LECTURE NOTES

ON

INDUSTRIAL ENGINEERING AND MANAGEMENT

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Industrial Engineering:

Introduction

- The American Institute of Industrial Engineers (AIIE) has defined the Industrial Engineering as "Concerned with design, improvement and installation of integrated systems of people, materials, equipment and energy."
- Industrial Engineering is going to play a pivotal role in increasing the productivity. It is the engineering approach to the detailed analysis of the use and cost of the resources of an organization. The main resources are men, money, materials, equipment and machinery.
- The Industrial Engineer carries out such analysis in order to achieve the objectives (to increase productivity or profits etc) and policies of the organization.

  Main function of an Industrial Engineer
    - Design of a system and management of that system
    - Productivity Improvement

Productivity Improvement means:

- More efficient use of resources
- Less waste per unit of input supplied
- Higher levels of output for fixed levels of input supplied

The inputs are:

- Human efforts
- Energy
- Materials
- Invested capital

Present state of Industrial Engineering:

- Value engineering
- Operation research
- CPM and PERT
- Human Engineering(Ergonomics)
- System analysis
- Advances in Information Technology and Computer packages
- Mathematical and statistical tools

Activities of Industrial Engineering:

- Selection of processes and assembling methods
- Selection and design of tools and equipment
- Design of facilities including plant location layout of buildings, machines and equipments material handling system, raw materials and finished goods storage facilities.
- Design and improvement of planning and control system for production, inventory, quality and plant maintenance and distribution systems.
- Developing a cost control system such as budgetary control, cost analysis and standard costing.
- Development of time standard, costing and performance standards
- Development and installation of job evaluation system
- Installation of wage incentives schemes
- Design and installation of value engineering and analysis system
- Operation research including mathematical techniques and statistical analysis
- Performance evaluation
- Organization and methods
- Project feasibility studies
- Supplier selection and evaluation

Objective of Industrial Engineering:

- To establish methods for improving the operations and controlling the production costs
- To develop programs for reducing those costs

Technique of Industrial Engineering :

- Method study
- Time study
- Motion study
- Financial and non-financial incentives
- Value analysis
- Production, planning and control
- Inventory control
- Job evaluation
- Material handling analysis

- Ergonomics(Human engineering)
- System analysis
- Operation research techniques
- Other techniques

Applications of Industrial Engineering :

- In health services
- In government organizations
- In banking
- Others such as marketing, finance, purchasing, industrial relations etc

OPERATION RESEARCH

Optimization techniques:

The word optimization is form optimum which implies a point at which the conditions are best and most favorable.

An optimum point may represent a maximum position or minimum position.

Method for optimizing:

a) Search
b) Differential calculus
c) Statistical methods
d) Linear programming
   i. Graphical method
   ii. Transportation method
   iii. Simplex method
e) Queuing theory
f) Dynamic programming

Application:

Load allocation problems, component selection, load sharing.

Operation research:

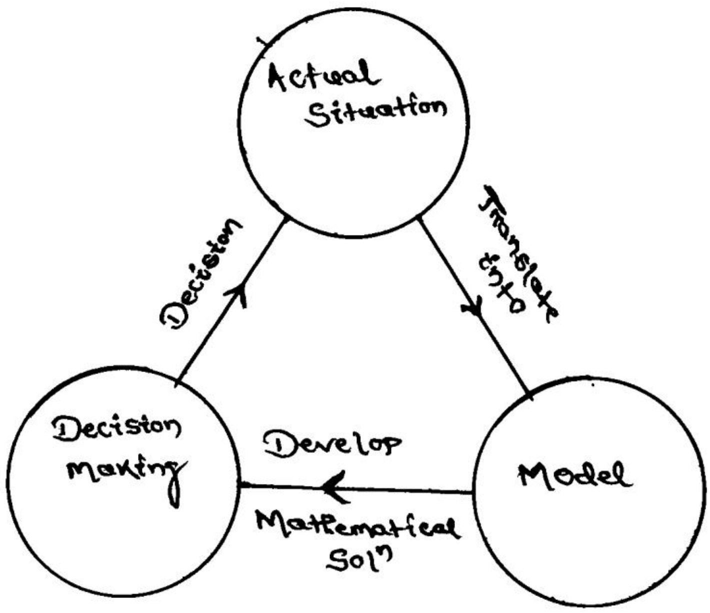
Operation research signifies research on operations. It is the organized application of modern science, mathematics and computer techniques to complex military, government, business or industrial problems arising in the direction and management of large systems of men, materials, money and machines

Methodology

1. Understand the actual real situation, capture the same and define the problem
2. Formulate a mathematical model
3. Develop a mathematical solution
4. Interpret the solution and prepare the information in such a form that it is meaningful, intelligible and quantitative. Translate it in to a decision.
5. Implement the decision to the real situation
6. Verify the results

Methods of operation research

1. Linear programming
   a) Graphical linear programming
   b) Transportation method
   c) Simplex method
2. Wait line queuing theory
3. Game theory
4. Dynamic programming



Linear programming

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.

Problem solving is based upon the system of linear equation:

Standard form of linear programming problem:

Let x_1, x_2, x_3 ………………..x_n are the decision variables.

Optimize (maximum or minimize)

$Z = c_1x_1 + c_2x_2 + \ldots\ldots\ldots + c_nx_n$ (objective function)

Subject to constraints

$a_{11}x_1 + a_{12}x_2 + \ldots\ldots\ldots + a_{1n}x_n \leq b_1$

$a_{21}x_1 + a_{22}x_2 + \ldots\ldots\ldots + a_{2n}x_n \leq b_2$

. . . .
. . . .
. . . .

$a_{m1}x_1 + a_{m2}x_2 + \ldots\ldots\ldots + a_{mn}x_n \leq b_n$

$x_1, x_2, x_3 \ldots\ldots\ldots x_n \geq 0$ (non-negative restriction)

where $c_1, c_2, c_3, \ldots\ldots\ldots c_n$ are cost or profit coefficients.

a_{ij} (i = 1, 2, 3,………n)

(j = 1, 2, 3,……..n)

$b_1, b_2, \ldots\ldots\ldots b_n$ are called requirement or availability.

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.

Formulation of LP problem:

1. From the given problem, identify the key decisions to be made.
2. Identify the decision variables, whose values give the solution to the problem.

3. Write the objective in the quantitative terms and express it as a function of linear variables.
4. Study the constraints and express them as a linear equation.

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 furniture manufacturer makes two products X_1 & X_2 namely chair and tables. Each chair contributes a profit of Rs 20 and each table that of Rs 40. Chairs and tables from raw material to finished product, are processed in 3 sections S_1, S_2, S_3. In section S_1 each chair (X_1) requires 1 Hr and each table (X_2) requires 4 Hrs of processing. In section S_2, each chair requires 3 Hrs and each table 1 Hr and in section S_3 the times are 1 and 1 Hr respectively. The manufacturer wants to optimize his profits if sections S_1, S_2, S_3 can be availed for not more than 24, 21 and 8 Hrs respectively.

ANS:

Let Chair = X_1

Table = X_2

Maximum $Z = 20X_1 + 40X_2$

	Chair	Table	Total
S_1	1	4	24
S_2	3	1	21
S_3	1	1	8

Subject to :

$X_1 + 4X_2 \leq 24$ (C_1)

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

$X_1 + X_2 \leq 8$ (C_3)

$X_1, X_2 \geq 0$ (C_4)

Where, C_1 is constraint No. 1.

C_2 is constraint No. 2.

C_3 is constraint No. 3.

C_4 is constraint No. 4.

Example 2: A firm can produce 3 types of cloth says A, B and C. Three kinds of wool are required for it say red wool, green wool and blue wool. One unit length of type A cloth needs 2 yards of red wool and 3 yards of blue wool. One unit length of type B cloth needs 3 yards of red wool, 2 yards green wool and 2 yards blue wool and one unit of type C cloth needs 5 yards of green and 4 yards of blue wool. The company has a stock of only 8 yards of red, 10 yards green wool and 15 yards of blue wool. The profit from sale of 1 unit length of type A is Rs 10, type B is Rs 8 and type C is Rs 5. Determine how the firm should use the available material so as to maximize the profit. Formulate this as LP problem.

ANS:

Let x_1, x_2 and x_3 be the no. of units of cloth of type A, type B and type C.

Objective is to maximize profit.

$Z = 10x_1 + 8x_2 + 5x_3$

Requirement wool	Clothes			Availability of
	A	B	C	
Red	2	3	___	8
Green	___	2	5	10
Blue	3	2	4	15

$2x_1 + 3x_2 \leq 8$

$2x_2 + 5x_3 \leq 10$

$3x_1 + 2x_2 + 4x_3 \leq 15$

Example 3 : 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.

ANS:

Max. $Z = 2x_1 + x_2$

$2x_1 + x_2 \leq 1000$

$x_1 \quad \leq 400$

$x_2 \quad \leq 700$

$x_1, x_2 \geq 0$

Graphical method:

1st step:

Formulate the LPM.

Max $Z = 20x_1 + 40x_2$

Subjected to $x_1 + 4x_2 \leq 24$ (c_1)

$3x_1 + x_2 \leq 21$ (c_2)

$x_1 + x_2 \leq 8$ (c_3)

$x_1, x_2 \geq 0$ (c_4)

c_1 is constrain no. 1 and so on.

2nd step:

2nd steps convert the constraint inequalities temporarily into equations.

$x_1 + 4x_2 = 24$ (c_1)

$3x_1 + x_2 = 21$ (c_2)

$x_1 + x_2 = 8$ (c_3)

3rd steps: Axis are marked on the graph paper and labeled with variables x_1 & x_2.

4th steps:

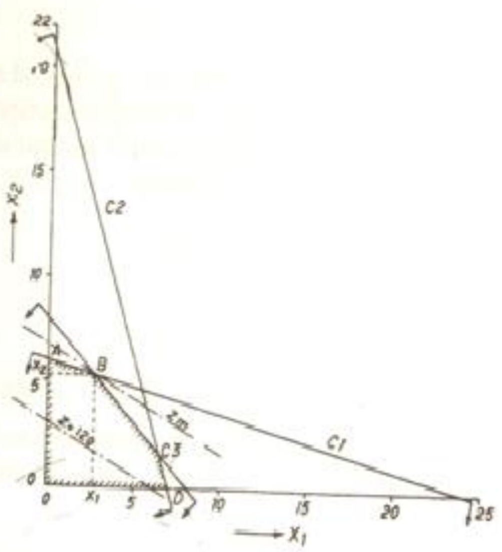
4th step is draw straight lines on the graph paper using constraint equations and to mark feasible solution on the graph paper.

Taking 1st constraint equation,

$x_1 + 4x_2 = 24$

$x_1 = 0, x_2 = 6$

$x_2 = 0, x_1 = 24$



Graphical method.

Mark the point of 24 at X_1 axis and point 6 on x_2 axis. The straight line represents c_1 equation.

Similarly, c_2 and c_3 can be plotted.

$3x_1 + x_2 = 21$	$x_1 + x_2 = 8$
$x_1 = 0, x_2 = 21$	$x_1 = 0, x_2 = 8$
$x_2 = 0, x_1 = 7$	$x_2 = 0, x_1 = 8$

According to constrain c_4, x_1 & x_2 are greater than or equal to zero, hence the marked area between $x_1 = x_2 = 0$ and c_1, c_2, c_3 represents the feasible solution.

5th step:

A dotted straight line representing the equation Z is drawn, assuming any suitable value of Z say 120.

$X_1 = 0, x_2 = 3$

$X_2 = 0, x_1 = 6$

6th steps:

A straight line Z_m 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 c_1 & c_3.

The co-ordinates at point B can be found by solving equation c_1 & c_3.

$x_1 + x_2 = 8$ (c_3)

$x_1 + 4x_2 = 24$ (c_1)

$3x_2 = 16 \Rightarrow x_2 = 5.3$

$3x_1 = 8 \Rightarrow x_1 = 2.7$

These values of x_1 and x_2 can also be read from the graph itself.

∴ The maximum value of Z is

$$Z_m = 20x_1 + 40x_2 = 20 \times \frac{8}{3} + 40 \times \frac{16}{3} = 266.6$$

NETWORK ANALYSIS

It is a system which plans projects both large and small by analyzing the project activities. Projects are broken down to individual tasks or activities, which are arranged in logical sequence.

Projects:

Project is any task which has definable beginning and definable end expenditure of one or more resources.

It is essential to manage effectively the projects through proper planning, scheduling and control as project requires a heavy investment, and is associated with risk and uncertainties.

Network scheduling:

It is a technique used for planning and scheduling large projects in the field of constructions, maintenance, fabrication and any other areas.

This technique is the method of minimizing the bottlenecks, delays and interruptions by determining the critical factors and coordinating various activities.

A network diagram:

A network diagram is constructed which presents visually the relationship between all the activities involved. Time, costs and other resources are allocated to different activities.

It helps designing, planning, coordinating, controlling and decision making in order to accomplish the project economically in the minimum available time with the limited available resources.

There are two basic planning and control techniques. They are Critical Path Method (CPM) and Program Evaluation and Review Techniques (PERT).

Objective of Network Analysis:

1. A powerful coordinating tool for planning, scheduling and controlling of projects.
2. Minimization of total project cost and time.
3. Effective utilization of resources and minimization of effective resources.

4. Minimization of delays and interruption during implementation of the project.

Application of Network Analysis (PERT and CPM):

1. Research and development projects.
2. Equipment maintenance and overhauling.
3. Construction projects (building, bridges, dams)
4. Setting up new industries
5. Planning and launching of new products.
6. Design of plants, machines and systems
7. Organization of big programs

Basic concepts in network:

Network:

It is a graphical representation of the project and it consists of series of activities arranged in a logical sequence and show the interrelationship between the activities.

Activities:

An activity is a physically identifiable part of the project, which consumes time and resources. Each activity has a definite start and end. It is represented by an arrow (→).

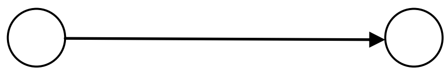
Event:

An event represents the start or completion of an activity. The beginning and end points of an activity are events.

Ex – Machining a component is an activity.

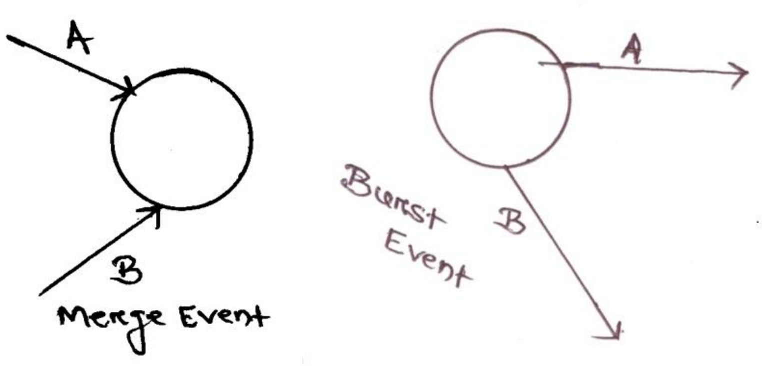
Start machining is an event.

Machining completed is an event.



Tail event Head event

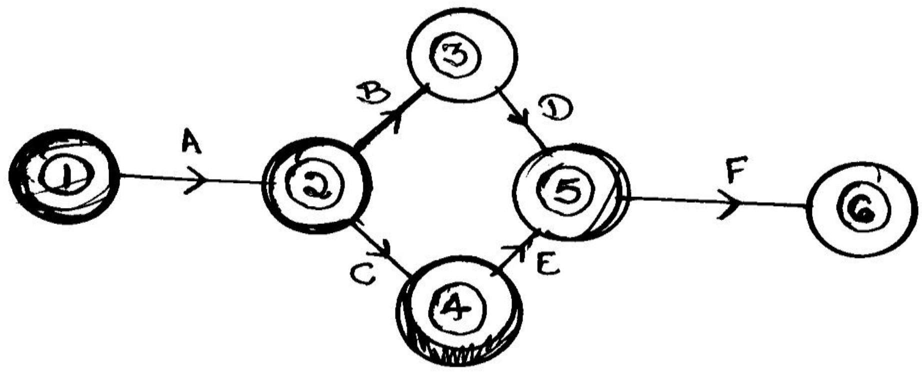
In a network a no. of activities may terminate into single node called merge node and a no. of activities may emanate from a single node called burst node.



Predecessor and successor activities:

All those activities, which must be completed before starting the activity under consideration are called its predecessor activities.

All the activities which nave to follow the activity under consideration are called its successor activities.



2-3, 2-4 are immediate successors

2-3 &2-4, 3-5, 4-5&5-1 are its successor's activities.

1-2, 2-3 are predecessors to 3-5.

2-3 is the immediate predecessors.

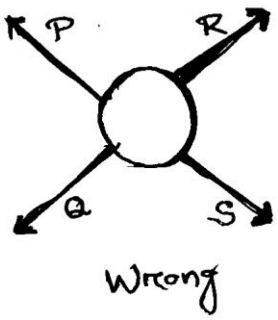
Path:

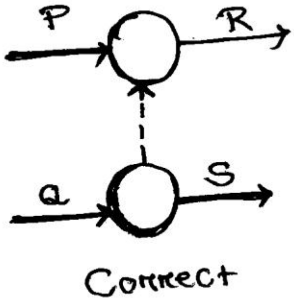
An unbroken chain of activities between two events is called a path.

Ex – A-B-D-F is a path connecting 1 & 6.

Dummy activity:

An activity which depicts the dependency or relationship over the other but does not consume time or resources. It is used to maintain the logical sequence. It is used to maintain the logical sequence. It is indicated by a dotted line.





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.

Duration:

Duration is the estimated or actual time required to complete a task or an activity.

Total project time:

It is the time which will be taken to complete the project and is found from the sequence of critical activities. It is the duration or critical path.

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. <u>Free float</u>:

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. <u>Independent float</u>:

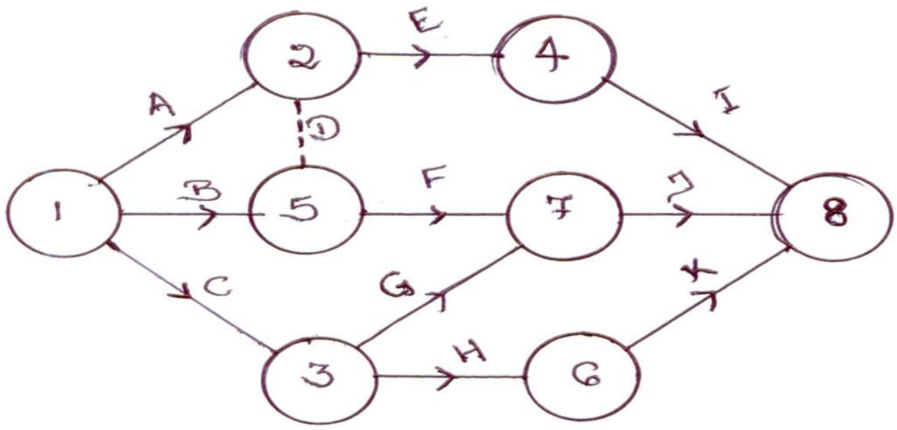
It can be used to advantage. If one is interested to reduce the effort on a non-critical activity in order to apply the effort on a critical activity by reducing the project duration.

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

If IF is negative, then taken as 0.

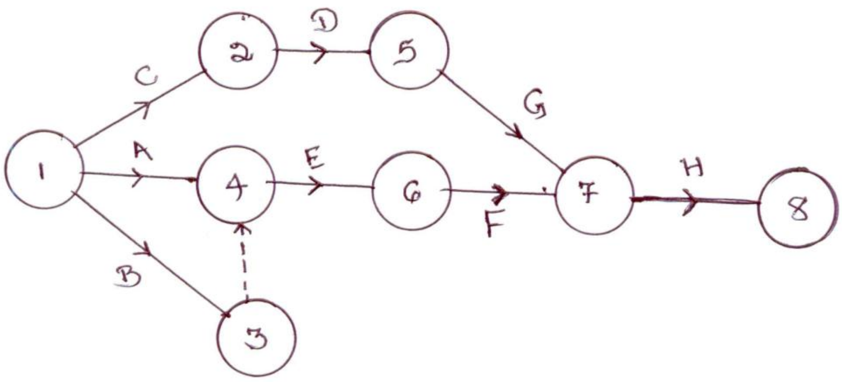
<u>Numbering of events (Fulkerson's rule)</u>:

1. The initial event which has all outgoing arrows with no incoming arrow is numbered '1'.
2. Delete all arrows coming out from node 1. This will convert some more nodes into initial events number these events 2, 3 etc.
3. Delete all the arrows going out from these numbered events to create more initial events. Assign next number to these events.
4. Continue until the final or terminal node which has all arrows coming in, with no arrow going out is numbered.



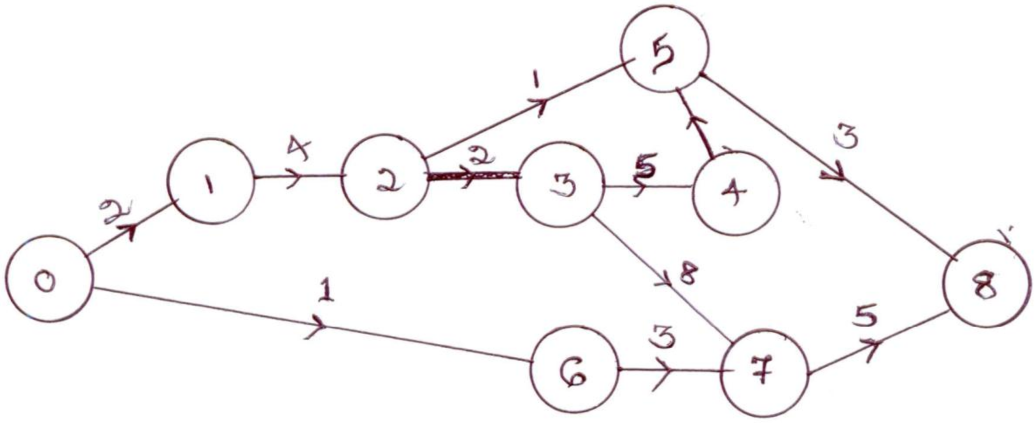
1. Construct the network from the information.

Activity	Immediate predecessor	Time
A	------	6
B	------	10
C	------	14
D	C	6
E	A, B	14
F	E, D	6
G	D	4
H	F, G	4



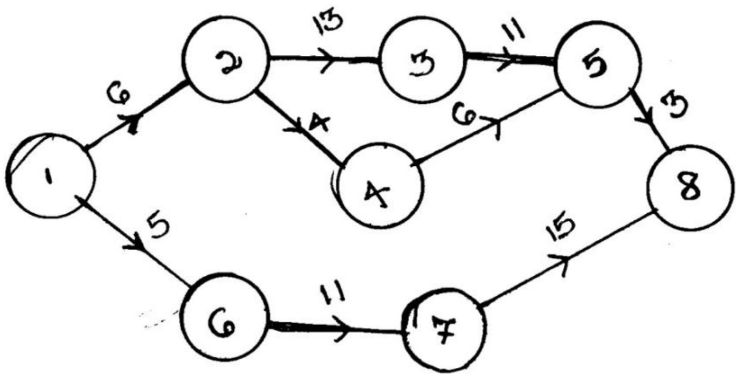
2. Construct the network from the information.

Activity No.	Duration	Activity No.	Duration
0-1	2	0-6	1
1-2	4	3-7	8
2-3	2	6-7	3
3-4	5	5-8	3
2-5	1	7-8	5
4-5	1		



3. 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.

Objective:

1. Determining the completion time for the project.
2. Earliest time when each activity can start.
3. Latest time when each activity can start without delaying the total project.
4. Determining the float for each activity.
5. Identification of the critical activities and critical path.

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

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 (t_0)
II. Most likely time (t_m)

III. Pessimistic time (t_p)

I. Optimistic time (t_0):

It is the shortest possible time in which an activity can be completed if everything goes perfectly without any complications.

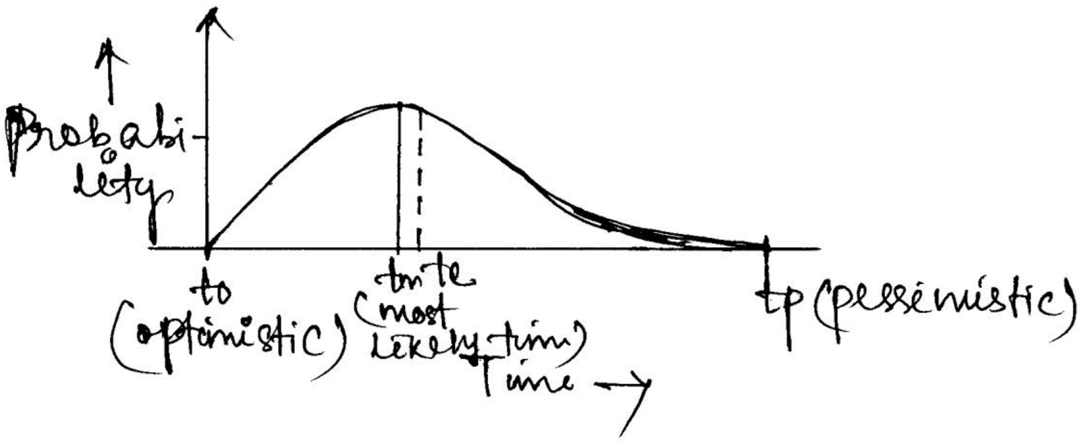
It is an estimate of minimum possible time to complete the activity under ideal condition.

II. Pessimistic time (t_p):

It is the longest time in which an activity can be completed if everything goes wrong.

III. Most likely time(t_m);

It is the time in which the activity is normally expected to complete under normal contingencies.



According to the β distribution curve

$$T_e = \frac{1}{6}t_0 + \frac{2}{3}t_m + \frac{1}{6}t_p$$

$$= \frac{t0 + 4tm + tp}{6}$$

The standard deviation of time required to complete each activity.

Standard deviation(σ) = $\frac{tp - t0}{6}$

Variance $\sigma^2 = (\frac{tp - t0}{6})^2$

Standard deviation of the time t_p to complete the project

$$= \frac{tp1 - to1}{6} + \frac{tp2 - to2}{6} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + \frac{tpn - to1}{6}$$

Mean, variance, standard deviation:

No. of days taken to dig a certain length of trench under varying condition.

48	76	52	40	50
49	60	62	53	50
53	56	67	62	60
61	46	72	70	58

Mean time or average time = 52.5 days

Standard deviation for each entry:

48 – 52.5 = -4.5

49 – 52.5 = -3.5

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Square the variation

$(-4.5)^2 = 20.25$

$(-3.5)^2 = 12.25$ …….. so on

$\frac{20.25 + 12.25 + \cdots\ldots\ldots}{Total\ no.of\ jobs\ (20)}$ = 6.52

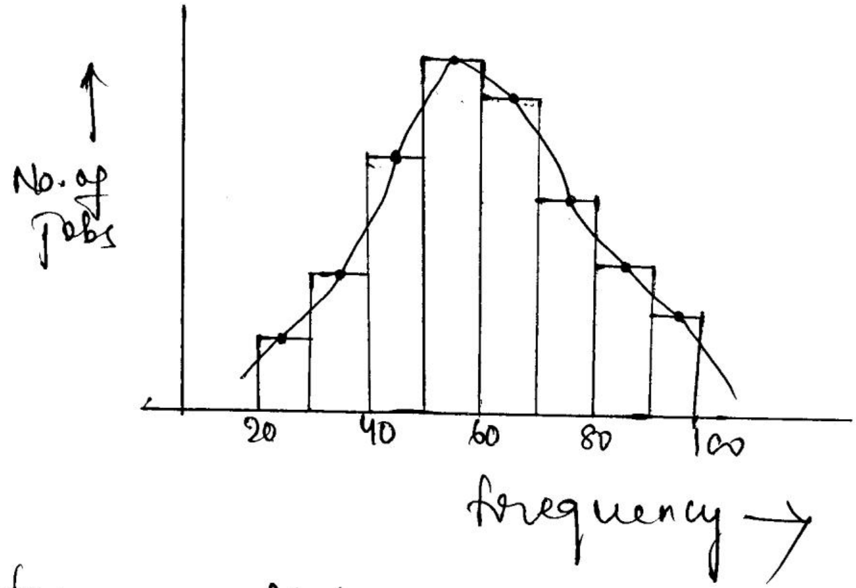
Square the deviations, add them and divide by no. of jobs to get variance.

Square rating the variance standard deviation can be found.

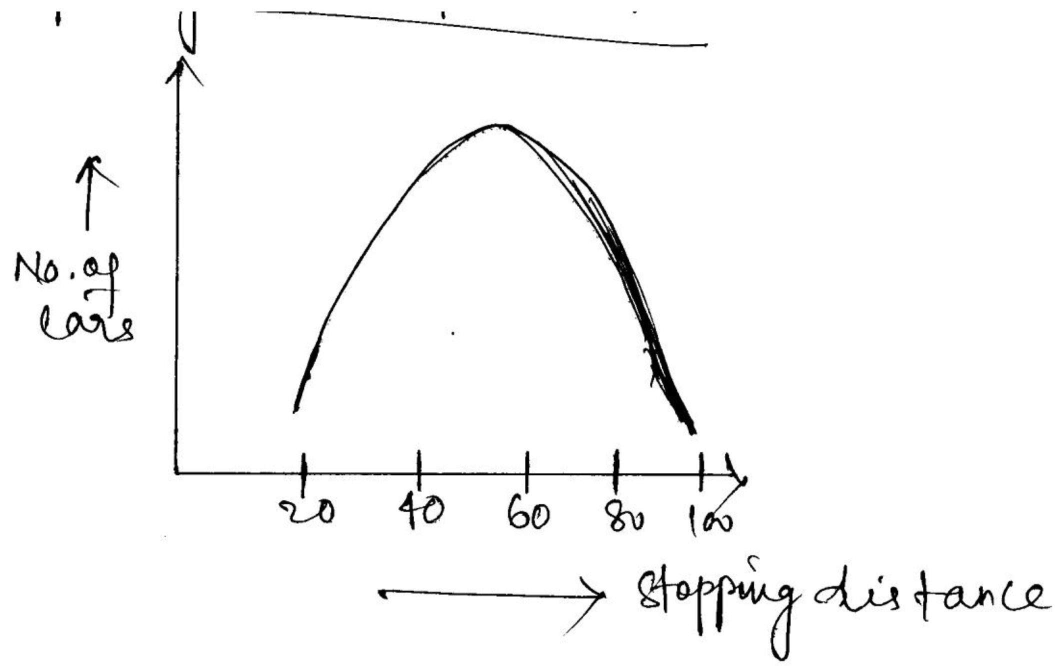
Example-1 : Stopping distance of a car is given

76	53	64	40	56	60	61
62	30	34	44	38	58	42
39	43	44	54	76	38	42
36	46	63	57	27	48	59
45	53	35	32	47	58	36
63	55	53	44	52	46	51
47	64	54	65	56	65	68
56	66	69	59	67	52	58
44	55	21	64	22	72	37
81	74	84	42	41	75	55

Car interval (in meters)	Tally	Frequency
20 to 29	III	3
30 to 39	IIIII IIIII	10
40 to 49	IIIII IIIII IIIII I	16
50 to 59	IIIII IIIII IIIII IIIII	20
60 to 69	IIIII IIIII IIIII	14
70 to 79	IIIII	5
80 to 89	II	2
		70



frequency distribution curve



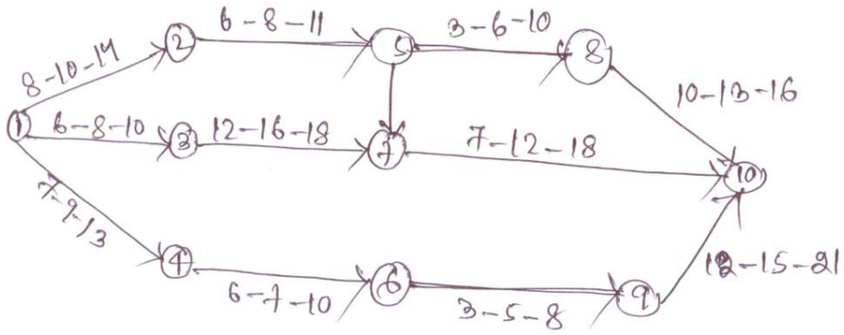
Probability of completion of the project within a scheduled time:

Time:

The probability of completion of the project within scheduled is computed as

1. Calculate the mean of the event time (t_e) by adding the times of the activities along the critical path leading to the event.
2. Calculate the variance of the event time by adding up the variances of the activities on the critical path. Take the square root of this variances to get T (standard deviation)
3. Compute standard normal variate

$$Z = \frac{Ts-Te}{\sigma T} \qquad Z = \frac{D-Te}{St}$$



There are 4 paths to reach 1 to 10.

A → 1-2-5-8-10

B → 1-2-5-7-10

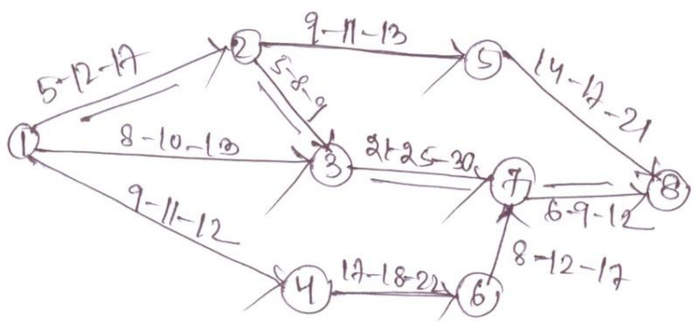
C → 1-3-7-10

D → 1-4-6-9-10

	Activity	t_0	t_m	T_p	T_e	Sum of t_e
	1-2	8	10	14	10.33	
Path A	2-5	6	8	11	8.17	37.67
	5-8	3	6	10	6.17	
	8-10	10	13	16	13	
	1-4	7	9	13	9.33	
Path D	4-6	6	7	10	7.33	37.34

	6-9	3	5	8		
	9-10	12	15	21		
Path C	1-3	6	8	10		35.84
	3-7	12	16	18		
	7-10	7	12	18		
Path B	1-2	8	10	14		37.84
	2-5	6	8	11		
	5-7	5	7	10		
	7-10	7	12	18		

Maximum time consumed is 37.84 is the critical path. So path B is the critical path.



Example – 2:

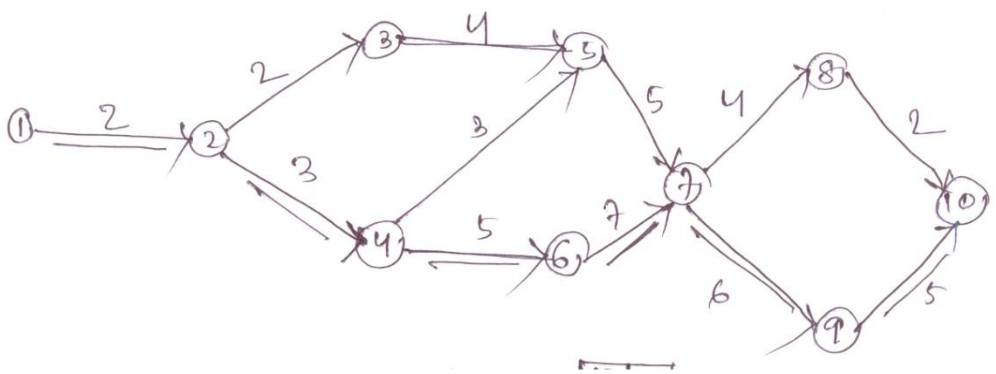
Construct the PERT network. Find the critical path and variance of each event. Find the project duration at 95 % probability.

Activity	Optimistic time	Pessimistic time	Most likely time
1-2	1	5	1.5
2-3	1	3	2
2-4	1	5	3

3-5	3	5	4
4-5	2	4	3
4-6	3	7	5
5-7	4	6	5
6-7	6	8	7
7-8	2	6	4
7-9	5	8	6
8-10	1	3	2
9-10	3	7	3

<u>Solution</u>:

Activity	t_o	t_p	t_m	t_e	Variance
1-2	1	5	1.5	2	4/9
2-3	1	3	2	2	1/9
2-4	1	5	3	3	4/9
3-5	3	5	4	4	4/9
4-5	2	4	3	3	1/9
4-6	3	7	5	5	4/9
5-7	4	6	5	5	1/9
6-7	6	8	7	7	4/9
7-8	2	6	4	4	4/9
7-9	5	8	6	6.16	1/4
8-10	1	3	2	2	1/9
9-10	3	7	3	5	4/9



The critical path is 1-2-4-6-7-9-10.

Expected duration of the project = 2+3+5+7+6.16+5 = 28.16 days

Project variance = 4/9+4/9+4/9+4/9+1/4+4/9 = 89/36

Z = $\frac{due\ date - expected\ date\ of\ of\ completion}{\sigma T}$

$= \frac{X-28.16}{89/36} = 0.8289$

⇨ X = 30.12 days

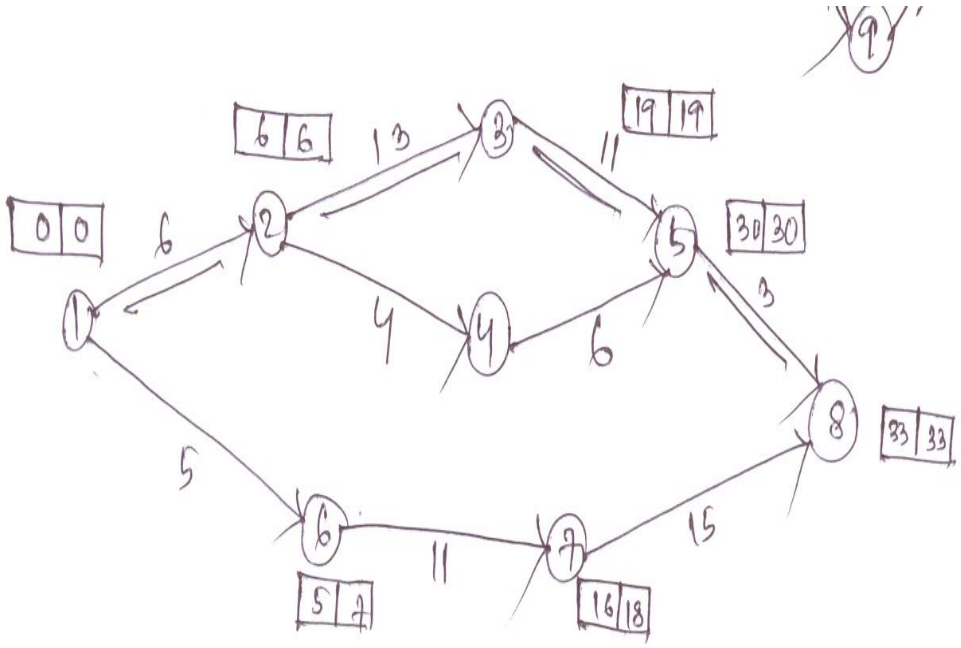
Example- 3:

A small engineering project consists of an activity. Three time estimates for each activity are given

a) Calculate values of expected time (t_e), standard deviation (s_t) and variance (v_t) for each activity.
b) Draw the network diagram and mark t_e on each activity.
c) Calculate EST and LFT and mark t_e on each activity.
d) Calculate total slack for each activity.
e) Indentify the critical paths and mark on the network diagram.
f) Find the length of critical paths or total project duration.
g) Calculate variance of critical path.
h) Calculate the probability that the jobs on the critical path will be finished by the due date of 38 days.
i) Calculate the approx probability that the jobs on the next most critical path will be completed by the due date of 38 days.
j) Estimate the probability that the entire project will be completed by the due date of 38 days.
k) If the project due date changes to 35 days what is the probability of not meeting the due date.
l) Find the due date which has a probability of 94.5 % of being met.

Solution:

Activity	T_o	T_m	T_p	T_e	V_t
1-2	2	5	14	6	4
1-6	2	5	8	5	1
2-3	5	11	29	13	16
2-4	1	4	7	4	1
3-5	5	11	17	11	4
4-5	2	5	14	6	4
6-7	3	9	27	11	16
5-8	2	2	8	3	1
7-8	7	13	31	15	16



Activity	EST	LST	LST - EST
1-2	0	0	0
1-6	0	2	2
2-3	6	6	0
2-4	6	20	14
3-5	19	19	0
4-5	10	24	14
6-7	5	7	2
5-8	30	30	0
7-8	16	18	2

e) Critical path is 1-2-3-5-8 and it is marked on the network diagram.

f) The length of the critical path or total project duration (T_e) is the sum of the duration of each critical activity = 6 + 13 + 11 + 3 = 33 days

g) Variance of the critical path is two of the each critical activity = 4 + 16 + 4 + 1 = 25

h) The probability that the project will meet the scheduled or due date is calculated from the $Z = \frac{D-Te}{St}$

Where T_e = total project duration

S_t = standard deviation = $\sqrt{varience}$

D = Due or scheduled deviations

$\therefore Z = \frac{38-33}{\sqrt{25}} = \frac{5}{5} = 1$ For Z = 1, probability = 0.841.

i) The next most critical path is 1-6-7-8 of 31 days.

Variance = 1+16+16 = 33 $s_t = \sqrt{33}$

Z = $\frac{38-31}{5.74}$ = 1.22

For Z = 1.22, probability = 0.888

PLANT LOCATION & LAYOUT

A plant is a place, where men, materials, money, equipment, machinery etc are brought together for manufacturing products.

The problem of plant location arises when starting a new concern or during the expansion of the existing plant.

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

Plant location involves two major activities

I. To select a proper geographic region
II. Selecting a specific site within the region

Plant location problem

1. Selection of region
2. selection as a community
3. selection of a particular site
   Conditions that demand city location
   Conditions that demand sub-urban location
   Conditions demanding rural location

Factors affecting plant location

1. Nearness to raw material – It will reduce the cost of transporting raw material from the vendor’s end to the plant sugar, cement, jute and cotton textiles.
2. Transport facilities – A lot of money is spent both in transporting the raw material and the finished goods speedy transport facilities ensure timely supply of raw materials to the company and finished goods to the customers, There are time basic modes of physical transportation, air, road, rail, water and pipe line.
3. Nearness to market – It reduces the cost of transportation as well as the chances of the finished products getting damaged and spoiled in the way.
4. Availability of labour – Suitable labour force, of right kind, of adequate size (number), and at reasonable rates with its proper attitude towards work are a few factors which govern plant location to major extent. The purpose of the management is to face less boycotts, strikes or lockout and achieve lower labour cost per unit of production.
5. Availability of fuel and power – Steel industries are located near source of fuel (coal) to cut down fuel transportation costs. Electric power should remain available continuously in proper quantity and at reasonable rates.

6. Availability of water - Depending on the nature of the plant, water should be available in adequate quantity and should be of proper quality water is essential for paper and chemical industries.
7. Climatic condition – Climate greatly influence human efficiency and behavior. Textile mills require humidity with the developments in the field of heating, ventilating and air conditioning, climate of the region doesn't present much problem of course control of climate needs money.
8. Financial and other aids – Certain states give aids as loans, feed money, machinery, built up sheds etc. to attract industrialist.
9. Land – Topography, area, the shape of the site, cost, drainage and other facilities, the probability of floods, earthquakes etc. influence the selection of plant location.
10. Community attitude – Community attitude towards their work and towards the prospective industries cab make or mar the industry. Success of an industry depends on the attitude of the local people whether they want work or not.
11. Supporting industries – All industries will not make all the components and parts by itself and it subcontracts the work to vendors
12. Social Infrastructures – Availability of community facilities like
    A. Housing facilities
    B. Recreational facilities
    C. Educational facilities
    D. Medical facilities

    are to be considered.
13. Law and taxation – the policies of the state gent and local bodies concerning labour laws, building codes, safely its are the factors that demand attention.

Plant layout:

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

It begins with the design of the factory building and goes up to the location and movement of a work table. All the facilities like equipments, raw materials, machinery, tools, fixtures, workers etc are given a proper place.

Plant layout is a plan of an optimum arrangement of facilities including personnel, operating equipment, storage space, material handling equipment and all other supporting services along with the design of best structure to contain all these facilities.

Plant layout problem (Need for the plant layout):

1. Changes in the product design.
2. Changes in the volume of demand for the company's product
3. Increasing frequency of accidents because of existing layout.
4. Plant and machinery becomes outdated and is to be replaced by new one

5. Poor working environment affecting worker efficiency and productivity.
6. Change in the location or markets.
7. Minimizing the cost through effective facilities location.

Objectives of plant layout:

1. Material handling and transportation is minimized and efficiently controlled.
2. Bottle necks and points of congestions are eliminated so that the raw material and semi finished goods move fast from one work station to another.
3. Workstations are designed suitably and properly.
4. Suitable places are allocated to production centers and service centers.
5. Movements made by the workers are minimized.
6. Waiting time of semifinished products is minimized.
7. Working conditions are safer, better and improved.
8. Increased flexibility of changes in product design and for future expansion.
9. Utilization of cubic space (length, width and height).
10. These are improved work methods and reduced production cycle times.
11. Plant maintenance is simpler.
12. Increased productivity and better product quality with reduced capital cost.
13. A good layout permits materials to move through the plant at the desired speed with the lowest cost.

Principle of plant layout:

1. Principle of integration:

    A good layout is one that integrates men, materials, machines and supporting services and other in order to get the optimum utilization of resources and maximum effectiveness.

2. Principle of minimum movements and material handling:

    The facilities should be arranged such that the total distances travelled by the men and materials should be minimum and as far as possible straight line movement is preferred. It is better to transport materials in bulk rather than in small amounts.

3. Principle of smooth and continuous flow :

    A good layout makes the materials to move in forward direction towards the completion stage. Bottle necks, congestion points and back tracking should be removed by proper line balancing techniques.

4. Principle of cubic space utilization :

    The good layout utilizes both horizontal and vertical space. Besides using the floor space of a room the ceiling height is also utilized. Boxes and bags containing raw material or goods cab be stacked are above the other to store more items in the same room.

5. Principle of safety and security and satisfaction :

   Working places safe-well ventilated and force from dust, noise, fumes, odours, and other hazardous conditions increase the operating efficiency of the workers and improve their morale.

6. Principle of maximum flexibility :

   The good layout is one that can be altered without much cost and time. The machinery is arranged in such a way that the changes of the production process can be achieved at the least cost or disturbance.

Advantage of plant layout:

1. Advantages to the worker
2. Advantages to the management
3. Advantages to manufacturing
4. Advantages to production control

Factors influencing plant layout

1. Type of production- Engg. Industry, process industry
2. Production system- Job shop, batch, mass production
3. Scale of production
4. Availability of total area
5. Arrangement of material handling system
6. Type of building- single storey, multi storey
7. Future expansion plan
8. Type of production facilities- Dedicated or general papers

Types of manufacturing system

1. Job type production:

   Manufacturing of one or few quantities of products designed and produced as per specifications high variety and low volume.

2. Batch production:

   Manufacture of limited no. of products produced at regular intervals and stocked at warehouse.

   Ex: Chemical, pharmaceutical, assembly stops.

3. Repetitive or mass production:

   Manufactures several standard products produced and stacked in the warehouses.

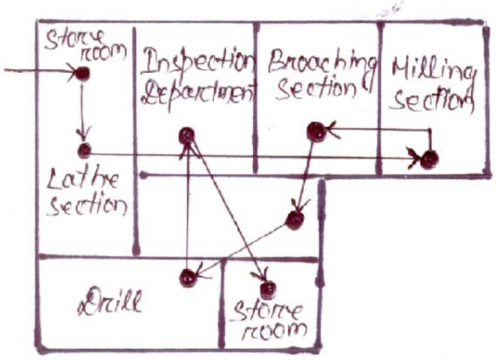
   High volume and low variety

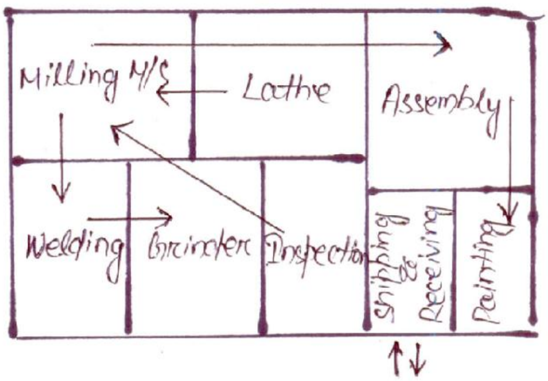
   Ex: plastic goods, manufacture & assembly stages of automobiles

Types of layout:

1. Process layout (Functional layout):

The layout is recommended for batch production. All machines performing similar type of operations are grouped at one location in the process layout.
Ex – all lathes, milling machine kept at one place
The arrangements of facilities are grouped together according to their functions.





Advantages:

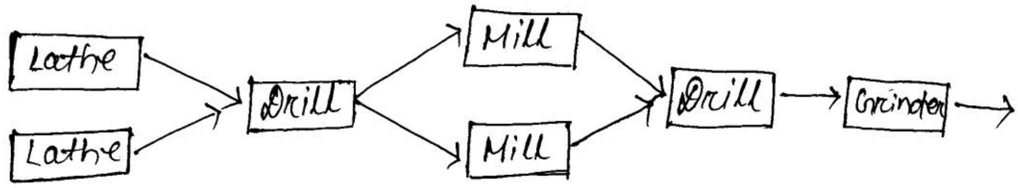
I. Wide flexibility exists during allotment of work to equipment and workers.
II. Better utilization of equipments
III. Lower investments on account of comparatively less no. of machine are used.
IV. Better product quality because to attend one type of machine.
V. Varieties of jobs coming as different job orders make the work more challenging and interesting.
VI. Workers in one section are one affected by the nature of another section.

Disadvantages:

I. For the same amount of production, more space is required.
II. Automatic material handling is difficult.
III. More materials in process remain in queue for further operation.
IV. Completion of same product takes more time.
V. Work-in-process inventory is large.
VI. Production planning and control is difficult.
VII. Raw materials have to travel larger distances for being processed to finished goods. Thus increases cost.
VIII. It means more inspections and efficient co-ordination.

2. Product layout (line layout):

The various operations on raw material are performed in a sequence and the machines are arranged in the sequence in which the raw material will be operated upon.



Advantage:

I. Less space requirements for the same volume of production.
II. Automatic material handling, less movements, so cost is reduced.
III. Less in process inventory.
IV. Product completes in lesser time.
V. Simplified production, planning and control
VI. Smooth and continuous work flow
VII. Less skilled workers can learn and serve the purpose

Disadvantage:

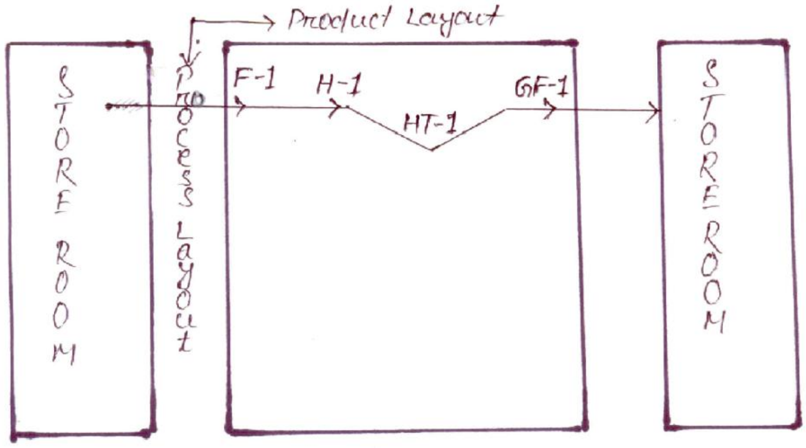
I. Lack of flexibility
II. Excessive idle time due to slowest machine
III. More machines to be purchased and kept which require high capital investment
IV. One inspector has to attend a no. of machine in a production line.
V. It is difficult to increase production beyond the capacities of the production lines.

3. Combination layout:

This is called the mixed type of layout usually a process layout is combined with the product layout.

Ex – refrigerator manufacturing uses a combination layout.

Manufacturing various components → process layout
For assembly of component → product layout



Ex – files, hacksaw, circular metal saws, wood saws.

4. <u>Fixed position layout</u>:

This is also called the project type of layout. The materials or major components remain in a fixed location and tools, machinery, men and other materials are brought to this location.

Ex – ship building, aircraft manufacturer

<u>Advantage</u>:

I. One or more skilled workers are engaged to one project
II. Least movement of materials
III. Maximum flexibility
IV. Different projects can be taken with the same layout.

<u>Disadvantages</u>:

I. Low content of work-in-progress
II. Low utilization of labour and equipment
III. High equipment handling cost

<u>Plant layout procedure</u>:

1. <u>Accumulate basic data</u>:

Such as

- Volume and rate of production
- Product specification and bill of material
- Process sheets indicating tools, equipments, the method and the product which will be manufactured
- Flow process charts
- Standard time to complete each operation

2. <u>Analyze and co-ordinate basic data</u>:

In order to

- The workforce size and type
- No. of workstation required
- Type of equipment required
- Storage and other space requirements
- Assembly chart and operation process chart help coordinating basic data

3. <u>Decide equipment and machinery required</u>:

   Can be calculated by

   - No. of articles to be produced
   - Capacity of each equipment
   - Time in which the order is to be completed

4. <u>Select the material handling system</u>:

   Which depends upon

   - Material or product to be moved
   - Container in which it will be moved
   - Length of movement
   - Frequency of movement
   - Speed of movement

5. <u>Sketch plan of the plot</u>:

   To mark building outline, roads, storage and service etc

   - The plan orientation should utilize maximum, the natural heat, light and other weather conditions.

6. <u>Determine a general flow pattern</u>:

   - The flow pattern of materials should be such that the distance involved is least between the store and the shipping department through the production centers.
   - There should be minimum back tracking
   - Based upon the process or product requirement process, product or combination layout.
   - Plant layout should be flexible to accommodate changes

7. <u>Design individual workstations</u>:

   To get optimum

   - Performance of operation
   - Material and space utilization
   - Safely and comfort of employees

8. <u>Assemble the individual workstation layout</u>: into total layout

9. <u>Calculate the storage spaced required</u>:

   By knowing

   - Volume of each store item

- No. of items to be kept at stores
- Time of keeping the item

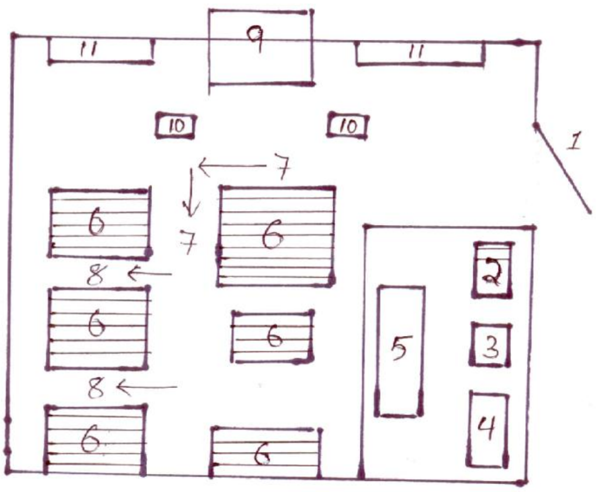
10. Make flow diagrams for workstations:
    And allocate them to areas on plot plan.
11. Plan and locate services areas such as offices, toilets, wash rooms, dispensary, cafeteria.
12. Make master layout by templates and models.
13. Check final layout:
    - Safe and economical material handling
    - Product design
    - Service area
    - Employee safety and comfort
14. Get official approval of the final layout about product drawings, BOM, man power requirements, estimated expenditure.
15. Install the approved layout.

Storage space requirements:

- Incoming new materials
- Checking and sorting the raw material
- Inspection of raw material
- Temporary storing the new material before it is placed at the proper location
- In process inventory
- Tools and other supplies
- Finished products

Space provided for above factors depends upon

1. Size and weight of raw material, in process goods and finished goods
2. Their quantity
3. Frequency of use



1. Incoming material receiving gate
2. Place for dumping raw material
3. Place for sorting and checking of raw material
4. Place for raw material inspection
5. Place for temporarily shorting the materials before putting them of racks.
6. Proper place for shorting each type of material
7. Main aisles
8. Side aisles
9. Service window
10. Boxes containing materials to be issued
11. Counters for keeping materials to be issued which have been brought from 6 and will be placed in 10

INVENTORY CONTROL

Introduction:

- In majority of the organization, cost of the material is a main part of selling price of the product. The interval between the receiving the purchased parts and transforming them into final products varies from industries to industries depending upon cycle time of manufacture.
- Materials are procured and held in the form of inventories.
- It acts as a buffer between supply and demand for efficient operation of the system.
- Stocking of anything that is tangible in order to meet the future demand is called inventory theory.

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.
  Ex – money kept in the shape of HSS bit MS rod milling

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.
- The objectives are
    1. To minimize investment in inventory
    2. To maximize the service levels to the firm's customers and its own operating department.

Types of inventories:

1. Raw inventories (raw materials):
    - Raw materials and semifinished 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
    - For proper operation, repair and maintenance during manufacturing cycle.

Reasons for keeping inventories:

- To stabilize production
- To take advertise of price discount
- To meet the demand during replenishment period
- To prevent loss of orders
- To keep pace with changing market conditions

Inventory control:

- Keeping track of inventory
- It is a planned approach of determining what to order, when to order and how much to order and how much to stock so that costs associated with buying and storing are optimal without interrupting production and sales.
- When should an order placed
- How much should be ordered order quantity

Objective 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

Advantages or benefits of inventory control

- One does not face shortage of materials
- Materials of good quality and procured in time minimized defect in finished goods.
- Delays in production schedules are avoided
- Production forgets are achieved
- Accurate delivery dates
- Economy in purchasing

Inventory control terminology:

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.

    Two type of costs- Fixed costs and variable costs.

    Fixed costs don't depend on the no. of orders whereas variable costs change w. r. t the no. of orders placed.

    I. Purchasing:

        The clerical and administrative cost associated with the purchasing, the cost of requisition material, placing the order, follow up, receiving and evaluating quotations.

    II. Inspection:

        The cost of checking material after they are received by the supplier for quantity and quality and maintaining records of the receipts.

    III. Accounting:

        The cost of checking supply against a given level of hand and this cost vary in direct proportion to the amount of holding and period of holding the stock in stores.

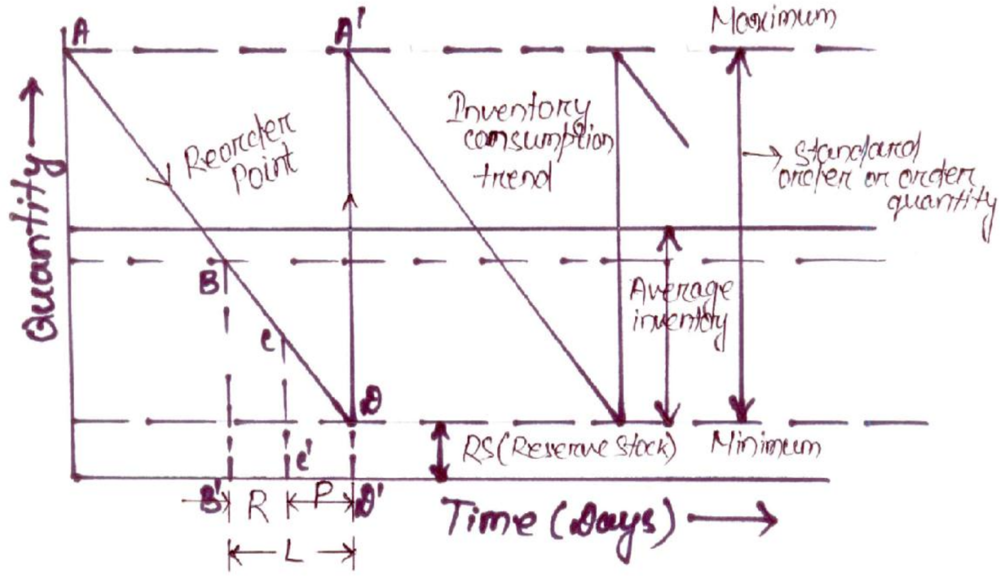
        This includes-

    I. Storage costs (rent, heating, lighting etc.)
    II. Handling costs (associated with moving the items. Such as labour cost, equipment for handling)
    III. Depreciation, taxes and insurance
    IV. Product deterioration and obsolescence
    V. Spoilage, breakage

Economic order quantity:

How much materials may be ordered at a time. An industry making bolts will definitely like to know the length of steel bars to be purchased at any one time. i.e. called EOQ.

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')

<u>Maximum quantity</u>- OA is the upper or max limit to which the inventory can be kept in the stores at any time.

<u>Minimum quantity</u>- OE is the lower or minimum limit of the inventory which must be kept in the stores at any time.

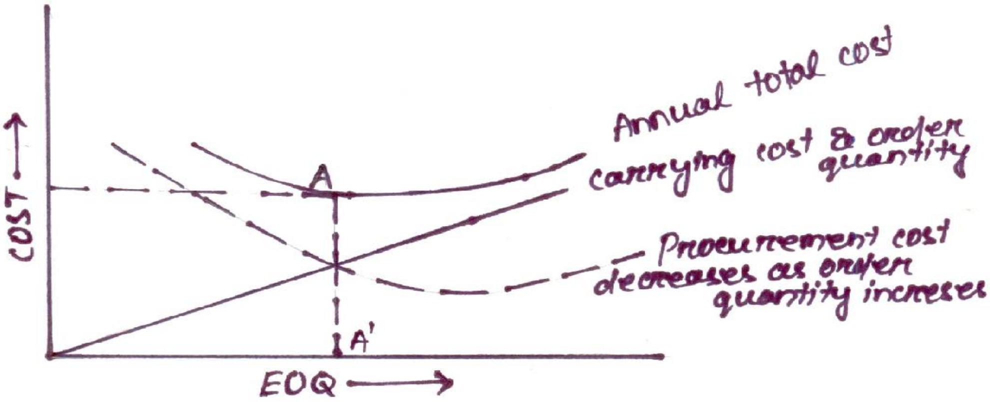
<u>Standard order (A'D)</u> - It is the difference between maximum and minimum quantity and is known as economical purchase inventory size.

<u>Reorder point (B)</u>- 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.

It includes-

a) Time to prepare purchase requisition and placing the order.
b) Time taken to deliver purchase order to the seller
c) Time for seller to get or prepare inventory
d) Time for inventory to be dispatched from the vendor’s end and to reach the costumer



Inventory procurement cost:

1. Receiving quotations
2. Processing purchase requisition
3. Following up and expediting purchase order
4. Receiving material and then inspect it
5. Processing seller’s invoice

Procurement cost decrease as order quantity increases.

Inventory carrying cost:

1. Interest on capital investment
2. Cost of storage facility, up-keep of material, record keeping
3. Cost involving deterioration and obsolescence
4. Cost of insurance, property tax.

Carrying cost directly proportional to the order size or order quantity

Mathematical 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 = $\frac{Total\ quantity}{EOQ} = \frac{U}{Q}$

Total procurement cost = No. of orders × cost involved in one order

$= \frac{U}{Q} \times P$

Average quantity = Q/2

Inventory carrying cost = average inventory × cost per item × cost of carrying inventory in %

$= \frac{Q}{2} \times C \times I$

Total cost (T) = a + b

$= \frac{U}{Q} \times P + \frac{Q}{2} \times C \times I$

To minimize cost, $\frac{dT}{dQ} = 0$

⇨ $\frac{d}{dQ}(\frac{U}{Q}P + \frac{Q}{2}CI) = 0$

⇨ $-UQ^{-2}P + CI/2 = 0$

⇨ $Q^2 = \frac{2UP}{CI}$

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

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 ≅ 5

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

Problem-2:

The rate of use of a particular raw material from stores is 20 units per year. The cost of placing and receiving on order is Rs 40. The cost of each unit is Rs 100. The cost of carrying inventory in percent per year is 0.16 and it depends upon the average stock. Determine the order quantity. If the lead time is 3 month, calculate the reorder point.

Answer:

U = 20 units

P = Rs 40 /-

C = Rs 100 /-

I = 0.16

$$EOQ = \sqrt{\frac{2UP}{CI}} = \sqrt{\frac{2 \times 20 \times 40}{100 \times 0.16}} = 10$$

L = 3 months

12 months = 20 units

3 months = $\frac{20}{12} \times 3$ = 5 units

Problem-3:

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 /-

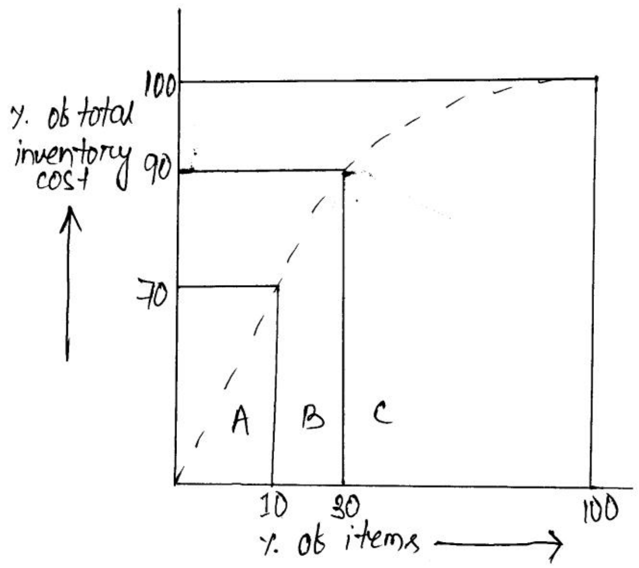
EOQ = $\sqrt{\frac{2UP}{CI}}$ = $\sqrt{\frac{2 \times 30000 \times 70 \times 100}{2 \times 12}}$ = 4183.3

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

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

ABC analysis:

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



1. <u>A-items</u>:

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

2. <u>B-items</u>;

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

3. <u>C-items</u>:

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

Advantage

I. Better planning and control
II. Increase inventory turn over
III. Effective management and control

Disadvantage

I. Periodic review to be dfdf

Procedure

1. Identify all the items used In industry
2. List all the items as per their value.
3. Count the no. of high valued, medium valued and law valued items
4. Find the % of high, medium and low valued items
   High valued contribute – 70% of total inv. Cost
   Medium valued contribute -20% of total inv. Cost
   Low valued contribute-10% of total inv. Cost
5. A graph can be plotted between % of items and % of total inventory cost

Production planning and control

Production –Production are manufactured by the transformation of raw material into finished goods

Planning- planning looks ahead, anticipates possible difficulties and decides in advance as to how the production is to be carried out.

Control- the control phase makes sure that programmed production is constantly maintained

Need for PPC-

- To achieve effective utilization of firms resources
- To achieve the production objectives with respect to quality, quantity, cost and timeliness of delivery.
- To obtain the uninterrupted production flow in order to meet customers demand w.r.t quality and committed delivery schedule.
- To help the company to supply a good quality products to the customer on the continuous basis at competitive rates

Objectives of PPC-

- Systematic planning of production activities to achieve the highest efficiency in production of goods
- To organize the production facilities like machines, men, etc. to achieve stated production objectives
- Optimum scheduling of resources
- To confirm to delivery commitments
- Materials planning & control
- To be able to make adjustments due to changes in demand and rush orders

Functions of production planning & control

1. Planning phase
    - Prior planning
        - Forecasting
        - Order writing
        - Product design
    - Active planning
        - Process planning & routing
        - Material control
        - Tool control
        - Loading
        - Scheduling

2. Action phase ----------------- Dispatching

3. Control phase
    - Process reporting — Data processing
    - Corrective action
        - Expediting
        - Replanning

a) Forecasting- estimation of type, quantity and quality of future work.
b) Order writing- giving authority to obne or more persons to undertake a particular job.
c) Product design- collection of information regarding specifications, bill of materials, drawings etc.
d) Process planning & routing- finding the most economical process of doing a work and then deciding how & where the work will be done
e) Material control- it involves determining the requirements and control of materials
f) Tool control- it involves determining the requirement and control of tools used
g) Loading- assignment of work to manpower machinery etc.

h) Scheduling- it is the time phase of loading & determines when and in what sequence the work will be required out. It fixes the starting as well as the finishing time for the job

i) Dispatching- it is the transition from planning to action phase. In this phase the worker is ordered to start the actual work.

j) Progress reporting- Data regarding the job progress is collected.
-It is interpreted by comparison with the preset level of performance.

k) Corrective action- 1. Expanding means taking action if the progress reporting indicates deviation of the plan from the originally set targets
2.Replanning of the whole affair becomes essential, in case expediting fails to bring the deviated plan to its actual path

Process planning-

Definition and concept

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

Information required to do process planning-

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

Process planning procedure-

1. Selection of process
    - a process is necessary in order to shape, form, condition and join materials and components with the help of machines and labour in order to convert raw material into a finished product.
    - One should select the most economical prcess and sequence that satisfies the product specifications
    - The selection of process depends upon

a) Current production commitments-
Its enough work has already been allocated to more efficient equipments, the current work may have to be passed on to less efficient m/c s to complete the same in time

b) Delivery date-
    - an early delivery date may
    - force the use of less efficient m/c s
    - rule out the use of special tools & jigs as they will take time for design and fabrication

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

d) Quality standards- Quality standards may limit the choice of making the product on a particular machine

2. Selection of material-
    - Material should be of right quality and chemical composition as per the product specifications
    - Shape and size of material should restrict the scrap(i.e. material removed for getting the product shape)

3. Selection of jigs, fixtures and other special attachments
These suppoting devices are necessary
    - To give higher production rate
    - To reduce cost of production pr piece

4. Selection of cutting tools and inspection gauges-
    - Reduce production time
    - Inspect accurately and at a faster rate

5. Make the process layout indicating every operation and the sequence in which each operation is to be carried out
6. Find sit-up time and standard time for each operation

7. Manifest process planning by documents such as operation and route sheets, which gives information about the operations required, the preferred sequence of operations, auxiliary tools required estimated operation times

Routing

- taking from raw material to the finished product, routing decides the path and sequence of operations to be performed on the job form one machine to another
- it determines what work is to be done and where and how it will be done

procedure

- the finished product is analysed from the manufacturing stand point in order to decide how many components can be made in the plant and how many others will be purchased form the outside through vendors, by sub contracting etc. make/buy decisions depends upon the work load in the plant, availability of equipment and personnel to manufacture all components and the economy associated with making all components within the plant itself
- A parts list and a BOM is prepared showing name of the part, quantity, material specifications amount of materials required etc. The necessary materials thus can be produced
- From production standards m/c capacities, m/c characteristics and the operations which must be performed at each stage of manufacture are established and listed in proper sequence on an operation and route sheet. the place of operations is also decided
- Operation and route sheet are separate. An operation sheet shows every thing about the operation, i.e. operation description, their sequence, type of machinery, tools, setup and operation times, where as a route sheet besides listing the sequence of operations and relation between operation and machine, also details the section and the m/c to whom the work will flow

Operation and route sheet								
Component No. __________					Drawing ____________			
Name of component ___________					Quality ____________			
Material ________________					To be completed on ________			
Routing		Operation No.	Operation description	Tools required	Fixtures	Time		
Section	Machine					Set up	Operation	total

The difference between an operation sheet and a route sheet is that an operation sheet remains same for the components it the order is repeated but the route sheet may have to be revised it certain machines are already committed to other jobs.

- The next step is to determine the lot size or the number of components to be manufactured in one lot or batch.
- Standard scrap factors and the places where scrap is very likely occur are identified causes for points out of control limits are explored and corrected. The variables like workers, machinery and schedules may adjust to minimize scrap.
- The cost of the component is analyzed and estimated through the information obtain in steps. The costs consist of material and labour charges and other specific and general indirect expenses.

Scheduling:

- Scheduling means when and in what sequence the work will be done. It involves deciding as to when the work will start and in a certain duration of time how much work will be finished.
- It determines which order will be taken up on which machine and in which department by which operator.

Scheduling procedure and techniques:

Master schedule:

Master schedule for the foundry shop Maximum production – 100 Hr Minimum production – 8 Hr			
Week-1	Week-2	Week-3	Week-4
15	15	20	15
25	25	12	10
20	28	32	
35			

- A master schedule resembles central office which possesses information about all the orders in hand.
- As the orders are received, depending upon their delivery dates they are worked on the master schedule when the shop capacity is full for the present week the newly acquired orders are carried over to due next week and so on.
- A master schedule updated continuously.

Advantages:

- It is simple and easy to understand.
- It can be kept current.
- It involves less cost to make it and maintain.
- It can be maintained by non-technical staff.
- A certain percentage of total weekly capacity can be allocated for rush orders.

Disadvantages:

- It provides only overall picture.
- It does not give detailed information.

Applications:

- For the purpose of loading the entire plant.
- In research and development organizations.
- For the overall planning in foundries, computer entries, repair shops etc.

Scheduling technique:

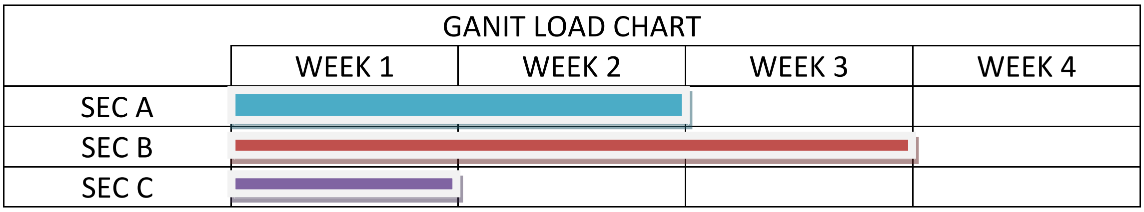
a) Perpetual schedule:

It is similar to master scheduling. It is simple and easy to understand. It involves less cost and can be maintained by clerical staff. The information is not clear when work will take place.

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

LOAD ANALYSIS SHEET			
	LOAD IN Hr/DAYS		
ORDER No.	SEC A	SEC B	SEC C
X-320	25	10	16
Y-210	10	15	10
Y-314	18	20	8
Z-150	8	25	------
.	.	.	.
.	.	.	.
.	.	.	.
.	.	.	.
.	.	.	.

ii. Weekly capacity of section is calculated by adding total load against each section.



Color bars are shows the actual work load against each section.

Dispatching:

- Dispatching is the physical handing over of a manufacturing order to the operating facility through the release of orders and instructions previously developed plan of activity (time and sequence) established by the scheduling section of the production planning and control department.
- Dispatcher transmits orders to the various shops.
- Dispatcher determines by whom the job shall be done and it coordinates production.
- It creates a direct link between production and sales.

Procedure:

The product is broken into different components and components into operations. A route sheet for the part C having three operations on it is shown.

ROUTE SHEET PART C
MATERIAL
OPERATION-1
OPERATION-2
OPERATION-3

a) Store issue order:

Authorize stores to deliver required raw material.

b) Tool order:

Authorize tool store to release the necessary tools. The tools can be collected by the tool room attendant.

c) Job order:

Instruct the worker to proceed with the operations and forms the basis for worker's pay.

d) Time ticket:

It records the beginning and ending time of the operations and forms the basis for worker's pay.

e) Inspection order:

Notify the inspectors to carry out necessary inspections and report the quality of the component.

f) Move order:

Authorized the movement of materials and components from one facility to another for further operations.

Process control:

It means trying to achieve the standards set i.e. a certain level of efficiency or a certain volume of production in a specified duration. The system of progress control should be such that it furnishes timely, adequate and accurate information about the progress made, delays and under or overloading.

Steps:

a) Setting up a system to watch and record the progress of the operating facility.
b) Making a report of the work progress or work accomplishment.
c) Transmission of report to
    i. Control group for necessary control action
    ii. Accounting group for recording material and labour expenditures.
d) Interpretation of the information contained in the progress report by the control group.
e) Taking corrective action if necessary.

PLANT MAINTENANCE

Plant-

A plant is a place, where men, materials, money, equipment, machinery, etc are brought together for manufacturing products.

Maintenance-

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 interrupter
- 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

IMP of maintenance-

- Equipment breakdown leads to an inevitable loss of production
- An improperly maintained or neglected plant will sooner or later require expensive and frequent repairs, because with the passage of time all machines or other facilities, building, etc wear out and need to be maintained to function properly.
- Plant maintenance plays a prominent in production management because plant breakdown creates problem such as- loss of production time
  - ✓ Rescheduling of production
  - ✓ Spoilt materials (because sudden stoppage of process damages in-process materials)
  - ✓ Failure to recover overheads (because loss in production hours)
  - ✓ Need for overtime
  - ✓ Need for subcontracting work
  - ✓ Temporary work shortage- workers require alteration work

Duties, functions and responsibilities of pant 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.
- Engineering and consulting services to production supervision are also the responsibility of maintenance department.

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) <u>Overhaul</u>-

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

f) <u>Construction</u>-

- 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) <u>Salvage</u>-

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

h) <u>Clerical jobs</u>-

- 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 maintenance:

Maintenance may be classified as

a) Corrective or breakdown maintenance
b) Scheduled maintenance
c) Preventive maintenance
d) Predictive maintenance

a) Corrective or 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.
- 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.

b) Scheduled maintenance:

- Scheduled maintenance is a stick-in-time procedure aimed at availing breakdowns
- Scheduled maintenance do inspection, lubrication, repair and overhaul of certain equipments are done in predetermined schedule.
- Schedule maintenance practice is generally followed for overhauling of machines, cleaning of water and other tanks, white washing of building etc.

c) Preventive maintenance:

- A system of scheduled, planned or preventive maintenance tries to minimize the problems of breakdown maintenance.
- It is a stich-in-time procedure.
- It locates weak spots (such as bearing surfaces, parts under excessive vibrations etc) in all equipments, proceeds them regular inspection and minor repairs reducing the danger of unanticipated breakdown.
- Preventive maintenance involves.
- Periodic inspection of equipment and machinery to prevent production breakdown an harmful depreciation.
- Upkeep of plant equipment to correct fault.

Objective of FM:

- To minimize the possibility of unanticipated production interruption and major breakdown by locationg the fault.
- To make plant equipment and machinery ready to use
- To maintain the optimum productive efficiency
- To maintain the operational accuracy
- To achieve maximum production and minimum repair cost
- To ensure safety of life and limbs of the workers

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.

d) 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 a rotating equipment predict an trouble, an electric cable excessively hot at one point predicts an trouble.
- In predictive maintenance, equipment conditions are measured periodically or on a continuous basis 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.

Recent developments in plant maintenance:

The management techniques used for plant maintenance to increase maintenance efficiency, reduce maintenance cost and to improve services.

A. Use of work study:

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

B. Use of network planning techniques:

- CPM has enables some firms to cut their down time by 20 to 30 %
- Maintenance costs have been cut down.
- CPM is useful for large maintenance projects
- 70 % of reduction in time for overhaul by central electricity board in Great Britain using network planning technique.
- PERT reduced shut down time 18 to 16 days 102 and added 90000 barrels to production volume of a refinery.

C. Use of operation research:

Operation research handles maintenance problems such as the economiv level of spare parts or when to replace an item etc.

D. Use of computers;

- More efficient and control over maintenance problems.
- Computer can prepare maintenance work orders giving accurate work order descriptions and job timing.
- Eliminate human error in preparing work order.
- Reduced cost of keeping records of equipments
- Reduced premature replacement of parts.

Quality Control

2.1 Introduction

The term quality is a relative term and has different meanings to different people. Quality is what customer wants. The concept of quality has changed over time from

Conformance to specification

⇓

Fitness for use

⇓

Affordable Excellence

When referring to a product, it generally signifies the degree of its excellence. The quality of a product consists of number of elements such as shape, size and finish etc. Known as quality characteristic (structural, sensory, Time-oriented, and ethical) and these are specified in part drawings or manufacturing drawings.

According to *American Society of Quality Control* Standard A3-1987. "Quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy a given need".

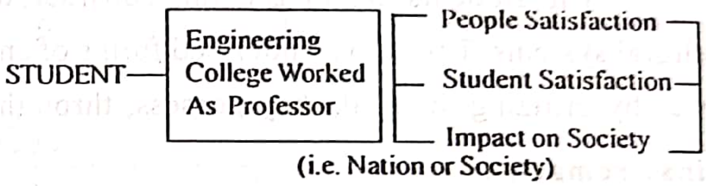
According to *Badiru* and *Ayeni* (1993), Quality si defined as "Quality refers to an equilibrium level of functionality possessed by a product or service based on the producer's capability and customer's need".

According to *Feigenbaum*, quality is defined as "The total composite product and service characteristics of engineering, Manufacturing, Marketing and Maintenance through which the product and service in use meet the expectation of the customers".

Quality does not necessarily mean "The best". The product should meet the desired requirements at lowest cost which imply "the best for he money". It may be mention here that quality is not absolute but is a relative term. High quality indicates high cost and vice versa.

Criterion :

Engineering Colleges are processing the students, after processing they are going to serve the nation in different direction. Based on people satisfaction, students satisfaction and impact on society we can say quality is good which is shown in fig. 1



Quality can be defined as the totality of the systems, resources and information devoted to maintaining and improving the quality and standards of the research and of students teaching and learning experiences

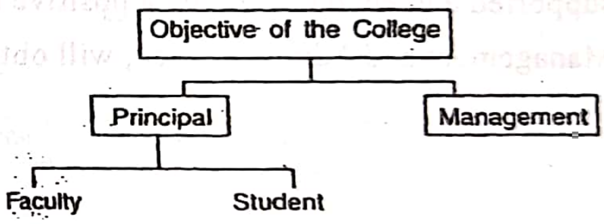


Fig.2.1 Showing the important points for Engg. Colleges

Aims and Objectives of Quality Control:

1. To make the company's/Producer's product more acceptable by the customer/consumer and thereby increase the sales of the company.
2. To achieve interchangeability.
3. To develop quality consciousness in the organisation/company.
4. To reduce the cost of production by proper control of outgoing product by reducing the defects.

Principles of Quality Control:

1. The quality control increases the sales volume and decreases the cost of production, distribution and hence mass production economical.
2. Under the present comparative manufacturing/market conditions, quality of the goods being manufactured is a variable having upward trend.
3. The conformance of finished products to the pre-decided standards and specifications should be accomplished by using preventive measures instead of going for corrective ones.

Advantages of Quality Control/Benefit of Quality Control:

1. It reduces the cost of inspection.
2. Minimum scrap or rework due to reduced defectives thus reducing wastage.
3. Reduced customer complaints.
4. Better customer satisfaction and employee satisfaction.
5. Good quality of the product improves reputation of the enterprise.
6. Quality control may lead to quality improvement of the product which in turn increases sales volume.

1.2 STATISTICAL QUALITY CONTROL (SQC) :

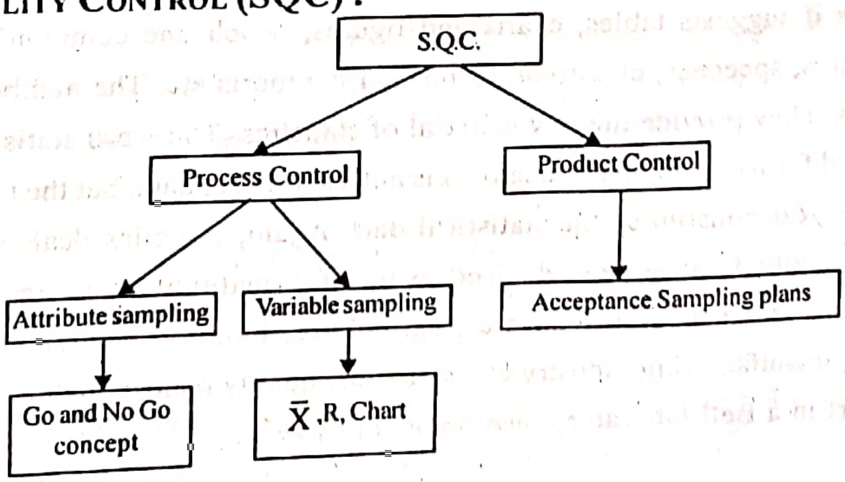


Fig.2.2 SQC

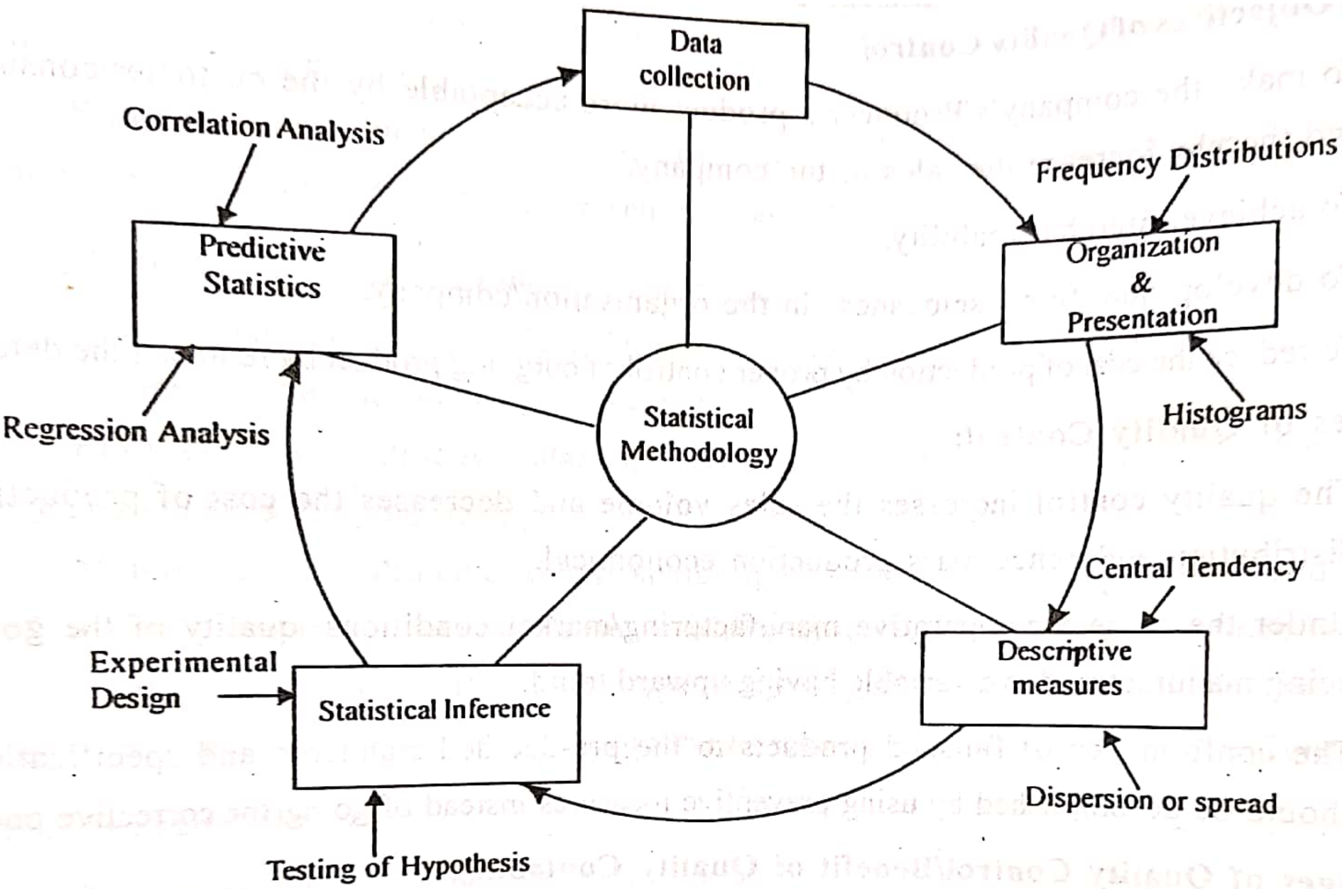


Fig.2.3 SQC methodology

Statistical quality control is systematic as compared to guesswork of haphazar process inspection and the mathematical or statistical approach neutralizes personal bias and uncovers poor judgement.

SQC is a technique of estimating the quality of the whole from the quality of samples.

Statistical quality control (SQC) is defined as the technique of applying statistical methods based on theory of probability to establish quality standards and to maintain it in the most economical manner.

The statistical methods help to increase the value of the ratio "$\left(\frac{\text{Quality}}{\text{Cost}}\right)$"

SQC consists of the following activities :

(a) Systematic collection and graphic recording of accurate data.

(b) Analysis of the data.

(c) Practical engineering or management action, if the information obtained indicates significant deviation from the specified limits.

Tolerance level (Quality)	Cost of achieving quality
A	

Fine Tolerance means high cost

B	

Course Tolerance means low cost

S.Q.C. is employed to ascertain whether the variation in quality of the product is due to chance cause or due to assignable cause. Chance variations cause about 85% of the problems in process while assignable variations account for only 15% of the problems.

Objectives of SQC

(i) To prevent the production of defective parts by inspecting them and establishing control over manufacturing process during production, instead of waiting to inspect them after they have been completed, when it is too late to take corrective action.

(ii) To reduce the cost of inspection and also ensure quality of the product by adopting a sampling inspection plan based on statistical methods.

Utility of Concept of Standard Error:

(a) The concept of standard error is used an instrument in testing a given hypothesis. If the difference between observed and expected means is more than 1.90 standard error (S.E), the result of the experiment does not support the hypotheis at 5% level of significance. We may use either 5% or 1% level of significance but in practice 5% level is more popular.

(b) The standard error provides an idea about the unreliability of a sample. The reciprocal of standard error (S.E) i.e. 1/S.E, is a measure of reliability or precision of the sample.

(c) With the help of standard error, we can determine the limits within which the parameter values (mean, median, standard deviation etc) are expected to lie.

Process Capability :

A process capability study is a determination of the total spread of the process as determined by measuring the product produced under controlled conditions.

The ability of a conversion system to produce the products that conforms to the design specifications. It is a range of variation from the design aspects under normal working environment. Since the natural tolerance spreads over -3σ and $+3\sigma$, the process capability = 6σ, assuming the process behaviour as normal, σ = Standard deviation of a quality parameter.

A process is defined to be any employment of resources for the purpose of production, the products of which may be tangible or intangible. In every process, precison or not, has a certain capability range within which it will operate. The limits of this range are known as the natural limits of the process and this natural range of variability is referred as process or machine capability.

It may be noted that the process capability is independent of the specification but is determined by

(i) the condition of the machine.
(ii) operator skill/aptitude.
(iii) Type of operation
(iv) Raw materials used
(v) tooling

Therefore the ability of a manufacturing process to keep within the tolerance is process capacity.

$$\boxed{\text{Process capability} = 6\sigma}$$

A complete analysis of process capabilities consists of 5 stages.

(i) The specification tolerance.

(ii) The determination of whether the process average is centered midway between the tolerance limits.

(iii) Measurement of piece to piece variability of process (inherent).

(iv) Measurement of the actual variability over a period of time.

(v) Causes of the difference between inherent and actual variability.

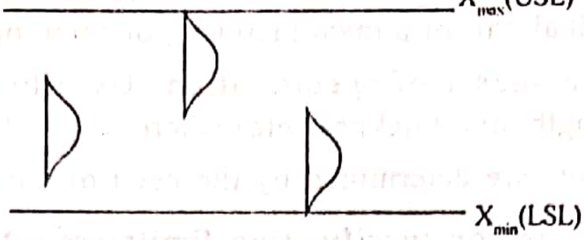
The possible three situations of a process in control to upper and lower specification limits are :

(1) If $(X_{max} - X_{min}) > 6\sigma$

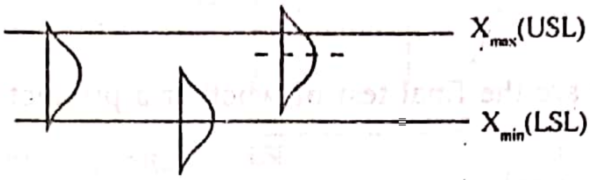
where $\sigma' = \dfrac{\bar{R}}{d_2}$

X_{max} = USL
X_{min} = LSL

The indicates the spread of the process ($6\sigma'$) is less than the difference between the USL and LSL.

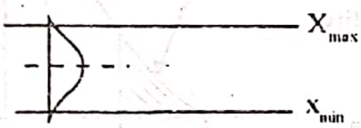


(2) If $(X_{max} - X_{min}) < 6\sigma'$



In the above case, defective parts will always be there.

(3) If $(X_{max} - X_{min}) = 6\sigma'$



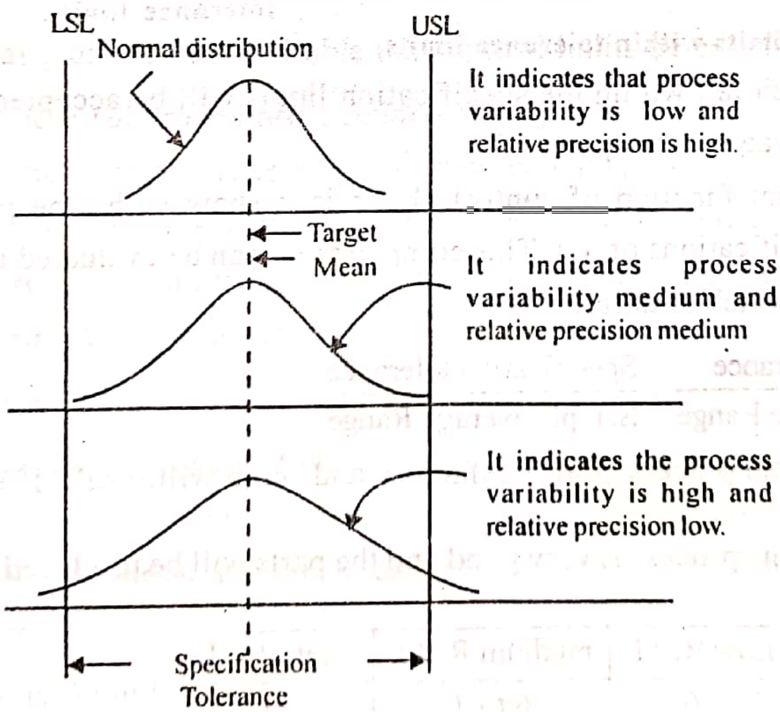


Fig.2.18 Comparative view of dispersion (process variability) and relative precision.

Tolerance or Specification limits:

Specification limit or tolerance limits is defined as limits that define the conformance boundaries for an individual unit of a manufacturing or semu operation.

Tolerances are a subset of specification. Usually tolerances person to physical requirements (such as length, dia. thickness etc) whereas specifications include all requirements.

Specification limits are determined by the need of the customer.

The terms tolerance or specification limits are often used interchangeably. These limits are not determined statistically but are fixed when the product is designed, keeping in view the use of the product.

Tolerance limits are the final test of whether a product will be acceptable or not.

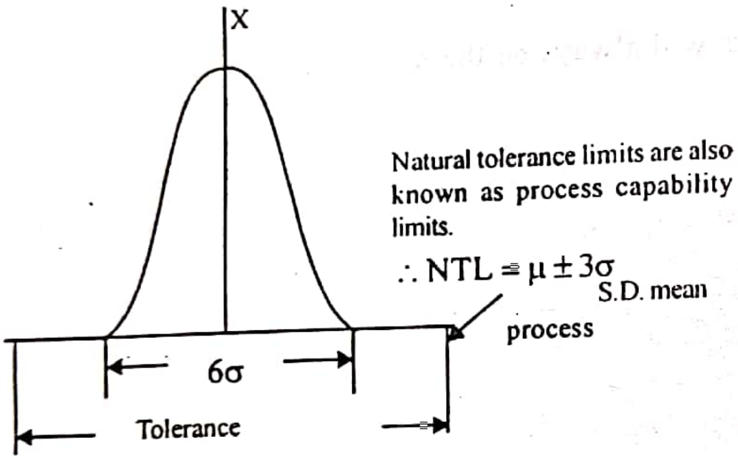


Fig.2.19 Statistical limits within tolerance limits

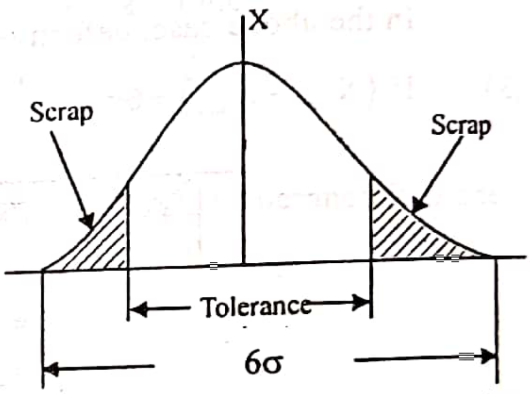


Fig.2.20 Statistical limits outside tolerance limits.

Those parts which fall within the specification limits will be accepted. The others can be retained for rework, salvage or scrap.

Another important function of control charts is it show withe the process capability is compatible with the specifications or not. This compatibility can be evaluated in terms of "Relative precision Index (RPI)" which is defined as :

$$R.P.I. = \frac{\text{Tolerance}}{\text{Average Range}} = \frac{\text{Specification tolerance}}{\text{Sample average Range}}$$

If R.P.I. is low, the process is unsatisfactory and scrap will result. If R.P.I. is medium the process is satisfactory.

If R.P.I. is high, the process is very good and the parts will be produced with little variation.

Sample size n	Low R.P.I.	medium R.P.I.	High R.P.I.
2	<6	6 to 7	>7
3	<4	4 to 5	>5
4	<3	3 to 5	>4
5 and 6	<2.5	2.5 to 3.5	>3.5

$$\therefore \text{R.P.I.} = \frac{USL_x - LSL_x}{R}$$

Process Capability Ratio :

Process capability Ratio (PCR)

$$= \frac{USL - LSL}{6\sigma}$$

$$= \frac{\text{difference between specification limits}}{\text{Natural process spread}}$$

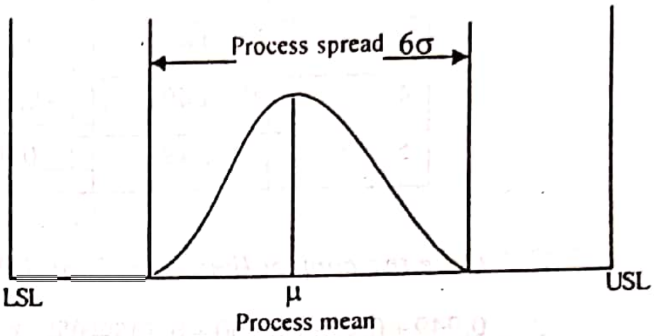


Fig.2.21

$\therefore PCR > 1$

Determining the trial control limits:

$$UCL_{\bar{x}} = \bar{\bar{X}} + A_2\bar{R}$$

$$LCL_{\bar{x}} = \bar{\bar{X}} - A_2\bar{R}$$

$$UCL_{\bar{R}} = D_4\bar{R}$$

$$LCL_{\bar{R}} = D_3\bar{R}$$

The fewer the subgroups used, the sooner the information thus obtained will provide a basis for action but the less the assurance that this basis for action is sound.

On statistical grounds it is desirable that control limits be based on at least 25 subgroups.

However, where subgroups are obtained slowly there is a natural desire on the part of those who initiated the control charts to draw some conclusions from them within a reasonable time. This impatience for an answer frequently leads to the policy of making preliminary calculations of control limits from the first 8 or 10 subgroups, with subsequent modification of limits as more subgroups are obtained.

Revised Control limits

The trial control limits served the purpose of determining whether past operations were in control. The continuing use of the control chart, with each out-of-control point used as a possible basis for hunting for an assignable cause of variation and taking action to eliminate that cause may require revised limits.

Revised limits should be reviewed from time to time as additional data are accumulated.

Example2. 5 *A company manufactures screws to a nominal diameter* 0.500 ± 0.030 cm. *Five samples were taken randomly from the manufactured lot and 3 measurements were taken on each sample at different lengths. The readings are shown in the table below.*

Sample No.	Measurements per sample (cm) x		
	1	2	3
1	0.488	0.489	0.505
2	0.494	0.495	0.499
3	0.498	0.515	0.487
4	0.492	0.509	0.514
5	0.490	0508	0.499

Calculate the control limits on $\bar{X}$ and R -charts and draw the charts.

Ans. $$\bar{\bar{X}} = \frac{0.949+0.496+0.500+0.505+0.499}{5} = 0.499$$

$$\bar{R} = \frac{0.017+0.005+0.028+0.022+0.018}{5} = 0.018$$

Trial Control limits

Control limits for R-chart.

$$UCL = D_4\bar{R} = 2.57 \times 0.018 = 0.0463$$

$$LCL = D_3\bar{R} = 0 \times 0.018 = 0 \qquad \text{(for n = 3)}$$

For $\bar{X}$ - charts

$$UCL = \bar{\bar{X}} + A_2\bar{R} = 0.499 + 1.02 \times 0.018 = 0.5174$$

$$LCL = \bar{\bar{X}} - A_2\bar{R} = 0.499 - 1.02 \times 0.018 = 0.4807$$

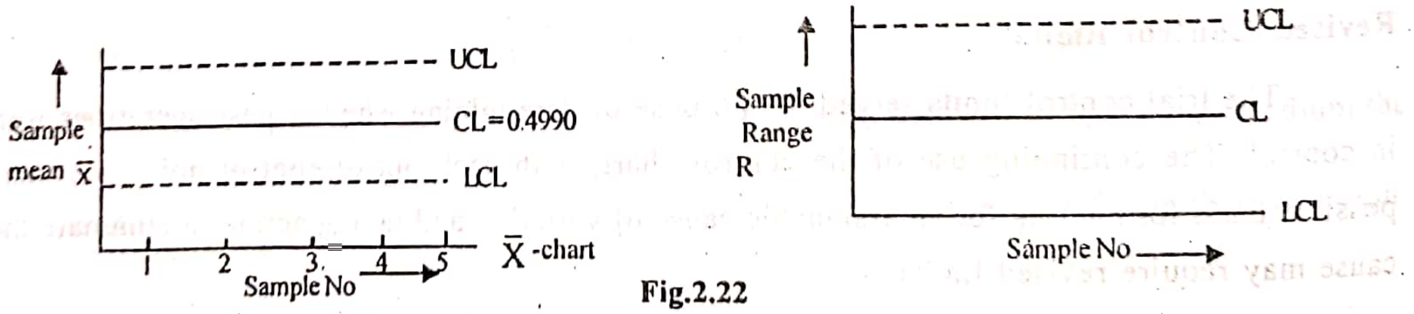


Fig.2.22

As no value of $\bar{X}$ or R is out of the control limits therefore, the trial control limits are the actual control limits. The process is operating free from assignable causes of variations and is only under the influence of chance causes of variations.

Example 2.6 *The fallowing are the mean lengths and ranges of lengths of a finished product from 10 samples each of size 5. The specification limits for length are* $200 \pm 5\text{cm}$. *Construct* $\bar{x}$ *and R charts and examine whether the process is under control and state your recommendations.*

Sample No	1	2	3	4	5	6	7	8	9	10
Mean $\bar{x}$	201	198	202	200	203	204	199	196	199	201
Range R	5	0	7	3	4	7	2	8	5	6

Assume for $n = 5$, $A_2 = 0.577$, $D_3 = 0$, $D_4 = 2.115$

Ans. The specification limits for length are given to be $200 \pm 5\,\text{cm}$

Hence, mean is known where as standard deviation is unknown.

Control limits for $\bar{X}$ chart

Control limit, $\text{Cl} = \mu = 200$

$$\text{UCL} = \mu + A_2\bar{R} = 200 + 0.577 \times 4.7 = 202.712$$

$$\text{LCL} = \mu - A_2\bar{R} = 200 - 0.577 \times 4.7 = 197.29$$

R-Chart

$\text{CL} = \bar{R} = 4.7$

$\text{UCL} = 9.941$

$\text{LCL} = 0$

All points lie within the control limits of R chart. The process variability is therefore, under control. However, 5, 6, 8 lie outside the control limits of $\bar{X}$ chart. The process should be halted to check whether there are any assignable causes.

Note : $\bar{X}$ – Chart

Centre line $= \bar{\bar{X}}$, when specification limits are not given

$= \mu = \dfrac{LSL + USL}{2}$, when specification limits are given.

The upper and lower process tolerance limits (also called natural tolerance limits) for individual values of x are computed by using

$$UTL_x = \bar{\bar{x}} + 3\frac{\bar{R}}{d_2} \qquad \left(\therefore\ \sigma = \frac{\bar{R}}{d_2}\right)$$

$$LTL_x = \bar{\bar{x}} - 3\frac{\bar{R}}{d_2}$$

Some examples of control by attributes are:

(1) Number of defectives in a lot.

(2) Number of mistakes on the part of a typist.

(3) Number of spots in a distempered wall.

(4) Number of complaints on a product per month, etc.

Three most commonly used charts for attributes are

(1) Control charts for fraction defective (P-chart)

(2) Number of defectives (np-chart)

(3) Number of defects (C-chart)

Control chart for fraction defective (p-chart)

$$p = \frac{d}{n} = \frac{\text{No. of defectives in a sample}}{\text{total no. of items in the sample}}$$

$$\bar{p} = \frac{\text{Total no of defective items in all the samples inspected}}{\text{Total no. of items in all the samples inspected}}$$

$$\text{Standard deviation } \sigma_p = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$\underset{LCL}{UCL} = \bar{p} \pm 3 \times \sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = \bar{p} \pm 3\sigma_p$$

Since the number of defectives cannot be negative, If LCL comes negative, it is taken as zero.

P - chart is used when the sample size does not remain uniform or it varies.

Control Charts: Control chart is a device to verify stability of the manufacturing process.

The schewant control chart (1931) is a visual display of the results of an inspection process. It has a central line and two control limits, upper and lower obtained form the data calculated from the law of probability.

(1) Control chart for measurable quality characteristics (variable)

(2) Control charts for attributes.

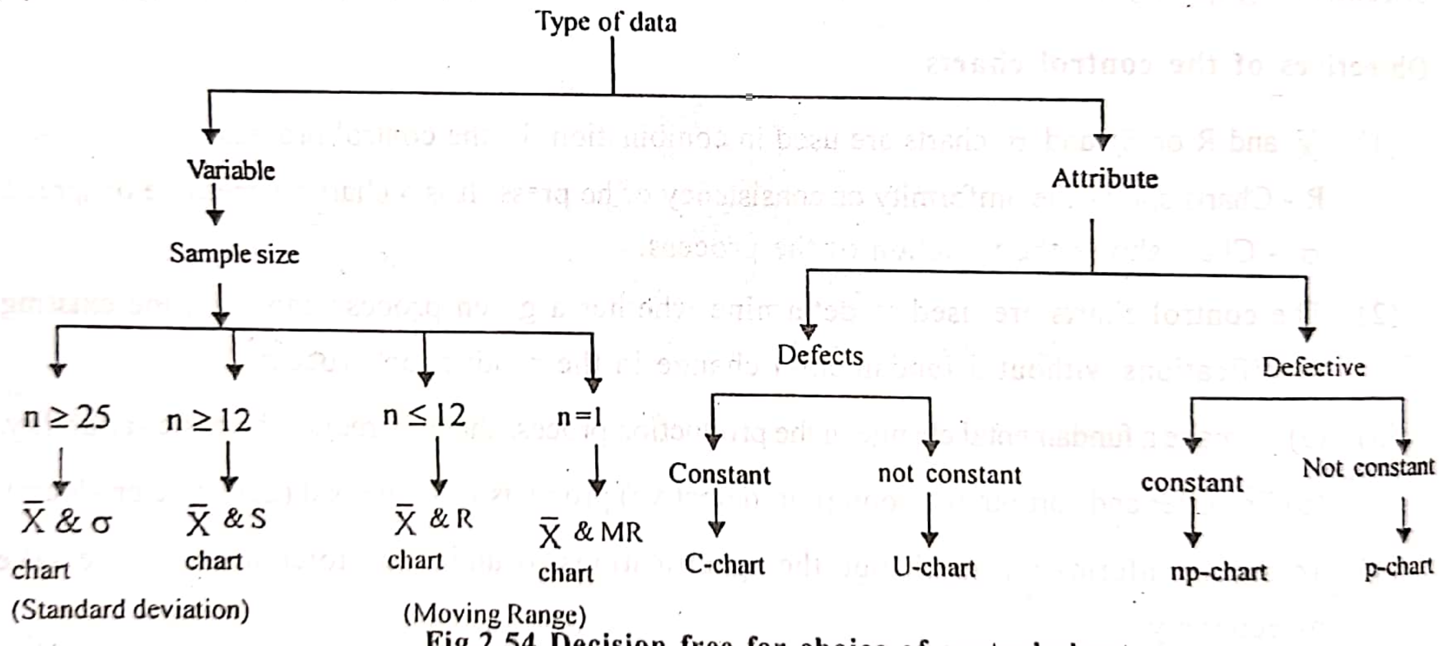


Fig.2.54 Decision free for choice of control chart.

A control chart can be defined as: A chronological (hour-by-hour, day-by-day) graphical comparison of actual product quality characteristics with limits reflecting the ability to produce as shown by past experience on the product characteristics.

Example 2.18 *A company manufactures screws to a nominal diameter of* 0.500 ± 0.030 *cm. Five samples were taken randomly from the manufactured lot and 3 measurements were taken on each sample at different lengths the readings are shown in the table below:*

Sample No.	Measurements per sample (cm) x		
	1	2	3
1	0.488	0.489	0.505
2	0.494	0.495	0.499
3	0.498	0.515	0.487
4	0.492	0.509	0.514
5	0.490	0.508	0.499

Calculate the control limits on $\bar{X}$ R-Charts and draw the charts.

Ans. Calculation of mean

For sample 1, $\bar{x}_1 = \dfrac{0.488 + 0.489 + 0.505}{3} = 0.49$

For sample 2, $\bar{x}_2 = \dfrac{0.494 + 0.495 + 0.499}{3} = 0.496$

$\bar{x}_3 = 0.500$, $\bar{x}_4 = 0.505$, $\bar{x}_5 = 0.499$

$$\bar{\bar{X}} = \frac{\bar{x}_1 + \bar{x}_2 + \bar{x}_3 + \bar{x}_4 + \bar{x}_5}{5} = 0.499$$

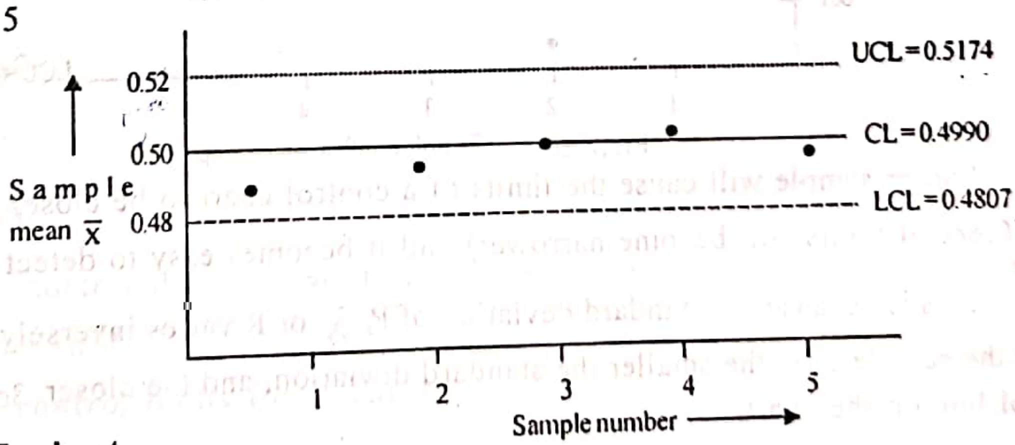


Fig. 2.55

Control limits for $\bar{X}$ chart

$$UCL = \bar{\bar{X}} + A_2\bar{R}$$

$$= 0.499 + 1.02 \times 0.018 = 0.5174$$

From table for n = 3, $A_2 = 1.02$

$$LCL = \bar{\bar{X}} - A_2\bar{R}$$

$$= 0.499 - 1.02 \times 0.018 = 0.4807$$

Calculation of Range

For sample 1, $R_1 = X_{max} - X_{min}$

$= 0.505 - 0.488 = 0.017$

$R_2 = 0.499 - 0.494 = 0.005$

$R_3 = 0.515 - 0.487 = 0.028$

$R_4 = 0.514 - 0.492 = 0.022$

$R_5 = 0.508 - 0.490 = 0.018$

$$\bar{R} = \frac{R_1 + R_2 + R_3 + R_4 + R_5}{5} = 0.018$$

Total Control limits

Control limits for R chart:

$$UCL = D_4\bar{R}$$

$$= 2.57 \times 0.018 = 0.0463$$

$$LCL = D_3\bar{R} = 0 \times 0.018 = 0.00$$

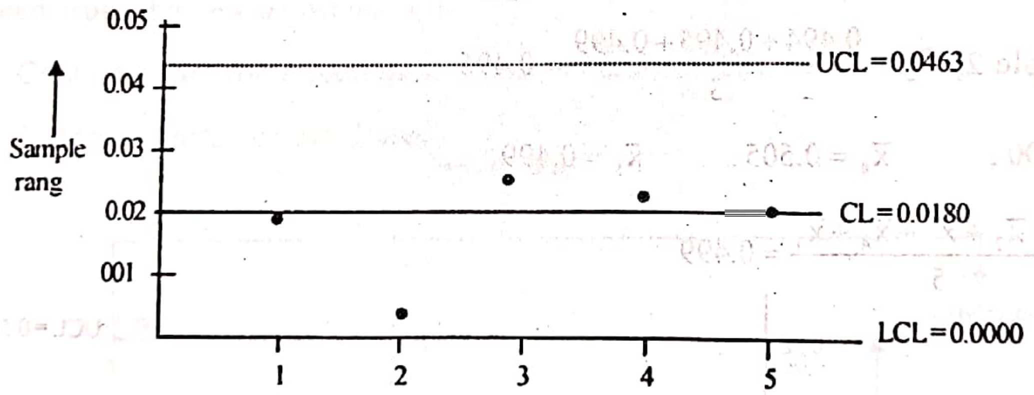


Fig.2.56

Larger sample will cause the limits of a control chart to be closer to control line on the chart (control limits will become narrower) and it becomes easy to detect small variations.

This is because the standard deviation of P, $\bar{X}$ or R varies inversely with $\sqrt{n}$. Hence, the larger the sample size, the smaller the standard deviation, and the closer 3σ limits will be to the control line on the chart.

Calculation Procedure for starting the Control charts:

(1) Calculate the average $\bar{X}$ and range R for each subgroup.

$$\therefore \bar{X} = \frac{x_1 + x_2 + x_3 + x_4 + x_5}{5}$$

Range, R = Highest value – smallest value.

(2) Calculate the grand average $\bar{\bar{X}}$ and average range $\bar{R}$

$$\therefore \bar{\bar{X}} = \frac{\Sigma \bar{X}}{N}$$

N = number of sub-groups

$$\bar{R} = \frac{\Sigma R}{N}$$

(3) Calculation of 3 sigma limits on control chart for $\bar{X}$ chart,

$$\therefore \sigma' = \frac{\bar{R}}{d_2}$$

$$\sigma_{\bar{x}} = \frac{\sigma'}{\sqrt{n}}$$

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

$$LCL\bar{X} = \bar{\bar{X}} - 3\sigma_{\bar{x}}$$

The formula for 3 sigma control limits on charts for $\bar{X}$ then become

$$LCL_{\bar{x}} = \bar{\bar{X}} + A_2\bar{R}$$

$$UCL_{\bar{x}} = \bar{\bar{X}} - A_2\bar{R}$$

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_1\bar{\sigma}$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2\bar{\sigma}$$

$$UCL_{\bar{X}} = \bar{X} + A\sigma'$$

$$LCL_{\bar{X}} = \bar{X}' - A\sigma'$$

The selection of control limits involves trade offs between two types of risks i.e. producer's risk (α) and consumer's risk(β).

(4) **Calculate the control limits for R chart.**

$$UCL_R = D_4\bar{R}$$

$$LCL_R = D_3\bar{R}$$

(5) Plot the $\bar{x}$ and chart : Central line as a solid horizontal line at $\bar{x}$. The upper and lower limits as dotted horizontal lines.

Example 2.19. *The following are the mean lengths and ranges of lengths of a finished product from 10 samples each of size 5. The specification limits for length are* 200 ± 5 *cm. Construct* $\bar{x}$, *and R charts and examine whether the process is under control and state your recommendations.*

Sample no.	1	2	3	4	5	6	7	8	9	10
Mean $\bar{x}$	201	198	202	200	203	204	199	196	199	201
Range R	5	0	7	3	4	7	2	8	5	6

Assume for $A = 5,\ A_2 = 0.577,\ D_3 = 0,\ and\ D_4 = 2.115$

Ans. Mean $= \bar{x} = 200$

$$UCL = \bar{x} + A_2\bar{R} = 202.712$$

$$\therefore R = \frac{\Sigma R_1}{10} = \frac{47}{10} = 4.7$$

$$LCL = \bar{x} - A_2\bar{R} = 197.29$$

$$UCL_{\bar{R}} = D_4\bar{R} = 9.941$$

$$LCL_{\bar{R}} = D_3\bar{R} = 0$$

Since all points lies within control for R chart the process variability is under control. For $\bar{x}$ the process is not in statistical control and needed check for assignable causes.

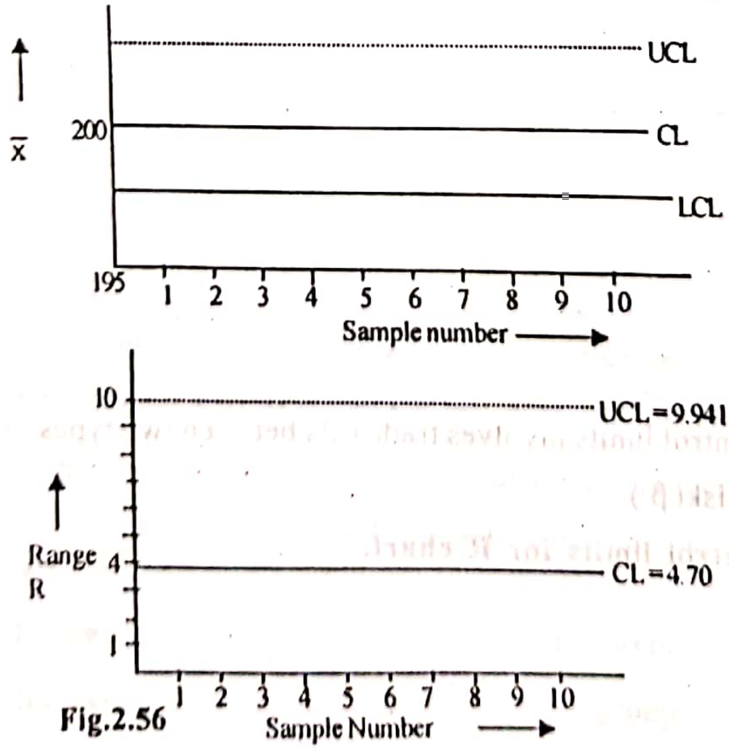


Fig.2.56

Comparison between $\overline{X}$, R chart and P-chart.

$\overline{X}$, R-charts	P-chart
(1) $\overline{X}$, R-Charts are control charts for variables.	(1) P-chart is a control chart for attributes.
(2) Data collection costs more.	(2) Data collection costs comparatively less.
(3) Sample size is smaller	(3) Sample size is comparatively larger.
(4) Variation is sample size influences the control limits more.	(4) Variation is sample size influences the control limits less.
(5) Sensitivity in detecting a shift is poorer comparatively.	(5) Sensitivity in detecting a shift is better.
(6) Separate charts are essential for each measured quality characteristics.	(6) One p-chart may be applied to any number of quality characteristics observed on one article at an inspection station.
(7) It is much superior for diagnosing the cause of change in dimension.	(7) It is much inferior for diagnosing of causes of trouble or rejection.

P-Chart

$$\therefore\ \overline{P} = \frac{\text{Total no. of defectives}}{\text{Total no. of items inspected.}}$$

$$UCL_p = \overline{P} + 3 \times \sqrt{\frac{\overline{P}(1-\overline{P})}{n}}$$

n - sample size

$$LCL_p = \overline{P} - 3 \times \sqrt{\frac{\overline{P}(1-\overline{P})}{n}}$$

The C-chart

$$\overline{C} = \frac{\text{No. of defects in all units inspected}}{\text{Total number of units inspected}}$$

Central line = $\overline{C}$

$$UCL = \overline{C} + 3 \times \sqrt{\overline{C}}$$

$$LCL = \overline{C} - 3 \times \sqrt{\overline{C}}$$

Inspection and Quality Control:

❖ One is reminded of quality long after price is forgotten.

❖ Each piece of scrap represents a loss to a company.

"Inspection is the process of measuring the quality of a product or service in terms of established standards" Dr. W.R. Speringle.

"Inspection is the art of comparing materials, products or performance, with established standards". Kimball.

"Inspection is the art of applying tests, preferably by the aid of measuring appliances to observe whether a given item of product is within the specified limit o variability" Alfred and Beaty.

Need for inspection (Objectives or purposes of inspection)

(1) To separate defective components from non-defective ones and thus to ensure the adequate quality of products.

(2) To locate defects in raw materials and flows in processes which otherwise cause problems at the final stage.

(3) To prevent further work being done on semi-finished products which are already detected as spoiled.

(4) To make sure that the product works and it works without hurting anybody i.e. its operation is safe.

(5) To detect sources of weakness and trouble in the finished products and thus to check the work of designers.

(6) Inspection builds up the reputation of the concern as it helps reducing the number of complaints from the customers.

(7) To protect consumer from receiving a product of sub standard quality by adapting inspection at various levels of manufacturing.

(8) To help the engineering and other depts concerned with production by compiling information regarding the performance of the product with specifications.

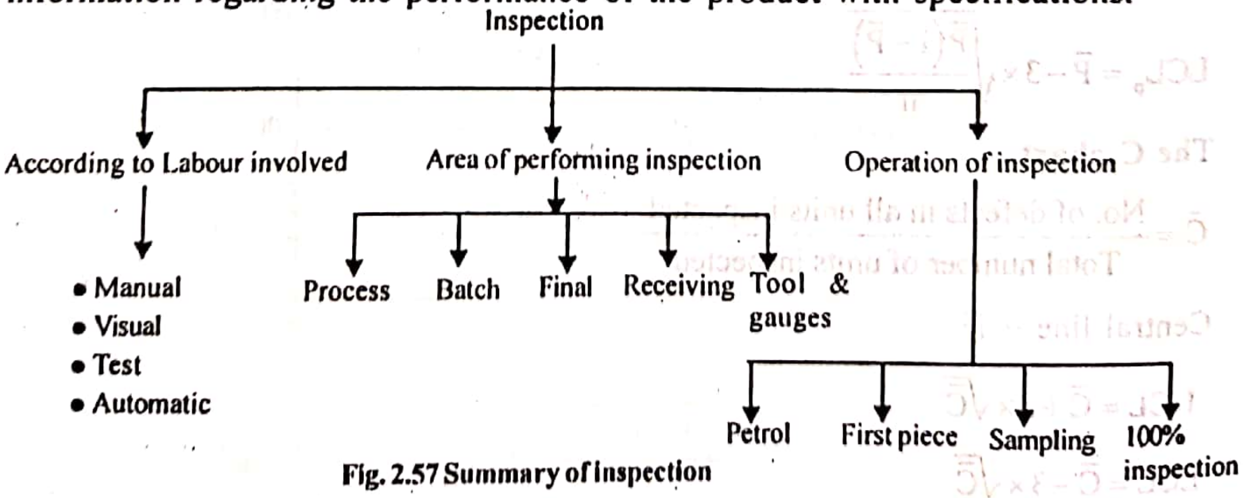


Fig. 2.57 Summary of Inspection

Common Probability Distribution

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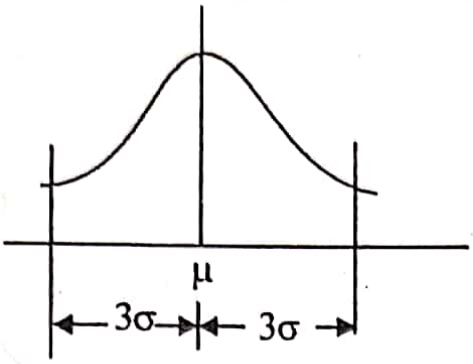
<tr><th>distribution</th><th>Form</th><th>Application</th></tr>
<tr><td>Normal</td><td>
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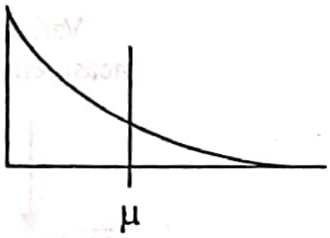
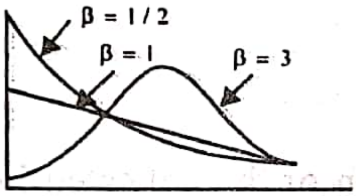
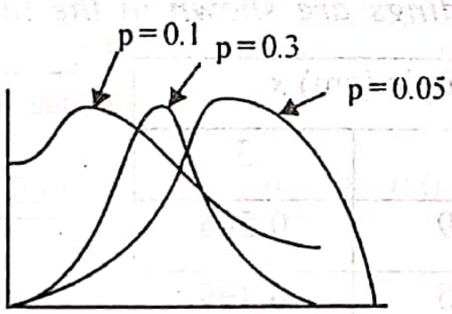
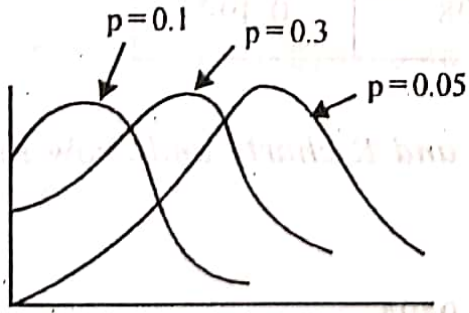
<tr><td>Exponential</td><td>
</td><td>When it is likely that more observations will occur below the average than above.</td></tr>
<tr><td>Wei bull</td><td>

α = Scale parameter
β = shape parameter</td><td></td></tr>
<tr><td>Poisson</td><td>

p = probability of occurrence
r = Number of occurrences</td><td>Same as bionomial</td></tr>
<tr><td>Binomial</td><td>
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Factor	$\bar{X}$-R charts	C-Charts	P-charts
Type of Data	Variable data	Attribute data	Attribute data
Advantages	(i) Provides maximum utilization of information drawn from data	(i) Data drawn from inspection records.	(i) Data drawn from the inspection records.
	(ii) Provides detailed information on process average and variation of control for individual dimensions.	(ii) Easy to understand	(ii) Easy to understand.
		(iii) Provides overall picture of quality.	(iii) Provide overall picture of quality.
		(iv) Focus on defectiveness in units of products.	
Disadvantages	(i) Trained personnel necessary for implementation	(i) Control of individual characteristics not possible	(i) Control of individual characteristics not possible
	(ii) Confusion between control limits and specification limits	(Ii) Different degrees of defectiveness of units of a product not recognized	(ii) Degree of defectiveness not recognized.
	(iii) Cannot be used with GO-No Go type of data.		
Application	Individual characteristic is controlled	Overall number of defects per unit is controlled	Overall fraction defective of a process is controlled.
Formulas	Control limits $=\bar{\bar{x}} \pm A_2\bar{R}$ $=\bar{\bar{x}} \pm 3\sigma_{\bar{x}}$ For R chart $UCL = D_4R, LCL = D_3\bar{R}$	Control limits $=\bar{C} \pm 3\sqrt{\bar{C}}$	Control limits $=\bar{P} \pm 3\sqrt{\frac{\bar{P}(1-\bar{P})}{n}}$

4.5 TOTAL QUALITY MANAGEMENT (TQM) :

A.V. Freign baum, 1983, Japan coined the term TQC. Which later become TQM.

Satisfying customer needs and expectations is a major theme in TQM without satisfied customers, market share will not grow, & revenue will not increase. Factors such as the quality of products and services and warranty policies offered by the competitor directly influence customer expectations. Customer surveys can help management determine discrepancies between expectations and satisfaction.

Quality is what customer wants. According to Badiru and Ayeri (1993) "Quality refers to an equilibrium level of functionality possessed by a product or service based on the producer's capability and customer's need.

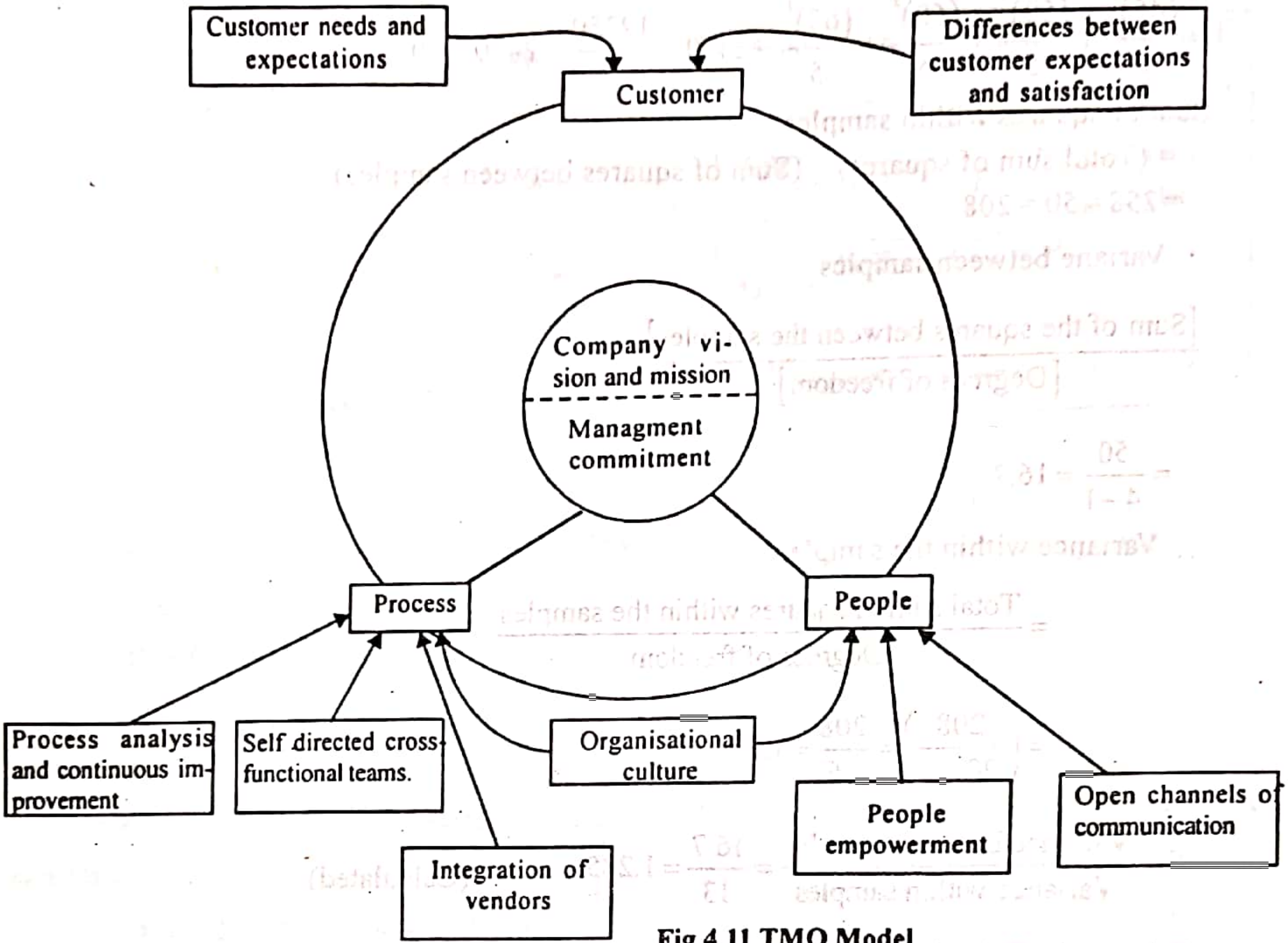


Fig.4.11 TMQ Model

Quality is a feature by which a thing is identified. Quality is never an accident, it s the result of intelligent efforts. It needs a will to produce superior things or services. Crossby stated "Quality is conformance to requirement or specification". Juran stated, "Quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs".

Customer satisfaction cannot be achieved by concentrating efforts upon any one area of the company/ plant alone, rather every phase i.e. marketing, reliability analysis, design, operation, inspection quality equipment, reject-troubleshooting eduction and training, maintainability studies, supplier's quality program, etc have to be considered. The fundamental factors affecting quality of products & service are management, market, money, men, materials, motivation, machines, modern information methods and mounting product requirements.

The major objectives to be attained by TQMs are as follows:

(i) Achieve zero-defects.

(ii) Minimising variance by eliminating waste.

Dimensions of TQM:

(i) Excellence (ii) Universality

(iii) Perpertuality.

TQM operation:

(i) People involvement (ii) Process/Product innovation.

(iii) Problem investigation (iv) Perpetual improvement.

Principles of TQM

(i) Agree customer requirements. i.e. Delight the customer is must.

(ii) Understand customers/suppliers. i.e. customer complaints, surveys, questionaires, contact feedback, retention etc.

(iii) Do the right things.

(iv) Do things right first time.

(v) Measure for success.

(vi) Continuous improvement is the good i.e. Reduction in scrap, rework, waste of humans, potential unnecessary processes, excess workers movement etc.

(vii) Management must lead.

(viii) Identifying training needs and relating them with individual capabilities and requirements is must.

(ix) Communication with staff at all levels regularly both formally an informally is must. Promote two way communication at all levels.

TQM culture : It is an organization culture to ensure things are done right first time. It basically aims to involve every person in every department of an organisation working together to eliminate errors and prevent waste.

According to Dr. Steve Smith on "Ten compelling reasons for TQM". which are highlighted as

(i) Committed customers.

(ii) Improved productivity.

(iii) Reduced costs.

(iv) Improved certainly in operations.

(v) Improved company image.

(vi) Dedicated management.

(vii) Increased number of employee participation.

4.6 ISO – 9000 :

The object of ISO is to promote the development of standardisation and related world activities with a view to faciliting international exchange of goods and services and develop co-operation in the sphere of intellectual, scientific, technological and economic activity.

ISO stands for international Organization for standardization. It is an international body which consists of representatives from more than 157 countries is located at Geneva, Switzerland and was established in 1946. 'ISO' is a Greak work means equal (ISO therm lines of a weather map Showing equal temperatures). As the European community moved towards the European Free Trade Agreement which went into effect at the end of 1992, quality management became a key strategic objective of standardisation (ISO). ISO adopted a series of written quality standards in 1987. These are called ISO-9000 standards and were revised in 1994. Organisations certified under the ISO-9000 standard are assured to have quality equal to their peer (Equal) organisations. The standards have been adopted in the USA as The ANSI/ASQC Q9000 –1994 series but are commonly referred to as ISO–9000. BIS (Bureau of Indian Standards) is the Indian representative to ISO. ISO and IEC (International Electro Technical Commission) operate jointly as a single system. These are non-governmental organizations which exist to provide common standards on international trade of goods and services.

The work of preparing international standards is normally carried out through ISO technical committee. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. Draft technical committees are circulated to the member bodies for approval before their acceptance as International standards by the ISO council. They are approved in accordance with ISO procedures requiring at least 75% approval by the member bodies voting.

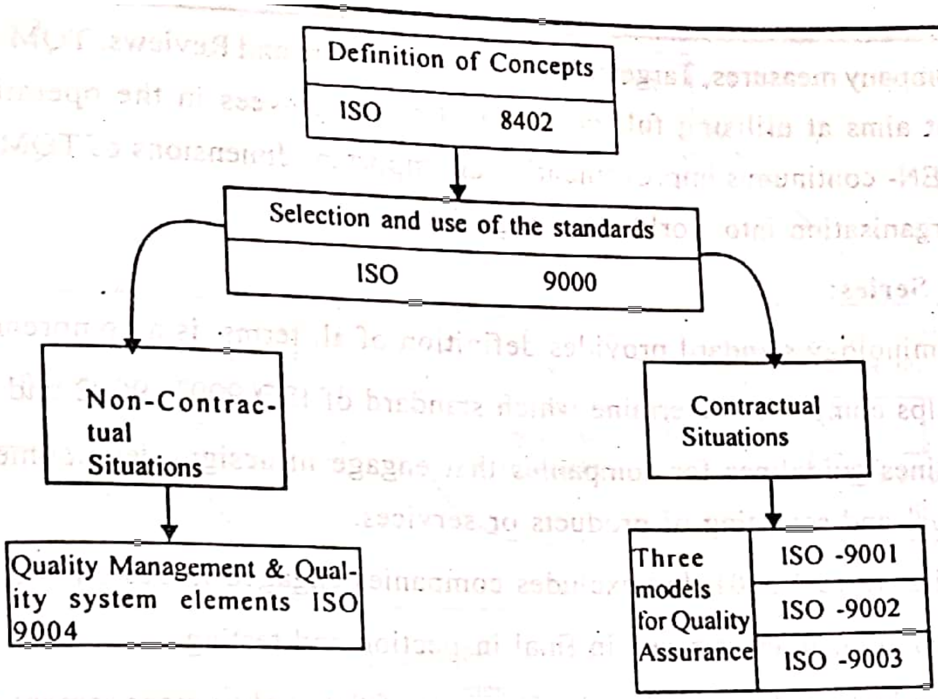
The texts of these standards released by the ISO central secretariat in Geneva are adapted as the IS-14000 series of standards by BIS. These standards embody comprehensive quality management concepts and guidance. The control (creation, modification and deleting) of all documents related to quality management is an important requirement of ISO-9000 covering elements such as drawings, specifications, blueprints, work instructions, test procedures, inspection reports, quality cost reports and calibration data.

ISO-9000 series has 5 international standards on quality management. They are

(i) ISO - 9000 (ii) ISO - 9001

(iii) ISO - 9002 (iv) ISO - 9003

(v) ISO - 9004



TQM Vs ISO 9000 :

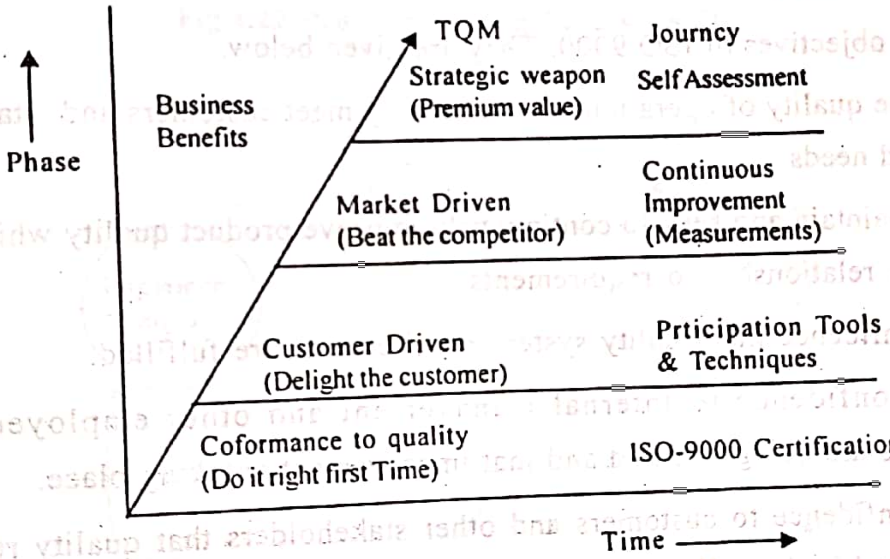


Fig.4.21 Role of ISO in TQM Journey

ISO-9000 is not TQM, but is a subcomponent of TQM and a good start on the TQM path.

ISO - 9000 provides means to establish well structured and organize systems.

ISO - 9000 is a set of standards and focuses on documents. It ignores human element. Whereas TQM focuses on developing human elements. ISO-9000 standards and TQM are different but are not in opposition. For an ISO certified company, it is not necessary that it is following the essentials of TQM. ISO only certifies that whatever is followed is being documented. The certification body does not share the responsibility that processes are perfectly ordered and everything is OK.

Objectives of Quality Circles

1. Respect humanity and build a happy bright work place, worthwhile to live.
2. To improve quality, productivity, safety and cost reduction.
3. To develop team spirit, cohesive culture among different levels and selection of the workers.
4. To offer opportunities to the employees to use their widwom and creativity.
5. To improve the life of the employees.
6. To promote self and mutual development including leadership quality.
7. To fulfill the self esteem and motivational needs of the employees.

Merits/ Benefits of Quality Circles:

Benefits can be divided into 2 groups.

(i) Benefits to the organization

(ii) Benefits to the workers.

Benefit to organisation

(i) Improved quality

(ii) Increased productivity.

(iii) Enhanced motivation.

(iv) Development of complete coherent problem solving methodology.

(v) Answer to the modern industrial dilemma of man as machine.

(vi) Absenteeism will be reduced.

(vii) Disciplinary problem will reduce.

(viii) Better supervision.

(ix) Communication will improve

(x) Reduction in costs.

Benefits to workers

(i) Enhances ability to work with others.

(ii) Improvement in attitude and behaviour of people.

(iii) Workers will take greater pride in their work.

(iv) Cooperation will increase.

(v) Provides a sense of participation in deciding company policies.

(vi) Better mutual trust.

(vii) Increased safety.

(viii) Better human relations.

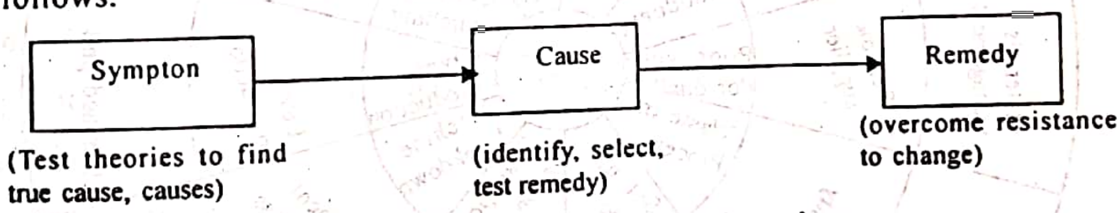
(ix) Improvements in the life-style of employees.

4.7 JUST IN TIME (JIT) CONCEPT:

JIT production system founded by Taguchi Ohno, Vice President of Toyata motor company of JAPAN in the year 1982 and was successfully implemented in the same plant, now being tried at various manufacturing industries all over the world. If we make our raw materials suppliers agree that they should deliver their goods only at the time and in the quantities we need them to, then we are almost eliminating raw materials inventories as well which means we have virtually zero inventories or near about zero. Company wide Quality Improvement (CQI) programme is fundamental to the achievement of JIT. "Just -in-time" is not a jargon term for a new concept. It represents a goal. That goal is the ultimate total elimination of inventory, minimal work-in-progress and is monitored by a constant reduction in so-called working capital i.e. money.

JIT is an approach to material management and control designed to produce or deliver parts and materials when required in production. The concept of JIT can be explained literally as getting an item just in time of need not earlier, not later. This reduces the inventory level to zero.

Thus with JIT system a large company that makes an assembled product will require its suppliers to deliver the components needed for the final product within a very short time interval before the assembly process. The time interval may be one day or less depending upon the reliability of the supplier regarding to make deliveries in schedule. This policy of JIT will fail miserably if the reliability of a supplier is not high. Some companies have a policy of not producing any thing until a customer is found. Therefore in JIT, the key theme is to work without buffer stock/with minimal buffer stock. According to Dr. Juran, every problem solving, every breakthrough, follows a universal sequences of events and all successful projects follow the sequence as follows.



JIT is both a philosophy and a set of methods for manufacturing.

Definition of JIT:

According to American Production and Inventory Control Society (APICS), JIT is defined as "A philosophy of manufacturing based on planned elimination of all waste and continuous improvement of productivity. It encompasses the successful execution of all manufacturing activities required to produce a final product, from engineering to delivery and including all stages of conversion from raw material onward. The primary elements of zero inventories (synonym for JIT) are to have only the required inventory when needed, to improve quality to

Inspection

"Inspection is the art of comparing materials, products or performance with established standards" – Kimball.

Planning for inspection

Where to inspection ? place.

When to inspection ? Time.

How to inspection? Method of inspection.

How much to inspection ? Degree of inspection accuracy, reliability.

Types inspection

Inspection of in case materials.

Inspection of process materials.

Inspection of finished goals.

Degree of inspection (Methods)

(1) Sampling inspection.

(2) 100% inspection.

Comparison between 100% inspection and sampling inspection.

100% Inspection	Sampling Inspection
(1) Total cost of inspection per lot is high.	(1) Total cost of inspection per lot is low more characteristics of each item could be studied.
(2) Quite time consuming if lot size is large.	(2) Decisions can be arrived at quickly.
(3) Generally not feasible due to limitations of skilled personal, complex instrumentation.	(3) Generally feasible.
(4) Complete accuracy of inference is seldom attained due to inspection errors arising out of fatigue negligence, difficulty of supervision etc.	(4) Inspection can be organized and controlled more efficiently, reasonable accuracy of inspection is possible, also measured sampling error can be obtained.
(5) More handling damage during inspection.	(5) Less handling damage during inspection.
(6) Not feasible when the inspection involved destructive tests.	(6) Only method possible when the inspection involves destructive tests.
(7) No risk or error due to sampling can be taken for critical parts, safety devices.	(7) A measurable risk due to sampling error will have to be tolerated.
(8) It is followed where a process is giving repeatedly defects.	(8) It generally employed where the inspection cost is higher destructive in nature.
(9) It is followed for inspection of life saving drugs, parts of aeroplanes, and parts of steam boilers and turbines because it involves the loss of precious human lines. Life of a candle or testing of electrical fuses.	(9) such a sharpness test of a razor blade breaking load test on a wire rope and firing test of ammunition etc.

Sampling Inspection:

A sample may be defined as the number of items or component parts, drawn from a lot batch or population (for inspection purposes).

The main purpose of acceptance sampling is to distinguish between good lots and bad lots, and to classify the lcts according to their acceptability or non-acceptability.

Sampling inspection can be defined as a technique to determine the acceptance or rejection of a lot or population on the basis of number of defective parts found in a random sample drawn from the lot. If the number of defective items doesn't exceed a predefined level the lot is accepted, otherwise it is rejected.

Advantages of Sampling inspection

(1) The items which are subjected to destructive test must be inspected by sampling inspection only.

(2) The cost and time required for sampling inspection is quite less as compare to 100% inspection.

(3) Problem of inspection fatigure which occurs in 100% inspection is eliminated.

(4) Smaller inspection staff is necessary.

(5) Less damage to products because only a few items are subjected to handling during inspection.

(6) The problem of monitory and inspector error introduced by 100% inspection is minised.

(7) It exerts more effective pressure on quality improvement. Since the rejection of entire lot on the basis of sampling brings much stronger pressure on quality improvement than the rejection of individual articles.

Limitations

(1) Risk of making wrong decisions

- A good lot may be rejected because the sample dram may bad.
- A really bad lot may be accepted because the sample drum may be good.

(2) The sample smoothly provides less information about the product than 100% inspection.

(3) Some extra planning and documentation is necessary.

The success of a sampling scheme depends upon the following factors:

(1) Randomness of samples.

(2) Sample size.

(3) Quality characteristic to be tested.

(4) Acceptance criteria.

(5) lot size.

Lot formation:

A lot is a collection of items from which a sample of two or more articles is drawn and inspected to determine its acceptability.

The lot should be as large as possible consistent with the above to take advantage of low proportional sampling costs.

Sampling methods

(1) Simple Random sampling.

(2) Stratified sampling.

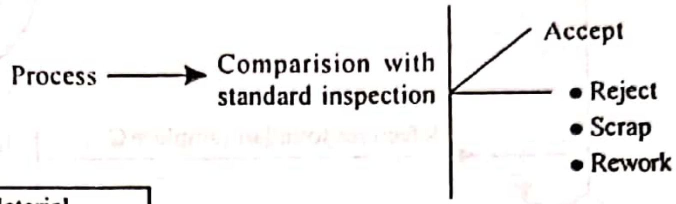
(3) Systematic sampling.

(4) Cluster sampling.

(5) Two stage sampling/sampling in stages.

Equal chance of being selected.

Sampling Inspection :



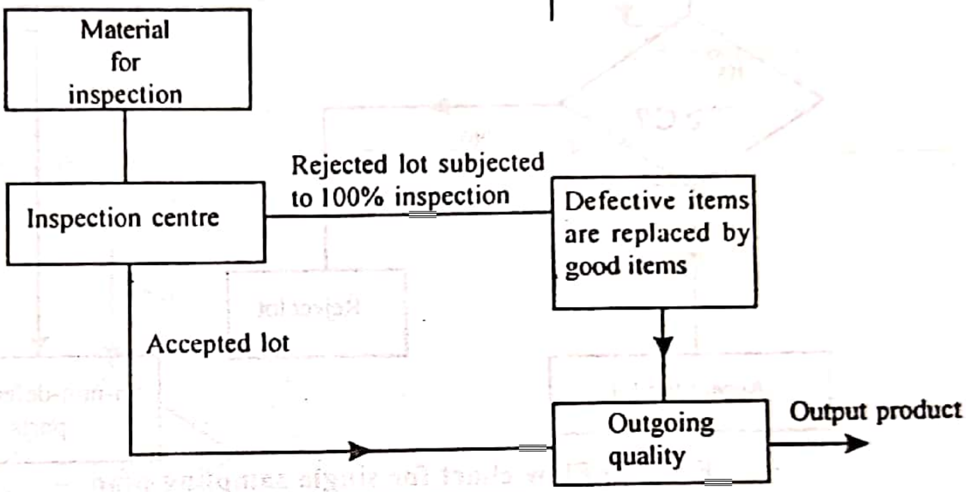


Fig.2.27 Principle of sampling inspection in any process.

Inspection is of two types

(i) 100% inspection

(ii) Sampling inspection.

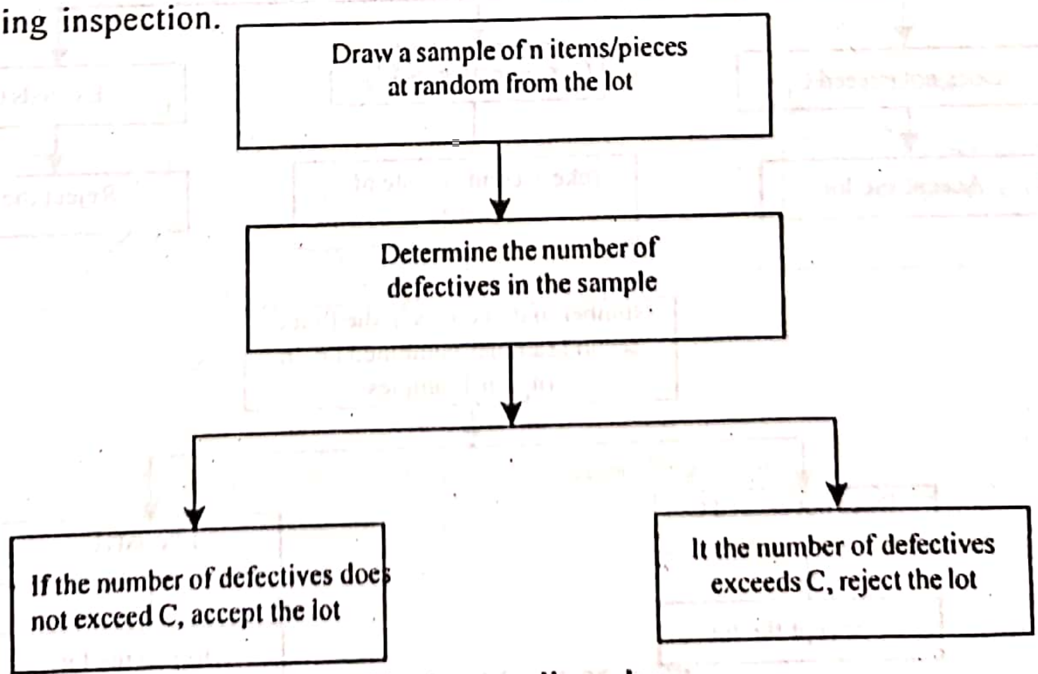


Fig.2.28 Single sampling plan.