost.

- **Safe and improved environments.** Working places should be safe, well ventilated and free from dust, noise, fumes, odours and other hazardous conditions and increase the operating efficiency of the workers and improve their morale.

3. Describe the factors governing or influencing the plant location.

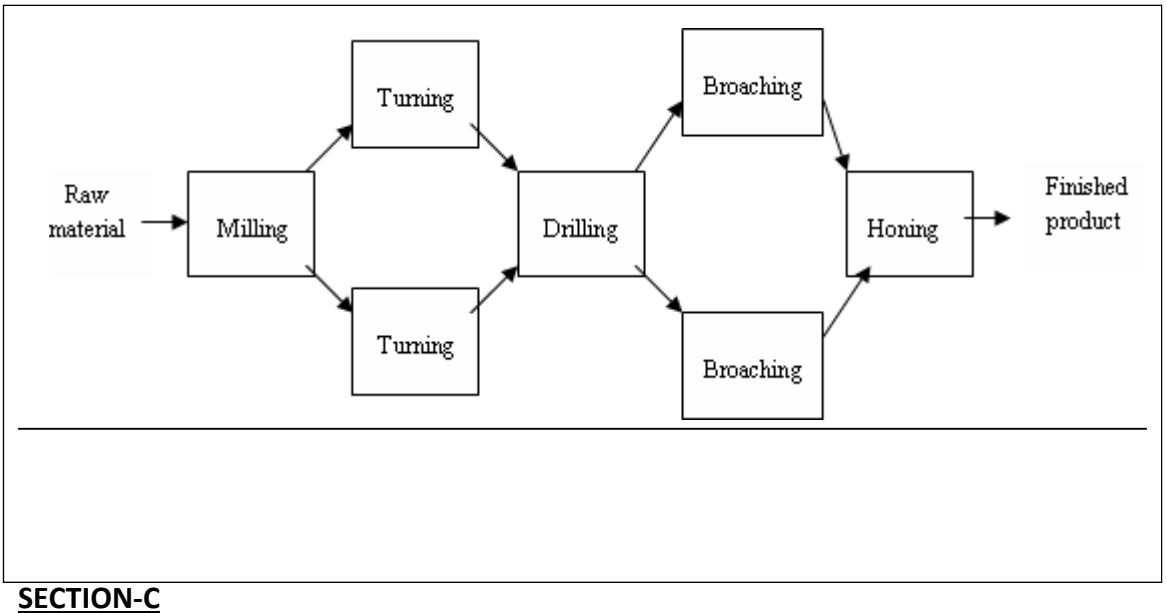
- **Nearness to raw materials**:-it will reduce the cost of transporting raw material from the vendor's end to the plant.
- **Transport facilities**:-depending upon the size of raw material and finished goods, a suitable method of transportation like roads, rail, water or air is selected and accordingly the plant location is decided.
- **Nearness to markets**:-it reduces the cost of transportation as well as the chances of finished products getting damaged and spoiled in the way, it can render quick service to the customers.
- **Availability of labour**:-stable labour force, of right kind, of adequate size, and at reasonable rates with its proper attitude towards work are a few factors which govern plant location to a major extent.
- **Availability of fuel and power**:-because of the wide spread use of electric power, in most cases fuel (coal, oil, etc) has not remained a deciding factor for plant location. Even then steel industries are located near source of fuel(coal) to cut down the fuel transportation costs.
- **Availability of water**:-water is used for processing, as in paper and chemical industries and is also required for drinking and sanitation purposes. Depending upon the nature of plant, water should be available in adequate quantity and should be of proper quality.

The following factors should also be considered for plant location.

ix) Climatic conditions.
x) Financial and other aids.
xi) Land.
xii) Community attitude.
xiii) Presence of related industries.
xiv) Existence of hospitals, marketing centres, schools, banks, post offices, clubs, etc.
xv) Housing facilities.
xvi) Security.

4. Describe Combination layout.

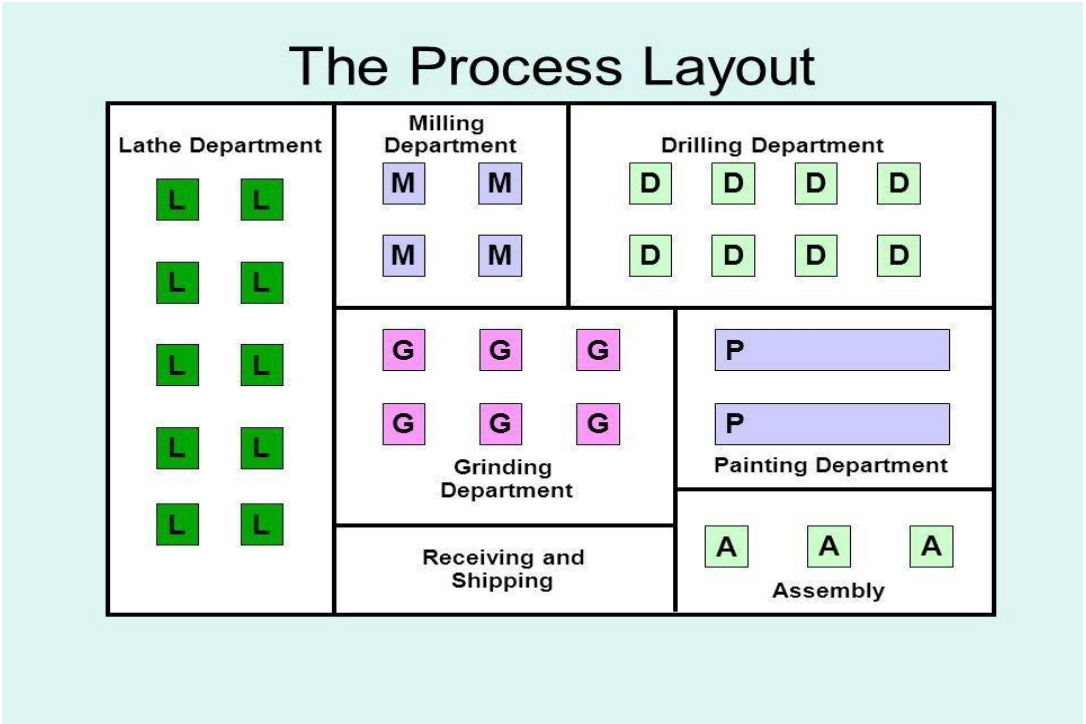
- A combination of process and product layouts combines the advantages of the both types of layouts. It is also known as group layout.
- Now a day's pure product or process layouts are rare, in combination layout where an item is being made in different types and sizes.
- In combination layout machinery is arranged in a process layout but the process grouping (a group of no. of similar machines) is then arranged in a sequence to manufacture various types and sizes of products.
- A combination layout is also useful when a number of items are produced in same sequences.
- Files, hacksaws, circular metal saws, wood saws etc. can be manufactured on a combination type of layout.



SECTION-C

1. **Describe Process layout with advantages and disadvantages.**

- Process lay out is also known as functional lay out and is characterized by keeping similar machines or similar operations at one location.
- For example all lathes will be at one place, all milling machines at another and so on, that is machines have been arranged according to their functions.
- This type of layout is generally employed for industries engaged in job order production.
- This type of layout is particularly used when low volume of production is needed at regular intervals or low volume and high variety of products is required.



Advantages

- There is a greater flexibility in utilization of equipment, machines and man power.
- Lower initial investment is required as comparatively less number of machines is required.
- Better product quality, because the supervisors and workers attend to one type of machines and operations.

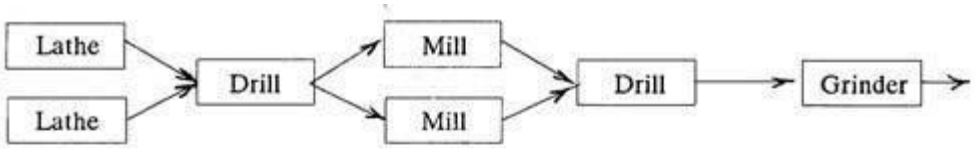
- Breakdown of machines can be easily handled by transferring the work to other machines.
- Varieties of job coming as different job orders make the work more interesting for the workers.
- Better utilization of the available equipment.

Disadvantages

- For the same amount of production, process lay out needs more space.
- Automatic material handling is extremely difficult.
- More material-in-process remains in queue for further operations.
- Completion of same product takes more time.
- Work-in-process inventory is large.
- Raw material has to travel larger distance for being processed to finished goods. This increases material handling and associated costs.

2. Describe Product layout with advantages and disadvantages.

- It is also known as line layout. Various operations on raw material are performed in a sequences and the machines are placed along the product flow line ,i.e machines are arranged in the sequence in which the raw material will be operated upon.
- This type of lay out is used for continuous production or mass production i.e. a continuous flow of in – process material towards the finished product stage.
- Ex:- Raw material from the store is fed to three lines X, Y and Z. Material in X line gets processed on machines D , E , F and G and meets material of Y line after it has been processed on the main assembly line machines A and B. Products of X and Y lines are assembled at W and get processed on machines H and I still another part comes from Z line and assembles with the main product at V. After that the total assembly gets worked on machines M , N, O and P and goes to the stock room.



A Simple product layout.

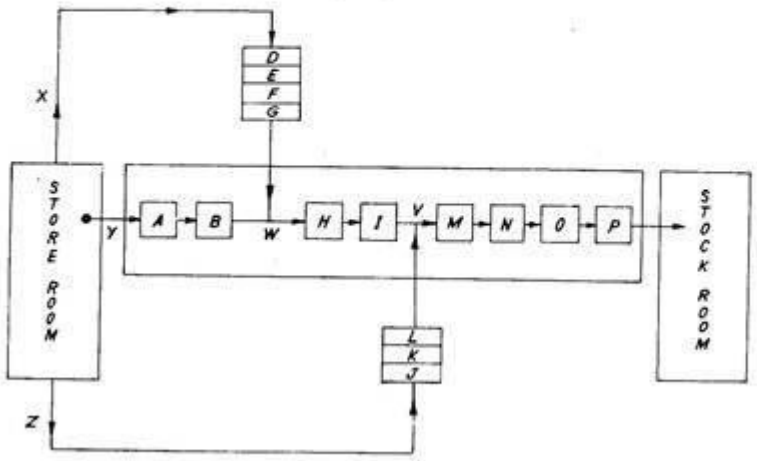


Fig. 4.2 Product layout.

Advantages

- Less space requirements for the same volume of productions.

- Automatic material handling, lesser material handling movements, times and costs.
- Less in-process inventory.
- Product completes in lesser time.
- Smooth and continuous work flow.
- Less skilled worker may serve the purpose.

Disadvantages

- The layout flexibility is considerably reduced.
- If any of the machines in the shop breaks down the other machines have to remain idle till that machine becomes again ready to commence operation.
- It is difficult to increase production beyond the capacities of the production lines.
- For expansion purpose, it is not possible to add more machines.
- Specialized and strict supervision is needed.

3. Briefly explain the plant layout procedure.

Plant layout procedure

- Accumulate basic data.
- Analyse and coordinate basic data.
- Decide the equipment and machinery required.
- Select the material handling system.
- Sketch plan of the plot for making factory building.
- Determine a general flow pattern.
- Design the individual work station.
- Assemble the individual layout into the total layout.
- Calculate storage space required.
- Make flow diagrams for work stations and allocate them to areas on plot plan.
- Plan and locate service areas.
- Make master layout.
- Check final layout.
- Get official approval of the final layout.
- Install the approved layout.

4. Briefly explain the storage space requirements in plant layout .

- Adequate storage space allocation to different materials and supplies is of great importance otherwise a small increase in their quantities may give rise to congestion and the whole storage system may be out of system.
- The space to be provided for above factors depends upon:
    i) Size and weight of raw material, in-process good and finished goods.
    ii) Their quantities.
    iii) Frequency of use.
- The following items and the amount of stock holding determine the storage space requirements:
    i) Incoming new materials.

ii) Checking and sorting the raw materials

iii) Inspection of raw materials.

iv) Temporarily storing the new material before it is placed at the proper location.

v) In-process inventory.

vi) Tools and other supplies.

vii) Finished products.

- Bins, drums, barrels, racks, shelves, tanks, pallets etc may be usefully employed for storage purposes.

  Ex.-

  i) Liquid materials are stored in drums, cans, barrels and bottles.

  ii) Gases are kept in cylinders whereas solid materials can be placed in boxes, barrels, bags, pallets, container etc.

  iii) Casting or forging can be stored in pallets and stocked in rows.

  iv) Toxic materials are generally stored in well ventilated areas.

- The storage space should be such that the materials can be quickly and easily taken out for delivery or stocked as soon as they are received in the factory.

Inventory control

Section - A

1. Define inventory control.

- Inventory control may be defined as the scientific method of finding out how much stock should be maintained in order to meet the production demands and be able to provide right type of material at right time in right quantities and at competitive price.

2. Classify different types of inventories a manufacturing organization keeps.

- Inventory may be classified as follows :

  (i) Raw inventories: - They include, raw material and semi finished products supplied by another firm and which are raw items for the present industry.

  (ii) In-process inventories: - They are semi-finished goods at various stages of manufacturing cycle.

  (iii) Finished inventories: - They are the finished goods lying in stock rooms and waiting dispatch.

  (iv) Indirect inventories: - They include lubricants and other items (like spare parts) needed for proper operation, repair and maintenance during manufacturing cycle.

3. What are the types of costs associated with inventory control?

- There are two types of costs associated with inventory, they are
- Inventory procurement costs:- which consist of expenditure connected with

i) Receiving quotations;

ii) Processing purchase requisition;

iii) Following up and expediting purchase order;

iv) Receiving material and then inspecting it; and

v) Processing seller's (vendor's) invoice.

Procurement costs decrease as the order quantity increases.

- Inventory Carrying costs, which vary with quantity ordered, base on average inventory and consist of :

  i) Interest on capital investment;

  ii) Cost of storage facility, up-keep of material, record keeping etc ;

  iii) Cost involving deterioration and obsolescence; and

  iv) Cost of insurance, property tax, etc.

4. What is EOQ?

- Economic order quantity (EOQ) is the order quantity of inventory that minimizes the total cost of inventory management.
- Economic Order Quantity (EOQ) is a production formula used to determines the most efficient amount of goods that should be purchased based on ordering and carrying costs. In other words, it represents the optimal quantity of inventory a company should order each time in order to minimize the costs associated with ordering and holding inventory.
- If C is the cost for one item, I is the cost of carrying inventory in percentage per period, including insurance, obsolescence, taxes etc, P is the Procurement cost associated with one order, and U is total quantity used per period say annually. Then Q the economic lot size or E.O.Q is, $Q = \frac{\sqrt{2UP}}{CI}$

5. What are the objectives of inventory control?

- The objectives are:

i) To minimize investment in inventory,

ii) To maximize the service levels to the firm's customers and its own operating departments.

6. State the advantages of maintaining inventory control.

- One does not face shortage of materials.
- Materials of good quality and procured in time minimises defects in finished goods.
- Delay in production schedules is avoided.
- Production targets are achieved.
- Accurate delivery dates can be ascertained and the industry builds up reputation and better relations with customers.

Section – B

1. What are the objectives of inventory control and how to achieve it?

- The objectives are:

i) To minimize investment in inventory,

i) To maximize the service levels to the firm's customers and its own operating departments.

ii) To avoid shortage of materials.

iii) Materials of good quality and procured in time minimises defects in finished goods.

iv) To avoid Delay in production schedules is.

v) To achieve Production targets.

- Inventory control aims at keeping track of inventories. In other words, inventories of required and in desired quantities should be made available to different departments as and when they need.
- This is achieved by,
  - Purchasing material at an economical price, at proper time and in sufficient quantities to run short of them at any instant.
  - Providing a suitable and secure storage location.
  - Providing enough storage space.
  - A definite inventory identification system.
  - Adequate and responsible store room staff.
  - Suitable requisition procedure.
  - Up-to-date and accurate record keeping.
  - Periodic inventory check up.
  - Division of inventory under A, B and C items, exercising the control accordingly and removing obsolete inventory.

2. Describe the functions of inventory control.

- Maintain smooth and efficient production flow.
- Purchase in desired quantities and thus nullify the effects of changes in prices or supply.
- Keeps a process continuous operating.
- Create motivational effect. A person may be tempted to purchase more displayed if inventories are in bulk.

Section – c

1. **Explain ABC analysis.**

Necessity:- As the size of the industry increases, the number of items to be purchased and then to be taken of also increases. Purchase and control of all items at a time and in bulk much before their use, irrespective of their usage value, price or procurement problems, blocks and involves a lot of money and man hours, and is therefore uneconomical. ABC analysis helps segregating the items from one another and tells how much valued the items is and controlling it to what extent is in the interest of the organization.

PROCEDURAL STEPS:-

1. Identify all the items used in an industry.
2. List all the items as per their value.
3. Count the number of high valued medium valued and low valued items.
4. Find the percentage of high, medium and low valued items. High valued items

Contribute for 70% or so of the total inventory cost and medium and low valued items, 20 and 10% respectively.

5. A graph can be plotted between percent of items (on X-axis) and per cent of total inventory cost (on Y-axis).

It can be seen that 70% of the total inventory cost is against 10% of the total items (called, A-items), 20% against 20%of the items (B-items)and 10% against a big bulk, i.e. 70% of the items(called C-items).

Thus ABC analysis furnishes the following information:-

A-ITEMS

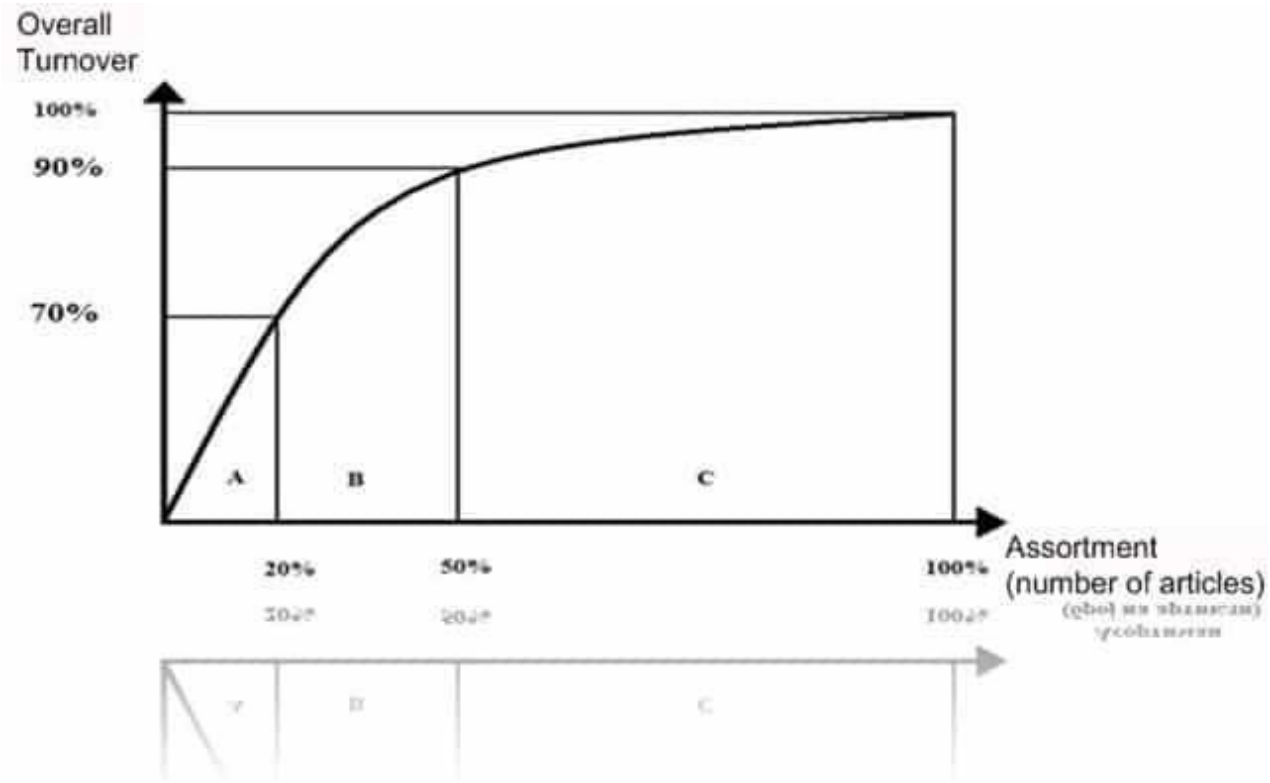
- A-items are high valued but are limited or few in number. They need careful and close inventory control. Minimum and maximum limits, and reorder point is set for A items. Such items should be thought of in advance and purchased well in time.
- A detailed record of their receipt and issues should be kept, and proper handling and storage facilities should be provided for them.
- Such items being costly are purchased in small quantities often and just before their use .This of course increases the procurement costs and involves a little risk of non-availability. However, the locked up inventory cost decreases and the problems of storage and care taking are minimized.
- A-items generally account for 70-80% of the total inventory cost and they constitute about 10% of the total items.

B-ITEMS

- B-items are medium valued and their number lies in between A and C-items. Such items need moderate control. They-are more important than C-items.
- They are purchased on the basis of past requirements, a record of receipts is issues are kept and a procurement order is placed as soon as the quantity touches reorder point.
- These items being comparatively less costly, a safety stock of up to 3 months may be kept, whereas it needs a stock of fortnight or so in the case of A-items. B-items also require careful storage and handling.
- In brief, B-items need every care but not so intensive as is required for A-items.
- B-items generally account for 20 to 15% of the total inventory cost and constitute about 15% to 20% of the total items.

C-ITEMS

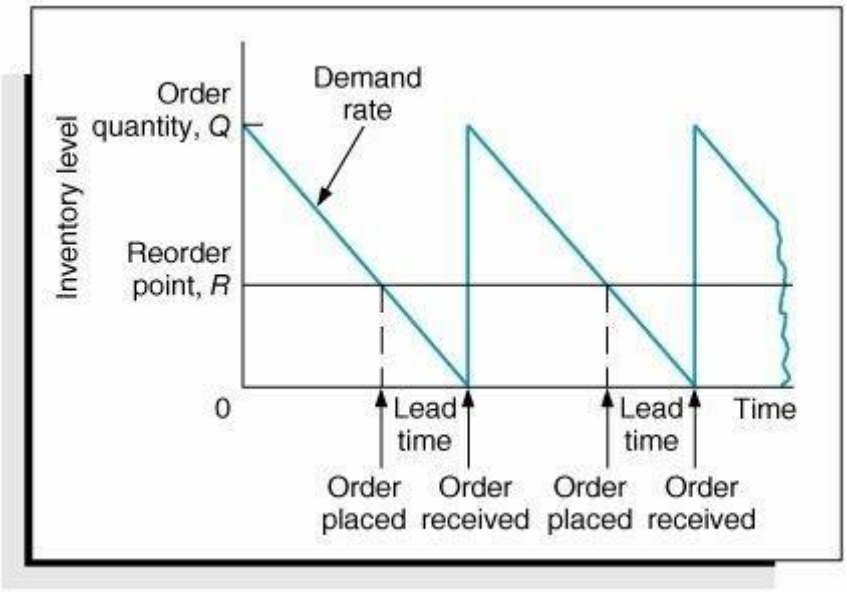
- C-items are row valued, but maximum numbered items.
- These items do not need any control, rather-controlling them to uneconomical.
- These are the least important items like clips, all pins, washer, rubber bands ,etc .They are generally produced just before they finish.
- C-items generally account for 10 to 5% of the total inventory cost and they constitute about 75%of the total items.



2. Briefly explain the EOQ model.

ECONOMIC ORDER QUANTITIY MODEL :-

- Economic order quantity (EOQ) is the order quantity of inventory that minimizes the total cost of inventory management.
- Economic Order Quantity (EOQ) is a production formula used to determine the most efficient amount of goods that should be purchased based on ordering and carrying costs. In other words, it represents the optimal quantity of inventory a company should order each time in order to minimize the costs associated with ordering and holding inventory.
- A problem which always remains is that how much material may be ordered at a time. An industry making bolts will definitely like to know the length of steel bars to be purchased at any one time. This length of steel bars is called “Economic order Quantity" and an economic order quantity is one which permits lowest cost per unit and is most advantageous.
- Before calculating economic order quantity it is necessary to become familiar with terms like maximum inventory, minimum inventory, standard order and order point, which are known as quantity Standards.
- Starting from an instant when inventory OA is in stores, it (inventory) consumes gradually in quantity from A along AD at a uniform rate. It is preknown that it takes L number of days between initiating order and receiving the required inventory. Therefore as the quantity reaches point B, purchase
- Requisition is initialled which takes from B to C that is time R. From C to D is the inventory procurement time P. At the point D when only reserve stock is left, the ordered material is supposed to reach and again the total quantity shoots to its maximum value, i.e. the point A, (A =A,).
- Maximum Quantity OA is the upper or maximum limit to which the inventory can be kept in the stores at any time.
- Minimum Quantity OE is the lower or minimum limit of the inventory which must be kept in the stores at any time.
- The purpose should be to hold enough and not excessive stock of material. Stock holding:-
  - i) Avoids running out of stock.
  - ii) Helps creating a buffer stock which may be utilized if the material falls below the minimum level.
  - iii) Makes sure the predefined delivery dates.
  - iv) Provides quick availability of materials.
  - v) Takes care of price fluctuations and shortage of inventory in the market.
  - vi) Advises regarding, obsolete and slow moving items.
  - vii) Helps in standardization and thus reducing the variety of items to be handled.



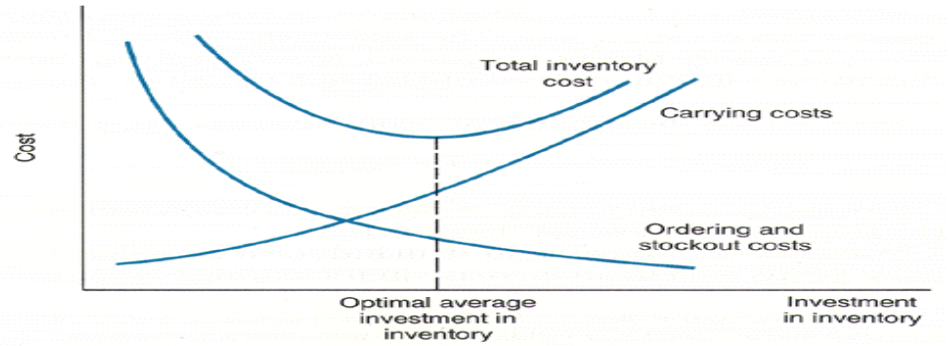
- Standard Oder:- (A'D) is the difference between maximum and minimum quantity and it is known as economical purchase inventory size.
- Reorder Point (B) indicates that it is high time to initiate a purchase order and if not done so the inventory may exhaust, and even reserve stock utilized before the new material arrives.
- From B^1 to $D^{1,}$ it is as lead time (L) and it may be calculated on the basis of past experience. It includes:-
  - i) Time to prepare purchase requisition and placing the order ;
  - ii) Time taken to deliver purchase order to the seller;
  - iii) Time for seller (vendor) to get or prepare inventory; and
  - iv) Time for the inventory to be dispatched from the vendor's end and to reach the customer.
- Time' (a) above is known as requisition time (R) and (b) +(c) +(d)is the procurement time (p).
- The economic lot size for an order or the economic order quantity depends upon two types of costs:
- Inventory procurement costs, which consist of expenditure connected with
  - i) Receiving quotations;
  - ii) Processing purchase requisition;
  - iii) Following up and expediting purchase order;
  - iv) Receiving material and then inspecting it; and
  - v) Processing seller's (vendor's) invoice.
  - vi) Procurement costs decrease as the order quantity increases.
- Carrying costs, which vary with quantity ordered, base on average inventory and consist of :
  - i) Interest on capital investment;

ii) Cost of storage facility, up-keep of material, record keeping etc ;

iii) Cost involving deterioration and obsolescence;

iv) Cost of insurance, property tax, etc.

- Carrying costs are almost directly proportional to the order size or lot size or order quantity, the procurement costs and inventory carrying costs have been plotted with respect to quantity in lot. Total cost is calculated by adding procurement cost and carrying cost. Total cost is minimum at the point A and thus A' represents the economic order quantity or economic lot size.



- Another method of finding E.O.Q. that is by mathematical means is given below:-
- If C is the cost for one item, I is the cost of carrying inventory in percentage per period, including insurance, obsolescence, taxes etc, P is the Procurement cost associated with one order, and U is total quantity used per period say annually. Then Q the economic lot size or E.O.Q is, $Q = \frac{\sqrt{2UP}}{CI}$.

1. **A company requires 16000 units of raw material costing Rs.2 per unit. The cost of placing an order is Rs. 45 and the carrying costs are 10% per year per unit of the average Inventories. Determine: (i) the economic order quantity, (ii) cycle time.**
2. **The rate of use of a particular raw material from stores is 20 units per year. The cost of placing and receiving an order is Rs.40. The cost of each unit is Rs 100. The cost of carrying inventory in percent per year is 0.16 and it depends upon the average stock. Determine the economic order quantity. If the lead time is 3 months, calculate the reorder point.**
3. **Find the economic order quantity from the following data:**
   - **i) Average annual demand = 30,000 units**
   - **ii) Inventory carrying cost = 12% of the unit value per year**
   - **iii) Cost of placing an order = Rs. 70**
   - **iv) Cost of unit = Rs. 2**
4. **Given data:**
   - **i) Annual usage, U= 60 unit**
   - **ii) ii) Procurement cost, P=Rs. 15 per order**
   - **iii) iii) Cost per piece, C=Rs. 100**
   - **iv) iv) Cost of carrying inventory I, a percentage including expenditure on obsolescence, taxes, insurance, deterioration etc. = 10%.**

   Calculate E.O.Q.

Plant maintenance

Section - A

1. **What is plant maintenance?**

- **Maintenance** on **plant** and equipment is carried out to prevent problems arising, to put faults right, and to ensure equipment is working effectively. **Maintenance** may be part of a planned programme or may have to be carried out at short notice after a breakdown. Maintenance of a machines means efforts directed towards the up keep and the repair of that machine.
- Every machine is thoroughly tested and inspected by the manufactures before selling it and by purchaser before it is put to use when it is used.
- It will be subjected to wears and tear hence proper attention should be given to protect the machine and it's components from undue wear and thus protects them from failures.

2. **Classify different types of plant maintenance.**

- According to size of industry, following are the types of plant maintenance used in industry:
  - Breakdown or Corrective maintenance
  - Scheduled maintenance
  - Preventive maintenance
  - Predictive maintenance

3. **State the objectives of plant maintenance.**

- The objective of plant maintenance is to achieve minimum breakdown and to keep the plant in good working condition at the lowest possible cost.
- Machine and other facilities should kept in such a condition which permits them to be used at their optimum capacity without any interruption or hindrance.
- Every machine is thoroughly tested and inspected by the manufactures before selling it and by purchaser before it is put to use when it is used. It will be subjected to wears and tear hence proper attention should be given to protect the machine and it's components from undue wear and thus protects them from failures.

4. **What do you mean by breakdown?**

- Corrective or breakdown maintenance implies that requires are made after the equipment is out of order and it cannot perform its normal function any longer ,e.g., an electronic motor will not start, a belt is broken, etc .

- **Typical Causes Of Equipment Break Down:**
  - Failure to replace worn out parts.
  - Luck of lubrications.
  - Neglected cooling system.
  - Indifference towards minor faults.
  - External factors

Section –B

1. **Describe the objectives of plant maintenance.**

- The objective of plant maintenance is to achieve minimum breakdown and to keep the plant in good working condition at the lowest possible cost.

- Machine and other facilities should kept in such a condition which permits them to be used at their optimum capacity without any interruption or hindrance.
- Maintenance division of a factory ensure the availability of the machines, buildings and services required by other section of the factory for the performance of their functions at optimum return on investment whether this investment be in material, machinery or personnel .
- Maintenance of a machines means efforts directed towards the up keep and the repair of that machine.

2. Explain scheduled maintenance with advantages.

- Scheduled maintenance is a stitch-in-time procedure aimed at avoiding breakdowns.
- Breakdowns can be dangerous to life and as far as possible should be minimize.
- Scheduled maintenance particle incorporates inspection, lubrication; repair and overhaul of certain equipments which if neglected can results in break down.
- Inspection, lubrication, servicing, etc., of these equipments are included in the predetermined schedule.
- Scheduled maintenance practice is generally followed for overhauling of machines, cleaning of water and other tanks, white-washing of buildings, etc.

3. Describe predictive maintenance.

- It comparatively a newer maintenance technique.
- It makes use of human senses or other sensitive instruments such as: Audio gauges, Vibration analyzers, Amplitude meters, Pressure, temperature and resistance strain gauges, etc., to predict troubles before the equipments fail.
- Ex: - Unusual sounds coming out of rotating equipment predicate a trouble; an electric cable excessively hot at one point predicates a trouble. Simple hand touch can point out many unusual conditions and thus predict a trouble.
- In predictive maintenance, equipment conditions are measured periodically or on a continuous basis and this enable maintenance men to take a timely action such as equipment adjustments, repair or overhaul.
- Predictive maintenance extends the service life of equipment without fear of failure.

4. What are the recent developments in plant maintenance?

- In recent years there has been a tendency to use a variety of management techniques for plant maintenance. These techniques have led to
  - An increase in maintenance efficiency.
  - Reduced maintenance cost.
  - Improved Services.

Use Of Work study:-

- Work study can improve maintenance scheduling and eliminate a great deal of frustration and anxiety on the part of production supervision.

Use Of Network Planning Techniques:-

- CPM has enabled some firms to cut their down time by 20 to 30%.
- Maintenance costs have been cut down.
- Plant utilization has been raised.
- CPM is very useful for planning and controls of large maintenance projects.
- Dramatic reductions in time (about70%) were experienced with the overhaul of generating plant by central electricity generating board in Great Britain, by using network planning techniques.

- When applied to the maintenance and overhaul of a refinery, PERT reduced its shutdown time from 18 to 16 days and thus added 90,000 barrels to its production volume.

Use Of Computers:-

- Computers when used for managing maintenance problems provide more efficient operation and control. Computers can prepare maintenance work orders giving accurate work order descriptions and job timing.

Section - C

1. Describe the duties and functions of plant maintenance department.

The different duties, functions and responsibility of the maintenance department are as follows:

- **Inspection:-**
  - Inspection is concerned with the routine schedule checks of the plant facilities to examine their conditions and to check for needed repairs.
  - Inspection ensures the safe and efficient operation of equipment and machinery.
- **Engineering:-**
  - Engineering involves alteration and improvements in existing equipments and building to minimize breakdowns.
  - Maintenance department also undertake engineering and supervision of constructional projects that will eventually become part of the plant.
- **Maintenance:-**
  - Maintenance of existing plant equipment.
  - Maintenance of existing plant building and other service facilities such as yard, central stores, roadways, etc.
  - Engineering and execution of planned maintenance, minor installation of equipment, building and replacements.
- **Repair:-**
  - Maintenance department carries out corrective repairs to alleviate unsatisfactory conditions found during maintenance inspection.
  - Such a repair is an unscheduled work often of an emergency nature, and is necessary to correct breakdowns and it includes trouble calls.
- **Overhaul:-**
  - Overhaul is a planned, scheduled reconditioning of plant facilities such as machinery, etc.
  - Overhaul involves replacement, reconditioning, reassembly, etc.
- **Construction:-**
  - In some organizations maintenance department is provided with equipment and personnel and it takes up construction job also.
  - Maintenance department handles construction of wood, brick and steel structures, cement and asphalt paving, electrical installation, etc.
- **Salvage:-**
  - Maintenance department may also handle disposition of scrap or surplus materials. This function involves,
  - Segregation, reclamation and disposition of production scrap, and
  - The collection and disposition of surplus equipments, materials and supplies.
- **Clerical Jobs:-**

- Maintenance department keeps records
- Of costs,
- Of time progresses on jobs,
- Pertaining to important features of buildings and production equipments; electrical installations; water, steam, air and oil lines ; transportation facilities, etc.
- Generation and distribution of power and other utilities.
- Administration and supervision of labour force.
- Providing plant production, including fire protection.
- Insurance Administration.
- Establishing and maintaining a suitable store of maintenance materials.
- Janitorial service.
- Housekeeping.
- Good housekeeping involves upkeep and cleaning of equipments, building, toilets, wash-room, etc.
- Pollution and noise abatement.

2. Explain breakdown maintenance with disadvantages.

- Corrective or breakdown maintenance implies that requires are made after the equipment is out of order and it cannot perform its normal function any longer ,e.g., an electronic motor will not start, a belt is broken, etc. Under such conditions, production department cells on the maintenance department to rectify the defect. The maintenance department cheeks into the difficulty and makes the necessary. After removing the fault, maintenance engineers do not attend the equipment again until another failure or breakdown occurs.
- After removing the Fault, maintenance engineer do not attend the equipment again until another failure or breakdown occurs.
- This type of maintenance may be quite justified in small factories which:
  i) Are indifferent to the benefits of scheduling;
  ii) Do not feel a financial justification for scheduling techniques; and
  iii) Gets seldom demands in excess of normal operating capacity.
- In many factories make-and-mend is the rule rather than the expectation.
- Breakdown maintenance particle is economical for those equipments whose down-time and repair costs are less this way than with any another type of maintenance.
- Breakdown maintenance involves little administrative work, few records and a comparative small staff.
- **Typical Causes Of Equipment Break Down:**
  i) Failure to replace worn out parts.
  ii) Luck of lubrications.
  iii) Neglected cooling system.
  iv) Indifference towards minor faults.
  v) External factors.
- **Disadvantages Of Breakdown Maintenance:**
  i) Breakdown generally occurs at in opportunity times. This leads to poor, hurried maintenance and excessive delays in productions.
  ii) Reduction of output.
  iii) Faster plant deterioration.
  iv) More spoilt material.

v) Direct loss of profit.

3. Explain preventive maintenance with objectives.

Preventive Maintenance:-

- Preventive maintenance is a system of scheduled, planned maintenance tries to minimize the problem of breakdown maintenance.
- It is a stitch-in-time procedure.
- It locates weak spots in all equipments, provides them regular inspection and minor repairs there by reducing the danger of unanticipated breakdown. The underlying principle of preventive maintenance is that prevention is better than cure.
- Periodic inspection of equipment and machinery to un cover conditions that lead to production breakdown and harmful depreciation.
- Upkeep of plant equipment to correct such conditions while they are still in a minor stage.

Objectives Of PM:-

- To minimize the possibility of unanticipated production interruption or major breakdown by locating or uncovering any condition.
- To make plant equipment and machinery always available and ready for use .
- To maintain the value of equipment and machinery by periodic inspections, repairs, overhauls, etc.
- To maintain the optimum productive efficiency of the plant equipment and machinery.
- To maintain the operational accuracy of the plant equipment.
- To reduced the work content of maintenance jobs.
- To achieve maximum production at minimum repair cost.
- To ensure safety of life and limbs of the workmen.

Advantages Of PM:-

- Reduced breakdowns and connected down-time.
- Lesser odd-time repairs and reduced overtime to the maintenance work-force.
- Greater safety for workers.
- Fewer large-scale and repetitive repairs.
- Low maintenance and repair costs.
- Less standard-by or reserve equipment, and spare parts.
- Identification of equipments requiring high maintenance cost.
- Lower unit cost of manufacture.
- Better product quality and fewer product rejects.
- Increased equipment life.

Operation Research (LPP) & Network Analysis

Section - A

1. **Define operation research.**
   - Operations research is the organised application of modern science, mathematics and computer techniques to complex military, government, business or industrial problems arising in the direction and management of large systems of men, materials, money and machines. The purpose is to provide the management with explicit quantitative understanding and assessment of complex situations; to have sounder basis for arriving at best decisions.
   - Operations Research signifies research on operations. However, it takes into consideration a particular view of operations and a particular kind of research.
2. **Define Linear Programming.**
   - Linear programming is powerful mathematical technique for finding the best use of the limited resources of a concern. It may be defined as a technique which allocates scarce available resources under conditions of certainty in an optimum manner, (i.e., maximum-minimum) to achieve the company objectives which may be, maximum overall profit, or minimum overall cost.
   - It had its early use for military applications but presently it is employed widely for business problems. It finds applications as resource allocation like crude oil distribution to refineries, production distribution; in agricultural works like blending fertilizers, selecting the right crop to be planted ; in army such as bombers placements, troops deployment; and in finance, personnel and advertising.
3. **Define event.**
   - An event is a specific instant of time which marks the start and the end of an activity.
   - Event consumes neither time nor resources.
   - It is represented by a circle and the event number is written within the circle. Event and node are synonyms. Examples of event are – Start the motor, loan, approved, etc.
4. **Define activity.**
   - Every project consists of a number of job operations or tasks which are called activities.
   - An activity is an even element of a project and it may be process, a material handling or material procurement cycle, etc. for example, 'Install machinery ',' arrange foreign exchange 'are activities.
   - An activity is shown by an arrow and it begins and ends with an event unlike event, an activity consumes time resources an activity may be performed by an individual or a group of individuals.
   - An activity is normally given a name like A, B, C, etc., which is marked bellow the arrow and the estimated time to accomplish the activity is marked above the arrow.
   - Activities are classified as: critical activity, non-critical activity and dummy activity
5. **Define float or slack.**
   - Float or slack, means spare time, a margin of extra time over and above its duration which a non-critical activity can consume without delaying the project.

- Float is the difference between the time available for completing an activity and the time necessary to complete the same.
- Slack is with reference to an event and float is with respect to an activity. In other words, slack is used with PERT and float with CPM—but in general practice, they may be used interchangeably.
- It is the additional time which a non-critical activity can consume without increasing the project duration. However, total float may affect the floats in previous and subsequent activities.

Total float=(LST-EST) or (LFT-EFT) and it can be negative also.

6. Define critical path.

- It is that sequence of activities which decide the total project duration. Critical path is formed by critical activities.
- A critical path consumes maximum resources. It is the longest path and consumes maximum time. A critical path has zero float.
- The expected completion dates cannot be met, if even one critical activity is delayed.
- A dummy activity joining to critical activities is also a critical activity.
- A critical path reveals those activities which must be manipulated by some means or the other if the scheduled completion dates are to be met.

7. Differentiate between EST and LST.

- **Earliest start time(EST):**- It is the earliest possible time at which an activity can start and is calculated by moving from first to last event in a network diagram.
- **Latest Start Time(LST):**- It is the latest possible time by which an activity can start. LST=LFT – duration of that activity.

8. Differentiate between EFT and LFT.

- **Earliest finish time(EFT):**- It is the earliest possible time at which an activity can finish. EFT=EST + duration of that activity.
- **Latest Finish Time(LFT):**- It is calculated by moving backward ,i.e., from last event time of the head event.

9. Define duration and total duration of activity.

- **Duration:**- Duration is the estimated or actual time required to complete a task or an activity.
- **Total project Time:**- It is the time which will be taken to complete a project and is found from the sequence of critical activities. In other words it is the duration of critical path.

10. Define Network Diagram.

Network diagram is the basic feature of network planning. It is a diagram which represents all the events and activities in sequence, along with their interrelationships and inters dependencies.

11. Where LPP is applied?

Linear programming can be applied effectively only if,

a) The objectives can be stated mathematically.
b) Resources can be measured as quantities (number, weight etc.).
c) There are too many alternate solutions to be evaluated conveniently.
d) The variables of the problem bear a linear (straight line) relationship, ie., a change in one variable produces proportionate changes in other variables. In other words, doubling the

units of resources will double the profit. Problem solving is based upon the system of linear equations.

12. What do you mean by CPM?

- CPM - (CRITICAL PATH METHOD):- CPM is a technique used for planning, controlling the most logical and economic sequence of operation for accomplishing a project.
- The network utilized in CPM is for optimising the use of limited resources, progress and control. CPM is applicable to both large and small projects.

13. How estimated time is calculated in PERT?

The t_o, t_m, t_p are combined statistically to develop the expected time for an activity. Therefore expected time **(t_e) =** $\frac{\mathbf{to}+(\mathbf{4}\times\mathbf{tm},)+\mathbf{tp}}{\mathbf{6}}$

t_o = optimistic time, t_m= most likely time, t_p = Pessimistic time

Section –B

1. What do you mean by PERT?

- PERT – (PROJECT EVALUATION AND REVIEW TECHNIQUE):- PERT describes basic network technique which includes planning, monitoring and control of projects.
- PERT finds application in planning and control of complex set of tasks, functions and relationships.
- PERT is a very useful device for planning the time and resources.
- PERT actually developed as a research and development planning tool where activity timing could not be estimated with enough certainty.
- Because of the uncertainty of activity timing PERT acquired the shape of probability concepts which helps in estimating activity timings.
- For dealing with uncertainties associated with different activities PERT approach the expected time for each activity from the following three estimation-
  - Optimistic time (t_o) - It is the shortest possible time in which an activity can be completed if everything goes exceptionally well.
  - Most likely time (t_m) – It is the time in which the activities are normally expected to complete under normal conditions.
  - Pessimistic time (t_p) – it is the time which an activity will take to complete in case of difficulties i.e. if mostly the things go wrong conditions. It is the longest of all the three estimations.
- The t_o, t_m, t_p are combined statistically to develop the expected time for an activity. Therefore expected time **(t_e) =** $\frac{\mathbf{to}+(\mathbf{4}\times\mathbf{tm},)+\mathbf{tp}}{\mathbf{6}}$
- **Standard deviation (S_t) = ($t_p - t_o$)/6**
- **Variance = $(S_t)^2$ = [($t_p - t_o$)/6]^2**

2. Define activity, critical activity, non-critical activity, dummy activity and critical path.

Activity:- Every project consists of a number of job operations or tasks which are called activities. An activity is an even element of a project and it may be process, a material handling or material procurement cycle, etc. for example, 'Install machinery ',' arrange foreign exchange 'are activities. An activity is shown by an arrow and it begins and ends with an event unlike event, an activity consumes time resources an activity may be performed by an individual or a group of individuals. An activity is normally given a name like A, B, C, etc., which is marked bellow the arrow and the estimated time to accomplish the activity is marked above the arrow

Activities are classified as:

i. **Critical Activities:-** In a network diagram critical diagram, critical activities are those which if consume more than their estimated time, the project will be delayed. An activity is called critical if it's earliest start time plus the time taken by it is equal to the latest finishing time. A critical activity is marked either by a thick arrow or to distinguish it from a mom-critical activities.

ii. **Non-Critical Activities:-** Such activities have provision so that, even if they consume a specified time over and above the estimated time, the project will not be delayed . Activities B and D are non-critical activities.

iii. **Dummy Activities:**- When two activities start at the same instant of time the head events are joined by a dotted arrow and this is known as a dummy activity. Dummy activity does not consume time. A dummy activity may be non-critical or critical. It becomes a critical activity when its earliest start time is same as its latest finishing time.

Critical Path:- It is that sequence of activities which decide the total project duration. Critical path is formed by critical activities. A critical path consumes maximum resources. It is the longest path and consumes maximum time. A critical path has zero float. The expected completion dates cannot be met, if even one critical activity is delayed. A dummy activity joining to critical activities is also a critical activity. A critical path reveals those activities which must be manipulated by some means or the other if the scheduled completion dates are to be met

3. Briefly explain about operation research.

Operations research is the organised application of modern science, mathematics and computer techniques to complex military, government, business or industrial problems arising in the direction and management of large systems of men, materials, money and machines. The purpose is to provide the management with explicit quantitative understanding and assessment of complex situations; to have sounder basis for arriving at best decisions.

Methodology of operations Research:-

Various steps involved are as follows :

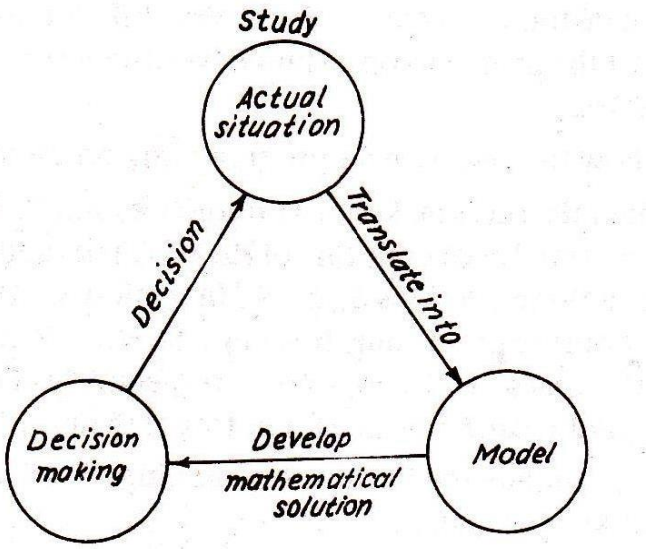
- Understand the actual real situation, capture the same and define the problem.
- Formulate a mathematical model
- Develop a mathematical solution - Data is supplied to the model. Information is computed, and results are analyzed to find the mathematical solution for alternative policies.
- Interpret the solution and prepare the information in such a form that it is meaningful, intelligible and quantitative. Translate it into a decision.
- Implement the decision to the real (actual) situation.
- Verify the results

After applying the solution to real situation, the actual results produced by the model must be tested statistically and verified to explore any significant deviation from the expected results. If found so, the model can be modified and again the cycle is repeated.

METHODS OF OPERATTONS RESEARCH:-

Various techniques used in Operations Research to solve optimization problems are as follows:

1. Linear programming:
   a) Graphical linear programming,
   b) Transportation Method :
      i. Vogel's Approximate Method.
      ii. North-West Corner Method.
   c) Simplex method,
2. Waiting line or Queuing theory.
3. Game theory.
4. Dynamic programming.



Operations Research Procedure.

4. What are the three possible times used in PERT?

- For dealing with uncertainties associated with different activities PERT approach the expected time for each activity from the following three estimation-
  - Optimistic time (t_o) - It is the shortest possible time in which an activity can be completed if everything goes exceptionally well.
  - Most likely time (t_m) – It is the time in which the activities are normally expected to complete under normal conditions.
  - Pessimistic time (t_p) – it is the time which an activity will take to complete in case of difficulties i.e. if mostly the things go wrong conditions. It is the longest of all the three estimations.
- The t_o, t_m, t_p are combined statistically to develop the expected time for an activity. Therefore expected time **(t_e) =** $\frac{\mathbf{to}+(\mathbf{4}\times\mathbf{tm},)+\mathbf{tp}}{\mathbf{6}}$
- **Standard deviation (S_t) = ($t_p - t_o$)/6**
- **Variance = $(S_t)^2$ = [($t_p - t_o$)/6]^2**

5. With the help of suitable example explain how a LPP formulate graphically?

EXAMPLE:- A furniture manufacturer makes two products x_1 and X_2, namely Chairs and Tables.

Each chair contributes a profit of Rs. 20 and €ach table that of Rs. 40. Chairs and Tables, from raw

material to finished product, are processed in three sections s_1, s_2, s_3. In section s_1 each chair (X_1) requires one hour and each table (X_2) requires 4 hours of processing. In section S_2, each chair requires 3 hours and each table one hour and in section S_3, the times are 1 and 1 hour respectively. The manufacturer wants to optimize his profits if sections S_1, S2 and s_3 can be availed for not more than24,21 and8 hours respectively.

Solution:- (Always use graph paper for solving LPP graphically)

The First Step is to formulate the linear programming model, i.e., a mathematical model from the data given above. The model is as under:

Maximize $Z = \text{Rs. } 20X_1 + \text{Rs. } 40X_2 \ldots\ldots\ldots\ldots (Z)$

Subject to $X_1 + 4X_2 \leq 24 \ldots\ldots\ldots\ldots (C_1)$

$3X_1 + X_2 \leq 21 \ldots\ldots\ldots\ldots (C_2)$

$X_1 + X_2 \leq 8 \ldots\ldots\ldots\ldots (C_3)$

$X_1, X_2 \geq 0 \ldots\ldots\ldots\ldots (C_4)$

C_1 is constraint No. 1 and so on.

The *Second Step* is to convert the constraint inequalities temporarily, into equations, *i.e.*,

$X_1 + 4X_2 = 24 \ldots\ldots\ldots\ldots (C_1)$

$3X_1 + X_2 = 21 \ldots\ldots\ldots\ldots (C_2)$

$X_1 + X_2 = 8 \ldots\ldots\ldots\ldots (C_3)$

In *Third Step* axis are marked on the graph paper and are labelled with variables X_1 and X_2.

Fourth Step is to draw straight lines on the graph paper using the constraint equations, and to mark the feasible solution on the graph paper. For example, taking first constraint equation.

$X_1 + 4X_2 = 24$

Substitute $X_1 = 0$, then $X_2 = 24/4 = 6$

Next, Substitute $X_2 = 0$, then $X_1 = 24$

Mark the point of 24 at X_1 axis and point of 6 on X_2 axis. Join them. This straight line represents C_1 equation. Similarly constraint equations C_2 and C_3 can be plotted (Fig. 11.2).

According to constraint C_4, X_1 and X_2 are greater than (or equal to) zero, hence the marked area (region) between $X_1=X_2=0$ and C_1, C_2, C_3 represents the feasible solution.

As the *Fifth Step*, a (dotted) straight line representing the equation (Z) is drawn, assuming any suitable value of Z say 120.

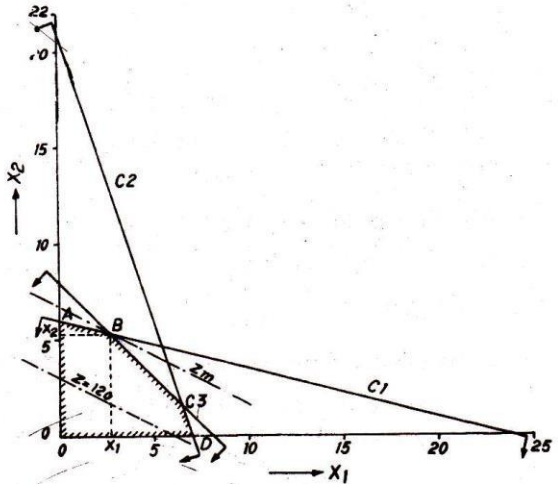
In the *Sixth step*, a straight line Z_m is drawn parallel to the line Z, at the farthest point of the region of feasible solution, *i.e.*, point B, at the intersection of C_1 and C_3. The co-ordinates of point B can be found by solving equations C_1 and C_3.

$$X_1+4X_2 = 24 \quad ...(C_1)$$
$$X_1+X_2=8 \quad ...(C_3)$$

Subtracting, $3X_2 = 16$, therefore, $X_2 = \frac{16}{3}$ and $X_1 = \frac{8}{3}$

These values of X_1 and X_2 can also be read from the graph itself. Thus the maximum value of Z is

$$Z_m = 20X_1+40X_2 = 20 \times\frac{8}{3} + 40 \times\frac{16}{3} = \frac{800}{3} = 266.6 \text{ (Ans)}$$



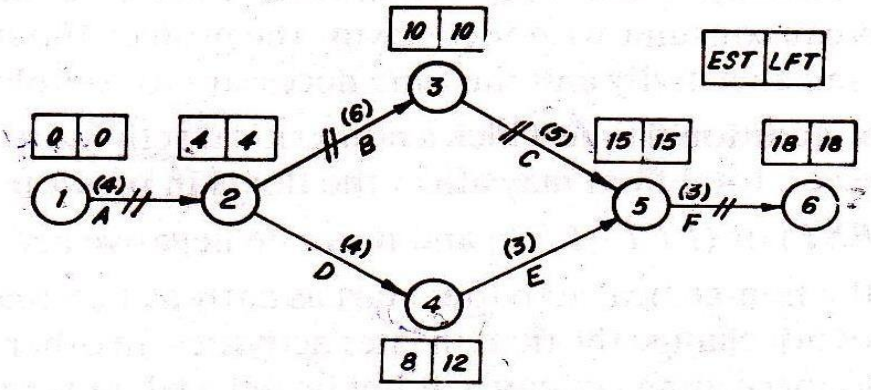
Section – C

1. Differentiate between PERT and CPM.

PERT	CPM
i. A probabilistic model with uncertainty in activity duration. Expected time is calculated from t_o, t_m and t_p.	A deterministic model with well-known activity times based upon past experience. It assumes that, the expected time is actually the time taken.
ii. An event-oriented approach.	An activity-oriented system.
iii. PERT terminology uses words like network diagram, events, and slack.	CPM terminology employs words like arrow diagram, nodes, and float.
iv. The use of dummy activities is required for representing the proper sequencing.	The use of dummy activities is not necessary. The arrow diagram thus becomes slightly simpler.
v. PERT basically does not demarcate between critical and non-critical activities.	CPM marks critical activities.
vi. PERT finds applications in projects where resources are always made available as and when required.	CPM is employed to those projects where minimum overall costs are of primary importance. There is better utilization of resources.
vii. Especially suitable in defense projects	Suitable for problems in industrial setting,

and R&D where activity times cannot be reliably predicted.	plant maintenance, civil construction projects, etc.

2. **A small engineering project consists 6 activities namely A, B, C,D, E, and F with duration of 4, 6, 5, 4, 3 and 3 days respectively. Draw the network diagram and calculate EST, LST, EFT, LFT and floats. Mark the critical path and find total project duration.**
3. Solution:-



(1) *EST* is calculated by starting from event-1, *i.e.*, activity *A* and giving it a time 0 (*EST*).

Now *EST* of activity *B*=0+duration of activity *A*=4

EST of activity *C*=*EST* of activity B+duration of activity *B*=4+6=10 and so on.

EST of activity *F* can be found by following two paths, *i.e.*, 1-2-3-5 and 1-2-4-3. The path 1-2-3-5 gives 15th day whereas the path 1-2-4-5 estimates 11th day as *EST* of activity *F*.

TABLE 10.1

Activity	*Duration (days)*	*EST*	*LST*	*EFT*	*LFT*	*Total Float*	*Free Float*	*Independent Float*
A	4	0	0	4	4	0	0	0
B	6	4	4	10	10	0	0	0
C	5	10	10	15	15	0	0	0
D	4	4	8	8	12	4	0	0
E	3	8	12	11	15	4	4	0
F	3	15	15	18	18	0	0	0
Col. 1	Col. 2	Col. 3 from N.W. diagram	Col. 4 *LFT* −*D*	Col. 5 *EST* +*D*	Col. 6 from N.W. diagram	Col. 7 *LST*−*EST* or *LFT*−*EFT*		

Naturally the bigger value (15) is selected because until activity *C* is completed which ought to finish on 15th day, activity *F* cannot be started.

EST for other activities is calculated by proceeding similarly, in the forward direction from the first event to the last event.

(2) *LFT* is calculated in a similar manner as *EST* but by proceeding backward from the last event to

the first one. For example

LFT for activity $F=18$

LFT for activity C and $E=18-$duration of activity $F=15$

LFT for activity D = *LFT* for activity E−duration of activity E

$= 15-3=12$ and so on.

(3) *LST* for each activity is calculated from the relation,

LST=*LFT* of an activity−duration of that activity.

For example, *LST* of activity $D=12-4=8$.

(4) *EFT* for each activity is calculated from the relation

EFT=*EST* of an activity+duration of that activity.

For example, *EFT* of activity $D=4+4=8$.

(5) Total float=(*LST*−*EST*) or (*LFT*−*EFT*)

For example, total float for activity

$D=(8-4)$ or $(12-8)=4$.

(6) Free float=*EST* of tail event−*EST* of head event−activity duration.

For example, free float for activity D,

$= 8-4-4=0$

(7) Independent float=*EST* of tail event−*LFT* of head event−activity duration.

For example, Independent float for activity D

$= 8-4-4=0$

(8) Critical path is one which consumes maximum time and it is 1-2-3-5-6. The total project duration, therefore, is

4+6+5+3=18days. (Ans).

4. **Maximize: Z=5X+6Y**
   Subject to: X+4Y ≤ 32; 2X+Y ≤ 36
5. **Maximize: Z=8X+6Y**
   Subject to: 4X+2Y ≤ 60; 2X+4Y ≤ 48
6. **Maximize: Z=10X+5Y**
   Subject to: 4X+5Y ≤ 100; 2X+4Y ≤ 80
7. **Minimize: Z=20X+10Y**
   Subject to: X+2Y ≥ 40; 4X+3Y ≥ 60; 3X+Y ≥ 30; X, Y≥ 0
8. **Maximize: Z=X+5Y when**
   Subject to: 5X+6Y ≤ 30; 3X+2Y ≤ 12; X,Y ≥ 0
9. **Minimize: Z=2x+3Ywhen**
   Subject to: x+Y≥6; 2x+Y≥7; x+4Y≥8; x,Y≥0

PRODUCTION, PLANNING AND CONTROL

INTRODUCTION:-

Products are manufacture by the transformation of raw material (in to finished goods).This is how production is achieved. Planning looks ahead, anticipates possible difficulties and decides an advance as to how the production, best, be carried out. The control phase makes sure that the programmed production is constantly maintained.

A production planning and control system has many functions to perform, some, before the arrival of raw material and tools, and others while the raw materials undergoes processing. The various functions are as follows:

a) Forecasting: Estimation of type, quantity and quality of future work.
b) Order writing: Giving authority to one or more persons to undertake a particular job.
c) Product design: Collection of information regarding specifications, bill of materials, drawing ,etc.
d) Process planning and routing: Finding the most economical process of doing a work and (then) deciding how and where the work will be done.
e) Material control: lt involves determining the requirements and control of materials.
f) Tool control: It involves determining the requirements and control of tools used.
g) Loading: Assignment of work to manpower, machinery etc.
h) Scheduling: It is the time phase of loading and determines when and in what sequence the work will be carried out. It fixes the starring as well as the finishing time for the job.
i) Dispatching: It is the transition from planning to action phase. In this phase the worker is ordered to start the actual work.
j) Progress reporting:
    i. Data regarding the job progress is collected.
    ii. It is interpreted by comparison with the preset level of performance.
k) Corrective action:
    i. Expediting means taking action if the progress reporting indicates a deviation of the plan from the originally set targets.
    ii. Replanning - Replanning of the whole affair becomes essential; in case expediting fails to bring the deviated plan to its actual (right) path.

Process Planning:-

Definition and Concept:-

- Process planning means the preparation of work detail plan.

- Since the process is required to manufacture a product, it is necessary to plan the process.
- Process planning is determined the most planning is determining the economical method of performing an operation or activity.
- Process planning comes after it has been decided as what is to be made.
- Process planning develops the broad plan of manufacture for the component or product.
- Process planning takes as its input the drawing or other specifications which show what is to be made and forecasts or orders which indicate the product quantity to be manufactured.

Information Required To Do Process Planning:-

- Quantity of work to be done along with product specifications.
- Quality of work to be completed.
- Availability of equipments, tools and personnel (giving dates, etc.).
- Sequence in which operations will be performed on the raw material.
- Names of equipments on which the operations will be performed.
- Standard time for each operation.
- When the operations will be performed.

Process Planning Procedure:-

The different steps involved are:

1. Selection Process:-

- A process is necessary in order to shape, form, condition and join materials and components with the help of machines and labour in order to convert raw material into a finished product.
- One should select the most economical process and sequence that satisfy the product specifications.

The selection of process depends upon:

a) Cur-rent production commitments. If enough work has already been allocated to more efficient Equipments, the current work may have to be passed on to less efficient machines to complete the same

In time.

b) Delivery date: An early delivery date may:
   i. Force the use of less efficient machines,
   ii. Rule out the use of special tools and jigs as they will take time for design and fabrication.

c) Quantity to be produced:

- Small quantity will not probably justify the high cost of preparation and efficient set-ups. Thus, quite possible they may have to be made on less efficient machines and vice-versa.

d) Quality standards :

- Quality standards may limit the choice of making the product on a particular machine, etc.

2. **Selection Of Material:-**
   - Material should be of right quality and chemical composition as per the product specifications.
   - Shape and size of material should restrict the scrap (i.e., material removed forgetting the product shape).
3. **Selection Of Jigs, Fixtures And Other Special Attachments:-**

These supporting devices are necessary:

- To give higher production rate;
- To reduce cost of production per piece.

4. **Selection Of Cutting Tools And Inspection Gauges:-**

They, respectively, are necessary to:

- Reduce production time.
- Inspect accurately and at a faster rate.

5. Make the process layout indicating every operation and the sequence in which each operation is to be carried out.
6. Find set-up time and standard time for each operation.
7. Manifest process planning by documents such as operation and Route sheets, which summarize the operations required, the preferred sequence of operations, auxiliary tools required, estimated operation times etc.

Scheduling:-

Concept: Scheduling means- when and in what sequence the work will be done. It involves deciding as to when the work will start and in certain duration of time how much work will be finished .Scheduling deals with orders machines, i.e., it determines which order will be taken up on which machine and in which department by which operator. While doing so, the aim is to schedule as large amount of work as the plant facilities can conveniently handle by maintaining a free flow of material along the production line.

Scheduling may be called the time phase of loading. Loading means the assignment of tasks or work to a facility whereas scheduling includes in addition, the specification of time and sequence in which the order/work will be taken up.

Factors Affecting scheduling:- The following factors affect production scheduling and are considered before establishing the scheduling plan.

a) External factors :
   1. Customer's demand,
   2. Customer’s delivery dates, and
   3. Stock of goods already lying with the dealers and retailer.

b) Internal factors :

1. Stock of finished goods with the firm,
2. Time interval reprocesses finished goods from raw material. In other words-how much time will be required to manufacture each component subassembly and then assembly (i.e., the final product),
3. Availability of equipment and machinery; their total capacity and specifications,
4. Availability of materials ; their quantity and specification,
5. Availability of manpower (number, type and kind of skill,
6. Additional manufacturing facilities if require, and
7. Feasibility of economic production runs.

Scheduling Procedure And Techniques:- Scheduling normally starts with the master schedule.

A-master schedule resembles central office which processes information about all the order in hand. Master schedule, is a weekly breakdown of the production requirements. The total capacity in any week is of 100 hours of work in foundry shop.

As the orders are received, depending upon their delivery dates they are marked on the master schedule, when the shop capacity is full for the present week the newly acquired orders are carried over to the next and so on. A master schedule is thus update continuously, It depicts a carried over to the next week and so on. A master schedule is thus updated continuously; it depicts a running total of the production requirements and shows the work ahead- yet to be completed. Master schedule is actually the basis for all subsequent scheduling techniques.

MASTER SCHEDULE FOR THE FOUNDRY SHOP

Maximum Production 100 hrs
Minimum Production 8 hrs

WEEK-1	WEEK-2	WEEK-3	WEEK-4
15	18	20	15
25	25	12	10
20	28	32	
35			

Master schedule for a foundry shop.

A Master Schedule possesses the following advantages, disadvantages and applications.

Advantages:-

1. It is simple and easy to understand,
2. It can be kept running (i.e., current),

3. It involves less cost to make it and maintain,
4. It can be maintained by non-technical staff, and
5. A certain percentage of total weekly capacity can be allocated for rush orders.

Disadvantages:-

1. It provides only overall picture, and
2. It does not give detailed information.

Applications:-

It finds applications:

1. In big firms, for the purpose of loading the entire plant,
2. In Research and Development organizations, and
3. For the overall planning in foundries, computer centres, repair shops, etc.

Perpetual Scheduling:-

Like master scheduling, it is also simple and easy to understand, is kept Current, involves less costs and can be maintained by clerical staff. But, the information which it provides is very gross and at the same time it is not clear from the chart-when the work will take place.

Making of perpetual schedule involves two steps:

i. Preparation of load Analysis sheet from the orders in hand.

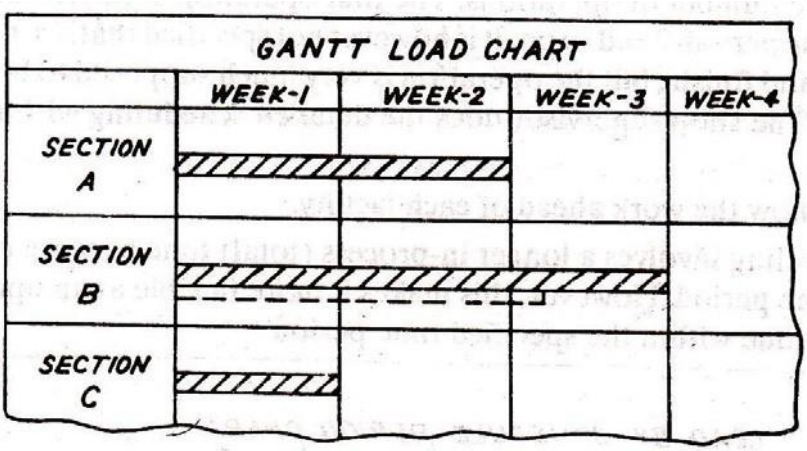
Figure :-

LOAD ANALYSIS SHEET

ORDER NO.	LOAD IN HOURS/DAYS SECTION A	SECTION B	SECTION C
X-320	25	10	16
Y-210	10	15	10
Y-314	18	20	8
Z-150	8	25	—
⋮	⋮	⋮	⋮

Load analysis sheet

ii. The total load against each section is added up and knowing the weekly capacity (department), of a section the number of weeks load against each department is calculated and plotted on a Gantt load chart as shown in Fig:-



Gantt load chart.

The shaded bars show the actual work load against each section.

Additional information, if any (regarding the work load), can be indicated by dotted line.

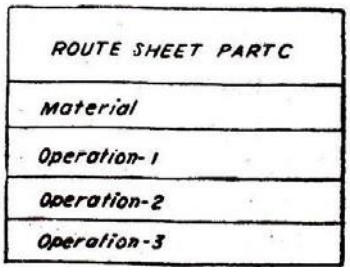
Dispatching:-

INTRODUCTOIN:- Function executes planning function. It is concerned with getting the work started. Dispatching ensures that the plans are properly implemented. It is the physical handing over of a manufacturing order to the operating facility (a worker) through the release of orders and instructions in accordance with a previously developed plan of activity (time and sequence) established by the scheduling section of the production planning and control department. Dispatcher transmits orders to the various shops. Dispatch function determines-by whom the job shall be done and it co-ordinates production. It is the key point of a production communication system. It creates a direct link between production and sales.

A dispatcher is familiar with the productive capacity of each equipment. He always keeps an eye over the progress of orders which move at different speeds on different routes.

Dispatch Procedure:-

The product is broken into different components and components into Operations. A route sheet for the part (component) C having three operations on it is shown in Fig:-



Route Sheet.

The various steps of dispatch procedure for each operation are listed below, in sequence.

(a) Store Issue Order: Authorize stores (department) to deliver require raw material.

(b) Tool Order: Authorise tool store to release the necessary tools. The tools can be collected by the tool room attendant.

(c) Job Oder: Instruct the worker to proceed with the operation.

(d) Time Ticket: It records the beginning and ending time of the operations and forms the basis for worker's 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 from one facility (machine) to another for further operations.

In addition, there are certain other dispatch aspects which have to be taken care of,

1. All production information should be available before hand.
2. Various order cards, and specification drawings should be ready.
3. Equipments should be ready for use.
4. Progress of various orders should be properly recorded on the Gantt charts or display boards.
5. All production records should be properly maintained.

Routing:-

INTRODUCTION:- Routing lays down the flow of work in the plant. It determines what work is to be done and where and how it will be done. Taking from raw material to the finished product, routing decides the path and sequence of operations to be performed on the job from one machine to another. The purpose is to establish the optimum sequence of operations. Routing is related to considerations of layout, temporary storage of in-process inventory and material handling.

Routing in continuous industries does not present any problem because of the product type of layout, where the equipment is laid as per the sequence of operations required to be performed on the components (from raw material to the finished products).

In open job shops, since, every time the job is new, though operation sheets (sometimes) may serve the purpose, but the route sheets will have to be revised and this involves a greater amount of work and expertise.

Routing Procedure:-

Various procedural steps are as follows:

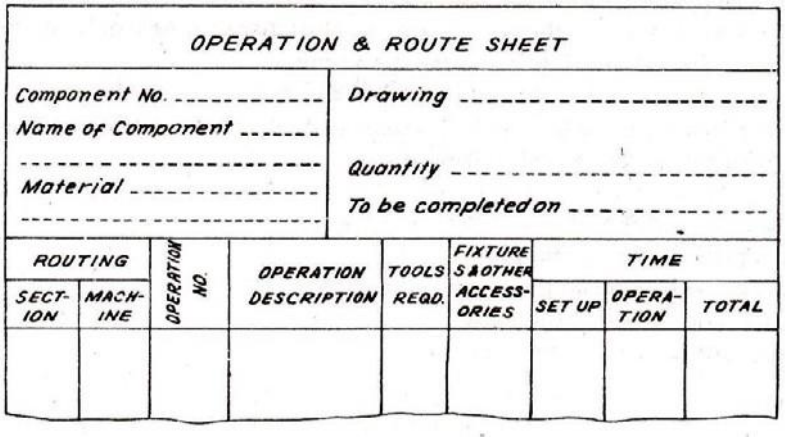
a) The finished product is analysed from the manufacturing standpoint in order to decide how many components can be made in the plant and how many others will be purchased (Make/Buy decision) from outside through vendors, by subcontracting, etc. Make/buy decision depends upon

the work load in the plant, availability of equipment and personnel to manufacture all components, and the economy associated with making all components within the plant itself.

b) A parts list and a bill of materials is prepared showing name of the part, quantity, material specifications, amount of materials required, etc. The necessary materials, thus, can be procured.

c) From production standards-machine capacities, machine characteristics and the operations which must be performed at each stage of manufacture are established and listed in proper sequence on an operation and route sheet, (See figure). The place where these operations will be performed is also decided.

Actually, operation sheet and route sheet are separate. An operation sheet shows everything about the operations, i.e., operation description, their sequence, type of machinery, tools, set up and operation times, whereas a route sheet besides listing the sequence of operations and relation between operation and machine, also details the section (department) and the machines to whom the work will flow. First two columns of Fig. are mainly those of route sheet which show the manufacturing route for given component.



OPERATION & ROUTE SHEET

Component No. ---------- Drawing ----------

Name of Component ------

---------- Quantity ----------

Material ----------

---------- To be completed on ----------

ROUTING		OPERATION NO.	OPERATION DESCRIPTION	TOOLS REQD.	FIXTURES & OTHER ACCESSORIES	TIME		
SECTION	MACHINE					SET UP	OPERATION	TOTAL

Operation and route sheet

The difference between an operation sheet and a route sheet is that an operation sheet remains same for the components if the order is repeated but the route sheet may have to be revised if certain machines are already committed to other orders (jobs) on hand. Except this small difference, both the sheets contain practically the same information and thus are generally combined into one sheet known as 'operation and route sheet'.

d) The next step is to determine the lot size or the number of components one lot or batch. to be manufactured in in the case of an order from a particular customer, it is generally equal to a number within 10% of the order quantity. In other cases the principle of economic batch quantity can be applied to determine the batch size.

e) Standard scrap factors (single or cumulative) and the places (i.e., after a particular operation or assembly) where scrap is very likely to occur are identified. The actual scrap in each can be

recorded on the control chart. Causes for points out of control limits are explored and corrected. The variable like workers, machinery and schedules may also be adjusted to minimize scrap.

f) The cost of the component is analysed and estimated through the information obtaine6 in steps (a) to (e) above. The cost consists of material and labour charges, and other specific and general indirect expenses.

Progress Control:-

INTRIDUCTION:- Once the actual production has started, it becomes essential to keep an eye at the progress of the work so that, if required, timely corrective action can be taken. progress control means - trying to achieve the standards set, i.e., a certain level of efficiency or a certain volume of production in a specified duration. The system of progress control should be such that it furnishes timely, adequate and accurate information about the progress made, delays and under- or over-loading.

Steps Followed In Progress Control:-

a) Setting up a system to watch and record the progress of the operating facility (production section).

b) Making a report of the work progress or work accomplishment.

c) Transmission of report to :
   1. Control group for necessary control action, and
   2. Accounting group for recording material and labour expenditures.

d) Interpretation of the information contained in the progress report by the control group.

e) Taking corrective action, if necessary.

INSPECTION AND QUALITY CONTROL

INSPECTION:

- Inspection is the continuous process adopted during various stages of manufacturing to control the product quality.
- Inspection is the art of comparing materials, products or performances with established standards.
- Inspection means checking the acceptability of manufactured products.
- The act of checking weather a product actually performs the function it is supposed to do or not, is called inspection.
- Inspection means checking of materials, manufactured products or components, standard parts at various stages of manufacturing by comparing them with suitable standards.

NEED OF INSPECTION:

- It helps to purchase good quality raw material, tools and equipments.

- It ensures that the parts, materials or components conform to established standards.
- It compares the product with the established standards, which helps in quality control.
- It finds the defect in raw material before use.
- It finds the defective parts and stops their further processing before assembly.
- It checks the finished product to measure its defects or weaknesses.
- It controls the cost of reproduction of products or other expenses of defective parts.
- It helps to maintain customer relationships by supplying no faulty products to them.
- It control workmanship of workers.
- It prevents further work on spoiled in-process products.
- It separates defective components from non-defective ones ensuring the quality of products.

PLANNING OF INSPECTION:

- ***What to inspect*? –** In the inspection the *parameters* (such as: diameter, length) are checked or inspected by the working persons. These parameters may be different for different kind of jobs. The inspector determines what parameters are to be inspected in inspection.
- ***When to inspect*? –** There are three basic steps for the *time of inspection* such as - incoming material inspection, material inspection at each and every stage of halt during the processes and final inspection of outgoing products. The inspector decides the time of inspection in these cases.
- ***Who should inspect*? –** Before the production process some *skilled persons* should appoint for the inspection of products for their accuracy.
- ***Where to inspect*?** – Generally three types of *places* are selected for inspection such as: floor, centralized or separate inspection room. The selection of places depends upon the manufacturing conditions.
- ***How to inspect? –*** The factors which influence the method of inspection includes type of product, operations involved etc.
- ***How much to inspect? –*** The degree of inspection depends upon many factors such as nature of the product, accuracy of the product, production process, reliability of standards, customers requirements and particular requirements of any manufacturing systems.

TYPES OF INSPECTION:

Depending upon the variety of products and requirements, inspections are classified as follows.

- **Remedial and Preventive Inspection –** In ***preventing inspection*** special attention is given to the accuracy of manufacturing process so that the possibility of defects and waste is completely removed. It is also known as constructive inspection. In ***remedial or corrective inspection*** the defective parts are detected and the good products are chosen among the defective parts.
- **Operative or Stage Inspection –** This inspection takes place at each stage or at the end of some functional operations. It eliminates the defective parts, checks the causes of defects, minimizes the wastage and and controls the cost.
- **Incoming or Receiving Inspection –** The inspection of raw materials, purchased parts, assemblies, equipments before its delivery for process is known as Incoming inspection. It controls the quality of the above and eliminates the material of below specifications.
- **In-process Inspection** – During the manufacturing process this inspection is done to control the quality at each and every stages by preventing the unnecessary hand work during assembly, large waste, extra work on defective products.

- **Final Inspection –** In this inspection the finished product is checked at its every surface manually and by using the testing equipments for the acceptance of the products.

FACTORS INFLUENCING THE QUALITY OF MANUFACTURE:

The following factors are generally affects the quality of manufacture.

- **Market demand –** It depends upon the demand of customers according to the product type, quality and quantity.
- **Man power –** Skilled persons are required for the quality design & quality manufacturing.
- **Materials –** Materials of right specification always gives good quality products, but it should be selected on the basis of production cost and requirements.
- **Money –** There is an important role of money to achieve quality. Investment is necessary at each stage of manufacturing for the maintenance, losses and improved products.
- **Management –** Managing committee should be conscious about the quality.
- **Machines and Methods –** To meet good quality improved machineries, good technologies and advanced methods are necessary.
- **Motivation of employees –** Employees should be motivated for the production of better quality products by doing some financial and non-financial benefits.
- **Modern information approaches –** The quality of products can be improved by adopting modern information approaches to various productions and marketing processes.

QUALITY CONTROL:

- Q*uality* suggests that the products are made according to the specifications determined by the customer's demand. It comes if the production and service is in economic conditions with the full certification of the customer.
- The quality of a product is known from the feedback received from end user or customer. In other words the quality means to enable production and service at most economical levels for full customer satisfaction.
- Quality is the degree of fitness which serves the purpose at the lowest cost. The quality of a product can be defined broadly in three aspects :
  - i) Quality design:- The quality of design concerned with durability, strength, interchangeability and chemical compositions of materials.
  - ii) Quality of performance:- The characteristics such as mechanical functioning, relative assembly measure the performance of the product.
  - iii) Quality appearance:- the characteristics such as size confirming to the drawings, finish and workmanship result in the quality of appearance.
- Q*uality control* prevents the product form rejection. It helps to maintain and achieve the quality as per the specification and demand of customer. Quality is to be planned, achieved, controlled and improved continuously.
- Quality control is a mechanism by which the products are made to the specifications determined by the customer's demand.
- A quality control system performs inspection, testing and analysis to know whether the quality of a product is as per laid standards or not.
- Quality control is industrial management technique by which products of uniform acceptable quality are manufactured.

NEED OF QUALITY CONTROL:

- To assure that only good quality products are sent to the customers.
- To bring down the effective overall cost so as to survive in the market competition by controlling the processes and reducing the waste and scraps.
- Find out a way-out of manufacturing difficulties.
- To bring the concept of interchangeability in the products.
- To reuse the rejected products, if possible.

STATISTICAL QUALITY CONTROL:

S*tatistical quality control* (SQC) is a method of applying the statistical techniques to the collection and analyzing the inspection and other data to achieve and maintain the economy in manufacturing process. It base on the theory of probability to control the quality deviations.

Advantage of SQC:

1. Cost effectiveness 2. Time reduction 3. Efficiency 4. Guaranteed Quality

5. Easy to adopt 6. Suitable for destructive tests

BASIC STATISTICAL CONCEPTS:

Concept of variation: We know that no two identical parts can be produce in manufacturing, but special care may be taken for preparing similar parts, considering some negligible variation.

Cause of variation: Various causes of variation are machine vibrations, tool wear, poor maintenance, friction or loss of lubrication, unskilled worker, and improper temperature etc.

Variables: These are the characteristics which can be actually measured such as length, mass.

Attributes: Attributes are the data which are discrete in nature, i.e. Characteristics showing an object confirming or not confirming the specification.

Frequency distribution: Frequency represents the number of repeated data or value in a lot or how many times a data/value are repeated in a lot. To count the frequency of a value, the measured data is tabulated in ascending or descending order. This is known as frequency distribution. It is used for analyzing the quality of the product.

There are two methods to represent data. Such as: Graphical representation of frequency distribution and Empirical description of distribution. Graphical representation includes two methods such as: Frequency Polygon and Histogram.

Frequency Polygon: It shows a plot between the frequency and observation. It gives a picture of frequency distribution.

Sorted dimensions of lot of 7 items

Sl. No.	*Dimension in mm*
1	25
2	26
3	26
4	27
5	27

Data grouped & frequency added

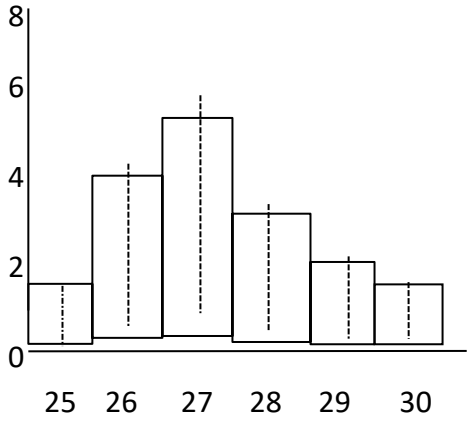
Sl. No.	*Dimension*	*Frequency*
1	25	1
2	26	2
3	27	3
4	30	1

Grouping of data for a fixed range interval

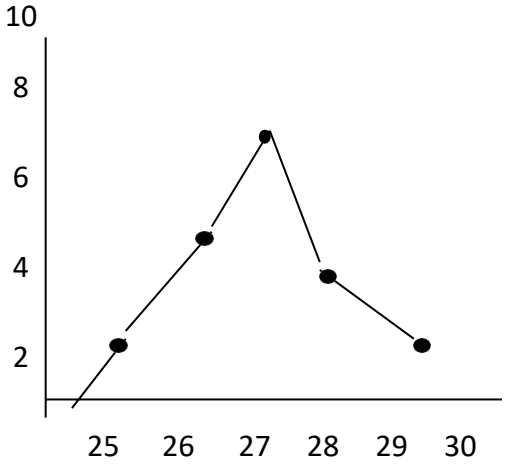
Class interval	*Frequency*	*Mid point*
24-26	3	25
27-29	3	28
30-32	1	31

Histogram: A histogram represents a bar chart where the base of rectangular bars represents the mid points of cell values and height is proportional to the frequency of occurrences of mid-points. It is used as a tool for the in-coming inspection.

If the histogram is symmetrical, it indicates that the overall process is normal and the variations are due to the chance causes. If the histogram is unsymmetrical, it shows the unreal process variation which needs improvements.



(Frequency Histogram)



(Frequency polygon)

EMPIRICAL / QUALITATIVE DISTRIBUTION:

There are three methods of representing central tendency such as mean, median and mode.

Mean/Arithmetic value/ Average value:

The arithmetic mean of a group of values is determined by adding the items and dividing the total by the number of items.

If X_1, X_2, X_3, …… X_n are the ***n*** values of the items in a sample, then their average mean is given by:

$$\bar{X} = \frac{X_1+X_2+X_3+\cdots+X_n}{n} = \frac{\Sigma}{n'}$$

If X_1 occurs f_1 times, X_2 occurs f_2 times, X_3 occurs f_3 times, …… X_n occurs f_n times, then we can write:

$$\boldsymbol{n} = f_1 + f_2 + f_3 + \ldots\ldots\ldots\ldots + f_n$$

And $$\bar{X} = \frac{f_1X_1+f_1X_2+f_1X_3+\cdots+f_1}{f_1+f_2+f_3+\ldots.+f_n} = \frac{\Sigma fX}{\Sigma f} \frac{\Sigma fX}{n}$$

Median:

When different items in a group are arranged in a serial order either ascending or descending, the middle item of this series is termed as median. It shows the average position.

If there are '*n*' observations where *n* is odd, then their median is given by: ($\frac{n+1}{2}$)th value.

If there are '*n*' observations where *n* is even, then their median is given by the average of (n/2)th and ($\frac{n}{2}$ +1) th value.

If the data is grouped in frequency format, then the median is given by: $M = L + \frac{(\frac{n}{2} - f_c)}{f_m} \times i$

Where, M = median

L = lower value of class having median

N = total number of values

*f*c = cumulative frequency of cells below 'L'

*f*m = frequency of median

i = class interval

Mode:

Mode is the most common value in the group occurring or repeating largest number of items. It is the value of the measurement which occurs with the greatest frequency or it is the observed value corresponding to the high point of graph. It is used to indicate a group.

Consider the recorded observation: 2, 3, 2, 4, 5, 2, 7, 6, 2, 4, 2. Here, 2 occurs repeatedly;
thus, mode = 2. If there will be two values which occurs equal number of times, then the two values will be considered as mode.

The empirical formula used to calculate mode is given by: $\text{Mode} = L + \frac{f_2}{f_1 + f_2} \times I$ Where, L = lower limit of class of mode

f_1 = frequency of class before the class of mode

f_2 = frequency of class after the class of mode

i = class interval

Dispersion:

The extent to which the data or value is distributed about the central tendency is known as the dispersion. It gives a better idea about the group. There are several measures of dispersion as follows.

1. **Range:**
   It is the difference between lowest and highest observed value in the group. It is used in control charts.
2. **Mean deviation:**

It is defined as the deviation or variation of each figure in the group from its arithmetic mean and all such deviations summed up and divided by the number of items in the group will give the mean deviation. i.e. mean deviation ($\bar{X}$) = $\frac{\sum(x-\bar{x})}{n}$

where $\bar{X}$ is the arithmetic mean

3. **Variance:**
   It is obtained by dividing the sums of the squares of the deviations from the arithmetic mean divided by the number of observations *n*. it is also the square of standard deviation.
   i.e. variance = $\frac{\sum(X-\bar{x})^2}{n}$
4. **Standard deviation:**
   The square root of variance is called as standard deviation. It is denoted by the symbol 'σ. It is defined as the root mean square of the differences between the observations and the mean.
   i.e. standard deviation (σ) = $\sqrt{\frac{\sum(X-\bar{x})^2}{n}}$
5. **Average of sample average:**
   To find out values of the standard deviation for whole production lot when a number of samples have been collected at random from a production lot with average, $\bar{x}$ calculated. For each sample, average of the sample average, $\bar{\bar{x}}$ is calculated. i.e. $\bar{\bar{x}} = \frac{\sum \bar{x}}{n}$, where n = number of samples & $\bar{x}$ = average of a single sample
6. **Average of sample range:**
   To know the range representative of the whole lot, average of sample range $\bar{R}$ is calculated. At first the range of number of samples is calculated and then the average of sample range is calculated.
   i.e. $\bar{R} = \frac{\sum R}{n}$, where n = number of samples

NORMAL DISTRIBUTION CURVES:

Normal curve is a graphical representation of a frequency distribution which indicates the distribution of the characteristic among the whole production lot. It may be of different shapes.

Characteristics of normal distribution curves:

1. The normal distribution curve is bell shaped and symmetrical about its mean value.
2. A population by infinite size is represented by it.
3. The mean ($\bar{X}$) and standard deviation (σ) of the normal distribution fully describe its curve.
4. Theoretically the normal distribution curve range is from - ∞ to + ∞. Practically the range is considered from 3 σ values to the left and 3 σ values to the right of the mean.
5. Mean is shown as zero.

In figure s symmetrical bell-shaped normal curve is shown. It extends from - ∞ to + ∞. The area contained in each column of the histogram is proportional to the frequency within its cell. There are two statistical controls average ($\bar{X}$) and standard deviation (σ) used to control the construction of curve. The number of cells is increased by decreasing the width of the cell, when number of observations is large. It is divided into six equal cells. The top line of the histogram approaches a smooth curve. The height of the curve at any point is proportional to the frequency at that point & area between any two limits is proportional to the frequency of occurrence within these limits.

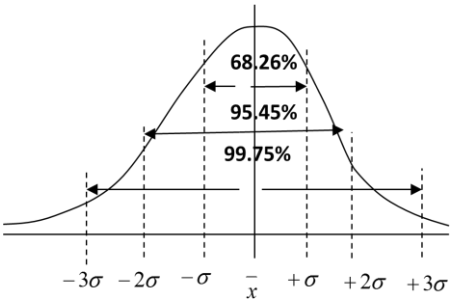
The mathematical equation of the normal curve is given by the formula:

$y = \frac{1}{\sigma\sqrt{2x}} \times e^{i}$ where, $i = \frac{(x-\bar{X})^2}{2\sigma^2}$

y = height of the curve at point *x* of the variable

$\bar{X}$ = population average or average of lot

σ = standard deviation of the population



(Normal Curve)

Binomial distribution:

The binomial theorem is used in binomial distribution. i.e. the expansion of $(p+q)^n$ gives the probability of any combination of 'p' and 'q' where 'p' represents the defectives and 'q' represents good or non-defective parts. The binomial theorem is stated as follows:

$$(p+q)^n = \sum_{k=0}^{n} \binom{n}{k} q^{k\, n-k} = p^n + np^{n-1}.q + \frac{(n+1)}{2!} . p^{n-2}q^2 + \ldots\ldots + q^n$$

Probability of 'r' defectives = ${}^nC_r\ q^{n-1}p^r$; where, ${}^nC_r = \frac{2!}{r!(n-r)!}$

The *average* of binomial distribution is given by: $\bar{X}$ = np

$\bar{X}$ = average number of defectives per sample n = size of random samples taken p = the fraction defective of sample

The *standard deviation* of binomial is given by: $\sigma = \sqrt{n\ p\ q} = \sqrt{n\ p\ (1-p)}$

Poisson's distribution:

This distribution is applicable where the probability of failure 'p' is very small. When there is large number of trials then failure occur at large intervals only. At this time Poisson's distribution is applicable for close approximation. The larger the value of n and smaller the value of p, the Poisson's approximation holds well.

In the Poisson's distribution the probability of finding 'k' defectives is given by:

$P(k) = \frac{\lambda^k . e^{-\lambda}}{k!}$ where, e = 2.71828 + (the base of natural algorithm)

λ = np (the average value of the expected number of defectives)

For the probability of 0 defectives $P(k) = e^{-\lambda}$

Average of the Poisson: average ($\bar{X}$) = np or λ

Standard deviation of Poisson: standard deviation = $\sqrt{n\ p}$ or $\sqrt{\lambda}$

CONTROL CHART:

A control chart is a graphical representation of the collected information. It is used for the study and control of the repetitive processes. It detects the variations in processing and shows the deviation in specified tolerance limit if exist. It is used to identify the quality variations and gives the good quality assurance at lower inspection cost.

Most commonly used control charts are:

1. Control charts for measurable quality characteristics or control charts for variables ($\bar{X}$ and R charts; $\bar{X}$ and σ charts)
2. Control charts for fraction defective (P-chart)
3. Control chart for number of defects per unit (C-chart)

The control charts for variables are useful for controlling the processes. The control charts for fraction defective and defects per unit are the attribute control charts.

Advantage of Control chart:

1. Control charts are used to indicate whether the process is in control or out of control.
2. It helps in decisions on acceptance or rejection of manufactured or purchased products.
3. It determines process variability.
4. It detects unusual variations occurring in a process.
5. It gives warning in time to rectify the process so that scrap or percentage rejection can be reduced.
6. It gives information about the selection of process and setting of tolerance limits.
7. The inspection work reduces.
8. It built up the organization reputation through customer's certification due to good quality of products.

TOTAL QUALITY MANAGEMENT:

Total quality management is an effective system adopted for quality development, quality maintenance and quality improvement of various groups in an organization to enable the production and services at the most economical levels to fulfill customer satisfaction.

Objectives:

1. Development of product specification based on needs of users and economical consideration. Meeting the customer requirements.
2. Interaction with product design.
3. Reliability and development testing.
4. Process capability studies.
5. Continuous improvement of quality at every level, at every place and at every stage.
6. Quality planning for control of production process / assembly operations.
7. Quality control of incoming materials.
8. Vendor quality control and vendor development.
9. Interaction and testing during manufacture.
10. Interaction with service engineering.
11. Training of staff and customers.
12. Cost reduction.
13. Quality audit etc.

Benefits of TQM:

1. It makes the company a leader not a follower.
2. It creates a direct connection between customers, management and workers. It leads to effective team worm.
3. It makes the company more sensitive to customer needs.

4. Better product quality.
5. Staffs are motivated and quality conscious.
6. Productivity improvement.
7. Reduced quality cost.
8. Enhances problem solving capacity.
9. Increased market.
10. Increase position in competitive market and profits.
11. Improvement of human relations and work area.
12. Better customer care and better satisfaction.
13. Employee empowerment.
14. Enhancement of job interest and security for employees.
15. More training and improvement in skills of employees.
16. More recognition for staffs.
17. Reduces employee gravience.