Industrial Engineering and Management (IE &M)

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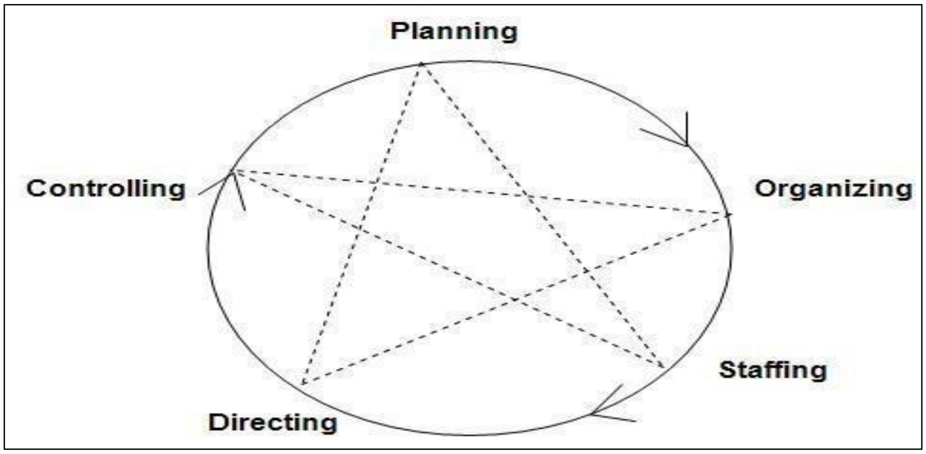
Management: Management is the art of getting things done to by a group of people with the effective utilization of available resources

Functions of Management:

Management has been described as a social process involving responsibility for economical and effective planning & regulation of operation of an enterprise in the fulfillment of given purposes.

It involves the following functions :

Planning, **Organizing**, **Staffing**, **Directing** and **Controlling**.



1. **Planning**
   It is the basic function of management. It deals with chalking out a future course of action & deciding in advance the most appropriate course of actions for achievement of pre-determined goals. According to KOONTZ, "Planning is deciding in advance - what to do, when to do & how to do. It bridges the gap from where we are & where we want to be". A plan is a future course of actions. It is an exercise in problem solving & decision making. Planning is determination of courses of action to achieve desired goals. Thus, planning is a systematic thinking about ways & means for accomplishment of pre-determined goals. Planning is necessary to ensure proper utilization of human & non-human resources. It is all pervasive, it is an intellectual activity and it also helps in avoiding confusion, uncertainties, risks, wastages etc.

2. **Organizing**
   It is the process of bringing together physical, financial and human resources and developing productive relationship amongst them for achievement of organizational goals. According to Henry Fayol, "To organize a business is to provide it with everything useful or its functioning i.e. raw material, tools, capital and personnel's". To organize a business involves determining & providing human and non-human resources to the organizational structure. Organizing as a process involves:

   - Identification of activities.
   - Classification of grouping of activities.
   - Assignment of duties.
   - Delegation of authority and creation of responsibility.
   - Coordinating authority and responsibility relationships.

3. **Staffing**

It is the function of manning the organization structure and keeping it manned. Staffing has assumed greater importance in the recent years due to advancement of technology, increase in size of business, complexity of human behavior etc. The main purpose o staffing is to put right man on right job i.e. square pegs in square holes and round pegs in round holes. According to Kootz & O'Donell, "Managerial function of staffing involves manning the organization structure through proper and effective selection, appraisal & development of personnel to fill the roles designed un the structure". Staffing involves:

- Manpower Planning (estimating man power in terms of searching, choose the person and giving the right place).
- Recruitment, Selection & Placement.
- Training & Development.
- Remuneration.
- Performance Appraisal.
- Promotions & Transfer.

4. Directing

It is that part of managerial function which actuates the organizational methods to work efficiently for achievement of organizational purposes. It is considered life-spark of the enterprise which sets it in motion the action of people because planning, organizing and staffing are the mere preparations for doing the work. Direction is that inert-personnel aspect of management which deals directly with influencing, guiding, supervising, motivating sub-ordinatefor the achievement of organizational goals. Direction has following elements:

- Supervision
- Motivation
- Leadership
- Communication

Supervision- implies overseeing the work of subordinates by their superiors. It is the act of watching & directing work & workers.

Motivation- means inspiring, stimulating or encouraging the sub-ordinates with zeal to work. Positive, negative, monetary, non-monetary incentives may be used for this purpose.

Leadership- may be defined as a process by which manager guides and influences the work of subordinates in desired direction.

Communications- is the process of passing information, experience, opinion etc from one person to another. It is a bridge of understanding.

5. Controlling

It implies measurement of accomplishment against the standards and correction of deviation if any to ensure achievement of organizational goals. The purpose of controlling is to ensure that everything occurs in conformities with the standards. An efficient system of control helps to predict deviations before they actually occur. According to *Theo Haimann*, “Controlling is the process of checking whether or not proper progress is being made towards the objectives and goals and acting if necessary, to correct any deviation”. According to Koontz & O’Donell “Controlling is the measurement & correction of performance activities of subordinates in order to make sure that the enterprise objectives and plans desired to obtain them as being accomplished”. Therefore controlling has following steps:

a. Establishment of standard performance.
b. Measurement of actual performance.
c. Comparison of actual performance with the standards and finding out deviation if any.
d. Corrective action.

Plant Location:

Plant location or the facilities location problem is an important strategic level decision making for an organization. One of the key features of a conversion process (manufacturing system) is the efficiency with which the products (services) or effectiveness are transferred to the customers. This fact will include the determination of where to place the plant or facility.

The selection of location is a key-decision as large investment is made in building plant and machinery. It is not advisable or not possible to change the location very often. So an improper location of plant may lead to waste of all the investments made in building and machinery, equipment.

Before a location for a plant is selected, long range forecasts should be made anticipating future needs of the company. The plant location should be based on the company's expansion plan and policy, diversification plan for the products, changing market conditions, the changing sources of raw materials and many other factors that influence the choice of the location decision. The purpose of the location study is to find an optimum location one that will result in the greatest advantage to the organization.

Need for Plant Location:

The need for select plant location due to following conditions such as

1. If an entrepreneur starts a new business.
2. When the current business until does not have any scope for expansion and it had outgrown its original facilities.
3. When a lease expires and landlord is not willing to extend its leasing contract.
4. In case of expansion of the business volume or the degree of market
5. If a firm thinks that there is a chance of decreasing the manufacturing cost by changing from one location to other location.
6. In other economic and social reasons such as improper labour supply, change of market conditions etc. for selecting a plant location.

It is very essential to consider all the economic factors influenced in plant location to select very difficult to select the place having all required facilities for starting a factory because there is some principles will be used such as cost of raw materials fabrication and the cost of marketing of finished products minimum must be selected.

There is some other needs of plant location such as to start new organization such as existing organisation and location for existing organization and global location

I. To select existing organization:

Cost economies are always important while selecting a location for the first time, but should keep in mind the cost of long-term business/organizational objectives. The following are the factors to be considered while selecting the location for the new organizations:

1. **Identification of region:** The organizational objectives along with the various long-term considerations about marketing, technology, internal organizational strengths and weaknesses, region specific resources and business environment, legal-governmental environment, social environment and geographical environment suggest a suitable region for locating the operations facility.
2. **Choice of a site within a region:** Once the suitable region is identified, the next step is choosing the best site from an available set. Choice of a site is less dependent on the organization's long- term strategies. Evaluation of alternative sites for their tangible and intangible costs will resolve facilities-location problem.

The problem of location of a site within the region can be approached with the following cost-oriented non-interactive model, *i.e.*, dimensional analysis.

3. **Dimensional analysis:** If all the costs were tangible and quantifiable, the comparison and selection of a site is easy. The location with the least cost is selected. In most of the cases intangible costs which are expressed in relative terms than in absolute terms. Their relative merits and demerits of sites can also be compared easily. Since both tangible and intangible costs need to be considered for a selection of a site, dimensional analysis is used.

Dimensional analysis consists in computing the relative merits (cost ratio) for each of the cost items for two alternative sites. For each of the ratios an appropriate weightage by means of power is given and multiplying these weighted ratios to come up with a comprehensive figure on the relative merit of two alternative sites i.e.,

$C1^M$, $C2^M$… Cz^M is the different costs associated with a site M on the 'z' different cost items. $C1^N$, $C2^N$, …, Cz^N are the different costs associated with a site N and W1, W2, W3, …, Wz are the Weightage given to these cost items, then relative merit of the M and site N is given by:

$$\left(C_1^M / C_1^N\right)^{W_1} \times \left(C_2^M / C_2^N\right)^{W_2}, \ldots, \left(C_z^M / C_z^N\right)^{W_z}$$

If this is > 1, site N is superior and vice-versa.

When starting a new factory, plant location decisions are very important because they have direct bearing on factors like, financial, employment and distribution patterns. In the long run, relocation of plant may even benefit the organization. But, the relocation of the plant involves stoppage of production, and also cost for shifting the facilities to a new location. In addition to these things, it will introduce some inconvenience in the normal functioning of the business. Hence, at the time of starting any industry, one should generate several alternate sites for locating the plant. After a critical analysis, the best site is to be selected for commissioning the plant. Location of warehouses and other facilities are also having direct bearing on the operational performance of organizations.

The existing firms will seek new locations in order to expand the capacity or to place the existing facilities. When the demand for product increases, it will give rise to following decisions:

- Whether to expand the existing capacity and facilities.
- Whether to look for new locations for additional facilities.
- Whether to close down existing facilities to take advantage of some new locations.

II. In Case of Location Choice for Existing Organisation

In this case a manufacturing plant has to fit into a multi-plant operations strategy. That is, additional plant location in the same premises and elsewhere under following circumstances:

1. Plant manufacturing distinct products.
2. Manufacturing plant supplying to specific market area.
3. Plant divided on the basis of the process or stages in manufacturing.
4. Plants emphasizing flexibility.

The different operations strategies under the above circumstances could be:

1. **Plants manufacturing distinct products:** Each plant services the entire market area for the organization. This strategy is necessary where the needs of technological and resource inputs are specialized or distinctively different for the different product-lines.

For example, a high quality precision product-line should not be located along with other product-line requiring little emphasis on precision. It may not be proper to have too many contradictions such as sophisticated and old equipment, highly skilled and semi-skilled personnel, delicates processes and those that could permit rough handlings, all under one roof and one set of managers. Such a setting leads to much confusion regarding the required emphasis and the management policies.

2. **Manufacturing plants supplying to a specific market area:** Here, each plant manufactures almost all of the company's products. This type of strategy is useful where market proximity consideration dominates the resources and technology considerations. This strategy requires great deal of coordination from the corporate office. An extreme example of this strategy is that of soft drinks bottling plants.

3. **Plants divided on the basis of the process or stages in manufacturing**: Each production process or stage of manufacturing may require distinctively different equipment capabilities, labour skills, technologies, and managerial policies and emphasis. Since the products of one plant feed into the other plant, this strategy requires much centralized coordination of the manufacturing activities from the corporate office that are expected to understand the various technological aspects of all the plants.

4. **Plants emphasizing flexibility:** This requires much coordination between plants to meet the changing needs and at the same time ensure efficient use of the facilities and resources. Frequent changes in the long-term strategy in order to improve be efficiently temporarily, are not healthy for the organization. In any facility location problem the central question is: 'Is this a location at which the company can remain competitive for a long time?'

III. In Case of Global Location

Because of globalization, multinational corporations are setting up their organizations in India and Indian companies are extending their operations in other countries. In case of global locations there is scope for virtual proximity and virtual factory.

VIRTUAL PROXIMITY

With the advance in telecommunications technology, a firm can be in virtual proximity to its customers. For a software services firm much of its logistics is through the information/ communication pathway. Many firms use the communications highway for conducting a large portion of their business transactions. Logistics is certainly an important factor in deciding on a location—whether in the home country or abroad. Markets have to be reached. Customers have to be contacted. Hence, a market presence in the country of the customers is quite necessary.

VIRTUAL FACTORY

Many firms based in USA and UK in the service sector and in the manufacturing sector often out sources part of their business processes to foreign locations such as India. Thus, instead of one's own operations, a firm could use its business associates' operations facilities. The Indian BPO firm is a foreign-based company's 'virtual service factory'. So a location could be one's own or one's business associates. The location decision need not always necessarily pertain to own operations.

Factors influencing in plant location:
It can be classified as two types such as general factors and specific factors such as

1. General factors:

1. Availability of land for present and future needs and cost of land and land development and building etc.
2. Availability of inputs such as labour, raw materials etc.
3. Closeness to the market places.
4. Stability of demand and availability of communication facilities.
5. Availability of necessary modes of transportation like road, rail, airport and waterways.
6. Availability of infrastructure facilities such as power, water and financial institutions, banks etc.
7. Disposal of waste and effluent and their impact of environment.
8. Government support, grant, subsidy, tax structure.
9. Availability of housing facilities and recreational facilities.
10. Demographic factors like population, trained man power, academic institutions, standard of living, and income level etc. security, culture of society and fuel cost.

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

1. The economic stability of the country and the concern of the country towards outside investments are to be considered.
2. The success of operation of the factory depends on the cultural factors, language and cultural differences which can present operating, control and even policy problems, units of measurement is also very important in international business.
3. Analysis must be based on the factors like wage rate, policy, duties etc.
4. The company can setup joint ventures with any leading local giants that will solve many

operational problems.

It is appropriate to divide the factors, which influence the plant location or facility location on the basis of the nature of the organisation as:

1. **General locational factors**, which include controllable and uncontrollable factors for all type of organizations.

2. **Specific locational factors** specifically required for manufacturing and service organizations. Location factors can be further divided into two categories:

Dominant factors are those derived from competitive priorities (cost, quality, time, and flexibility) and have a particularly strong impact on sales or costs. Secondary factors also are important, but management may downplay or even ignore some of them if other factors are more important.

General Locational Factors

Following are the general factors required for location of plant in case of all types of organizations.

CONTROLLABLE FACTORS

1. Proximity to markets
2. Supply of materials
3. Transportation facilities
4. Infrastructure availability
5. Labour and wages
6. External economies

UNCONTROLLABLE FACTORS

7. Government policy
8. Climate conditions
9. Supporting industries and services
10. Community and labour attitudes
11. Community
12. Infrastructure.

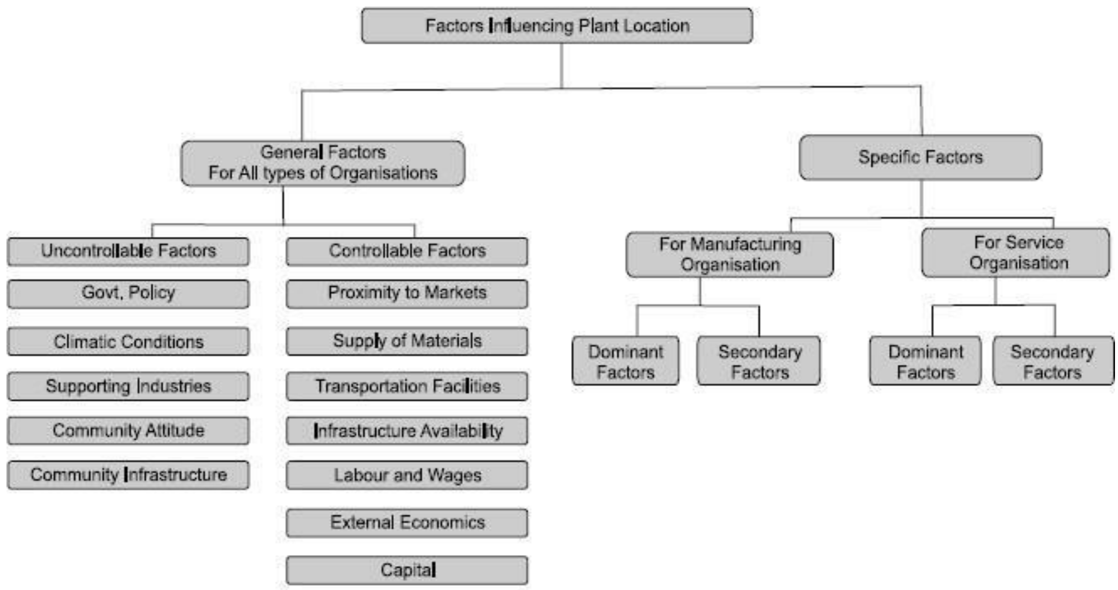


Fig. 4.1 Factors influencing plant location

DOMINANT FACTORS for Manufacturing Organization

Factors dominating location decisions for new manufacturing plants can be broadly classified in six groups. They are listed in the order of their importance as follows.

1. Favourable labour climate
2. Proximity to markets
3. Quality of life
4. Proximity to suppliers and resources
5. Utilities, taxes, and real estate costs

SECONDARY FACTORS for Manufacturing Organization

There are some other factors needed to be considered, including room for expansion, construction costs, accessibility to multiple modes of transportation, the cost of shuffling people and materials between plants, competition from other firms for the workforce, community attitudes, and many others. For global operations, firms are emphasizing local employee skills and education and the local infrastructure.

DOMINANT FACTORS for Service Organization

The factors considered for manufacturers are also applied to service providers, with one important addition — the impact of location on sales and customer satisfaction. Customers usually look about how close a service facility is, particularly if the process requires considerable customer contact.

TRANSPORTATION COSTS AND PROXIMITY TO MARKETS

For warehousing and distribution operations, transportation costs and proximity to markets are extremely important. With a warehouse nearby, many firms can hold inventory closer to the customer, thus reducing delivery time and promoting sales.

LOCATION OF COMPETITORS

One complication in estimating the sales potential at different location is the impact of competitors. Management must not only consider the current location of competitors but also try to anticipate their reaction to the firm's new location. Avoiding areas where competitors are already well established often pays. However, in some industries, such as new-car sales showrooms and fast-food chains, locating near competitors is actually advantageous. The strategy is to create a critical mass, whereby several competing firms clustered in one location attract more customers than the total number who would shop at the same stores at scattered locations. Recognizing this effect, some firms use a follow –the leader strategy when selecting new sites.

SECONDARY FACTORS

Retailers also must consider the level of retail activity, residential density, traffic flow, and site visibility. Retail activity in the area is important, as shoppers often decide on impulse to go shopping or to eat in a restaurant. Traffic flows and visibility are important because businesses customers arrive in cars. Visibility involves distance from the street and size of nearby buildings and signs. High residential density ensures night time and weekend business when the population in the area fits the firm's competitive priorities and target market segment.

Mathematical model for plant location

Various models are available which help to identify the ideal location. Some of the popular models are:
1. Factor rating method
2. Weighted factor rating method
3. Load-distance method
4. Centre of gravity method
5. Break-even analysis.

1. Factor rating Method or Location factor rating method:

The process of selecting a new facility location involves a series of following steps:
1. Identify the important location factors.
2. Rate each factor according to its relative importance, i.e., higher the ratings is indicative of prominentfactor.
3. Assign each location according to the merits of the location for each factor.
4. Calculate the rating for each location by multiplying factor assigned to each location with basic factorsconsidered.
5. Find the sum of product calculated for each factor and select best location having highest total score.

Problem: Let us assume that a new medical facility, Health-care, is to be located in Delhi. The location factors, factor rating and scores for two potential sites are shown in the following table. Which is the best location based on factor rating method?

Sl. No.	Location factor	Factor rating	Rating	
			Location 1	Location 2
1.	Facility utilization	8	3	5
2.	Total patient per month	5	4	3
3.	Average time per emergency trip	6	4	5
4.	Land and construction costs	3	1	2
5.	Employee preferences	5	5	3

SOLUTION

Sl. No.	Location factor	Factor rating (1)	Location 1		Location 2	
			(Rating) (2)	Total= (1) . (2)	(Rating) (3)	Total = (1) . (3)
1.	Facility utilization	8	3	24	5	40
2.	Total patient per month	5	4	20	3	15
3.	Average time per emergency trip	6	4	24	5	30
4.	Land and construction costs	3	1	3	2	6
5.	Employee preferences	5	5	25	3	15
			Total	96	Total	106

The total score for location 2 is higher than that of location 1. Hence location 2, is the best choice.

2. Weighted factor rating method:

In this method to merge quantitative and qualitative factors, factors are assigned weights based on relative importance and weightage score for each site using a preference matrix is calculated. The site with the highest weighted score is selected as the best choice.

Problem: Let us assume that a new medical facility, Health-care, is to be located in Delhi. The location factors, weights, and scores (1 = poor, 5 = excellent) for two potential sites are shown in the following table.What is the weighted score for these sites? Which is the best location?

Sl. No.	Location factor	Weight	Scores	
			Location 1	Location 2
1.	Facility utilization	25	3	5
2.	Total patient km per month	25	4	3
3.	Average time per emergency trip	25	3	3
4.	Land and construction costs	15	1	2
5.	Employee preferences	10	5	3

SOLUTION: The weighted score for this particular site is calculated by multiplying each factor's weightby its score and adding the results:

Weighted score location 1 = 25 × 3 + 25 × 4 + 25 × 3 + 15 × 1 + 10 × 5
= 75 + 100 + 75 + 15 + 50 = 315

Weighted score location 2 = 25 × 5 + 25 × 3 + 25 × 3 + 15 × 2 + 10 × 3
= 125 + 75 + 75 + 30 + 30 = 335

Location 2 is the best site based on total weighted scores.

3. Load-distance Method:

The load-distance method is a mathematical model used to evaluate locations based on proximity factors. The objective is to select a location that minimizes the total weighted loads moving into and out of the facility. The distance between two points is expressed by assigning the points to grid coordinates on a map. An alternative approach is to use time rather than distance.

DISTANCE MEASURES

Suppose that a new warehouse is to be located to serve Delhi. It will receive inbound shipments from several suppliers, including one in Ghaziabad. If the new warehouse were located at Gurgaon, what would be the distance between the two facilities? If shipments travel by truck, the distance depends on the highway system and the specific route taken. Computer software is available for calculating the actual mileage between any two locations in the same county. However, for load-distance method, a rough calculation that is either Euclidean or rectilinear distance measure may be used. Euclidean distance is the straight-line distance, or shortest possible path, between two points.

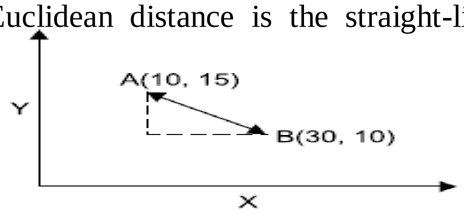


Fig: Distance between point A and point B

The point A on the grid represents the supplier's location in Ghaziabad, and the point B represents the possible warehouse location at Gurgaon. The distance between points A and B is the length of the hypotenuse of a right triangle, or

$$d_{AB} = \sqrt{((X_A - X_B)^2 + (Y_A - Y_B)^2}$$

where,

dAB = distance between points A and B XA = x-coordinate of point A

YA = y-coordinate of point A XB = x-coordinate of point B YB = y-coordinate of point B

Rectilinear distance measures distance between two points with a series of 90° turns as city blocks. Essentially, this distance is the sum of the two dashed lines representing the base and side of the triangle in figure. The distance travelled in the x-direction is the absolute value of the difference in x-coordinates. Adding this result to the absolute value of the difference in the y-coordinates gives

$$D_{AB} = |X_A - X_B| + |Y_A - Y_B|$$

Problem: The new Health-care facility is targeted to serve seven census tracts in Delhi. The table given below shows the coordinates for the centre of each census tract, along with the projected populations, measured in thousands. Customers will travel from the seven census tract centres to the new facility when they need health-care. Two locations being considered for the new facility are at (5.5, 4.5) and (7, 2), which are the centres of census tracts C and F. Details of seven census tract centres, co-ordinate distances along with the population for each centre are given below. If we use the population as the loads and use rectilinear distance, which location is better in terms of its total load-distance score?

Sl. No.	Census tract	(x, y)	Population (l)
1	A	(2.5, 4.5)	2
2	B	(2.5, 2.5)	5
3	C	(5.5, 4.5)	10
4	D	(5, 2)	7
5	E	(8, 5)	10
6	F	(7, 2)	20
7	G	(9, 2.5)	14

SOLUTION: Calculate the load-distance score for each location. Using the coordinates from the above table. Calculate the load-distance score for each tract.

Using the formula DAB = |XA – XB| + |YA – YB|

Census tract	(x, y)	Population (l)	Locate at (5.5, 4.5)		Locate at (7, 2)	
			Distance (d)	Load-distance	Distance (d)	Load-distance
A	(2.5, 4.5)	2	3 + 0 = 3	6	4.5 + 2.5 = 7	14
B	(2.5, 2.5)	5	3 + 2 = 5	25	4.5 + 0.5 = 5	25
C	(5.5, 4.5)	10	0 + 0 = 0	0	1.5 + 2.5 = 4	40
D	(5, 2)	7	0.5 + 2.5 = 3	21	2 + 0 = 2	14
E	(8, 5)	10	2.5 + 0.5 = 3	30	1 + 3 = 4	40
F	(7, 2)	20	1.5 + 2.5 = 4	80	0 + 0 = 0	0
G	(9, 2.5)	14	3.5 + 2 = 5.5	77	2 + 0.5 = 2.5	35
			Total	239	Total	168

4. Centre of Gravity:

Centre of gravity is based primarily on cost considerations. This method can be used to assist managers in balancing cost and service objectives. The centre of gravity method takes into account the locations of plants and markets, the volume of goods moved, and transportation costs in arriving at the best location fora single intermediate warehouse.

The centre of gravity is defined to be the location that minimizes the weighted distance between the warehouse and its supply and distribution points, where the distance is weighted by the number of tones supplied or consumed. The first step in this procedure is to place the locations on a coordinate system. The origin of the coordinate system and scale used are arbitrary, just as long as the relative distances are correctly represented. This can be easily done by placing a grid over an ordinary map. The centre of gravity is determined by the formula.

$$C_X = \frac{\sum D_{ix} . W_i}{\sum W_i} \qquad C_Y = \frac{\sum D_{iy} . W_i}{\sum W_i}$$

Where, C_X = x-coordinate of the centre of gravity C_Y = y-coordinate of the centre of gravity D_{ix} = x-coordinate of location i

Diy = y-coordinate of location i

Problem: The new Health-care facility is targeted to serve seven census tracts in Delhi. The table given below shows the coordinates for the centre of each census tract, along with the projected populations, measured in thousands. Customers will travel from the seven census tract centres to the new facility when they need health-care. Two locations being considered for the new facility are at (5.5, 4.5) and (7, 2), which are the centres of census tracts C and F. Details of seven census tract centres, coordinate distances along with the population for each centre are given below. Find t

Sl. No.	Census tract	(x, y)	Population (l)
1	A	(2.5, 4.5)	2
2	B	(2.5, 2.5)	5
3	C	(5.5, 4.5)	10
4	D	(5, 2)	7
5	E	(8, 5)	10
6	F	(7, 2)	20
7	G	(9, 2.5)	14

S e

P

Sl. No.	Census tract	(x, y)	Population (l)	Lx	Ly
1	A	(2.5, 4.5)	2	5	9
2	B	(2.5, 2.5)	5	12.5	12.5
3	C	(5.5, 4.5)	10	55	45
4	D	(5, 2)	7	35	14
5	E	(8, 5)	10	80	50
6	F	(7, 2)	20	140	40
7	G	(9, 2.5)	14	126	35
		Total	68	453.50	205.50

Next we find C_X and C_y.

$$C_X = 453.5/68 = 6.67$$

$$C_y = 205.5/68 = 3.02$$

The centre of gravity is (6.67, 3.02). Using the centre of gravity as starting point, managers can now search in its vicinity for the optimal location.

5. Break-even Analysis:

Break even analysis implies that at some point in the operations, total revenue equals total cost. Break even analysis is concerned with finding the point at which revenues and costs agree exactly. It is called 'Break-even Point'. The Figure portrays the Break Even Chart: Breakeven point is the volume of output at which neither a profit is made nor a loss is incurred.

The Break Even Point (BEP) in units can be calculated by using the relation:

$$BEP = \frac{\text{Fixed Cost}}{\text{Contribution per unit}} = \frac{\text{Fixed Cost}}{\text{Selling Price} - \text{Variable Cost per unit}} = \frac{F}{S - V} \text{ units}$$

The Break Even Point (BEP) in Rs. can be calculated by using the relation:

$$BEP = \frac{\text{Fixed Cost}}{\text{PV Ratio}} = \frac{\text{Fixed Cost}}{\left\{\frac{\text{Sales} - \text{Variable Cost}}{\text{Sales}}\right\}} = \frac{F}{\phi} \text{ Rs.}$$

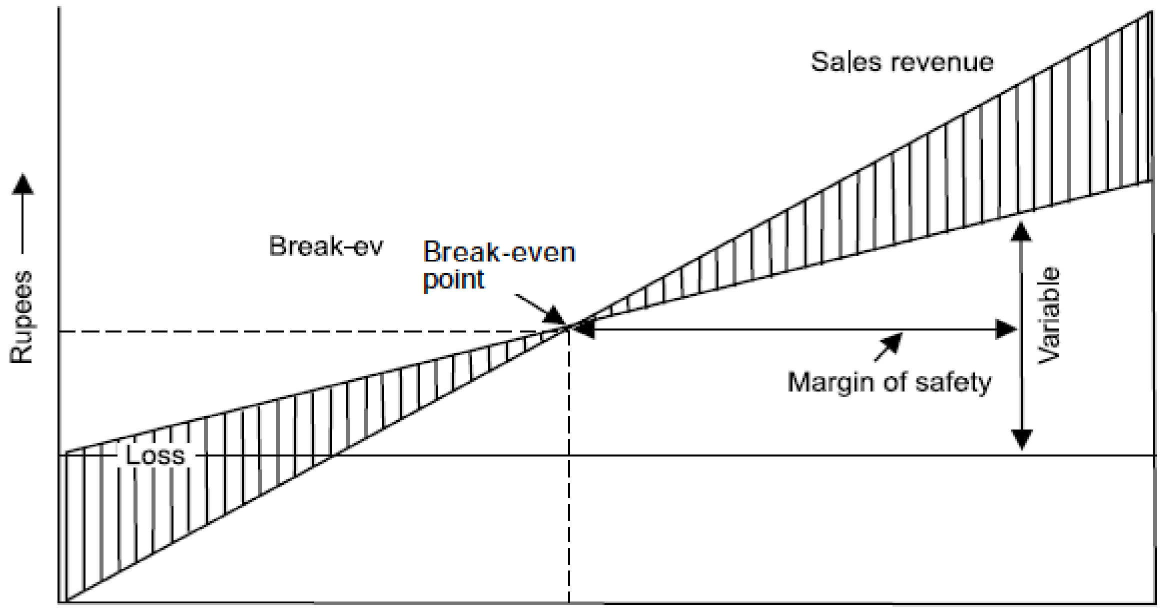


Fig: Units of output or percentage of capacity

	Location X	Location Y	Location Z
Fixed Costs	Rs. 150,000	Rs. 350,000	Rs. 950,000
Variable Costs	Rs. 10	Rs. 8	Rs. 6

Plotting the break even chart for each location can make economic comparisons of locations. This will be helpful in identifying the range of production volume over which location can be selected.

Problem: Potential locations X, Y and Z have the cost structures shown below. The ABC company has a demand of 1,30,000 units of a new product. Three potential locations X, Y and Z having following cost structures shown are available. Select which location is to be selected and also identify the volume ranges where each location is suited?

SOLUTION: Solve for the crossover between X and Y:

$$10X + 150{,}000 = 8X + 350{,}000$$
$$2X = 200{,}000$$
$$X = 100{,}000 \text{ units}$$

Solve for the crossover between Y and Z:

$$8X + 350{,}000 = 6X + 950{,}000$$
$$2X = 600{,}000$$
$$X = 300{,}000 \text{ units}$$

Therefore, at a volume of 1, 30,000 units, Y is the appropriate strategy. From the graph we can interpret that location X is suitable up to 100,000 units, location Y is suitable up to between 100,000 to 300,000 units and location Z is suitable if the demand is more than 300,000 units.

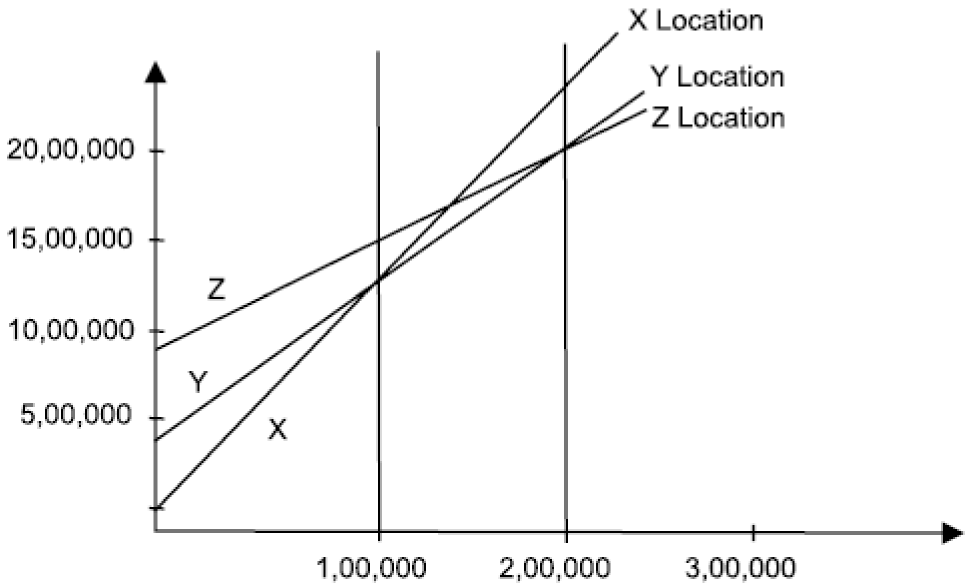


Figure: BEP chart

PLANT LAYOUT

The term 'Plant layout' refers to the physical arrangement of production facilities. It is the configuration of departments, work centres and equipment in the conversion process. It is a floor plan of the physical facilities, which are used in production.
According to Moore "Plant layout is a plan of an optimum arrangement of facilities including personnel, operating equipment, storage space, material handling equipment and all other supporting services along with the design of best structure to contain all these facilities".

Objectives of Plant Layout

The primary goal of the plant layout is to maximize the profit by arrangement of all the plant facilities to the best advantage of total manufacturing of the product.
The objectives of plant layout are:
1. Streamline the flow of materials through the plant.
2. Facilitate the manufacturing process.
3. Maintain high turnover of in-process inventory.
4. Minimize materials handling and cost.
5. Effective utilization of men, equipment and space.
6. Make effective utilization of cubic space.
7. Flexibility of manufacturing operations and arrangements.
8. Provide for employee convenience, safety and comfort.
9. Minimize investment in equipment.
10. Minimize overall production time.
11. Maintain flexibility of arrangement and operation.
12. Facilitate the organizational structure.

CLASSIFICATION OF LAYOUT

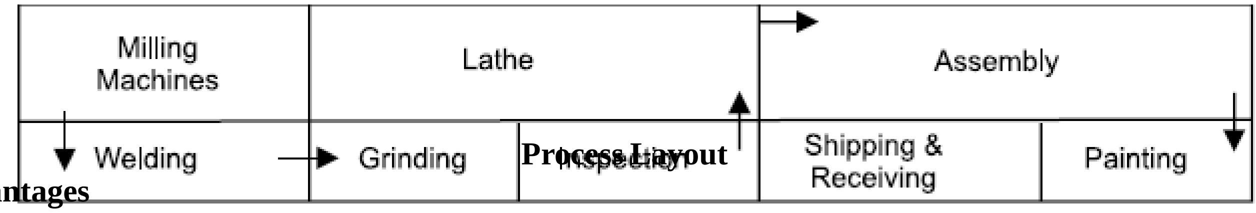
Layouts can be classified into the following five categories:
1. Process layout
2. Product layout
3. Combination layout
4. Fixed position layout
5. Group layout

1. Process layout

Process layout is recommended for batch production. All machines performing similar type of operations are grouped at one location in the process layout e.g., all lathes, milling machines, etc. are grouped in the shop will be clustered in like groups.

Thus, in process layout the arrangement of facilities are grouped together according to their functions. A typical process layout is shown in Fig. 4.5. The flow paths of material through the facilities from one functional area to another vary from product to product. Usually the paths are long and there will be possibility of backtracking.

Process layout is normally used when the production volume is not sufficient to justify a product layout. Typically, job shops employ process layouts due to the variety of products manufactured and their low production volumes.



Process Layout

Advantages

1. In process layout machines are better utilized and fewer machines are required.
2. Flexibility of equipment and personnel is possible in process layout.
3. Lower investment on account of comparatively less number of machines and lower cost of general purpose machines.
4. Higher utilization of production facilities.
5. A high degree of flexibility with regards to work distribution to machineries and workers.
6. The diversity of tasks and variety of job makes the job challenging and interesting.
7. Supervisors will become highly knowledgeable about the functions under their department.

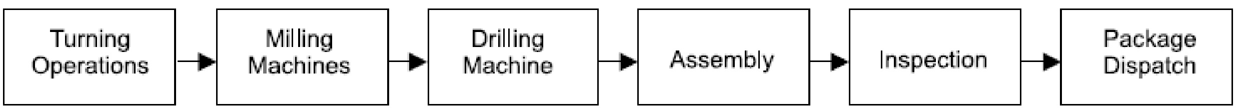
Limitations

1. Backtracking and long movements may occur in the handling of materials thus, reducing material handling efficiency.
2. Material handling cannot be mechanised which adds to cost.
3. Process time is prolonged which reduce the inventory turnover and increases the inprocess inventory.
4. Lowered productivity due to number of set-ups.
5. Throughput (time gap between in and out in the process) time is longer.
6. Space and capital are tied up by work-in-process.

2. Product layout

In this type of layout, machines and auxiliary services are located according to the processing sequence of the product. If the volume of production of one or more products is large, the facilities can be arranged to achieve efficient flow of materials and lower cost per unit. Special purpose machines are used which perform the required function quickly and reliably.

The product layout is selected when the volume of production of a product is high such that a separate production line to manufacture it can be justified. In a strict product layout, machines are not shared by different products. Therefore, the production volume must be sufficient to achieve satisfactory utilization of the equipment. A typical product layout is shown in figure.



Product layout

Advantages

1. The flow of product will be smooth and logical in flow lines.
2. In-process inventory is less.
3. Throughput time is less.
4. Minimum material handling cost.

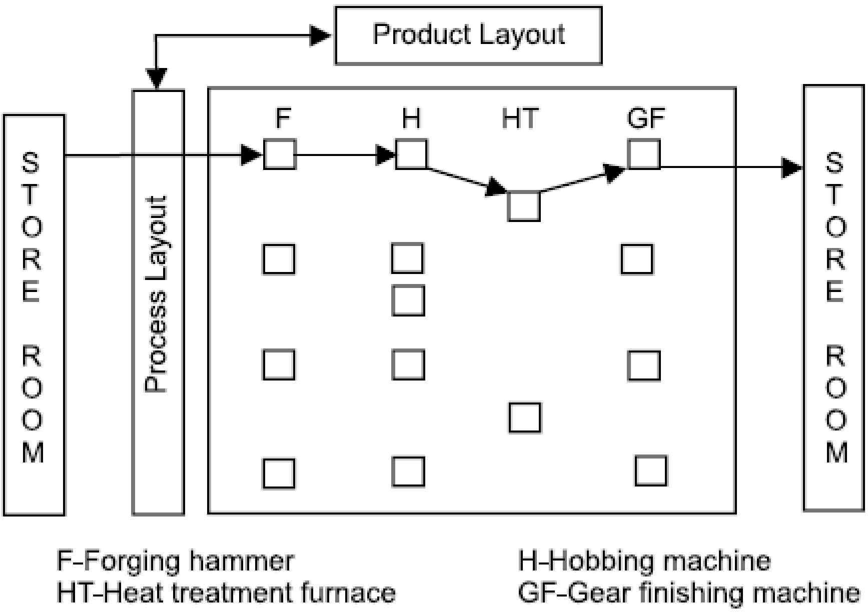
5. Simplified production, planning and control systems are possible.
6. Less space is occupied by work transit and for temporary storage.
7. Reduced material handling cost due to mechanised handling systems and straight flow.
8. Perfect line balancing which eliminates bottlenecks and idle capacity.
9. Manufacturing cycle is short due to uninterrupted flow of materials.
10. Small amount of work-in-process inventory.
11. Unskilled workers can learn and manage the production.

Limitations

1. A breakdown of one machine in a product line may cause stoppages of machines in thedownstream of the line.
2. A change in product design may require major alterations in the layout.
3. The line output is decided by the bottleneck machine.
4. Comparatively high investment in equipments is required.
5. Lack of flexibility. A change in product may require the facility modification.

3. Combination Layout

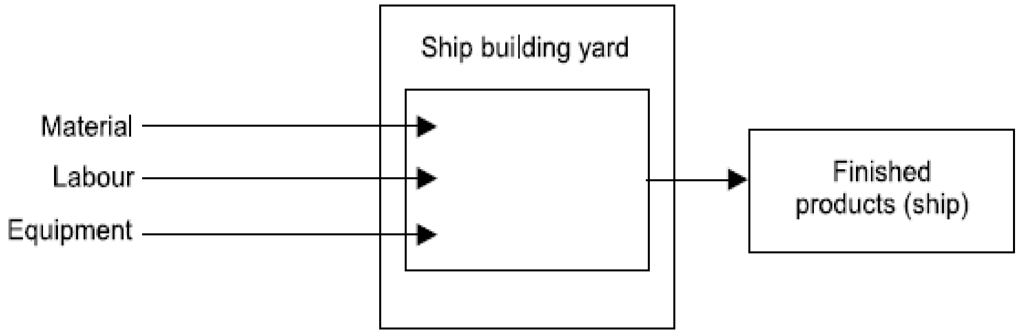
A combination of process and product layouts combines the advantages of both types of layouts. A combination layout is possible where an item is being made in different types and sizes. Here machinery is arranged in a process layout but the process grouping is then arranged in a sequence to manufacture various types and sizes of products. It is to be noted that the sequence of operations remains same with the varietyof products and sizes. Figure shows a combination type of layout for manufacturing different sized gears.



Combining layout for making different types of size and gears

4. Fixed Position Layout

This is also called the **project type** of layout. In this type of layout, the material, or major components remain in a fixed location and tools, machinery, men and other materials are brought to this location. This type of layout is suitable when one or a few pieces of identical heavy products are to be manufactured and when the assembly consists of large number of heavy parts, the cost of transportation of these parts is very high.



Fixed Position Layout

Advantages

1. Helps in job enlargement and upgrades the skills of the operators.
2. The workers identify themselves with a product in which they take interest and pride in doing the job.
3. Greater flexibility with this type of layout.
4. Layout capital investment is lower.

Disadvantages

1. Personal and equipment movement is increased
2. It is also result in duplicate equipment.
3. Requires great skill for personnel and general supervision.
4. It is also result in increased space and greater work-in-process.

5. Group Layout (or Cellular Manufacturing Layout)

There is a trend now to bring an element of flexibility into manufacturing system as regards to variation in batch sizes and sequence of operations. A grouping of equipment for performing a sequence of operations on family of similar components or products has become all the important.

Group Technology (GT) is the analysis and comparisons of items to group them into families with similar characteristics. GT can be used to develop a hybrid between pure process layout and pure flow line (product) layout. This technique is very useful for companies that produce variety of parts in small batches to enable them to take advantage and economics of flow line layout.

The application of group technology involves two basic steps; first step is to determine component families or groups. The second step in applying group technology is to arrange the plants equipment used to process a particular family of components. This represents small plants within the plants. The group technology reduces production planning time for jobs. It reduces the set-up time

Thus group layout is a combination of the product layout and process layout. It combines the advantages of both layout systems. If there are m-machines and n-components, in a group layout (Group- Technology Layout), the m-machines and n-components will be divided into distinct number of machine- component cells (group) such that all the components assigned to a cell are almost processed within that cell itself. Here, the objective is to minimize the intercell movements.

The basic aim of a group technology layout is to identify families of components that require similar of satisfying all the requirements of the machines are grouped into cells. Each cell is capable of satisfying all the requirements of the component family assigned to it.

The layout design process considers mostly a single objective while designing layouts. In process layout, the objective is to minimize the total cost of materials handling. Because of the nature of the layout, the cost of equipments will be the minimum in this type of layout. In product layout, the cost of materials handling will be at the absolute minimum. But the cost of equipments would not be at the minimum if the equipments are not fully utilized.

In-group technology layout, the objective is to minimize the sum of the cost of transportation and the cost of equipments. So, this is called as multi-objective layout. A typical process layout is shown in figure.

Advantages of Group Technology Layout

Group Technology layout can increase—

1. Component standardization and rationalization.
2. Reliability of estimates.
3. Effective machine operation and productivity.
4. Custom
er service.

It can
decrease
the—

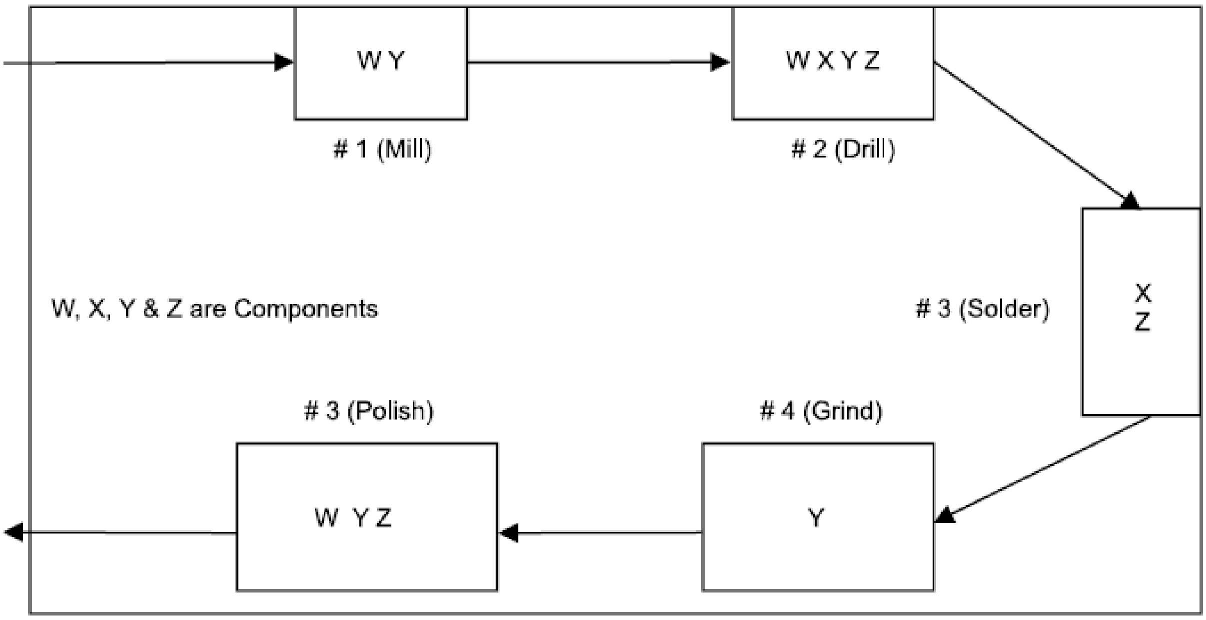
1. Paper work and overall production time.
2. Work-in-progress and work movement.
3. Overall cost.

Disadvantages of Group Technology Layout

1. Involves less manufacturing flexibility
2. Increases the machine down time as machine as grouped as cells which may not be functionalthroughout the production process
3. Duplicate parts of equipment are used as it is very difficult for transferring the parts between cellscausing the rise in production inefficiencies.

Suitability of cellular layout:

1. Cellular layout helps in producing products having different parts.
2. It can apply in the work centers having easily movable machine tools.
3. It is used when the production of a product is independent of its capacity.



Group Layout or Cellular Manufacturing Layout

UNIT IV INVENTORY CONTROL

1. Introduction
Inventory is defined as the list of movable goods which are necessary to manufacture a product and to maintain the equipments and machinery in good working order/condition.

Classification

Broadly Classified into

- Direct inventory
- Indirect inventory

i. Direct inventory
It plays direct role in the manufacture of product such as:

- Raw materials
- Inprocess inventories (= work in progress)
- Purchased parts (purchasing of some components instead of manf. in the plant)
- Inished goods.

ii. Indirect inventory
it helps the raw materials to get converted into finished part. such as:

 Tools

 Supplies

- miscellaneous consumable – brooms, cotton, wool, jute,etc.
- welding electrode, solders etc.
- abrasive mat – emery cloth, sand paper etc.
- brushes, maps, etc.
- oil greases etc.
- general office supplies – candles, sealing wax etc.
- printed forms such as – envelope, letter heads, quotation forms etc.

Inventory control means – making the desired items of required quality and quantity available to various departments/section as & when they need.

(c) Relevant costs

The relevant costs for how much & when decisions of normal inventory keeping one:

1. Cost of capital
Since inventory is equivalent to locked-up working capital the cost of capital is an important relevant cost. this is the opportunity cost of investing in inventory.

2. Space cost
Inventory keeping needs space and therefore, how much and when question of inventory keeping are related to space requirements. This cost may be the rent paid for the space.

3. Materials handling cost
The material need to be moved within the warehose and the factory and the cost associated with the

internal movement of materials (or inventory) is called materials handling cost.

4. Obsolescence, spoilage or Deterioration cost
If the inventory is procured in a large quantity, there is always a risk of the item becoming absolutedue to a change in product design or the item getting spoiled because of natural ageing process.

Such cost has a relation to basic question of how much and when?

5. Insurance costs
There is always a risk of fire or theft of materials. a firm might have taken insurance against suchmishaps and the insurance premium paid are the relevant cost.

6. Cost of general administration
Inventory keeping will involve the use of various staffs. with large inventories, the cost of general administration might go up.

7. Inventory procurement cost
Cost associated with the procurement activities such as tendering, evaluation of bids, ordering, follow-up the purchase order, receipt and inspection of materials etc. is called inventory procurement cost.

(c) Basic EOQ model

EOQ = Economic Order Quantity.

EOQ represent the size of the order (or lot size) such that the sum of

carrying cost (due to holding the inventory) and ordering cost is minimum. it is shown by point A of figure 2.1.

As mentioned earlier, the two most important decisions related to inventory control are:

- When to place an order? &
- How much to order?

. This model is called Basic Economic Order Quantity model

Assumptions

The following assumptions are considered for the sake of simplicity of model.

1) Demand (D) is assumed to be uniform.
2) The purchase price per unit (P) is independent of quantity ordered.
3) The ordering cost per order (Co) is fixed irrespective of size f lot.
4) The carrying cost/holding cost (Cc) is proportional to the quantity stored.
5) Shortage are not permitted i.e., as soon as the level of inventory reaches zero, the inventory is replenished.
6) The lead time (LT) for deliveries (i.e. the time of ordering till the material is delivered) is constant and is known with certainty.

QUALITY CONTROL

DEFINITION OF QUALITY:

- The meaning of "Quality" is closely allied to cost and customer needs. "Quality" may simply be defined as **fitness for purpose at lowest cost**.
  - ✓ The component is said to possess good quality, if it works well in the equipment for which it is meant.
- Quality is the 'totality of features and characteristics' both for the products and services that can satisfy both the explicit and implicit needs of the customers.
- "Quality" of any product is regarded as the degree to which it **fulfills the requirements of the customer.**
- "Quality" means **degree of perfection**. Quality is not absolute but it can only be judged or realized by comparing with standards. It can be determined by some characteristics namely, design, size, material, chemical composition, mechanical functioning, workmanship, finish and other properties.

MEANING OF CONTROL

Control is a system for measuring and **checking (inspecting)** a phenomenon. It suggests when to inspect, how often to inspect and how much to inspect. In addition, it incorporates a feedback mechanism which explores the causes of poor quality and takes corrective action.

Control differs from 'inspection', as it ascertains quality characteristics of an item, compares the same with prescribed quality standards and separates defective items from non-defective ones. Inspection, however, does not involve any mechanism to take corrective action.

MEANING OF QUALITY CONTROL

Quality Control is a systematic **control of various factors that affect the quality of the product**. The various factors include material, tools, machines, type of labour, working conditions, measuring instruments, etc.

Quality Control can be defined as the entire collection of activities which **ensures that the operation will produce the optimum Quality products at minimum cost.**

As per A.Y. Feigorbaum Total Quality Control is: "***An effective system for integrating the quality development, Quality maintenance and Quality improvement efforts of the various groups in an organization so as to enable production and services at the most economic levels which allows full customer satisfaction.***

In the words of Alford and Beatly, ***"Quality Control" may be broadly defined as that "Industrial management technique means of which products of uniform accepted quality are manufactured." Quality Control is concerned with making things right rather than discovering and rejecting those made wrong.***

FACTORS AFFECTING QUALITY

In addition to **men, materials, machines and manufacturing conditions** there are some other factors which affect the product quality. These are:

- Market Research i.e. in depth into demands of purchaser.
- Money i.e. capability to invest.
- Management i.e. Management policies for quality level.
- Production methods and product design.

Modern quality control begins with an evaluation of the customer's requirements and has a part to play at every stage from goods manufactured right through sales to a customer, who remains satisfied.

OBJECTIVES OF QUALITY CONTROL

- To decide about the standard of quality of a product that is easily acceptable to the customer and at the same time this standard should be economical to maintain.
- To take different measures to improve the standard of quality of product.
- To take various steps to solve any kind of deviations in the quality of the product during manufacturing.

FUNCTIONS OF QUALITY CONTROL DEPARTMENT

- Only the products of uniform and standard quality are allowed to be sold.
- To suggest method and ways to prevent the manufacturing difficulties.
- To reject the defective goods so that the products of poor quality may not reach to the customers.
- To find out the points where the control is breaking down and to investigate the causes of it.
- To correct the rejected goods, if it is possible. This procedure is known as rehabilitation of defective goods.

ADVANTAGES OF QUALITY CONTROL

- Quality of product is improved which in turn increases sales.
- Scrap rejection and rework are minimized thus reducing wastage. So the cost of manufacturing reduces.
- Good quality product improves reputation.
- Inspection cost reduces to a great extent.
- Uniformity in quality can be achieved.
- Improvement in manufacturer and consumer relations.

STATISTICAL QUALITY CONTROL (S.Q.C):

- **Statistics**: Statistics means data, a good amount of data to obtain reliable results. The science of statistics handles this data in order to draw certain conclusions.

- **S.Q.C:** This is a quality control system employing the statistical techniques to control quality by performing inspection, testing and analysis to conclude whether the quality of the product is as per the laid quality standards.

Using statistical techniques, S.Q.C. collects and analyses data in assessing and controlling product quality. The technique of S.Q.C. was though developed in 1924 by Dr.WalterA.Shewartan American scientist; it got recognition in industry only second world war. The technique permits a more fundamental control.

"Statistical quality control can be simply defined as an economic & effective system of maintaining & improving the quality of outputs throughout the whole operating process of specification, production & inspection based on continuous testing with random samples." -YA LUN CHOU

"Statistical quality control should be viewed as a kit of tools which may influence decisions to the functions of specification, production or inspection. -EUGENE L. GRANT

The fundamental basis of S.Q.C. is the theory of probability. According to the theories of probability, the dimensions of the components made on the same machine and in one batch (if measured accurately) vary from component to component. This may be due to inherent machine characteristics or the environmental conditions. The chance or condition that a sample will represent the entire batch or population is developed from the theory of probability.

Relying itself on the probability theory, S.Q.C. evaluates batch quality and controls the quality of processes and products. S.Q.C. uses three scientific techniques, namely;

- Sampling inspection
- Analysis of the data, and
- Control charting

ADVANTAGES OF S.Q.C

S.Q.C is one of the tool for scientific management, and has following main advantages over 100 percent inspection:

- **Reduction in cost:** Since only a fractional output is inspected, hence cost of inspection is greatly reduced.
- **Greater efficiency:** It requires lesser time and boredom as compared to the 100 percent inspection and hence the efficiency increases.
- **Easy to apply:** Once the S.Q.C plan is established, it is easy to apply even by man who does not have extensive specialized training.
- **Accurate prediction**: Specifications can easily be predicted for the future, which is not possible even with 100 percent inspection.
- **Can be used where inspection is needs destruction of items:** In cases where destruction of product is necessary for inspecting it, 100 percent inspection is not possible (which will spoil all the products), sampling inspection is resorted to.
- **Early detection of faults:** The moment a sample point falls outside the control limits, it is taken as a danger signal and necessary corrective measures are taken. Whereas in 100 percent inspection, unwanted variations in quality may be detected after large number of defective items have already been produced. Thus by using the control charts, we can know from graphic picture that how the production is proceeding and where corrective action is required and where it is not required.

PROCESS CONTROL

Under this the quality of the products is controlled while the products are in the process of production.

The process control is secured with the technique of control charts. Control charts are also used in the field of advertising, packing etc. They ensure that whether the products confirm to the specified quality standard or not.

Process Control consists of the systems and tools used to ensure that processes are well defined, performed correctly, and maintained so that the completed product conforms to established requirements. Process Control is an essential element of managing risk to ensure the safety and reliability of the Space Shuttle Program. It is recognized that strict process control practices will aid in the prevention of process escapes that may result in or contribute to in-flight anomalies, mishaps, incidents and non-conformances.

The five elements of a process are:

- People – skilled individuals who understand the importance of process and change control
- Methods/Instructions – documented techniques used to define and perform a process
- Equipment – tools, fixtures, facilities required to make products that meet requirements
- Material – both product and process materials used to manufacture and test products
- Environment – environmental conditions required to properly manufacture and test products

PROCESS CONTROL SYSTEMS FORMS

Process control systems can be characterized as one or more of the following forms:

- **Discrete** – Found in many manufacturing, motion and packaging applications. Robotic assembly, such as that found in automotive production, can be characterized as discrete process control. Most discrete manufacturing involves the production of discrete pieces of product, such as metal stamping.
- **Batch** – Some applications require that specific quantities of raw materials be combined in specific ways for particular durations to produce an intermediate or end result. One example is the production of adhesives and glues, which normally require the mixing of raw materials in a heated vessel for a period of time to form a quantity of end product. Other important examples are the production of food, beverages and medicine. Batch processes are generally used to produce a relatively low to intermediate quantity of product per year (a few pounds to millions of pounds).
- **Continuous** – Often, a physical system is represented through variables that are smooth and uninterrupted in time. The control of the water temperature in a heating jacket, for example, is an example of continuous process control. Some important continuous processes are the production of fuels, chemicals and plastics. Continuous processes in manufacturing are used to produce very large quantities of product per year (millions to billions of pounds).

STATISTICAL PROCESS CONTROL (SPC)

SPC is an effective method of monitoring a process through the use of control charts. Much of its power lies in the ability to monitor both process center and its variation about that center. By collecting data from samples at various points within the process, variations in the process that may affect the quality of the end product or service can be detected and corrected, thus reducing waste as well as the likelihood that problems will be passed on to the customer. It has an emphasis on early detection and prevention of problems.

CONTROL CHARTS

Since variations in manufacturing process are unavoidable, the control chart tells when to leave a process alone and thus prevent unnecessary frequent adjustments. Control charts are graphical representation and are based on statistical sampling theory, according to which an adequate sized random sample is drawn from each lot. Control charts detect variations in the processing and warn if there is any departure from the specified tolerance limits. These control charts immediately tell the undesired variations and help in detecting the cause and its removal.

In control charts, where both upper and lower values are specified for a quality characteristic, as soon as some products show variation outside the tolerances, a review of situation is taken and corrective step is immediately taken.

If analysis of the control chart indicates that the process is currently under control (i.e. is stable, with variation only coming from sources common to the process) then data from the process can be used to predict the future performance of the process. If the chart indicates that the process being monitored is not in control, analysis of the chart can help determine the sources of variation, which can then be eliminated to bring the process back into control. A control chart is a specific kind of run chart that allows significant change to be differentiated from the natural variability of the process.

The control chart can be seen as part of an objective and disciplined approach that enables correct decisions regarding control of the process, including whether or not to change process control parameters. Process parameters should never be adjusted for a process that is in control, as this will result in degraded process performance.

In other words, control chart is:

- A device which specifies the state of statistical control,
- A device for attaining statistical control,
- A device to judge whether statistical control has been attained or not.

PURPOSE AND ADVANTAGES:

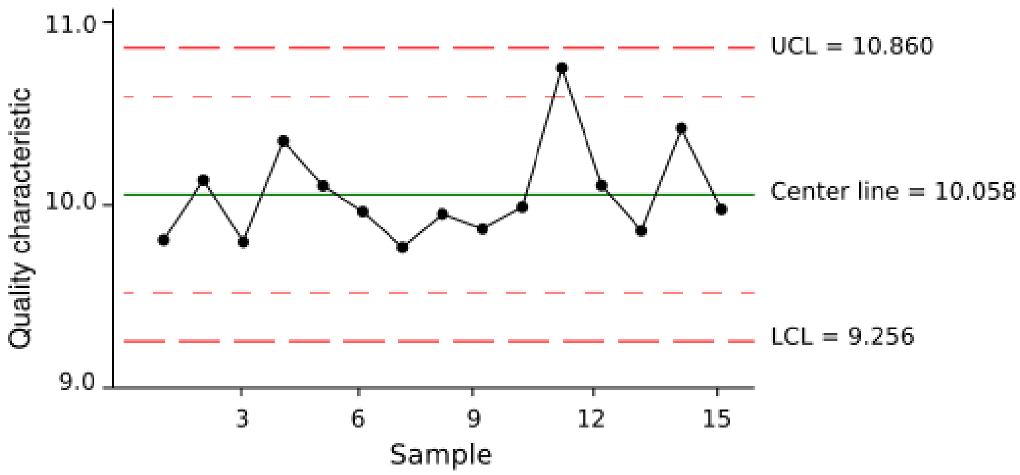
1. A control charts indicates whether the process is in control or out of control.
2. It determines process variability and detects unusual variations taking place in a process.
3. It ensures product quality level.
4. It warns in time, and if the process is rectified at that time, scrap or percentage rejection can be reduced.
5. It provides information about the selection of process and setting of tolerance limits.
6. Control charts build up the reputation of the organization through customer's satisfaction.

A control chart consists of:

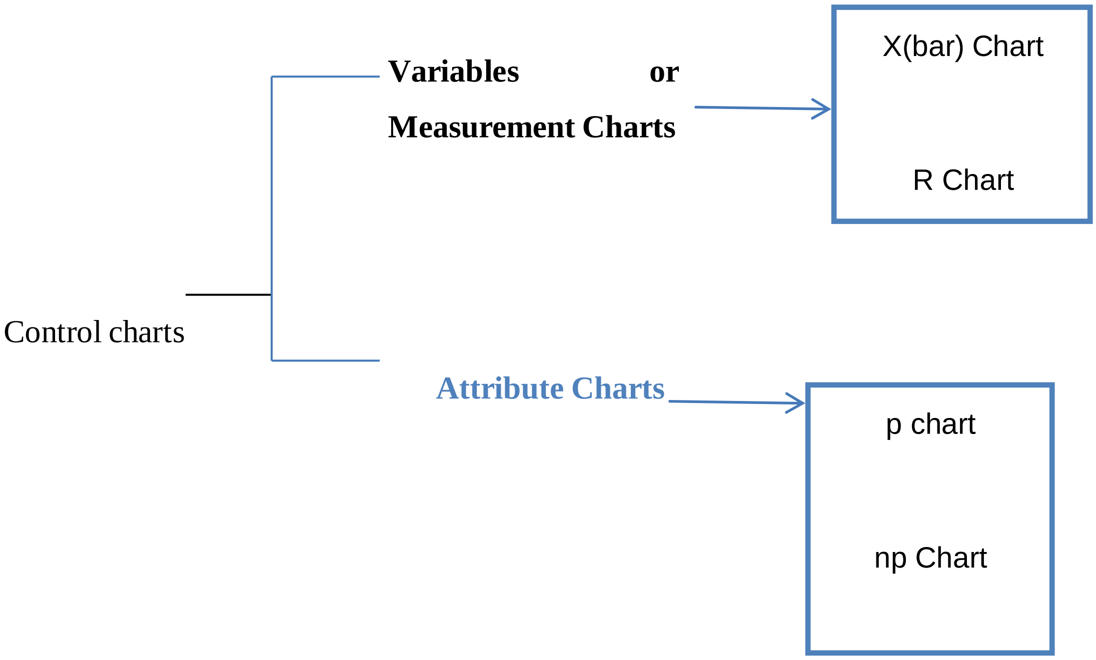
- Points representing a statistic (e.g., a mean, range, proportion) of measurements of a quality characteristic in samples taken from the process at different times [the data]
- The mean of this statistic using all the samples is calculated (e.g., the mean of the means, mean of the ranges, mean of the proportions)
- A center line is drawn at the value of the mean of the statistic
- The standard error (e.g., standard deviation/sqrt(n) for the mean) of the statistic is also calculated using all the samples
- Upper and lower control limits (sometimes called "natural process limits") that indicate the threshold at which the process output is considered statistically 'unlikely' are drawn typically at 3 standard errors from the center line

The chart may have other optional features, including:

- Upper and lower warning limits, drawn as separate lines, typically two standard errors above and below the center line
- Division into zones, with the addition of rules governing frequencies of observations in each zone
- Annotation with events of interest, as determined by the Quality Engineer in charge of the process's quality



TYPES OF CONTROL CHARTS



Control charts can be used to measure any characteristic of a product, such as the weight of a cereal box, the number of chocolates in a box, or the volume of bottled water. The different characteristics that can be measured by control charts can be divided into two groups: **variables** and **attributes.**

- A ***control chart for variables*** is used to monitor characteristics that can be measured and have a continuum of values, such as height, weight, or volume. A soft drink bottling operation is an example of a variable measure, since the amount of liquid in the bottles is measured and can take on a number of different values. Other examples are the weight of a bag of sugar, the temperature of a baking oven, or the diameter of plastic tubing.
- A ***control chart for attributes***, on the other hand, is used to monitor characteristics that have discrete values and can be counted. Often they can be evaluated with a simple yes or no decision. Examples include color, taste, or smell. The monitoring of attributes usually takes less time than that of variables because a variable needs to be measured (e.g., the bottle of soft drink contains 15.9 ounces of liquid). An attribute requires only a single decision, such as yes or no, good or bad, acceptable or unacceptable (e.g., the apple is good or rotten, the meat is good or stale, the shoes have a defect or do not have a defect, the lightbulb works or it does not work) or counting the number of defects (e.g., the number of broken cookies in the box, the number of dents in the car, the number of barnacles on the bottom of a boat).

CONTROL CHARTS FOR VARIABLES VS. CHARTS FOR ATTRIBUTES

A comparison of variable control charts and attribute control charts are given below:

- Variables charts involve the measurement of the job dimensions and an item is accepted or rejected if its dimensions are within or beyond the fixed tolerance limits; whereas as attribute chart only differentiates between a defective item and a non-defective item without going into the measurement of its dimensions.

- Variables charts are more detailed and contain more information as compared to attribute charts.
- Attribute charts, being based upon go and no go data (which is less effective as compared to measured values) require comparatively bigger sample size.
- Variables charts are relatively expensive because of the greater cost of collecting measured data.
- Attribute charts are the only way to control quality in those cases where measurement of quality characteristics is either not possible or it is very complicated and costly to do so—as in the case of checking colour or finish of a product, or determining whether a casting contains cracks or not. In such cases the answer is either yes or no.

ADVANTAGES OF ATTRIBUTE CONTROL CHARTS

Attribute control charts have the advantage of allowing for quick summaries of various aspects of the quality of a product, that is, the engineer may simply classify products as acceptable or unacceptable, based on various quality criteria. Thus, attribute charts sometimes bypass the need for expensive, precise devices and time-consuming measurement procedures. Also, this type of chart tends to be more easily understood by managers unfamiliar with quality control procedures; therefore, it may provide more persuasive (to management) evidence of quality problems.

ADVANTAGES OF VARIABLE CONTROL CHARTS

Variable control charts are more sensitive than attribute control charts. Therefore, variable control charts may alert us to quality problems before any actual "unacceptables" (as detected by the attribute chart) will occur. Montgomery (1985) calls the variable control charts *leading indicators* of trouble that will sound an alarm before the number of rejects (scrap) increases in the production process.

COMMONLY USED CHARTS

1. (X-Bar) and R charts, for process control.
2. P chart, for analysis of fraction defectives
3. C chart, for control of number of defects per unit.

- **Mean (x-Bar) ($\bar{x}$) Charts**

A mean control chart is often referred to as an ***x-bar chart.*** It is used to monitor changes in the mean of a process. To construct a mean chart we first need to construct the center line of the chart. To do this we take multiple samples and compute their means. Usually these samples are small, with about four or five observations. Each sample has its own mean. The center line of the chart is then computed as the mean of all sample means, where _ is the number of samples:

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:
   a. It tells when to leave the process alone and when to chase and go for the causes leading to variation;
   b. It secures information in establishing or modifying processes, specifications or inspection procedures;
   c. It controls the quality of incoming material.
7. X-Bar and R charts when used together form a powerful instrument for diagnosing quality problems.

Range (R) charts

These are another type of control chart for variables. Whereas x-bar charts measure shift in the central tendency of the process, range charts monitor the dispersion or variability of the process. The method for developing and using R-charts are the same as that for x-bar charts. The center line of the control chart is the average range, and the upper and lower control limits are computed. The R chart is used to monitor process variability when sample sizes are small (n<10), or to simplify the calculations made by process operators. This chart is called the R chart because the statistic being plotted is the sample range.

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 X-bar chart.

Plotting of $\bar{X}$ and R charts:

A number of samples of component coming out of the process are taken over a period of time. Each sample must be taken at random and the size of sample is generally kept as 5 but 10 to15 units can be taken for sensitive control charts. For each sample, the average value $\bar{X}$ of all the measurements and the range R are calculated. The grand average $\bar{\bar{X}}$ (equal to the average value of all the average $\bar{X}$) and $\bar{R}$ ($\bar{R}$ is equal to the average of all the ranges R) are found and from these we can calculate the control limits for the $\bar{X}$ and R charts. Therefore,

$$\bar{\bar{x}} = \frac{\bar{x}_1 + \bar{x}_2 + \cdots + \bar{x}_m}{m}$$

$$\bar{R} = \frac{R_1 + R_2 + \cdots + R_m}{m}$$

Variablcs Data ($\bar{x}$ and R Control Charts)

$\bar{x}$ Control Chart

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

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

CL = $\bar{\bar{x}}$

R Control Chart

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

LCL = $\bar{R}\, D_3$

CL = $\bar{R}$

Here the factors A_2, D_4 and D_3 depend on the number of units per sample. Larger the number, the close the limits. The value of the factors A_2, D_4 and D_3 can be obtained from S.Q.C tables. However for ready reference these are given below in tabular form:

n	A_2	D_3	D_4	d_2
2	1.880	0.000	3.267	1.128
3	1.023	0.000	2.574	1.693
4	0.729	0.000	2.282	2.059
5	0.577	0.000	2.114	2.326
6	0.483	0.000	2.004	2.534
7	0.419	0.076	1.924	2.704
8	0.373	0.136	1.864	2.847
9	0.337	0.184	1.816	2.970
10	0.308	0.223	1.777	3.078

Notation:

n or m= sample size

Example

Piston for automotive engine are produced by a forging process. We wish to establish statistical control of inside diameter of the ring manufactured by this process using *x* and *R* charts.

Twenty-five samples, each of size five, have been taken when we think the process is in control. The inside diameter measurement data from these samples are shown in table.

Sample Number	Observations					$\bar{x}_i$	R_i
1	74.030	74.002	74.019	73.992	74.008	74.010	0.038
2	73.995	73.992	74.001	74.011	74.004	74.001	0.019
3	73.988	74.024	74.021	74.005	74.002	74.008	0.036
4	74.002	73.996	73.993	74.015	74.009	74.003	0.022
5	73.992	74.007	74.015	73.989	74.014	74.003	0.026
6	74.009	73.994	73.997	73.985	73.993	73.996	0.024
7	73.995	74.006	73.994	74.000	74.005	74.000	0.012
8	73.985	74.003	73.993	74.015	73.988	73.997	0.030
9	74.008	73.995	74.009	74.005	74.004	74.004	0.014
10	73.998	74.000	73.990	74.007	73.995	73.998	0.017
11	73.994	73.998	73.994	73.995	73.990	73.994	0.008
12	74.004	74.000	74.007	74.000	73.996	74.001	0.011
13	73.983	74.002	73.998	73.997	74.012	73.998	0.029
14	74.006	73.967	73.994	74.000	73.984	73.990	0.039
15	74.012	74.014	73.998	73.999	74.007	74.006	0.016
16	74.000	73.984	74.005	73.998	73.996	73.997	0.021
17	73.994	74.012	73.986	74.005	74.007	74.001	0.026
18	74.006	74.010	74.018	74.003	74.000	74.007	0.018
19	73.984	74.002	74.003	74.005	73.997	73.998	0.021
20	74.000	74.010	74.013	74.020	74.003	74.009	0.020
21	73.982	74.001	74.015	74.005	73.996	74.000	0.033
22	74.004	73.999	73.990	74.006	74.009	74.002	0.019
23	74.010	73.989	73.990	74.009	74.014	74.002	0.025
24	74.015	74.008	73.993	74.000	74.010	74.005	0.022
25	73.982	73.984	73.995	74.017	74.013	73.998	0.035
						$\Sigma = 1850.028$	0.581
						$\bar{\bar{x}} = 74.001$	$\bar{R} = 0.023$

So,

$$\bar{\bar{X}} = 74.001$$

R = 0.023

From S.Q.C tables (Fig.3) for sample size 5

A_2=0.58, D_4=2.11 and D_3= 0

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

= 74.001+ 0.58(0.023)

= 74.01434

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

= 74.001- 0.58(0.023)

= 73.98766

UCL (R chart) =

= 2.11*0.023

= 0.04853

LCL (R chart) =

= 0*0.023

= 0

Now $\bar{X}$ and R charts are plotted on the plot as shown in Fig.1 and Fig.2

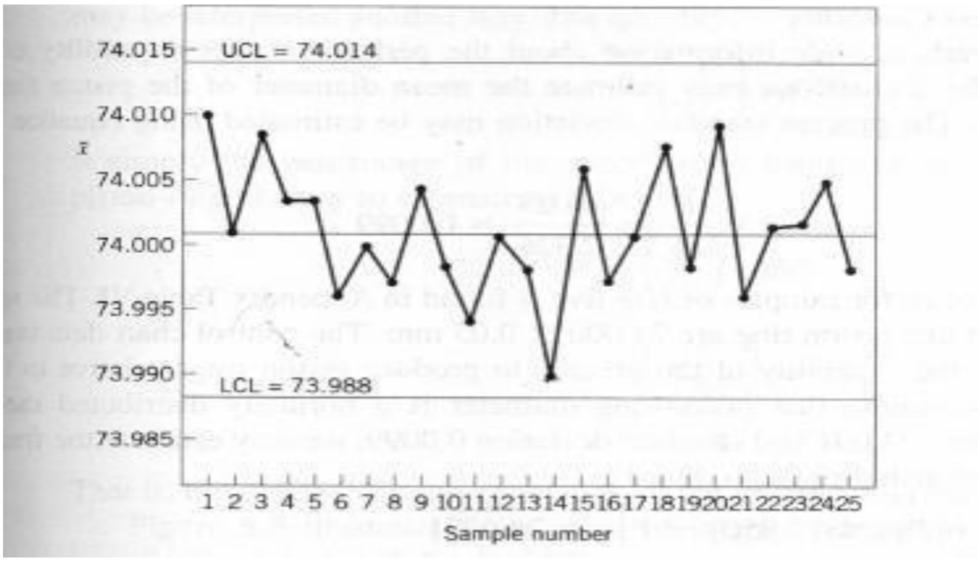


Fig.1: $\bar{X}$ Chart

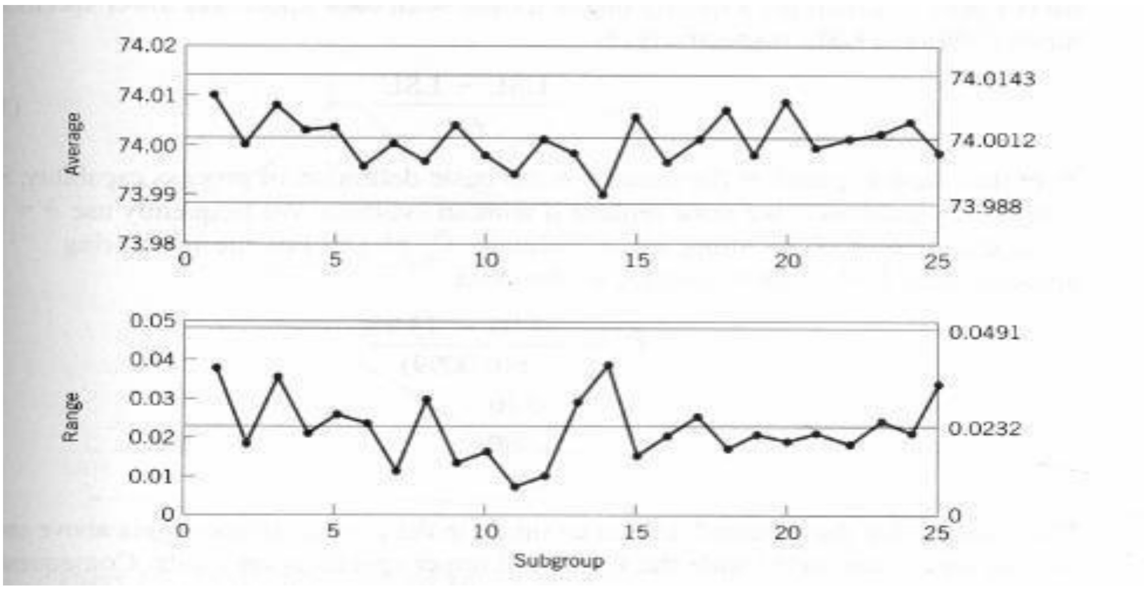


Fig.2: R Chart

Inference:

In the $\bar{X}$ chart, all of the time the plotted points representing average are well within the control limits but if some samples fall outside the control limits then it means something has probably gone wrong or is about to go wrong with the process and a check is needed to prevent the appearance of defective products.

Observations in Sample, n	Chart for Averages			Chart for Standard Deviations						Chart for Ranges						
	Factors for Control Limits			Factors for Center Line		Factors for Control Limits				Factors for Center Line		Factors for Control Limits				
	A	A_2	A_3	c_4	$1/c_4$	B_3	B_4	B_5	B_6	d_2	$1/d_2$	d_3	D_1	D_2	D_3	D_4
2	2.121	1.880	2.659	0.7979	1.2533	0	3.267	0	2.606	1.128	0.8865	0.853	0	3.686	0	3.267
3	1.732	1.023	1.954	0.8862	1.1284	0	2.568	0	2.276	1.693	0.5907	0.888	0	4.358	0	2.574
4	1.500	0.729	1.628	0.9213	1.0854	0	2.266	0	2.088	2.059	0.4857	0.880	0	4.698	0	2.282
5	1.342	0.577	1.427	0.9400	1.0638	0	2.089	0	1.964	2.326	0.4299	0.864	0	4.918	0	2.114
6	1.225	0.483	1.287	0.9515	1.0510	0.030	1.970	0.029	1.874	2.534	0.3946	0.848	0	5.078	0	2.004
7	1.134	0.419	1.182	0.9594	1.0423	0.118	1.882	0.113	1.806	2.704	0.3698	0.833	0.204	5.204	0.076	1.924
8	1.061	0.373	1.099	0.9650	1.0363	0.185	1.815	0.179	1.751	2.847	0.3512	0.820	0.388	5.306	0.136	1.864
9	1.000	0.337	1.032	0.9693	1.0317	0.239	1.761	0.232	1.707	2.970	0.3367	0.808	0.547	5.393	0.184	1.816
10	0.949	0.308	0.975	0.9727	1.0281	0.284	1.716	0.276	1.669	3.078	0.3249	0.797	0.687	5.469	0.223	1.777
11	0.905	0.285	0.927	0.9754	1.0252	0.321	1.679	0.313	1.637	3.173	0.3152	0.787	0.811	5.535	0.256	1.744
12	0.866	0.266	0.886	0.9776	1.0229	0.354	1.646	0.346	1.610	3.258	0.3069	0.778	0.922	5.594	0.283	1.717
13	0.832	0.249	0.850	0.9794	1.0210	0.382	1.618	0.374	1.585	3.336	0.2998	0.770	1.025	5.647	0.307	1.693
14	0.802	0.235	0.817	0.9810	1.0194	0.406	1.594	0.399	1.563	3.407	0.2935	0.763	1.118	5.696	0.328	1.672
15	0.775	0.223	0.789	0.9823	1.0180	0.428	1.572	0.421	1.544	3.472	0.2880	0.756	1.203	5.741	0.347	1.653
16	0.750	0.212	0.763	0.9835	1.0168	0.448	1.552	0.440	1.526	3.532	0.2831	0.750	1.282	5.782	0.363	1.637
17	0.728	0.203	0.739	0.9845	1.0157	0.466	1.534	0.458	1.511	3.588	0.2787	0.744	1.356	5.820	0.378	1.622
18	0.707	0.194	0.718	0.9854	1.0148	0.482	1.518	0.475	1.496	3.640	0.2747	0.739	1.424	5.856	0.391	1.608
19	0.688	0.187	0.698	0.9862	1.0140	0.497	1.503	0.490	1.483	3.689	0.2711	0.734	1.487	5.891	0.403	1.597
20	0.671	0.180	0.680	0.9869	1.0133	0.510	1.490	0.504	1.470	3.735	0.2677	0.729	1.549	5.921	0.415	1.585
21	0.655	0.173	0.663	0.9876	1.0126	0.523	1.477	0.516	1.459	3.778	0.2647	0.724	1.605	5.951	0.425	1.575
22	0.640	0.167	0.647	0.9882	1.0119	0.534	1.466	0.528	1.448	3.819	0.2618	0.720	1.659	5.979	0.434	1.566
23	0.626	0.162	0.633	0.9887	1.0114	0.545	1.455	0.539	1.438	3.858	0.2592	0.716	1.710	6.006	0.443	1.557
24	0.612	0.157	0.619	0.9892	1.0109	0.555	1.445	0.549	1.429	3.895	0.2567	0.712	1.759	6.031	0.451	1.548
25	0.600	0.153	0.606	0.9896	1.0105	0.565	1.435	0.559	1.420	3.931	0.2544	0.708	1.806	6.056	0.459	1.541

For $n > 25$.

$$A = \frac{3}{\sqrt{n}} \quad A_3 = \frac{3}{c_4\sqrt{n}} \quad c_4 \cong \frac{4(n-1)}{4n-3}$$

$$B_3 = 1 - \frac{3}{c_4\sqrt{2(n-1)}} \quad B_4 = 1 + \frac{3}{c_4\sqrt{2(n-1)}}$$

$$B_5 = c_4 - \frac{3}{\sqrt{2(n-1)}} \quad B_6 = c_4 + \frac{3}{\sqrt{2(n-1)}}$$

Fig.3

PROCESS OUT OF CONTROL

After computing the control limits, the next step is to determine whether the process is in statistical control or not. If not, it means there is an external cause that throws the process out of control. This cause must be traced or removed so that the process may return to operate under stable statistical conditions. The various reasons for the process being out of control may be:

1. Faulty tools
2. Sudden significant change in properties of new materials in a new consignment
3. Breakout of lubrication system
4. Faults in timing of speed mechanisms.

PROCESS IN CONTROL

If the process is found to be in statistical control, a comparison between the required specifications and the process capability may be carried out to determine whether the two are compatible.

Conclusions:

When the process is not in control then then the point fall outside the control limits on either $\bar{x}$ or R charts. It means assignable causes (human controlled causes) are present in the process. When all the points are inside the control limits even then we cannot definitely say that no assignable cause is present but it is not economical to trace the cause. No statistical test can be applied. Even in the best manufacturing process, certain errors may develop and that constitute the assignable causes but no statistical action can be taken.

CONTROL CHARTS FOR ATTRIBUTES

Control charts for attributes are used to measure quality characteristics that are counted rather than measured. Attributes are discrete in nature and entail simple yes-or-no decisions. For example, this could be the number of nonfunctioning lightbulbs, the proportion of broken eggs in a carton, the number of rotten apples, the number of scratches on a tile, or the number of complaints issued. Two of the most common types of control charts for attributes are p-charts and c-charts.

- **P-charts** are used to measure the proportion of items in a sample that are defective. Examples are the proportion of broken cookies in a batch and the proportion of cars produced with a misaligned fender. P-charts are appropriate when both the number of defectives measured and the size of the total sample can be counted. A proportion can then be computed and used as the statistic of measurement.

1. It can be a fraction defective chart.
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 alone.

Plotting of P-charts: By calculating, first, the fraction defective and then the control limits.

The process is said to be in control if fraction defective values fall within the control limits. In case the process is out of control an investigation to hunt for the cause becomes necessary.

The mean proportion defective ($\overline{p}$):

$$\overline{p} = \frac{\text{Total Number of Defectives}}{\text{Total Number Inspected}}$$

The standard deviation of p:

$$\sigma_{\overline{p}} = \sqrt{\frac{\overline{p}(1-\overline{p})}{n}}$$

where n = sample size.

Control Limits are:

$$UCL = \overline{p} + Z^{*}\sigma_{\overline{p}} \qquad LCL = \overline{p} - Z^{*}\sigma_{\overline{p}}$$

or

$$UCL = \overline{p} + Z^{*}\sqrt{\frac{\overline{p}(1-\overline{p})}{n}} \qquad LCL = \overline{p} - Z^{*}\sqrt{\frac{\overline{p}(1-\overline{p})}{n}}$$

Usually the Z value is equal to 3 (as was used in the X and R charts), since the variations within three standard deviations are considered as natural variations. However, the choice of the value of Z depends on the environment in which the chart is being used, and on managerial judgment.

- **C-charts** count the actual number of defects. For example, we can count the number of complaints from customers in a month, the number of bacteria on a petri dish, or the number of barnacles on the bottom of a boat. However, we cannot compute the proportion of complaints from customers, the proportion of bacteria on a petri dish, or the proportion of barnacles on the bottom of a boat.

Defective items vs individual defects

The literature differentiates between *defect* and *defective*, which is the same as differentiating between *nonconformity* and *nonconforming units*. This may sound like splitting hairs, but in the interest of clarity let's try to unravel this man-made mystery.

Consider a wafer with a number of chips on it. The wafer is referred to as an "item of a product". The chip may be referred to as "a specific point". There exist certain specifications for the wafers. When a particular wafer (e.g., the item of the product) does not meet at least one of the specifications, it is classified as a nonconforming item. Furthermore, each chip, (e.g., the specific point) at which a specification is not met becomes a defect or nonconformity.

So, a nonconforming or defective item contains at least one defect or nonconformity. It should be pointed out that a wafer can contain several defects but still be classified as conforming. For example, the defects may be located at noncritical positions on the wafer. If, on the other hand, the number of the so-called "unimportant" defects becomes alarmingly large, an investigation of the production of these wafers is warranted.

Control charts involving counts can be either for the *total number* of nonconformities (defects) for the sample of inspected units, or for the *average number* of defects per inspection unit.

Defect vs. Defective

- ‘Defect’ – a single nonconforming quality characteristic.
- ‘Defective’ – items having one or more defects.

C charts can be plotted by using the following formulas:

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

$$\bar{c} = \frac{\text{total number of defects}}{\text{total number of samples}}$$

THE PRIMARY DIFFERENCE BETWEEN USING A P-CHART AND A C-CHART IS ASFOLLOWS.

A P-chart is used when both the total sample size and the number of defects can be computed.

A C-chart is used when we can compute *only* the number of defects but cannot compute the proportion that is defective.

ACCEPTANCE SAMPLING

“Acceptance Sampling is concerned with the decision to accept a mass of manufactured items as conforming to standards of quality or to reject the mass as non-conforming to quality. The decision is reached through sampling.”

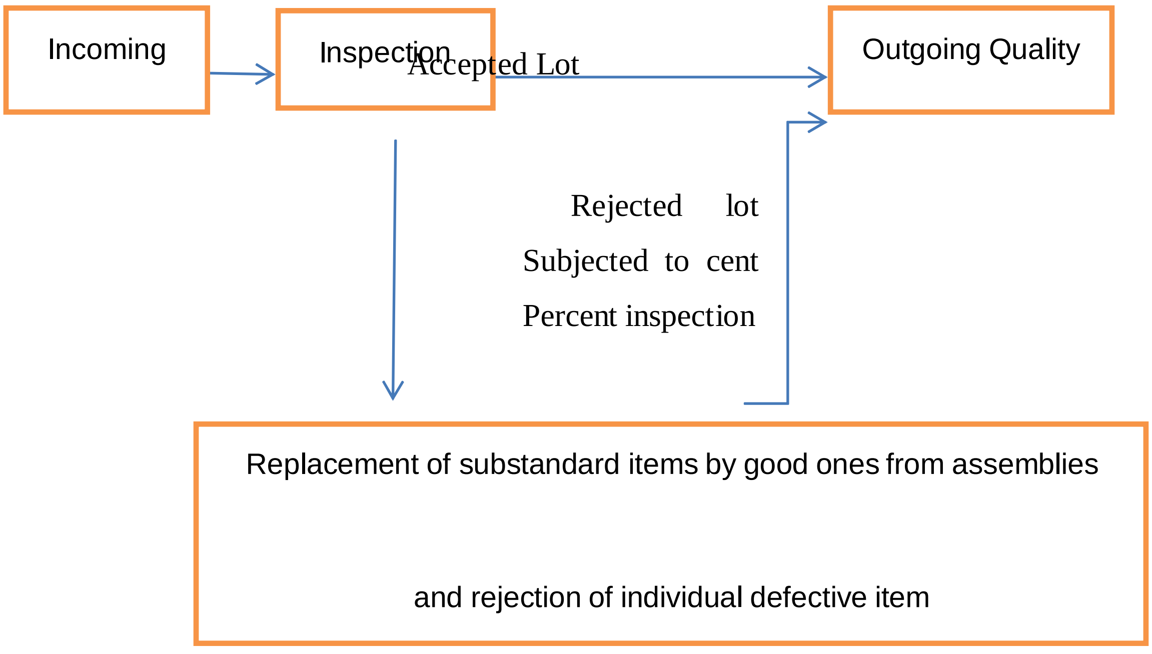
- SIMPSON AND KAFKA

Acceptance sampling uses statistical sampling to determine whether to accept or reject a production lot of material. It has been a common quality control technique used in industry and particularly the military for contracts and procurement. It is usually done as products leave the factory, or in some cases even within the factory. Most often a producer supplies a consumer a number of items and decision to accept or reject the lot is made by determining the number of defective items in a sample from the lot. The lot is accepted if the number of defects falls below where the acceptance number or otherwise the lot is rejected

For the purpose of acceptance, inspection is carried out at many stages in the process of manufacturing. These stages may be: inspection of incoming materials and parts, process inspection at various points in the manufacturing operations, final inspection by a manufacturer of his own product and finally inspection of the finished product by the purchaser.

Inspection for acceptance is generally carried out on a sampling basis. The use of sampling inspection to decide whether or not to accept the lot is known as Acceptance Sampling. A sample from the inspection lot is inspected, and if the number of defective items is more than the stated number known as acceptance number, the whole lot is rejected.

The purpose of Acceptance Sampling is, therefore a method used to make a decision as to whether to accept or to reject lots based on inspection of sample(s).



Acceptance sampling is the process of randomly inspecting a sample of goods and deciding whether to accept the entire lot based on the results. Acceptance sampling determines whether a batch of goods should be accepted or rejected.

Acceptance Sampling is very widely used in practice due to the following merits:

1. Acceptance Sampling is much less expensive than 100 percent inspection.
2. It is general experience that 100 percent inspection removes only 82 to 95 percent of defective material. Very good 100 percent inspection may remove at the most 99 percent of the defectives, but still cannot reach the level of 100 percent. Due to the effect of inspection fatigue involved in 100 percent inspection, a good sampling plan may actually give better results than that achieved by 100 percent inspection.
3. Because of its economy, it is possible to carry out sample inspection at various stages.

Inspection provides a means for monitoring quality. For example, inspection may be performed on incoming raw material, to decide whether to keep it or return it to the vendor if the quality level is not what was agreed on. Similarly, inspection can also be done on finished goods before deciding whether to make the shipment to the customer or not. However, performing 100% inspection is generally not economical or practical, therefore, sampling is used instead.

Acceptance Sampling is therefore a method used to make a decision as to whether to accept or to reject lots based on inspection of sample(s). The objective is not to control or estimate the quality of lots, only to pass a judgment on lots.

Using sampling rather than 100% inspection of the lots brings some risks both to the consumer and to the producer, which are called the consumer's and the producer's risks, respectively. We encounter making decisions on sampling in our daily affairs.

AN INTRODUCTION TO TOTAL QUALITY MANAGEMENT (TQM)

At its core, Total Quality Management (TQM) is a management approach to **long-term success through customer satisfaction.**

In a TQM effort, all members of an organization participate in improving processes, products, services and the culture in which they work.

Total Quality Management (TQM) is an approach that seeks to improve quality and performance which will meet or exceed customer expectations. This can be achieved by integrating all quality-related functions and processes throughout the company. TQM looks at the overall quality measures used by a company including managing quality design and development, quality control and maintenance, quality improvement, and quality assurance. TQM takes into account all quality measures taken at all levels and involving all company employees.

TQM can be defined as the management of initiatives and procedures that are aimed at achieving the delivery of quality products and services.

PRINCIPLES OF TQM

A number of key principles can be identified in defining TQM, including:

- Executive Management – Top management should act as the main driver for TQM and create an environment that ensures its success.
- Training – Employees should receive regular training on the methods and concepts of quality.
- Customer Focus – Improvements in quality should improve customer satisfaction.
- Decision Making – Quality decisions should be made based on measurements.
- Methodology and Tools – Use of appropriate methodology and tools ensures that non-conformances are identified, measured and responded to consistently.
- Continuous Improvement – Companies should continuously work towards improving manufacturing and quality procedures.
- Company Culture – The culture of the company should aim at developing employees ability to work together to improve quality.
- Employee Involvement – Employees should be encouraged to be pro-active in identifying and addressing quality related problems.

A core concept in implementing TQM is Deming’s 14 points, a set of management practices to help companies increase their quality and productivity:

1. Create constancy of purpose for improving products and services.
2. Adopt the new philosophy.
3. Cease dependence on inspection to achieve quality.
4. End the practice of awarding business on price alone; instead, minimize total cost by working with a single supplier.
5. Improve constantly and forever every process for planning, production and service.
6. Institute training on the job.
7. Adopt and institute leadership.
8. Drive out fear.
9. Break down barriers between staff areas.
10. Eliminate slogans, exhortations and targets for the workforce.
11. Eliminate numerical quotas for the workforce and numerical goals for management.
12. Remove barriers that rob people of pride of workmanship, and eliminate the annual rating or merit system.
13. Institute a vigorous program of education and self-improvement for everyone.
14. Put everybody in the company to work accomplishing the transformation.

TEAM APPROACH

TQM stresses that quality is an organizational effort. To facilitate the solving of quality problems, it places great emphasis on teamwork. The use of teams is based on the old adage that “two heads are better than one.”Using techniques such as brainstorming, discussion, and quality control tools, teams work regularly to correct problems. The contributions of teams are considered vital to the success of the company. For this reason, companies set aside time in the workday for team meetings.

Teams vary in their degree of structure and formality, and different types of teams solve different types of problems. One of the most common types of teams is the **quality circle,** a team of volunteer production employees and their supervisors whose purpose is to solve quality problems. The circle is usually composed of eight to ten members, and decisions are made through group consensus. The teams usually meet weekly during work hours in a place designated for this purpose. They follow a preset process for analyzing and solving quality problems. Open discussion is promoted, and criticism is not allowed. Although the functioning of quality circles is friendly and casual, it is serious business. Quality circles are not mere “gab sessions.” Rather, they do important work for the company and have been very successful in many firms.

THE SEVEN TOOLS OF QUALITY CONTROL

1. Cause and effect analysis
2. Flowcharts
3. Checklists
4. Control techniques including Statistical quality control and control charts.
5. Scatter diagram
6. Pareto analysis which means identification of vital few from many at a glance. This is used for fixing the priorities in tackling a problem.
7. Histograms.

Cause-and-Effect Diagrams

Cause-and-effect diagrams are charts that identify potential causes for particular quality problems. They are often called fishbone diagrams because they look like the bones of a fish. A general cause-and-effect diagram is shown in Figure 5-8. The “head” of the fish is the quality problem, such as damaged zippers on a garment or broken valves on a tire. The diagram is drawn so that the “spine” of the fish connects the “head” to the possible cause of the problem. These causes could be related to the machines, workers, measurement, suppliers, materials, and many other aspects of the production process. Each of these possible causes can then have smaller “bones” that address specific issues that relate to each cause. For example, a problem with machines could be due to a need for adjustment, old equipment, or tooling problems. Similarly, a problem with workers could be related to lack of training, poor supervision, or fatigue.

Cause-and-effect diagrams are problem-solving tools commonly used by quality control teams. Specific causes of problems can be explored through brainstorming.

The development of a cause-and-effect diagram requires the team to think through all the possible causes of poor quality.

Flowcharts

A flowchart is a schematic diagram of the sequence of steps involved in an operation or process. It provides a visual tool that is easy to use and understand.

By seeing the steps involved in an operation or process, everyone develops a clear picture of how the operation works and where problems could arise.

Checklists

A checklist is a list of common defects and the number of observed occurrences of these defects. It is a simple yet effective fact-finding tool that allows the worker to collect specific information regarding the defects observed. The checklist in Figure 5-7 shows four defects and the number of times they have been observed.

It is clear that the biggest problem is ripped material. This means that the plant needs to focus on this specific problem—for example, by going to the source of supply or seeing whether the material rips during a particular production process.

A checklist can also be used to focus on other dimensions, such as location or time.

For example, if a defect is being observed frequently, a checklist can be developed that measures the number of occurrences per shift, per machine, or per operator. In this fashion we can isolate the location of the particular defect and then focus on correcting the problem.

Control Charts

Control charts are a very important quality control tool. We will study the use of control charts at great length in the next chapter. These charts are used to evaluate whether a process is operating within expectations relative to some measured value such as weight, width, or volume. For example, we could measure the weight of a sack of flour, the width of a tire, or the volume of a bottle of soft drink.When the production process is operating within expectations, we say that it is "in control."

To evaluate whether or not a process is in control, we regularly measure the variable of interest and plot it on a control chart. The chart has a line down the center representing the average value of the variable we are measuring. Above and below the center line are two lines, called the upper control limit (UCL) and the lower control limit (LCL). As long as the observed values fall within the upper and lower control limits, the process is in control and there is no problem with quality. When a measured observation falls outside of these limits, there is a problem.

Scatter Diagrams

Scatter diagrams are graphs that show how two variables are related to one another. They are particularly useful in detecting the amount of correlation, or the degree of linear relationship, between two variables. For example, increased production speed and number of defects could be correlated positively; as production speed increases, so does the number of defects. Two variables could also be correlated negatively, so that an increase in one of the variables is associated with a decrease in the other. For example, increased worker training might be associated with a decrease in the number of defects observed.

The greater the degree of correlation, the more linear are the observations in the scatter diagram. On the other hand, the more scattered the observations in the diagram, the less correlation exists between the variables. Of course, other types of relationships can also be observed on a scatter diagram, such as an inverted. This may be the case when one is observing the relationship between two variables such as oven temperature and number of defects, since temperatures below and above the ideal could lead to defects.

Pareto Analysis

Pareto analysis is a technique used to identify quality problems based on their degree of importance. The logic behind Pareto analysis is that only a few quality problems are important, whereas many others are not critical. The technique was named after Vilfredo Pareto, a nineteenth-century Italian economist who determined that only a small percentage of people controlled most of the wealth. This concept has often been called the 80–20 rule and has been extended too many areas. In quality management the logic behind Pareto's principle is that most quality problems are a result of only a few causes. The trick is to identify these causes.

One way to use Pareto analysis is to develop a chart that ranks the causes of poor quality in decreasing order based on the percentage of defects each has caused. For example, a tally can be made of the number of defects that result from different causes, such as operator error, defective parts, or inaccurate machine calibrations. Percentages of defects can be computed from the tally and placed in a chart like those shown in Figure 5-7.We generally tends to find that a few causes account for most of the defects.

Histograms

A **histogram** is a chart that shows the frequency distribution of observed values of a variable. We can see from the plot what type of distribution a particular variable displays, such as whether it has a normal distribution and whether the distribution is symmetrical.

In the food service industry the use of quality control tools is important in identifying quality problems. Grocery store chains, such as Kroger and Meijer, must record and monitor the quality of incoming produce, such as tomatoes and lettuce. Quality tools can be used to evaluate the acceptability of product quality and to monitor product quality from individual suppliers. They can also be used to evaluate causes of quality problems, such as long transit time or poor refrigeration.
Similarly, restaurants use quality control tools to evaluate and monitor the quality of delivered goods, such as meats, produce, or baked goods.

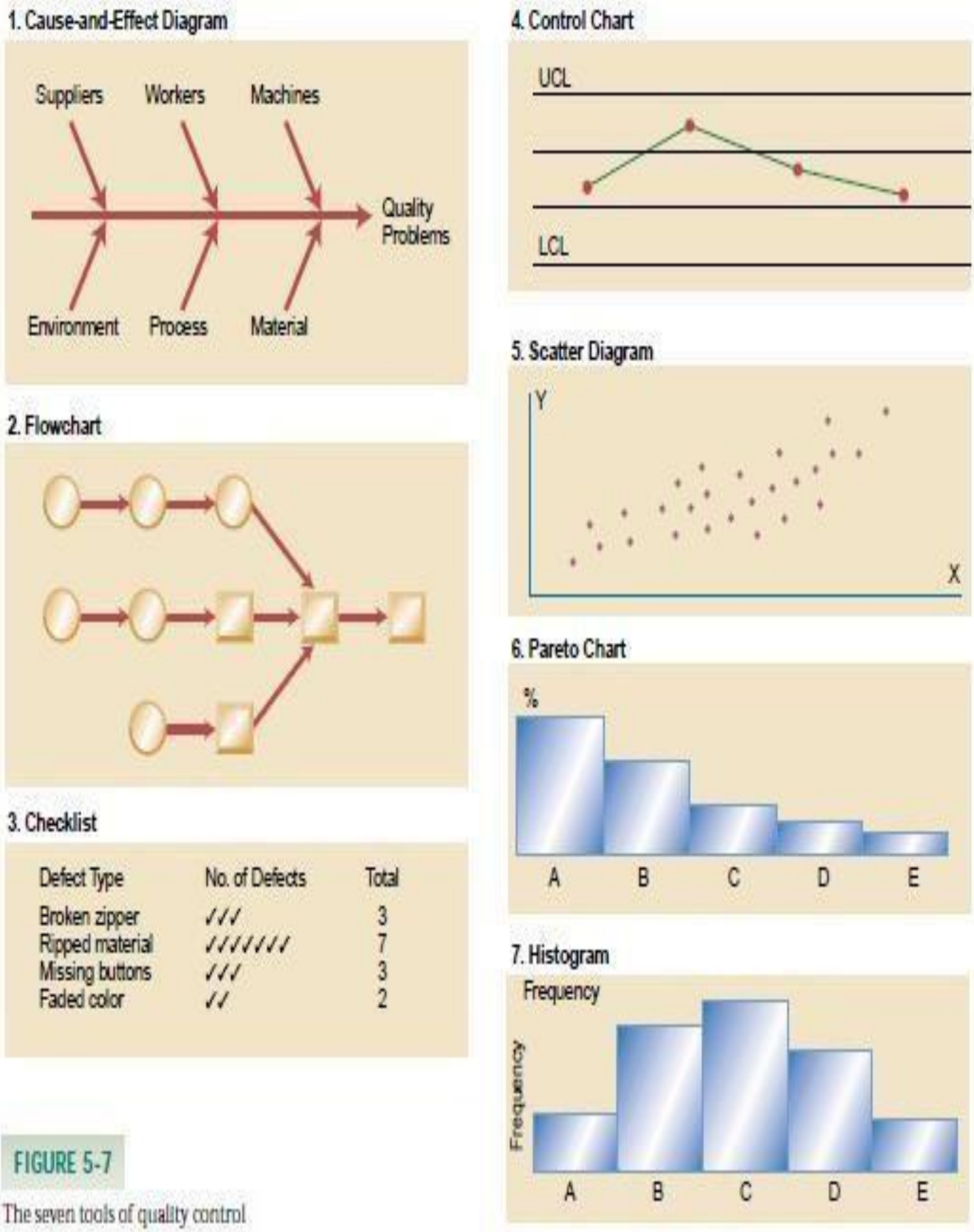


FIGURE 5-7

The seven tools of quality control

Techniques of TQM

ISO 9000 Standards

Increases in international trade during the 1980s created a need for the development of universal standards of quality. Universal standards were seen as necessary in order for companies to be able to objectively document their quality practices around the world. Then in 1987 the International Organization for Standardization (ISO) published its first set of standards for quality management called ISO 9000. The International

Organization for Standardization (ISO) is an international organization whose purpose is to establish agreement on international quality standards. It currently has members from 91 countries, including the United States. To develop and promote international quality standards, ISO 9000 has been created. ISO 9000 consists of a set of standards and a certification process for companies. By receiving ISO 9000 certification, companies demonstrate that they have met the standards specified by the ISO.

The standards are applicable to all types of companies and have gained global acceptance. In many industries ISO certification has become a requirement for doing business. Also, ISO 9000 standards have been adopted by the European Community as a standard for companies doing business in Europe.

In December 2000 the first major changes to ISO 9000 were made, introducing the following three new standards:

- **ISO 9000:2000**–Quality Management Systems–Fundamentals and Standards: Provides the terminology and definitions used in the standards. It is the starting point for understanding the system of standards.
- **ISO 9001:2000**–Quality Management Systems–Requirements: This is the standard used for the certification of a firm's quality management system. It is used to demonstrate the conformity of quality management systems to meet customer requirements.
- **ISO 9004:2000**–Quality Management Systems–Guidelines for Performance: Provides guidelines for establishing a quality management system. It focuses not only on meeting customer requirements but also on improving performance.

These three standards are the most widely used and apply to the majority of companies.

However, ten more published standards and guidelines exist as part of the ISO 9000 family of standards.

To receive ISO certification, a company must provide extensive documentation of its quality processes. This includes methods used to monitor quality, methods and frequency of worker training, job descriptions, inspection programs, and statistical process-control tools used. High-quality documentation of all processes is critical.

The company is then audited by an ISO 9000 registrar who visits the facility to make sure the company has a well-documented quality management system and that the process meets the standards. If the registrar finds that all is in order, certification is received.

Once a company is certified, it is registered in an ISO directory that lists certified companies. The entire process can take 18 to 24 months and can cost anywhere from $10,000 to $30,000. Companies have to be recertified by ISO every three years.

One of the shortcomings of ISO certification is that it focuses only on the process used and conformance to specifications. In contrast to the Baldrige criteria, ISO certification does not address questions about the product itself and whether it meets customer and market requirements. Today there are over 40,000 companies that are ISO certified. In fact, certification has become a requirement for conducting business in many industries.

ISO 14000 Standards

The need for standardization of quality created an impetus for the development of other standards. In 1996 the International Standards Organization introduced standards for evaluating a company's environmental responsibility. These standards, termed ISO 14000, focus on three major areas:

- Management systems standards measure systems development and integration of environmental responsibility into the overall business.
- Operations standards include the measurement of consumption of natural resources and energy.
- Environmental systems standards measure emissions, effluents, and other waste systems.

With greater interest in green manufacturing and more awareness of environmental concerns, ISO 14000 may become an important set of standards for promoting environmental responsibility.

Benchmarking

Benchmarking is the process of comparing one's business processes and performance metrics to industry bests or best practices from other industries. Dimensions typically measured are quality, time and cost. In the process of best practice benchmarking, management identifies the best firms in their industry, or in another industry where similar processes exist, and compares the results and processes of those studied (the "targets") to one's own results and processes. In this way, they learn how well the targets perform and, more importantly, the business processes that explain why these firms are successful.

Benchmarking is used to measure performance using a specific indicator (cost per unit of measure, productivity per unit of measure, cycle time of x per unit of measure or defects per unit of measure) resulting in a metric of performance that is then compared to others

Also referred to as "best practice benchmarking" or "process benchmarking", this process is used in management and particularly strategic management, in which organizations evaluate various aspects of their processes in relation to best practice companies' processes, usually within a peer group defined for the purposes of comparison. This then allows organizations to develop plans on how to make improvements or adapt specific best practices, usually with the aim of increasing some aspect of performance. Benchmarking may be a one-off event, but is often treated as a continuous process in which organizations continually seek to improve their practices.

Six Sigma

Six Sigma is a set of tools and strategies for process improvement originally developed by Motorola in 1985. Six Sigma became well known after Jack Welch made it a central focus of his business strategy at General Electric in 1995, and today it is used in different sectors of industry.

Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in manufacturing and business processes. It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people within the organization ("Champions", "Black Belts", "Green Belts", "Orange Belts", etc.) who are experts in these very complex methods.

Each Six Sigma project carried out within an organization follows a defined sequence of steps and has quantified value targets, for example; process cycle time reduction, customer satisfaction, reduction in pollution, cost reduction and/or profit increase. The term *Six Sigma* originated from terminology associated with **manufacturing**, specifically terms associated with statistical modeling of manufacturing processes. The maturity of a manufacturing process can be described by a *sigma* rating indicating its yield or the percentage of defect-free products it creates.

A six sigma process is one in which 99.99966% of the products manufactured are statistically expected to be free of defects (3.4 defects per million), although, as discussed below, this defect level corresponds to only a 4.5 sigma level. Motorola set a goal of "six sigma" for all of its manufacturing operations, and this goal became a byword for the management and engineering practices used to achieve it.

Methods

Six Sigma projects follow two project methodologies inspired by Deming's Plan-Do-Check-Act Cycle. These methodologies, composed of five phases each, bear the acronyms DMAIC and DMADV.[11]

- DMAIC is used for projects aimed at improving an existing business process.
- DMADV is used for projects aimed at creating new product or process designs.

DMAIC

The DMAIC project methodology has five phases:

- ***D**efine* the problem, the voice of the customer, and the project goals, specifically.
- ***M**easure* key aspects of the current process and collect relevant data.
- ***A**nalyze* the data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. Seek out root cause of the defect under investigation.

- ***I**mprove* or optimize the current process based upon data analysis using techniques such as design of experiments, poka yoke or mistake proofing, and standard work to create a new, future state process. Set up pilot runs to establish process capability.
- ***C**ontrol* the future state process to ensure that any deviations from target are corrected before they result in defects. Implement control systems such as statistical process control, production boards, visual workplaces, and continuously monitor the process.