# PLANT ENGINEERING

**PLANT LOCATION**: Plant location refers to the choice of region and the selection of a particular site for setting up a business or factory. But the choice is made only after considering cost and benefits of different alternative sites. It is a strategic decision that cannot be changed once taken. If at all changed only at considerable loss, the location should be selected as per its own requirements and circumstances.

**PLANT LAYOUT**: Plant layout refers to the arrangement of physical facilities such as machinery, equipment, furniture etc. within the factory building in such a manner so as to have quickest flow of material at the lowest cost and with the least amount of handling in processing the product from the receipt of material to the shipment of the finished product.

**FEATURES GOVERNING PLANT LOCATION**: The important considerations for selecting a suitable location are given as follows:

a) Natural or climatic conditions.

b) Availability and nearness to the sources of raw material.

c) Transport costs-in obtaining raw material and also distribution or marketing finished products to the ultimate users.

d) Access to market: small businesses in retail or wholesale or services should be located within the vicinity of densely populated areas.

e) Availability of Infrastructural facilities such as developed industrial sheds or sites, link roads, nearness to railway stations, airports or sea ports, availability of electricity, water, public utilities, civil amenities and means of communication are important, especially for small scale businesses.

f) Availability of skilled and non-skilled labour and technically qualified and trained managers.

g) Banking and financial institutions are located nearby.

h) Locations with links: to develop industrial areas or business centers result in savings and cost reductions in transport overheads, miscellaneous expenses.

i) Strategic considerations of safety and security should be given due importance.

j) Government influences: Both positive and negative incentives to motivate an entrepreneur to choose a particular location are made available. Positive includes cheap overhead facilities like electricity, banking transport, tax relief, subsidies and liberalization. Negative incentives are in form of restrictions for setting up industries in urban areas for reasons of pollution control and decentralization of industries.

k) Residence of small business entrepreneurs want to set up nearby their homelands

**OBJECTIVES OF PLANT LAYOUT:** An efficient plant layout is one that can be instrumental in achieving the following objectives:

a) Proper and efficient utilization of available floor space

b) To ensure that work proceeds from one point to another point without any delay

c) Provide enough production capacity.

d) Reduce material handling costs

e) Reduce hazards to personnel

f) Utilize labour efficiently

g) Increase employee morale
h) Reduce accidents
i) Provide for volume and product flexibility
j) Provide ease of supervision and control
k) Provide for employee safety and health
l) Allow ease of maintenance
m) Allow high machine or equipment utilization
n) Improve productivity

## PRINCIPLES OF PLANT LAYOUT:

**(i) Principle of Space Utilization:**
All available cubic space should be effectively utilized – both horizontally and vertically.

**(ii) Principle of Flexibility:**
Layout should be flexible enough to be adaptable to changes required by expansion or technological development.

**(iii) Principle of Interdependence:**
Interdependent operations and processes should be located in close proximity to each other; to minimize product travel.

**(iv) Principle of Overall Integration:**
All the plant facilities and services should be fully integrated into a single operating unit; to minimize cost of production.

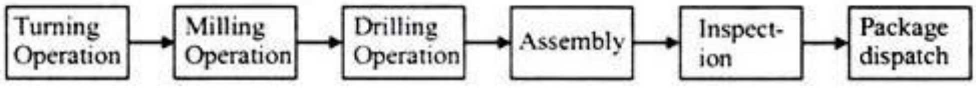
**(v) Principle of Safety:**
There should be in-built provision in the design of layout, to provide for comfort and safety of workers.

**(vi) Principle of Smooth Flow:**
The layout should be so designed as to reduce work bottlenecks and facilitate uninterrupted flow of work throughout the plant.

**(vii) Principle of Economy:**
The layout should aim at effecting economy in terms of investment in fixed assets.

**PRODUCT LAYOUT:** In this type of layout, all the machines are arranged in the sequence, as required to produce a specific product. It is called line layout because machines are arrange in a straight line. The raw materials are fed at one end and taken out as finished product to the other end.

Special purpose machines are used which perform the required jobs (i.e. functions) quickly and reliably.




**Advantages:**
1. Reduced material handling cost due to mechanized handling systems and straight flow
2. Perfect line balancing which eliminates bottlenecks and idle capacity.
3. Short manufacturing cycle due to uninterrupted flow of materials

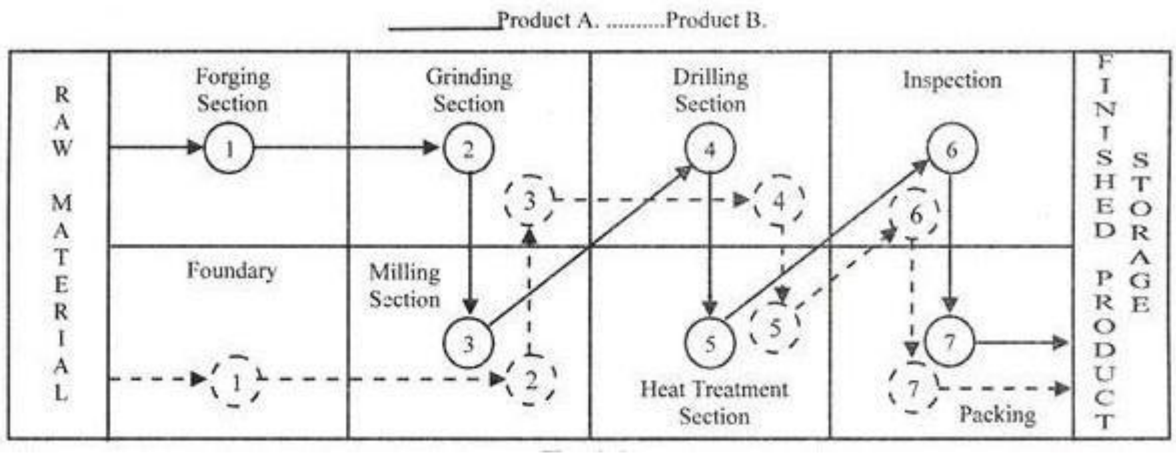
4. Simplified production planning and control; and simple and effective inspection of work.
5. Small amount of work-in-progress inventory
6. Lesser wage cost, as unskilled workers can learn and manage production.

**Disadvantages:**

1. Lack of flexibility of operations, as layout cannot be adapted to the manufacture of any other type of product.
2. Large capital investment, because of special purpose machines
3. If one or two lines are running light, there is considerable machine idleness.
4. A single machine breakdown may shut down the whole production line,
5. Specialized and strict supervision is essential.

**PROCESS LAYOUT:** In this type of layout machines of a similar type are arranged together at one place. E.g. Machines performing drilling operations are arranged in the drilling department, machines performing casting operations be grouped in the casting department. Therefore the machines are installed in the plants, which follow the process layout.

This layout is commonly suitable for non-repetitive jobs. Same type of operation facilities are grouped together such as lathes will be placed at one place all the drill machines are at another place and so on.




**Advantages of Process Layout:**

(i) There will be less duplication of machines. Thus total investment in equipment purchase will be reduced.
(ii) It offers better and more efficient supervision through specialization at various levels.
(iii) There is a greater flexibility in equipment and man power thus load distribution is easily controlled.
(iv) Better utilization of equipment available is possible.
(v) Breakdown of equipment can be easily handled by transferring work to another machine/ work station.
(vi) There will be better control of complicated or precision processes, especially where much inspection is required.

**Limitations of Process Layout:**

(i) There are long material flow lines and hence the expensive handling is required.

(ii) Total production cycle time is more owing to long distances and waiting at various points.

(iii) Since more work is in queue and waiting for further operation hence bottlenecks occur.

(iv) Generally more floor area is required.

(v) Since work does not flow through definite lines, counting and scheduling is more tedious.

(v)Specialization creates monotony and there will be difficulty for the laid workers to find job in other industries.

**COMBINATION LAYOUT:** Certain manufacturing units may require all three processes namely intermittent process (job shops), the continuous process (mass production shops) and the representative process combined process [i.e. miscellaneous shops].

In most of industries, only a product layout or process layout or fixed location layout does not exist. Thus, in manufacturing concerns where several products are produced in repeated numbers with no likelihood of continuous production, combined layout is followed. Generally, a combination of the product and process layout or other combination are found, in practice, e.g. for industries involving the fabrication of parts and assembly, fabrication tends to employ the process layout, while the assembly areas often employ the product layout. In soap, manufacturing plant, the machinery manufacturing soap is arranged on the product line principle, but ancillary services such as heating, the manufacturing of glycerin, the power house, the water treatment plant etc. are arranged on a functional basis.

# PLANT MAINTENANCE

**INTRODUCTION:**
A plant is a place, where men, materials, money, equipment, machinery, etc are brought together for manufacturing products.
Maintenance of facilities and equipment in good working condition is essential to achieve specified level of quality and reliability and efficient working. It helps in maintaining and increasing the operational efficiency of plant facilities and contributes to revenue by reducing operating of production.

**OBJECTIVES OF PLANT MAINTENANCE:**

- To achieve minimum breakdown and to keep the plant in good working condition at the lowest possible cost.
- To keep the m/c in such a condition that permit to use without any interruption
- To increase functional reliability of production facilities
- To maximize the useful life of the equipment
- To minimize the frequency of interruption to production by reducing breakdown
- To enhance the safety of manpower

**DUTIES, FUNCTIONS AND RESPONSIBILITIES OF PLANT MAINTENANCE DEPARTMENT:**

**A) INSPECTION:**
- Inspection is concerned with the routine schedule checks of the plant facilities to examine their condition and to check for needed repairs
- Inspection ensures the safe and efficient operation of equipment and machinery
- Frequency of inspections depends upon the intensity of the use of the equipment
- Items removed during maintenance and overhaul operation are inspected to determine flexibility of repairs
- Maintenance items received from vendors are inspected for their fitness

**B) ENGINEERING**:
- Engineering involves alterations and improvements in existing equipments and building to minimize breakdowns
- Maintenance department also undertakes engineering and supervision of constructional projects that will eventually become part of the plant.

**C) MAINTENANCE:**
- Maintenance of existing plant equipment.
- Maintenance of existing plant buildings and other service facilities such as yards, central stress, roadways.
- Minor installation of equipments, building and replacements

- Prevent breakdown by well-conceived plans of inspection, lubrication, adjustments, repair and overhaul.

**D) REPAIR:**

- Maintenance department carries corrective repairs to avoid unsatisfactory conditions found during preventive maintenance inspection.
- Such a repair work is of an emergency nature and is necessary to correct breakdowns.

**E) OVERHAUL:**

- Overhaul is a planned, schedule reconditioning of plant facilities such as machinery etc.
- It involves replacement, reconditioning, reassembly etc.

**F) CONSTRUCTION:**

- In some organizations, maintenance department is provided with equipment and personnel and it takes up construction job also.
- It handles construction of wood, brick and steel structures, electrical installation etc.

**G) SALVAGE:**

- It may also handle disposition of scrap or surplus materials.
- This involves segregation and disposition of production scrap.

**H) CLERICAL JOB:**

- Maintenance department keeps records of cost, of time progress on jobs, electrical installations, water, steams, air and oil lines, transport facilities.

**I) GENERATION AND DISTRIBUTION OF POWER.**

**J) PROVIDING PLANT PROTECTION**

**K) ESTABLISHING AND MAINTAINING A SUITABLE STORE OF MAINTENANCE MATERIALS**

**L) HOUSE KEEPING**

**M) POLLUTION AND NOISE CONTROL**

**TYPES OF PLANT MAINTENANCE:**

**PREVENTIVE MAINTENANCE:**

1. A system of scheduled, planned or preventive maintenance tries to minimize the problems of breakdown maintenance.
2. It is a stitch-in-time procedure.
3. It locates weak spots (such as bearing surfaces, parts under excessive vibrations etc) in all equipments, provides them regular inspection and minor repairs reducing the danger of unanticipated breakdown.
   It involves;

- Periodic inspection of equipment and machinery to prevent production breakdown and harmful depreciation.
- Upkeep of plant equipment to correct fault.

Advantages:

- Reduces breakdown and down-time
- Lesser odd-time repairs
- Greater safety for workers
- Low maintenance and repair cost
- Increased equipment life.
- Better product quality.

**BREAKDOWN MAINTENANCE:**

- Corrective or breakdown maintenance implies that repairs are made after the equipment is out of order and it cannot perform its normal function any longer.
  Ex – electric motor will not start, a belt is broken etc.
- Under such conditions, production department calls on the maintenance department to rectify the defect. The maintenance department checks into the difficulty and makes the necessity repairs.
- After removing the fault, maintenance engineers do not attend the equipment again until another failure or breakdown occurs.
- Breakdown maintenance is economical for those equipment whose down-time and repair costs are less.
- Breakdown type maintenance involves little administrative work, few records and comparative small staff.

  Causes of equipment breakdown:

- Lack of lubrication
- Neglected cooling system
- Failure to replace worn out parts
- External factors (too higher or too voltage)

Disadvantages of breakdown maintenance:

- Breakdowns occur at inopportunity times, which lead to poor, hurried maintenance and excessive delays in production.

- Reduction of output
- More spoilt material
- Increased chances of accidents and less safety to both workers and machines
- Direct loss of profit.
- Breakdown maintenance cannot be employed to cranes, lifts, hoists and pressure vessels.

**SCHEDULED MAINTENANCE:**

- Scheduled maintenance is a stitch-in-time procedure aimed at availing breakdowns
- Schedule maintenance practice is generally followed for overhauling of machines, cleaning of water and other tanks, white washing of building etc.
- Scheduled maintenance practice incorporates inspection, lubrication, repair and overhaul of certain equipments which if neglected can result in breakdown

**PREDICTIVE MAINTENANCE:**

- It is a newer maintenance technique
- It uses human senses or other sensitive instruments such as audio gauges, vibration analysers, amplitude meters, pressure, temperature and resistance strain gauges to predict troubles before the equipment fails.
- Unusual sound coming out of rotating equipment predict a trouble, an electric cable excessively hot at one point predicts a trouble.
- In predictive maintenance, equipment conditions are measured periodically or on a continuous basis which enables maintenance men to take timely action such as equipment adjustments, repair and overhaul.
- It extends the service life of an equipment without fear of failure

# OPERATIONS RESEARCH

**INTRODUCTION:** Operations Research (OR) is a discipline that helps to make better decisions in complex scenarios by the application of a set of advanced analytical methods. It couples theories, results and theorems of mathematics, statistics and probability with its own theories and algorithms for problem solving. Applications of OR techniques spread over various fields in engineering, management and public systems.

Operation research signifies research on operations. It is the organized 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.

**APPLICATION:**

1. Allocation and Distribution in Projects
2. Production and Facilities Planning
3. Programme Decisions:
4. Marketing
5. Organization Behaviour
7. Research and Development

**LINEAR PROGRAMMING PROBLEM:** Linear programming is powerful mathematical technique for finding the best use of 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 to achieve the company objectives which may be maximum overall profit or minimum overall cost.

LP can be applied effectively only if

a) The objectives can be stated mathematically

b) Resources can be measured as quantities (no. weight etc)

c) There are too many alternate solutions to be evaluated conveniently

d) The variables of the problem bear a linear relationship i.e. Doubling the units of resources will double the profit.

LPP can solved by two methods.

1. Graphical method: when two decision variables are involved. This is simple.
2. Simplex method: useful for any no. of decision variable in the problem and no. of constraints.

**Graphical method:**

Simple two dimensional linear programming problems can be easily and rapidly solved by this technique. This method can be easily be applied upto 3 variables.

**EXAMPLE 1**: A company produces two types of dolls A and B. Doll A is of superior quality and B is of lower quality. Profit on doll A and B is Rs 5 and Rs 3 respectively. Raw material required for each doll A is twice that is required for doll B. The supply of raw material is only 1000 per day of doll B. Doll A requires a special crown and only 400 such clips are available per day. For doll B 700 crowns are available per day. Find graphically the product mix so that the company makes maximum profit.

**ANSWER**:

## Graphical method:

1st step:
Formulate the LPM.

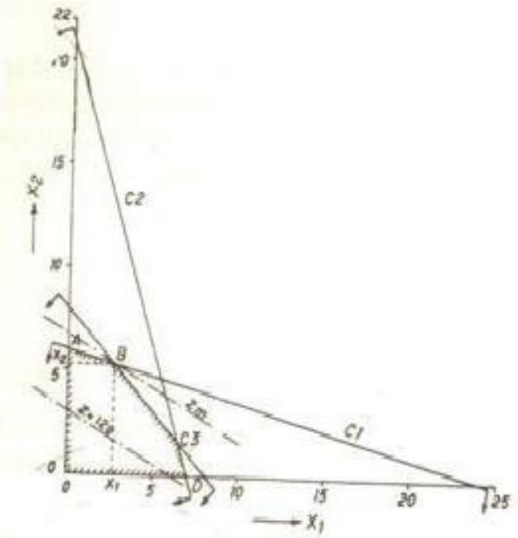
Max Z = 20x1 + 40x2
Subjected to x1 + 4x2 24 (c1)
3x1 + x2 21 (c2)
x1 + x2 8 (c3)
x1, x2 0 (c4)
c1 is constrain no. 1 and so on.

2nd step
2nd steps convert the constraint inequalities temporarily into equations.
x1 + 4x2 = 24 (c1)
3x1 + x2 = 21 (c2)
x1 + x2 = 8 (c3)

3rd step
Axis are marked on the graph paper and labeled with variables x1 & x2.

4th step
4th step is draw straight lines on the graph paper using constraint equations and to mark feasible solution on the graph paper.

Taking 1st constraint equation,
x1 + 4x2 = 24
x1 = 0, x2 = 6
x2 = 0, x1 = 24



Graphical method.

Mark the point of 24 at X1 axis and point 6 on x2 axis. The straight line represents c1 equation.
Similarly, c2 and c3 can be plotted.
According to constrain c4, x1 & x2 are greater than or equal to zero, hence the marked area between x1 = x2 = 0 and c1, c2, c3 represents the feasible solution.

5th step:
A dotted straight line representing the equation Z is drawn, assuming any suitable value of Z say 120.
X1 = 0, x2 =3
X2 = 0, x1 =6

6th step:
A straight line Zm is drawn parallel to the line Z, at the furthest point of the region of feasible solution i.e. point B, at the intersection of c1 & c3.
The co-ordinates at point B can be found by solving equation c1 & c3.
$x_1 + x_2 = 8$ (c3)
$x_1 + 4x_2 = 24$ (c1)
$3x_2 = 16 \Rightarrow x_2 = 5.3$
$3x_1 = 8 \Rightarrow x_1 = 2.7$

These values of x1 and x2 can also be read from the graph itself.
The maximum value of Z is
$Zm = 20x_1 + 40x_2 = 20 + 40 =$ **266.6**

**Terms related to network planning methods:**
**Event (node):**
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 no. is written within the circle.
Ex – start the motor, loan approved.

**Activity**: Every project consists of a no. of job operations or tasks which are called activities. An activity is an element of project and it any be a process, a material handling or material procurement cycle.
Ex – install machinery, arrange foreign exchange.

It is shown by an arrow and it begins and ends with an event. An activity is normally given a name like A, B, C etc i.e. marked below the arrow and the estimated time to accomplish the activity is marked above the arrow.

Activities are classified as:
1. **Critical activities**: In a network diagram, critical activities are those which if consume more than their estimated time the project will be delayed. An activity is called critical if its 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 (//).

2. **Non critical activities:** Such activities have provision (slack or float) so that even if they consume a specified time over and above the estimated time, the project will not be delayed.

3. **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 dummy activity. It does not consume time. It may be non-critical or critical. It becomes a critical activity when its EST = LFT.

**Critical path**:

It is that sequence of activities which decide the total project duration. It is formed by critical activities. A critical path consumes maximum resources. It is the longest path and consumes maximum time. It has zero float. The expected completion data cannot be met, if even one critical activity is delayed. A dummy activity joining two critical activities is also a critical activity

**Earliest start time (EST):**

It is the earliest possible time at which activity can start and is calculated by moving from first to last event in a network diagram.

**Earliest finish time (EFT):**

It is the earliest possible time at which activity can finish. i.e. (EST + D)

**Latest finish time (LFT):**

It is calculated by moving backward i.e. from last event to first event of the network diagram. It is the last event time of the head event

**Latest start time (LST):**

It is the least possible time by which an activity can start.

LST = LFT – duration of that activity

**Float or slack:**

Slack is with reference to an event and float is with respect to an activity. It means spare time, a margin of extra time over and above its duration which a noncritical 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.

There are three type of float.

**1. Total float:**

It is the additional time which a non-critical activity can consume without increasing the project duration.

TF = LST – EST or LFT – EFT and it can be – ve.

**2. Free float:**

If all the non critical activities start as early as possible, the time is the free float.

FF = EST of tail event – EST of head event – activity duration

**3. Independent float:**

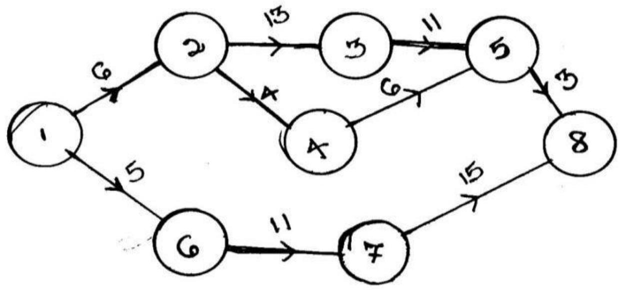
It can be used to advantage. If one is interested to reduce the effort on a non-critical activity in order to apply the effort on a critical activity by reducing the project duration.

IF = EST of tail event – LFT of head event – activity duration.

If IF is negative, then taken as 0.

**EXAMPLE:**
Construct the network from the information.

| Activity | Time | Activity | Time |
|---|---|---|---|
| 1-2 | 6 | 3-5 | 11 |
| 1-6 | 5 | 4-5 | 6 |
| 2-3 | 13 | 6-7 | 11 |
| 2-4 | 4 | 5-8 | 3 |
| ------ | ------ | 7-8 | 15 |




Critical Path Method:
In the critical path method the activity times are known with certainty. For each activity EST and LST are computed. The path with the longest time sequence is called critical path. The length of the critical path determines the minimum time in which the entire project can be completed. The activities on the critical path are called critical activities.

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

| Activity | Duration (days) | EST | LST (LFT - D) | EFT (EST + D) | LFT | TF |
|---|---|---|---|---|---|---|
| A | 4 | 0 | 0 | 4 | 4 | 0 |
| B | 6 | 4 | 4 | 10 | 10 | 0 |
| C | 5 | 10 | 10 | 15 | 15 | 0 |
| D | 4 | 4 | 8 | 8 | 12 | 4 |
| E | 3 | 8 | 12 | 11 | 15 | 4 |
| F | 3 | 15 | 15 | 18 | 18 | 0 |

**ANSWER:** Critical path = 1-2-3-5-6
Total project duration = 4+6+5+3 = 18 days

**Programme Evaluation Review Technique (PERT):**
PERT takes into account the uncertainty of activity times. It is a probabilistic model with uncertainty in activity duration.
It makes use of three time estimates.
I. Optimistic time (t0)
II. Most likely time (tm)
III. Pessimistic time (tp)

**I. Optimistic time (t0):**
It is the shortest possible time in which an activity can be completed if everything goes perfectly without any complications.
It is an estimate of minimum possible time to complete the activity under ideal condition.
**II. Pessimistic time (tp):**
It is the longest time in which an activity can be completed if everything goes wrong.
**III. Most likely time(tm);**
It is the time in which the activity is normally expected to complete under normal contingencies.

**DIEEFERENCE BETWEEN PERT AND CPM:**

The most important differences between PERT and CPM are provided below:

1. PERT is a project management technique, whereby planning, scheduling, organising, coordinating and controlling uncertain activities are done. CPM is a statistical technique of project management in which planning, scheduling, organising, coordination and control of well-defined activities take place.
2. PERT is a technique of planning and control of time. Unlike CPM, which is a method to control costs and time.
3. While PERT is evolved as a research and development project, CPM evolved as a construction project.
4. PERT is set according to events while CPM is aligned towards activities.
5. A deterministic model is used in CPM. Conversely, PERT uses a probabilistic model.
6. There are three times estimates in PERT, i.e. optimistic time (to), most likely time(tm), pessimistic time (tp). On the other hand, there is only one estimate in CPM.
7. PERT technique is best suited for a high precision time estimate, whereas CPM is appropriate for a reasonable time estimate.
8. PERT deals with unpredictable activities, but CPM deals with predictable activities.

# 3. INVENTORY CONTROL

**INVENTORY:**

Inventory is a detailed list of those movable items which are necessary to manufacture a product and to maintain the equipment and machinery in good working order.

It represents those items which are either stocked for sale or they are in the process of manufacturing or they are in the form of materials which are yet to be utilized.

**INVENTORY CONTROL:**

It 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 the right quantities and at competitive prices.

**CLASSIFICATION OF INVENTORIES:**

**1. Raw inventories:**

- Raw materials and semi-finished products supplied by another firm which are raw items for present industry.
- Raw materials are those basic unfabricated materials which have not undergone any operation since they are received from the suppliers. Ex – round bars, angles, channels, pipes etc

**2. Work-in-progress inventories:**

- Semifinished products at various storages of manufacturing cycle
- The items or materials in partially completed condition of manufacturing

**3. Finished inventories:**

- They are the finished goods lying in stock rooms and waiting dispatch.

**4. Indirect inventories:**

- The inventories refer to those items which do not form the part or the final product but consumed in the production process.
  Eg – machine spares, oil, grease, spare parts, lubricants

**OBJECTIVES OF INVENTORY CONTROL:**

- Purchasing material at economical price at proper time and in sufficient quantity as not to run slow
- Providing a suitable and secure storage location
- To maintain timely record of inventories of all the items
- A definite inventory identification system
- Adequate and responsible store room staff
- Suitable requisition procedure
- To provide a reserve stock

**FUNCTIONS OF INVENTORY:**

- **Meeting customer demand:** Maintaining finished goods inventory allows a company to immediately fill customer demand for product. Failing to maintain an adequate supply of finished goods inventory can lead to disappointed potential customers and lost revenue.
- **Protecting against supply shortages and delivery delays:** A supply chain is only as strong as its weakest link, and accessibility to raw materials is sometimes disrupted. That's why some companies stockpile certain raw materials to protect themselves from disruptions in the supply chain and avoid idling their plants and other facilities.
- **Separating operations in a process:** Inventory of subassemblies or partially processed raw material is often held in various stages throughout a process. Work in process inventory (or WIP) protects an organization when interruptions or breakdowns occur within the process. Maintaining WIP allows other operations to continue even when a failure exists in another part of the process.
- **Smoothing production requirements and reducing peak period capacity needs:** Businesses that produce nonperishable products and experience seasonal customer demand often try to build up inventory during slow periods in anticipation of the high-demand period. This allows the company to maintain adequate levels during peak periods and still meet higher customer demand.
- **Taking advantage of quantity discounts:** Many suppliers offer discounts based on certain quantity breaks because large orders tend to reduce total processing and shipping costs while also allowing suppliers to take advantage of economies of scale in their own production processes.

**TERMS USED IN INVENTORY CONTROL:**

**1. Demand:**
It is the no. of items (products) required per unit of time. The demand may be either deterministic or probabilistic in nature.

**2. Order cycle:**
The time period between two successive orders is called order cycle.

**3. Lead time:**
The length of the time between placing an order and receipt of items is called lead time.

**4. Safety stock:**
It is also called butter stock or minimum stock. It is the stock or inventory needed to account for delays in materials supply and to account for sudden increase in demand due to rush orders.

**5. Inventory turnover:**
It the company maintains inventories equal to 3 months consumption it means that inventory turnover is 4 times a year i.e. the entire inventory is used up and replaced 4 times a year.

**6. Reorder level:**
It is the point at which the replenishment action is initiated. When the stock level reaches ROL the order is placed for the item.

**7. Reorder quantity:**

This is the quantity of material to be ordered at the reorder level. This quantity equals to the EOQ.

**COST ASSOCIATED WITH INVENTORY:**

**1. Purchase (or production) cost:**

The value of an item is its unit purchasing or production cost.

**2. Capital cost:**

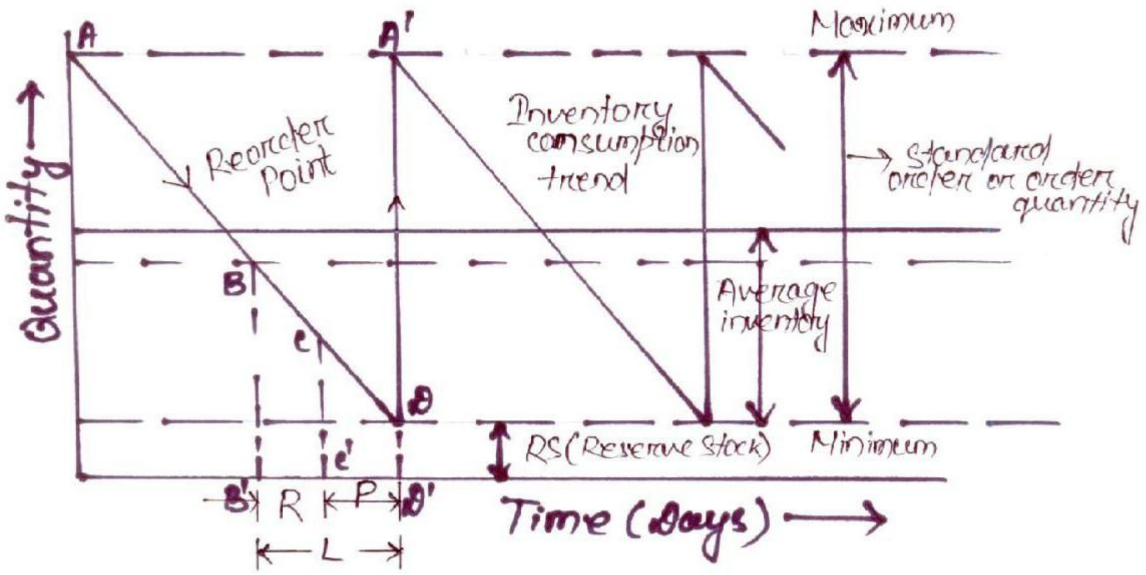
The amount invested in an item is an amount of capital not available for other purchases.

**3. Ordering cost:**

It is also known as procurement cost or replenishment cost or acquisition cost.

**ECONOMIC ORDER QUANTITY:**

The Economic Order Quantity (EOQ) is the number of units that a company should add to inventory with each order to minimize the total costs of inventory—such as holding costs, order costs, and shortage costs. An economic order quantity is one which permits lowest cost per unit and is most advantageous.



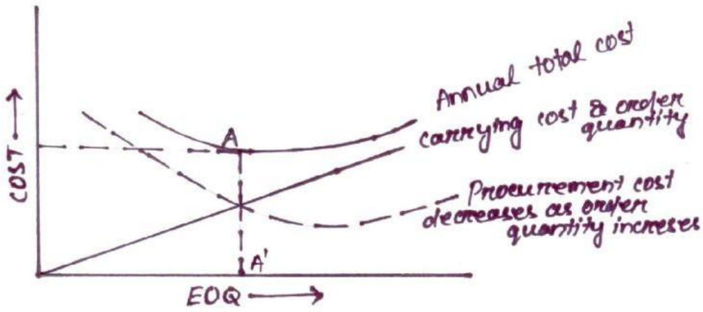

Starting from an instant when inventory OA is in the stores, it consumes gradually in quantity from A along AD at a uniform rate. We know it takes L no. of days between initiating order and receiving the required inventory. As quantity reaches point B, purchase requisition is initiated which takes form B to C that is time R. from C to D is the procurement time P. At the point D when only resource 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 max 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.

**Standard order (A'D)** - It is the difference between maximum and minimum quantity and is known as economical purchase inventory size.

**Reorder point (B)-** It indicates that it is high time to initiate a purchase order if not done so the inventory may exhaust, even reserve stock utilized before the new material arrives. From B' to D' it is lead time and it may be calculated on the basis of past experience.




**DERIVATION OF EOQ:**

Let Q is the economic lot size or EOQ
C is the cost for one item.
I is the cost of carrying inventory in percentage per period
P is the procurement cost associated with one order
U is the total quantity used per period.
No. of purchase orders to be furnished = U/Q
Total procurement cost = No. of orders × cost involved in one order= U/Q X P
Average quantity = Q/2
Inventory carrying cost = average inventory × cost per item × cost of carrying inventory in %= Q/2 X C X I
Total cost (T) = a + b = U/Q X P + Q/2 X C X I
To minimize cost, dT/dQ = 0
**Or Q =** $\sqrt{2UP/CI}$

Problem-1:

I. Annual usage (U) = 60 units
II. Procurement cost (P) = Rs 15
III. Cost per price (C) = Rs 100
IV. Cost of carrying inventory (I) = 10 %

Calculate EOQ.

Answer:

$$Q = \sqrt{\frac{2UP}{CI}}$$

$$= \sqrt{\frac{2 \times 60 \times 15 \times 100}{100 \times 10}} = 13.41$$

No. of orders per year = $\frac{60}{13.41} = 4.47 \cong 5$

$\therefore$ EOQ = $\frac{60}{5}$ = 12 units (rounded)

**PROBLEM 2:**

Find economic order quantity from following data.

Average annual demand = 30000 units

Inventory carrying cost = 12 % of the unit value per year

Cost of unit = Rs 2 /-

Answer:

Given, U = 30000

I = 12 %

P = 70

C = 2 /-

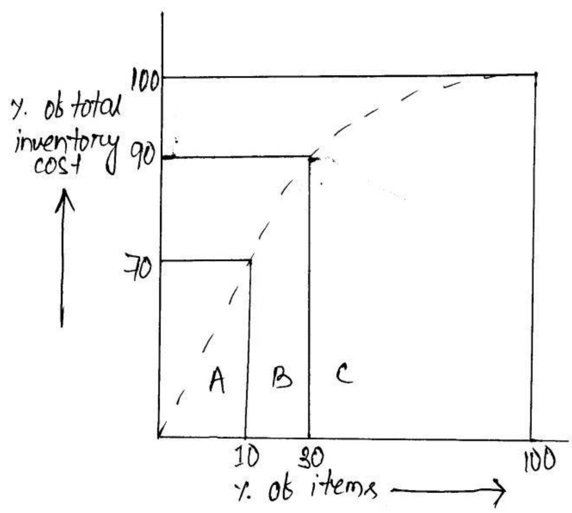
$$EOQ = \sqrt{\frac{2UP}{CI}} = \sqrt{\frac{2 \times 30000 \times 70 \times 100}{2 \times 12}} = 4183.3$$

$$\text{No. of orders} = \frac{30000}{4183.3} = 7.17 \cong 7$$

$$EOQ = \frac{30000}{7} = 4285.7 \cong 4286 \text{ (rounded)}$$

**ABC ANALYSIS:**

ABC analysis helps in differentiating the items from one another and tells how much valued the item is and controlling it to what extent is in the interest of an organization.



**A-ITEMS:**

A items are high valued but are limited or few in number. They need careful and close inventory control and proper handling and storage facilities should be provided for them.

A items generally contribute 70-80 % of the total inventory cost and 10 % of the total items.

**B-ITEMS:**

B-items are medium valued and their umber lies in between A and C items. They need moderate control. They are purchased on the basis of past requirements.

B-items generally contribute 20-15 % of total inventory cost and 15-20 % of the total items.

**C-ITEMS:**

C-items are low valued, but maximum numbered items. These items do not need any control. These are least important items, like clip, all pins, washers, rubber bands. No record keeping is done.

C-items generally contribute 10-5 % of the total inventory cost and constitute 75 % of the total items

**PROCEDURE:**

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

High valued contribute – 70% of total inventory Cost

Medium valued contribute -20% of total inventory Cost

Low valued contribute-10% of total inventory Cost

6. A graph can be plotted between % of items and % of total inventory cost.

# INSPECTION AND QUALITY CONTROL

**INSPECTION AND QUALITY CONTROL:**

Inspection means acceptability of a manufactured product. It measures the qualities of a product or service in terms of predefined standards. Product quality may be specified by its strength hardness, shape, surface finish, dimensions etc.

Quality control (QC) is a procedure or set of procedures intended to ensure that a manufactured product or performed service adheres to a defined set of quality criteria or meets the requirements of the client or customer.

**TYPES OF INSPECTION:**

- **FLOOR INSPECTION:**

In this system, the inspection is performed at the place of production. It suggests the checking of materials in process at the machine or in the production time by patrolling inspectors. These inspectors move from machine to machine and from one to the other work centers. Inspectors have to be highly skilled.

- **CENTRALISED INSPECTION:**

Inspection is carried in a central place with all testing equipment; sensitive equipment is housed in air-conditioned area. Samples are brought to the inspection floor for checking. Centralized inspection may locate in one or more places in the manufacturing industry.

- **COMBINED INSPECTION:**

Combination of two methods whatever may be the method of inspection, whether floor or central. The main objective is to locate and prevent defect which may not repeat itself in subsequent operation to see whether any corrective measure is required and finally to maintain quality economically.

- **FUNCTIONAL INSPECTION:**

These system only checks for the main function, the product is expected to perform. Thus an electrical motor can be checked for the specified speed and load characteristics. It does not reveal the variation of individual parts but can assure combined satisfactory performance of all parts put together.

- **FIRST PIECE INSPECTION:**

First piece of the shift or lot is inspected. This is particularly used where automatic machines are employed. Any discrepancy from the operator as machine tool can be checked to see that the product is within in control limits.

- **PILOT PIECE INSPECTION:**

This is done immediately after new design or product is developed. If production is affected to a large extent, the product is manufactured in a pilot plant. This is suitable for mass production and products involving large number of components such as automobiles, aero planes etc., and modification in design or manufacturing process is done until satisfactory performance is assured or established.

- **FINAL INSPECTION:**

This is also similar to functional or assembly inspection. This inspection is done only after completion of work. This is widely employed in process industries where there are not possible such as, electroplating or anodizing products. This is done in conjunction with incoming material inspection.

## FACTORS INFLUENCING THE QUALITY OF MANUFACTURE:

- **MONEY:**

Most important factor affecting the quality of a product is the money involved in the production itself. In the present day of tough and cut throat competition, companies are forced to invest a lot in maintaining the quality of products.

- **MATERIALS:**

To turn out a high quality product, the raw materials involved in production process must be of high quality.

- **MANAGEMENT:**

Quality control and maintenance programmes should have the support from top management. If the management is quality conscious rather than merely quantity conscious, organisation can maintain adequate quality of products.

- **PEOPLE:**

People employed in production, in designing the products must have knowledge and experience in their respective areas.

- **MARKET:**

Market for the product must exist before quality of the product is emphasized by management. It is useless to talk about the quality when the market for the product is lacking. For example, there is no demand for woolen garments in the hot climates (e.g., Southern part of India).

- **MACHINES AND METHODS:**

To maintain high standards of quality, companies are investing in new machines and following new procedures and methods these days.

## STATISTICAL QUALITY CONTROL:

Statistical quality control refers to the use of statistical methods in the monitoring and maintaining of the quality of products and services. One method, referred to as acceptance sampling, can be used when a decision must be made to accept or reject a group of parts or items based on the quality found in a sample. A second method, referred to as statistical process control, uses graphical displays known as control charts to determine whether a process should be continued or should be adjusted to achieve the desired quality.

## CONTROL CHARTS:

Control chart is a graphical representation of the collected information. The information pertains to the measured or otherwise judged quality characteristics of the items or the samples. A control chart detects variations in the processing and warns if there is any departure from the specified tolerance limits.

**TYPES OF CONTROL CHARTS:**

**(a) $\bar{X}$ Chart**

1. It shows changes in process average and is affected by changes in process variability.
2. It is a chart for the measure of central tendency.
3. It shows erratic or cyclic shifts in the process.
4. It detects steady progress changes, like tool wear.
5. It is the most commonly used variables chart.
6. When used along with $R$ chart :

(*i*) it tells when to leave the process alone and when to chase and go for the causes leading to variation ;

(*ii*) it secures information in establishing or modifying processes, specifications or inspection procedures ; and

(*iii*) it controls the quality of incoming material.

7. $\bar{X}$ and $R$ charts when used together form a powerful instrument for diagnosing quality problems.

**(b) R-Chart**

1. It controls general variability of the process and is affected by changes in process variability.
2. It is a chart for measure of spread.
3. It is generally used along with an $\bar{X}$-chart.

**Plotting of $\bar{X}$ and $R$ Charts.** A good number of samples of items coming out of the machine are collected at random at different intervals of times and their quality characteristics (say diameter or length etc.) are measured.

For each sample, the mean value and range is found out. For example, if a sample contains 5 items, whose diameters are $d_1, d_2, d_3, d_4$ and $d_5$, the sample average,

$\bar{X} = d_1 + d_2 + d_3 + d_4 + d_5/5$ and range,

$R$ = maximum diameter − minimum diameter.

A number of samples are selected and their average values and range are tabulated. The following example will explain the procedure to plot $\bar{X}$ and $R$ charts.

**EXAMPLE:**

| Sample No. (sample size-5) | $\overline{X}$ | $R$ |
|---|---|---|
| 1 | 7.0 | 2 |
| 2 | 7.5 | 3 |
| 3 | 8.0 | 2 |
| 4 | 10.0 | 2 |
| 5 | 9.5 | 3 |
| 6 | 11.0 | 4 |
| 7 | 11.5 | 3 |
| 8 | 4.0 | 2 |
| 9 | 3.5 | 3 |
| 10 | 4.0 | 2 |
| | $\Sigma \overline{X} = 76$ | $\Sigma R = 26$ |

$\overline{\overline{X}} = \Sigma \overline{X}$/No. of samples

$\overline{R} = \Sigma R$/No. of samples

Therefore, $\overline{\overline{X}} = \frac{76}{10} = 7.6$

and $\overline{R} = \frac{26}{10} = 2.6$

For $\overline{X}$ chart ;

Upper control limit (UCL) $= \overline{\overline{X}} + A_2\overline{R}$

Lower control limit (LCL) $= \overline{\overline{X}} - A_2\overline{R}$

For $R$ chart :

Upper control limit (UCL) $= D_4\overline{R}$

Lower control limit (LCL) $= D_3\overline{R}$

The values of various factors (like $A_2$, $D_4$ and $D_3$), based on Normal Distribution can be found from the following table :

| Sample size (No. of items in a sample) | $A_2$ Limit average | $D_3$ Range lower limit | $D_4$ Range upper limit |
|---|---|---|---|
| 2 | 1.88 | 0 | 3.27 |
| 3 | 1.02 | 0 | 2.57 |
| 4 | 0.73 | 0 | 2.28 |
| 5 | 0.58 | 0 | 2.11 |
| 6 | 0.48 | 0 | 2.00 |
| 8 | 0.37 | 0.14 | 1.86 |
| 10 | 0.31 | 0.22 | 1.78 |
| 12 | 0.27 | 0.28 | 1.72 |

Values of $A_2$, $D_3$ and $D_4$ for sample sizes 7, 9 and 11 can be (approximately) determined by taking the mean value of sample sizes 6 & 8, 8 & 10 and 10 & 12 respectively.

Sample size in this problem is 5, therefore,

$A_2 = 0.58$, $D_3 = 0$ and $D_4 = 2.11$

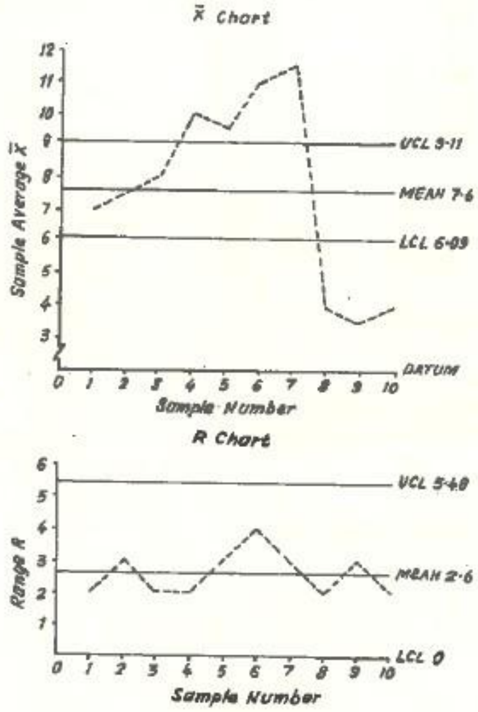
Thus, for $\overline{X}$ chart :

$$\begin{aligned} UCL &= 7.6 + (0.58 \times 2.6) \\ &= 7.6 + 1.51 = 9.11 \\ LCL &= 7.6 - (0.58 \times 2.6) \\ &= 6.09. \end{aligned}$$

and for $R$ chart :

$$\begin{aligned} UCL &= 2.11 \times 2.6 = 5.48 \\ LCL &= D_3 \times \overline{R} = 0 \times \overline{R} = 0. \end{aligned}$$

From the $\overline{X}$ chart, it appears that the process became completely out of control from 4th sample onwards.




## (c) p-Chart

1. It can be a fraction defective chart or % defective chart (100 p).

2. Each item is classified as good (non-defective) or bad (defective).

3. This chart is used to control the general quality of the component parts and it checks if the fluctuations in product quality (level) are due to chance cause alone.

4. It can be used even if sample size is variable (*i.e.*, different for all samples), but calculating control limits for each sample is rather cumbersome.

**EXAMPLE:**

| *Date* | | *Number of pieces inspected (a)* | *Number of defective pieces found (b)* | *Fraction defective p=(b)/(a)* | *% defective 100 p* |
|---|---|---|---|---|---|
| November | 4 | 300 | 25 | 0.0834 | 8.34 |
| November | 5 | 300 | 30 | 0.1000 | 10.00 |
| November | 6 | 300 | 35 | 0.1167 | 11.67 |
| November | 7 | 300 | 40 | 0.1333 | 13.33 |
| November | 8 | 300 | 45 | 0.1500 | 15.00 |
| November | 10 | 300 | 35 | 0.1167 | 11.67 |
| November | 11 | 300 | 40 | 0.1333 | 13.33 |
| November | 12 | 300 | 30 | 0.1000 | 10.00 |
| November | 13 | 300 | 20 | 0.0666 | 6.66 |
| November | 14 | 300 | 50 | 0.1666 | 16.66 |
| Total number of days | = 10 | 3000 | 350 | | |

Upper control limit, UCL $= \bar{p} + 3.\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$

Lower control limit, LCL $= \bar{p} - 3.\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$

where

$$\bar{p} = \frac{\text{Total number of defective pieces found}}{\text{Total number of pieces inspected}}$$

$$\bar{p} = \frac{350}{3000} = 0.1167$$

and $n$ = number of pieces inspected every day

= 300

$$\text{Therefore, } \sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = \sqrt{\frac{0.1167 \times (1-0.1167)}{300}}$$

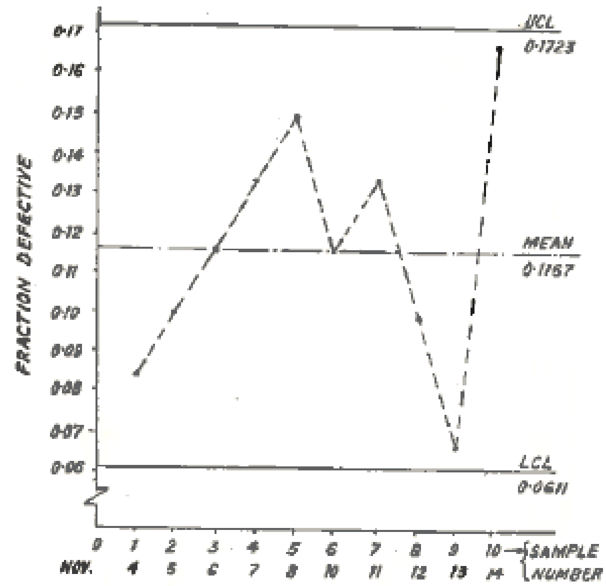
$$= \sqrt{\frac{0.1167 \times 0.8333}{300}}$$

$$= 0.01852$$

$$\text{and} \quad 3.\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.01852 \times 3 = 0.05556$$

Thus, UCL = 0.1167 + 0.05556 = 0.17226 = 0.1723 (Approx.)

LCL = 0.1167 − 0.05556 = 0.06114 = 0.0611 (Approx.)



(*d*) *C*-Chart

1. It is the control chart in which number of defects in a piece or a sample are plotted.

2. It controls number of defects observed per unit or per sample.

3. Sample size is constant.

4. The chart is used where average number of defects are much less than the number of defects which would occur otherwise if everything possible goes wrong.

5. Whereas, *p*-chart considers the number of defective pieces in a given sample, *C*-chart takes into account the number of defects in each defective piece or in a given sample. A defective piece may contain more than one defect, for example a cast part may have blow holes and surface cracks at the same line.

6. The *C*-chart is preferred for large and complex parts. Such parts being few and limited, however, restrict the field of use for *C*-chart (as compared to *p*-chart).

*C*-chart is plotted in the same manner as *p*-chart except that the control limits are based on Poisson Distribution which describes more appropriately the distribution of defects.

$$\text{UCL} = \bar{C} + 3\sqrt{\bar{C}}$$

$$\text{LCL} = \bar{C} - 3\sqrt{\bar{C}}$$

# PRODUCTION PLANNING & CONTROL (PPC)

## 1. Definition & objective of PPC

**Introduction**:

Production is an organized activity of converting raw materials into useful products. But before starting the actual production process planning is done –

- To anticipate possible difficulties.
- To decide in advance – how the production processes be carriedout in a best & economical way to satisfy customers.

However, only planning of production is not sufficient. Hence management must take all possible steps to see that plans chalked out by the planning department are properly adhered to and the standard sets are attained. In order to achieve it, control over production process is exercised.

## Objective:

Therefore, the ultimate objective of production planning and control isto produce products of

- right quality
- in right quantity
- at right time

By using the best and least expensive methods/procedure.

## **Definition:**

PPC may be defined as the direction and co-ordination of the firms materials and physical facilities towards the attainment of pre-specified production goals in the most efficient and economical way.

## **Function of PPC:**

The various functions of PPC dept. can be systematically written as:

1. Planning phase
   - Prior planning → forecasting, Order writing, Product design information
   - Active planning → Process planning & routingMaterials req. planning, tools req. planning, Loading scheduling

Action phase – Dispatching

Control phase
   - → Progress reporting
   - → Corrective action

Explanation of each term

(a) Forecasting: Estimation of quality & quantity of future work.

(b) Order writing: Giving authority to one or more persons to do a particular job.

(c) Product design information: Collection of information regarding specification, bill of materials, drawing.

(d) Process planning and routing: Finding the most economical process of doing work and then deciding how and where the work will be done?

(e) Materials planning: It involves the determination of materials requirement.

(f) Tools planning: It involves the requirements of tools to be used.

(g) Loading: Assignment of work to men & m/c.

(h) Scheduling: When and in what sequence the work will be carried out. It fixes the starting and 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 in collected.
ii. It is compared with the present level of performance.

(k) Corrective action: Expediting the action if the progress deviates from the planning.

(c) Aggregate Planning

Intermediate range planning which is done for a period of 3-12 monthsof duration is called Aggregate Planning as obvious from the following diagram.

Planning process

↓ ↓ ↓

| | | |
|---|---|---|
| Long range planning (= strategic planning)(for1-5 years of duration) | Intermediate range planning (=aggregate planning)(for 3-12 months) | Short term planning (for scheduling and planning for day to day shop floor activities). (for 1-90 days) |

Aggregate plans acts as an interface (as shown below by planninghierarchy) between strategic decision and short term planning.

## **Planning hierarchy**

Strategic decision

(1-5 months)

↓

Aggregate planning

(3-12 months)

↓

Short term planning

(1-90 days)

Aggregate planning typically focuses on manipulating several aspects ofoperations –

- Aggregate production volume
- Inventory level
- Personal level
- Machinery & other facility level

To minimize the total cost over some planning horizon while satisfyingdemand and policy requirements.

In brief, the objectives of aggregate planning are to develop plans thatare feasible and optimal.

Aggregate Planning

| Aggregate production planning<br>(it indicates the level of output) | Aggregate capacity planning<br>(keep desired level) |
| --- | --- |

## Characteristic of aggregates planning

**Forecasting:**

The aggregate plan is based on satisfying expected intermediate- term demand, so accurate forecasts of these demands are necessary, because seasonal variation patterns are usually important in aggregate planning.

In addition to demand, wage rates, material prices and holding costs can change enough to affect the optimal plans. But these forecasts are relatively easy to obtain because, they are specified in contractual agreements.

Identifying the planning variables

The two most important planning variables are:

- The amount of products to produce during each time period. and
- The amount of direct labours needed.

Two in-direct variables are:

- The amount of product to add to/remove from inventory.
- The amount of workforce/labour should be increased/decreased.

## Implementing an Aggregate plan

Aggregate plans are normally generated by using → Optimisation method.During a

planning period

Employees may produce more/less than expected.
Actual demand may not be same as predicted.
More employees leave the company than expected.
More/less may be hired than expected
Inventory may sometimes be damaged and so on.

Therefore, the 6-12 months aggregate plan devised for one period may nolonger be optimal for the next several months.

We do not simply generate one plan for the next 12months and keep that plan. Until it has been completely implemented. Aggregate planning is a dynamic process that requires constant updating.

In actual practice, we first develop an aggregate plan that identifies the best things to do during each period of planning horizon to optimize the long term goal of the organization. We then implement only the 1st period of plan; as more information becomes available, we update and revise the plan. Then action is implemented in the first period of the revised plan, gather more information and update again. This is illustrated in the following.

| | | | | | | |
|---|---|---|---|---|---|---|
| Implement1st period | Jan | Feb | Mar | April | May | June |
| | | | ↓ | Update & revise the plan | | |
| Implement1st period | Feb | Mar | April | May | June | July |
| | | | ↓ | Update and revise the plan | | |
| Implement1st period | Mar | April | May | June | July | Aug ↓ |

## Decision option in Aggregate Planning

The decision options are basically of 2 types.

i. Modification of demand
ii. Modification of supply.

## i. Modification of demand

The demand can be modified in several ways-

### a) Differential pricing

It is often used to reduce the peak demand or to increase the off period demand. Some examples are:

Reducing the rates of off season fan/woolen items.

Reducing the hotel rates in off season.

Reducing the electric charge in late night etc.

### b) Advertising and promotion

These methods are used to stimulate/smooth out the demand. The time for the advertisement is so regulated as to increase the demand during off period and to shift demand from peal period to the off period.

### c) Backlogs

Through the creation of backlogs, the manufacturer ask customer to wait for the delivery of the product, thereby shifting te demand from peak period to off period.

### d) Development of complementary products

Manufacturer who produce products which are highly seasonal in nature, apply this technique. Ex- Refrigerator Company produce room heater. TV Company produce DVD etc.

## ii. Modification of supply

There are various methods of modification of supply

### a) Hiring ad lay off employees

The policy varies from company to company. The men power/work force varies from peak period to slack/of period. Accordingly hiring/lay off employee is followed without affecting the employee morale.

### b) Overtime and under time

Overtime and under time are common option used in cases oftemporary change of demand.

### c) Use of part time or temporary labour

This method is attractive as payment for part time/temporarylabour is less.

### d) Subcontracting

The subcontracting may supply the entire product/some of thecomponents needed for the products.

### e) Carrying inventories

It is used by manufacturer who produces item in a particularseason and sell them throughout the year.

Aggregate planning strategies

| Pure strategy | Mixed strategy |
|---|---|
| If the demand and supply is regulatedby any one of the following strategies.<br>(a) Utilizing inventory through constant workforce.<br>(b) Varying the size of workforce.<br>(c) Sub contracting<br>(d) Making changes in demand pattern. | If the demand and supply is regulated by mixture of the strategies as mentioned aside, it is called mixed strategy. |

## (C) Materials Requirement Planning (MRP)

In manufacturing a product, the firm has to plan materials so that right quantity of materials is available at the right time for each component/subassembly of the product. The various activities interlinked with MRP is stated in the following.

## Objective of MRP

1. **Inventory Reduction**: MRP determines how many of a component are needed and when to meet the master production schedule. It enables the manager to procure that components as and when it is needed. As a result it avoids cost of carrying inventory.
2. **Reduction in production and Delivery Lead Time:** MRP co-ordinates inventories procurement and production decision and it helps in delay in production.
3. **Realistic commitment**: By using MRP in production the likely delivery time to customers can be given.

4. **Increased Efficiency**: MRP provides close co-ordination among various departments and work centers as product buildup progresses through them. Consequently, the production can proceed with fewer indirect personnel.

## MRP calculation

The terminologies which are involved in doing MRP calculations are:

Projected requirements
Planned order release
Economic order quantity
Scheduled receipts (receipts)
Stock on hand

Master production schedule gives particulars about demands of the final assembly for the period in the planning horizon. These are known a projected requirements of the final assembly.

The projected requirements of the subassemblies which are in the next immediate level just below the final product can be calculated only after completing MRP calculation for the final products. Similarly the projected requirements of the subassemblies which are in the 2nd level can be calculated only after completing the MRP calculation for the respective subassemblies in the 1st level. Like this the projected requirements for all subassemblies can be calculated.

Stock on hand is the level of inventory at the end of each period. Generally the initial on hand quality if exists for the final product/each subassembly is given in the input. For each period, the stock on hand is computed by using the following formula.

$SOH_t = SOH_{t-1} + R_t - PR_t$ --------------------------(1)

Where, $SOH_t$ = Stock on hand at the end of period t.

$SOH_{t-1}$ = Stock on hand at the end of period t-1.

$R_t$ = The scheduled receipt at the beginning of the period t through an order which has been placed at some early period.

$PR_t$ = Projected requirement of the period t.

Planned order release is the plan (i.e., quantity and date) to initiate the purchase. The planned order release for the period t is nothing but placing an order if the stock on hand ($SOH_t$) at the beginning of period t is less than the projected requirement ($PR_t$). Genarally the size of the order = Economic Order Quantity (EOQ).

The EOQ is calculated by using the following formula

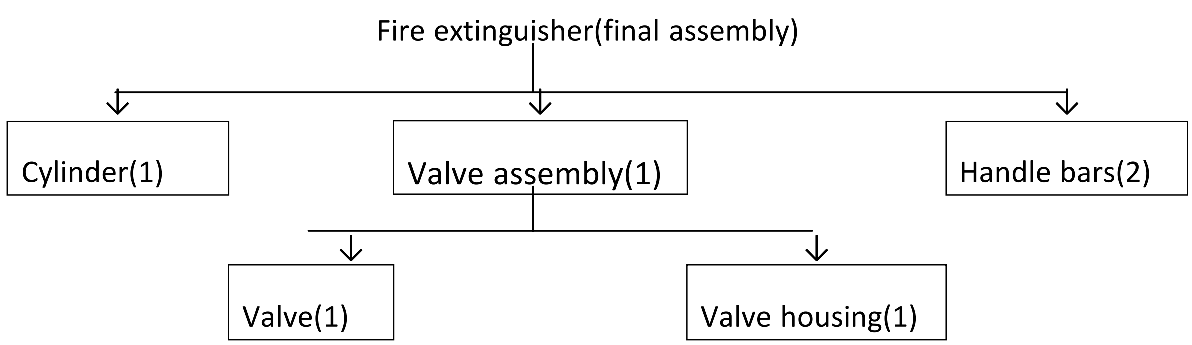
i.e., $EOQ = \sqrt{\frac{2DCo}{Ci}}$

where, D = Average demand/week

Co = ordering cost, Ci = earning same time cost/week

## Example (to demonstrate MRP calculation)

In order to demonstrate the working of MRP, let us consider manufacturing of five extinguisher as stated in the following.




The master production schedule to manufacture the fire extinguisher is givenin Tab-1.

## Tab-1: Master production schedule

| Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Demand | 100 | | 150 | 140 | 200 | 140 | | 300 |

The details of bill of materials along with economic order quantity andstock on for the final product and subassemblies are shown in Tab-2.

Tab-2: Details of Bill of materials

| Parts required | Order quantity | No. of units | Lead time (week) | Stock on hand |
|---|---|---|---|---|
| Fire extinguisher | 300 | 1 | 1 | 150 |
| Cylinder | 450 | 1 | 2 | 350 |
| Valve assemblies | 400 | 1 | 1 | 325 |
| Valve | 350 | 1 | 1 | 150 |
| Valve housing | 450 | 1 | 1 | 350 |
| Handle bars | 700 | 2 | 1 | 650 |

Lead time internal between placement of order receipt of materials. Complete

the material requirements plan for the fire extinguisher, cylinder, valve assembly, valve, valve housing, and handle bars and show whatthey must be released in order to satisfy the master production schedule.

Solution:

(a) MRP calculation for fire extinguisher

The projected requirements for the fire extinguisher is same as masterproduction schedule as shown Tab-1.

One unit of fire extinguisher require

One unit of cylinder

One unit of valve assembly, and
Two units of handle bars.

The MRP calculations for the fire extinguisher are shown in Tab-3.Tab-3: MRP calculations for fire extinguisher

EOQ = 300, Lead time = 1 week

| Period | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Projected requirement | | 100 | | 150 | 140 | 200 | 140 | | 300 |
| Stock in hand | 150 | 50 | 50 | 200 (-100) | 60 | 160 (-140) | 20 | 20 | 20 (-280) |
| Plannedorder release | | | 300 | | 300 | | | 300 | |
| Receipt | | | | 300 | | 300 | | | 300 |

Similarly the MRP calculation may also be carried out for other components.

## Routing

Routing may be defined as the "selection of proper follow which each part of the product will follow, while being transferred from raw material to finished products. Path of the products will also give sequence of operations to be adopted while manufacturing."

In other words, routing means determination of most advantageous path to be followed from department to department and machine to machine till raw materials get its final shape.

Routing determines the best and cheapest sequence of operations and to see that this sequence is rigidly followed.

Routing is an important function of PPC because it has a direct bearing on the "time" as well as "cost" of the operation. Defective routing may involve back tracking and long routes. This will unnecessarily prolong the processing time. moreover, it will increase the cost of material handling. Routing is affected by plant layout. In fact, routing and affected by plant layout are closely related. In product layout the routing is short and simple while under the process layout it tends to be long and complex.

## Routing Procedure

1. **Analysis of the product:** the finished product is analysed and broken into number of components required for the product.
2. **Make and buy decision:** It means to decide whether all components are to be manufactured in the plant or some are to be purchased from outside. make and buy decision depends upon
   - The work load in the plant already existing
   - Availability of equipments
   - Availability of labour
   - Economy consideration
3. **Raw materials requirements**

   A part list and bill of materials is prepared showing name of part,quantity materials specification, amount of materials required etc.

4. Sequence of operations which the raw materials are to undergo are listed.
5. Machines to be used, their capacity is also listed.
6. Time required for each operation and subassemblies are listed.
7. The low size is also recorded.

The data thus obtained is utilized for preparing master route sheets and operation charts. the master route sheets give the information regarding the time when different activities are to be initiated and finished, to obtain the product and required time.

The next step is to prepare the route sheet for the individual item or component.

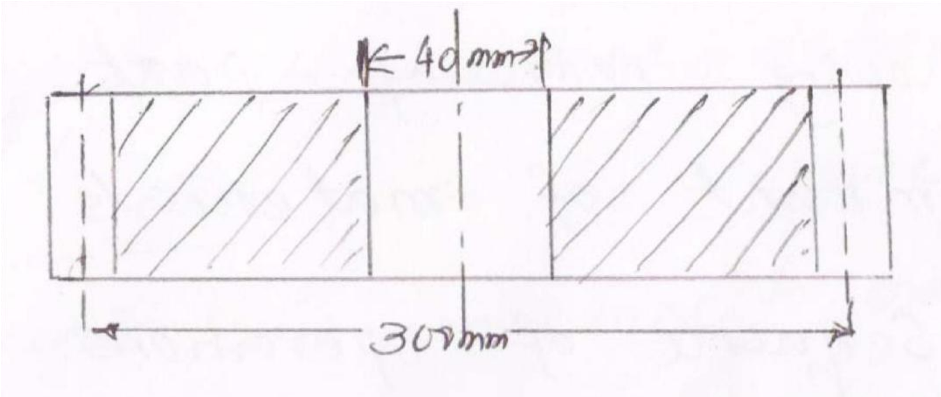
## Route sheet

The operation sheet and the route sheet differs only slightly. An operation sheet shows everything about the operation i.e. operation descriptions, their sequence, type of machinery, tools, jigs & fixture required, setup & operation time etc. whereas, the route sheet also details the section (or department) and the particular machine on which the work is to be done. the operation sheet will remain the same if the order is repeated but the route sheet may have to be revised if certain machines are already engaged to order. except thin small difference, both seets contain practically the same iformation and thus generally combined into one sheet known as operation and route sheet as shown in fig 1.1.

Part no. – A/50 Name

– Gear Material – m.s.

Quantity – 100 Nos




| Department | Machine | Operation | Description | Tool | Jigs/Fixture | time | |
|---|---|---|---|---|---|---|---|
| | | | | | | setup | operation |
| Smithy | Power hammer PH/15 | 1<br>2 | Forging<br>Punching hole | -<br>- | -<br>- | 4hrs<br>1hrs | 30 min.<br>25 min. |
| Heat treatment | Furnace F/H/4 | 3 | Normalizing | - | - | 4 hrs | 4 hrs. |
| Machine shop | Centre lathe CL-5 | 4 | Face 2 end.<br>Turn onter & inner face | Lathe tool | Chuck | 15 min | 1hr. |
| | Milling m/c Mm/15 | 5 | Cut teeth | Side & face cutter | Dividing head | 40 min | 5 hrs |
| | Slotter SL/7 | 6 | Make the key way | Slotting tool | - | 10 min | 30 min. |

## Advantages of Routing

1. Efficient use of available resources.

2. Reduction in manufacturing cost.
3. Improvement in quantity and quality of the o/p.
4. Provides the basis for scheduling and loading.

## Scheduling

Scheduling may be defined as the assignment of work to the facility with the specification of time, and the sequence in which the work is to be done. Ex- time Table scheduling is actually time phasing of loading. the facility may be man power, machines or both. scheduling deals with orders and machines. it determines which order will be taken up on which machine in which department at what time and by which operator.

## Objectives Loading and Scheduling

1. Scheduling aims to achieve the required rate of o/p with a minimum delay and disruption in processing.
2. To provide adequate quarters of goods necessary to maintain finished product at levels predetermined to meet the delivery commitment.
3. The aim of loading and scheduling is to have maximum utilization of men, machines and materials by maintaining a free flow of materials along the production line.
4. To prevent unbalanced allocation of time among production departments.
5. To keep the production cost minimum.

## Factors Affecting Scheduling

**(A) External Factors**

1. Customers demand
2. Customers delivery dates
3. Stock of goods already lying with the dealers & retailers.

**(B) Internal Factors**

1. Stock of finished good with firm
2. Time interval to manufacture each component, subassembly and then assembly.
3. Availability of equipments & machinery their capacity & specification.

4. Availability of materials
5. Availability of manpower

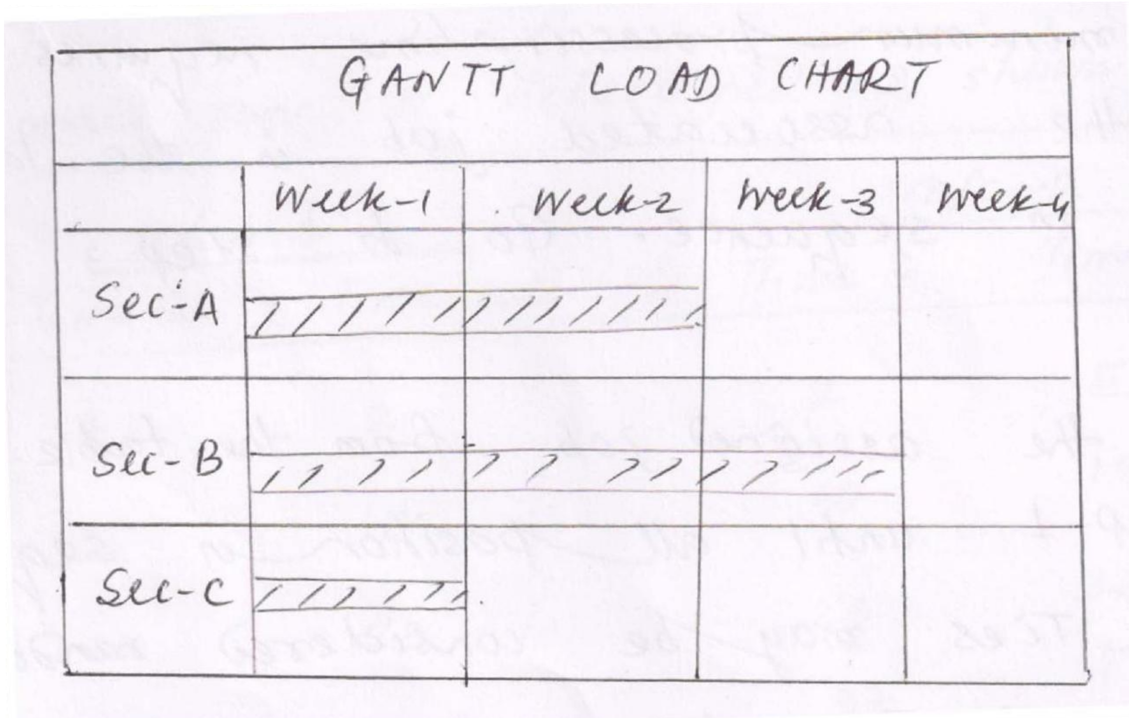
## Scheduling Procedure

Scheduling normally starts with mater schedule. The following tableshows master schedule for a foundry shop.

| MASTER SCHEDULING FOR FOUNDRY SHOP. Maximum production capability/week = 100 | | | | | |
|---|---|---|---|---|---|
| Order no. | Week-1 | Week-2 | Week-3 | Week-4 | Week-5 |
| 1. | 15 | 18 | 20 | 15 | 18 |
| 2. | 25 | 25 | 20 | 25 | 20 |

After master production schedule is made, the detailed schedules are thought of and made for each component, subassemblies, assemblies. The Gantt chars is a popular method commonly used in scheduling technique.

An example of Gantt chart is shown below. The hatched zone indicatesactual work load against each section.




Instead of section, it may be m/c / other facilities. now a days computers are used to do this chart for different components/ m/c etc through readily available production software.

## Machine loading using johnson's Rule

Loading may be defined as the assignment of work to a facility. the facility may be people, equipment, machine work groups or an entire plant. Therefore, machine loading is the process of assigning work to machine.

Johnson's Rule is most popular method of assigning jobs in a most optimum way such that the job can be produced with a minimum time & minimum idle time of the machine.

Case @ n Jobs in 2 machines

| Job (s) | Machine-1 | Machine-2 |
|---|---|---|
| 1 | $t_{11}$ | $t_{12}$ |
| 2 | $t_{21}$ | $t_{22}$ |
| 3 | $t_{31}$ | $t_{32}$ |
| : | : | : |
| i | $ti_1$ | $ti_2$ |
| : | : | : |
| n | $tn_1$ | $tn_2$ |

## Methodology/Procedure

**Step – 1**. Find the minimum time among $t_{i1}$ & $t_{i2}$

**Step – 2** If the minimum processing time requires m/c-1, place the associated job in the 1st available position in sequence.

**Step – 2** If the minimum processing time requires m/c-2 place the associated job in the last available position in sequence. Go to Step – 3.

**Step – 3**. Remove the assigned job from the table and return to step – 1 until all position in sequence are filled. (Tiles may be considered read only)

The above algorithm is illustrated with following example.

Example.- Consider the 2 machines and Six jobs follow shop scheduling problem. Using John son's algorithm obtain the optimal sequence which will minimize the make span. Find the value of make span.

| Job | Time taken by m/cs, hr | |
|---|---|---|
| | 1 | 2 |
| 1. | 5 | 4 |
| 2. | 2 | 3 |
| 3. | 13 | 14 |
| 4. | 10 | 1 |
| 5. | 8 | 9 |
| 6. | 12 | 11 |

**Solution** - The working of the algorithm is Summerised in the form of a tablewhich is shown below.

| Stage | Unscheduled | Min, tik | Assignment | Partial/full sequence |
|---|---|---|---|---|
| 1. → | 123456 | $t_{42}$ | Job 4 → [6] | *****4 |
| 2. → | 12356 | $t_{21}$ → | Job 2 → [1] | 2****4 |
| 3. → | 1356 → | $t_{12}$ → | Job1 → [5] | 2***14 |
| 4. → | 356 → | $t_{51}$ → | Job 5 → [2] | 25**14 |
| 5. → | 36 → | $t_{62}$ → | Job 6 → [4] | 25*614 |
| 6. → | 3 → | $t_{31}$ → | Job 3 → [3] | 253614 |

Now the optimum sequence – <u>2-5-3-6-1-4.</u>

The make span is determined as shown below

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

The make span for this optimum schedule/assignment is 53 hrs.Case

(b) n jobs in 3 machines as shown is the following

| Job | m/c-1 | m/c-2 | m/c-3 |
|---|---|---|---|
| 1 | $t_{11}$ | $t_{12}$ | $t_{13}$ |
| 2 | $t_{21}$ | $t_{22}$ | $t_{23}$ |
| 3 | $t_{31}$ | $t_{32}$ | $t_{33}$ |
| : | : | : | : |
| : | : | : | : |
| : | : | : | : |
| n | $t_{n1}$ | $t_{n2}$ | $t_{n3}$ |

One can extend the Johnson's algorithm to this problem if any of thefollowing 2 conditions is satisfied.

If min of $t_{i1} \geq$ max $t_{i2}$

If min $t_{i3} \geq$ max $t_{i2}$, then an hypothetical problem with 2 machines and n jobs (as shown below) can be treated. the objective is to obtain optimal sequence for the data given in the following table. later the make span can be obtained (for the optimal sequence) using the data of original table.

## Hypothetical 2 m/cs Problem

| Job | Hy p m/ c-A | Hyp m/c-B |
|---|---|---|
| 1 | $t_{11}+t_{12}$ | $t_{12}+t_{13}$ |
| 2 | $t_{21}+t_{22}$ | $t_{22}+t_{23}$ |
| : | : | : |
| i | $t_{i1}+t_{i2}$ | $t_{i2}+t_{i3}$ |
| : | : | : |
| n | $t_{n1}+t_{n2}$ | $t_{n2}+t_{n3}$ |

**Dispatching**

It is concerned with starting the processes. It gives necessary authority to start a particular work, which has already being planned under Routing and scheduling. For starting the work, essential orders and instructions are given.
Therefore, the complete definition of dispatching →

"Released of order and instructions for the starting of production for any item in accordance with the route sheet and scheduled chart."

## Function of Dispatching

1. After dispatching is done, required materials are moved from stores to m/c(s) and from operation to operation.
2. Authorizes to take work in hand as per schedule.
3. To distribute m/c loading and schedule charts route sheets and other necessary instructions and forms.

4. To issue inspection orders, clearly stating the type of inspection requiredat various stages.
5. To order too section for issuing proper tools, jigs, fixtures and other essential articles.

## Forms used in Dispatching

Following are some of the more common forms used in dispatching.

(a) Work orders: while starting the production, work orders are issued to departments to commence the desired lot of product.
(b) Time cards: Each operator is supplied with this card in which he mentions the time taken by each operation and other necessary information's. there are helpful for wage payment.
(c) Inspection Tickets: These tickets are sent to the inspection department which shows the quality of work required and stages at which inspection is to be carried out.
(d) Move Tickets: These tickets are used for authorizing over the movement of material from store to shop and from operation to operation.
(e) Tool & Equipment Tickets: It authorizes the tool department that new tools, gauges, jigs, fixtures and other required equipment may be issued to shop.