UNIT-4

STATISTICAL QUALITY CONTROL

SYLLABUS:

STATISTICAL QUALITY CONTROL: Quality control, its importance, SQC, attribute sampling inspection with single and double sampling, Control charts – *X* and R – charts *X* AND *S* charts and their applications, numerical examples.

TOTAL QUALITY MANAGEMENT: Zero defect concept, Quality circles, Implementation, applications, ISO quality systems. Six Sigma - Definition, Basic concepts.

INTRODUCTION

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

DEFINITION

Statistical quality control refers to the use of statistical methods in the monitoring and maintaining of the quality of products and services.

The process of applying statistical principals to solve the problem of controlling the quality control of a product or service is called statistical quality control.

MEANING AND IMPORTANCE:

Present era is the 'Era of Quality'. In this age of cutthroat competition and large scale production, only that manufacturer can survive who supplies better quality goods and renders service to-the consumers. In fact quality control has become major consideration before establishing an industrial undertaking. Proper quality control ensures most effective utilisation of available resources and reduction in cost of production.

The word quality control comprises of two words viz., quality and control. It would be appropriate to explain these two words separately to understand clearly the meaning of quality control.

According to Dr. W.K. Spriegel "The quality of a product may be defined as the sum of a number of related characteristics such as shape, dimension, composition, strength, workmanship, adjustment, finish and colour".

In the words of John D. McIIellan, "Quality is the degree to which a product conforms to specifications and workmanship standards".

It is clear from these definitions that quality refers to various characteristics of a product and their excellence. Quality is a relative term and is never absolute depending upon the use of the product and circumstances under which it is used.

SOME OF THE IMPORTANT DEFINITIONS OF QUALITY CONTROL ARE ENUMERATED AS UNDER:

"Quality control may be defined as that industrial management technique or group of techniques by means of which products of uniform acceptable quality are manufactured. It is indeed the mechanism by which products are made to measure up to specifications determined from customer's demand and transformed into sales, engineering and manufacturing requirements. It is concerned with making things right rather than the discovering and rejecting those made wrong". By — **Alford and Beatty**

"Quality control means the recognition and removal of identifiable causes and defects, and variables from the set standards". By — **J.A. Shubin.**

"Quality control is used to connote all those activities which are directed for defining, controlling and maintaining quality". By — **K.G. Lockyer.**

"Quality control is systematic control by management of the variables in the manufacturing process that affect goodness of the end-product." By — **H.N. Broom.**

"Quality control is systematic control of these variables in the manufacturing process which affect the excellence of the end product. These variables result from the application of materials, men, machines and manufacturing condition. The production system possesses those inputs to produce desirable outputs.

Only when these variables in the inputs are regulated to the extent that they do not deviate unnecessarily from the excellence of the manufacturing process as reflected in the quality of the finished product, can the control of quality be said to exist. " By — **Bethel**, **At water and Stackman**

"Quality control includes techniques and systems for the achievement of the required quality in the articles produced and for the elimination of sub-standard goods." By — **Tome, Simen and HcGill.**

"Quality control is a system of inspection, analysis and action applied to a manufacturing process so that, by inspecting a small portion of the product currently produced, an analysis of its quality can be made to determine what action is required on the operation in order to achieve and maintain the desired level of quality." By — **Joseph Manueb.**

"Quality control is a technique of scientific management which has the object of improving industrial efficiency by concentrating on better standards of quality and on controls to ensure that these standards are always maintained. It is not intended to show what is wrong with current technology, but rather to establish what can be achieved with existing methods when they are operated correctly." By — **D.J. Desmond.**

From the above mentioned definitions, it is clear that quality control is concerned with controlling the negative variables which affect the ultimate quality of a product and in a broader sense it is concerned with the performance of those activities leading to fulfilment the company's objectives.

IMPORTANCE OR BENEFITS OF QUALITY CONTROL

Some of the importance or benefits of quality control are:

1. Encourages quality consciousness.
2. Satisfaction of consumers.
3. Reduction in production cost.
4. Most effective utilisation of resources.
5. Reduction in inspection costs.
6. Increased goodwill.
7. Higher morale of employees.
8. Improved employer-employee relations.
9. Improved techniques and methods of production.
10. Effective advertisement.
11. Facilitates price fixation.
12. Increased sales.

1. **Encourages quality consciousness:** The most important advantage derived by introducing quality control is that it develops and encourages quality consciousness among the workers in the factory which is greatly helpful in achieving desired level of quality in the product.
2. **Satisfaction of consumers:** Consumers are greatly benefited as they get better quality products on account of quality control. It gives them satisfaction.
3. **Reduction in production cost:** By undertaking effective inspection and control over production processes and operations, production costs are considerably reduced. Quality control further checks the production of inferior products and wastages thereby bringing down the cost of production considerably.
4. **Most effective utilisation of resources:** Quality control ensures maximum utilisation of available resources thereby minimising wastage and inefficiency of every kind.
5. **Reduction in inspection costs:** Quality control brings about economies in inspection and considerably reduces cost of inspection.
6. **Increased goodwill:** By producing better quality products and satisfying customer's needs, quality control raises the goodwill of the concern in the minds of people. A reputed concern can easily raise finances from the market.

7. **Higher morale of employees:** An effective system of quality control is greatly helpful in increasing the morale of employees, and they feel that they are working in the concern producing better and higher quality products.
8. **Improved employer-employee relations:** Quality control develops to better industrial atmosphere by increasing morale of employees which ensures cordial employer-employee relations leading to better understanding and closeness between them.
9. **Improved techniques and methods of production:** By supplying technical and engineering data for the product and manufacturing processes, improved methods and designs of production are ensured by quality control.
10. **Effective advertisement:** Organisations producing quality products have effective advertisement. They win the public confidence by supplying those better quality products.
11. **Facilitates price fixation:** By introducing quality control measures, uniform products of same quality are produced. This greatly facilitates the problem of price fixation. One price of standard products becomes prevalent in the market.
12. **Increased sales:** Quality control ensures production of quality products which is immensely helpful in attracting more customers for the product thereby increasing sales. It is greatly helpful in maintaining existing demand and creating new demand for the product. It has been rightly pointed out that quality control is a powerful instrument with the help of which markets both at home and abroad can be expanded.

OBJECTIVES OF QUALITY CONTROL:

Following are the important objectives of quality control:

1. To establish the desired quality standards which are acceptable to the customers?
2. To discover flaws or variations in the raw materials and the manufacturing processes in order to ensure smooth and uninterrupted production.
3. To evaluate the methods and processes of production and suggest further improvements in their functioning.
4. To study and determine the extent of quality deviation in a product during the manufacturing process.
5. To analyse in detail the causes responsible for such deviation.
6. To undertake such steps which are helpful in achieving the desired quality of the product.

METHODS OR TOOLS OF QUALITY CONTROL:

Any variations in the quality of a product, i.e., standards set are mainly caused by variations in raw material, men, machines, methods, and procedures of procedures of production and inspection. In order to produce the

quality products, these variations need to be checked and controlled. There are mainly two methods of quality control.

These are:

1. Inspection:
2. Statistical Quality Control:

1. INSPECTION:

Inspection, in fact, is the common method used for quality control purposes not only in production but also in services.

As regards inspection in production, there are three important aspects involved in it:

(i) Product Inspection: As the name itself suggests, the product inspection relates to the final product sent into the market. The main purpose of product inspection is to ensure that the products sent into the market comply with the set standard for quality. In other words, it is to ensure that the product ready for sale is perfect and free of defects.

(ii) Process Inspection: Process inspection proceeds to product inspection. It is aimed at ensuring that the raw material and machines and equipment's used in the production process are of prescribed quality and mark.

Process inspection benefits the unit in two ways:

(1) It ensures the manufacturing of a quality product.

(2) It saves wastages of material by preventing process bottlenecks.

(iii) Inspection Analysis:

This is a method based on the analyses of inspections made. The conclusions derived from the inspection analyses help the entrepreneur locate the exact points in manufacturing process where faults lie. In other words, it enables the entrepreneur to identify the points at which deviations from standard set start. Quality control through Inspection Method is shown in the following Figure 1.

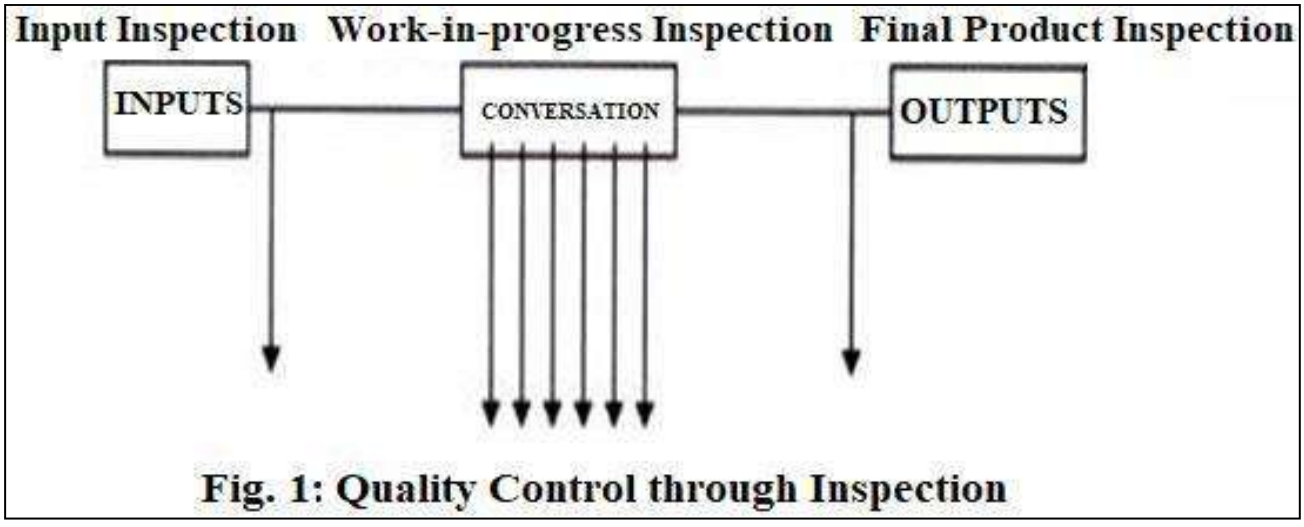


Fig. 1: Quality Control through Inspection

2. STATISTICAL QUALITY CONTROL:

It is an advanced method or technique used to control the quality of a product. This method is based on statistical techniques to determine and control the quality. Sampling, probability, and other statistical inferences are used in this method for controlling the quality of a product. It is widely used in process control in continuous process industries and in industries producing goods on a mass scale.

PRINCIPLES OF (STATISTICAL) QUALITY CONTROL:

The principles that govern the control of quality in manufacturing are:

1. Control of quality increases output of saleable goods, decreases costs of production and distribution, and makes economic mass production possible.
2. The quality of manufactured goods is variable with an upward trend under conditions of competitive manufacturing.
3. The conformance of finished product to its design specifications and standards should be accomplished by avoiding the making of non-conforming materials rather than by storing the good from the bad after manufacturing is completed.

Rice has pointed out that it is necessary to fit the organisation and procedure of quality control to the situation in each plant. To do this, certain fundamental principles of statistical Quality Control must be adhered to for success in applying these techniques to manufacturing processes. Rice has stated the principles of statically quality control:

1. Variability exists in every repetitive operation, statistical methods enable management to determine what the expected or chance variability of the process is, and thus isolates the excessive variations due to an assignable cause from those due to chance. These may then be studied for the cause and corrective steps taken.
2. Wherever like products are turned out in quantity, statistical quality control techniques are applicable.
3. A state of statistical quality control, in which an operation produces articles that remain consistently within their range of chance variation, so that no assignable or findable cause is present, is not usually found where statistical control techniques have not been used.
4. Quality must be built into a product. It cannot be introduced through inspection. In the words of W. C. Deming “not how much product, but how much acceptable product is what counts.”
5. A state of control must be established at a satisfactory quality level before maximum efficiency in the operation can be obtained. The controlled process to be satisfactory must produce a satisfactory average product as well as are that does not vary from the average more than would be expected by chance.

TECHNIQUES OF APPLYING STATISTICAL QUALITY CONTROL:

Important techniques of applying statistical quality control are:

(A) Quality Control Charts and

(B) Acceptance Sampling.

QUALITY CONTROL CHART:

The control chart is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average **(Control Limit (CL))**, an upper line for the **upper control limit (UCL)** and a lower line for the **lower control limit (LCL).** These lines are determined from historical data. By comparing current data to these lines, you can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation).

Control charts for variable data are used in pairs. The top chart monitors the average, or the cantering of the distribution of data from the process. The bottom chart monitors the range, or the width of the distribution. If your data were shots in target practice, the average is where the shots are clustering, and the range is how tightly they are clustered. Control charts for attribute data are used singly.

WHEN TO USE A CONTROL CHART?

- ❖ When controlling ongoing processes by finding and correcting problems as they occur.
- ❖ When predicting the expected range of outcomes from a process.
- ❖ When determining whether a process is stable (in statistical control).
- ❖ When analyzing patterns of process variation from special causes (non-routine events) or common causes (built into the process).
- ❖ When determining whether your quality improvement project should aim to prevent specific problems or to make fundamental changes to the process.

CONTROL CHART BASIC PROCEDURE:

- ✓ Choose the appropriate control chart for your data.
- ✓ Determine the appropriate time period for collecting and plotting data.
- ✓ Collect data, construct your chart and analyze the data.
- ✓ Look for "out-of-control signals" on the control chart. When one is identified, mark it on the chart and investigate the cause. Document how you investigated, what you learned, the cause and how it was corrected.

Out-of-control signals:

- ❖ A single point outside the control limits. In Figure 2, point sixteen is above the **UCL** (upper control limit).
- ❖ Two out of three successive points are on the same side of the centerline and farther than 2 σ from it. In Figure 2, point 4 sends that signal.
- ❖ Four out of five successive points are on the same side of the centerline and farther than 1 σ from it. In Figure 2, point 11 sends that signal.

- A run of eight in a row are on the same side of the centerline. Or 10 out of 11, 12 out of 14 or 16 out of 20. In Figure 2, point 21 is eighth in a row above the centerline.
- Obvious consistent or persistent patterns that suggest something unusual about your data and your process.
- Continue to plot data as they are generated. As each new data point is plotted, check for new out-of-control signals.
- When you start a new control chart, the process may be out of control. If so, the control limits calculated from the first 20 points are conditional limits. When you have at least 20 sequential points from a period when the process is operating in control, recalculate control limits.

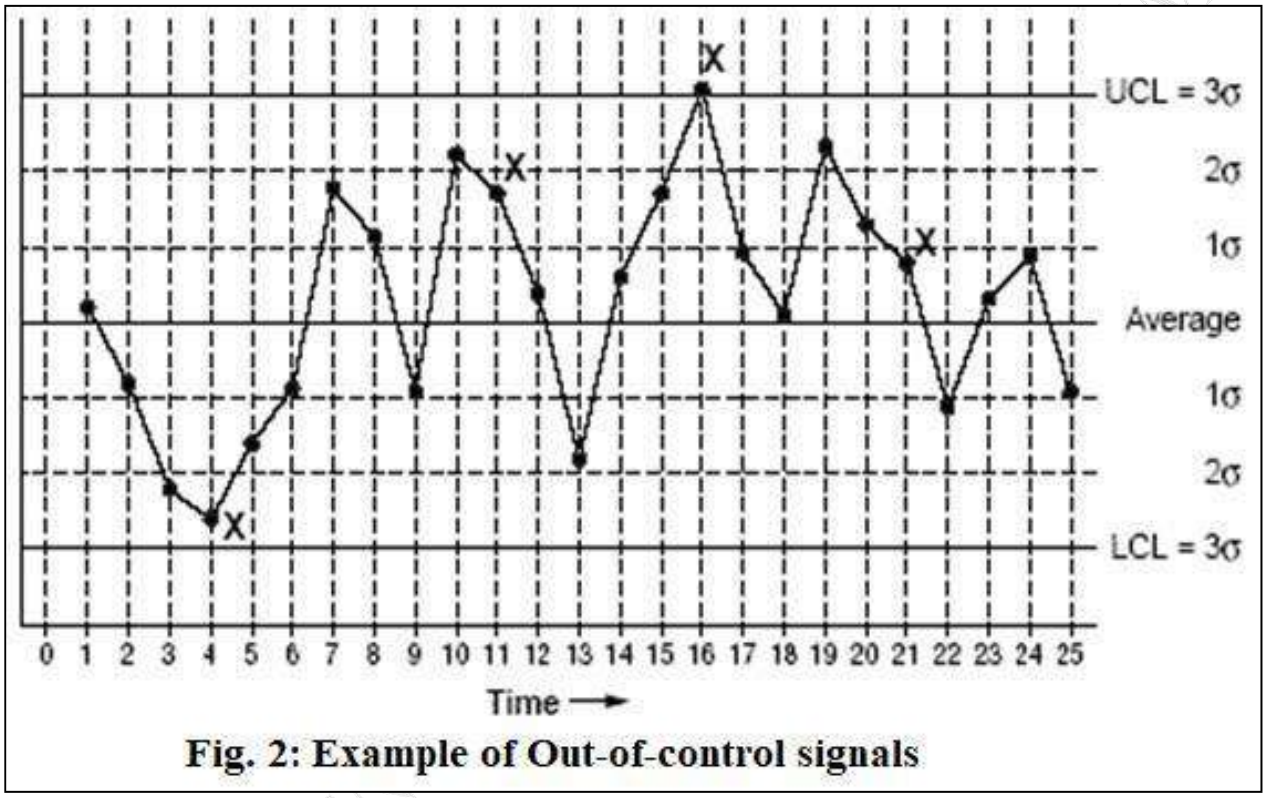


Fig. 2: Example of Out-of-control signals

Control charts show the performance of a process from two points of view. First, they show a snap-shot of the process at the moment the data are collected. Second, they show the process trend as time progresses. Process tends are important because they help in identifying the out-of-control as time progresses.

CLASSIFICATION OF CONTROL CHARTS

I. CONTROL CHARTS FOR VARIABLES:

These charts are used to achieve and maintain an acceptable quality level for a process, whose output product can be subjected to quantitative measurement or dimensional check such as size of a whole i.e. diameter or depth, length of a screw/bolt, wall thickness of a pipe etc.

These are used for measureable, quality characteristics. Let the quality characteristics of all the products be measured in subgroups. The subgroups are the samples having fixed number of items/products/component taken at random over a period of time.

The mean and the standard deviations of the quality characteristics are calculated for each sample and the following situations regarding the process may be encountered during practice.

ADVANTAGES OF CONTROL CHARTS FOR VARIABLES:

Various advantages of control charts for variables are as follows:

(1) **Ensures product quality level:** Control charts warn in time, if required rectification is done well in time the scrap and percentage rejection can be reduced, thus ensures product quality level.

(2) **The inspection work is reduced:** A control chart indicates whether the process is in control or out of control thus information about the selection of process and tolerance limits are provided.

(3) The control charts separate out the chance and assignable causes of variations in the observation thus substantial quality improvement is possible.

(4) Determines process variability and detects unusual variations taking place. So reputation of the concern/firm can be built by application of these charts.

OBJECTIVES OR PURPOSE OF CONTROL CHARTS FOR VARIABLES:

Various objectives of control charts for variables are as follows:

(1) To establish whether the process is in statistical control and in which case the variability is attributable to chance. The variability that is inherent in the process cannot be removed, unless there is a change in the basic conditions under which the production system/process is operating.

(2) It guides the production engineer in determining whether the process capability is compatible with the design specifications.

(3) To detect the trend of the observations for further planning, adjustment and resetting tools.

(4) To get prior information regarding the process, if that is likely to go out to control.

TABLE 1: Factors used for determining control limits in the $\bar{x}$ and R quality control charts.

(Based on normal distribution)

No. of Units in the sample (n)	Factor for $\bar{x}$ chart (A_2)	Factors for R chart	
		Lower Control Limit (D_3)	Lower Control Limit (D_4)
2	1.88	0	3.27
3	1.02	0	2.57
4	0.73	0	2.28
5	0.58	0	2.11
6	0.48	0	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.18	1.82
10	0.31	0.22	1.78
11	0.29	0.26	1.74
12	0.27	0.28	1.72
13	0.25	0.31	1.69
14	0.24	0.33	1.67
15	0.22	0.35	1.65
16	0.21	0.36	1.64
17	0.20	0.38	1.62
18	.019	0.39	1.61
19	0.19	0.40	1.61
20	0.18	0.41	1.59

Procedure for Constructing -R Charts

These charts are drawn as follows:

Step-1: A number of samples of components coming out of the process are taken over a period of time, each sample consisting of a number unit's n (n is usually 4 or 5 units or some times more). The quality measurements x_1, x_2, x_3.....x_n are taken.

Step-2: For each sample the average value x of all the measurements and the range R (i.e., the difference between the highest and the lowest readings) are calculated.

Then $\bar{\bar{x}}$ and $\bar{R}$ are computed as follows:

$\bar{\bar{x}} = \frac{\bar{x_1}+\bar{x_2}+\bar{x_3}+\cdots\cdots\bar{x_m}}{m}$ (Where, m are the number of successive samples)

Step-3: After calculating x and R the control limits of the X and R charts are calculated as follows with UCL and LCL as abbreviation for upper control limit and lower control limits.

$\bar{x}$ Chart: - U.C.L. = $\bar{\bar{x}} + A_2\bar{R}$ if A_2 is given

or $= \bar{\bar{x}} + \frac{3\bar{R}}{d_2\sqrt{n}}$ if d_2 is given

L.C.L. = $\bar{\bar{x}} - A_2\bar{R}$ if A_2 is given

or $= \bar{\bar{x}} - \frac{3\bar{R}}{d_3\sqrt{n}}$ if d_3 is given

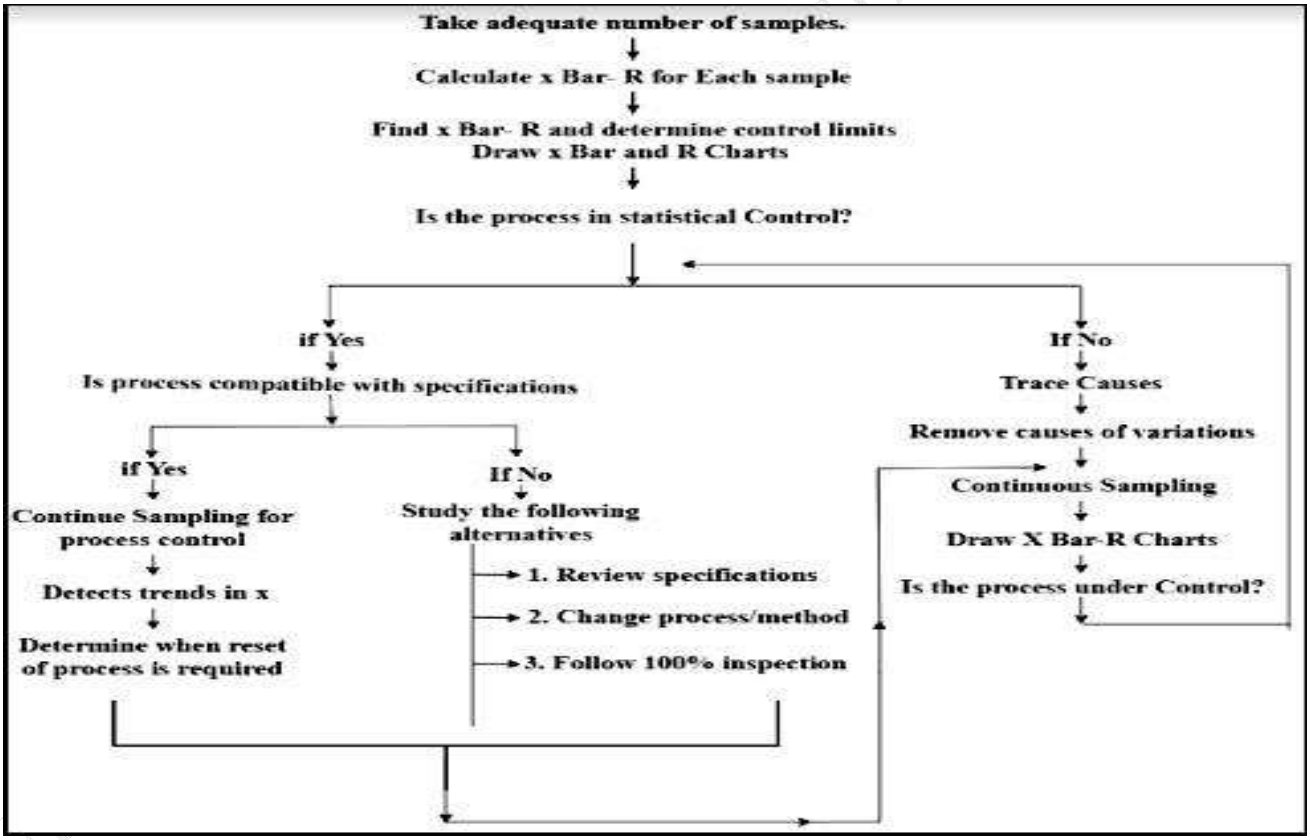
R Chart: - U.C.L. = $D_4\bar{R}$ if D_4 is given

or $= \bar{R}[\frac{1+3d_3}{d_2}]$ if d_2, & d_3 is given

L.C.L. = $D_3\bar{R}$ if D_3 is given

or $= \bar{R}[\frac{1-3d_3}{d_2}]$ if d_2, & d_3 is given

Where the factors A_2, D_4 and D_3 depend on the number of items per sample and the larger this number, the closer the limits. Table.1 gives values for these factors for various sample sizes. As long as the X and R values for each sample are within the control limits the process is said to be in statistical control.



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

$$UCL_{\bar{X}} = \bar{\bar{X}} + A\,\bar{R}$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - A\,\bar{R}$$

Control limits for R-Chart

$$UCL_R = B\,\bar{R}$$

$$LCL_R = C\,\bar{R}$$

Where A, B, C are different sample sizes are given in the table

Table for ABC Values

S.No.	Sample size *n*	Mean Factor A	Upper Range Factor B	Lower Range Factor C
1	2	1.88	3.27	0.00
2	3	1.02	2.57	0.00
3	4	0.73	2.28	0.00
4	5	0.58	2.11	0.00
5	6	0.48	2.00	0.00
6	7	0.42	1.92	0.08
7	8	0.37	1.86	0.14
8	9	0.34	1.82	0.18
9	10	0.31	1.78	0.22
10	11	0.29	1.74	0.26
11	12	0.27	1.72	0.28
12	13	0.25	1.69	0.31
13	14	0.24	1.67	0.33
14	15	0.22	1.65	0.35
15	16	0.21	1.64	0.36
16	17	0.20	1.62	0.38
17	18	0.19	1.61	0.39
18	19	0.19	1.60	0.40
19	20	0.18	1.59	0.41

THE STEPS IN CONSTRUCTING AN X BAR - S CONTROL CHART:

The steps in constructing the X Bar - S chart are given below. Most of the time you will use a software program to generate control charts. However, it is important to understand how the control charts are constructed and the steps in constructing them.

1. Gather the data.

Select the subgroup size (n). Typical subgroup sizes for an X Bar - S chart are 10 or more. However, you can use the X Bar - S chart with any size subgroup of two or more. The concept of rational subgroup should be considered. The objective is to minimize the amount of variation within a subgroup. This helps you "see" the variation in the averages chart easier.

Select the frequency with which the data will be collected. This will be part of the rational subgrouping. Time is always important in taking data and in interpreting the data. Data should be collected in the order in which they are generated (in most cases).

Select the number of subgroups (k) to be collected before control limits are calculated. You can start a control chart with only 5 subgroups. You will need to recalculate the averages and control limits for each new subgroup until you have at least twenty subgroups of data.

For each subgroup, record the individual sample results. For each subgroup, calculate the subgroup average (X): where X1, X2, etc. are the individual sample results and n is the subgroup size:

$$\overline{X} = \frac{\sum X_i}{n} = \frac{X_1 + X_2 + ... + X_n}{n}$$

For each subgroup, calculate the subgroup standard deviation:

2. Plot the data.

Select the scales for the x and y axes for both the X Bar and S charts

Plot the subgroup standard deviations (s) on the s chart and connect consecutive points with a straight line.

Plot the subgroup averages on the X chart and connect consecutive points with a straight line.

3. Calculate the overall process averages and control limits.

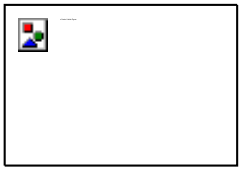
Calculate the average standard deviation (s), where s1, s2, etc. are the standard deviations for subgroups 1, 2, etc. and k is the number of subgroups:

Plot s on the s chart as a solid line and label.

Calculate the overall process average, where X_1, X_2, etc. are the subgroup averages for subgroups 1, 2, etc:

Plot the overall process average on the X chart as a solid line and label.

Calculate the control limits for the s chart. The upper control limit is given by UCLs. The lower control limit is given by LCLs. B4 and B3 are control chart constants that depend on the subgroup size.



Plot the control limits on the chart as dashed lines and label.

Calculate the control limits for the X chart. The upper control limit is given by UCL_X. The lower control limit is given by LCL_X. A3 is a control chart constant that depends on the subgroup size.

$$UCL_X = \overline{\overline{X}} + A_3 \overline{s}$$

$$LCL_X = \overline{\overline{X}} - A_3 \overline{s}$$

Plot the control limits on the X chart as dashed lines and label.

4. Interpret both charts for statistical control.

Always consider variation first. If the s chart is out of control, the control limits on the X chart are not valid since you do not have a good estimate of s. All tests for statistical control apply to the X chart. Points beyond the control limits, number of runs and length of runs apply to the s chart.

5. Calculate the process standard deviation, if appropriate.

If the s chart is in statistical control, the process standard deviation can be calculated as:

c4 is a control chart constant that depends on subgroup size.

If the control charts indicate that the process is in statistical control, extend the control limits into the future and monitor the process performance using these control limits. If the control charts indicated that there are special causes of variation, find the reason for the special cause of variation and remove it from the process. Once you have 20 points in a row in statistical control, recalculate the control limits based on that data, and use those limits in the future.

X Bar - S CONTROL CHART CONSTANTS for constructing the chart are given in table 1 & table 2 above.

II. CONTROL CHARTS FOR ATTRIBUTES:

These charts are used to achieve and maintain an acceptable quality level for a process whose output products are not subjected to dimensional or quantitative measurement but can be classified as good or bad or acceptable and non-acceptable.

For example surface finish of a product brightness of an item is either acceptable or not acceptable.

In inspection by variables as is done in x and R charts, actual measurement of the dimensions is required that is sometimes difficult as well as uneconomical.

There is another way of inspection also i.e., inspection by attributes. In this method actual measurements are not done, instead the number of faults or defectives are counted. The size of the defect and its location are not so important.

We can also say that the products are inspected the same way as by ‘Go’ and ‘No Go’ gauges. The products are either accepted or rejected and their actual dimensions are not measured

For example 100 fan blades are inspected out of which 12 are found to be defective so those 12 pieces are rejected.

The four most commonly used control charts for attributes are:

(1) Control charts from fraction defectives (p-charts)

(2) Control charts for number Defectives (n p charts)

(3) Control charts for percent defectives chart or 100 p-charts.

(4) Control charts for number of defects per unit or C-chart.

(1) CONTROL CHARTS FOR FRACTION DEFECTIVE (P-CHART):

Let samples of size n be taken randomly from the production process or output at different time intervals. If d is the number of defectives in a sample, then the fraction defective in the sample.

Or Actual number of defectives, 

If $\bar{p}$ is the proportion of defectives produced by the entire processing or the average fraction defective and it is given by

$\bar{p}$ The p-chart is based on binomial distribution. The binomial distribution has the standard deviation σ_p which is given by the relation.

Thus the control limits for the p-chart are:

Central Line CL = 

Upper control Limit UCL = 

Lower control Limit LCL = $\bar{P} - 3\sigma_p = \bar{P} - 3\sqrt{\frac{P(1-\bar{P})}{n}}$

Since the number of defective products cannot be negative if LCL sometimes comes out to be negative, it is taken as zero, p-chart is used to plot and control fraction defectives when the sample size remains uniform or it varies.

(2) CONTROL CHARTS FOR NUMBER OF DEFECTIVES (np-CHART):

Using the same notations as in p-chart the standard deviation and control limits of np-chart are as follows:

Standard deviation 

Control Limits CL = 

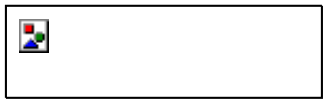
UCL = 

LCL = 

(3) CONTROL CHARTS FOR PERCENT DEFECTIVE (100 P-CHART):

Using the same notation as in p, np charts, the standard deviation and control limits are as follows:

Central Line, CL = 

UCL = 

LCL = $100 \times \bar{P} - 3\sigma_{100p}$

(4) CONTROL CHARTS FOR NUMBER OF DEFECTS PER UNIT (C-CHART):

This is another method of plotting attribute characteristics. In number of cases, it is more convenient to work with number of defects per unit rather than with fraction defective. The R-chart is used for the control of the number of defects observed per unit.

The difference between p-chart and the r-chart is that the former takes into account the number of items found defective in a given sample size (each defective item may have one or more defects in it) while the latter records the number of defects found in a given sample size.

Although the application of c-chart is somewhat limited, compared with p-chart, there are instances in industry where it is very useful e.g. in the control of number of defects in a bus body, an aircraft a T.V. set, a computer, welding defect in a truss etc.

The construction of the control chart is similar to that of the p-chart except that here the control limits are based on the Poisson distribution which has often been found fit to describe distribution of defects.

The standard deviation in this case is given by

Where  is the average number of defects?

The control limits for c-chart are:

CL = 

UCL = 

LCL = 

These control limits are for constant sample size i.e., for a single unit only. In case the sample consists of a numbers of unit's n, the average number of defects per unit

Control limits will be

CL = $\bar{U}$

UCL = $\bar{U} + 3\sqrt{\frac{U}{n}} = \bar{U} + 3\sqrt{\bar{c}}$

LCL = 

Whenever  so that LCL is negative, it is taken as being 0.

CONTROL CHARTS FOR ATTRIBUTES:

Control Limits for P-Chart

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

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

Where

p = Process percent defective of a sample

= (Number of defective Items in a sample size)

$\bar{p}$ = Process mean percent defective

n = Sample size

k = Number of samples

σ_p = Standard deviation of percent defectives

Control Limits for C-Chart

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

$$LCL_c = \bar{c} - 3\sqrt{\bar{c}}$$

Where $\bar{c}$ is the mean number of non-conformities?

APPLICABILITY OF P-CHARTS:

(1) np or Number of defective chart is used where group size or sample size i.e. n is constant.

(2) p-chart of fraction defective chart and 100 p or percent defective charts can be used where sample size is variable or constant.

COMPARISON OF $\bar{X}$ -R-CHARTS AND P-CHARTS:

$\bar{x}$ – R-Charts:

(1) These are Control Charts for variables.

(2) Cost of data collection is more due to actual dimensional measurements.

(3) Sample sizes are small.

(4) The control limits are affected by sample size.

(5) For different measurable quality characteristics different charts are to be drawn.

(6) The method is much superior in diagnosing of causes of variability.

P-Charts:

(1) These are Control Charts for attributes.

(2) Data collection is comparatively cheaper.

(3) Larger size samples are to be taken.

(4) There is less effect of the sample size over control limits.

(5) Same P-chart may be applied to any number of quality characteristics on one item under inspection.

(6) The method is comparatively inferior regarding diagnosing the causes of trouble or rejections.

ADVANTAGES OF STATISTICAL QUALITY CONTROL:

Following are the important benefits derived from the technique of statistical qualify control:

(1) Lesser cost of inspection: Statistical quality control is based on sampling technique which involves lesser cost of inspection thereby cost of production is considerably reduced.

(2) Increase in profits: By minimising rejections, statistical quality control ensures the production of standard products which bring higher profits for the producer.

(3) Setting tolerance limits: Quality control charts clearly lay down the tolerances limits beyond which the product is to be rejected. The results shown by these charts are more authentic and correct.

(4) Develops quality consciousness: Statistical quality control is greatly helpful in developing the feeling of quality consciousness among the workers working in an organisation. This improves their functioning and reduces the number of defective operations undertaken by them.

(5) Enhances reputation of the concern: By adopting the techniques of statistical quality control, pre-determined quality of the product is achieved and consumers get desired quality products. This brings good name to the firm and increases its goodwill among the people.

(6) Improved relations between vendor and customers: It is greatly helpful in improving relations between supplier and the purchaser of material, by clearly fixing the tolerance limits with regard to quality of the goods supplied. This minimises the possibility of any dispute between both the parties.

Besides the above mentioned benefits, statistical quality control ensures smooth and unrestricted production by removing breakdown of machinery and work stoppages as it greatly helps in detection of the troubles soon, which are immediately corrected without delay.

Table 1: Constants for constructing control charts.

Observations in Subgroup, n	c4 for Limits based on Subgroup Sigma	d2 for Xbar Limits based on Subgroup Range	d3 for Range Limits
2	0.7979	1.128	0.853
3	0.8862	1.693	0.888
4	0.9213	2.059	0.88
5	0.94	2.326	0.864
6	0.9515	2.534	0.848
7	0.9594	2.704	0.833
8	0.965	2.847	0.82
9	0.9693	2.97	0.808
10	0.9727	3.078	0.797
11	0.9754	3.173	0.787
12	0.9776	3.258	0.778
13	0.9794	3.336	0.77
14	0.981	3.407	0.763
15	0.9823	3.472	0.756
16	0.9835	3.532	0.75
17	0.9845	3.588	0.744
18	0.9854	3.64	0.739
19	0.9862	3.689	0.734
20	0.9869	3.735	0.729
21	0.9876	3.778	0.724
22	0.9882	3.819	0.72
23	0.9887	3.858	0.716
24	0.9892	3.895	0.712
25	0.9896	3.931	0.708

Table 2: Used for alternate forms of calculations.

Observations in Subgroup, n	A2 for Xbar Limits based on Range	A3 for Xbar Limits based on Sigma	B3 for Sigma chart LCL	B4 for Sigma chart UCL	D3 for Range chart LCL	D4 for Range chart UCL
2	1.88	2.659	0	3.267	0	3.267
3	1.023	1.954	0	2.568	0	2.574
4	0.729	1.628	0	2.266	0	2.282
5	0.577	1.427	0	2.089	0	2.114
6	0.483	1.287	0.03	1.97	0	2.004
7	0.419	1.182	0.118	1.882	0.076	1.924
8	0.373	1.099	0.185	1.815	0.136	1.864
9	0.337	1.032	0.239	1.761	0.184	1.816
10	0.308	0.975	0.284	1.716	0.223	1.777
11	0.285	0.927	0.321	1.679	0.256	1.744
12	0.266	0.886	0.354	1.646	0.283	1.717
13	0.249	0.85	0.382	1.618	0.307	1.693
14	0.235	0.817	0.406	1.594	0.328	1.672
15	0.223	0.789	0.428	1.572	0.347	1.653
16	0.212	0.763	0.448	1.552	0.363	1.637
17	0.203	0.739	0.466	1.534	0.378	1.622
18	0.194	0.718	0.482	1.518	0.391	1.608
19	0.187	0.698	0.497	1.503	0.403	1.597
20	0.18	0.68	0.51	1.49	0.415	1.585
21	0.173	0.663	0.523	1.477	0.425	1.575
22	0.167	0.647	0.534	1.466	0.434	1.566
23	0.162	0.633	0.545	1.455	0.443	1.557
24	0.157	0.619	0.555	1.445	0.451	1.548
25	0.153	0.606	0.565	1.435	0.459	1.541

PROBLEMS ON CONTROL CHARTS FOR THE VARIABLE TYPE OF DATA (X BAR AND R CHARTS)

Example 1: A team collected the variables data recorded in the table below.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
X1	6	2	5	3	2	5	4	7	2	5	3	6	4	5	3	6
X2	5	7	6	6	8	4	6	4	3	5	1	4	3	4	4	2
X3	2	9	4	6	3	8	3	4	7	2	6	2	6	6	7	4
X4	7	3	2	7	5	4	6	5	1	6	5	2	6	2	3	4

Use these data to answer the following questions and plot a Control Chart:

1. What type of Control Chart would you use with these data?
2. Why?
3. What are the values of X-Bar for each subgroup?
4. What are the values of the ranges (R) for each subgroup?
5. What is the grand mean for the X-Bar data?
6. What is the average of the range (R) values?
7. Compute the values for the upper and lower control limits for both the upper and lower plotting areas.
8. Plot the Control Chart.
9. Are there any signals of special cause variation? If so, what rule did you apply to identify the signal?

Solution:

1. X-Bar and R.
2. There is more than one measurement within each subgroup.
3. For values of X-Bar for each subgroup Refer to table 1.
4. For values of the ranges for each subgroup Refer to table 1.

Table 1. Shows X-Bar and ranges for each subgroup

	X1	X2	X3	X4	X Bar	R
1	6	5	2	7	5	5
2	2	7	9	3	5.25	7
3	5	6	4	2	4.25	4
4	3	6	6	7	5.5	4
5	2	8	3	5	4.5	6
6	5	4	8	4	5.25	4
7	4	6	3	6	4.75	3
8	7	4	4	5	5	3
9	2	3	7	1	3.25	6
10	5	5	2	6	4.5	4
11	3	1	6	5	3.75	5
12	6	4	2	2	3.5	4
13	4	3	6	6	4.75	3
14	5	4	6	2	4.25	4
15	3	4	7	3	4.25	4

16	6	2	4	4	4	4

5. Grand Mean of X,

Control Limit $\bar{\bar{x}} = \frac{\overline{x_1} + \overline{x_2} + \overline{x_3} + \cdots \ldots \ldots \overline{x_m}}{m}$

$$\bar{\bar{x}} = \frac{5 + 5.25 + 4.25 + 5.5 + 4.5 + 5.25 + 4.75 + 5 + 3.25 + 4.5 + 3.75 + 3.5 + 4.75 + 4.25 + 4.25 + 4}{16}$$

$$\bar{\bar{x}} = \frac{71.75}{16} = 4.484 \ (Center\ Line\ of\ X\ bar\ chart)$$

6. Average of the range values $\bar{R}$

$$\bar{R} = \frac{5+7+4+4+6+4+3+3+6+4+5+4+3+4+4+4}{16}$$

$$\bar{R} = \frac{70}{16} = 4.375 \ (Center\ Line\ for\ R\ chart)$$

7. $\bar{x}$ Chart: - U.C.L. = $\bar{\bar{x}} + A_2\bar{R}$ if A_2 is given

or $= \bar{\bar{x}} + \frac{3\bar{R}}{d_2\sqrt{n}}$ if d_2 is given

L.C.L. = $\bar{\bar{x}} - A_2\bar{R}$ if A_2 is given

or $= \bar{\bar{x}} - \frac{3\bar{R}}{d_2\sqrt{n}}$ if d_3 is given

R Chart: - U.C.L. = $D_4\bar{R}$ if D_4 is given

or $= \bar{R}[\frac{1+3d_3}{d_2}]$ if d_2, & d_3 is given

L.C.L. = $D_3\bar{R}$ if D_3 is given

or $= \bar{R}[\frac{1-3d_3}{d_2}]$ if d_2, & d_3 is given

Now: $\bar{x}$ Chart: U.C.L. = $\bar{\bar{x}} + A_2\bar{R}$

$$= 4.484 + A_2 4.375 \ (if\ A_2 = 0.729\ for\ sample\ size\ 4)$$

$$= 4.484 + (0.729 \times 4.375) = 7.67$$

Lower Control Limit, L.C.L. = $\bar{\bar{x}} - A_2\bar{R}$ if A_2 is given

$$= 4.484 - A_2 4.375 (if\ A_2 = 0.729\ for\ sample\ size\ 4)$$

$$= 4.484 - (0.729 \times 4.375) = 1.29$$

$\bar{R}$ Chart:

Upper Control Limit, U.C.L. = $D_4\bar{R}$ if D_4 is given

$$= D_4 \times 4.375 \ (if\ D_4 = 2.282\ for\ sample\ size\ 4)$$

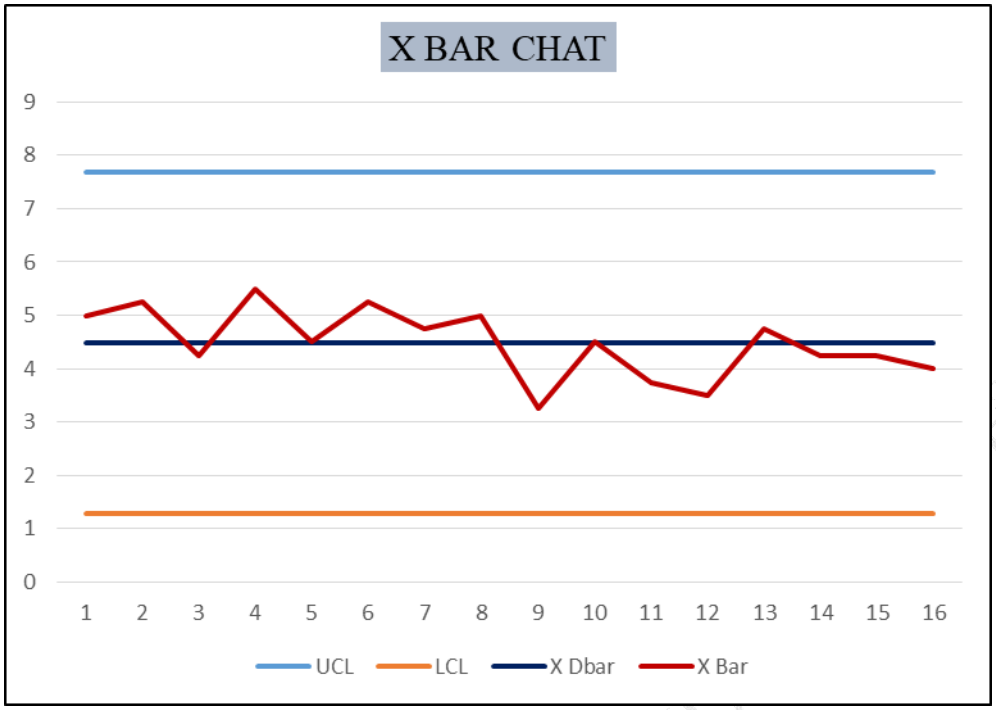
$$= 2.282 \times 4.375 = 9.98 \approx 10$$

Lower Control Limit, L.C.L. = $D_3\bar{R}$ if D_4 is given

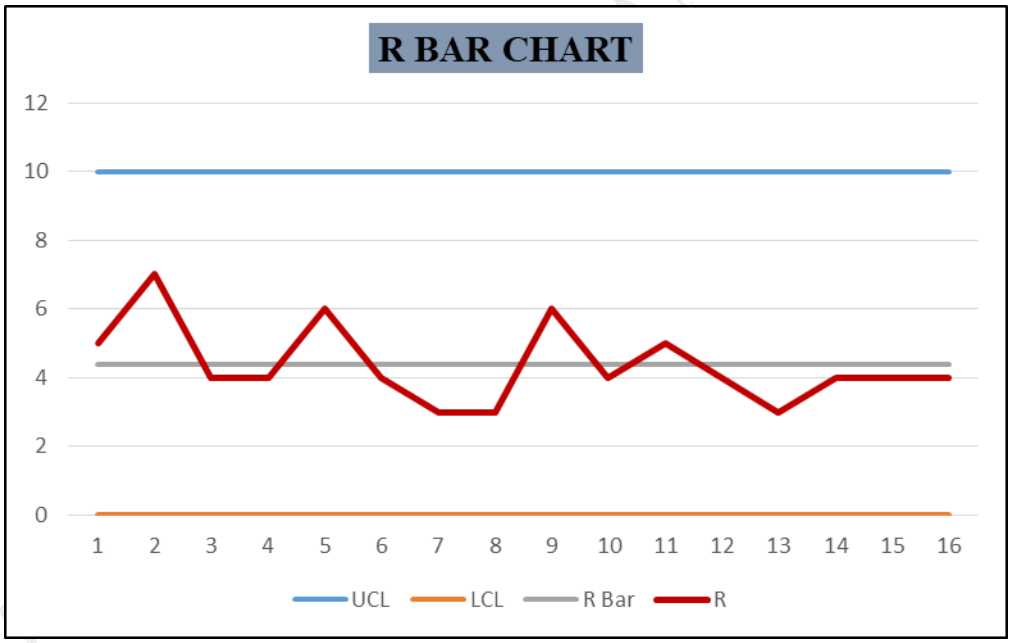
$$= D_3 \times 4.375 \ (if\ D_3 = 0\ for\ sample\ size\ 4)$$

$= 0 \times 4.375 = 0$

8. Plotting the Control Chart using – X bar – chart



Plotting the Control Chart using – R – Chart



9. There is no out of control signals and all the subgroups are accepted.

Example 2: A team collected the variables data recorded in the table below.

	1	2	3	4	5	6	7	8	9
X1	15.3	14.4	15.3	15.0	15.3	14.9	15.6	14.0	14.0
X2	14.9	15.5	15.1	14.8	16.4	15.3	16.4	15.8	15.2
X3	15.0	14.8	15.3	16.0	17.2	14.9	15.3	16.4	13.6
X4	15.2	15.6	18.5	15.6	15.5	16.5	15.3	16.4	15.0
X5	16.4	14.9	14.9	15.4	15.5	15.1	15.0	15.3	15.0

Use these data to answer the following questions and plot a Control Chart:

1. What type of Control Chart would you use with these data?

2. Why?
3. What are the values of X-Bar for each subgroup?
4. What are the values of the ranges for each subgroup?
5. What is the grand mean for the X-Bar data?
6. What is the average of the range values?
7. Compute the values for the upper and lower control limits for both the upper and lower plotting areas.
8. Plot the Control Chart.
9. Are there any signals of special cause variation? If so, what rule did you apply to identify the signal?

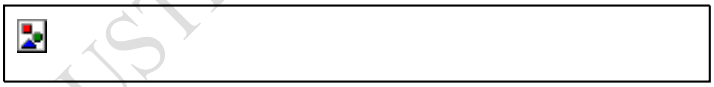
Solution:

1. X-Bar and R.
2. There is more than one measurement within each subgroup.
3. For values of X-Bar for each subgroup Refer to table 1.
4. For values of the ranges for each subgroup Refer to table 1.

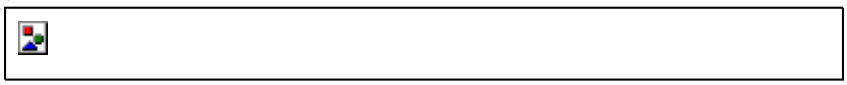
Table 1. Shows X-Bar and ranges for each subgroup

	X1	X2	X3	X4	X5	X Bar	R
1	15.3	14.9	15	15.2	16.4	15.36	1.5
2	14.4	15.5	14.8	15.6	14.9	15.04	1.2
3	15.3	15.1	15.3	18.5	14.9	15.82	3.6
4	15	14.8	16	15.6	15.4	15.36	1.2
5	15.3	16.4	17.2	15.5	15.5	15.98	1.9
6	14.9	15.3	14.9	16.5	15.1	15.34	1.6
7	15.6	16.4	15.3	15.3	15	15.52	1.4
8	14	15.8	16.4	16.4	15.3	15.58	2.4
9	14	15.2	13.6	15	15	14.56	1.6

5. Grand Mean of X,



6. Average of the range values



$$\bar{R} = \frac{16.4}{9} = 1.822 \ (Center\ Line\ for\ R\ chart)$$

7. $\bar{x}$ Chart: - U.C.L. = $\bar{\bar{x}} + A_2\bar{R}$ if A_2 is given

or $= \bar{\bar{x}} + \frac{3\bar{R}}{d_2\sqrt{n}}$ if d_2 is given

L.C.L. = $\bar{\bar{x}} - A_2\bar{R}$ if A_2 is given

or $= \bar{\bar{x}} - \frac{3\bar{R}}{d_3\sqrt{n}}$ if d_3 is given

R Chart: - U.C.L. = $D_4\bar{R}$ if D_4 is given

or $= \bar{R}[\frac{1+3d_3}{d_2}]$ if d_2, & d_3 is given

L.C.L. = $D_3\bar{R}$ if D_3 is given

or $= \bar{R}[\frac{1-3d_3}{d_2}]$ if d_2, & d_3 is given

Now: $\bar{x}$ Chart: U.C.L. = $\bar{\bar{x}} + A_2\bar{R}$

$$= 15.217 + A_2 1.822 \ (if\ A_2 = 0.577\ for\ sample\ size\ 5)$$
$$= 15.217 + (0.577 \times 1.822) = 16.95$$

Lower Control Limit, L.C.L. = $\bar{\bar{x}} - A_2\bar{R}$ if A_2 is given

$$= 15.217 - A_2 1.822 (if\ A_2 = 0.577\ for\ sample\ size\ 5)$$
$$= 15.217 - (0.577 \times 1.822) = 13.49$$

$\bar{R}$ Chart:

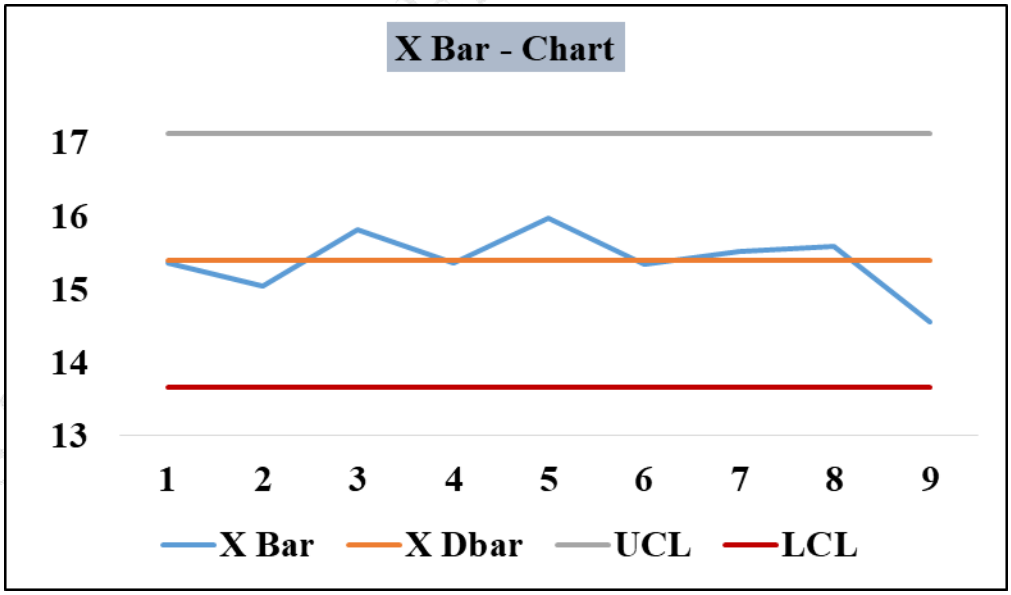
Upper Control Limit, U.C.L. = $D_4\bar{R}$ if D_4 is given

$$= D_4 \times 1.822 \ (if\ D_4 = 2.114\ for\ sample\ size\ 5)$$
$$= 2.282 \times 1.822 = 3.85 \approx 4$$

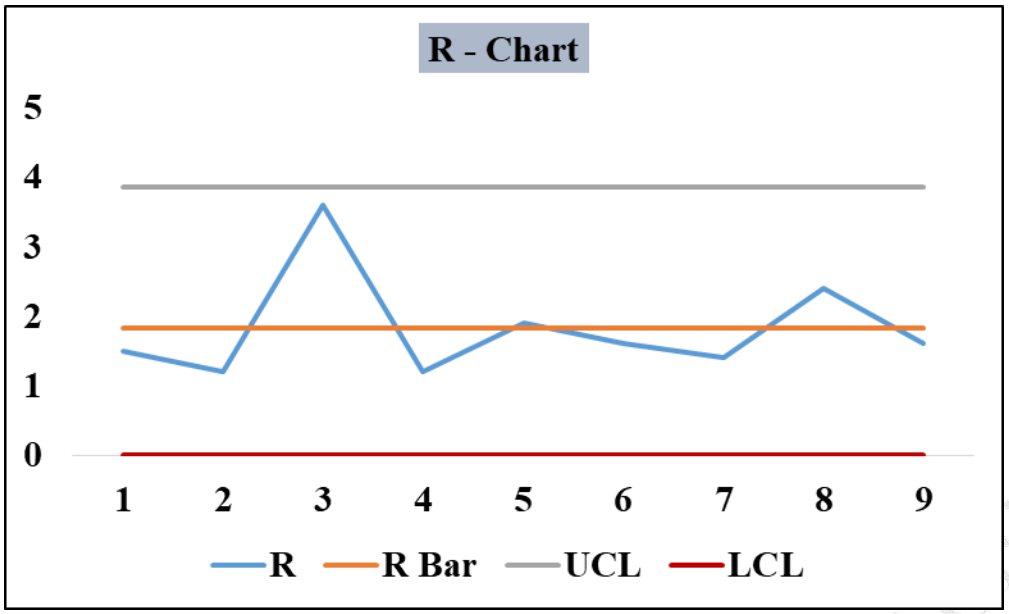
Lower Control Limit, L.C.L. = $D_3\bar{R}$ if D_4 is given

$$= D_3 \times 1.822 \ (if\ D_3 = 0\ for\ sample\ size\ 4)$$
$$= 0 \times 1.822 = 0.00$$

8. Plotting the Control Chart using – X bar – Chart



Plotting the Control Chart using – R – Chart



9. There is no out of control signals from X Bar and R Charts and all the subgroups are accepted.

Example 3: Mean values and ranges of data from 20 samples (sample size = 4) are shown in the table below:

S. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Mean of Sample	10	15	12	11	9	11	11	9	10	11	12	13	12	12	11	15	12	15	11	10
Range	4	4	5	4	5	6	4	4	4	6	5	4	4	3	3	4	4	3	3	4

Solution:

Given Data:

No. of Sample size, n = 4

To Find:

Range $\bar{R}$

Control Limit $\bar{\bar{X}}$,

Upper Control Limit (UCL)

Lower Control Limit (LCL)

We Know:

Control Limit $\bar{\bar{x}} = \frac{\overline{x_1} + \overline{x_2} + \overline{x_3} + \cdots \ldots\ldots \overline{x_m}}{m}$

$\bar{x}$ Chart: - U.C.L. = $\bar{\bar{x}} + A_2\bar{R}$ if A_2 is given

or $= \bar{\bar{x}} + \frac{3\bar{R}}{d_2\sqrt{n}}$ if d_2 is given

L.C.L. = $\bar{\bar{x}} - A_2\bar{R}$ if A_2 is given

or $= \bar{\bar{x}} - \frac{3\bar{R}}{d_2\sqrt{n}}$ if d_3 is given

R Chart: - U.C.L. = $D_4\bar{R}$ if D_4 is given

or $= \bar{R}\left[\frac{1+3d_3}{d_2}\right]$ if d_2, & d_3 is given

L.C.L. $= D_3\bar{R}$ if D_3 is given

or $= \bar{R}\left[\frac{1-3d_3}{d_2}\right]$ if d_2, & d_3 is given

Now:

Control Limit $\bar{\bar{x}} = \frac{\overline{x_1} + \overline{x_2} + \overline{x_3} + \cdots \ldots\ldots \overline{x_m}}{m}$

$$\bar{\bar{x}} = \frac{10+15+12+11+9+11+11+9+10+11+12+13+12+12+11+15+12+15+11+10}{20}$$

$$\bar{\bar{x}} = \frac{232}{20} = 11.6 \ (Center\ Line\ of\ X\ bar\ chart)$$

Range,

$$\bar{R} = \frac{4+4+5+4+5+6+4+4+4+6+5+4+4+3+3+4+4+3+3+4}{20}$$

$$\bar{R} = \frac{83}{20} = 4.15 \ (Center\ Line\ for\ R\ chart)$$

$\bar{x}$ Chart:

Upper Control Limit, U.C.L. $= \bar{\bar{x}} + A_2\bar{R}$ if A_2 is given

$$= 11.6 + A_2 4.15 \ (if\ A_2 = 0.729\ for\ sample\ size\ 4)$$
$$= 11.6 + (0.729 \times 4.15) = 14.63$$

Lower Control Limit, L.C.L. $= \bar{\bar{x}} - A_2\bar{R}$ if A_2 is given

$$= 11.6 - A_2 4.15 \ (if\ A_2 = 0.729\ for\ sample\ size\ 4)$$
$$= 11.6 - (0.729 \times 4.15) = 8.57$$

$\bar{R}$ Chart:

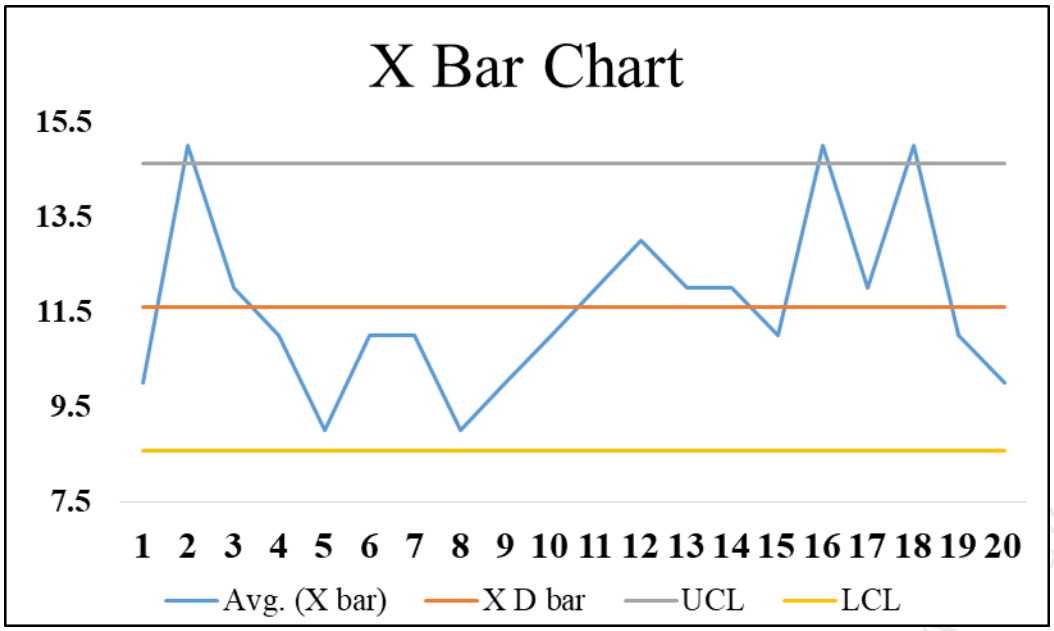
Upper Control Limit, U.C.L. $= D_4\bar{R}$ if D_4 is given

$$= D_4 \times 4.15 \ (if\ D_4 = 2.282\ for\ sample\ size\ 4)$$
$$= 2.282 \times 4.15 = 9.47 \approx 9.5$$

Lower Control Limit, L.C.L. $= D_3\bar{R}$ if D_3 is given

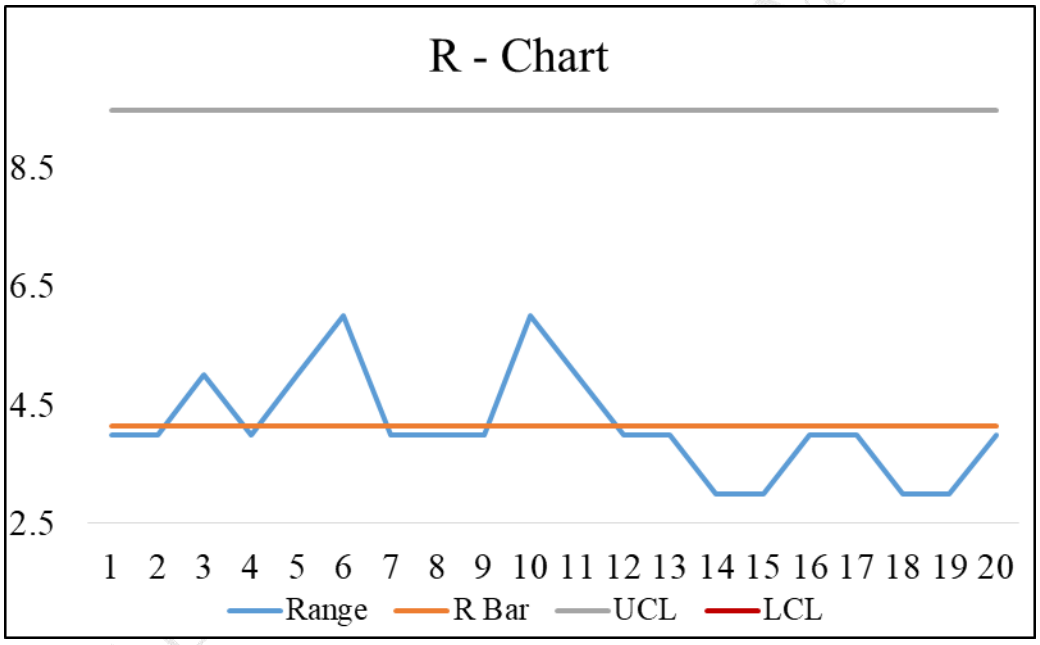
$$= D_3 \times 4.15 \ (if\ D_3 = 0\ for\ sample\ size\ 4)$$
$$= 0 \times 4.15 = 0$$

Know we have to draw Control chart using – X bar – chart



Comment: Sample data at S.N 2, 16, and 18 are slightly above the UCL. Hence, the process is not under control.

Know we have to draw Control chart using – R bar – chart



Comment: From the above control chart all the points are within control limits. Hence the quality is considered to be under control.

In order to assure for the quality we have to delete the subgroups 2, 16 and 18 and again we will calculate greater mean and range values.

Now,

Control Limit $\bar{\bar{x}} = \frac{\overline{x_1} + \overline{x_2} + \overline{x_3} + \cdots \ldots \ldots \overline{x_m}}{m}$

$$\bar{\bar{x}} = \frac{10 + 12 + 11 + 9 + 11 + 11 + 9 + 10 + 11 + 12 + 13 + 12 + 12 + 11 + 12 + 11 + 10}{17}$$

$$\bar{\bar{x}} = \frac{187}{17} = 11 \ (Center\ Line\ of\ X\ bar\ chart)$$

Range,

$$\bar{R} = \frac{4 + 5 + 4 + 5 + 6 + 4 + 4 + 4 + 6 + 5 + 4 + 4 + 3 + 3 + 4 + 3 + 4}{17}$$

$\bar{R} = \frac{72}{17} = 4.23\ (Center\ Line\ for\ R\ chart)$

$\bar{x}$ Chart:

Upper Control Limit, U.C.L. = $\bar{\bar{x}} + A_2\bar{R}$ if A_2 is given

$$= 11 + A_2 4.23\ (if\ A_2 = 0.729\ for\ sample\ size\ 4)$$
$$= 11 + (0.729 \times 4.23) = 14.083$$

Lower Control Limit, L.C.L. = $\bar{\bar{x}} - A_2\bar{R}$ if A_2 is given

$$= 11 - A_2 4.23\ (if\ A_2 = 0.729\ for\ sample\ size\ 4)$$
$$= 11 - (0.729 \times 4.23) = 7.91$$

$\bar{R}$ Chart:

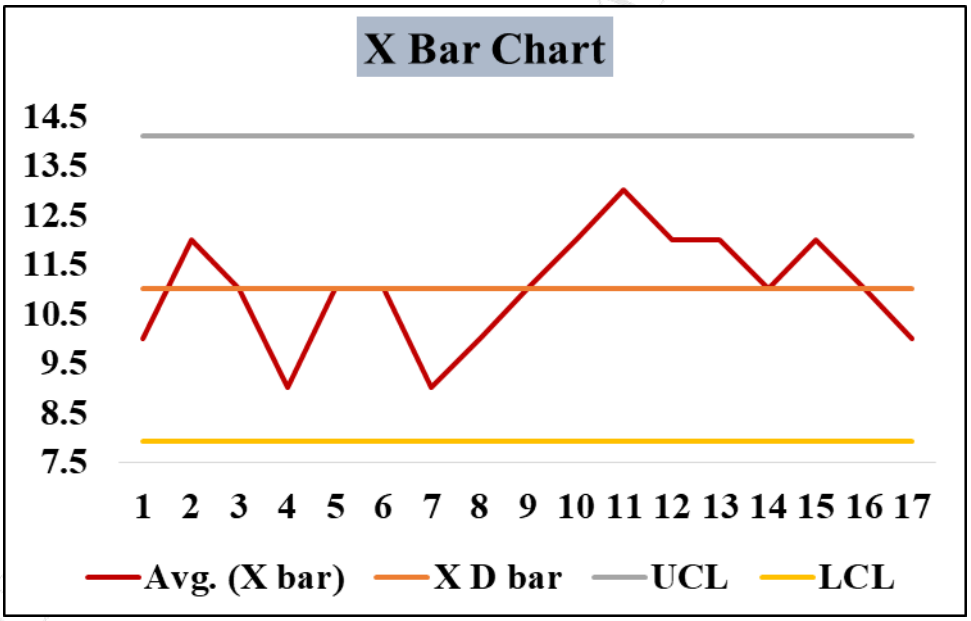
Upper Control Limit, U.C.L. = $D_4\bar{R}$ if D_4 is given

$$= D_4 \times 4.23\ (if\ D_4 = 2.282\ for\ sample\ size\ 4)$$
$$= 2.282 \times 4.23 = 9.65$$

Lower Control Limit, L.C.L. = $D_3\bar{R}$ if D_3 is given

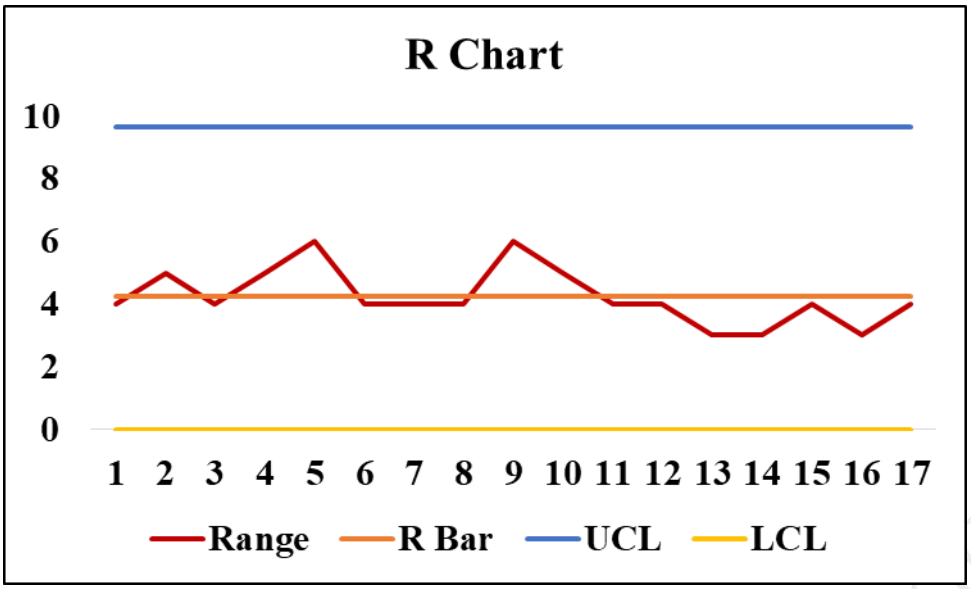
$$= D_3 \times 4.23\ (if\ D_3 = 0\ for\ sample\ size\ 4)$$
$$= 0 \times 4.23 = 0$$

Know we have to draw Control chart using – X bar – chart



Comment: From the above control chart all the points are within control limits. Hence the quality is considered to be under control.

Know we have to draw Control chart using S – Chart



Comment: From the above control chart all the points are within control limits. Hence the quality is considered to be under control.

PROBLEMS ON CONTROL CHARTS FOR THE VARIABLE TYPE OF DATA (X BAR AND S CHARTS)

Example 1: The following is a small example of a quantitative process, calculate the subgroup means and standard deviations, then plot the means and calculate the upper and lower control limits for the X bar and S chart.

	M1	M2	M3	M4
S1	2.3	2.2	2.4	2.3
S2	2.1	2.2	2.3	2.4
S3	2	2.1	2.2	2.1
S4	2	2.2	2.1	2.3
S5	2.5	2.1	2.4	2.3

Solution:

Given data:

No. of Groups/Samples, k=5

No. of Subgroups/Observations, n=4

To find:

1. Grand Mean $\bar{\bar{x}}$,
2. Values of Sigma, S,
3. Average of Sigma values $\bar{S}$,

We know that

$$\text{Grand Mean/Control Limit } \bar{\bar{x}} = \frac{\overline{x_1} + \overline{x_2} + \overline{x_3} + \cdots \ldots \ldots \overline{x_n}}{n}$$

$$\text{Standard Deviation, } S = \sqrt{\frac{\Sigma_1^n (X_i - \bar{X})^2}{n-1}}$$

$$\text{Average of Sigma values } \bar{S} = \frac{\Sigma_1^k S_i}{k}$$

For X-Bar Chart

$$\text{Control Limit, } \bar{\bar{x}} = \frac{\overline{x_1}+\overline{x_2}+\overline{x_3}+\cdots\ldots\ldots\overline{x_k}}{k}$$

$UCL = \bar{\bar{X}} + A_3\bar{S}$

$LCL = \bar{\bar{X}} - A_3\bar{S}$

For Sigma (S) Chart

$$\text{Control Limit, } \bar{S} = \frac{\Sigma_1^k S_i}{k}$$

$$UCL = B_4\bar{S}$$

$LCL = B_3\bar{S}$

Know:

For X-Bar Chart

Control Limit, $\bar{\bar{x}} = \frac{\overline{x_1}+\overline{x_2}+\overline{x_3}+\cdots\ldots\ldots\overline{x_k}}{k}$

$$\bar{\bar{x}} = \frac{2.30 + 2.25 + 2.10 + 2.15 + 2.33}{5}$$

$$= \frac{11.13}{5} = 2.225$$

$$\bar{\bar{x}} = 2.225$$

$$\text{Standard Deviation, } S_i = \sqrt{\frac{\Sigma_1^n (X_i - \bar{X})^2}{n-1}}$$

1. 
2. 
3. 
4. 
5. 

$$\bar{S} = \frac{\Sigma_1^k S_i}{k} = \frac{S_1+S_2+S_3+\cdots S_i}{k}$$

$$\bar{S} = \frac{0.0816 - 0.1291 + 0.0816 + 0.1291 + 0.01708}{5}$$

$$\bar{S} = \frac{0.5923}{5}$$

$$\bar{S} = 0.1185$$

$UCL = \bar{\bar{X}} + A_3\bar{S}$

$UCL = 2.225 + A_3 0.1185\ (A_3 = 1.628\ for\ sub\ group\ 4)$

$UCL = 2.225 + (1.628 \times 0.1185)$

$$\boldsymbol{UCL = 2.4179}$$

$LCL = \bar{\bar{X}} - A_3\bar{S}$

$LCL = 2.225 - A_3 0.1185$ $(A_3 = 1.628\ for\ sub\ group\ 4)$

$LCL = 2.225 - (1.628 \times 0.1185)$

$$\boldsymbol{LCL = 2.0320}$$

$LCL = \bar{\bar{X}} - A_3\bar{S}$

For Sigma (S) Chart

Control Limit, $\bar{S} = \frac{\Sigma_1^k S_i}{k}$

$$\boldsymbol{\bar{S} = 0.1185}$$

$UCL = B_4\bar{S}$

$LCL = B_3\bar{S}$

$\bar{S}$ Chart:

Upper Control Limit, U.C.L. $= B_4\bar{S}$

$= B_4 \times 0.1185$ $(if\ B_4 = 2.266\ for\ sample\ size\ 4)$

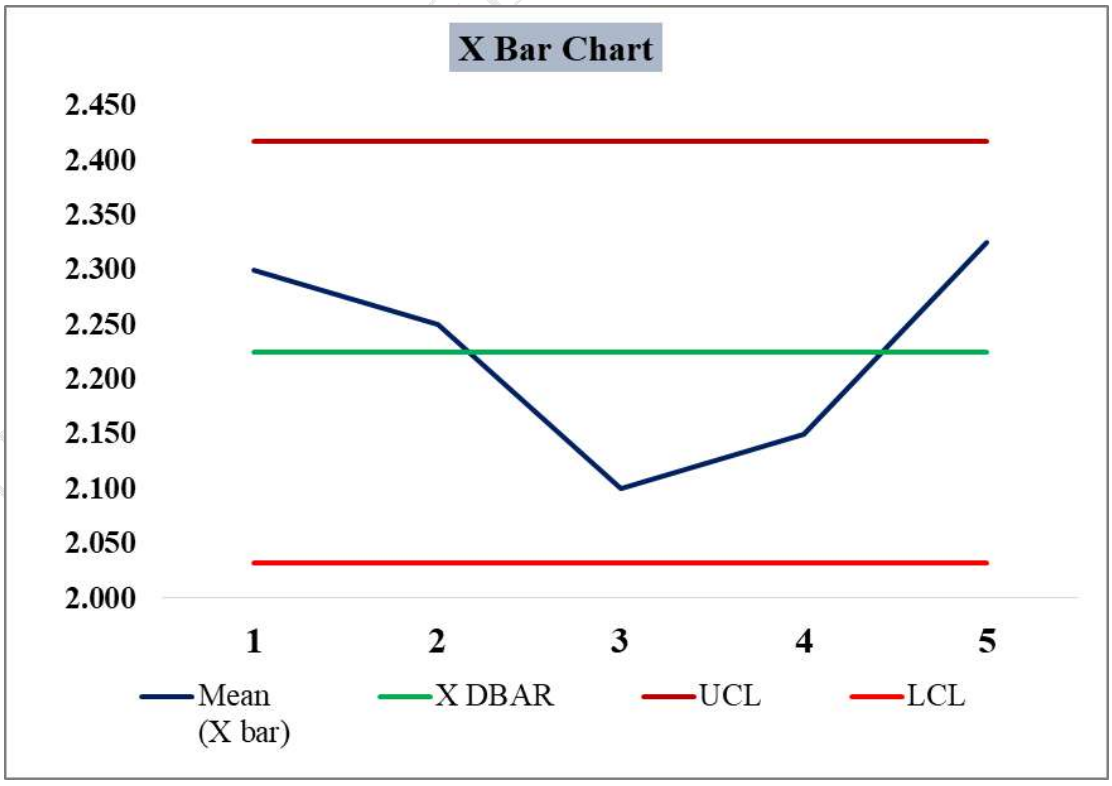
$= 2.266 \times 0.1185 = 0.268$

Lower Control Limit, L.C.L. $= B_3\bar{S}$

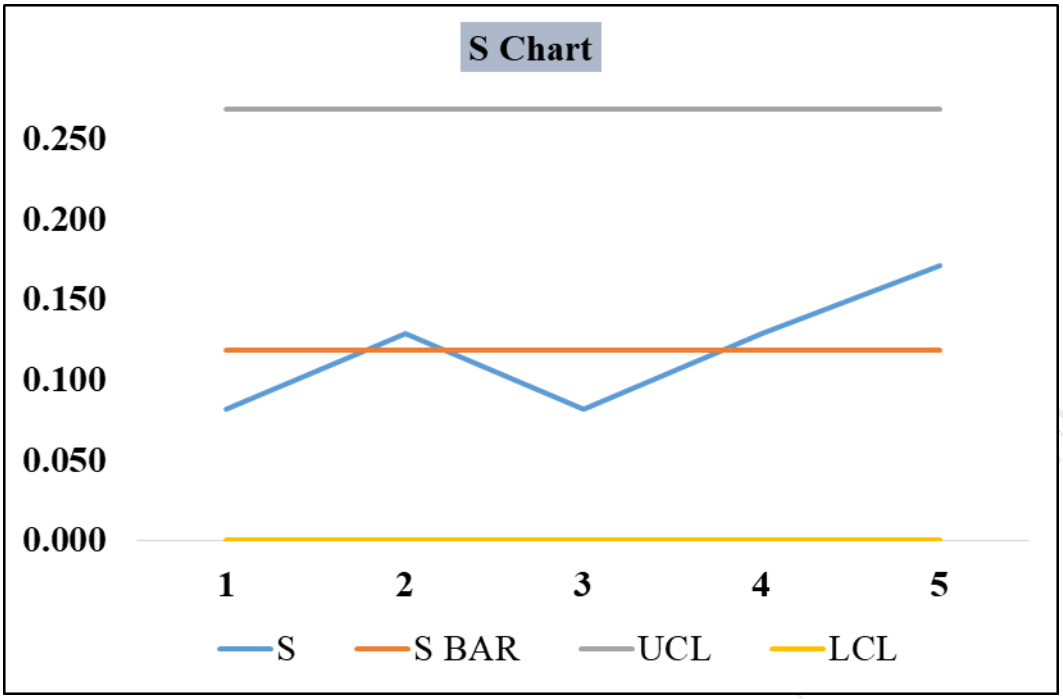
$= B_3 \times 0.1185$ $(if\ B_3 = 0\ for\ sample\ size\ 4)$

$= 0 \times 0.1185 = 0.00$

Plotting the Control Chart using X bar – Chart



Plotting the Control Chart using S – Chart



From the above two control charts we see that there is no special control signals. Therefore the samples are accepted.

Example 2: Given the following data for subgroups sizes of 8, construct the X Bar and S chart

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12
X-Bar	540	534	545	561	576	523	571	547	584	552	541	545
S	26	23	24	27	25	50	29	29	23	24	28	25

Sample No.	13	14	15	16	17	18	19	20	21	22	23	24	25
X-Bar	546	551	522	579	549	508	569	574	563	561	548	556	553
S	26	24	29	26	28	23	22	28	33	23	25	27	23

(Note: For sub-group size of 8 we have A_3 =1.099, B_3 = 0.185 & B_4 = 1.815**)**

Solution:

Given Data:

1. No. of samples, K=25
2. No. of Observation's/Sub-Groups/Sample Size, n=8

To Find:

1. Grand Mean $\bar{\bar{x}}$,
2. Average of Sigma values $\bar{S}$,

We know that

$$\text{Grand Mean/Control Limit } \bar{\bar{x}} = \frac{\overline{x_1} + \overline{x_2} + \overline{x_3} + \cdots \ldots \ldots \overline{x_n}}{n}$$

$$\text{Standard Deviation, } S = \sqrt{\frac{\Sigma_1^n (X_i - \bar{X})^2}{n-1}}$$

Average of Sigma values $\bar{S} = \frac{\Sigma_1^k S_i}{k}$

For X-Bar Chart

Control Limit, $\bar{\bar{x}} = \frac{\bar{x_1}+\bar{x_2}+\bar{x_3}+\cdots\ldots\ldots\bar{x_k}}{k}$

$UCL = \bar{\bar{X}} + A_3\bar{S}$

$LCL = \bar{\bar{X}} - A_3\bar{S}$

For Sigma (S) Chart

Control Limit, $\bar{S} = \frac{\Sigma_1^k S_i}{k}$

$UCL = B_4\bar{S}$

$LCL = B_3\bar{S}$

Know:

For X-Bar Chart

Control Limit, $\bar{\bar{x}} = \frac{\bar{x_1}+\bar{x_2}+\bar{x_3}+\cdots\ldots\ldots\bar{x_k}}{k}$

$\bar{\bar{x}} = \frac{540+534+545+561+576+523+571+547+584+552+541+545+546+551+522+579+549+508+569+574+563+561+548+556+553}{25}$

$= \frac{13798}{25} = 551.92$

$$\bar{\bar{x}} = 551.92$$

$$\bar{S} = \frac{\Sigma_1^k S_i}{k} = \frac{S_1 + S_2 + S_3 + \cdots S_{25}}{k}$$

$\bar{S} = \frac{26+23+24+27+25+50+29+29+23+24+28+25+26+24+29+26+28+23+22+28+33+23+25+27+23}{25}$

$\bar{S} = \frac{670}{25}$

$$\bar{S} = 26.80$$

$UCL = \bar{\bar{X}} + A_3\bar{S}$

$UCL = 551.92 + (A_3 \times 26.80)\ (A_3 = 1.099 for\ sub\ group\ 8)$

$UCL = 551.92 + (1.099 \times 26.80)$

$$UCL = 581.313$$

$LCL = \bar{\bar{X}} - A_3\bar{S}$

$LCL = 551.92 - (A_3 \times 26.80)\ (A_3 = 1.099\ for\ sub\ group\ 8)$

$LCL = 551.92 - (1.099 \times 26.80)$

$$LCL = 522.247$$

For Sigma (S) Chart

Control Limit, $\bar{S} = \frac{\Sigma_1^k S_i}{k}$

$$\bar{S} = 26.80$$

$$UCL = B_4\bar{S}$$

$LCL = B_3\bar{S}$

$\bar{S}$ Chart:

Upper Control Limit, U.C.L. $= B_4\bar{S}$

$$= B_4 26.80 \ (if \ B_4 = 1.815 \ for \ sample \ size \ 8)$$

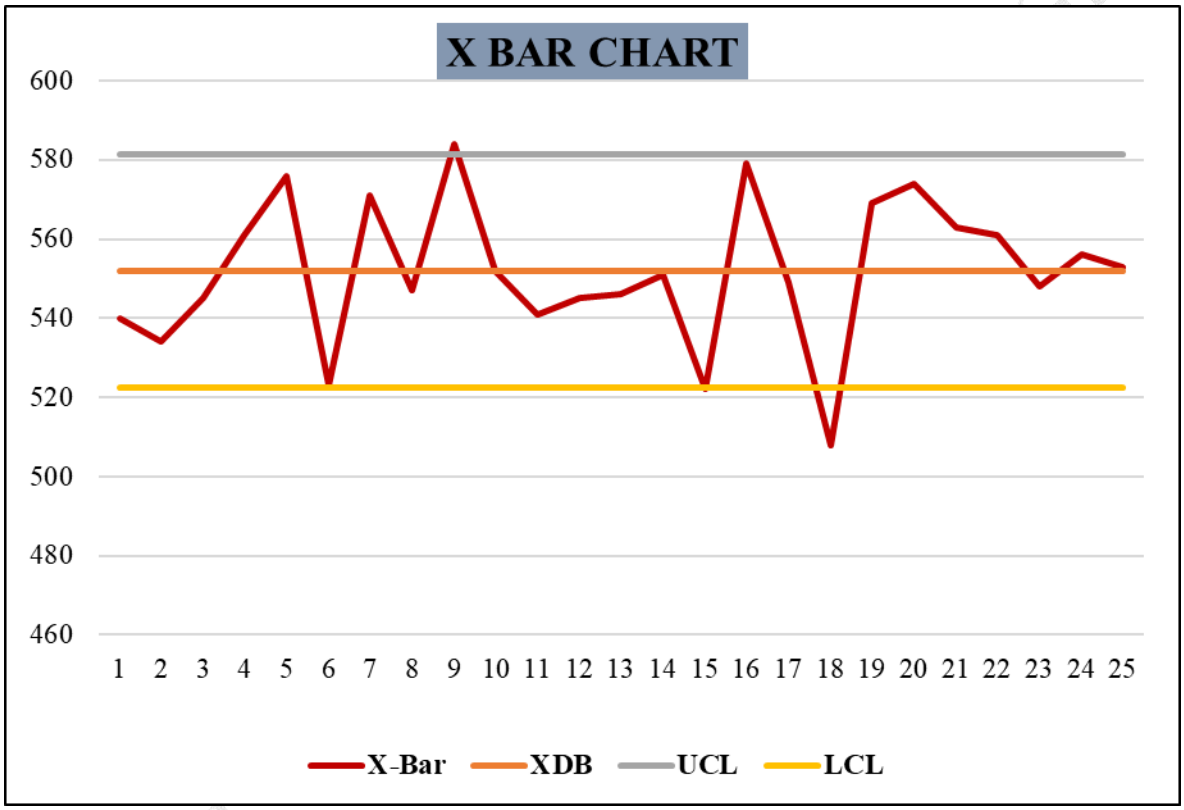
$$= 1.815 \times 26.80 = \mathbf{48.642}$$

Lower Control Limit, L.C.L. $= B_3\bar{S}$

$$= B_3 \times 26.80 \ (if \ B_3 = 0.185 \ for \ sample \ size \ 8)$$

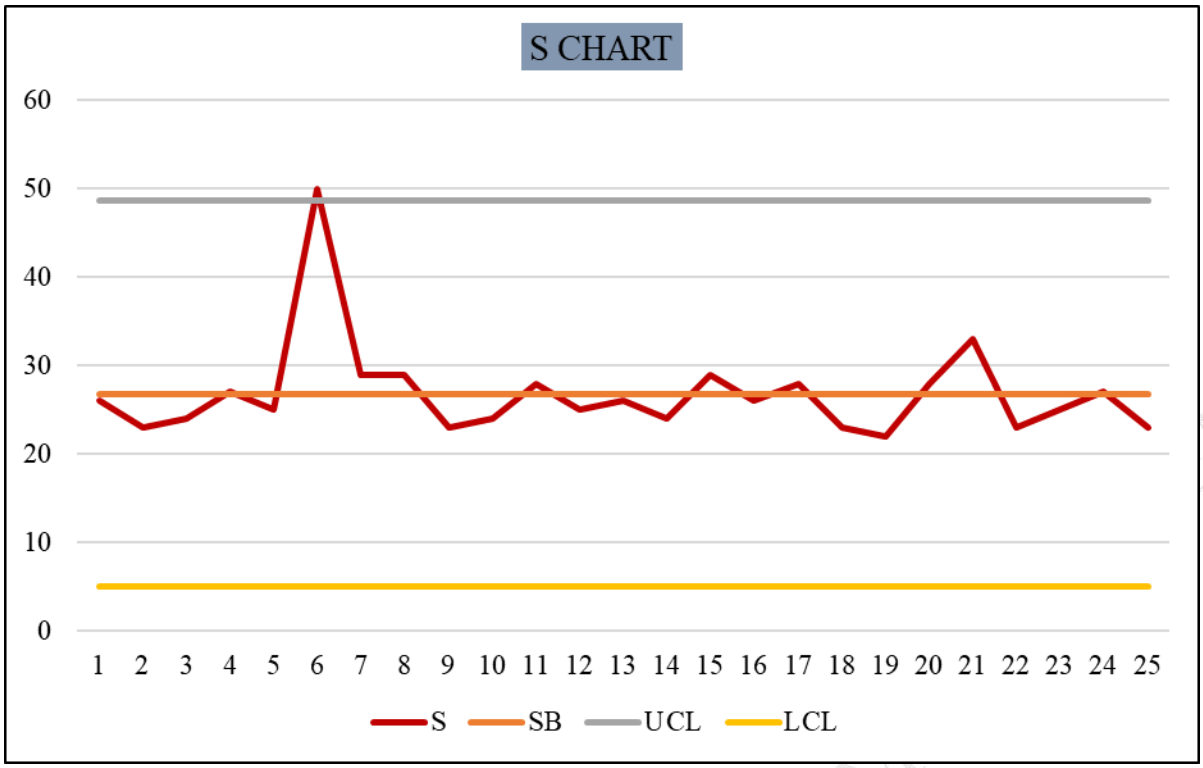
$$= 0.185 \times 26.80 = \mathbf{4.958}$$

Plotting the Control Chart using X bar – Chart



From the X Bar Chart we observed that sub groups 9 and 18 are out of control. So sub groups 9 and 18 are deleted and check for quality again.

Plotting the Control Chart using S – Chart



From the S chart we observed that sub group 6 has the special signal control i.e., out of control signal, in-order to accept the quality check we need to delete the sub group 6 and see that there is no special control signals.

Know the subgroups 6, 9 and 18 are eliminated and further the quality check will be done.

Know,

For X-Bar Chart

Control Limit, $\bar{\bar{x}} = \frac{\bar{x}_1+\bar{x}_2+\bar{x}_3+\cdots\ldots\ldots\bar{x}_k}{k}$

$$\bar{\bar{x}} = \frac{540 + 554 + 545 + 561 + 576 + 571 + 547 + 552 + 541 + 545 + 546 + 551 + 522 + 579 + 549 + 569 + 574 + +563 + 561 + 548 + 556 + 555}{22}$$

$$= \frac{12183}{22} = 553.77$$

$$\bar{\bar{x}} = 553.773$$

$$\bar{S} = \frac{\Sigma_1^k S_i}{k} = \frac{S_1 + S_2 + S_3 + \cdots S_{25}}{k}$$

$$\bar{S} = \frac{26+23+24+27+25+29+29+24+28+25+26+24+29+26+28+22+28+33+23+25+27+23}{22}$$

$$\bar{S} = \frac{574}{22} = 26.09$$

$$\bar{\bar{S}} = 26.091$$

$$UCL = \bar{\bar{X}} + A_3\bar{S}$$

$$UCL = 553.77 + (A_3 \times 26.09)\ (A_3 = 1.099 for\ sub\ group\ 8)$$

$$UCL = 553.77 + (1.099 \times 26.09)$$

$$\boldsymbol{UCL = 582.45}$$

$$LCL = \bar{\bar{X}} - A_3\bar{S}$$

$$LCL = 553.77 - (A_3 \times 26.09)\ (A_3 = 1.099\ for\ sub\ group\ 8)$$

$LCL = 553.77 - (1.099 \times 26.09)$

$$\boldsymbol{LCL = 525.10}$$

For Sigma (S) Chart

$$\text{Control Limit, } \bar{S} = \frac{\Sigma_1^k S_i}{k}$$

$$\boldsymbol{\bar{S} = 26.09}$$

$$UCL = B_4\bar{S}$$

$LCL = B_3\bar{S}$

$\bar{S}$ Chart:

Upper Control Limit, U.C.L. $= B_4\bar{S}$

$= B_4 26.09 \ (if\ B_4 = 1.815\ for\ sample\ size\ 8)$

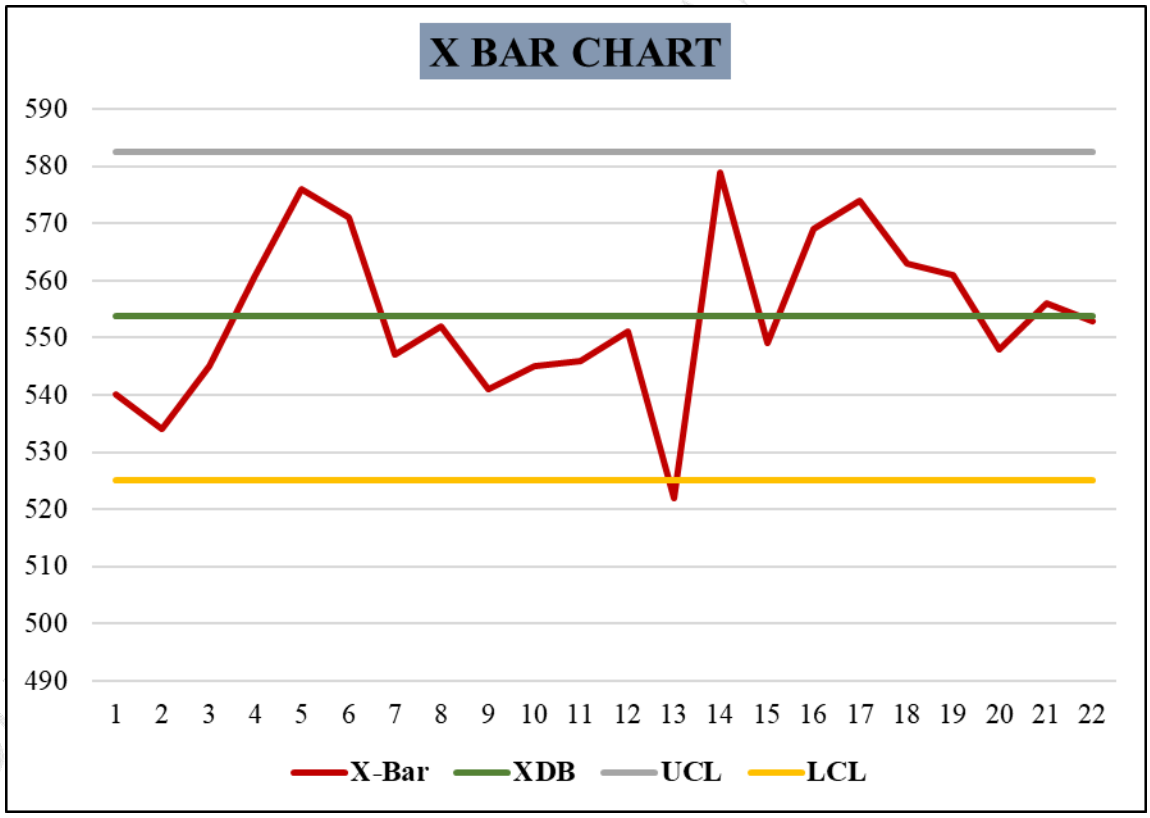
$= 1.815 \times 26.09 = 47.36$

Lower Control Limit, L.C.L. $= B_3\bar{S}$

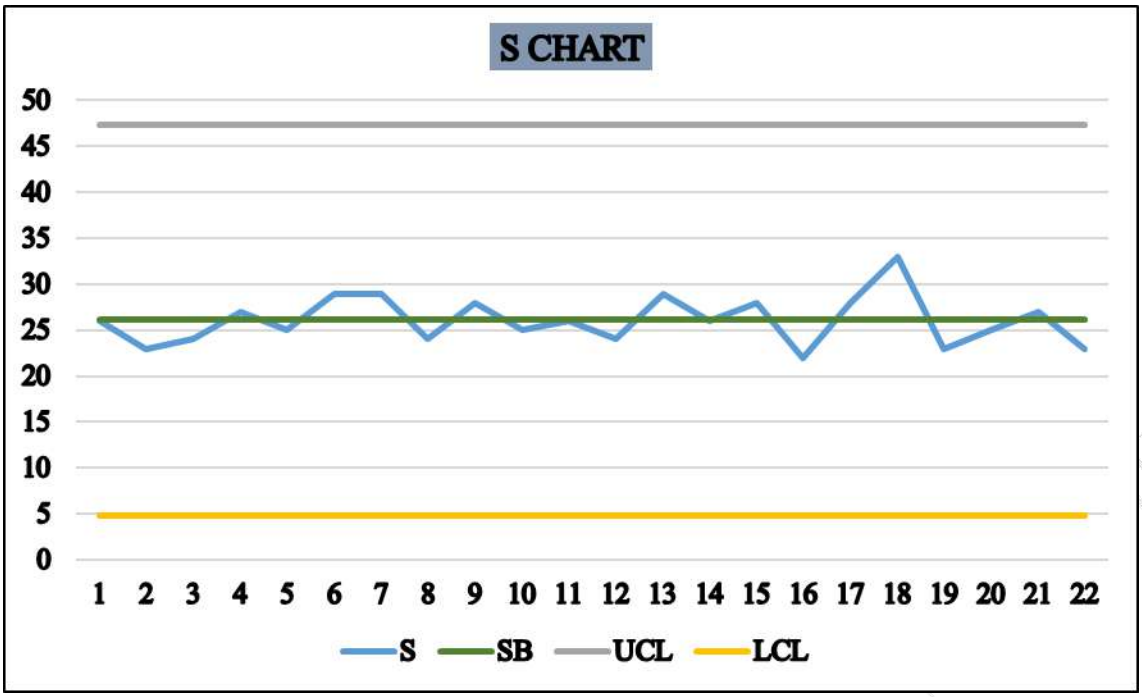
$= B_3 \times 26.09 \ (if\ B_3 = 0.185\ for\ sample\ size\ 8)$

$= 0.185 \times 26.09 = 4.827$

Plotting the Control Chart using X bar – Chart



Plotting the Control Chart using X bar – Chart



We observed that from X Bar chart sub group 13 has the special (Out of Control) signal control, so we eliminate sub-group 13 and proceed for further inspection.

Know,

For X-Bar Chart

Control Limit, $\bar{\bar{x}} = \frac{\bar{x}_1+\bar{x}_2+\bar{x}_3+\cdots\ldots\ldots\bar{x}_k}{k}$

$$\bar{\bar{x}} = \frac{540 + 554 + 545 + 561 + 576 + 571 + 547 + 557 + 541 + 545 + 546 + 551 + 579 + 549 + 567 + 574 + 563 + 561 + 548 + 556 + 553}{22}$$

$$= \frac{12183}{21} = 553.77$$

$$\bar{\bar{x}} = 553.77$$

$$\bar{S} = \frac{\Sigma_1^k S_i}{k} = \frac{S_1 + S_2 + S_3 + \cdots S_{25}}{k}$$

$$\bar{S} = \frac{26+23+24+27+25+29+29+24+28+25+26+24+26+28+22+28+33+23+25+27+23}{21}$$

$$\bar{S} = \frac{574}{21} = 26.09$$

$$\bar{S} = 26.09$$

$$UCL = \bar{\bar{X}} + A_3\bar{S}$$

$$UCL = 553.77 + (A_3 \times 26.09)\ (A_3 = 1.099 for\ sub\ group\ 8)$$

$$UCL = 553.77 + (1.099 \times 26.09)$$

$$\boldsymbol{UCL = 582.45}$$

$$LCL = \bar{\bar{X}} - A_3\bar{S}$$

$$LCL = 553.77 - (A_3 \times 26.09)\ (A_3 = 1.099\ for\ sub\ group\ 8)$$

$$LCL = 553.77 - (1.099 \times 26.09)$$

$$\boldsymbol{LCL = 525.10}$$

For Sigma (S) Chart

Control Limit, $\bar{S} = \frac{\Sigma_1^k S_i}{k}$

$$\bar{S} = 26.09$$

$$UCL = B_4\bar{S}$$

$LCL = B_3\bar{S}$

$\bar{S}$ Chart:

Upper Control Limit, U.C.L. $= B_4\bar{S}$

$= B_4 26.09$ $(if\ B_4 = 1.815\ for\ sample\ size\ 8)$

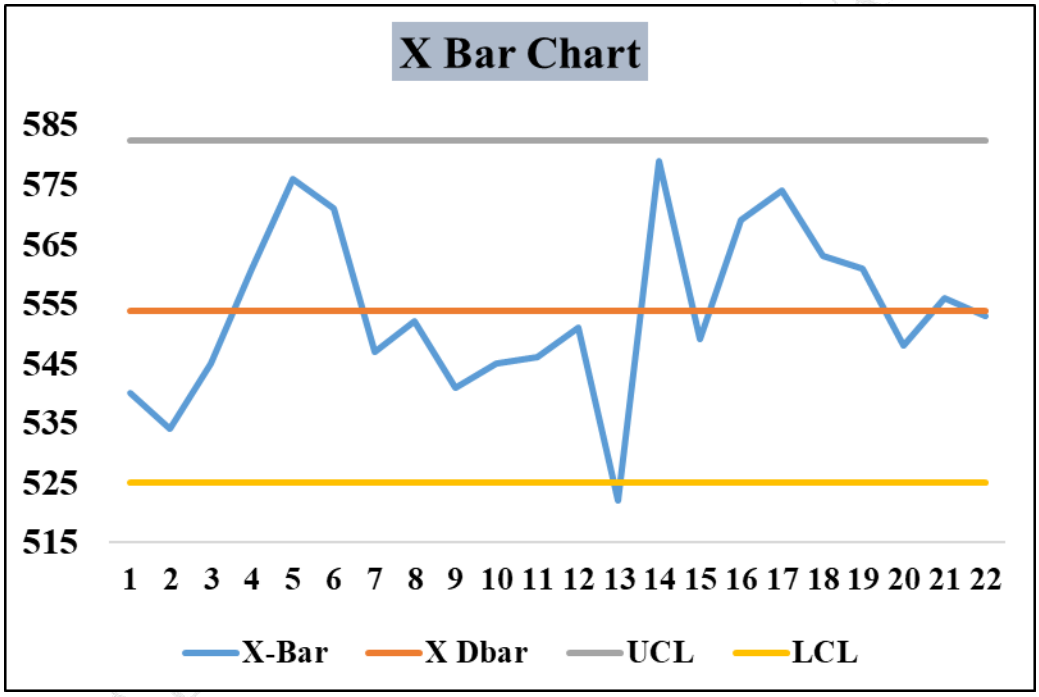
$= 1.815 \times 26.09 = 47.36$

Lower Control Limit, L.C.L. $= B_3\bar{S}$

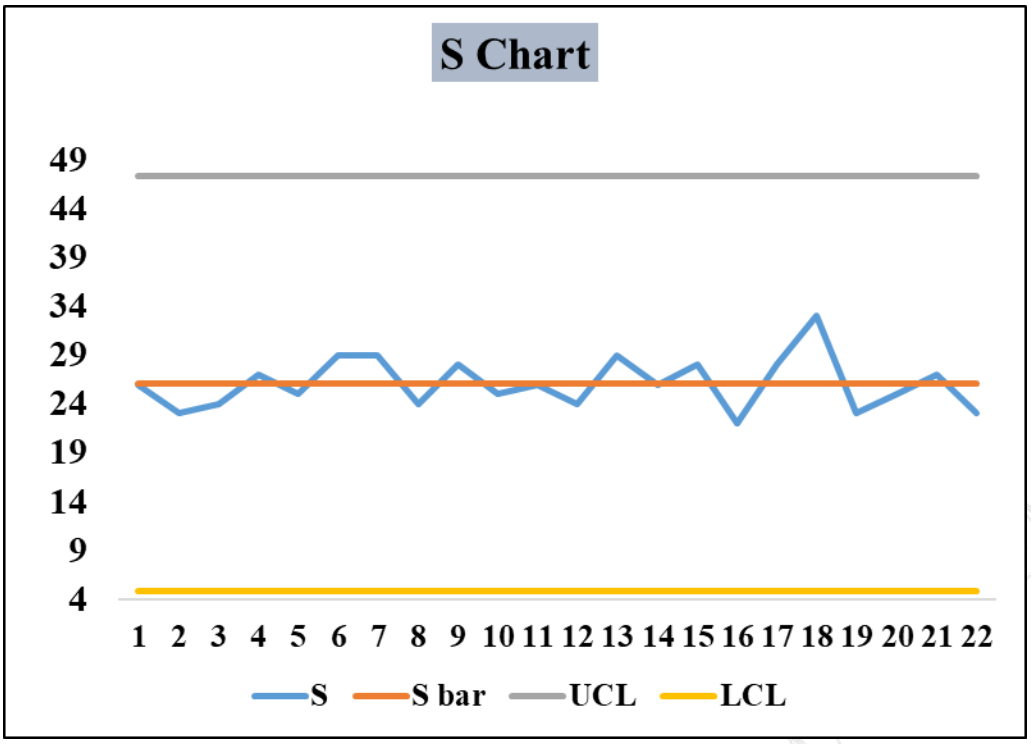
$= B_3 \times 26.09$ $(if\ B_3 = 0.185\ for\ sample\ size\ 8)$

$= 0.185 \times 26.09 = 4.827$

Plotting the Control Chart using X bar – Chart



Plotting the Control Chart using X bar – Chart



We observed that from X Bar chart sub group 13 has the special (Out of Control) signal control, so we eliminate sub group 13 and proceed for further inspection.

SAMPLING INSPECTION:

Sample: It is defined as the number of items or components, parts, drawn from a lot, batch or population (for inspection purpose)

Statistical method of obtaining representative data or observations from a group (lot, batch, population, or universe).

With a single grain of rice, an Asian housewife tests if all the rice in the pot has boiled; from a cup of tea, a tea-taster determines the quality of the brand of tea; and a sample of moon rocks provides scientists with information on the origin of the moon. This process of testing some data based on a small sample is called sampling.

Inspection: Any item or component or product which is manufactured is required to perform certain functions. The act of checking whether component or part actually does so or not is called inspection. In other words, inspection means checking the acceptability of the manufactured product.

Sampling: Sampling is an act of drawing samples from a batch on random basis. Sampling depends upon statistical probability and therefore samples must be collected from all sides and different depths of the box containing the lot or batch, so that every part has an equal chance of being selected. The samples should be collected at regular intervals (say every hour, every four hour, every day, selected).

Sampling Inspection: It is a technique to determine whether a lot or population should be rejected or accepted on the basis of the number of defective parts found in a random sample drawn from the lot.

TYPES ACCEPTANCE SAMPLING PLANS

1) Lot by Lot - Single Sampling

2) Lot by Lot - Double Sampling
3) Continuous Sampling
4) Sequential Sampling

2) <u>Lot by Lot - Single Sampling:</u>

- A lot size (N) of product is delivered to the quality check or inspection position.
- A sample size (n) is selected randomly from the lot.
- If the number of defects or defectives in the sample exceed the acceptance number (c or AN), the entire lot is rejected.
- If the number of defects or defectives in the sample does not exceed the acceptance number, the entire lot is accepted.
- Rejected lots are usually detailed 100% for the requirements that caused the rejection.
- In some cases the lot may be scrapped.
- Accepted lots are screened, rejected lots are sent to their destination. The rejected lots may be submitted for re-inspection.

Or

They are the number of items to be sampled (n) and a pre-specified acceptable number of defects (c). If there are fewer or equal defects in the lot than that of the acceptance number **c**, and then the whole batch will be accepted. If there are more than c defects, the whole lot will be rejected or subjected to 100% screening.

3) <u>Lot by Lot - Double Sampling:</u>

- A lot size (N) of product is delivered to the quality check or inspection position.
- Two sample sizes (n1, n2) and two acceptance numbers (c1, c2 or AN1, AN2) are specified.

A first sample of size n1 is taken.

- If the number of defects or defectives in the first sample exceed c1, the lot is rejected and a second sample is not taken.
- If the number of defects or defectives in the first sample do not exceed c1, the lot is accepted and a second sample is not taken.
- If the number of defects or defectives in the first sample are more than c1 but less than or equal to c2, a second sample n2 is selected and inspected.

If a second sample is inspected:

a) And defects or defectives in combined first and second sample do not exceed c2, the lot is accepted.
b) And defects or defectives in combined samples exceed c2, the lot is rejected.
   i. Rejected lots are detailed or scrapped.
   ii. Accepted lots and detailed rejected lots are sent to their destination

Or

Often a lot of items is so good or so bad that we can reach a conclusion about its quality by taking a smaller sample than would have been used in a single sampling plan. If the number of defects in this smaller sample (of size n1) is less than or equal to some lower limit (c1), the lot can be accepted. If the number of defects exceeds an upper limit (c2), the whole lot can be rejected. But if the number of defects in the n1 sample is between c1 and c2, a second sample (of size n2) is drawn. The cumulative results determine whether to accept or reject the lot. The concept is called double sampling.

4) Continuous Sampling:

- Continuous sampling is used where product flow is continuous and not feasible to be formed into lots.
- Two parameters are specified in a continuous sampling plan. The first is the frequency of checking f and the second is the clearing number i. The frequency f is expressed as 1/10, 1/20, 1/X, etc. and i is a number such as 20 or 50.
- When inspection begins, the product is checked 100% until i parts are found to be defect free. At this time, one out of X shall be inspected. If f = 1/10, then one out of 10 parts will be checked. The sampling will continue until a defect is found. When a defect is found, 100% inspection shall resume and the cycle starts over. When i parts are found to be defect free, the sample 1/X shall start again.
- In most cases, the inspector will not perform the 100% inspection. The inspector will mark the last sampled part and the manufacturing department will perform the 100% inspection or detailing operation.

5) Sequential Sampling:

- The inspector will select one part from the lot and check for the specified requirements.
- The part is classified as good or defective.
- A chart is specified for various sequential sampling plans. The required quality levels determine the acceptance, rejection, and continue sampling regions on the chart. The chart shows the inspector what decision to make after each sample is inspected. The lot will either be accepted rejected or another sample will be taken. This procedure is done on a lot by lot basis. The advantage of this type of sampling plan is that a decision could be made based on a relatively small sample.
- Rejected lots are detailed 100% (usually by the manufacturing department). Accepted and screened rejected lots are sent to their destination.

Or

Multiple sampling is an extension of double sampling, with smaller samples used sequentially until a clear decision can be made. When units are randomly selected from a lot and tested one by one, with the cumulative number of inspected pieces and defects recorded, the process is called **sequential sampling**

TOTAL QUALITY MANAGEMENT

INTRODUCTION

Total Quality Management (TQM) is a comprehensive concept and not related only to the quality of goods and services. It suggests that high quality standards (e.g., ISO 9000) should be maintained in other aspects of management such as production cost, marketing, sales promotion, etc. For such quality/efficiency in all aspects of business management, consciousness/awareness needs to be developed at all levels and among employees working in all departments of the enterprise. Employees must be motivated for maintaining high quality standards. In addition, their cooperation/involvement is necessary for maintaining efficiency in all aspects of business management. In brief, quality management is not the responsibility of management alone. Participation/involvement of both parties (management and employees) is essential for achievement of quality and other benefits.

The concept of TQM is closely related to the concept of quality circles which is very popular and also successful in Japan. Quality circles are work groups that meet frequently to study the ways and means to improve quality, reduce cost, eliminate wastages and solve other production problems. Here, employees are associated with quality, cost, efficiency, productivity, consumer service and satisfaction. This creates background for the concept of TQM.

TQM reflects the culture of an Organisation. It indicates consumer oriented, quality-oriented management philosophy. It is a commitment to quality by all managers and workers. TQM is a philosophy for achieving customer satisfaction which involves all - managers, employees and users. It is management by commitment and not management by control. This technique is to be introduced through quality circles. The route to TQM is through application of simple tools followed by Organisation change and culture change.

Total quality management is based on the following four powerful elements:

1) Focus on customer expectations,
2) Employee's involvement,
3) Mastery of process's
4) Team Work.

Focus on Customers:-Customers are the source of all the revenue that flows through the corporation. Their satisfaction keeps the money flowing especially in an open market where competitors are wooing them too. The focus of TQM is on customer satisfaction on quality, cost and delivery through improved organisational quality of processes. According to British Quality Association (BQA), TQM is a corporate business management philosophy which recognised that customer's needs and business goals are inseparable.

Employee Involvement:-Employees involvement is the most important recognised feature of TQM. In fact, quality is a team work of all employees. Their participation and co-operation are required to be taken at all levels. TQM is possible only through participative management. Under TQM, employees will be motivated to participate actively in the process of quality improvement through incentives and recognition of contribution for achieving quality standards.

Formation of Quality Improvement Teams:-A cornerstone of TQM is the team building that leads to commitment to improvement. Such teams include quality steering teams, corrective actions teams and so on. Such teams motivate employees and facilitate quality improvement.

Management's Involvement:-TQM is a systems approach in managing business and improving overall performance. It needs total commitment from the top management to provide viable leadership to the whole approach. Top level management has to take number of initiatives in order to start the process of TQM. In fact, TQM cannot have a good take off without total commitment of CEO and other senior executives.

BENEFITS OR ADVANTAGES OF TQM:

- **Customer Satisfaction:**-TQM is basically for the satisfaction and welfare of customers. Needs and expectations of customers are given special attention in TQM. The attention is on customers and zero defect goods will be supplied to them. As a result, there will be reduction in the complaints of consumers/customers. TQM is not for profit-making at the cost of customers but it is for giving satisfaction and welfare to them.
- **Quality Improvement:**-One major advantage of a TQM is quality improvement at all levels and in all activities. There is a systematic attempt to eliminate deficiencies such as production scrap or rework, customer complaints and material shortages. The cornerstone of any successful TQM system is the organised elimination of waste. The rejection rate in the production process will be low and this minimizes waste of materials and human efforts. Due to quality improvement, the sales and profits will also increase. The company will also develop goodwill and market recognition as supplier of quality goods.
- **Absence of Additional Investment:**-One advantage of TQM is that TQM does not require any additional investment. It improves operational quality as well as reduces cost. This technique is quite convenient to developing countries which are facing financial difficulties due to various reasons. TQM gives many benefits but without additional financial burden.
- **Raises Competitiveness:**-TQM technique is useful for raising quality and reducing costs. This naturally raises competitiveness in the domestic as well as global markets. TQM technique is useful for exports by raising global competitiveness.
- **Facilitates Expansion and Diversification:**-TQM leads to large turnover and high profits along with market reputation and consumer support. The company can use this profit for the execution of its expansion and diversification programmes. In brief, TQM facilitates expansion and diversification of business.
- **Provides Trained and Motivated Employees:**-TQM philosophy has its positive impact on employees. They are given proper training, monetary and non-monetary incentives, attractive working conditions and proper treatment. Workers take pride in manufacturing defect-free products.

Miscellaneous Advantages: TQM technique offers other advantages as noted below:

- Long-term consumer support,

- ❖ Prestigious position in international marketing,
- ❖ High standard of living to employees, and
- ❖ Cost control.

ZERO DEFECTS

Introduction

Philip B. Crosby was an eminent Quality Guru, born in 1926, began his quality career as a reliability engineer. He later participated in the Martin missile experience that spawned the genesis of the Zero Defect movement. He worked in Quality Management for 14 years in ITT as a Corporate Vice President and Director Quality. In 1974 he published Quality is Free, which became a bestseller. In response to the interest shown in the book, he left his organization that year to set up Philip Crosby Associates Incorporated.

Philip B. Corsby published his second best seller, Quality without Tears, in 1979. Other books associated with his name are

- ❖ The Art of Getting Your Own Sweet Way
- ❖ More Things
- ❖ The Eternally Successful Organization and Leading
- ❖ The Art of Becoming and Executive

Do It Right First Time (DIRFT) and Zero Defect

Corsby is very much popular for these two concepts named as **Do It Right First Time and Zero Defects**.

The concept of Zero Defect (ZD) promotes a constant, conscious desire to do a job right the first time [Halpin, 1966], where the performance of the individual have a crucial role. A way to efficient performance is by constant awareness; where the workers task is important, the product the worker is working on is important and the effort by the worker is not neglected by the management. To strive against the concept Zero Defect five requirements must be fulfilled. In theory it describes the ideal state but in reality the process is confronted with different kinds of disturbances increasing the risk of errors in manufactured products.

1) The right Sourcing – Concerning the quality of the purchased components, products or material.
2) The right Process and Technology – Accentuate the requirements on accomplishing key activities i.e. Process Improvement and Tooling Management.
3) The right Service and Support Systems – Focusing on support functions in manufacturing channels or cells.
4) The right People – Educating and developing personnel, competent staff can prevent more that defects occurs comparing to the installation of a new process or device.
5) The right Organization and Methods – Concentrate on the organization and management that operates the manufacturing process. Careful guidance and directions to increase efficiency of the employee on a day to day basis.

DEFINITION

It is a management tool aimed at the reduction of defects through prevention. It is directed at motivating people to prevent mistakes by developing a constant, conscious desire to do their job right the first time."

"The quality manager must be clear, right from the start, that zero defects is not a motivation program. Its purpose is to communicate to all employees the literal meaning of the words 'zero defects' and the thought that everyone should do things right the first time."

Corsby **defined the quality as the conformance** to the requirements which the company itself has established for its products based upon the customer's needs. He believes that most companies have systems that allow deviation from actual requirement. The cost that they spend on doing the wrong things right in subsequent chances is 20% of their revenue in manufacturing companies and 35% of operating expenses for service companies. He believed that workers should not be the prime responsible for the poor quality, in fact Management set the standard of quality and workers follow them therefore the initiative comes from the top. Doing things right first time will not prevent people from making mistakes, but will encourage everyone to improve continuously. He strongly emphasized on the top- down approach, since he believes that senior management is entirely responsible for quality. The ultimate goal is to train all the staff and give them the tools for quality improvement, to apply the basic precept of Prevention Management in every area.

PRINCIPLES OF ZERO DEFECTS

Quality is conformance to requirements:-Every product or service has a requirement according to the customer needs. If these requirement are achieved by the product when comes to use of the customer then this product categorize as the quality product. for example if low cost Ink pen full fill the requirement of writing without any blot and skip on the paper then it is called the quality product in comparison of the a precious gold plated pen if it will not write good and neat on the paper. Hence if a product meets the requirement of the customer then it conforms the quality of the product, no matter how costly it is.

Defect prevention is preferable to quality inspection and correction:-It is better to prevent the defect at its origin rather to inspect it in the process and then correct it. It saves lot of human power and cost of inspection and correction. For example If a person changes the poor condition brake shoes of his bike before next riding then it will prevent lot of energy of the rider and reduce the risk of accident on the road and generation of new defect in the bike due to poor condition brake shoes which observed later and needs the correction and in turn of high cost of repair.

Standard of Quality is always be ZERO DEFECT, not close enough:-If any product does not meet the requirements then the product is not the quality product even if it close to meet the requirement, because on the basis of Zero Defect any non-conformance is not, for granted. The product is not acceptable and categorize as under quality product.

Quality is measure on the basis of Price - Price of Non Conformance (PONC):-This is the key principle, Crosby's believed that every defect incur a cost. To find and correct and prevent this defect organization introduces many steps like Inspection, Time, Rework, Scrape, Collection of data of customer satisfaction etc. All these steps required a huge amount of money and so lot of revenue has lost to maintain all steps to prevent the defects and therefore to maintain the Quality, cost must considered. Every non-conformance contributes a cost in terms of loss of revenue due to it.

QUALITY CIRCLE (QC)

INTRODUCTION

Quality Circles are usually characterized as small, voluntary groups of employees set up to meet periodically for such practical purposes as: Pinpointing, examining, analyzing and solving problems in areas including knowledge management, innovation, work relations, quality, productivity, safety, cost, etc.

Enhancing communication between employees and management on the above areas Quality Circles can only thrive if management will take action on the recommendations of the Circle. When the management has no interest in participation as is often the case, the Circles simply disintegrate.

Dewar, President of the International Association of QCs, defines QCs as "a way of capturing the creative and innovative power that lies within the work force"

A quality circle is a small group of volunteers (usually 3 to 12 employees) doing similar work. They meet regularly under the leadership of their immediate supervisor, or some one chosen among the circle to identify problems, set priorities, discover causes and propose solutions. These may concern quality, productivity, safety, job structure, process flow, control mechanism, aesthetics of the work area etc.

According to Maurice Alston,

"Quality Circles are small groups of people doing similar work who, together with their supervisors volunteer to meet for an hour a week to study and solve work related problems which affect them. Circle leaders and members are trained in simple problem solving techniques which identify causes and develop solutions. At an appropriate time, presentations are made by the quality circles to the management who decide whether to accept, modify or decline the proposals"

Quality Circle is a participative management system in which workers make suggestions and improvements for the betterment of organisation

DEFINITION:

A Quality Circle typically is a small group of volunteers consisting of first-line employees who meet regularly to identify, analyze and solve problems in their area of work to continually improve the quality, productivity and related issues of their work, products and services. These Small groups:-Operate autonomously, Utilize quality control Concepts and Techniques and other Improvement tools, Tap members' creativity and promote self and mutual development. The Size of the QC group should be 7(max.) including facilitator (No. of executives in the QC group should not exceed 2 including facilitator). It can be more than two, for the departments where executive strength is considerably more.

CONCEPT OF QUALITY CIRCLE:

The Quality Circle concept has three major attributes; these are:

1) QC is a form of participative management.
2) QC is a human resource development technique.
3) QC is a problem solving technique.

OBJECTIVES OF QUALITY CIRCLES:

- To improve the quality and productivity and thus contribute to the improvements and development of the enterprise.
- To reduce the cost of products or services by waste reduction, safety, effective utilisation of resources, avoiding unnecessary errors and defects.
- To identify and solve work related problems those interfere with production.
- To tap the creative intelligence of the persons working in the organization and to make full use of its human resources.
- To permit employees to develop and use greater amount of knowledge and skill and motivate them to apply to a wide range of challenging tasks.
- To improve communication within the organization.
- To increase employees' loyalty and commitment to the organization and its goals.
- To respect humanity and build a happy bright work place environment which is meaningful to work in.
- To enrich human capability, confidence, moral, attitude and relationship.
- To satisfy the human needs of recognition, achievement and self-development.

ADVANTAGES OF QUALITY CIRCLES:

- Promote high level of productivity and quality-mindedness.
- Self and mutual development of employees.
- Creating team spirit and unity of action.
- Increased motivation, job satisfaction and pride in their work.
- Reduced absenteeism and labour turnover.
- Developing sense of belongingness towards a particular organization.
- Waste Reduction.

- Cost reduction.
- Improved communication.
- Safety improvement.
- Increased utilization of human resource potential.
- Enhancement in consciousness and moral of employees through recognition of their activities.
- Leadership development.
- Trained staff.

DISADVANTAGES/PROBLEMS WITH QC:

- Inadequate Training
- Unsure of Purpose
- Not truly Voluntary
- Lack of Management Interest
- Quality Circles are not really empowered to make decisions.

ISO QUALITY SYSTEM:

It is the system that an organisation uses to manage the quality of their services or products. Quality management systems are only one type of management system; other examples include financial management systems, safety management systems and environmental management systems.

The official definition of a quality system from **ISO** (the International Organization for Standardization) is *"The management system used to direct and control an organization with regard to quality".* But that's a bit of a mouthful, and not overly clears (as with many of their definitions).

Think of it as the system that your company uses to plan, create, develop, make and/or deliver your services or products.

A quality management system consists of various elements.

ISO 9001 groups them into 4 categories:

⇒ ***Management:*** Planning, goals & objectives, reviewing progress.

⇒ ***Resources:*** People, tools, equipment etc.

⇒ ***Services or Products "realization"*:** Whatever is involved in creating or delivering them, and lastly the

⇒ ***Monitor, Measurement & Checking*:** The all-important feedback loop.

Quality is something every company strives for and is often times very difficult to achieve. Complications concerning efficiency and quality present themselves every day in business, whether an important document cannot be found or a consumer finds a product not up to their expectations. How can a company increase the quality of its products and services? The answer is ISO 9000.

As standards go, ISO 9000 is one of the most widely recognized in the world. ISO 9000 is a quality management standard that presents guidelines intended to increase business efficiency and customer

satisfaction. The goal of ISO 9000 is to embed a quality management system within an organization, increasing productivity, reducing unnecessary costs, and ensuring quality of processes and products.

ISO 9001:2008 is applicable to businesses and organizations from every sector. The process oriented approach makes the standard applicable to service organizations as well. Its general guidelines allow for the flexibility needed for today's diverse business world.

ISO 9000 PRINCIPLES:

A Customer Focus:-As stated before, the customer is the primary focus of a business. By understanding and responding to the needs of customers, an organization can correctly targeting key demographics and therefore increase revenue by delivering the products and services that the customer is looking for. With knowledge of customer needs, resources can be allocated appropriately and efficiently. Most importantly, a business's dedication will be recognized by the customer, creating customer loyalty. And customer loyalty is return business.

Good Leadership:-A team of good leaders will establish unity and direction quickly in a business environment. Their goal is to motivate everyone working on the project, and successful leaders will minimize miscommunication within and between departments. Their role is intimately intertwined with the next ISO 9000 principle.

Involvement of People:-The inclusion of everyone on a business team is critical to its success. Involvement of substance will lead to a personal investment in a project and in turn create motivated, committed workers. These people will tend towards innovation and creativity, and utilize their full abilities to complete a project. If people have a vested interest in performance, they will be eager to participate in the continual improvement that ISO 900 facilitates.

Process Approach to Quality Management:-The best results are achieved when activities and resources are managed together. This process approach to quality management can lower costs through the effective use of resources, personnel, and time. If a process is controlled as a whole, management can focus on goals that are important to the big picture, and prioritize objectives to maximize effectiveness.

Management System Approach:-Combining management groups may seem like a dangerous clash of titans, but if done correctly can result in an efficient and effective management system. If leaders are dedicated to the goals of an organization, they will aid each other to achieve improved productivity. Some results include integration and alignment of key processes. Additionally, interested parties will recognize the consistency, effectiveness, and efficiency that come with a management system. Both suppliers and customers will gain confidence in a business's abilities.

Continual Improvement:-The importance of this principle is paramount, and should a permanent objective of every organization. Through increased performance, a company can increase profits and gain an advantage over competitors. If a whole business is dedicated to continual improvement, improvement activities will be aligned, leading to faster and more efficient development.

Ready for improvement and change, businesses will have the flexibility to react quickly to new opportunities.

Factual Approach to Decision Making:-Effective decisions are based on the analysis and interpretation of information and data. By making informed decisions, an organization will be more likely to make the right decision. As companies make this a habit, they will be able to demonstrate the effectiveness of past decisions. This will put confidence in current and future decisions.

Supplier Relationships:-It is important to establish a mutually beneficial supplier relationship; such a relationship creates value for both parties. A supplier that recognizes a mutually beneficial relationship will be quick to react when a business needs to respond to customer needs or market changes. Through close contact and interaction with a supplier, both organizations will be able to optimize resources and costs.

SIX-SIGMA:

EVOLUTION OF SIX SIGMA:

- The concept of Six -Sigma quality evolved Motorola Corporation USA in late 70's.
- **Mikel J. Hary,** introduced the concept of Six Sigma to Motorola. It based on statistics.
- Its evolution was the result of **Bob Galvin's expectations the CEO of Motorola Corporation** in 1981 in order to effect a tenfold improvement in product failure levels over a 5 year period.
- **Bill Smith**, an engineer of company, who is now called father of Six-Sigma conducted a statistical correlation between life of the product and the defect detected during the manufacturing of the product.
- He conducted that if a product has been found defective and corrected during the production process, chances were high that other defects had been missed and would show up later during usage.
- **Mikel J. Hary** suggested that breaking down and studying processes is a key element of result oriented quality programs. This helps in tracking down the root cause of defects.
- Hence Six Sigma was evolved by **Bill Smith and Mikel J. Hary** as a 6 Step methodology with focus on defect reduction and improvement in yield through statistics.
- UN till 1994, Six Sigma remains within the boundary of Motorola. Motorola reported $16 billion saving in 10 years of implementation of Six Sigma. Outer world know about Six- Sigma but not how to implement it. Now it has adopted by approx. more 50% organization in the world.

WHAT IS SIGMA?

- We all know about the average and also working with it in professional as well as general life like average income, average height, average marks, average weight etc. This average is the number which represents whole group of numbers and can be find out as follows **Average or Mean Value=(Sum of all values / No. of values)**
- Each value in the group has certain distance from the mean value. This distance is called the deviation of the value from its mean.
- When we calculate the deviation for the whole group we call it **Standard Deviation or Sigma.**

- Hence Sigma represents the **Standard Deviation** which is used to measure the spread of any process from its mean value.
- If the value of Sigma increases this means the deviation of the process from the mean value increases. Therefore the value of Sigma must be as low as possible.

STANDARD DEVIATION (σ):

Standard deviation is defined as the square root of the arithmetic mean of the squares of the deviation of the values taken from the mean and is calculated as follows

$$\sigma = \sqrt{\frac{\Sigma(X - \bar{X})^2}{N}}$$

Also called root mean square deviation and denoted by small Greak letter **"σ"** and read as sigma.

SIX-SIGMA SCALE

One more important thing is the number in front of Sigma tells the Sigma level. As much as the process comes in our control the possibility of defect occurrence goes down and Sigma level goes up. Hence at Six Sigma level the possibility of defect occurrence is very low. The fig. of Six Sigma Scale shown below explains clearly.

Six Sigma Scale

Sigma Level	Defect Rate (PPM)	Yield in %	Cost of Poor Quality (% of Sales)	Competitive Level
6σ	3.4	99.99966	<10%	World Class
5σ	233	99.9767	10 to 15%	
4σ	6210	99.3790	15 to 20%	Industry Average
3σ	66807	93.3193	20 to 30%	
2σ	308537	69.1462	30 to 40%	Non-Competitive
1σ	690000	.....	74%	

WHY SIX SIGMA FOUND PLACES SO QUICKLY?

After open to the world Six-Sigma fixed its place very quickly. It has a strong reason which shown in the Six Sigma scale. Some of them are mentioned below.

- It is result oriented.
- It makes the organization more competitive.
- It increases the customer satisfaction.

- ❖ It is cost saving.
- ❖ It smooth's the process.
- ❖ It reduces the defect occurrences.

Above all Six Sigma counted the defect in number per million rather in percentage. I would like to clear it by this example. Suppose Vendor A and Vendor B offers to supply the cap of a pen to a pen manufacturing company Say 'C'. Vendor A commit that the Lot of Caps he will send has 99.3790% pcs OK and Vendor B commit that the lot he will send has 99.9767 % pcs OK but he will charge little more than the Vendor A. Which Vendor will be selected by the Manufacturer C? If cost is taken into consideration then Vendor A will be selected because in terms of OK percentage it is very small difference but on the basis of Six Sigma Vendor A supplying 6210 defective pcs per million and working at 4Sigma level while Vendor B supplying 233 defective pcs per million and working on 5 Sigma level. So the difference of defective pcs are very high but it is not reflected in percentage scale and for every defective pc of Cap the pen manufacturer has to bear the cost of defective pen which in turn will go very high. So on the basis of Six Sigma Scale the Manufacturer should select the Vendor B. This will certainly save the cost and reduce the customer complaints of the manufacturer and return a high profit margin and goodwill.

Few Definitions for Six-Sigma

"In layman language , Six Sigma is 3.4 defects per million i.e. if an organization produces 1 million of its products and 3.4 pcs are found defective out of 1 million then the organization follows the 6 Sigma standard, defects per million is the indicator of Six Sigma standard."

Few more advanced definitions are below

According to Dr. Mikel J. Harry, CEO of Six Sigma Academy, Phoenix USA:

1) Six-Sigma is a statistical measurement, which helps us establish our course and gauge our pace in the race for total customer satisfaction. It tells us how good our products, services and processes really are. It allows us to draw comparisons with other similar or dissimilar products, services and processes. We can see where we need to go and what we must do to get there.
2) It is a business strategy which makes the customers more satisfied. It can greatly help us to gain competitive edge. This is because, as we improve the sigma rating of the process, the product quality improves and costs go down.
3) It is a philosophy. It is an outlook, a way that we perceive and work within the business world around us. Essentially, the philosophy is one of working smarter, not harder. This translates to making fewer and fewer mistakes in everything we do. from the way we manufacture products to the way we fill out a purchase order. As we discover and neutralize harmful sources of variation, our sigma rating goes up. Again this means our process capability improves and the defects (mistakes) go away.

According to Mr. Jack Weich, the CEO of the General Electric Co., USA:

1) Six-Sigma is a disciplined Quality Improvement methodology that focuses om moving every process that touches the customers --every product and service--towards near perfect quality. It is measure of the company's quality.
2) Six Sigma is more than a quantitative statistical measure of processes; it embraces every aspect of work, using a disciplined, fact based approach to problem--solving. It is a new way of thinking about work and customer value. It is also a powerful force to create one corporate culture, some of it is bureaucracy busting -pushing down decision -making to lowest practical levels, empowering employees. At the other end i.e. more complicated challenges-including lean manufacturing initiatives and variability reduction.

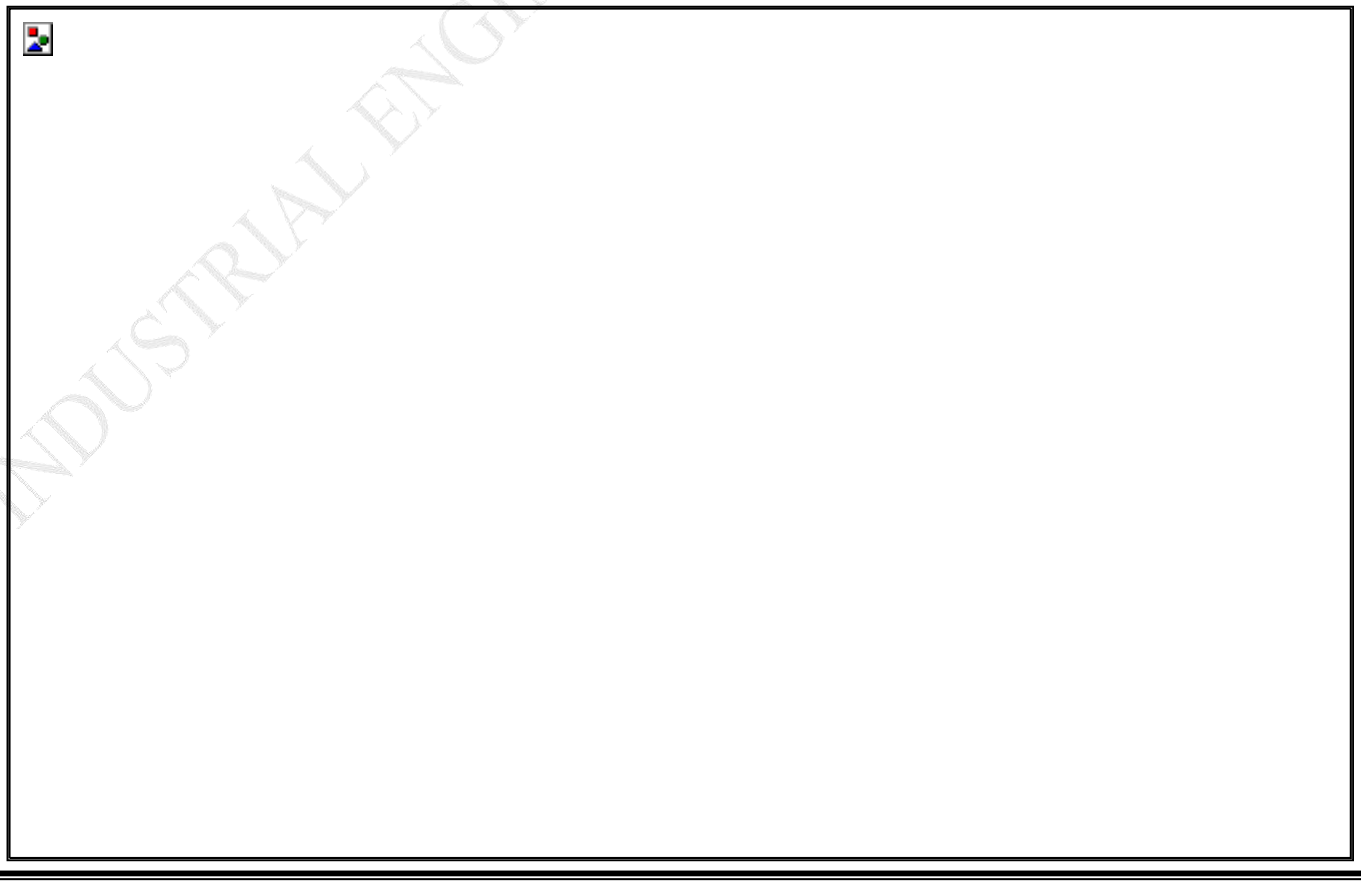
For successful implementation of Six Sigma, the company should be:

- ❖ Open to change
- ❖ Hungry to learn
- ❖ Anxious to move quickly to good Idea.

IMPLEMENTATION/PROCESS OF SIX-SIGMA:

Six-Sigma is implemented by the **DMAIC** methodology which mentioned here. The fig. shows the **DMAIC** Stair i.e. the Steps of **DMAIC methodology** through which the Six Sigma project progress. The Steps are

1) Define
2) Measure
3) Analysis
4) Improve
5) Control



Understanding DMAIC methodology

DMAIC methodology is the way through which the Six Sigma project progress. All steps of DMAIC methodology is explained briefly as below.

- **Define:**-Define is the first step in which the problem/opportunity is clearly identified. If the problem is solved or get rid then how much benefit to the organization in terms of profit margin or cost saving?
- **Measure:**-The second step is ranking of opportunities on basis of risk priority i.e. impact and effort.
- **Analysis:**-This is the step at which new goals are set and the road are prepared for cover the distance from the current level to the target level. Statistical tools as well as conventional quality techniques like Brainstorming, Root -cause Analysis, Fishbone Diagram, Pareto analysis etc. may be used for carrying out the analysis.
- **Improvement:**- At this step we measure how much we improve from our current sigma level and how much we have to improve to achieve the desired level.
- **Control:**-This is the last step here we record all improvements and parameters otherwise we lost the control over the target achievement and go back to previous stage. So control means document the all parameters and makes it as a new system.

The objective of **Six Sigma quality** is to reduce process output variation so that on a long term basis, which is the customer's aggregate experience with our process over time, this will result in no more than **3.4 defect parts per million (i.e. 10 lakhs) (PPM) opportunities (or 3.4 defects per million opportunities – DPMO). F**or a process with only one specification limit (upper or lower), this results in six process standard deviations between the mean of the process and the customer's specification limit (hence, Six Sigma). For a process with two specification limits (upper and lower), this translates to slightly more than six process standard deviations between the mean and each specification limit such that the total defect rate corresponds to equivalent of six process standard deviations.

ADVANTAGES OF SIX-SIGMA:

(1) Six Sigma is driven by the customer and thus aims to achieve maximum customer satisfaction and minimizing the defects. It targets the customer delight and new innovative ways to exceed the customer expectations.

(2) Implementation of Six Sigma methodology leads to rise of profitability and reduction in costs. Thus improvements achieved are directly related to financial results.

(3) Six Sigma is successfully implemented in virtually every business category including return on sales, return on investment, employment growth and stock value growth.

(4) Six Sigma targets Variation in the processes and focuses on the process improvement rather than final outcome.

(5) Six Sigma is prospective methodology as compared to other quality programs as it focuses on prevention on defects rather than fixing it.

(6) It is attentive to the entire business processes and training is integral to the management system where the top down approach ensures that every good thing is capitalized and every bad thing is quickly removed.

DISADVANTAGES OF SIX-SIGMA:

(1) Applicability of Six Sigma is being argued among the Six Sigma critics. They opined that the quality standards should be according to specific task and measuring 3.4 defects per million as standard leads to more time spent in areas which are less profitable.

(2) Six Sigma gives emphasis on the rigidity of the process which basically contradicts the innovation and kills the creativity. The innovative approach implies deviations in production, the redundancy, the unusual solutions, insufficient study which are opposite to Six Sigma principles.

(3) People argue that Six Sigma is a bit gimmicky and simply a rebranding of the continues improvement techniques and tools as practiced by Toyota. It thus promotes outsourcing of improvement projects with lack of accountability.

(4) Six Sigma implementation constantly require skilled man force. Thus control and employee dedication are hard to accomplish if it is not implemented regularly.

(5) While converting the theoretical concepts into practical applications there are lot to real time barriers which needs to be resolved.

IMPORTANT QUESTIONS IN UNIT - IV FROM PREVIOUS QUESTION PAPERS

1. Explain SQC with advantages, limitations and applications. [7M] April- 2015 Set 1
2. What is the importance of quality control? Explain. [8M] April- 2015 Set 1
3. Explain the concept of zero defects. [7M] April- 2015 Set 1
4. What is the prominence of ISO quality system? [8M] April- 2015 Set 1
5. Define the concept of inspection and explain various types of inspections. [7M] May/June-2015 Set 1
6. Define control charts. What are the objectives and importance of control charts? [8M] May/June-2015 Set 1
7. Define quality circles. Explain its features and objectives. [8M] May/June-2015 Set 1
8. Define Six-sigma. State its features and objectives. [7M] May/June-2015 Set 1
9. Define statistical quality control? Explain the significance and advantages of statistical Quality control? [7M] May/June-2015 Set 2
10. How do you draw inferences from a control chart? How can you improve the process by using control charts? [8M] May/June-2015 Set 2
11. Write about ISO and explain the benefits of ISO registration. [8M] May/June-2015 Set 2
12. Discuss in detail the various applications of quality circle in the maintenance of quality production. [7M] May/June-2015 Set 2
13. Define acceptance sampling. What are the various methods of acceptance sampling? [8M] May/June-2015 Set 3
14. Discuss in detail the applications of control charts. [7M] May/June-2015 Set 3
15. Briefly explain the structure of quality circles. [8M] May/June-2015 Set 3
16. Write the advantages and disadvantages of Six-Sigma. [7M] May/June-2015 Set 3
17. Define quality. Explain the importance of quality in the changing techno-economic scenario. [8M] May/June-2015 Set 4
18. Explain the parameters affecting acceptance sampling plans. [7M] May/June-2015 Set 4
19. Write in detail about the step by step implementation of a quality circle. [8M] May/June-2015 Set 4
20. Explain zero defect? How do you develop Hassle-free organisation with zero defect programme? [7M] May/June-2015 Set 4
21. Define 'Quality' and explain the factors that influence the quality of a product. [7M] Dec – 2015 Set 1
22. Discuss the importance of quality in the changing techno economic scenario. [8M] Dec – 2015 Set 1
23. Define TQM. What are the essential elements of TQM? [8M] Dec – 2015 Set 1
24. Explain the benefits of TQM. [7M] Dec – 2015 Set 1
25. State the importance of Quality control. [4M] April - 2016 set 1

26. Explain the need and procedure for conducting work sampling study. [4M] April - 2016 set 1

27. The following table gives the coded measurement obtained from 20 subgroups of 5 each:

Subgroups No.	Statistics				
Groups	**1**	**2**	**3**	**4**	**5**
1	-1	2	1	0	1
2	2	0	1	0	1
3	1	1	0	0	1
4	2	1	0	-1	0
5	1	-1	0	0	-1
6	-1	-1	2	0	2
7	-1	-1	0	-2	1
8	1	1	2	-1	0
9	2	1	-1	0	0
10	-2	1	-2	2	1
11	0	1	-3	2	1
12	2	1	-1	0	0
13	0	1	-3	2	1
14	0	0	-1	0	1
15	-1	2	1	1	2
16	1	-1	2	0	2
17	2	1	-1	0	0
18	2	0	1	0	1
19	0	1	1	-1	1
20	3	-3	1	1	1

i. Construct the $\bar{X}$ and R charts and plot the points on the chart.

ii. What will be the control limits on $\bar{X}$ and R charts for immediate future?

iii. Estimate the value of σ. [8M] April - 2016 set 1

28. Explain in detail about the need of ISO quality systems in an industry. [8M] April - 2016 set 1

29. Explain the term TQM. [4M] April - 2016 set 2

30. Construct (X Bar) and R-charts for the following information and state whether the process is in control. For each of the following, (X Bar) has been computed from a sample of 5 units drawn at an interval of 1 hour from an ongoing manufacturing process. [8M] April - 2016 set 2

S.No.	X_1 (10 AM)	X_2 (11 AM)	X_3 (12 PM)	X_4 (01 PM)	X_5 (02 PM)
1	10.02	10.15	9.85	10.02	9.97
2	9.97	9.98	9.96	9.92	10.05
3	10.08	10.02	10.1	10	10.01
4	9.92	10.12	10.08	10.02	10.05

5	10.02	10.06	10.04	9.95	9.89

31. Explain six sigma concept. How do you think that this concept would improve the productivity?

[8M] April - 2016 set 2

32. Define zero defect concept. [4M] April - 2016 set 3

33. Construct control chart X Bar - R for the following data on the basis of 12 samples collected from a process, 5 data points are taken every hour. Comment on the state of control, assuming that these are the first data. What will be future control limit? [8M] April - 2016 set 3

1	2	3	4	5	6	7	8	9	10	11	12
42	42	19	36	42	51	60	18	15	69	64	61
65	45	24	54	51	74	60	20	30	109	90	78
75	68	80	69	57	75	72	27	39	113	93	94
78	72	81	77	59	78	95	42	62	118	109	109
87	90	81	84	78	132	138	60	84	153	112	136

34. What is Quality circle? How the implementation of Quality circle enhance the Production?

[8M] April - 2016 set 3

35. Define SQC. [3M] April - 2016 set 4

36. The following data (two subgroup of size 4), is from two different machines which are supposed to be alike. Plot the necessary chart to show whether their product would support this assumption. If they don't, does this prove the machines are not essentially alike? [8M] April - 2016 set 4

Machine 1			**Machine 2**		
Subgroup	**Average**	**Range**	**Subgroup**	**Average**	**Range**
1	2.77	0.06	1	2.53	0.12
2	2.70	0.29	2	2.67	0.30
3	2.78	0.19	3	2.66	0.17
4	2.67	0.12	4	2.57	0.25
5	2.75	0.34	5	2.60	0.24
6	2.77	0.23	6	2.60	0.05
7	2.75	0.17	7	2.70	0.30
8	2.73	0.06	8	2.56	0.04
9	2.76	0.23	9	2.70	0.19
10	2.63	0.20	10	2.67	0.08
11	2.73	0.17	11	2.60	0.11
12	2.74	0.28	12	2.63	0.14
13	2.73	0.26	13	2.71	0.24

14	2.72	0.13	14	2.63	0.31
15	2.73	0.13	15	2.75	0.17

37. Describe the key steps involved in the process of getting registered to ISO 9000 certification.

[8M] April - 2016 set 4

38. The following data were obtained over a 5-day period to indicate X and R chart for a quality characteristic of a certain manufacturing product that had required a substantial amount of rework. All the figures apply to the product made on a single machine by a single operator. The sample size was 4. Two samples were taken per day. Comment on the process using X and R charts. [15M] Nov/Dec 2016 set 1

Sample No.	Observation's			
	1	2	3	4
1	11	12	13	10
2	6	10	10	11
3	11	12	9	12
4	14	10	8	13
5	12	11	11	10
6	11	10	10	12
7	10	12	13	13
8	10	11	11	10
9	12	13	11	12
10	11	13	9	9

39. State and explain the concept of six sigma with suitable examples [15M] Nov/Dec 2016 set 1

40. What are quality circles and explain the purpose of it. [4M] Nov/Dec 2016 set 1

41. What is the philosophy of TQM? [9M] Nov/Dec 2016 set 1

42. Comment on single and double sampling plans and their applications. [7M] Nov/Dec 2016 set 1

43. The following data were obtained over a 5-day period to indicate X and R chart for a quality characteristic of a certain manufacturing product that had required a substantial amount of rework. All the figures apply to the product made on a single machine by a single operator. The sample size was 3. Two samples were taken per day. Comment on the process using X and R charts. [15M] April - 2017 set 1

Sample No.	Observation's		
	1	2	3
1	11	8	8
2	10	12	13
3	10	12	12

4	12	13	11
5	10	13	7
6	10	12	13
7	7	10	8
8	11	12	9
9	10	9	8
10	8	11	11

44. Explain the applications of quality circles in management. [8M] April - 2017 set 1
45. Briefly explain the concept of six sigma. [7M] April - 2017 set 1
46. Explain the concept of Zero defect. [4M] April - 2017 set 1
47. What do you understand from process control? Explain. [8M] April - 2017 set 1
48. State the benefits and limitations of TQM. [8M] April - 2017 set 1
49. Give a brief note on quality circles. [4M] April - 2017 set 2
50. Define control chart and state the objectives of X and R charts. [8M] April - 2017 set 2
51. Describe the various elements of TQM in brief. [8M] April - 2017 set 2
52. Explain Six Sigma concept [4M] April - 2017 set 3
53. Describe the method of constructing X and R chart and explain how these charts help in determining lack of control. [8M] April - 2017 set 3
54. Define TQM. State the guiding principles of TQM. [8M] April - 2017 set 3
55. Explain the importance of quality control. [4M] April - 2017 set 4
56. Explain the theory underlying control charts for fraction defective. [8M] April - 2017 set 4
57. What is meant by process capability? How will you determine the same? [8M] April - 2017 set 4
58. Describe the method of constructing X and R chart and explain how these charts help in determining lack of control. [7M] Nov - 2017 set 1
59. Define the concept of inspection and explain various types of inspections. [8M] Nov - 2017 set 1
60. Explain the applications of quality circles in management. [7M] Nov - 2017 set 1
61. Briefly explain the concept of six sigma. [8M] Nov - 2017 set 1
62. What is SQC and list out its benefits? [4M] Nov - 2017 set 1
63. What are quality circles and explain the purpose of it. Explain how it is beneficial to organization. [8M] Nov - 2017 set 1
64. Explain the objectives of ISO quality systems and discuss the major clauses in it. [8M] Nov - 2017 set 1
65. What is quality control? How is it different from inspection? [3M] April - 2018 set 1
66. Define quality and explain the factors that influence the quality of a product. [8M] April - 2018 set 1
67. The following table gives the number of defects in a casting used for making crank case of diesel engine.

Casting No.	1	2	3	4	5	6	7	8	9	10
No. of Defects	15	11	25	10	12	20	15	10	17	13

Construct an appropriate control chart with the control limits and comment on the process.

[8M] April - 2018 set 1

68. Explain the significance of statistics in quality control? [4M] April - 2018 set 2

69. In a manufacturing unit, a sample of 5 sheets is taken every one hour. The data collected from the measurement of thickness of these sheets is tabulated below: [10M] April - 2018 set 2

Sample No.	Thickness in mm for 5 sheets				
	I	II	III	IV	V
1	25	31	22	26	24
2	32	31	30	34	33
3	35	34	33	32	32
4	26	25	29	30	25
5	33	34	30	29	33
6	34	32	31	28	27

Draw the control chart for mean and range, and establish whether the process is under control?

70. Write about ISO and explain the benefits of ISO registration? [6M] April - 2018 set 2

71. Write about quality circles. [4M] April - 2018 set 3

72. Gopal industries want to set-up a control chart for the number of defective units for its toaster production line. 25 Random samples of 400 units each inspected and the number of defective units in each sample were noted as follows. Draw suitable control for the data. [8M] April - 2018 set 3

Sample No.	No. of Defectives	Sample No.	No. of Defectives
1	17	14	19
2	26	15	19
3	22	16	8
4	24	17	8
5	30	18	23
6	35	19	20
7	15	20	18
8	19	21	18
9	23	22	13
10	18	23	20
11	15	24	14
12	21	25	17

73. What is the need for ISO 9000 standards? What are the various certifications under this umbrella of ISO 9000? Explain. [8M] April - 2018 set 3

74. What is quality control? How is it different from inspection? [4M] April - 2018 set 4

75. Define total quality management? Describe the various elements of TQM in brief.[8M] April - 2018 set 4

76. Define control chart and state the objectives of *X Bar* and R charts [8M] April - 2018 set 4

77. What is quality control? [4M] Nov - 2018 Set 1

78. Define quality and explain the factors that influence the quality of a product. [7M] Nov - 2018 Set 1

79. The following table gives the number of defects in a casting used for making crank case of diesel engine.

Casting No.	1	2	3	4	5	6	7	8	9	10
No. of Defects	15	11	25	10	12	20	15	10	17	13

Construct an appropriate control chart with the control limits and comment on the process.

[7M] Nov - 2018 Set 1

80. Describe the general structure for double sampling plan. What are their advantages and disadvantages?

[15M] Nov - 2018 Set 1