LECTURE NOTES

ON

MET 601 (INDUSTRIAL ENGINEERING & QUALITY CONTROL)

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1. PLANT LOCATION AND LAYOUT

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

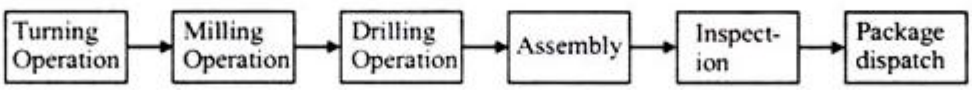
g) Increase employee morale
h) Reduce accidents
i) Provide for volume and product flexibility
j) Provide ease of supervision and control
k) Provide for employee safety and health
l) Allow ease of maintenance
m) Allow high machine or equipment utilization
n) Improve productivity

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

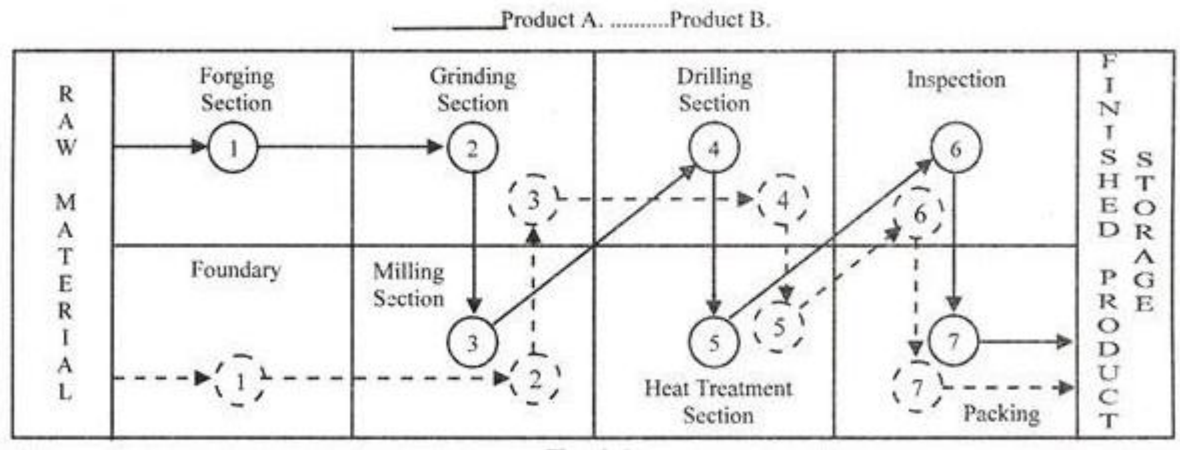
4. Simplified production planning and control; and simple and effective inspection of work.
5. Small amount of work-in-progress inventory
6. Lesser wage cost, as unskilled workers can learn and manage production.

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.

2. 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.

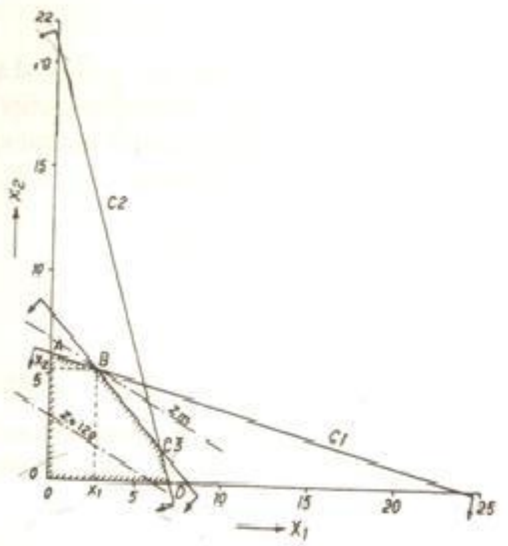
Max Z = 20x1 + 40x2
Subjected to x1 + 4x2 24 (c1)
3x1 + x2 21 (c2)
x1 + x2 8 (c3)
x1, x2 0 (c4)
c1 is constrain no. 1 and so on.

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.
x1 + x2 = 8 (c3)
x1 + 4x2 = 24 (c1)
3x2 = 16 => x2 = 5.3
3x1 = 8 => x1 = 2.7

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

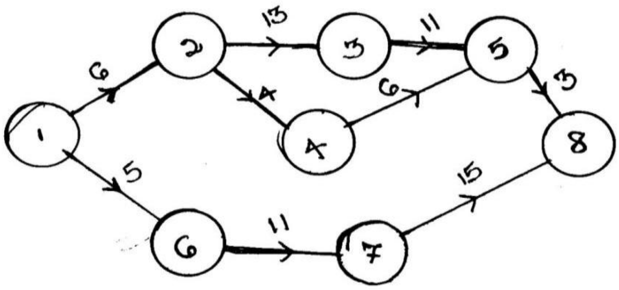
It can be used to advantage. If one is interested to reduce the effort on a non-critical activity in order to apply the effort on a critical activity by reducing the project duration.

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:

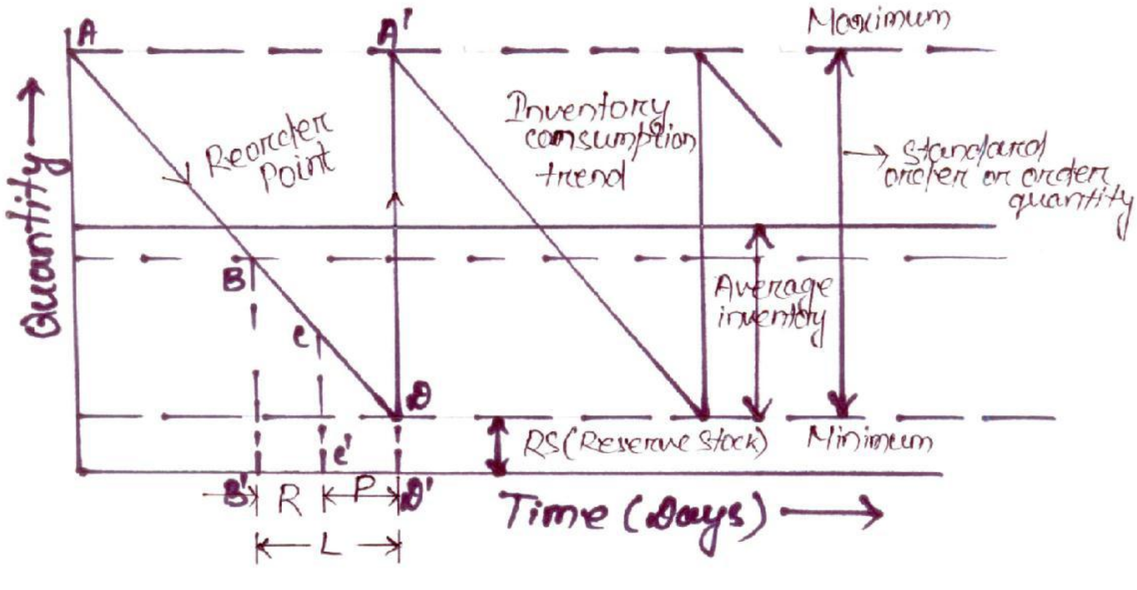
The amount invested in an item is an amount of capital not available for other purchases.

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.



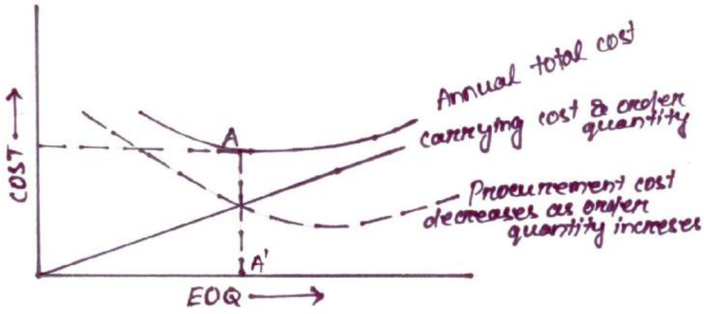
Starting from an instant when inventory OA is in the stores, it consumes gradually in quantity from A along AD at a uniform rate. We know it takes L no. of days between initiating order and receiving the required inventory. As quantity reaches point B, purchase requisition is initiated which takes form 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 /-

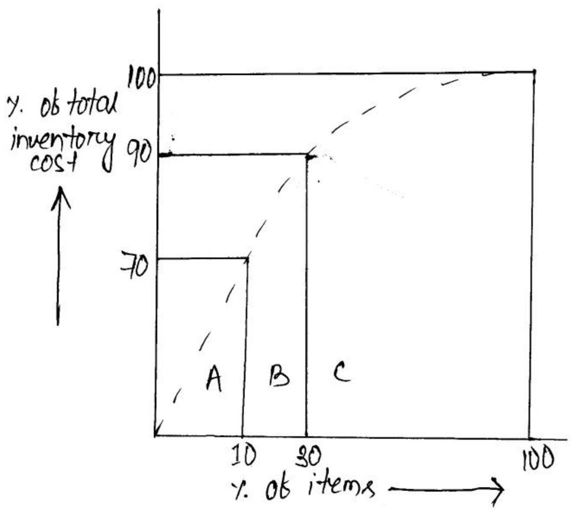
$$EOQ = \sqrt{\frac{2UP}{CI}} = \sqrt{\frac{2 \times 30000 \times 70 \times 100}{2 \times 12}} = 4183.3$$

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

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

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:

1. Identify all the items used in 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 % 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

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

4. 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

5. 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)	$\bar{X}$	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
	$\Sigma \bar{X} = 76$	$\Sigma R = 26$

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

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

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

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

For $\bar{X}$ chart ;

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

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

For R chart :

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

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

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 $D_4 = 2.11$

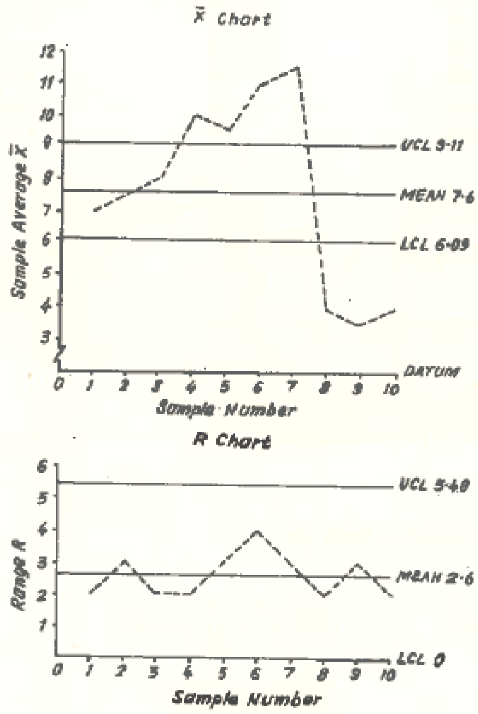
Thus, for $\bar{X}$ chart :

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

and for R chart :

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

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		

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

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

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

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

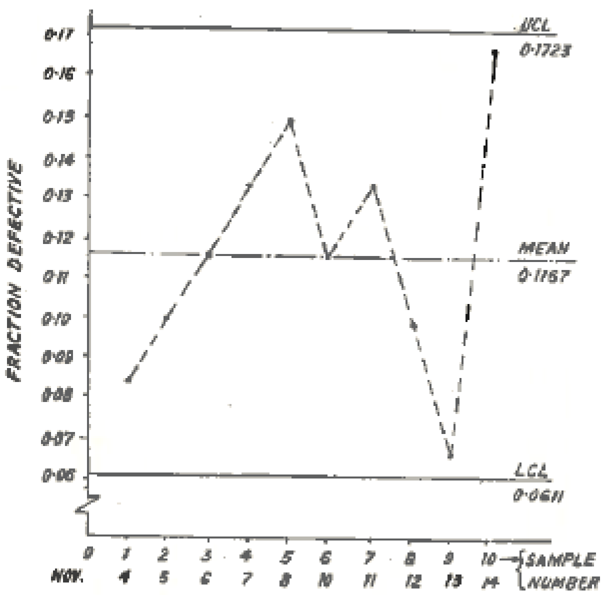
$$= \sqrt{\frac{0.1167 \times 0.8333}{300}}$$

$$= 0.01852$$

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

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.

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

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

6. CONTEMPORARY QUALITY MANAGEMENT CONCEPTS

TOTAL QUALITY MANAGEMENT:

Total Quality management is defined as a continuous effort by the management as well as employees of a particular organization to ensure long term customer loyalty and customer satisfaction.
Total quality management ensures that every single employee is working towards the improvement of work culture, processes, services, systems and so on to ensure long term success.
Total Quality management can be divided into four categories:

- Plan
- Do
- Check
- Act

Also referred to as PDCA cycle.

- **PLANNING PHASE**

Planning is the most crucial phase of total quality management. In this phase employees have to come up with their problems and queries which need to be addressed. They need to come up with the various challenges they face in their day to day operations and also analyze the problem's root cause. Employees are required to do necessary research and collect relevant data which would help them find solutions to all the problems.

- **DOING PHASE**

In the doing phase, employees develop a solution for the problems defined in planning phase. Strategies are devised and implemented to overcome the challenges faced by employees. The effectiveness of solutions and strategies is also measured in this stage.

- **CHECKING PHASE**

Checking phase is the stage where people actually do a comparison analysis of before and after data to confirm the effectiveness of the processes and measure the results.

- **ACTING PHASE**

In this phase employees document their results and prepare themselves to address other problems.

IMPORTANCE OF QUALITY MANAGEMENT

- Quality management" ensures superior quality products and services
- Quality management" ensures superior quality products and services
- Quality management" ensures superior quality products and services
- Quality Management ensures increased revenues and higher productivity for the organization.
- Quality management helps organizations to reduce waste and inventory

ISO 9000:

The ISO 9000 family of quality management systems (QMS) standards is designed to help organizations ensure that they meet the needs of customers and other stakeholders while meeting statutory and regulatory requirements related to a product or service. ISO 9000 deals with the fundamentals of quality management systems, including the seven quality management principles upon which the family of standards is based.

The ISO 9000 series are based on seven quality management principles (QMP)

The seven quality management principles are:

- QMP 1 – Customer focus
- QMP 2 – Leadership
- QMP 3 – Engagement of people
- QMP 4 – Process approach
- QMP 5 – Improvement
- QMP 6 – Evidence-based decision making
- QMP 7 – Relationship management

Evolution of ISO 9000 standards

The ISO 9000 standard is continually being revised by standing technical committees and advisory groups, who receive feedback from those professionals who are implementing the standard.

ISO 14000:

ISO 14000 is a family of standards related to environmental management that exists to help organizations (a) minimize how their operations (processes, etc.) negatively affect the environment (i.e. cause adverse changes to air, water, or land); (b) comply with applicable laws, regulations, and other environmentally oriented requirements; and (c) continually improve in the above.

ISO 14000 is similar to ISO 9000 quality management in that both pertain to the process of how a product is produced, rather than to the product itself.

JIT (JUST IN TIME MANUFACTURING):

Just in Time (JIT), as the name suggests, is a management philosophy that calls for the production of what the customer wants, when they want it, in the quantities requested, where they want it, without it being delayed in inventory.

So instead of building large stocks of what you think the customer might want you only make exactly what the customer actually asks for when they ask for it. This allows you to concentrate your resources on only fulfilling what you are going to be paid for rather than building for stock.

Within a Just in Time manufacturing system, each process will only produce what the next process in sequence is calling for.

BENEFITS OF JUST-IN-TIME MANUFACTURING:

1. **Reduction in Inventory costs**; One of the main aims with any JIT implementation is to improve stock turns and the amount of stock being held. Personal experience has seen reductions of more than 90% stock in some industries. Along with the reduction in the stock come many other associated benefits.
2. **Reduction in space required**: By removing large amounts of stock from the system and moving processes closer together we will often see a significant reduction in the amount of floor space being used.
3. **Reduction in handling equipment and other costs**: If you don't have to move large batches there is less need for complex machinery to move them and all of the associated labor and training.
4. **Lead time reductions**: One of the most significantly impacted areas is that of the time it takes for products to flow through the process. Instead of weeks or months most JIT implementations result in lead times of hours or a few days.
5. **Improved Quality**: The removal of large batch manufacturing and reduction in handling often results in significant quality improvements; often in the region of 25% or more.
6. **Productivity increases**: To achieve JIT there are many hurdles that must be overcome with regards to how the process will flow. These will often result in productivity improvements of 25% upwards.
7. **Problems are highlighted quicker**: Often this is cited as being a negative aspect of JIT in that any problems will often have an immediate impact on your whole production process. However this is the perfect way to ensure that problems are highlighted and solved immediately when they occur.
8. **Employee empowerment**: One requirement of JIT as with most other aspects of Lean manufacturing is that employees are heavily involved in the design and application of your system.

SIX SIGMA:

Six Sigma is a business management strategy which aims at improving the quality of processes by minimizing and eventually removing the errors and variations. According to Six Sigma any process which does not lead to customer satisfaction is referred to as a defect and has to be eliminated from the system to ensure superior quality of products and services.

Following are the two Six Sigma methods:

- DMAIC
- DMADV

DMAIC focuses on improving existing business practices. DMADV, on the other hand focuses on creating new strategies and policies.

DMAIC has Five Phases

D - Define the Problem. In the first phase, various problems which need to be addressed to are clearly defined. Feedbacks are taken from customers as to what they feel about a

particular product or service. Feedbacks are carefully monitored to understand problem areas and their root causes.
M - Measure and find out the key points of the current process. Once the problem is identified, employees collect relevant data which would give an insight into current processes.
A - Analyze the data. The information collected in the second stage is thoroughly verified. The root cause of the defects are carefully studied and investigated as to find out how they are affecting the entire process.
I - Improve the current processes based on the research and analysis done in the previous stage. Efforts are made to create new projects which would ensure superior quality.
C - Control the processes so that they do not lead to defects.

DMADV Method

D - Design strategies and processes which ensure hundred percent customer satisfaction.
M - Measure and identify parameters that are important for quality.
A - Analyze and develop high level alternatives to ensure superior quality.
D - Design details and processes.
V - Verify various processes and finally implement the same.

7 S:

Sort: During the Sort step employees go beyond just categorizing items, identifying and marking for removal anything that does not belong. Only essential items should be in a specific work area, and anything that is nonessential should be located elsewhere or eliminated altogether.
Straighten: The Straighten step is about more than just organizing the work area. The primary objective of this step is to arrange equipment and supplies in a way that optimizes process efficiency. Items should be kept in the proper order based on how the process is conducted, and located in a way that makes it easy for workers to access them when they are needed. Some companies refer to this step as ***Set in Order***.
Shine: Also called Sweeping, Cleanliness or Scrub, this third step addresses the importance of routine cleaning and organizing of the work area, typically at the end of each shift or workday. Cleaning is not something that is done only when the mess goes beyond a threshold of tolerance, but rather consistently throughout operations. This ensures that items are where they should be and in usable condition and that there is no cumulative increase in disorder.
Standardize: As with all aspects of Lean Six Sigma, 7S requires a commitment to standardizing processes and procedures. It is only through standardization of the first three steps of 5S or 7S that companies can be sure expectations are clear and communicated effectively and that procedures are followed consistently. This typically involves written documentation, which may include schedules and role descriptions.
Sustain: Maintaining improvements is a key tenet of Six Sigma, and 7S stresses this priority as well. Leaders must commit to maintaining the practices of 7S on an ongoing basis, and must establish procedures to address problems that arise and changes that may be needed as business operations evolve.
Safety: This component of 7S simply requires attention to safety throughout the other steps. It is particularly prominent in manufacturing and laboratory settings and in other

contexts where potentially dangerous equipment or substances may be involved, and less prominent in office settings.
Spirit: As leaders understand the impact of company culture and the importance of respect for employees, the need for this additional component becomes clear. While some organizations successfully implement the traditional 5S method, many are choosing to add Spirit as an additional piece to make explicit the reliance on the people factor and the need to continually keep it in mind as other steps are undertaken.

LEAN MANUFACTURING:
Lean manufacturing is a methodology that focuses on minimizing waste within manufacturing systems while simultaneously maximizing productivity. Also known as lean production, or just lean, the integrated socio-technical approach is based on the Toyota Production System and is still used by that company, as well as myriad others, including Caterpillar Inc. and Nike.

FIVE PRINCIPLES OF LEAN MANUFACTURING:

1. **Identify value from the customer's perspective:** Value is created by the producer, but it is defined by the customer. In other words, companies need to understand the value the customer places on their products and services, which, in turn, can help them determine how much money the customer is willing to pay. The company must strive to eliminate waste and cost from its business processes so that the customer's optimal price can be achieved at the highest profit to the company.

2. Map the value stream: This principle involves recording and analyzing the flow of information or materials required to produce a specific product or service with the intent of identifying waste and methods of improvement. The value stream encompasses the product's entire lifecycle, from raw materials through to disposal.

Companies must examine each stage of the cycle for waste -- or muda in Japanese. Anything that does not add value must be eliminated. Lean thinking recommends supply chain alignment as part of this effort.

3. Create flow: Eliminate functional barriers and identify ways to improve lead time to ensure the processes are smooth from the time an order is received through to delivery. Flow is critical to the elimination of waste. Lean manufacturing relies on preventing interruptions in the production process and enabling a harmonized and integrated set of processes in which activities move in a constant stream.

4. Establish a pull system: This means you only start new work when there is demand for it. Lean manufacturing uses a pull system instead of a push system.

With a push system, used by manufacturing resource planning (MRP) systems, inventory needs are determined in advance and the product is manufactured to meet that forecast. However, forecasts are typically inaccurate, which can result in swings between too much inventory and not enough, as well as subsequent disrupted schedules and poor customer service.

In contrast to MRP, lean manufacturing is based on a pull system in which nothing is bought or made until there is demand. Pull relies on flexibility and communication.

5. Pursue perfection with continual process improvement or kaizen: Lean manufacturing rests on the concept of continually striving for perfection, which entails targeting the root causes of quality issues and ferreting out and eliminating waste across the value stream.