A LECTURE NOTE
ON
TH.1 INDUSTRIAL ENGINEERING & MANAGEMENT
SEMESTER -6

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Mechanical Engineering

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CONTENTS

1. PLANT ENGINEERING

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

SELECTION OF SITE OF INDUSTRY:

The problem of site selection of a factory can be solved in the following three stages:
1) Selection of the region.
2) Selection of the locality,
3) Selection of actual site.

1) Selection of the region:

Generally, the geographical area is divided on the basis of natural regions or political boundaries within the nation (for example, Maharashtra State, Gujarat State, U.P. State etc.). The suitability of various regions are considered on the basis of comparative cost advantages available out of the possible regions.

Some of the major considerations in selecting the region.

a) Availability and proximity of raw-materials,
b) Vicinity of the market,
c) Labour supply
d) Climatic conditions

2) Selection of the Locality:

After selecting the region, the specific locality within the region is considered.
Generally, following alternatives are open in selecting the locality.
a) Urban area.
b) Rural area.
c) Suburban area in the vicinity of the urban area.
The following factors must be considered while selecting the location of the factory:
1. Availability of Raw-materials.
2. Proximity to markets.
3. Availability of labour.
4. Transport and communication facilities.
5. Availability of power and fuel.
6. Climatic conditions.
7. Availability of water.
8. Ancillary Industries.
9. Financial and other aids.
10. Business and commercial facilities.

1. Availability of Raw-Material. (Nearness to supply of raw-material).
As far as possible the site selected should be near the source of raw-materials, so that the cost of transportation can be minimized and the storing cost can be reduced due to shorter lead time.
If the raw-materials are heavy and bulky or cheap but loses a good amount of weight during processing, it becomes essential to select a site near to the source of raw material.

2. Proximity to markets.

The cost of transporting finished goods, advertising and distribution etc. will be greatly reduced if the factory is located near the market. Nearness to market is an important factor in the following cases:

a) Industries using light raw-materials of high value.

b) Industries producing perishable, fragile or heavy products.

c) For the industries providing technical advice and services (such as tool and die companies) this will help in ensuring prompt service to customers.

- If the product enjoys scattered market then nearness of the market is not a deciding factor in the selection of site.

3. Availability of labour.

Availability of right kind of labour force in required numbers at reasonable rates is also a deciding factor in selection of site. Unskilled labour is amply available at major industrial centres and rural areas. However, the firms requiring skilled labour should be situated near the urban areas.

- The glass and bangle industries in Firozabad, woollen carpets in Mirzapur, Silk sarees at Kanziwaram etc. are mainly due to highly skilled labour for that particular industry being available at the place.

4. Transport and communication facilities.

Transport facilities are needed for transporting raw materials, parts and finished goods. Generally industries have a tendency to locate the industrial units near the railway station, highway or port areas.

Railways are cheaper but involve delays. Road transport is quick, it is convenient for door to door service, but it is costlier. So a balance should be achieved between the two according to the need of the unit. Generally long distances are covered by Railway transport and short distances by road transport. Communication facilities like mail, telephone, telegraph etc. must be adequate. Regularity of service, safety, speed and low cost are essential both for transport and for communication.

5. Availability of power and fuel.

Coal, electricity, oil and natural gas are the important sources of power in the industries. The availability of reliable and cheap power supply is an important factor in the location of electro-chemical industries, iron and steel industries, glass, pulp and paper industries etc. for example, Tata iron and steel industry is established near the coal mines of Bihar.

6. Climatic conditions.

Climatic conditions largely affect certain production process also the efficiency of the employees. For example, textile mills require moist climate that is why most of the textile mills are situated at Bombay and Ahmedabad. For agro-base industries like tea and coffee or rubber plantations, climatic conditions play a decisive role in the selection of the site.

- However, with the development of air-conditioning techniques, it is possible to control the temperature as well as humidity in the factory according to the requirements, though at the additional costs.

7. Availability of water.
Water is used in industries for processing as in paper in chemical industries, for generation of power in hydroelectric power plants and is also required for drinking sanitary purposes etc. Depending upon the nature of plant water should be available in adequate quantity and should be proper quality (clean and pure).

8. Ancillary Industries.
The existence of ancillary industries in the nearby area may avail certain economic advantages. Many industries such as processing and assembly industries are not producing all the parts of their product but purchase some of the parts from ancillary industries producing it. The products produced by ancillary industries then forms a raw-material for such industries.

9. Financial and other aids.
For the development of backward regions central as well as Stale Government provide certain incentives and facilities such as cash-subsidy, concessional financial assistance, land, power and other facilities at cheaper rates, tax concessions etc.

10. Business and commercial facilities.
For day-to-day management of finance and working capital needs, banking services are considered highly desirable. Facilities for depositing surplus cash, discounting of bills, sending outstation cheques for collection and withdrawals, for meeting the cash shortages nearness to banking facilities is essential.

3) Selection of actual site:

A. URBAN AREA

Advantages

1. Excellent communication network.
2. Good transportation facilities for material and people.
3. Availability of skilled and trained manpower.
4. Factory in the vicinity of the market hence high local demand.
5. Excellent sourcing (subcontracting) facilities.
6. Good educational, recreational and medical facilities.

Disadvantages

1. High cost of land compared to rural area.
2. Sufficient land is not available for expansion.
3. Labour cost is high due to high cost of living.
4. Industrial unrest due to trade union activities.
5. Management labour relations are much influenced by union activities.
6. Municipal and other authority restrictions on buildings etc.
7. High labour turnover.

B. RURAL AREA

Advantages

1. Cheaper and ample availability of site.
2. Cheaper labour rates.
3. Less turnover of labours because of limited mobility.
4. No municipal restrictions.
5. Good industrial relations.
6. Scope for expansion and diversification.

Disadvantages

1. Poor transportation network.
2. No good communication facilities.
3. Sourcing of components and materials should be from outside.
4. Far away from market.
5. High absenteeism during harvest season.
6. No educational, medical and recreational facilities.

C. SUBURBAN AREA

Advantages

1. Land available at cheaper rate compared to urban location.
2. Infrastructure facilities are developed by promotional agencies.
3. Because of nearness to city availability of skilled manpower.
4. Educational, medical facilities are available because of nearness to city.

Limitations

1. Due to concentration the suburban area will become crowdy and will become urban in turn within short period.
2. High mobility of workers and hence higher labour turnover.
3. Government incentive and subsides to promote industry.

PLANT LOCATION: Plant location refers to the choice of region and the selection of a particular site for setting up a business or factory. It is defined as that location which, in consideration of all factors affecting products delivered to customers cost of product to be manufactured, will afford the enterprise he greatest advantages obtained by virtue of location".

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

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

a) Proper and efficient utilization of available floor space
b) To ensure that work proceeds from one point to another point without any delay
c) Provide enough production capacity.
d) Reduce material handling costs
e) Reduce hazards to personnel
f) Utilize labour efficiently
g) Increase employee morale
h) Reduce accidents
i) Provide for volume and product flexibility
j) Provide ease of supervision and control
k) Provide for employee safety and health
l) Allow ease of maintenance
m) Allow high machine or equipment utilization
n) Improve productivity

PRINCIPLES OF PLANT LAYOUT:

(i) Principle of Space Utilization:

All available cubic space should be effectively utilized – both horizontally and vertically.

(ii) Principle of Flexibility:

Layout should be flexible enough to be adaptable to changes required by expansion or technological development.

(iii) Principle of Interdependence:

Interdependent operations and processes should be located in close proximity to each other; to minimize product travel.

(iv) Principle of Overall Integration:

All the plant facilities and services should be fully integrated into a single operating unit; to minimize cost of production.

(v) Principle of Safety:

There should be in-built provision in the design of layout, to provide for comfort and safety of workers.

(vi) Principle of Smooth Flow:

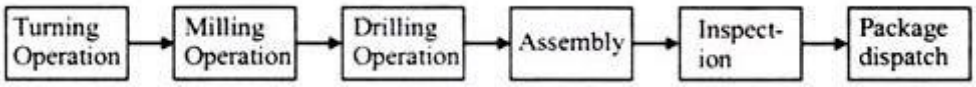
The layout should be so designed as to reduce work bottlenecks and facilitate uninterrupted flow of work throughout the plant.

(vii) Principle of Economy:

The layout should aim at effecting economy in terms of investment in fixed assets.

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

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



Advantages:

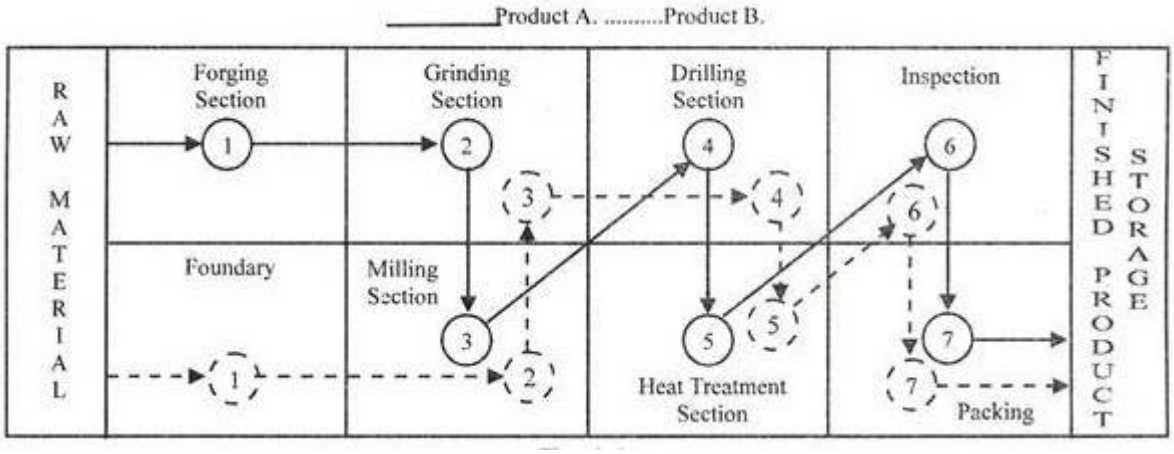
1. Reduced material handling cost due to mechanized handling systems and straight flow
2. Perfect line balancing which eliminates bottlenecks and idle capacity.
3. Short manufacturing cycle due to uninterrupted flow of materials
4. Simplified production planning and control; and simple and effective inspection of work.
5. Small amount of work-in-progress inventory
6. Lesser wage cost, as unskilled workers can learn and manage production.

Disadvantages:

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

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

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



Advantages of Process Layout:

(i) There will be less duplication of machines. Thus total investment in equipment purchase will be reduced.

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

Limitations of Process Layout:
(i) There are long material flow lines and hence the expensive handling is required.
(ii) Total production cycle time is more owing to long distances and waiting at various points.
(iii) Since more work is in queue and waiting for further operation hence bottlenecks occur.
(iv) Generally more floor area is required.
(v) Since work does not flow through definite lines, counting and scheduling is more tedious.
(v)Specialization creates monotony and there will be difficulty for the laid workers to find job in other industries.

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

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

TECHNIQUES OR TOOLS USED FOR GOOD PLANT LAYOUT:
An ideal plant layout should provide the optimum relationship among output, floor area and manufacturing process. It facilitates the production process, minimizes material handling, time and cost, and allows flexibility of operations, easy production flow, makes economic use of the building, promotes effective utilization of manpower, and provides for employee's convenience, safety, comfort at work, maximum exposure to natural light and ventilation. It is also important because it affects the flow of material and processes, labour efficiency, supervision and control, use of space and expansion possibilities etc.

In designing or improving the plan of plant layout, certain techniques or tools are developed and are in common use today. The techniques or tools are as follows:

1. Charts and Diagrams:

In order to achieve work simplification, production engineers make use of several charts and diagrams for summarizing and analyzing production process and procedure. These include

Operation process chart: It subdivides the process into separate operations and inspection. When a variety of parts and products are manufactured which follow a different path across several floor areas, an operation process chart may be necessary for the important material items or products. The flow lines of the charts indicate the sequence of all operation in the manufacturing cycle.

Flow process chart: This chart is the graphic summary of all the activities taking place on the production floor of an existing plant. By preparing this type of chart, it can be found out as to where operations can be eliminated, rearranged, combined, simplified or subdivided for greater economy.

Process flow diagram: The diagram is both supplement and substitute of process flow chart. It helps in tracing the movement of material on a floor plan or layout drawing. A diagram may be drawn to scale on the original floor plan to show the movement of work. It is a good technique to show long materials hauls and backtracking of present layouts, thereby indicating how the present layout may be improved. Colored lines can show the flow of several standards products.

2. Machines Data Card:

This card provides full information necessary for the placement and layout of equipment. The cards are prepared separately for each machine. The information generally given on these cards include facts about the machine such as capacity of the machines, space occupied, power requirements, handling devices required and dimensions .

3. Templates:

Template is the drawing of a machine or tool cut out from the sheet of paper. Cutting to scale shows the area occupied by a machine. The plant layout engineer prepares a floor plan on the basis of reel vent information made available to him. The template technique is an important technique because (i) it eliminates unnecessary handlings, (ii) minimize backtracking of materials, (iii) it makes the mechanical handling possible, (iv) it provides a visual picture of proposed or existing plan of layout at one place, (v) it offers flexibility to meet future changes in the production requirements.

4. Scale Models:

Though the two-dimensional templates are now in extensive use in the fields of layout engineering but it is not much use to executives who cannot understand and manipulate them. One important drawback of template technique is that it leaves the volume, depth, height and clearance of the machines to the imaginations of the reader of the drawing. These drawbacks of the template technique have been removed through the development of miniature scale models of machinery and equipment cast in metal. The miniature machines and models of material handling equipment are placed in a miniature plant and moved around in pawn on a chessboard.

5. Layout Drawings: Completed layouts are generally represented by drawings of the plant showing wall, columns, stairways, machines and other equipment's, storage areas and office areas.

MATERIAL HANDLING:
Material handling ranges from movement of raw material, work in progress, finished goods, rejected, scraps, packing material, etc. These materials are of different shape and sizes as well as weight. Material handling is a systematic and scientific method of moving, packing and storing of material in appropriate and suitable location.

The main objectives of material handling are as follows:

- It should be able determine appropriate distance to be covered.
- Facilitate the reduction in material damage as to improve quality.
- Reducing overall manufacturing time by designing efficient material movement.
- Improve material flow control.
- Creation and encouragement of safe and hazard-free work condition.
- Improve productivity and efficiency.
- Better utilization of time and equipment.

PRINCIPLES OF MATERIAL HANDLING:

- **Planning Principle**: It establishes a plan which includes basic requirements, desirable alternates and planning for contingency.
- **Unit Load Principle**: Handle product in a unit load as large as possible
- **Space Utilization Principle**: Encourage effective utilization of all the space available
- **Standardization Principle**: It encourages standardization of handling methods and equipment.
- **Ergonomic Principle**: It recognizes human capabilities and limitation by design effective handling equipment.
- **Energy Principle**: It considers consumption of energy during material handling.
- **Ecology Principle**: It encourages minimum impact upon the environment during material handling.
- **Flexibility Principle**: Encourages of methods and equipment which are possible to utilize in all types of condition.
- **Simplification Principle**: Encourage simplification of methods and process by removing unnecessary movements
- **Gravity Principle**: Encourages usage of gravity principle in movement of goods.
- **Safety Principle**: Encourages provision for safe handling equipment according to safety rules and regulation
- **Computerization Principle**: Encourages of computerization of material handling and storage systems
- **Cost Principle**: Encourages cost benefit analysis of all solutions available
- **Maintenance Principle**: Encourages preparation of plan for preventive maintenance and scheduled repairs
- **Obsolescence Principle**: Encourage preparation of equipment policy as to enjoy appropriate economic advantage.

PLANT 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.

IMPORTANCE OF PLANT MAINTENANCE:

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

TYPES OF PLANT MAINTENANCE:

PREVENTIVE MAINTENANCE:

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

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

Advantages:

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

BREAKDOWN MAINTENANCE:

- Corrective or breakdown maintenance implies that repairs are made after the equipment is out of order and it cannot perform its normal function any longer.
  Ex – electric motor will not start, a belt is broken etc.
- Under such conditions, production department calls on the maintenance department to rectify the defect. The maintenance department checks into the difficulty and makes the necessity repairs.
- After removing the fault, maintenance engineers do not attend the equipment again until another failure or breakdown occurs.

- Breakdown maintenance is economical for those equipment whose down-time and repair costs are less.
- Breakdown type maintenance involves little administrative work, few records and comparative small staff.

Causes of equipment breakdown:

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

Disadvantages of breakdown maintenance:

- Breakdowns occur at inopportunity times, which lead to poor, hurried maintenance and excessive delays in production.
- Reduction of output
- More spoilt material
- Increased chances of accidents and less safety to both workers and machines
- Direct loss of profit.
- Breakdown maintenance cannot be employed to cranes, lifts, hoists and pressure vessels.

SCHEDULED MAINTENANCE:

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

PREDICTIVE MAINTENANCE:

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

2. OPERATIONS RESEARCH

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

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

APPLICATION:

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

LINEAR PROGRAMMING PROBLEM: Linear programming is powerful mathematical technique for finding the best use of limited resources of a concern. It may be defined as a technique which allocates scarce available resources under conditions of certainty in an optimum manner to achieve the company objectives which may be maximum overall profit or minimum overall cost.

LP can be applied effectively only if

a) The objectives can be stated mathematically

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

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

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

LPP can solved by two methods.

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

Graphical method:

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

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

ANSWER:

Graphical method:

1st step:
Formulate the LPM.

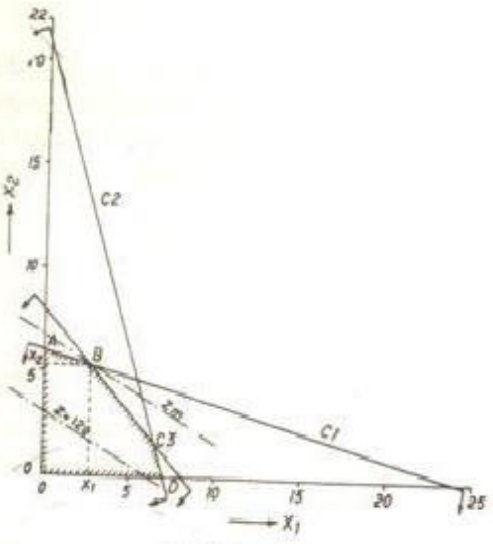
Max Z = 20x1 + 40x2
Subjected to x1 + 4x2 24 (c1)
3x1 + x2 21 (c2)
x1 + x2 8 (c3)
x1, x2 0 (c4)
c1 is constrain no. 1 and so on.

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

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

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

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



Graphical method.

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

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

6th step:
A straight line Zm is drawn parallel to the line Z, at the furthest point of the region of feasible solution i.e. point B, at the intersection of c1 & c3.
The co-ordinates at point B can be found by solving equation c1 & c3.
x1 + x2 = 8 (c3)
x1 + 4x2 = 24 (c1)
3x2 = 16 => x2 = 5.3
3x1 = 8 => x1 = 2.7

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

Terms related to network planning methods:
Event (node):
An event is a specific instant of time which marks the start and the end of an activity. Event consumes neither time nor resources. It is represented by a circle and the event no. is written within the circle.
Ex – start the motor, loan approved.

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

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

Activities are classified as:
1. **Critical activities**: In a network diagram, critical activities are those which if consume more than their estimated time the project will be delayed. An activity is called critical if its earliest start time plus the time taken by it is equal to the latest finishing time. A critical activity is marked either by a thick arrow or (//).

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

3. **Dummy activities**: When two activities start at the same instant of time, the head events are joined by a dotted arrow and this is known as dummy activity. It does not consume time. It may be non-critical or critical. It becomes a critical activity when its EST = LFT.

Critical path:

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

Earliest start time (EST):

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

Earliest finish time (EFT):

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

Latest finish time (LFT):

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

Latest start time (LST):

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

LST = LFT – duration of that activity

Float or slack:

Slack is with reference to an event and float is with respect to an activity. It means spare time, a margin of extra time over and above its duration which a noncritical activity can consume without delaying the project.

Float is the difference between the time available for completing an activity and the time necessary to complete the same.

There are three type of float.

1. Total float:

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

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

2. Free float:

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

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

3. Independent float:

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

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

If IF is negative, then taken as 0.

EXAMPLE:
Construct the network from the information.

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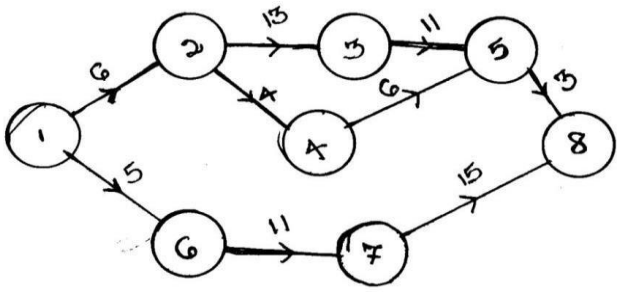


Critical Path Method:
In the critical path method the activity times are known with certainty. For each activity EST and LST are computed. The path with the longest time sequence is called critical path. The length of the critical path determines the minimum time in which the entire project can be completed.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

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

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

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

Programme Evaluation Review Technique (PERT):

PERT takes into account the uncertainty of activity times. It is a probabilistic model with uncertainty in activity duration.

It makes use of three time estimates.

I. Optimistic time (t0)

II. Most likely time (tm)

III. Pessimistic time (tp)

I. Optimistic time (t0):

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

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

II. Pessimistic time (tp):

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

III. Most likely time(tm);

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

DIEEFERENCE BETWEEN PERT AND CPM:

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

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

3. INVENTORY CONTROL

INVENTORY:

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

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

INVENTORY CONTROL:

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

CLASSIFICATION OF INVENTORIES:

1. Raw inventories:

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

2. Work-in-progress inventories:

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

3. Finished inventories:

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

4. Indirect inventories:

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

OBJECTIVES OF INVENTORY CONTROL:

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

FUNCTIONS OF INVENTORY:

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

BENEFITS OF INVENTORY CONTROL:

1. Improvement in customer's relationship because of the timely delivery of the goods and services.
2. Smooth and uninterrupted production and hence no stock out.
3. Helps in minimizing loss due to deterioration obsolescence damage.
4. Economy in purchasing.
5. Eliminates the possibility of duplicate ordering.

TERMS USED IN INVENTORY CONTROL:

1. Demand:
It is the no. of items (products) required per unit of time. The demand may be either deterministic or probabilistic in nature.
2. Order cycle:
The time period between two successive orders is called order cycle.
3. Lead time:
The length of the time between placing an order and receipt of items is called lead time.
4. Safety stock:
It is also called butter stock or minimum stock. It is the stock or inventory needed to account for delays in materials supply and to account for sudden increase in demand due to rush orders.

5. Inventory turnover:

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

6. Reorder level:

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

7. Reorder quantity:

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

COST ASSOCIATED WITH INVENTORY:

1. Purchase (or production) cost:

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

2. Capital cost:

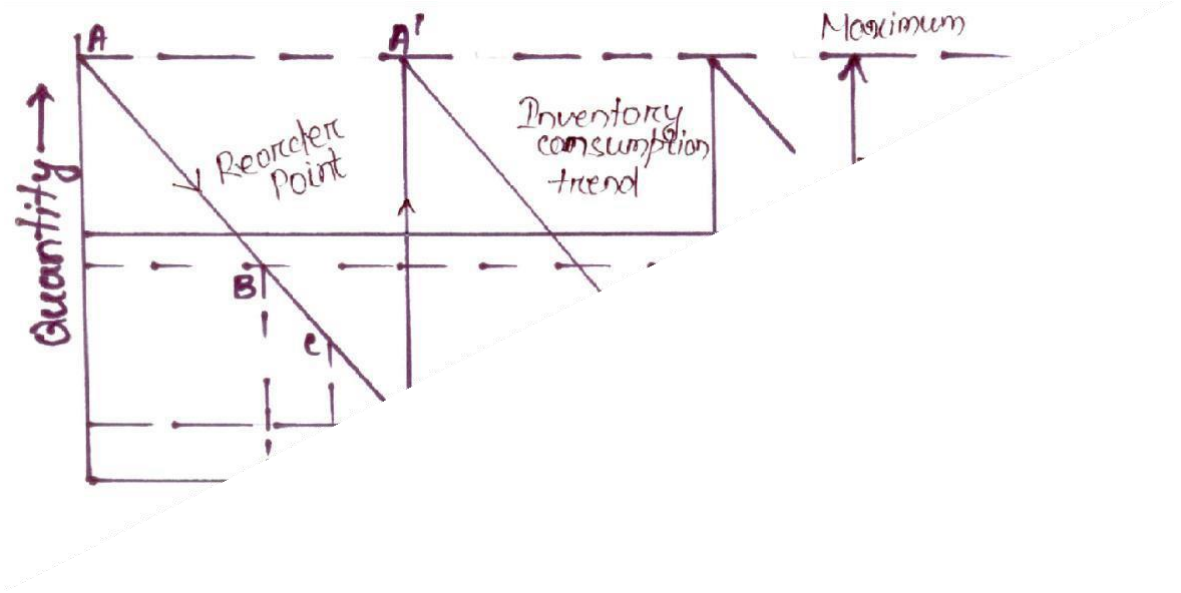
The amount invested in an item is an amount of capital not available for other purchases.

3. Ordering cost:

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

ECONOMIC ORDER QUANTITY:

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



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

requisition is initiated which takes form B to C that is time R. from C to D is the procurement time P. At the point D when only resource stock is left, the ordered material is supposed to reach and again the total quantity shoots to its maximum value i.e. the point A'(A=A').

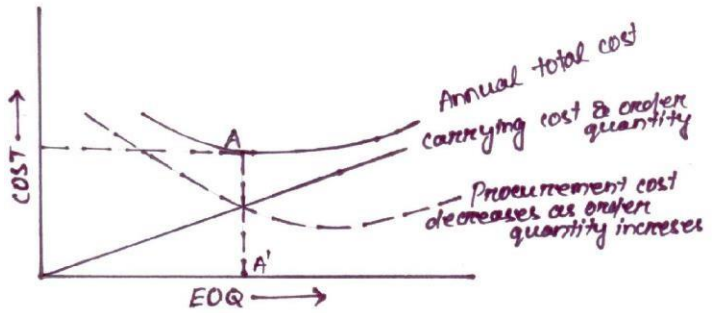
Maximum quantity- OA is the upper or max limit to which the inventory can be kept in the stores at any time.

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

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

Reorder point (B)- It indicates that it is high time to initiate a purchase order if not done so the inventory may exhaust, even reserve stock utilized before the new material arrives.

From B' to D' it is lead time and it may be calculated on the basis of past experience.



DERIVATION OF EOQ:

Let Q is the economic lot size or EOQ

C is the cost for one item.

I is the cost of carrying inventory in percentage per period

P is the procurement cost associated with one order

U is the total quantity used per period.

No. of purchase orders to be furnished = U/Q

Total procurement cost = No. of orders × cost involved in one order= U/Q X P

Average quantity = Q/2

Inventory carrying cost = average inventory × cost per item × cost of carrying inventory in %= Q/2 X C X I

Total cost (T) = a + b = U/Q X P + Q/2 X C X I

To minimize cost, dT/dQ = 0

Or Q = $\sqrt{2UP/CI}$

Problem-1:

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

Calculate EOQ.

Answer:

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

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

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

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

PROBLEM 2:

Find economic order quantity from following data.

Average annual demand = 30000 units

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

Cost of unit = Rs 2 /-

Answer:

Given, U = 30000

I = 12 %

P = 70

C = 2 /-

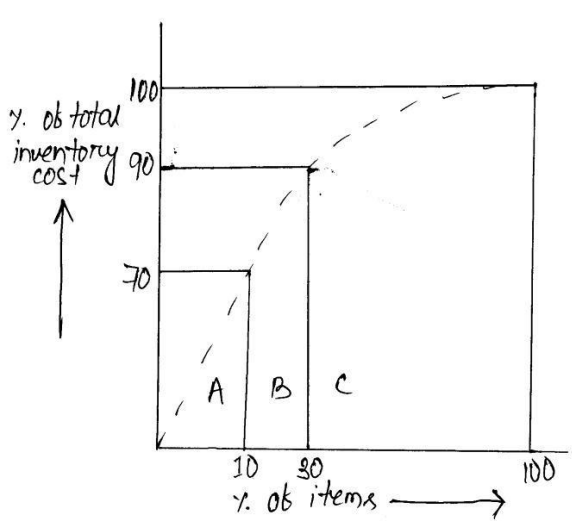
$$EOQ = \sqrt{\frac{2UP}{CI}} = \sqrt{\frac{2 \times 30000 \times 70 \times 100}{2 \times 12}} = 4183.3$$

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

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

ABC ANALYSIS:

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



A-ITEMS:

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

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

B-ITEMS:

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

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

C-ITEMS:

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

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

PROCEDURE:

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

High valued contribute – 70% of total inventory Cost

Medium valued contribute -20% of total inventory Cost

Low valued contribute-10% of total inventory Cost

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

4. INSPECTION AND QUALITY CONTROL

INSPECTION AND QUALITY CONTROL:

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

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

PLANNING OF INSPECTION:

1. **Why to inspect?**
   In this step we find out the necessity of doing inspection. The purpose for which the inspection is to be done should be clearly laid down.

2. **What to inspect?**
   In this step the product, tool, raw material or finished product is selected upon which the inspection is to be done. In other words, in this step the thing is selected which is to be inspected.

3. **When to inspect?**
   Under this step after selection of article upon which inspection is to be done, the time is decided when it is to be done. Date and time are decided when it will be carried out.

4. **Where to inspect?**
   After selection of the product and deciding the time when to inspect, the next step is to decide the place of venue where the inspection is to be done (i.e., in factory or outside the factory or in inspection room, etc.).

5. **What method of inspection?**
   In this step, the decision is taken that how the inspection will be done. Whether it is to be done manually by machines or with the special purpose equipments.

6. **Who will inspect?**
   Finally, the name of person who will do the inspection is decided upon.

TYPES OF INSPECTION:

- **FLOOR INSPECTION:**

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

- **CENTRALISED INSPECTION:**

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

- **COMBINED INSPECTION:**

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

- **FUNCTIONAL INSPECTION:**

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

- **FIRST PIECE INSPECTION:**

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

- **PILOT PIECE INSPECTION:**

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

- **FINAL INSPECTION:**

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

ADVANTAGES & DISADVANTAGES OF QUALITY CONTROL:

Advantages	Disadvantages
• It can help to prevent faulty goods and services being sold. • It is not disruptive to production-workers continue producing, inspectors do the checking. • As with any quality system, the business may benefit from an improved reputation for quality and this may increase sales.	• It does not prevent waste of resources when products are faulty. • The process of inspecting the goods or service costs money, e.g. the wages paid to the inspectors, the cost of testing goods in the laboratory. • It does not encourage all workers to be responsible for quality.

FACTORS INFLUENCING THE QUALITY OF MANUFACTURE:

- **MONEY:**

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

- **MATERIALS:**

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

- **MANAGEMENT:**

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

- **PEOPLE:**

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

- **MARKET:**

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

- **MACHINES AND METHODS:**

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

STATISTICAL QUALITY CONTROL: (SQC)

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

CONTROL CHARTS:

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

TYPES OF CONTROL CHARTS:

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

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

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

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

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

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

(*b*) **R-Chart**

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

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

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

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

R = maximum diameter − minimum diameter.

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

EXAMPLE:

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

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

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

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

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

For $\bar{X}$ chart;

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

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

For R chart:

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

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

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

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

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

Sample size in this problem is 5, therefore,

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

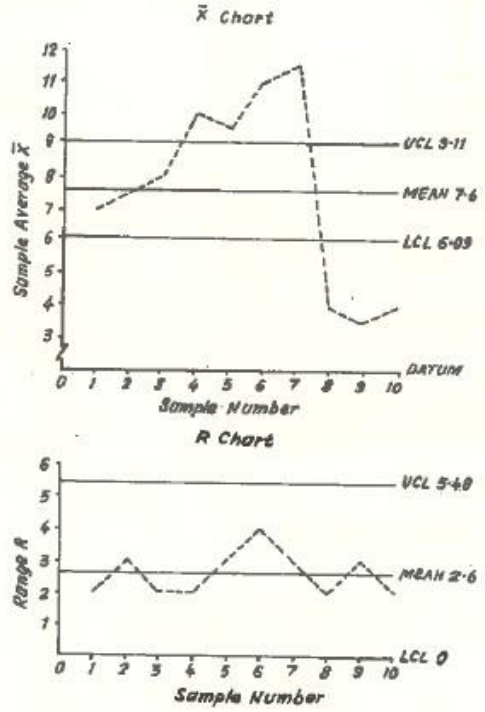
Thus, for $\bar{X}$ chart:

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

and for R chart:

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

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



(c) p-Chart

1. It can be a fraction defective chart or % defective chart (100 p).
2. Each item is classified as good (non-defective) or bad (defective).
3. This chart is used to control the general quality of the component parts and it checks if the fluctuations in product quality (level) are due to chance cause alone.
4. It can be used even if sample size is variable (*i.e.*, different for all samples), but calculating control limits for each sample is rather cumbersome.

EXAMPLE:

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

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

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

where

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

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

and n = number of pieces inspected every day

= 300

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

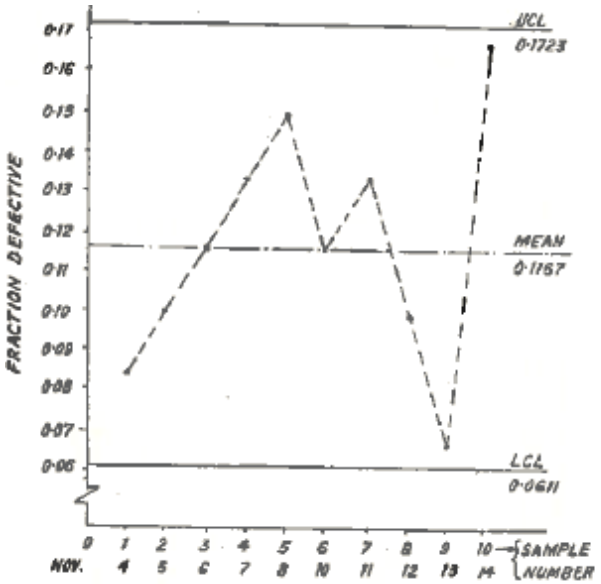
$$= \sqrt{\frac{0.1167 \times 0.8333}{300}}$$

$$= 0.01852$$

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

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

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



(*d*) *C*-Chart

1. It is the control chart in which number of defects in a piece or a sample are plotted.
2. It controls number of defects observed per unit or per sample.
3. Sample size is constant.
4. The chart is used where average number of defects are much less than the number of defects which would occur otherwise if everything possible goes wrong.
5. Whereas, *p*-chart considers the number of defective pieces in a given sample, *C*-chart takes into account the number of defects in each defective piece or in a given sample. A defective piece may contain more than one defect, for example a cast part may have blow holes and surface cracks at the same line.
6. The *C*-chart is preferred for large and complex parts. Such parts being few and limited, however, restrict the field of use for *C*-chart (as compared to *p*-chart).

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

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

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

QUALITY MANAGEMENT SYSTEM:

A Quality Management System is a set of processes defined and implemented to enable an organization to satisfy the needs of its customers. It is a defined and documented approach that guides all levels of management, all departments of an organization as well as all suppliers of the organization in marching towards a common goal – Understanding Customer needs and requirements and delivering products and services that caters their needs.

QMS brings a defined approach to achieve the objectives of an organization. Therefore, it provides the management team a clearly defined path that will lead to success.

1. It sets a standardized requirement for all functions and departments. Therefore, assessing the process performance or providing them the expectations from the management becomes a simple task
2. Implementation of QMS increases the confidence level of the customers on your product/service. Thus, the revenue and market share of an organization goes up.
3. Implementation of QMS increases the effective use of resources
4. It enables an organization to understand its pain areas, customer complaints and concerns, and work towards it.

CONCEPT OF ISO 9001:2008:

ISO 9001:2008 specifies requirements for a quality management system where an organization;

- needs to demonstrate its ability to consistently provide product that meets customer and applicable statutory and regulatory requirements, and
- aims to enhance customer satisfaction through the effective application of the system, including processes for continual improvement of the system and the assurance of conformity to customer and applicable statutory and regulatory requirements.

All requirements of ISO 9001:2008 are generic and are intended to be applicable to all organizations, regardless of type, size and product provided.

BENEFITS OF ISO FOR THE ORGANISATION:

1. **Increased efficiency** – Implement processes and procedures which are based on a quality focus.
2. **Increased revenue** – win more contracts and tenders, whilst streamlining your processes and identifying opportunities for cost savings.
3. **Greater employee morale** – by ensuring that all employees are working to one agenda you can reduce errors and increase productivity.
4. **International recognition** – recognized in approximately 188 countries, ISO 9001 can help you to access international trade.
5. **Better supplier relationships** – business has credibility through the reputation of ISO 9001, providing suppliers with greater confidence in what you do.
6. **Improved record keeping** – as with any management system, ISO 9001 ensures you document your processes from start to finish. Helping you to handle customer complaints and improve process efficiency.
7. **Improved customer satisfaction** – ensure you have a feedback system in place which will help you to understand your customers' needs, identify areas for improvement and reduce wasted resources.
8. **Continuous improvement** – using non-conformity reporting and trend analysis, you can spot areas for improvement and stay ahead of the competition.

ISO CERTIFICATION PROCESS/PROCEDURE:

ISO refers to International Organization for Standardisation. It is an independent organisation that provides standards in terms of quality, safety, and efficiency of products and services provided by businesses. With the increasing competition among the business, it is important to deliver high quality of goods & services in order to sustain in the market. ISO certification helps to improve your business credibility as well as overall efficiency of the business.

First of all, you need to choose the type of ISO certification required for your business. There are various types of ISO certification available such as:

- ISO 9001:2008 – Quality Management
- ISO 14001 – Environmental Management
- ISO 27001 – Information security Management
- ISO 22008 – Food Safety Management and so on.

PROCESS FOR ISO CERTIFICATION IN INDIA:

- **Create an application /contract**

The applicant and the registrar should agree on a contract. This contract usually defines rights and obligations of both parties and includes liability issues, confidentiality, and access rights.

- **Quality Documents Review**

The ISO auditor will view all your quality manuals and documents related to various policies and procedures being followed in the organization. Review of existing work will help the ISO auditor to identify the possible gaps against the requirements stipulated in the ISO standards.

- **Make an Action Plan**

After the ISO auditor communicates the existing gaps in your organization, you should prepare an action plan to eliminate these gaps. Prepare the list of the required tasks to be performed to bring the desired changes in your organization. You may be required to give training to your employees to work efficiently while adapting to new procedures. Make all the employees aware of the ISO standards in terms of work efficiency and quality standards.

Initial Certification Audit

The initial certification audit is divided into two categories- **Stage 1 and Stage 2**.

Stage 1: The ISO auditor will audit the changes made by you in the organization. They will then try to identify the possible non-conformities in your systems and procedures to the desired quality management system. They will divide these non-conformities into minor and major non-conformities. The applicant must carefully assess all these non-conformities and get it aligned as per the desired quality standards through modification in the techniques and processes used by the organisation.

Stage 2: After all the required changes are done in the organisation, the ISO auditor does the final auditing. The auditor will check whether all the non-conformities have been eliminated or not as per ISO quality standards. If the ISO auditor is satisfied, they will prepare the final ISO audit report and forward it to the registrar.

- **Completing the ISO Certification**

After all non-conformities are addressed and all the findings are put in the ISO audit report, the registrar will grant you the ISO certification.

- **Cost involved in the ISO Certification Process**

Cost for getting ISO certification is not fixed and varies from organization to organization. The ISO certification agency calculates the cost of ISO certification separately for each organization after considering them on different parameters such as-

- Number of employees
- Number of Processes
- Level of risk associated with the scope of services of the organisation
- Complexity of the management system
- The number of working shifts etc.

- **Time involved in the ISO Certification Process**

Time taken in completing the whole process of ISO certification also varies from organization to organization. The fair idea can be given by the ISO certification agency after assessing the size of the company. Generally, the time required to complete the process of ISO certification is approximate:

- Small organisations: 6-8 months
- Medium organisations: 8-12 months
- Large organisation: 12-15 months

JIT (JUST IN TIME MANUFACTURING):

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

So instead of building large stocks of what you think the customer might want you only make exactly what the customer actually asks for when they ask for it. This allows you to

concentrate your resources on only fulfilling what you are going to be paid for rather than building for stock.
Within a Just in Time manufacturing system, each process will only produce what the next process in sequence is calling for.

BENEFITS OF JIT MANUFACTURING:

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

SIX SIGMA:

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

- DMAIC
- DMADV

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

DMAIC has Five Phases

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

DMADV Method

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

7 S:

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

Safety: This component of 7S simply requires attention to safety throughout the other steps. It is particularly prominent in manufacturing and laboratory settings and in other contexts where potentially dangerous equipment or substances may be involved, and less prominent in office settings.
Spirit: As leaders understand the impact of company culture and the importance of respect for employees, the need for this additional component becomes clear. While some organizations successfully implement the traditional 5S method, many are choosing to add Spirit as an additional piece to make explicit the reliance on the people factor and the need to continually keep it in mind as other steps are undertaken.

LEAN MANUFACTURING:
Lean manufacturing is a methodology that focuses on minimizing waste within manufacturing systems while simultaneously maximizing productivity.

FIVE PRINCIPLES OF LEAN MANUFACTURING:

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

2. **Map the value stream:** This principle involves recording and analyzing the flow of information or materials required to produce a specific product or service with the intent of identifying waste and methods of improvement.

Companies must examine each stage of the cycle for waste -- or muda in Japanese. Anything that does not add value must be eliminated.

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

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

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

5. PRODUCTION PLANNING AND CONTROL

Production planning and control may be defined as the direction and co-ordination of the firm's material and physical facilities towards the attainment of pre-specified production goals, in the most efficient and economical manner.

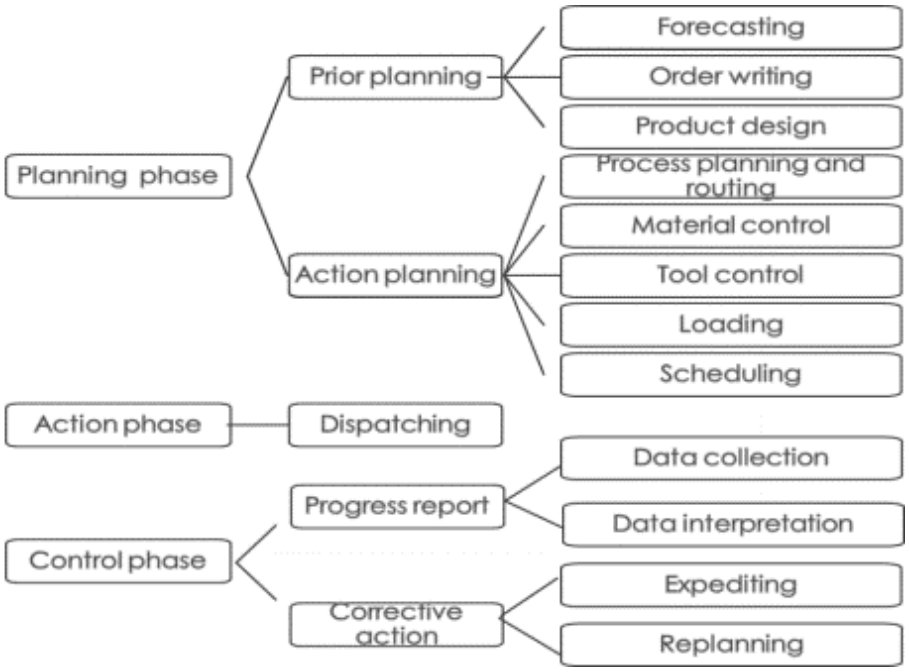
OBJECTIVES OF PPC:

1. To design a system and plan, by which production may be carried out with a view to meet promised delivery date consistent with minimum cost and quality standard.
2. To ensure efficient utilization of production facilities.
3. To coordinate the production activities of different departments.
4. To maintain adequate but not excessive stock of raw materials, work in process and of finished goods to meet production requirements and delivery schedules at the most economical level.
5. To ensure production of right product in right quality at the right time.
6. To maintain flexibility in manufacturing operations, to accommodate rush jobs or to meet contingencies.
7. Ensuring smooth flow of materials by eliminating bottlenecks if any, in production.

FUNCTIONS OF PPC:

Three main phases of PPC:

1. Planning phase 2. Action phase 3. Follow up or control phase



Prior Planning: Prior planning implies that a course of action is established in advance. The whole activity must be planned and exists on paper before the very first action takes place.

1. Fore-casting (Estimation of future work): Fore-casting is defined as the estimation of future activities i.e. the estimation of type, quantity and quality of future work. These estimates provide the basis for establishing the future requirement for men, materials, machines, time and money.

2. Order writing (Preparation of work authorisation): If the work is to be controlled, it must begin with a specified documents authorising it. So it means giving the authority to one or more persons to do a particular job.

3. Product design (Preparation of specifications): After the work authorisation has been prepared the next step is to collect the information necessary to describe the work in details. This includes blue prints or drawings, a list of specification, a bill of material and so on

Action Planning: In any type of work activity the following steps are necessary for planning details of the work to be done:

1. Process planning: The determination of most economical method of performing an activity, all factors being considered. Routing. The arrangement of work stations is determined by the route.

2. Material control: Determination of material requirements and control of material (inventory control).

3. Tool control: Tool control may be subdivided into two categories :

(a) Design and procurement of new tools.

(b) Control storage and maintenance of tools after procurement.

4. Loading: Determination and control of equipment and manpower requirements. Loading may be defined as the assignment of work to the facility. The facility may be equipment, manpower or both.

5. Scheduling: Determination when the work is to be done. Scheduling consists of time phasing of loading (workload) i.e., setting both, starting and ending time for the work to be done.

The common practice dictates that routing, loading and scheduling be performed simultaneously.

Action Phase: – The work is started in the action phase. There is only one production planning activity in action phase i.e., dispatching. Dispatching is the transition from the

planning phase to action phase. – It consists of actual release of detailed work authorisation to the work centres.

Follow up or Control Phase: – Once the work is started in an activity it is necessary to evaluate continuously the progress in terms of plan so that deviations can be detected and corrected as quickly as possible.

The control phase accordingly consists of two parts:

Progress report:

1. Progress reporting: (Data collection). The first step in progress reporting is to collect data for what is actually happening in the activity (Progress of work).

2. Data interpretation. After the data has been collected, then it is necessary to interpret it by comparing the actual performance against the plan.

Corrective Action:

1. Expediting. If the data collected from the production unit indicates that there is significant deviation from the plan and the plan cannot be changed, then some action must be taken to get back on plan.

2. Replanning. It should be emphasized that the plan is not to be changed but to be followed, however, if after expediting to correct deviation it is found that, it is impossible to perform according to plan. It would be necessary to replan the whole affair. It may also be found that there were errors made while developing the original plan. In all such cases replanning is necessary.

FORECASTING:

- Forecasting means estimation of type, quantity and quality of future works, example sales etc.
- Forecast represents a commitment on the part of the sales department and each of its divisions of expected sales. It becomes a goal against which the effectiveness of the sales department will be measured.
- Forecasting plays a crucial role in the development of plans for the future.
- Sales budget or estimate forms the basis for manufacturing budget. it is the sales forecast which enables to determine production quantities, labor, equipments and raw materials requirement.
- A sales forecast should be accurate, simple and easy to understand and economical.

FORECASTING TECHNIQUES:

1. **Historic estimate**: This technique makes use of the assumption that what happened in past will happen in future, for example if a concern has sold 5000 blankets in winter last year it will be able to sell the same quantity in winter this year also.

2. **Sales force estimate**: This technique is based upon the principle that the persons in contact with the market know best about the future market trends. Individual salesman makes sales estimate of the territories and submit it with the district sales manager who analyzes it, modifies it and sends the same to factory sales manager. Factory sales manager in consultation with other related factory executives formulates the final estimate of the sales.
3. **Trend line technique**: This technique is employed when there is an appreciable amount of historical data and this technique is more reliable than the historic estimate method.
4. **Market survey or market research technique:** This technique finds application when a concern introduces a new product in the market and is interested to estimate its sales forecast for a new product naturally no historic or past data regarding sales will be available.
5. **Delphi method**: In this method a panel of experts is interrogated by a sequence of questionnaires in which the response to one questionnaire is used to produce the next questionnaire. The method collates opinion from experts to arrive at a reliable decision. It has fair to very good accuracy for short- and long-term forecasts.
6. **Judgmental techniques**: These involve opinion of consumers and customers like questionnaires related to buying their product may be sent to a selected group of consumers and to the customers who have already purchased the product the information thus received can be very useful in estimating the product performance and its probable demand in future.
7. **Prior knowledge**: This is used by ancillary units which are more or less a part of the large organization. The large organization informs each ancillary unit how many component parts to make. The forecast estimate is needed only to establish the material and tool requirements etc.
8. **Forecasting by past average:** If our objective is the forecast or predict the sales of an item for the next sales period, then using this method forecasted sales for next period is equal to average sales for previous period.

Example

Period No.	*Sales*
1	7
2	5
3	9
4	8
5	5
6	8

Forecasted sales for period no. $7 = \frac{7+5+9+8+5+8}{6} = 7$

STEPS IN PRODUCTION PLANNING AND CONTROL:

The four stages or steps in production planning and control are:

- Routing,
- Scheduling,
- Dispatching, and
- Follow-up.

Initial two steps i.e., Routing and Scheduling, relate to production planning.
Last two steps i.e., Dispatching and Follow-up, relate to production control.

1. Routing:

Routing is the first step in production planning and control.

- Routing can be defined as the process of deciding the path (route) of work and the sequence of operations.
- Routing fixes in advance:

The quantity and quality of the product.
The men, machines, materials, etc. to be used.
The type, number and sequence of manufacturing operations, and
The place of production.

In short, routing determines 'What', 'How much', 'With which', 'How' and 'Where' to produce.

- Routing may be either very simple or complex. This depends upon the nature of production. In a continuous production, it is automatic, i.e., it is very simple. However, in a job order, it is very complex.
- Routing is affected by the human factor. Therefore, it should recognize human needs, desires and expectations. It is also affected by plant-layout, characteristics of the equipment, etc.
- The main objective of routing is to determine (fix) the best and cheapest sequence of operations and to ensure that this sequence is followed in the factory.
- Routing gives a very systematic method of converting raw-materials into finished goods. It leads to smooth and efficient work. It leads to optimum utilization of resources; namely, men, machines, materials, etc. It leads to division of labor. It ensures a continuous flow of materials without any backtracking. It saves time and space. It makes the work easy for the production engineers and foremen. It has a great influence on design of factory's building and installed machines.

2. Scheduling:

Scheduling is the second step in production planning and control. It comes after routing.

- Scheduling means to:

Fix the amount of work to do.
Arrange the different manufacturing operations in order of priority.
Fix the starting and completing, date and time, for each operation.

- Scheduling is also done for materials, parts, machines, etc. So, it is like a time-table of production.
- Time element is given special importance in scheduling. There are different types of schedules; namely, Master schedule, Operation schedule and Daily schedule.
- Scheduling helps to make optimum use of time. It sees that each piece of work is started and completed at a certain predetermined time. It helps to complete the job systematically and in time. It brings time coordination in production planning. All this helps to deliver the goods to the customers in time. It also eliminates the idle capacity. It keeps labor continuously employed.
- So, scheduling is an important step in production planning and control. It is essential in a factory, where many products are produced at the same time.

3. Dispatching:

Dispatching is the third step in production planning and control. It is the action, doing or implementation stage. It comes after routing and scheduling.

- Dispatching means starting the process of production. It provides the necessary authority to start the work. It is based on route-sheets and schedule sheets.
- Dispatching includes the following:

Issue of materials, tools, fixtures, etc., which are necessary for actual production.
Issue of orders, instructions, drawings, etc. for starting the work.
Maintaining proper records of the starting and completing each job on time.
Moving the work from one process to another as per the schedule.
Starting the control procedure.
Recording the idle time of machines.

- Dispatching may be either centralized or decentralized:

Under centralized dispatching, orders are issued directly by a centralized authority.
Under decentralized dispatching, orders are issued by the concerned department.

4. Follow-up:

Follow-up or Expediting is the last step in production planning and control. It is a controlling device. It is concerned with evaluation of the results.

- Follow-up finds out and removes the defects, delays, limitations, bottlenecks, loopholes, etc. in the production process. It measures the actual performance and

compares it to the expected performance. It maintains proper records of work, delays and bottlenecks. Such records are used in future to control production.

- Follow-up is necessary when production decreases even when there is proper routing and scheduling. Production may be disturbed due to break-downs of machinery, failure of power, shortage of materials, strikes, absenteeism, etc.
- Follow-up removes these difficulties and allows a smooth production.

TYPES OF PRODUCTION:

1. MASS PRODUCTION: Manufacture of discrete parts or assemblies using a continuous process are called mass production. This production system is justified by very large volume of production. The machines are arranged in a line or product layout.

Advantages:

1. Higher rate of production with reduced cycle time.
2. Higher capacity utilisation due to line balancing.
3. Less skilled operators are required.
4. Low process inventory.
5. Manufacturing cost per unit is low.

Limitations:

1. Breakdown of one machine will stop an entire production line.
2. Line layout needs major change with the changes in the product design.
3. High investment in production facilities.
4. The cycle time is determined by the slowest operation

2. BATCH PRODUCTON: It is characterized by the manufacture of limited number of products produced at regular intervals and stocked awaiting sales.

Advantages:

1. Better utilization of plant and machinery.
2. Promotes functional specialization.
3. Cost per unit is lower as compared to job order production.
4. Lower investment in plant and machinery.
5. Flexibility to accommodate and process number of products.
6. Job satisfaction exists for operators.

Limitations:

1. Material handling is complex because of irregular and longer flows.
2. Production planning and control is complex.
3. Work in process inventory is higher compared to continuous production.

3. JOB ORDER PRODUCTION: It is characterized by manufacturing of one or few quantities of products designed and produced as per the specifications of customers within prefixed time and cost. The distinguishing feature of this is low volume and high variety of products.

Advantages:

1. Because of general purpose machines and facilities variety of products can be produced.
2. Operators will become more skilled and competent, as each job gives them learning opportunities.
3. Full potential of operators can be utilized
4. Opportunity exists for creative methods and innovative ideas.

Limitations:

1. Higher cost due to frequent set up changes.
2. Higher level of inventory at all levels and hence higher inventory cost.
3. Production planning is complicated.
4. Larger space requirements

PRINCIPLES OF PRODUCT AND PROCESS PLANNING:

- **Product planning** is the evaluation of the range, specification, and pricing of new and existing products according to the present and future market requirements and competition.

Objectives of Product planning:

1. To meet the customer needs, it is product planning that identifies the customer needs, requirements, aspirations, likes and preferences and guides the firm's resources and efforts towards the accomplishment
2. To spot-light firm's strengths and weaknesses, so that firm can work on the weakness and improve the product.
3. To fortify better resource utilization, product planning helps to develop new product and modify existing ones in a way better utilization of resources can be achieved, it reduces the cost of the product.
4. To guarantee a firm's survival, product planning predicts what likely to changes in products, technologies, product ideas, inputs so that the latest can be given to the consumers.

Principles of Product Planning:

1. Research prior to production:

Before making a decision to manufacture a new product, market research should be carried out extensively. The company must know beforehand what should be produced and for whom? It must decide on the characteristics of the product that can meet the requirements of the people.

2. Possibility of production method:

What kind of production method would be followed and is it practicable to develop exactly what the consumer wants? This possibility should also be examined before taking a decision of producing a new product.

3. Modification in existing lines:

The existing producing lines should also be diagnosed to ascertain whether they can be improved upon to meet the new requirements of the consumer or a new product to be developed. If it is possible to modify the existing line, then to what extent it should be done?

4. Elimination in the product:

Product planning involves the decision of elimination of unprofitable product line so that the resources may be used to some products profitably.

5. Improvement in the product:

Product planning includes decision regarding the improvement of existing product in terms of quality, packing etc., taking into consideration the competitors' strategies in the market.

6. Price Determination:

Determining the price of the product is one of the main elements of the planning. Would the price be fixed based on the basis of the prices of competitors for the same product or on the basis of cost of production or on the basis of the forces of its demand and supply in the market?

7. Commercialization of product:

Product planning includes products commercialization and sale of product which can earn a good profit for the company on one hand and satisfy the needs of the consumers on the other. It also provides for the attractive introduction of new products in the market.

8. Coordination:

Product planning also attempts to coordinate the various products and their efforts so that the company can maintain or improve its competitive position. It can be achieved by taking timely decisions from time to time. Thus, it is clear from the study of various elements of product planning that every decision from the start of an idea of producing to its execution from the product line forms the part of the product planning.

PROCESS PLANNING:

Process planning can also be defined as the systematic determination of the methods by which a product is to be manufactured economically and competitively. It consists of planning, selecting and specifying processes, machine tools and other equipment to convert raw material into finished and assembled products.

Principles of Process Planning:

General principles for evaluating or enhancing processes are as follows:

1. First define the outputs, and then look toward the inputs needed to achieve those outputs.
2. Describe the goals of the process, and assess them frequently to make sure they are still appropriate. This would include specific measures like quality scores and turnaround times.
3. When mapped, the process should appear as a logical flow, without loops back to earlier steps or departments.
4. Any step executed needs to be included in the documentation. If not, it should be eliminated or documented, depending on whether or not it's necessary to the process.
5. People involved in the process should be consulted, as they often have the most current information.

Learning Resources:			
Sl. No.	***Name of Authors***	***Title of the Book***	***Name of the Publisher***
1	O.P.KHANNA	INDUSTRIAL ENGINEERING & MANAGEMENT	DHANPAT RAI & SONS
2	MARTAND TELSANG	INDUSTRIAL ENGG & PRODUCTION MANAGEMENT	S.CHAND
3	M.MAHAJAN	STATISTICAL QUALITY CONTROL	DHANPAT RAI &SONS