Industrial Engineering

Published By:

Physics Wallah

ISBN: 978-93-94342-39-2

Mobile App: Physics Wallah (Available on Play Store)

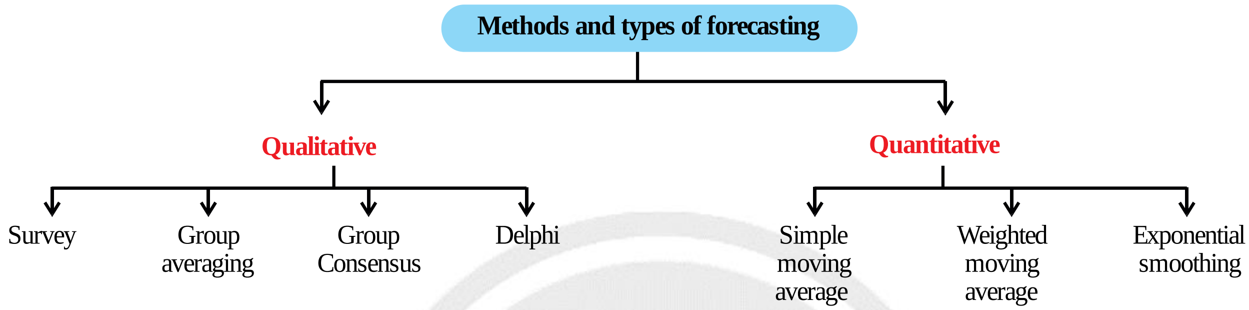
Website: www.pw.live

Email: support@pw.live

Industrial

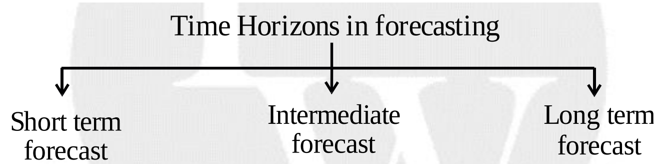
INDEX

1 FORECASTING



1.1 Forecasting

- DEMAND forecast is basically concerned with the estimation of DEMAND.



Note:

- To make the proper arrangement for training the personnel is not a purpose of long-term forecasting
- Direct survey method can be used for forecasting the sales potential of a new product.
- For sales forecasting, pooling of expert opinions is made use of in Delphi technique.
- Rolling horizon in forecast is used for easy updating of changes and maintaining same length of forecast horizon by adding a new period when one period is over.

1.2 Quantitative Forecasting

- This method is generally used for **short-** and medium-term forecasting.
- **<u>Time series model</u>**: In this method the variable that is being forecast is decomposed into its components (N)
- **<u>Associative model</u>**: Used when changes in one or more independent variables can be used to predict the changes in the dependent variable

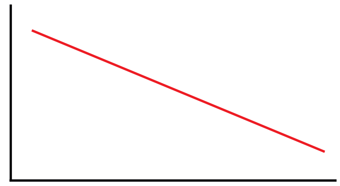


Fig. 1.1 Trend Component

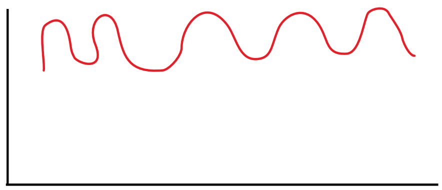


Fig. 1.2 Seasonal Component

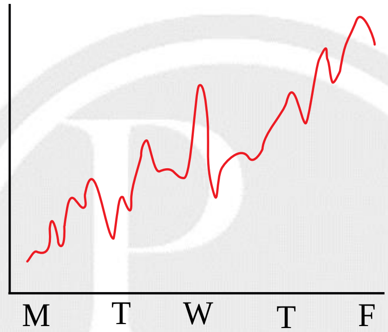


Fig. 1.3 Random Component

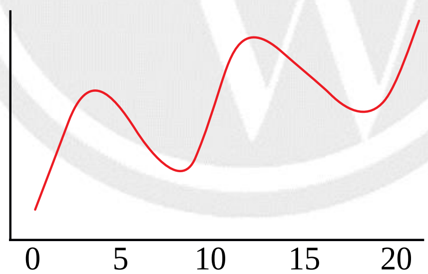


Fig. 1.4 Cyclical Component

Note:

- ***Time series*** analysis technique of sales-forecasting can be applied to only **medium** and **short-range** forecasting.
- ***Qualitative*** information about the market is necessary for **long-range** forecasting.

1.3 Simple Moving Average

Moving Average obtained by adding and averaging the value from a given number of periods repeatedly, each time deleting the oldest value and adding a new value.

1.4 Weighted Moving Average

In this method the weights are given to the values vary, the highest weight is given to the latest value and the weight decreases as the values become old.

1.5 Exponential Smoothing

- Assumes the most recent observations have the highest predictive value
- The weightage of the data diminishes exponentially as the data become older
- **Gives more weight to recent time periods**

$$F_{t+1} = F_t + \underbrace{\alpha\left(D_t - F_t\right)}_{e_t}$$

F_{t+1} = Forecast value for time t + 1
D_t = Actual value at time t
α = Smoothing constant

OR

$F_{t+1} = \alpha D_t + \alpha(1-\alpha) D_{t-1} + \alpha(1-\alpha)^2 D_{t-2} + \ldots$
$F_{t+1} = F_t + \alpha (D_t - F_t)$
If $\alpha = 0$ $F_{t+1} = F_t$ ---------------- STABLE
If $\alpha = 1$ $F_{t+1} = D_t$ ---------------- RESPONSIVE

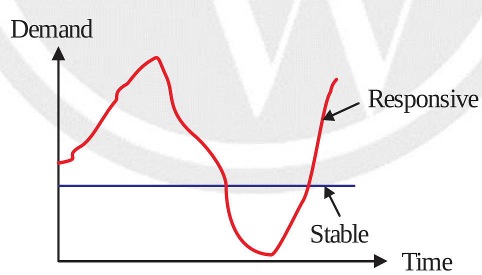


Fig. 1.5 Demand v/s time

Note:

- ***Higher the value of α***, more responsive the forecast will be and this is desirable for forecasting of ***new products***.
- Whereas ***lower value of α*** makes the forecast more stable and this desirable for ***old and stable products***.

1.6 Error Analysis

It is assumed that the forecasting model should over estimate and under estimate with equal magnitude so that the errors produces by forecasting model will fit into a Normal distribution curve.

1.7 Measuring Forecasting Accuracy

• Mean Absolute Deviation (MAD) • *measures the total error in a forecast without regard to sign*	$\text{MAD} = \dfrac{\sum_{i=1}^{N} \lvert \text{Demand} - \text{forecast} \rvert}{n}$
• Cumulative Forecast Error (CFE) • *Measures any bias in the forecast*	$\text{CEF} = \sum_{i=1}^{N} (\text{Demand} - \text{forecast})$
• Mean Square Error (MSE) • *Penalizes larger errors*	$\text{MSE} = \sum_{i=1}^{N} \dfrac{(\text{Demand} - \text{forecast})^2}{n}$
• Tracking Signal • Measures if your model is working • **Good tracking signal has low values**	$\text{TS} = \dfrac{\text{CFE}}{\text{MAD}}$
• Mean Error of BIAS	$\dfrac{\sum_{i=1}^{N} (D_f - F_t)}{N}$

❑❑❑

2 BREAK EVEN ANALYSIS

2.1 Total Cost of a Product is the Sum of *Fixed Cost* & *Variable Cost*.

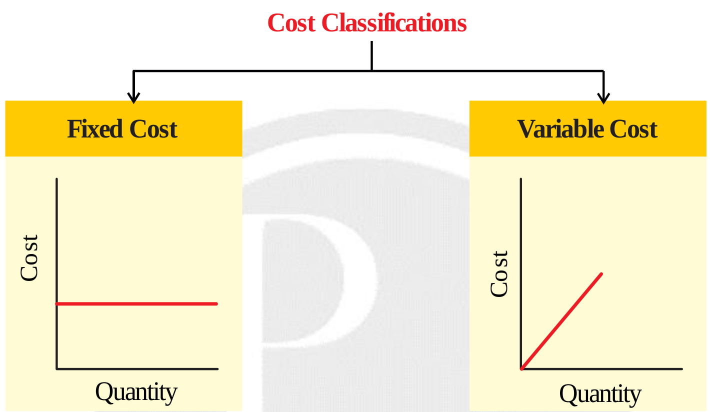


Fig. 2.1 **Fig. 2.2**

- Fixed cost = F
- Variable cost/unit = V
- Selling price/unit = S
- number of units being produce = Q
- total cost (TC) = F + VQ
- total revenue (TR) = SQ
- profit (P) = SQ – (F + VQ)
- At break-even point profit = 0
- TR = TC

$SQ^x = F + VQ^x$

$Q^x = F/(S - V)$

$SQ > VQ$

$S > V$

$Q^x = Q_{BE}$ = Break even quantity

Break-Even Chart

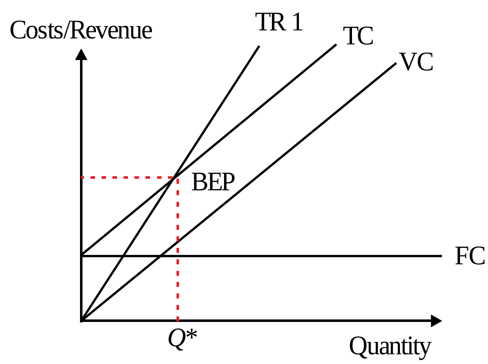


Fig. 2.3 Cost vs quantity

2. 2 Another Use of BEP to Compare two Machines/Processes

Where, F_A = Machine A fixed cost

F_B = Machine B fixed cost

V_A = Machine B variable cost

Q = Quantity

At break-even point

Total cost of machine A = Total cost of machine B

$$F_A + QV_A = F_B + QV_B$$

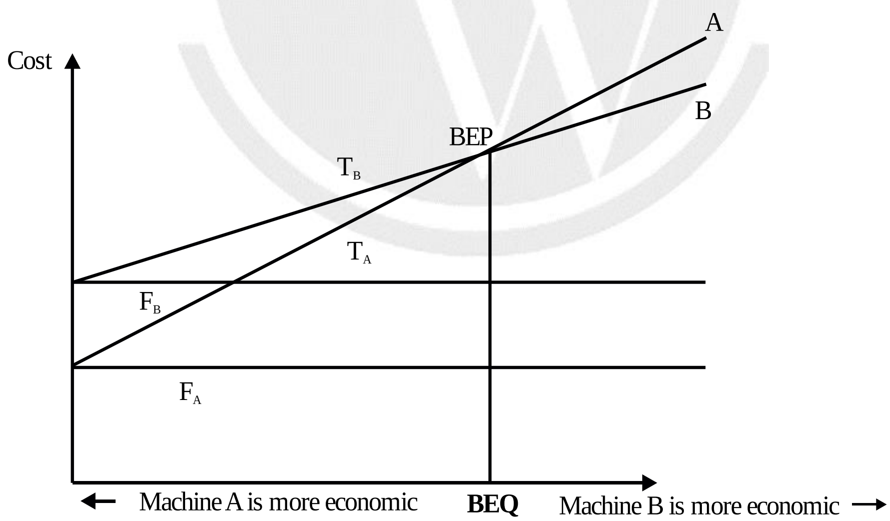


Fig. 2.4

2.3 Contribution

Contribution is the measure of economic value that tells how much the sale of one unit of the product will ***contribute to cover fixed cost, with the remainder going to profit***

Contribution = Sales – Total Variable Cost (Q.V)

Contribution = F + P

2.4 Profit Volume Ratio or Margin of Safety (%)

The margin of safety is simple the excess of actual output over the break-even output. In terms this is simply the excess of sales revenue over the break-even sales revenue.

$$\text{MoS (\%)} = \left(\frac{\text{Actual sales} - \text{Break even sales}}{\text{Actual sales}}\right) \times 100$$

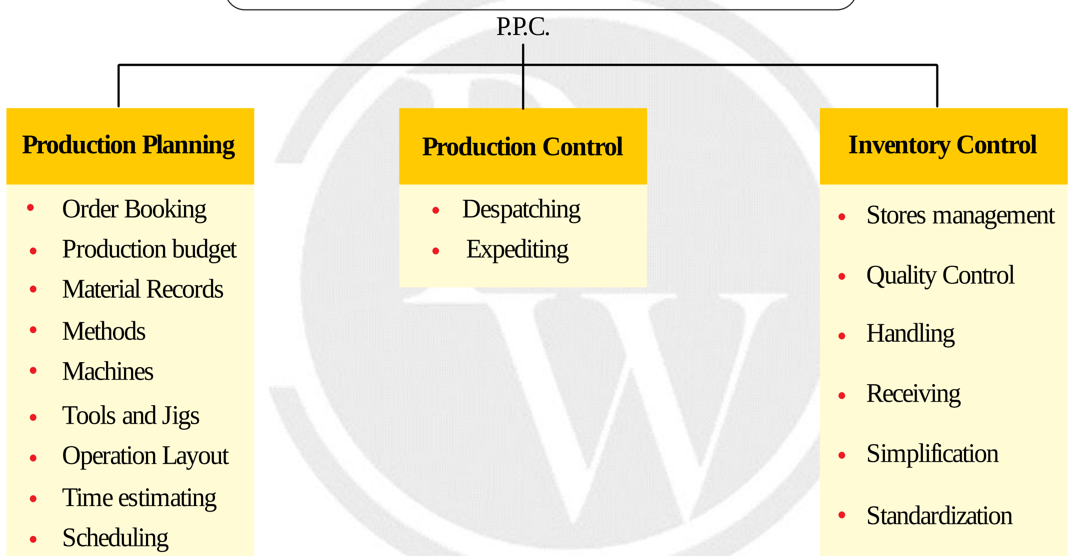
❑❑❑

3 PRODUCTION PLANNING & CONTROL

3.1 Production Planning and Control

- PPC acts as the nerve center for planning the activity and sending the continuous stream of directions to all manufacturing departments.

ORGANISATION CHART FOR P.P.C. DEPARTMENT



3. 2 PPC Includes the following Function and Activities

3.2. 1 Routing

Routing consists of deciding the path the item would take in its transformation from raw material to final product. It involves the creation of a rout sheet which contains the following information.

Note:

- **Routing in production planning and control refers to the** Sequence of operations to be performed.
- The routing function in a production system design is concerned with optimizing material flow through the plant.
- The correct sequence of these activities is
  (a) Analysis of the product and breaking it down into components
  (b) Taking makes or buys decision
  (c) Determination of operations and processing time requirement
  (d) Determination of the lot size

3. 2. 2 Loading

The work of transformation of the raw material has to be converted into workloads on individual machine. This process is known as loading.

3. 2. 3 Balancing

It is the process of insuring that the individual work load on each of the machine is more or less and the same.

3. 2. 4 Scheduling

- Firstly, think about the same points,
  (a) When the work will be done
  (b) Within, what time it will be completed
  (c) Component design
  GANT chart, PERT & CPM are the tools of scheduling

Note:

- Scheduling–
  (a) is a general time table of manufacturing
  (b) is the time phase of loading
  (c) is loading all the work in process on
- Preparation of master production schedule is an iterative process
- Schedule charts are made with respect to jobs while load charts are made with respect to machines.
- Sales forecast, Component design, & Time standards are to be considered for production scheduling.
- Machine load chart gives simultaneously, information about the progress of work and machine loading.

3.2. 5 Dispatch

It deals with the smooth introduction of work on to the shop floor. It includes release of work orders, release of tools, drawing etc. On the shop floor in there required sequence. ***Authorizing a production work order to be launched*.**

> **Note:**
> In a low volume production, the dispatching function is not concerned with *Requisition of raw materials, parts and components*

3. 2. 6 Follow Up

This function of PPC deals with the control or the feedback part to ensure smooth running of all the previous operation

3.3 Sequencing and Scheduling

In this topic we *determine order (sequence) for a series of job* to be done on a finite number of service facilities in some pre-assigned order so as to **optimize the total cost(time) involved.**

3.4 Sequencing of N Jobs on 1 M/C

- There are certain parameters which are relevant in case of scheduling of N Jobs on 1 M/C:
  - **(a) Job flow time:** the flow time for a job is the time from some starting point until that job is completed.
  - **(b) Make span time:** it is the time when processing begins on the first job in the set until the last one is completed.
  - **(c) Mean flow time:** total flow time divided by number of jobs
  - **(d) Average tardiness:** the tardiness of the job is the amount of time after its due date that the JOB is completed. If the JOB is completed before due date then the tardiness is ZERO

3.5 Sequencing of N Jobs on 1 M/C

- **Shortest Processing Time (SPT**). Jobs with the shortest processing time are scheduled first

  NOTE: It minimizes average flow time and total cost
- **Earliest Due Date (EDD).** Jobs are sequenced according to their due dates.
  NOTE: It minimizes tardiness
- Critical Ratio (CR)

  CR = Due Date/Processing Time
  Schedule the job with increasing order of CR value.
- **Slake time remaining (STR).** This rule sequencing the job in increasing order of their slack time remaining.

  STR = Due Date – Processing Time

3.6 Algorithm of Johnson's Rule

(1) Identify the job with the smallest processing time (on either machine)

(2) If the smallest processing time involves:

(a) Machine 1, schedule the job at the beginning of the schedule

(b) Machine 2, schedule the job toward the end of the schedule

(3) If there is some unscheduled job, go to step 1 otherwise stop.

(4) If $M1_k = M2_r$ then in this case process the k^{th} job first and r^{th} job last.

If both equal values occur on machine M1 then select the one which has lowest value on M2 first. If both equal values occur on machine M2 then select the one with the lowest value on M1 first.

❑❑❑

4 LINEAR PROGRAMMING

Mathematical programming is used to find the best or optimal solution to a problem that requires a decision or set of decisions about how best to use a set of limited resources to achieve a state goal of objectives.

- $C_1, C_2 \ldots\ldots C_n$= are known as profit coefficient.
- $a_1, a_2 \ldots\ldots a_{mn}$ = are known as technological coefficient.
- $b_1, b_2 \ldots\ldots b_n$ = are known as Resource variable

  LT two variable equation

  $a_1x+b_1y \le c_1$

  $a_2x+b_2y \le c_2$

  where $x_1, x_2 \ge 0$

  objective $Z = c_1x + c_2y$

4. 1 Infinite Solution/Multiple Solution

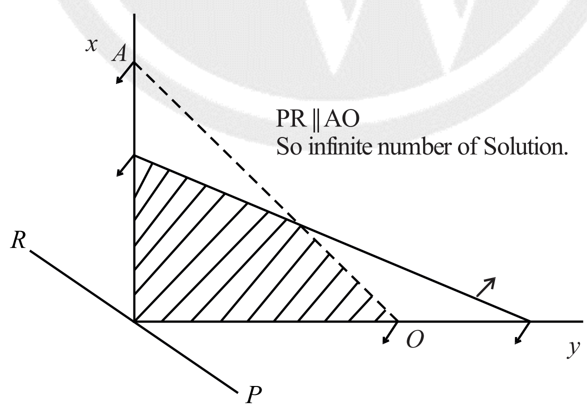


Fig. 4. 1 Infinite Solution

4. 2 Unbounded Solution

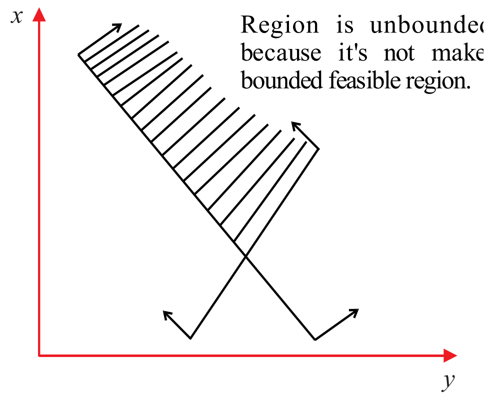


Fig. 2 Unbounded Solution

4. 3 No solution

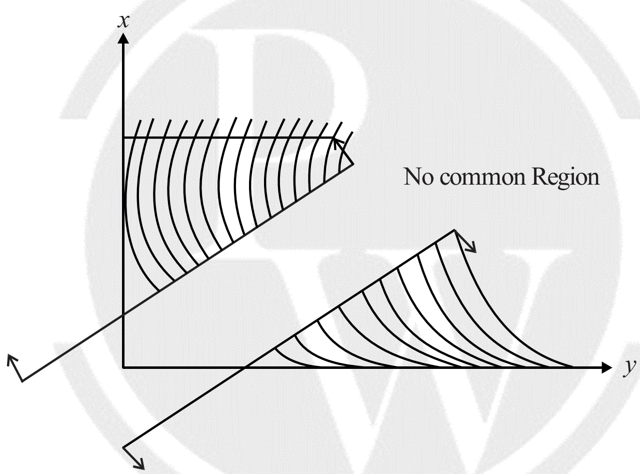


Fig. 3 No Solution

❑❑❑

5 ASSIGNMENT (HUNGARIAN ALGORITHM)

An assignment problem is a special type of transportation problem in which the objective is to assign a number of origins to an equal number of destinations at a minimum cost (or maximum profit).

Formulation of an assignment problem: There are n person and n machine.

Let C_{ij} be the cost if the i^{th} person is assigned to the j^{th} job.

- $C_1, C_2 \ldots\ldots C_n$= are known as profit coefficient.
- $a_1, a_2 \ldots\ldots a_{mn}$ = are known as technological coefficient.
- $b_1, b_2 \ldots. b_n$ = are known as Resource variable

5. 1 Mathematical formulation of the Assignment Problem

$$\text{Minimize}(Z) = \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} X_{ij}$$

Subjected to the restrictions

$$X_{ij} = \begin{cases} 1 \text{ if the } j^{th} \text{ person is assigned } j^{th} \text{ job} \\ 0 \text{ if not} \end{cases}$$

5. 2 Steps for solving Assignment Problem

We make Use of HUNGRIAN ALOGORITHM

(1) Select the minimum entry from each column and subtract that entry from rest of the entries in that column.

(2) Repeat step Number 1 for each Row.

(3) Cover all the Zero's by Drawing minimum number of Lines.

(4) If the number of lines is less than the No. of Rows or columns then select the minimum entry out of all the uncovered entries. Subtract that entry from all the uncovered entry and add that selected entry at the junction.

(5) Repeat step No. 4 and proceed till the No. of lines equal to No. of Rows or Column.

(6) When the No. of lines becomes equal to No. of Rows or Column then select that Row or Column that has minimum No of Zeros and make the corresponding assignment.

5. 3 No of decision variables and constraints →

For $n \times n$ assignment problem → No. of decision variables = n^2

5. 4 For $n \times n$ transportation problem →

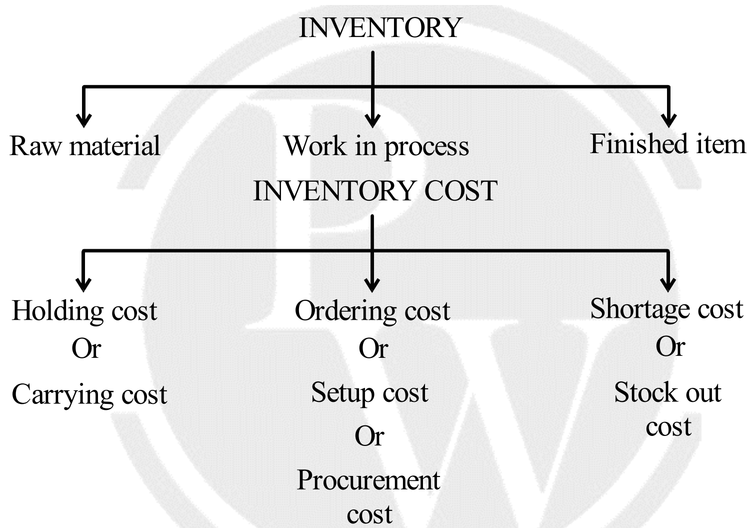
No. of constraints = $2n$

❑❑❑

6 INVENTORY CONTROL

6.1 Inventory

Inventory is the raw, component parts, work-in-process, or finished products that are held at a location in the supply chain.



6.2 Model 1

(1) Deterministic Model (EOQ)

Assumption of this model

(i) Demand D is known with certainty.
(ii) Usage rate is constant.
(iii) Shortage not allowed.
(iv) Lead time constant and known with certainty.
(v) Order cost is fixed "O".
(vi) Holding cost/item/unit time $\mathbf{C_h}$ is know
(vii) No quantity discount is offered.

(2) EOQ Model

Where:

D = Annual Demand

Q^* = Optimal order quality

O = Ordering cost

C_h = holding cost

P = purchasing cost

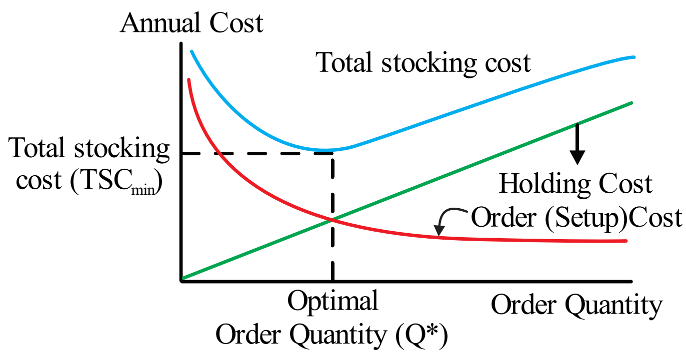


Fig. 6.1 – Basic EOQ

$$\text{Total stocking cost (TSC)} = \frac{D}{Q^*}O + \frac{Q^*}{2}C_h$$

$$\text{Total material cost (TMC)} = \frac{D}{Q^*}O + \frac{Q^*}{2}C_h + PD$$

(3) EOQ Formula:

Where:

D = Annual Demand

Q^* = Optimal order quality

O = ordering cost

Ch = holding cost

P = purchasing cost

$$(TSC)_{min} = \frac{D}{Q^*}O + \frac{Q^*}{2}C_h \quad \text{or} \quad TSC_{min} = \sqrt{2ODC_h}$$

$$(TMC) = \frac{D}{Q^*}O + \frac{Q^*}{2}C_h + PD$$

$$\text{Economic Order EOQ } (Q^*) \Rightarrow Q^* = \sqrt{\frac{2OD}{C_h}}$$

6.3 Model 2

EOQ Model with Quantity Discount

Supplier commonly offer a quantity discount for sufficiently large number of units purchased at once. The basic objective behind the model is to MINIMIZE TOTAL MATERIAL COST per year.

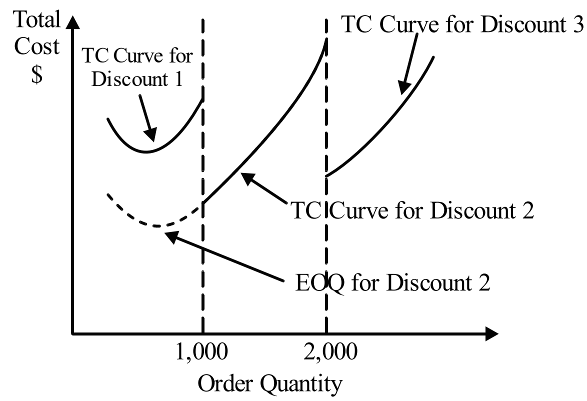


Fig. 6.2 – Discount Model

6. 4 Model 3

Economic Production Quantity (EPQ)

A problem frequently encountered by the manufactures is to determine how many units of products to produce during a production run. This quantity is known as EPQ.

Where

M = manufacturing rate

D = consumption rate

O = ordering cost

Ch = holding cost

I_{max} = maximum inventory

TSC_{min} = minimum total stocking cost

EPQ = economic production quantity

t_1 = production time

$t_1 + t_2$ = cycle time

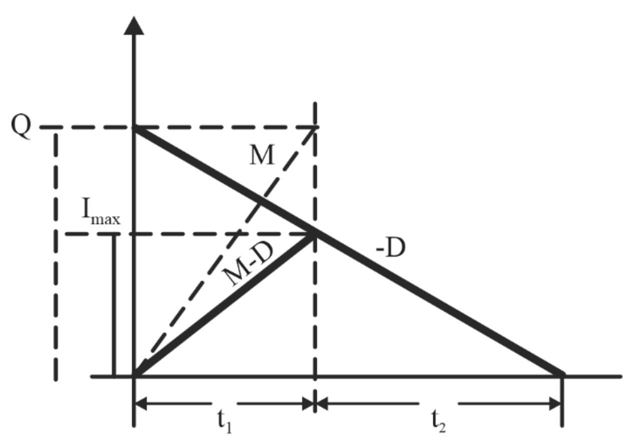


Fig. 6.3 – Production Model

$$I_{max} = (1 - D/M)Q$$

$$\text{EPQ (Optimum lot size)} = \sqrt{\frac{2OD}{C_h\left(1-\frac{D}{M}\right)}}$$

$$TSC_{min} = \sqrt{2ODC_h\left(1-\frac{D}{M}\right)}$$

6. 5 Model 4

Shortage Model

- This inventory model taking care of shortage.
- In actual practice shortage may take place and hence shortage cost also need to be considered.
- Shortages may also be allowed for certain advantages:

(i) Shortage increases the cycle time and hence spread the ordering cost over a longer period of time

(ii) Shortage result in decreased net stock inventory resulting in decreased inventory carrying cost.

$$Q^* = \sqrt{\frac{2OD}{C_h}}\sqrt{\frac{C_h + C_s}{C_s}}$$

$$I_{max} = \sqrt{\frac{2OD}{C_h}}\sqrt{\frac{C_s}{C_h + C_s}}$$

$$\text{Min cost / time} = \sqrt{2ODC_h}\sqrt{\frac{C_s}{C_h + C_s}}$$

6. 6 Selective Control System

Inventory management is based on selective control depending on item to be stored, upon the value or the importance. The selective inventory management plays a very important role in the minimize the inventory cost.

6. 6. 1 ABC Analysis

What is ABC analysis?

Always better Control

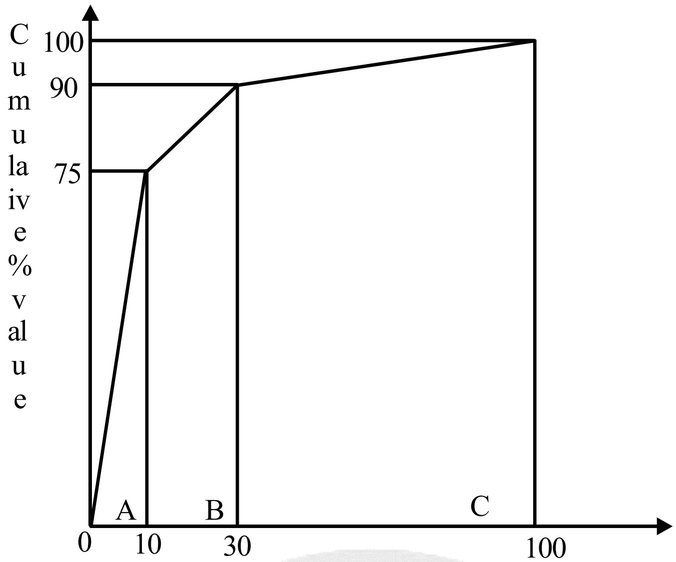


Fig. 6.4 – ABC Analysis

6. 6. 2 VED Analysis

- Vital Essential Desirable
- In this system items are classified on the bases of their importance.

  (i) Absence of vital item will stop the system.

  (ii) Absence of essential item will reduce the efficiency of system &

  (iii) Absence of desirable item has no immediate effect on the system

6. 6. 3 SDE Analysis

This is based on relative case of availability.

(i) S-Scarce item
(ii) D-Difficult item
(iii) E-Easily available

6. 6. 4 FNSD Analysis

This is analysis divided items into four categories in the descending order of their consumption rate.

(i) F-fast
(ii) N-Normal
(iii) S-slow
(iv) D-Dead

❑❑❑

7 TRANSPORTATION

7.1 Objective of Transportation is to Minimize the total Transportation Cost.

From Plant	To Warehouse				Plant Capacity
	S	N	P	M	
J	Xis	Xin	Xip	Xim	100
S	Xss	Xsn	Xsp	Xsm	300
T	Xts	Xtn	Xtp	Xtm	200
Warehouse Demand	150	100	200	150	600

Total plant capacity must equal total warehouse demand.

- If $\sum$ supply = $\sum$ demand = > balance problem
- If $\sum$ supply < $\sum$ demand = > Add dummy factory having unit cost Zero
- If $\sum$ supply > $\sum$ demand = > Add dummy ware house having unit cost Zero

7. 2 Stages of solving transportation problem

(a) To find initial Feasible solution

- **Northwest corner method:** The North West corner rule is a technique for calculating an initial feasible solution for a transportation problem. In this method, we must select basic variables from the upper left cell, i.e., the North-west corner cell
- **Least cost method:** This method consists in allocating as much as possible in the lowest cost cell and then further allocation is done in the cell/cells with second lowest cost and so on.
- **Vogel's approximation method (penalty cost method):** Vogel's Approximation Method (VAM) is **one of the methods used to calculate the initial basic feasible solution to a transportation problem**. However, VAM is an iterative procedure such that in each step, we should find the penalties for each available row and column by taking the least cost and second least cost

(b) After finding the basic feasible solution check Degeneracy

Check for Degeneracy

A = Number of allocations in transportation table

If $m + n - 1 = A \Rightarrow$ No Degeneracy in problem

If $m + n - 1 > A \Rightarrow$ Degeneracy

(c) Getting optimal Solution

(i) Stepping Stone Method

(ii) U-V Method [MODI Method]

❑❑❑

8 PERT & CPM

8.1 PERT and CPM (NETWORK ANALYSIS)

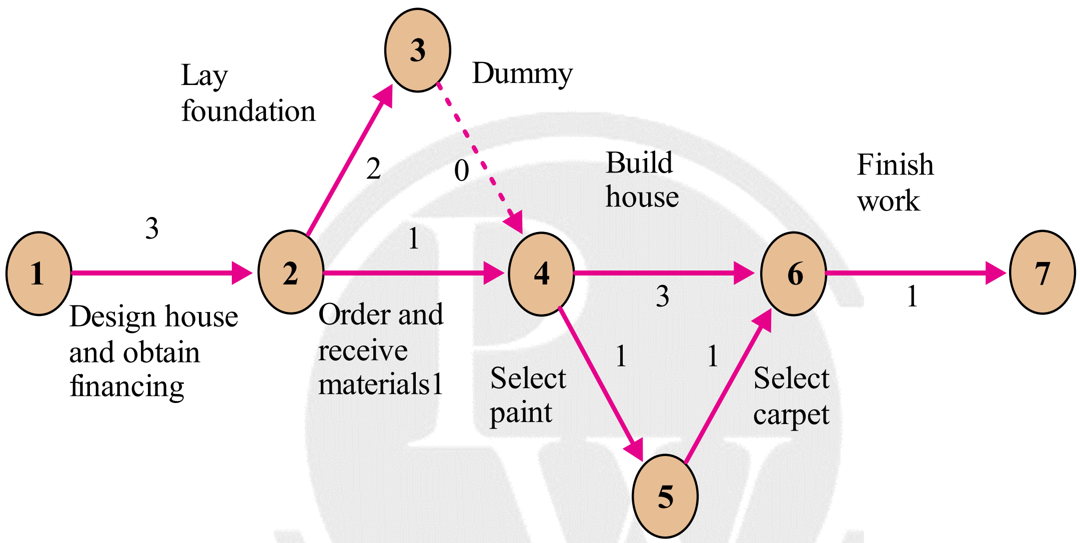


Fig. 8.1 Network Diagram

8.2 Critical Path Method (CPM)

- Deterministic Model
- Activity oriented

E_i Earliest start time for activity

L_i Latest start time for activity

E_J Earliest finished time for activity

L_J Latest finished time for activity

8. 3 Float (Extra time)

- **Total float** represents the maximum time within which an activity can be delayed **without affecting the project completion time**.

  $TF = L_j - E_i - T_{ij}$

- **Free float** is the extra time available with an activity without affecting any successor activity.

  $FF = E_j - E_i - T_{ij}$

- **Safety float** is the extra time available with an activity without affecting the Latest start time of successor activity.

  $SF = L_j - L_i - T_{ij}$

- **Independent float** is the extra time available with an activity *without affecting Earliest & Latest time of other activities*.

  $IF = E_j - L_i - T_{ij}$

8. 4 Project Evaluation Review Technique (PERT)

- Probabilistic model.
- Event oriented time estimate for the activity are based upon three different values:

  (a) Most optimistic time. (t_o)
  (b) Most pessimistic time. (t_p)
  (c) Most likely time. (t_m)

- The distribution followed by t_o, t_p & t_m is β distribution. $T_p \geq t_m \geq t_0$
- The distribution followed by project completion time is normal distribution.
- Expected time $= t_e = \left[\dfrac{t_0 + 4t_m + t_p}{6}\right]$
- Standard deviation $= (\sigma) = \dfrac{t_p - t_o}{6}$
- Variance (V) $= \sigma^2 = \left(\dfrac{t_p - t_o}{6}\right)^2$
- Probability that the project will be completed in a given time. (T)
- The expected completion time (from Critical path) (t_{cp})
- Standard deviation of critical path (σ_{cp})
- Z stands for standard Normal variable.

$$(Z) = \left(\frac{T - t_{cp}}{\sigma_{cp}}\right)$$

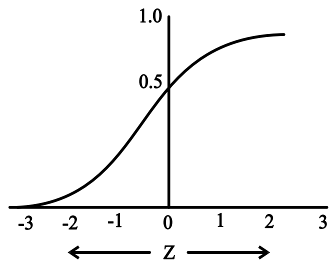


Fig. 8.2 Standard Normal Variable

z = 0, Probability = 50%

z = ± 1, Probability = 68.3%

z = ± 2, Probability = 95.5%

z = ± 3, Probability = 99.7%

❑❑❑

9 QUEUING THEORY

9. 1 Queuing Theory

A queue represents items or people awaiting sevice

Fig. 9.1 Queue

9. 2 The Queuing Cost Trade-Off

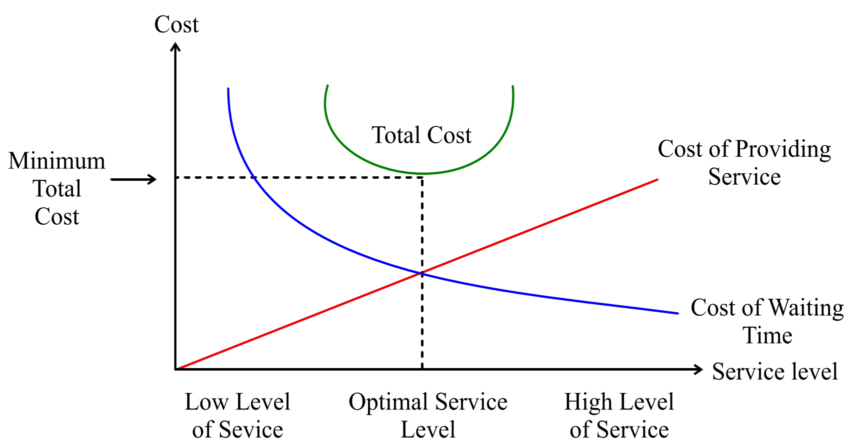


Fig. 9.2 Cost v/s service level

9. 3 Components of a Basic Queuing Process

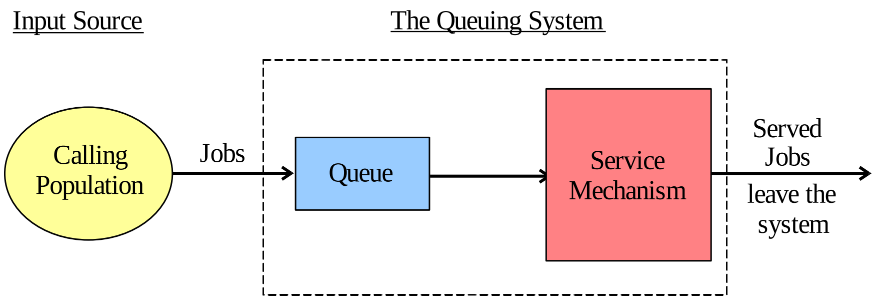


Fig. 9.3 Queuing model

9. 4 Characteristics of Queuing Model

9. 4. 1 Arrival Pattern of Customer

- It can be spaced by equal and unequal time intervals however in most of the cases random arrival is observed which is best described by ***POISSON process***. If the arrivals are governed by Poisson process then the time between successive arrival is ***NEGATIVE EXPONENTIALLY*** distributed.
- The mean arrival rate is denoted by λ

Theorem:

- If n, the number of arrivals in t, follow the Poisson distribution,

$$\frac{e^{-\lambda t}(\lambda t)^n}{n!}$$

- Then T (inter-arrival time) obeys the negative exponential law

$$\lambda e^{-\lambda T}$$

9. 4. 2 Service Pattern

- Unlike arrival process there is no standard probability distribution for service process. In fact, in many cases actual data is used for describing the service time. However, if the service time are ***EXPONENTIALLY DISTRIBUTED*** then the Queuing model become simple.
- If there is infinite number of servers then all the customers are served instantaneously on arrival, and there will be no queue.
- The mean service rate is denoted by **μ**

9.4.3 The Queue Discipline

It is a rule according to which the customers are selected for service when a queue has been formed. The most common disciplines are

(a) FCFS
(b) FIFO
(c) LIFO
(d) SIRO

9.4.4 Customer behavior

(a) Balking
When the customer decided not to enter the queue if the queue is very long.

(b) Reneging
Customer enters the queue but leaves after some time tie without getting service.

(c) Jockeying
Switching of queues

9.4.5 Size of population

- In most of the cases the capacity of the system is limited. The entire sample of customer from which a few visit the service facility is known as calling population.
- Size of calling population can be finite or infinite.

9.5 Kendall's Notation for Representing Queuing Models

(a|b|c) : (d|e)

a = Probability distribution of arrival time

b = probability distribution of service time

c = Number of Servers

d = capacity of the system (size of calling population)

e = Queue Discipline

$$\rho = \frac{\lambda}{\mu}$$

- Traffic intensity factor or utilization factor or channel efficiency or percentage time the server is busy or probability that the customer has to wait.
- The average service rate must always exceed the average arrival rate.

$\mu > \lambda$

- Otherwise, the queue will grow to infinity (∞)

9.6 Model I (M | M | 1): (∞ | FCFS)

- This denotes a Queuing model in which *arrivals* are generated by *Poisson Process* (inter arrival time are exponentially distributed), *service time* are *exponentially distributed* has single server, infinite calling population & service rule FCFS.
- L_s = Expected system/line length i.e., expected number of customers in the system

  $= \frac{\rho}{1-\rho}$

- L_q = Expected queue length i.e., expected number of customers in the Queue

  $L_q = L_s - \rho$

- W_q = Expected waiting time per customer in the Queue.

  $= \frac{\lambda}{\mu(\mu-\lambda)}$

- W_s = Expected waiting time per customer in the system

  $W_s = W_q + \frac{1}{\mu}$

- P_0 = Probability that the service facility is Idle or there are Zero customer in system probability that the customer does not have to wait

  $= 1 - \rho$

- P_0 = Probability of n customer in the system

  $= \rho^n \times P_0$

- L_n = Expected length of Non-empty Queue

  $\frac{1}{1-\rho}$

- $P(Wq \geq t)$ = Probability that the waiting time in the Queue is greater than equal to t

  $= \rho e^{-(\mu-\lambda)t}$

- $P(Ws \geq t)$ = Probability that the waiting time in the system is greater than equal to t

  $e^{-(\mu-\lambda)t}$

9.7 Little's law

$\Rightarrow L = \lambda W$ $\qquad L_q = \lambda W_q$

9. 8 Model II (M | M | 1): (N | FCFS)

- This model differs from that of Model I in the sense that the maximum number of customers in the system is limited to N. Arrivals will not exceed N in any case.

$$P_0 = \frac{1-\rho}{1-\rho^{(N+1)}}$$

$$P_n = \left[\frac{1-\rho}{1-\rho^{(N+1)}}\right]\rho^n$$

$$L_s = P_0 \sum_{n=0}^{N} n\rho^n$$

$$L_q = L_s - \rho$$

$$W_s = L_s / \lambda$$

$$W_q = W_s - (1/\mu)$$

9. 9 Model No. III (M | G | 1): (∞/FCFS)

σ = Standard deviation for service tie

$$L_q = \frac{\lambda^2\sigma^2 + \rho^2}{2(1-\rho)}$$

$$W_q = \frac{L_q}{\lambda}$$

$$L_s = L_q + \rho$$

$$W_s = W_q + \frac{1}{\mu}$$

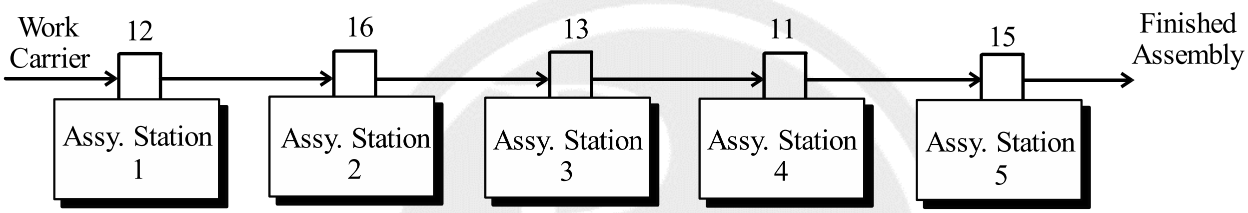
❑❑❑

10 PLANT LAYOUT, MRP & CONTROL CHART

10.1 Line Balancing

The problem is to arrange the individual processing and assembly tasks at the workstations so that the total time required at each workstation is approximately the same.

Nearly impossible to reach perfect balance



- Total work content (TWC) = $\sum T_{si}$
- Line efficiency $= \dfrac{TWC}{N(T_c)}$
- Theoretically minimum number of work station

  $$N_{min} = \frac{TWC}{(T_c)}$$

- Balance delay = 1 – Line efficiency
- The objective of line balancing is to combine various operation on different work station in such a way that ***the processing time at each work station is almost the same and equal to the cycle time***

  $$T_{cycle} \geq T_{system\,max}$$

- Entire job is divided into different element each operation is performed on work piece is known as work element.
- Specific location on the line at which few operations have to be performed is a work station.
- Station time (Tsi) must lie between cycle time and maximum of all work element time (Max $\{T_{iN}\}$):

  $$\text{Max}\{T_{iN}\} \leq T_{si} \leq T_c$$

10. 2 Control Chart

- Control charts are statistical tool, showing whether a process is in control or not.
- It is a graphical tool for monitoring the activities of an ongoing process also referred as ***Shewhart*** control charts.

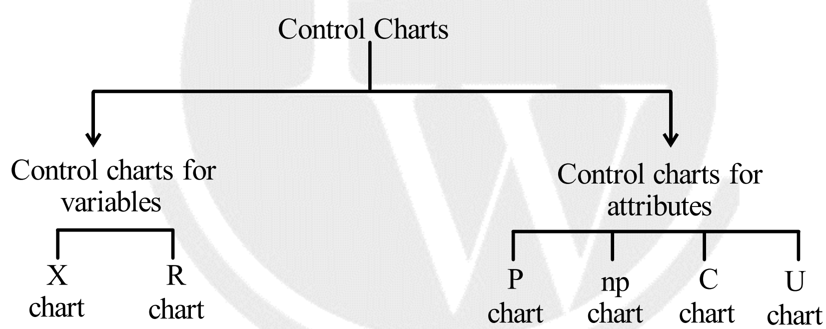
10. 3 Causes of variation in Quality

- **Variation due to chance cause is**: variation due to chance causes conform to normal distribution curve and they are not very high magnitude and also known as RANDOM VARIATION.
- These causes are natural to any manufacturing process and are beyond human control. Like slight variation in temperature, pressure and humidity, etc.
- **Variation due Assignable cause is**: variation due to assignable causes do not conform to any standard distribution. They can be found out and completely eliminated.
- Some of the assignable causes of variation are defective raw material, improper machine setups, worn equipment's, unskilled workers.

10. 4 Types of process data

- **Variable:** continuous data. Things we can measure. Example includes length, weight, time, temperature, diameter etc.
- **Attribute:** discrete data. Things we CAN'T count and can only be classified as good or bad. Examples includes number or percent defective items in a lot, number of defects per item etc.

10. 5 Types of control chart



10.6 Material Requirement Planning

10.6.1 MRP

"MRP constitutes a set of techniques that use bill of material inventory data, and the master production schedule to calculate requirements for materials."

10. 6. 2 Objective of MRP

- Inventory reduction
- Avoid delays
- Realistic commitments
- Increased efficiency

10. 6. 3 Major inputs of MRP System

(a) Bill of Material

- Product structure file
- Determines which component items need to be scheduled

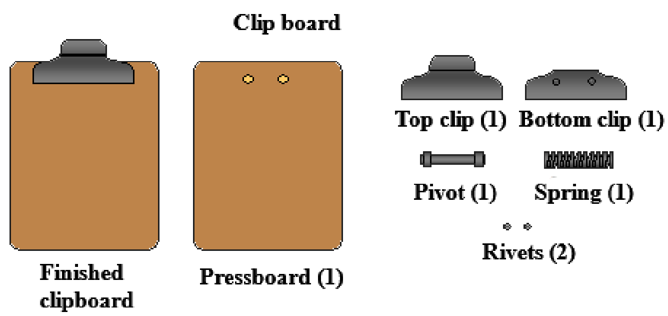


Fig. 10.1

(b) Master Production Schedule (MPS)

- It is the schedule, which shows the number and timing of all end items to be produced over a planning horizon.

	PERIOD				
MPS ITEM	1	2	3	4	5
Clipboard	85	95	120	100	100
Lap desk	0	50	0	50	0
Lapboard	75	120	47	20	17
Pencil Case	125	125	125	125	125

(c) Inventory Record

- Contains an extensive amount of information on every item that is produced, ordered, or inventoried in the system

10. 7 Plant layouts

"Plant layout ideally involves: -

(a) Allocation of space and

(b) Arrangement of equipment in such a manner that overall operating costs are minimized".

Objectives of Layout

The basic objective of layout design is to facilitate a smooth flow of work, material, and information through the system. Supporting objectives generally involve the following:

(a) To use workers and space efficiently.
(b) To avoid bottlenecks.
(c) To minimize material handling costs.
(d) To eliminate unnecessary movements of workers or materials.
(e) To minimize production time or customer service time.
(f) To design for safety

Different types of common layouts

Commonly, the layouts are of the following types:

(a) Product or line layout.

(b) Process or functional layout.

(c) Fixed position layout

(d) Cellular or group technology layout.

10. 8 Product or line layout

(a) The materials move from one workstation to another sequentially without any backtracking or deviation.

(b) Materials are fed into 1st machine and semi-finished goods travel automatically from machine to machine.

(c) The output of one machine becoming input of the next.

Ex: Food Processing Unit, Paper mill

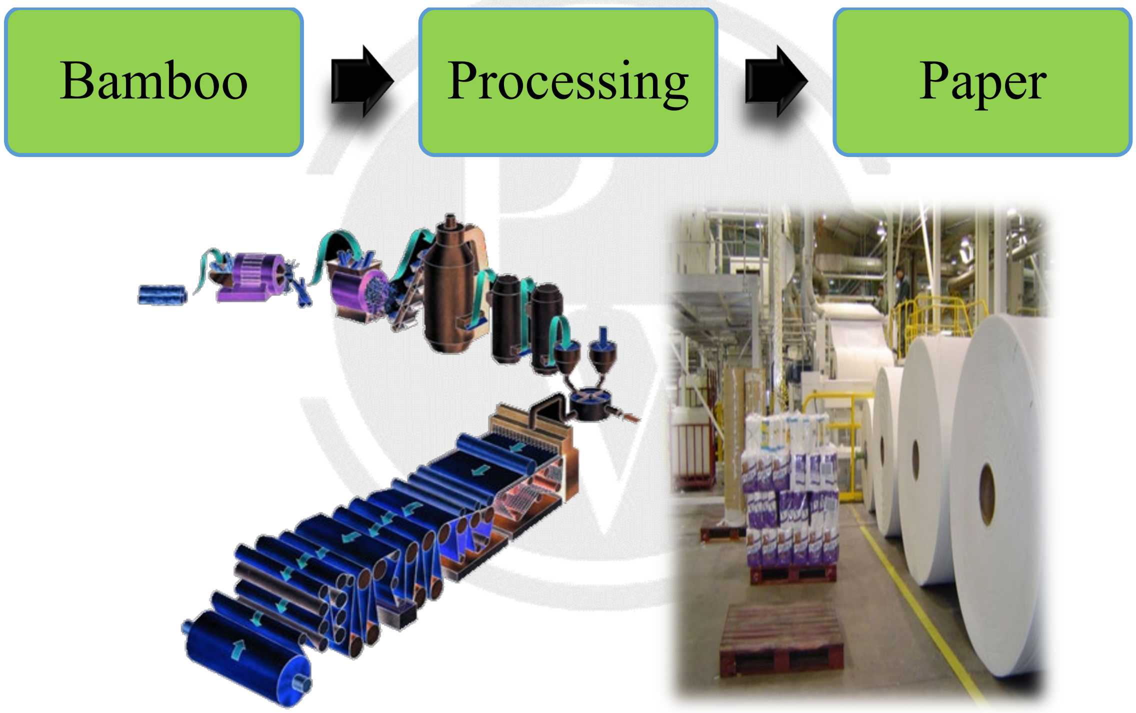


Fig. 10.2 Product layout

10. 9 Process or functional layout

- In this type of layout machines of a similar type are arranged together at one place.
- The work has to be allocated to each department in such a way that no machines are chosen to do as many different jobs as possible.
  Eg: Process oriented layout for a hospital

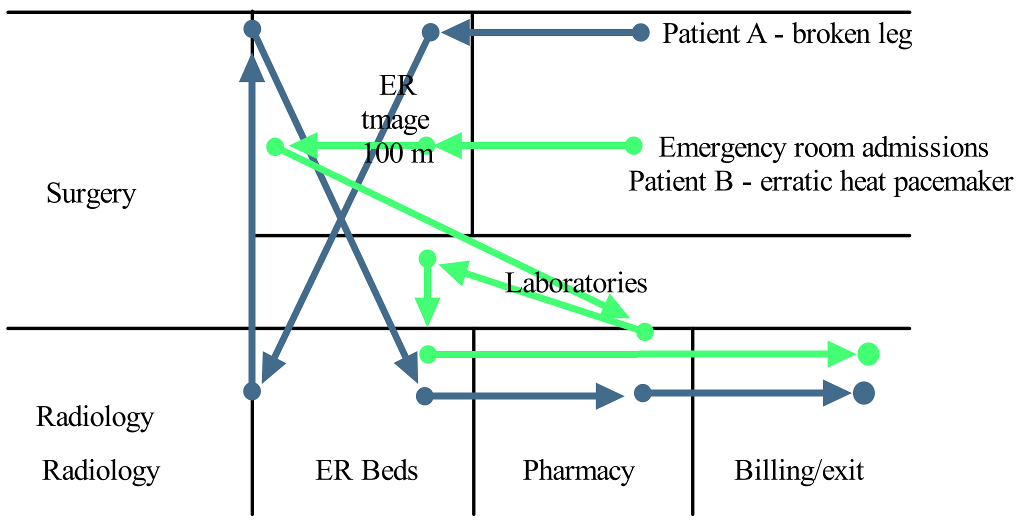


Fig. 10.3 Process layout

10. 10 Fixed Position Layout

- Here, Major products being produced is fixed at one location.
- All other facilities are brought and arranged around the work center.

  Ex: Ship building, Dam construction, flyover construction.

Fig. 10.4 Fixed layout

10. 11 Cellular or Group Layout

- "Group technology is the technique of identifying and bringing together related or similar parts in production process in order to utilize the inherent economy of flow production methods."
- This layout is suitable for a manufacturing environment in which *large variety of products are needed in small volumes* (or batches).
- Every cell contains a group of machines which are dedicated to the production of a family of parts.

10. 12 Process flow before the group technology

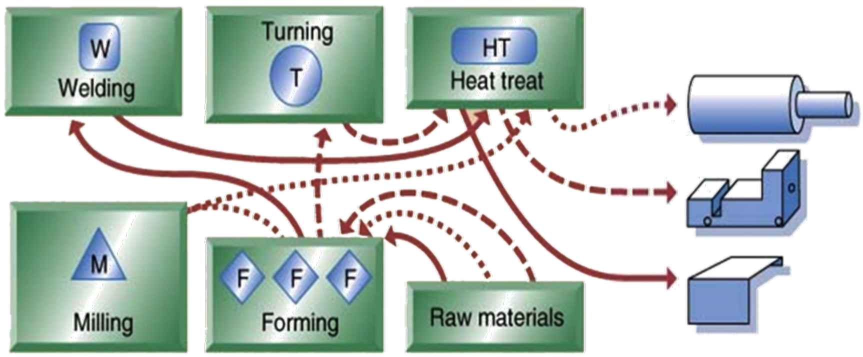


Fig. 10.5

Process flow after the group technology

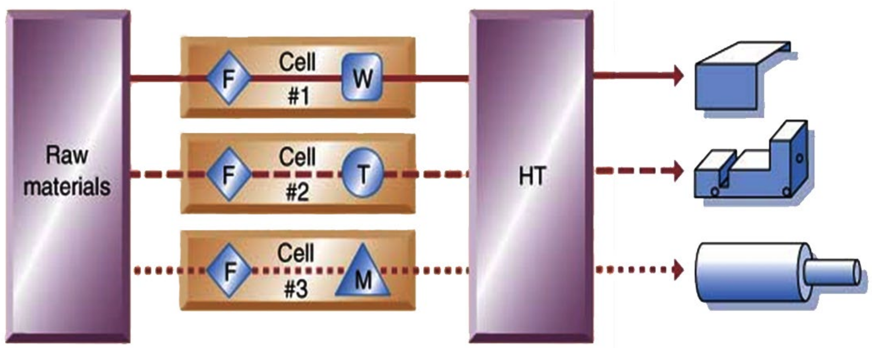


Fig. 10.6

❑❑❑