COURSE MATERIAL
ON
OPERATION MANAGEMENT

Subject Code - 18 MBA 205

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Name : BIDHU BHUSAN NAYAK

Email - bidhubhusan04@gmail.com

INSTITUTE OF MANAGEMENT AND INFORMATION TECHNOLOGY (IMIT), Cuttack

MODULE-1

CLASSIFICATION OF PRODUCTION SYSTEM

Basis	Classifications	Examples
Type of output	Products	Consumer goods like TV, radio, furniture etc.
		Producer goods like lathe, milling machine etc.
	Services	Transportation, health, entertainment, banking services, education system etc.
Type of flow	Projects	Construction of buildings, dam etc.
	Job shop	Hospital, auto repair, machine shop, furniture company etc.
	Flow shop	High Vol. TV factory etc.
	Continuous process	Postal services, telephone company
Type of specification under service type	Customized	Power corporation, medical care, legal services
	Standardized	Insurance etc.

Flow Shop:

This is a conversion process in which successive units of output undergo same sequence of operations using specialized equipments usually positioned along a production line, e.g. auto assembly, assembly of T.V.s and assembly of Computer keyboards etc.

Factors Influencing Plant Location

The factors which influence plant location can be classified into general factors and specific factors.

General Factors:

1) Availability of land for present and future needs and cost of land and land development and building etc.
2) Availability of inputs such as labour, raw materials, etc nearer to raw markets. (Reduced cost of transportation, regular and proper supply of materials uninterrupted by transportation breakdown, savings in case of storage of materials).
3) Closeness to market places.
4) Stability of demand.
5) Availability of communication facilities.
6) Availability of necessary modes of transportation like road, rail, airport and waterways.
7) Availability of infrastructure facilities such as power, water, financial institutions, banks etc.
8) Disposal of waste and effluent and their impact on environment.
9) Govt. support, grant, subsidy, tax structure.
10) Availability of housing facilities and recreational facilities.
11) Demographic factors like population, trained men power, academic institutions, standard of living, income level etc.
12) Security, Culture of society.
13) Fuel cost.

Specific Factors:

A multinational company, desiring to set up plant should consider the following aspects in addition to normal factors.

1) The economic stability of the country and concern of the country towards outside investments.
2) The success of operations of a factory depends upon the cultural factors, language and cultural differences. Units of measurements are also very important in international business.
3) Analysis must be based on factors like wage rate, policy, duties etc.
4) The company can set up joint ventures with any leading local giants that will solve many operational problems.

Availability of Raw materials and labour:-

One of the most important considerations in selection of plant location has been the availability of raw materials registered. The biggest advantage of availability of Raw material at the location of Industry is that it involves less transportation cost.

If the raw materials are perishable and to be consumed as such then industries always tend to locate nearer to war material service. Ex: cement & steel industries. In case of small scale industries, these could be food and fruit processing, jams, juices & ketchups etc.

Availability of registered manpower skilled in specific trades may be yet another deciding factor for the location of skill-intensive industries. The location of glass industry at Firozabad, the woolen carpet industry at Mirzapur, the lock industry at Aligarh and manufacture of silk sarees at Dharmavaram and

Kanjeevaram in south are examples of industries which are located near supply centers of skilled labour.

Labour, however, may be a deterrent factor in development of industries in a particular area. The attitude of workers, union activities and industrial disputes drive away the existing factories and discourage new industrialists from locating new factories in particular places.

Q^{n}.) There are two sites considered for locating a plant. The details are given in the following table.

Cost of Items	**Cost per unit of product at various stages**	
	Site-1	**Site-2**
Quantitative Factors		
1) Raw materials and other supplies	1,50,000	1,30,000
(Rs)	60,000	58,000
2) Fuel & Power (Rs)	5,000	7,000
3) Water (Rs)	1,60,000	1,25,000
4) Labour & Supervisor (Rs)	12,00,000	12,19,000
5) Land & Building (Rs)	1,50,000	1,40,000
6) Distribution Expenses (Rs)	1,10,000	1,20,000
7) Freight Incoming (Rs)	4,000	2,000
8) Taxes (Rs)		
Qualitative Factor		
1) Communication facilities	Good	Excellent
2) Housing facilities	Very Good	Good
3) Cost of living	High	Normal

<u>Work Study</u>

In today's competitive business environment, it is necessary that employees work harder, be more productive to minimize cost of production. Work study deals with the techniques of method study and work measurement, which are employed to ensure the best possible use of human, machine and material resources in carrying out a specified activity.

Work study aims to find ways of doing work and avoid waste in all its forms.

Work study has two broad areas i.e. method study and time study.

Method Study: - It is concerned with finding the facts about a situation and after a critical examination of these facts, developing a new and better method of doing that work.

Time Study: - It is concerned with the establishment of time standards for a qualified worker to perform a job at a defined level of performance.

Method study must recede time study before any attempt is made to set standards for various jobs.

Benefits of Work Study:-

1) Increased productivity.
2) Reduced manufacturing costs.
3) Improved work place
4) Fair wages to employees
5) Better working conditions to employees.
6) Reduced material handling costs.

7) Provides a standard of performance to measure labour efficiency.
8) Better Industrial relations and employee morale.
9) Basis for sound incentive schemes.
10) Provides job satisfaction to employees.

The criteria for the best method could be an increase in job satisfaction and individual morale, reduction in Physiological fatigue, decrease in number of accidents and personal injuries.

Steps in method study:

1) **Select**: - Select the work to be studied.
2) **Record**: - all the relevant facts of the present (or proposed) method by direct observation.
3) **Examine**: - Examine the facts critically in sequence.
4) **Develop**: - Develop the best method i.e. the most practical, economic and effective method under existing circumstances.
5) **Install**: - Install that method as standard practice.
6) **Maintain**: - Maintain that standard practice by regular routine check.

Inventory Management: What is it?

This is synonymous with the term Inventory Control. All of you know, what is **inventory**? It was discussed in first module under various responsibilities of a production or operation manager. For recapitulation, Inventory consists of **Raw materials**, **semi-finished goods** (Work in Process abbreviated as WIP) and **Finished** but **unsold** goods. There are certain costs relevant to inventory like carrying cost (which is also known as holding cost), ordering cost etc. With increase in the size of the inventory carrying cost increases on the other hand, ordering cost decreases. It has been explained number of times in class, why? I'm just repeating it. **Carrying cost** includes cost of capital, space cost, material handling cost, obsolescence cost, insurance costs etc. The more inventory you have, the more space you need to store, more capital is locked on them (because if you purchase lot of raw material for producing your product and at the moment you need a part of it that means you have to store it in your go down for meeting future needs, if the capital was not invested on this inventory it could have been invested on productive purposes). The more the inventory, space cost – rent paid for space – is more. At the same time, the more the amount of goods purchased in an order, less the number of orders to be placed for meeting the needs on an annual basis. **Ordering cost** is the cost of placing an order related to clerical paper work, cost of receiving and inspection (cost is involved in paying salaries to inspectors for inspecting goods when a lot goods is received as per new order). For example, now during Covid-19 Pandemic hospitals need PPEs for their health workers. Suppose a hospital needs 5000 PPEs for next six months, hospitals are left with options of either bringing it in one lot or in two lots (or say, five lots). So management of hospital has to make a decision relating to inventory level. If it purchases in one order, then ordering cost will be low but carrying cost will be high because hospital has to carry the stocks of PPEs to future. On the other hand, ordering cost is low because it has to place only one order.

So what we conclude is, neither excess inventory nor too low inventory is desirable. Excess inventory results in excessive carrying cost. Every management in the world attempts to reduce cost incurred. Too low an inventory results in a loss situation also. E.g.:- If you are in some business suppose apparel business, you are purchasing from wholesaler and supplying to customer. You are having very low stocks of a dress item. Suddenly demand comes from nowhere. That means you will not be able to deliver the customer the desired product. Isn't it? For that you lost something that is called **Lost Sales**. Apart from that also goodwill of customer is lost. So being an Operation Manager you have to manage the inventory levels of your organization. Neither too high nor too low is acceptable. Here comes the term **Inventory Management** or **Inventory Control**.

INVENTORY DECISIONS:

The inventory decisions taken by Inventory Managers generally are following two types.

1) When to replenish the inventory of item.
2) How much of an item to order when inventory of that item is to be replenished.

Replenishment:- means when stock is consumed you have to place orders to make up for that consumption.

There are various models of inventory. But the model in your syllabus is **Purchase Model with Instantaneous Replenishment and without shortages**;

In this model of inventory, orders of equal sizes are placed at periodical intervals. Items once ordered reach in no time i.e. the **Lead Time** is zero. So what is Lead Time? Lead time is the time gap between placement of order and receipt of goods. Once you place an order, it is not necessary that goods will be received suddenly. Some time is required. That time is known as **Lead time**. In this case Lead Time is assumed to be Zero. We know that the more goods you purchase in bulk, the less price you pay per unit. That is known as **Quantity Discount**. Assuming that there is no such Quantity discount offer, the purchase price per unit is the same irrespective of order size, items are consumed at a constant rate.

Let D = Annual Demand in Units

C_D = Ordering Cost/Order

C_C = Carrying Cost/Unit/Year

P = Purchase Price/Unit

Q = Order Size

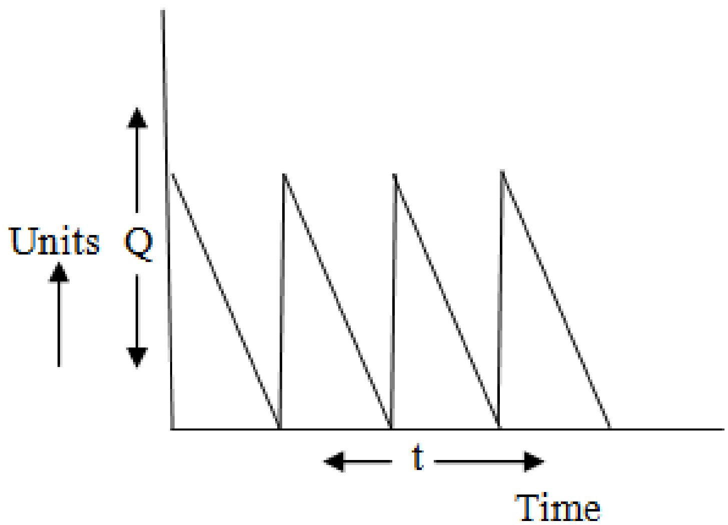


Fig-2

Number of orders/year= $\frac{D}{Q}$ ($\because$ Annual Demand = D units

and in one order goods received = Q Units)

Ordering Cost/Year = $\frac{D}{Q} \times C_O$ ($\because$ C_O = Ordering cost per order

For placing one order

cost incurred = C_O.

For placing $\frac{D}{Q}$ numbers of order,

ordering cost incurred = $\frac{D}{Q} \times C_O$)

For calculation of carrying cost, we do not have a fixed amount of inventory throughout the year. From the above fig i.e. fig-2, you see at t=0, Q units are received and are consumed (goods are sold supposedly at a constant rate) and at t=t, Q=0. So we have to take average inventory for calculation of carrying cost annually.

Carrying cost or holding cost is normally expressed in terms of carrying cost or holding cost/unit/yr. i.e. cost incurred to carry one unit of inventory for one year. Sometimes, it is also expressed in terms of percentage of purchase price of a product. Purchase price/unit means price you pay for purchasing one unit of finished product if you are a seller and one unit of Raw material from supplier if you are a producer.

Q^n.1) Beta Industry estimates that it will use 24,000 units of its product for the forthcoming year. The ordering cost is Rs. 150 per order and the carrying cost per unit per year is 20 percent of the purchase price per unit which is Rs. 50.

Find

a) Economic order size
b) Number of orders per year.
c) Time between successive orders.

Sol^n: - a) EOQ $(Q^x) = \sqrt{\frac{2CoD}{i \times P}}$ ($\because$ carrying cost/unit is expressed as percentage of purchase price/unit)

$$= \sqrt{\frac{2 \times 150 \times 24000}{.2 \times 50}}$$

$= \sqrt{720000} = 898.52 = 849$ units ($\because$ 52 units can't exist physically)

b) Number of orders/year

$$= \frac{D}{Qx} = \frac{24000}{849} = 28.25/\text{yr}$$

c) Time between consecutive orders

$$= \frac{Qx}{D} = \frac{849}{24000}\text{ yr} = 0.035 \text{ year}$$

Q^n.2) Ram Industry needs 5400 units/year of a bought out component which will be used in its main product. The ordering cost is Rs 250 per order and the carrying cost per unit per year is Rs 30. Find

a) Economic order quantity.
b) Number of orders per year.
c) Time between successive orders.

Sol^n: - In this question, carrying cost is directly given i.e. Cc/Unit/Year

a) $\text{EOQ} = \sqrt{\frac{2CoD}{Cc}}$

$$= \sqrt{\frac{2\times250\times5400}{30}}$$

C_O = Rs 250/order (Ordering cost per order)

D = 5400 units (Annual demand)

C_C = Rs 30 (Carrying cost / unit)

$$Q^x = \sqrt{\frac{500\times5400}{30}} = \sqrt{90000} = 300 \text{ units}$$

b) Number of orders per year

$$= \frac{D}{Qx} = \frac{5400}{300} = 18$$

c) Time between consecutive orders

$$= \frac{Qx}{D} = \frac{300}{5400}\,\text{yr} = 0.056 \text{ year}$$

Material Requirement Planning (M.R.P):

An inventory of an item is called **independent demand** when the demand for such an item is **not dependent** upon the demand for another item whereas an inventory of an item is categorized as **dependent demand** when demand for such an item is **dependent** upon another item. Independent demand is demand for finished product e.g. a computer, a car, or a pizza. Dependent demand on the other hand, is demand for component in parts or subassemblies. E.g. chips on computer, tyres on car, cheese on pizza etc.

One approach to manage the availability of dependent-demand items is to keep a high stock of all the items that might be needed to produce the end items and when stock on hand drops below a reorder level, items are produced or bought to replenish the stock to the maximum level. But this approach is very costly due to excessive inventory of components, sub assemblies.

An alternative approach to manage dependent-demand items is to plan for procurement or manufacture of specific components that will be required to produce required quantities of end product as per Master Production Schedule (MPS). The technique is known as **Material Requirement Planning** (MRP) technique.

MRP is a computer based system in which the given MPS is exploded into required amounts of raw materials, parts and sub assemblies, needed to produce the end items in each time (week or month). The gross requirement of these materials is reduced to net requirements by taking into account that material that is in inventory.

Objectives of MRP

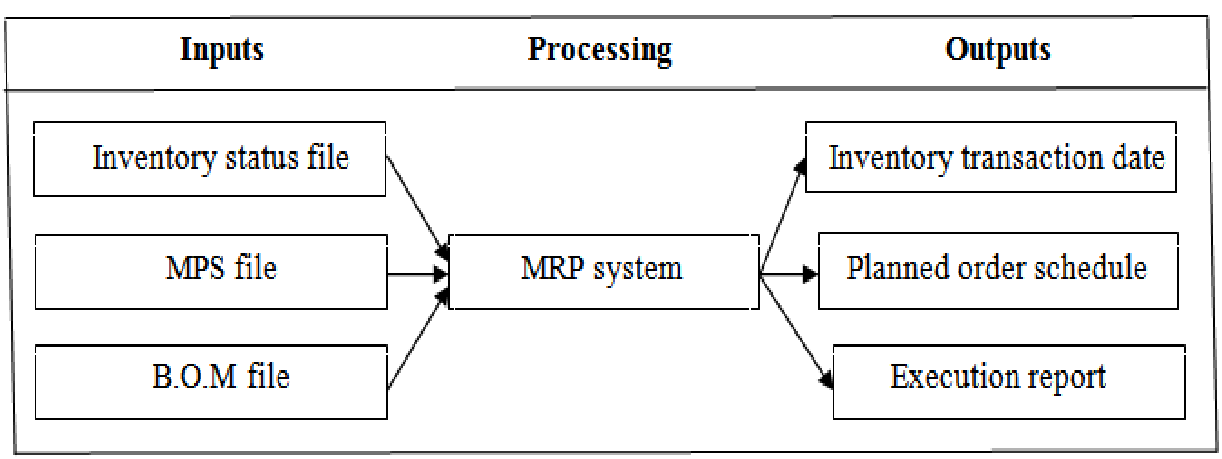
1) To improve customer service by meeting delivery schedules promised and shortening delivery lead times.
2) To reduce inventory costs by reducing inventory levels.
3) To improve plant operating efficiency by better use of productive resources.

The theme of **MRP** is "**getting the right materials** (whether bought out or in-house manufactured) **to the right place at the right time in right quantities**.

MRP System inputs:

The entire MRP system is driven by **MPS**, the **Bill of materials** (BOM) file and **inventory status** file.

Operation of MRP system



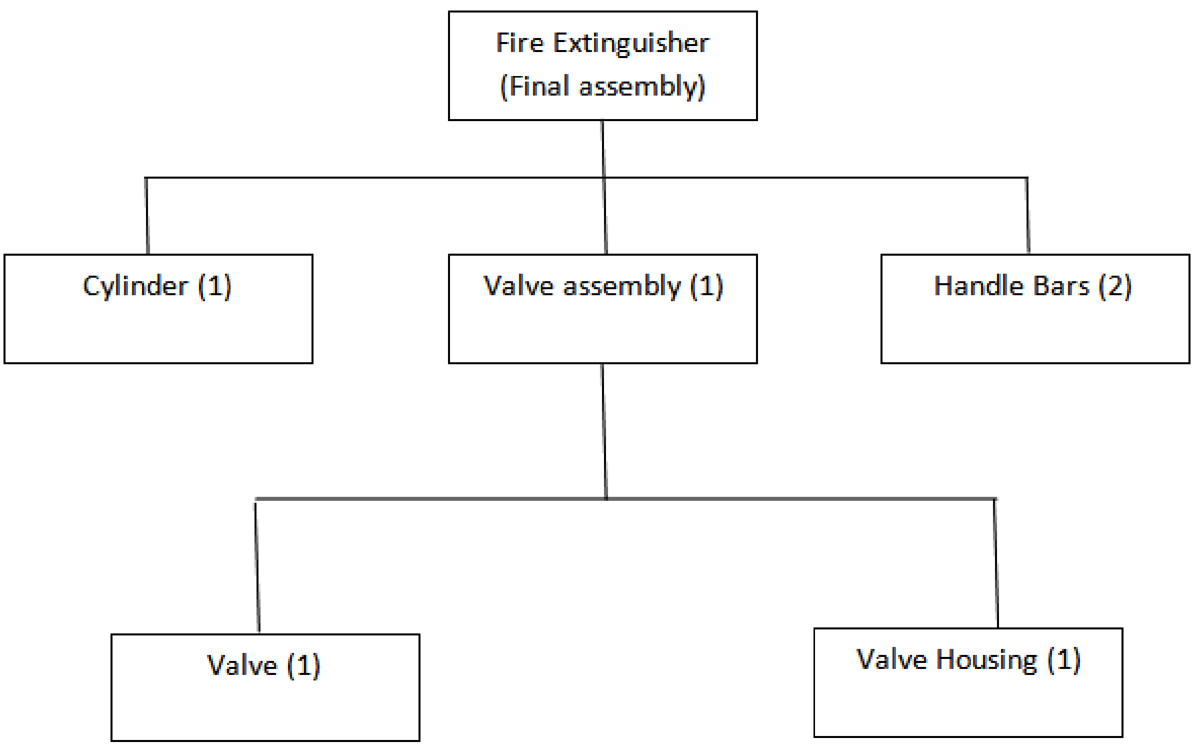
1) **Master Production Schedule (MPS)**:-

The MPS specifies what end product are to be produced and when. The planning schedule should be long enough to cover the cumulative lead times of all components that must be purchased or manufactured to meet the end product requirements.

2) **Bill of Material, File or Product Structure File (BOM)**:-

This file gives the information on all the materials, components, parts that go into the end product. The BOM can be regarded as having a series of levels, each of which represents a stage in the manufacture of end product. The highest level (or zero level) of BOM represents end products.

For example: - a firm has planned to manufacture fire extinguisher whose B.O.M. is as shown below.



BOM of fire extinguisher Fig.

MODULE-2

MRP Concept:-

Terminologies used in doing MRP calculations are as follows.

- Projected requirements
- Planned order release
- Economic order Quantity
- Stock on hand.

MPS (Master Production Schedule) gives particulars about demands of final assembly for products. These are known as Projected Requirements of Final assembly. The projected requirements of subassemblies which are in the next immediate level just below the final product can be calculated only after the MRP calculations for final product. Similarly projected requirements for components in the second level can be calculated only after MRP calculations for the components in the first level.

Stock on Hand is level of inventory at the end of each period. For each period, the stock on-hand is computed by using following formula.

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

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

SOH_{t-1} = Stock on hand at end of period (t−1)

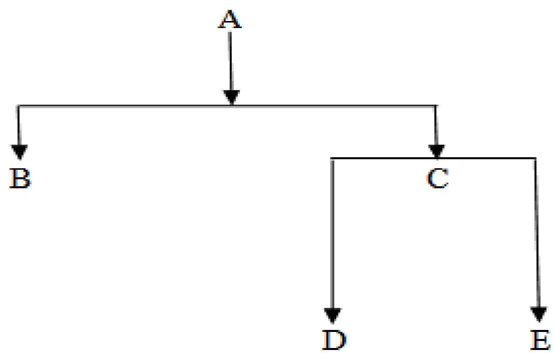
R_t = Receipt (Scheduled receipt) at beginning of period t.

Qn.: Consider the manufacture of toy. The Master Production Schedule to manufacture the toy is given in the following table.

Master Production Schedule

Week	1	2	3	4	5	6	7	8
Demand	200	-	100	175	300	200	-	250

The BOM structure is given in following figure.



The details of BOM along with EOQ and SOH for final product and subassemblies are shown in following table.

Details of BOM

Part Reqd.	Order Quantity	No. of Units	LT (Week)	SOH
A	350	1	2	200
B	450	1	1	400
C	400	1	1	375
D	375	1	1	250
E	400	1	2	425

Complete MRP plan for main product A as well B.

<u>MRP calculations for A</u>

EOQ=350, LT=2 week

Period	0	1	2	3	4	5	6	7	8
Projected requirements		200	-	100	175	300	200	-	250
Receipts				350		350	350		
SOH	200	0	0	250	75	125	275	275	25
				-100		-225	-75		
Planned order release		350		350	350				

MRP Calculations for B

EOQ=450, LT=1 Week

Period	0	1	2	3	4	5	6	7	8
Projected Requirements		350		350	350				
Receipts				450	450				
SOH	400	50	50	150 −300	250 −200	250	250	250	250
Planned Order Release			450	450					

Projected requirement of B is same as planned order release of final product A because 1 unit of A requires 1 unit of B.

Project Management:

What is a Project?

Project: A Project is an organized endeavor to accomplish a specified non-routine or low volume task. Projects are, by nature, not repetitive, however they take significant amount of time to complete and are complex enough to be managed as separate undertaking.

Management of a Project is slightly different from management of routine business activities. The objective of a project team is to accomplish its assigned mission and disband.

A Project consists of interrelated activities which are to be executive in a certain order before the entire task is completed. The activities are interrelated in a logical sequence which is known as **Precedence relationship**. A particular activity of a project can't be started until all its immediate preceding activities are finished.

Examples of Project are as follows:-

1) Construction of house
2) Construction of bridge
3) Construction of dam
4) Commissioning of Power plant
5) New Product development
6) Missile launching
7) Conduct of Election in a country or a state etc.

Every Project is unique in itself in same way or other.

Importance of Project Management

Organizations need Project management because project management (i) ensures that customer requirements are met (ii) eliminates duplication of work (iii) reduces the number of tasks that could be overlooked during the project (iv) ensures that projects are in control both in terms of project completion time and project cost.

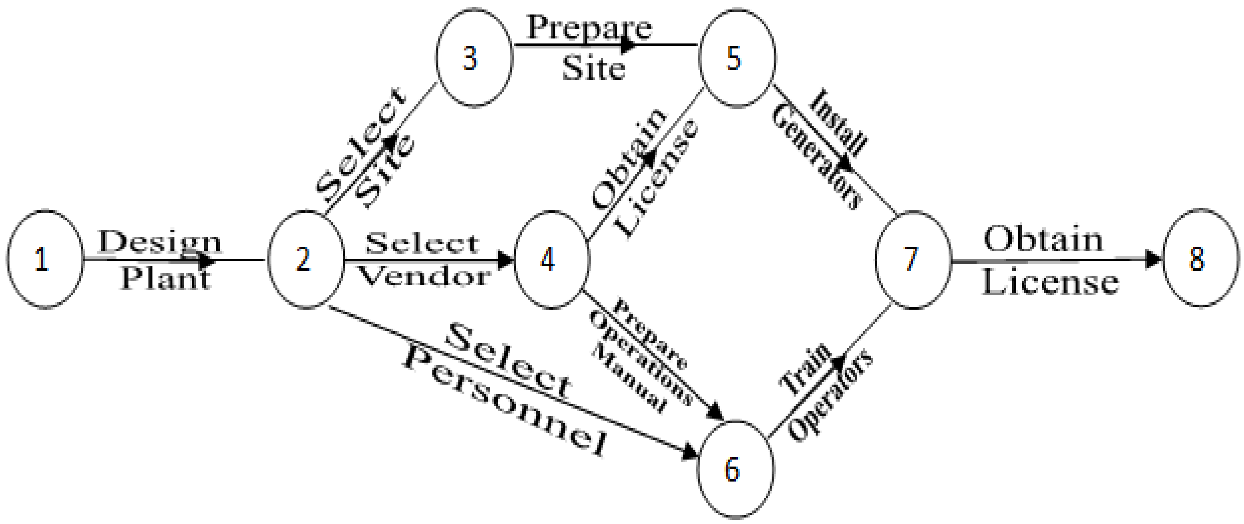
Network techniques used for Project Scheduling

Mainly, PERT and CPM are the network techniques used for Project Scheduling, prior to go into details of Network techniques we must know some network fundamentals.

Network Fundamentals

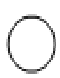
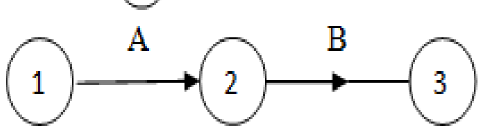
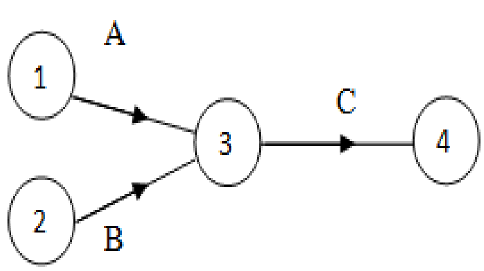
A network diagram is a model that uses small circles (nodes) connected by lines or branches (arcs) to represent precedence relationships. Networks are frequently used to show the precedence relationship among activities. **PERT**

(Programme Evaluation and Review Technique) and **CPM** (Critical Path Method) are network techniques for analysis system. Some activities can be done concurrently, whereas others have precedence relationships.



Network diagram for power plant construction

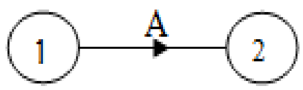
Commonly used Network Symbols:

Symbol	**Meaning**
	Activity
	Dummy activity
	Event
	Activity A must be completed before activity B can begin.
	Activities A and B must be completed before activity C can start. Activities A and B can occur concurrently.

Terms used in Network Based Scheduling Techniques.

1) **Activity**: - An effort required to complete a part of a Project. (⟶)
2) **Event**: - Event marks the beginning or end of an activity within the Project.

e.g.:-

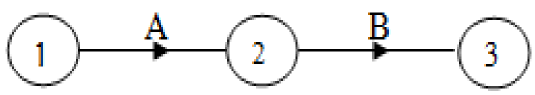


1 and 2 → Events

A → Activity.

3) **Predecessor activity**: - An activity that must occur before another activity.

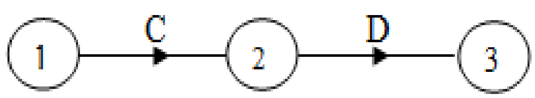
e.g.:-



Activity 'A' is predecessor activity of activity 'B'

4) **Successor activity**: - An activity that must occur after completion of another activity.

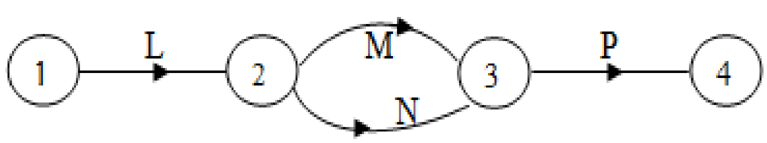
e.g.:-



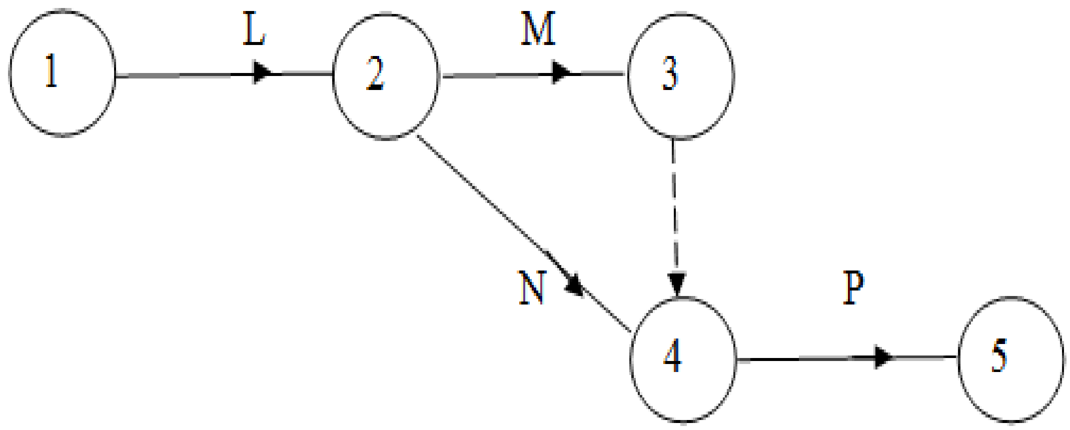
Activity 'D' is successor activity of activity 'C'

5) **Dummy activity**: - An activity that consumes zero time and zero money. This activity is needed to maintain precedence relationship in Network diagram.

e.g.:-



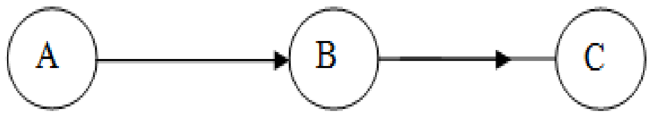
In the above diagram two activities M and N are having same event number 2 and 3. This diagram is wrong since **no two activities can be represented by the same set of event numbers**. The above diagram can be correctly drawn by inserting a **Dummy** activity as shown below.



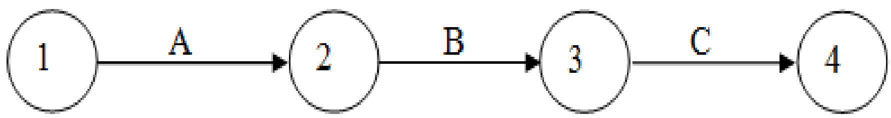
1) **Activity Duration**: - This is the time required to complete an activity.
2) **Earliest Start Time (EST)**:- The earliest that an activity can start.
3) **Earliest Finish Time (EFT)**:- The earliest that an activity can finish.
4) **Latest Start Time (LST):-**The latest that an activity can start without causing a delay in completion of the project.
5) **Latest Finish Time (LFT):-** The latest that an activity can finish without causing a delay in completion of Project.
6) **Slack: -** The amount of time that an activity can slip without causing a delay in the completion of the project. It is also known as float.
7) **Critical activity**: - An activity that has no room for schedule slippage. If it slips the entire project completion will be delayed: An activity with zero slack.
8) **Critical Path**: - The chain of critical activities for the project. The longest path through the Network.

Networking Conventions

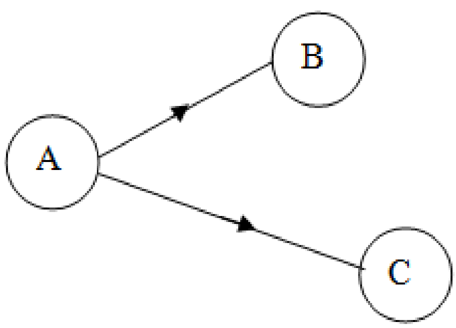
Two conventions are used for developing a Network. One convention uses circles to represent the project activities, with arrows linking them together to show the sequence in which they are performed. This is called Activity-on-Node (AON) Convention.



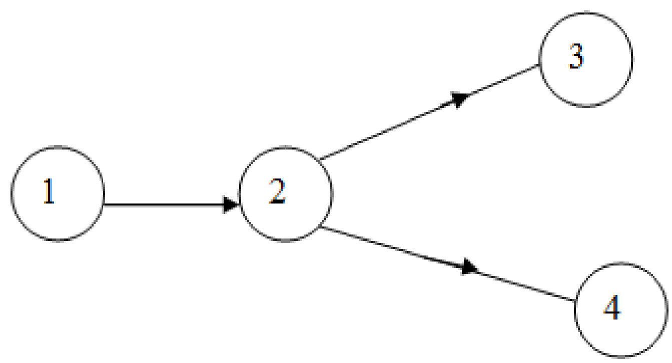
The same can be drawn on Activity on Arrow diagram (A – O – A) as follows.



AON Convention



AOA Convention



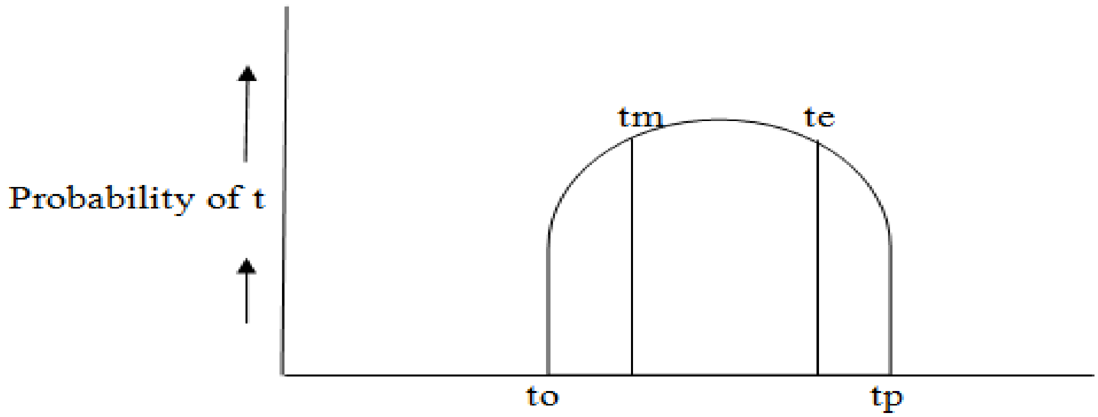
A must be completed before B or C can begin.

In **A-O-A** convention, circles or nodes represent events. Event consumes no resources, whereas activity consumes resources. Activities are represented in arrows.

The A-O-A diagram is commonly used in Project Management.

Programme Evaluation and Review Technique

It is a probabilistic model. In this model, three time estimates are used. Expected duration of an activity is a weighted average of three estimates.



→ Activity duration 't' (in days)

The average or expected time is,

$$te = \frac{to + 4tm + tp}{6}$$

where te = expected activity time

to = optimistic time

tp = pessimistic time

tm = Most likely time

to (optimistic time):- is the time estimate that has a very small probability of being reached. This is time estimate of an activity when everything seems to be alright.

tp (pessimistic time) :- is the time estimate of an activity when everything goes wrong. Probability is quite low of order of 1 in 100.

tm (most likely time) :- This is the time the activity would most often require if the work were done again and again under identical conditions. This distribution is called β distribution. PERT is used for non-repetitive projects. Time estimates are not known with certainty. PERT technique has been used for projects such as developing missiles, nuclear powered submarines.

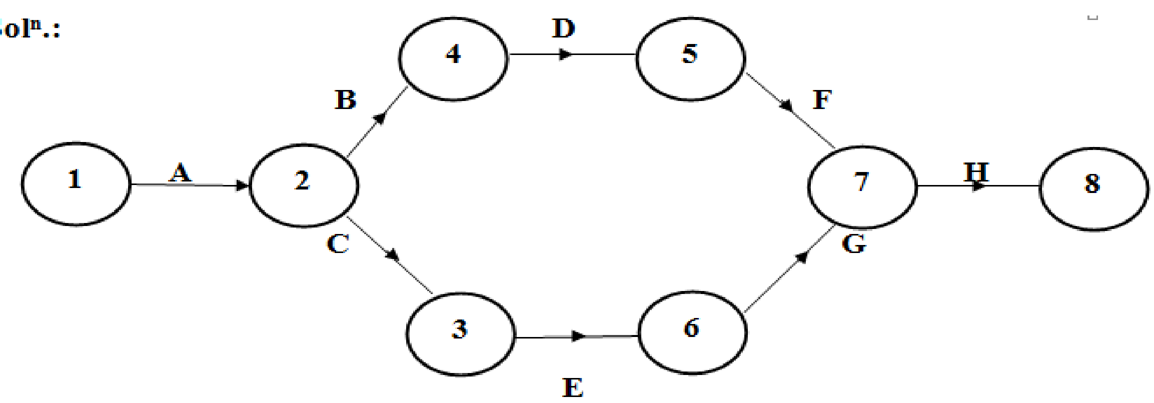
<u>Critical Path Method</u>

CPM refers to a quantitative technique which when applied to network planning helpful in calculating the minimum time and the sequence of tasks needed to complete the project. This technique is used for construction projects like bridges, building dams, canals etc. time estimates of each activity is known with certainty, Actual time is used for each activity. This is called a deterministic model.

Q^n.: Draw the network diagram for the data given below.

Activity	Immediate Predecessor Activity
A	**-**
B	**A**
C	**A**
D	**B, C**
E	**C**
F	**D**
G	**E**
H	**F, G**

Sol^n.:



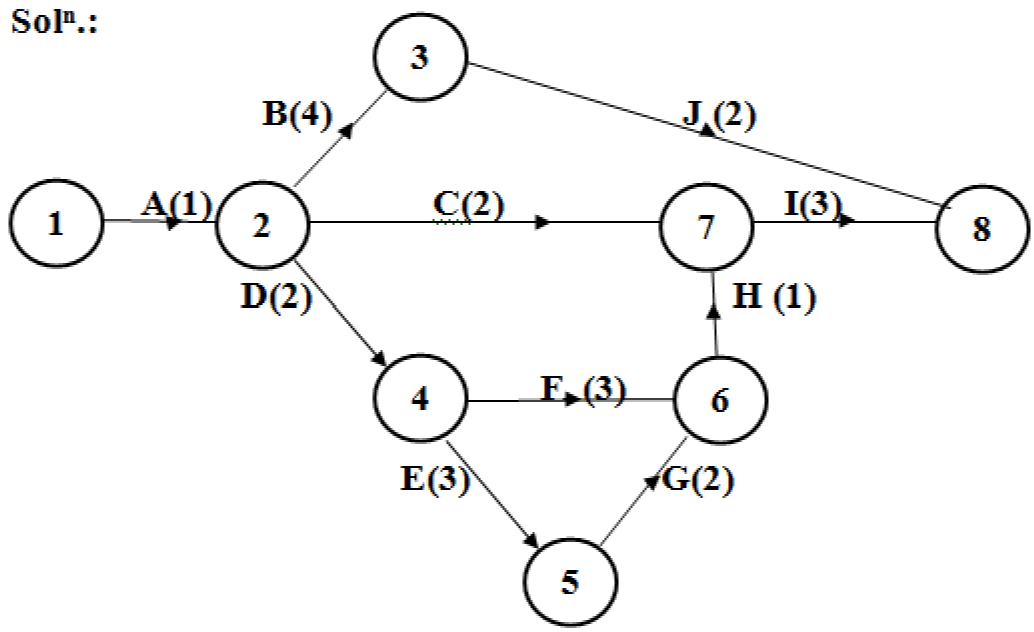
Activity 3-4 is a dummy activity

Q^{n}.: Consider the following problem involving activities from A to J.

Activity	Immediate Predecessors	Duration (Months)
A	-	1
B	A	4
C	A	2
D	A	2
E	D	3
F	D	3
G	E	2
H	F, G	1
I	C, H	3
J	B	2

Construct CPM network

Sol^{n}.:

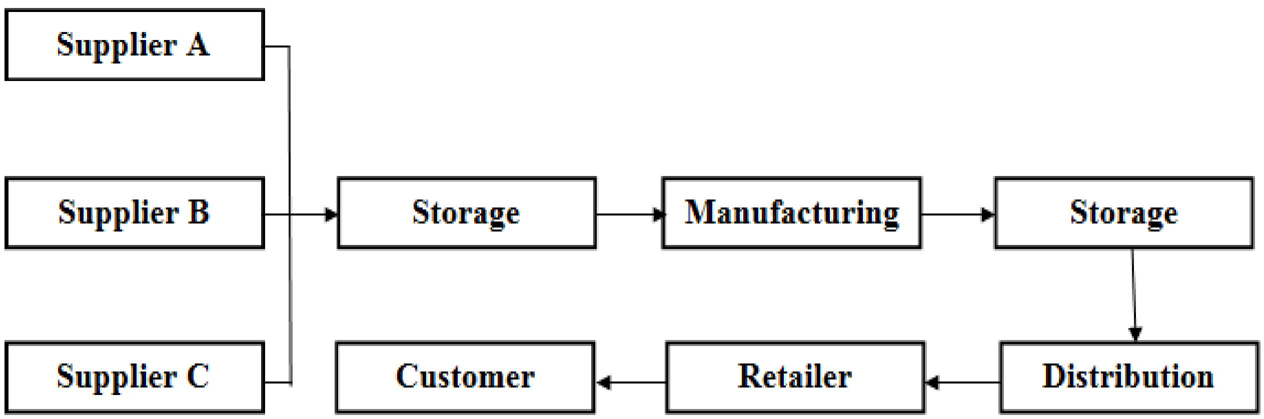


MODULE-3

Supply Chain Management

A supply chain is a sequence of suppliers, warehouses, operation and retail outlets. Different companies may have different supply chains due to the nature of their operations and whether they are manufacturing or a service operation.

Supply chain for a Manufacturing organization:-



A large company will have several supply chains, large companies such as P and G or GE may use 50 to 100 different supply chains to bring their products to the market. There has been a great deal of interest recently in industry and academia in the subject of supply chain management. The reasons for this are

(i) The total time for materials to travel through the entire supply chain can be quite long (say 6 months to one year or more). Since materials spend so much time waiting in inventory, there is great opportunity to reduce the total supply chain cycle time leading to a corresponding reduction in inventory, increased flexibility, reduced costs and better deliveries.

(ii) Many companies have drastically improved their internal operations and now find it necessary to consider relations with external customers and suppliers in the supply chain to gain further improvements.

Supply Chain:

A supply chain consists of all activities involved, directly or indirectly, in fulfilling customer's request. It not only includes the manufacturers and suppliers, but also transporters, warehouses, retailers and customers themselves. Within a manufacturing organization, supply chain includes functions such as new product development, marketing, operations, distribution, and finance and customer service.

A supply chain is dynamic and involves constant flow of materials, information and fund between different stages. Each stage of supply chain performs different processes and interacts with other stages of supply chain. Supply chain activities begin with a customer order and end when a satisfied customer has paid for his or her purchase.

A typical supply chain may include the following stages.

- Customer
- Retailers
- Wholesalers/distributors
- Manufacturers
- Component/raw material Suppliers

Objectives of Supply Chain

(i) To maximize overall value generated.

(ii) To achieve maximum supply chain profitability. Supply chain profitability is total profit to be shared across all supply chain stages.

(iii) To reduce supply chain costs to minimum possible level.

Quality Control

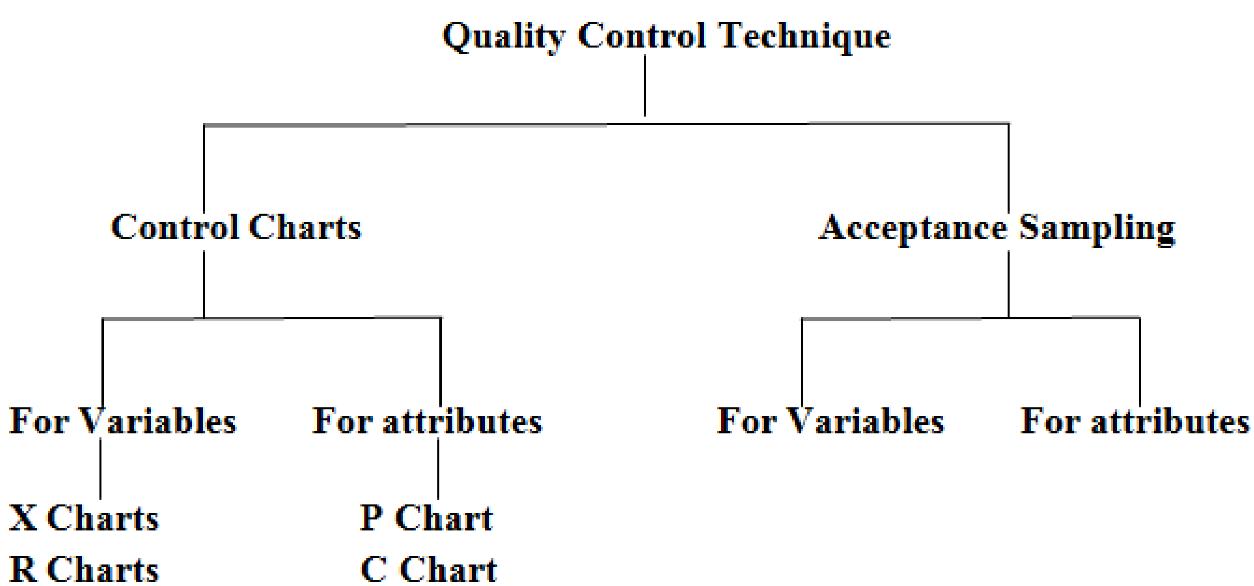
Quality:-

In any business organization, profit is the ultimate goal. To achieve this, there are several approaches. Profit may be maximized by cutting costs for same selling price per unit. In a competitive environment, goods and services produced by a firm should have minimum required quality. Extra quality means extra cost.

Quality is a measure of how close the good or service is to standard.

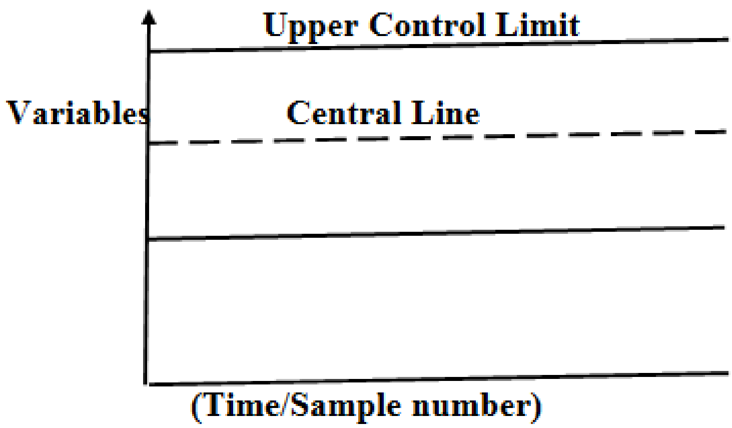
Quality standards may be any one or a combination of attributes/variables of product being manufactured. The attributes include performance, reliability, appearance, commitment to delivery time etc. Variables may be measurement like length, width, height, diameter etc. The characteristics related to services are meeting promised due dates, safety, comfort, security etc.

Classification of Quality Control Techniques



Control Charts

Control Charts show the performance of a process from two points of view. First they show a snap-shot of process at the moment the data are collected. Second, they show the process trend as time progresses.



X – axis shows observation numbers in sequence. The Y – axis shows sample values of the observation. There are three lines, namely upper control limit (UCL), lower control limit (LCL), and central line. The central line is w.r.t avg. of observations.

Control Chart for Variables

$\bar{X}$ Chart and $\bar{R}$ Chart

Control limits for $\bar{X}$ - Chart

Upper control limit,

$$UCL_{\bar{X}} = \bar{\bar{X}} + 3\sigma_{\bar{X}}$$

$$= \bar{\bar{X}} + \frac{3\sigma}{\sqrt{n}}$$

Where $\bar{X}$ = mean of a sample

$\bar{\bar{V}}$ = mean of sample means

where

R = Range of a sample observations

σ_R = Standard deviation of R

Procedure to construct $\overline{X}$-chart and R-chart

1. Identify the process to be controlled.
2. Select the variable of interest.
3. Decide a suitable sample size (n) and number of samples to be collected (k).
4. Collect the specified number of samples over a given time interval.
5. Find the measurement of interest for each piece within the sample.
6. Obtain mean ($\overline{X}$) of each sample $(\overline{X} = [\Sigma X_i]/n)$.

   Also obtain the range (R) of each sample (R = max X_i – min X_i).

   Then obtain $\bar{\bar{X}}$ and $\bar{R}$ $\{\bar{\bar{X}} = [\Sigma \overline{X}]/k,\ \bar{R} = \Sigma R/k\}$.
7. Establish control limits for $\overline{X}$ and R-charts.

   In practice, the calculations of control limits based on standard deviation are a cumbersome process. Hence, they are established using table values (A, B and C) which are used as factors in the formulas to establish control limits.

   Control limits for $\overline{X}$

   $$UCL_{\overline{X}} = \bar{\bar{X}} + A\bar{R}$$
   $$LCL_{\overline{X}} = \bar{\bar{X}} - A\bar{R}$$

   Control limits for R

   $$UCL_R = B\bar{R}$$
   $$LCL_R = C\bar{R}$$

   The values for A, B and C for different sample sizes are given in Table below. The values of the factors are based on normal distribution.
8. Incorporate the control limits on $\overline{X}$ and R-charts.

9. Plot $\overline{X}$ and R-values in $\overline{X}$ and R-charts, respectively.
10. Hunt for assignable causes when the process is out of control.

We can say that a process is out of control if

(i) Some points are outside the extreme control limits (UCL and LCL).
(ii) There exists a predominant trend among the plots of the points on one side of the chart with respect to the central line, and
(iii) There exists an erratic shift in the process.

When $\overline{X}$-chart is used along with R-chart, it tells when to leave the process alone and when to chase and hunt for the cause which leads to variation.

Table for Factors of Control Charts

Sample Size n	Mean Factor A	Upper Range Factor B	Lower Range Factor C
2	1.88	3.07	0.00
3	1.02	2.57	0.00
4	0.73	2.28	0.00
5	0.58	2.11	0.00
6	0.48	2.00	0.00
7	0.42	1.92	0.08
8	0.37	1.86	0.14
9	0.34	1.82	0.18
10	0.31	1.78	0.22
11	0.29	1.74	0.26
12	0.27	1.72	0.28
13	0.25	1.69	0.31
14	0.24	1.67	0.33
15	0.22	1.65	0.35
16	0.21	1.64	0.36
17	0.20	1.62	0.38
18	0.19	1.61	0.39
19	0.19	1.60	0.40
20	0.18	1.59	0.41

Q^n.: The following data were obtained over a five-day period to indicate $\overline{X}$ and R control chart for a quality characteristic of a certain manufacturing product that had required a substantial amount of network. All the figures apply to the product made on a single machine by a single operator. The sample size was 5. Two samples were taken per day. Comment on the process using $\overline{X}$ and R charts.

Sample Number	Observations 1	2	3	4	5	$\overline{X}$	R
1	10	12	13	8	9	10.4	5
2	7	10	8	11	9	9.0	4
3	11	12	9	12	10	10.8	3
4	10	9	8	13	11	10.2	5
5	8	11	11	7	7	8.8	4
6	11	8	8	11	10	9.6	3
7	10	12	13	13	9	11.4	4
8	10	12	12	10	12	11.2	2
9	12	13	11	12	10	11.6	3
10	10	13	7	9	12	10.2	6

$\Sigma X = 103.2 \quad \Sigma R = 39$

$$X = \Sigma X/k = 103.2/10 = 10.32$$

$$\bar{R} = \Sigma R/k = 39/10 = 3.9$$

The value for A, B and C for the sample size of 5 are given below,

For n=5, A=0.58, B=2.11 and C=0

Control limits for $\overline{X}$

$$UCL_{\overline{X}} = \overline{X} + AR = 10.32 + .58 \times 3.9$$
$$= 10.32 + 2.262 = 12.582$$

$$LCL_{\overline{X}} = \overline{X} - AR = 10.32 - 0.58 \times 3.9$$
$$= 10.32 - 2.262 = 8.058$$

Control limits for R

$$UCL_R = BR = 2.11 \times 3.9 = 8.229$$
$$LCL_R = CR = 0 \times 3.9 = 0$$

The above control limits for $\overline{X}$ and R-charts are shown in the figures given below. The sample $\overline{X}$ and R-values are also plotted on the respective figures.

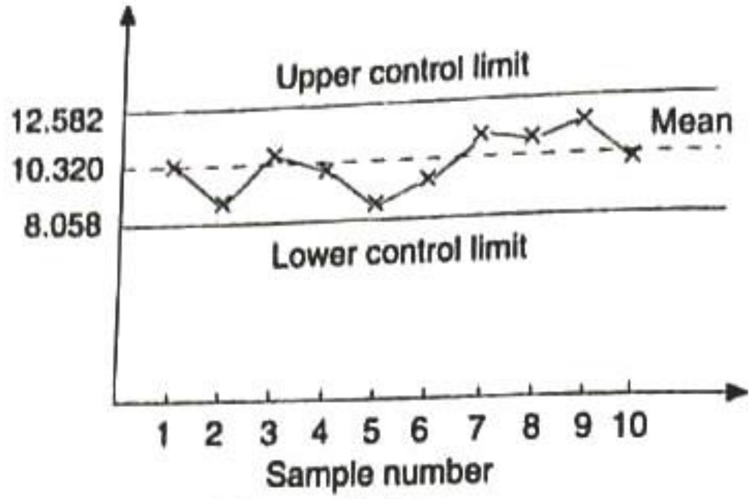


Fig. on $\overline{X}$-chart.

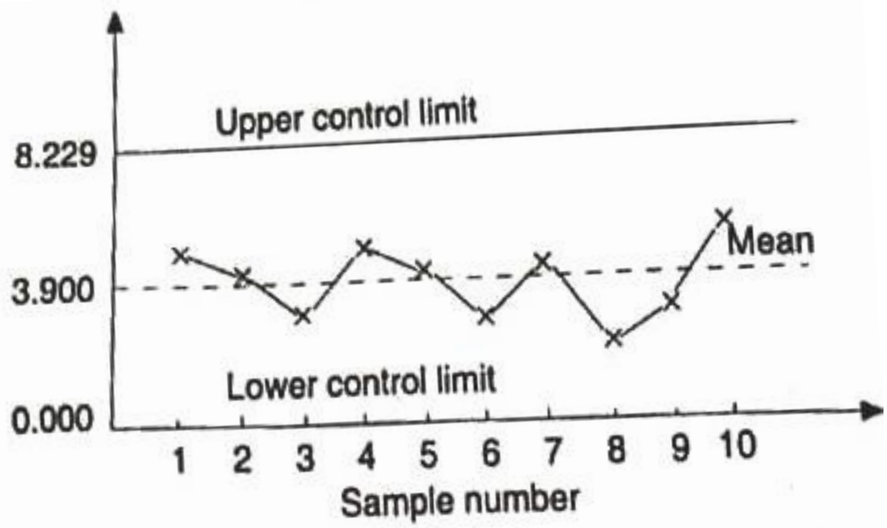


Fig. on R-chart.

Comment. All the points in $\overline{X}$-chart are within the control. All the points on the R-chart are also within the control limits. But, there is a dominant up-trend towards right hand side of $\overline{X}$ chart. So we will have to hunt for reasons for variations. This may be due to tool wear, operator fatigue, etc.

Control Charts for Attributes

In many situations, quality measurements are expressed as attributes (good or bad etc). In such situations, the percent defective chart (P-chart) or the number of defectives per sample area (C-chart) are considered to be more suitable control charts to control the quality.

Both charts convey a similar type of information, but P-chart is based on a normal distribution, and the C-chart is based on the Poisson distribution.

P-chart. The other name for P-chart is percent defective chart. The purposes of this chart are summarized below.

(a) To discover the average proportion of non conforming articles or parts submitted for inspection over a period of time.

(b) To bring to the management attention, if there is any change in average quality level.

The formulas for control limits are as follows:

$$UCL_p = \bar{p} + 3\sqrt{\bar{p}(1-\bar{p})/n} = \bar{p} + 3\sigma_p$$

$$LCL_p = \bar{p} - 3\sqrt{\bar{p}(1-\bar{p})/n} = \bar{p} - 3\sigma_p$$

where

p = process percent defective of a sample
= (Number of defective items in a sample)/n

$\bar{p}$ = Process mean per cent defective

n = Sample size

k = Number of samples

σ_p = Standard deviation of per cent defectives

Example: Alpha electronic company manufactures cathode ray tubes on mass production basis. At some intermediate point of production line, 15 samples of size 50 each have been taken. Tubes within each sample were classified into good or bad. The related data are given in the following table. Construct a P-chart with 3 sigma limit and comment on the process.

Sample Number	**Number of Defective Tubes**	**Percentage of Defective Tubes**
1	10	0.20
2	10	0.20
3	9	0.18
4	10	0.20
5	4	0.08
6	6	0.12
7	2	0.04
8	3	0.06
9	9	0.18
10	4	0.08
11	8	0.16
12	11	0.22
13	8	0.16
14	10	0.20
15	9	0.18

$$\bar{p} = 113/(15 \times 50) = 0.151$$

$$UCL_p = \bar{p} + 3\sqrt{\bar{p}(1-\bar{p})/n}$$

$$UCL_p = 0.151 + 3\sqrt{0.151(1-0.151)/50}$$

$$= 0.301$$

$$LCL_p = 0.151 - 3\sqrt{0.151(1-0.151)/50}$$

$$= .001 = 0 \text{ (Approx.)}$$

The limits are incorporated in the following figure along with the sample observations.

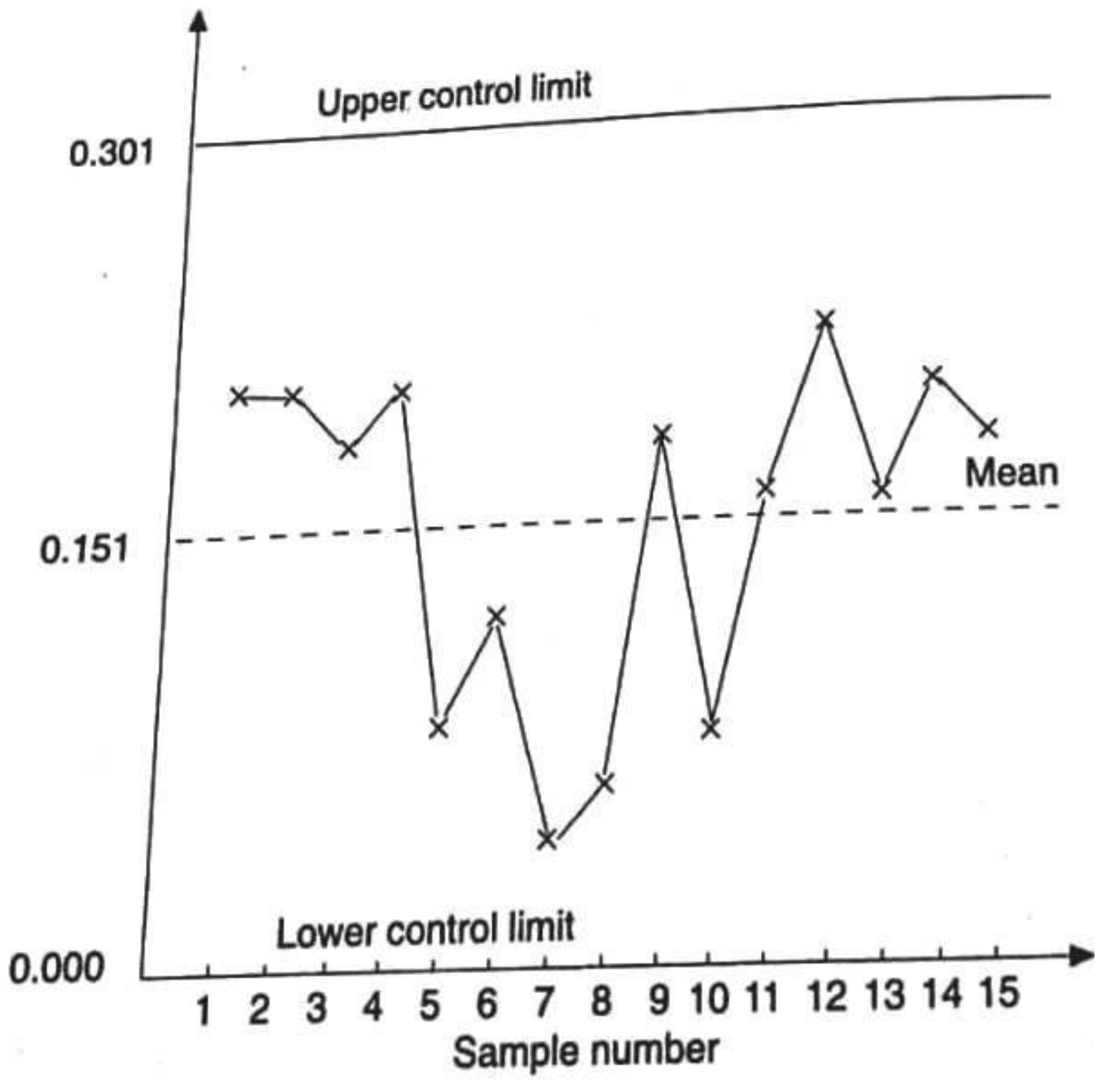


Fig. *P*-chart.

Solution. From this figure, it is clear that all the points are within the control limits. But, there is an upswing towards the right hand side of the figure. This means that there is predominant up-trend which may take the process out of control in future, if no corrective action is taken.

Content of ISO 9000

ISO 8402 deals with standardization of quality vocabulary. ISO 9000 is actually a series of guidelines for selection and use of the appropriate systems standards of ISO 9001, ISO 9002 or ISO 9003. Thus, ISO 9000 is the road map to the entire series. ISO 9004 helps building up a quality system that can fit to a specific situation. It offers guidelines for interpreting the elements required in ISO 9001, ISO 9002 or ISO 9003. There are 20 chapters in ISO 9004, viz: (1) scope and field of application, (2) references, (3) definitions, (4) management responsibility, (5) quality system principles (structure of the quality system, documentation and auditing of the quality system), (6) economics (quality-related cost considerations), (7) quality in marketing, (8) quality in specification and design, (9) quality in procurement, (10) quality in production (process control), (11) control of production, (12) product verification (inspection and testing), (13) control of measuring and test equipment, (14) non-conformity (control of non-confirming product), (15) corrective action, (16) handling and post production actions (storage, packing, delivery and after-sales service), (17) quality documentation and records, (18) personnel (testing), (19) product safety and liability, and (20) statistical methods. After a company adopts ISO 9000, an independent official certifying body will assess the company. The assessor will check whether the company, desirous of the certification, has covered the basic quality elements pertaining to its industry, business, and customers. The firm then gets certified to either ISO 9001, ISO 9002, or ISO 9003.

ISO 9001 is the most difficult of the three standards to be chosen for certification, because it includes all the twenty elements. This comprehensive certification is desired by manufacturing organizations which design their own products. For ISO 9002 certification, two of those twenty elements are dropped viz. design and servicing, so as to focus more on manufacturing. ISO 9002 applies to firms which provide goods and/or services as per the design or specifications given by the customer. Many process industries used to opt for the ISO 9002 certification as they thought that their activities neither involve design nor servicing. However, now many of these firms are seeing the parallels between R&D and ‘design’ (under the ISO) and hence opting for the comprehensive ISO 9001 certification. The ISO 9003 standard drops most of manufacturing, leaving only final testing and inspection. ISO 9003 certification is generally desired by organizations like the testing laboratories which inspect and test the supplied products. This ISO standard is the least comprehensive of the three.

It may be worth repeating that ISO 9000 series is a system standard and not a product quality standard. If a firm gets ISO 9000 certification, it does not automatically mean that the firm’s products/services are superior in quality to the other firm which has not opted for such certification. For instance, for a long time, Japanese firms producing excellent quality products have not bothered to obtain the ISO certification. This does not make their products and services inferior in quality.

Benefits from ISO 9000

There are many benefits of getting an ISO certification:

1. ISO 9000 certification has become the de facto minimum requirement for those wishing to compete globally.
2. All actions in preparing for ISO 9000 certification and in maintaining the certification would result in streamlining of the quality management system which may lead to improvements in product quality. The extent of improvement may vary from one firm to another.

SIX SIGMA

The term 'Six Sigma' indicates that

(a) this is a quantitative methodology, and
(b) it is much more stringent that the traditional 'three sigma' statistical process control (SPC) model.

One may indeed look at Six Sigma as the big brother of traditional SPC. But, that would amount to taking a very narrow view of Six Sigma. First of all, in statistical terms, the change from three sigma to six sigma is a drastic change. The table given below depicts this.

TABLE: What do Various Sigma Levels Mean?

Sigma Level	Yield %	Defects per Million Opportunities
1	30.9	6,90,000
2	69.2	3,08,537
3	93.3	66,807
4	99.4	6,210
5	99.98	233
6	99.9997	3.4

In purely statistical terms, having six sigma control limits on either side of the mean of a process is so stringent a control that it ceases to be just a control methodology. Rather, the traditional corrective mechanisms used for the three sigma process controls will not work here. In order to get the level of perfection needed for this new six sigma, an adjustment to the process here and a tinkering to the process there will not at all suffice. Six Sigma requires that an organization takes a huge and sustained initiative to bring about a transformation in the way it functions in all areas of its endeavor.

Why Do Companies Need Six Sigma?

Technological Complexities and Multi-stage Processes Today, the technology of products like computers is such that it has to totally defect-free. The need for 'zero defects' is acutely felt in these technologically advanced times. To add to the woes, manufacturing has become a more complex activity than in the earlier days – it has now multiple processes following each other. Defects can arise at any or all of these successive processes.

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