Types of the control charts

- Variables control charts
  - Variable data are measured on a continuous scale. For example: time, weight, distance or temperature can be measured in fractions or decimals.
  - Applied to data with continuous distribution

  Eg: X chart and R chart

- Attributes control charts
  - Attribute data are counted and cannot have fractions or decimals. Attribute data arise when you are determining only the presence or absence of something: success or failure, accept or reject, correct or not correct. For example, a report can have four errors or five errors, but it cannot have four and a half errors.
  - Applied to data following discrete distribution

  Eg: P chart and C chart

(http://www.asq.org/learn-about-quality/data-collection-analysis-tools/overview/control-chart.html)

Two types :

- P-chart & C-chart for attributes
- Mean X and range R for variables

P chart

- Also called the percent defective chart

- Uses the proportion of defective items in a sample as the sample statistic.
- P-chart can be used when it is possible to distinguish between defective and non defective items and to state the number of defectives as a percentage of the whole.

Control Charts for Attributes –P-Charts & C-Charts

Attributes are discrete events: yes/no or pass/fail

- Use P-Charts for quality characteristics that are discrete and involve yes/no or good/bad decisions
  - Number of leaking caulking tubes in a box of 48
  - Number of broken eggs in a carton

- Use C-Charts for discrete defects when there can be more than one defect per unit
  - Number of flaws or stains in a carpet sample cut from a production run
  - Number of complaints per customer at a hotel

P-Chart Example: A production manager for a tire company has inspected the number of defective tires in five random samples with 20 tires in each sample. The table below shows the number of defective tires in each sample of 20 tires. Calculate the control limits.

Sample	Number of Defective Tires	Number of Tires in each Sample	Proportion Defective
1	3	20	.15
2	2	20	.10
3	1	20	.05
4	2	20	.10
5	1	20	.05
Total	9	100	.09

Solution:

$$CL = \bar{p} = \frac{\#\text{Defectives}}{\text{Total Inspected}} = \frac{9}{100} = .09$$

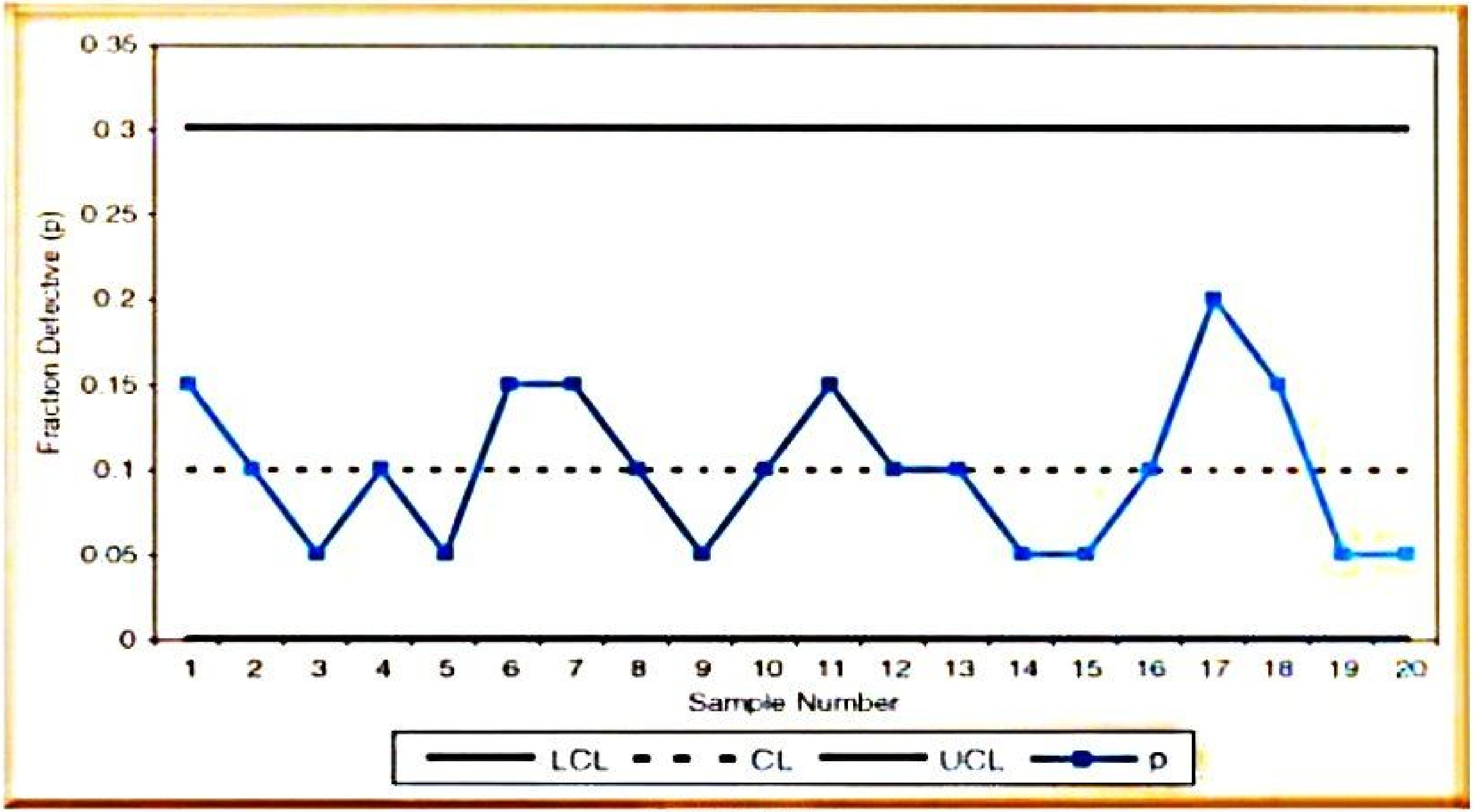
$$\sigma_p = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = \sqrt{\frac{(.09)(.91)}{20}} = 0.064$$

$$UCL_p = \bar{p} + z(\sigma) = .09 + 3(.064) = .282$$

$$LCL_p = \bar{p} - z(\sigma) = .09 - 3(.064) = -.102 = 0$$

- UCL= UPPER CONTROL LIMIT
- LCL= LOWER CONTROL LIMIT
- Z= the no. of standard deviations from the process average.=3
- P= process % defective of a sample
- P bar =process mean percent defective

P- Control Chart



C -Chart

- Also called the number of defective per sample area.
- It applies to the no. of nonconformities in sample of constant size
- C=no. of nonconformities in each sample.
- The CL of this chart are based on poisson distribution.

Application of c chart

- To control the no. of nonconforming rivets in an aircraft wing.
- To control the number of imperfection observed in a galvanized sheet
- To control the no. of defects in final assemblies(like TV, radio, computer)

C-Chart Example: The number of weekly **customer complaints** are monitored in a large hotel using a c-chart. Develop **three sigma control limits** using the data table below.

Week	Number of Complaints
1	3
2	2
3	3
4	1
5	3
6	3
7	2
8	1
9	3
10	1
Total	**22**

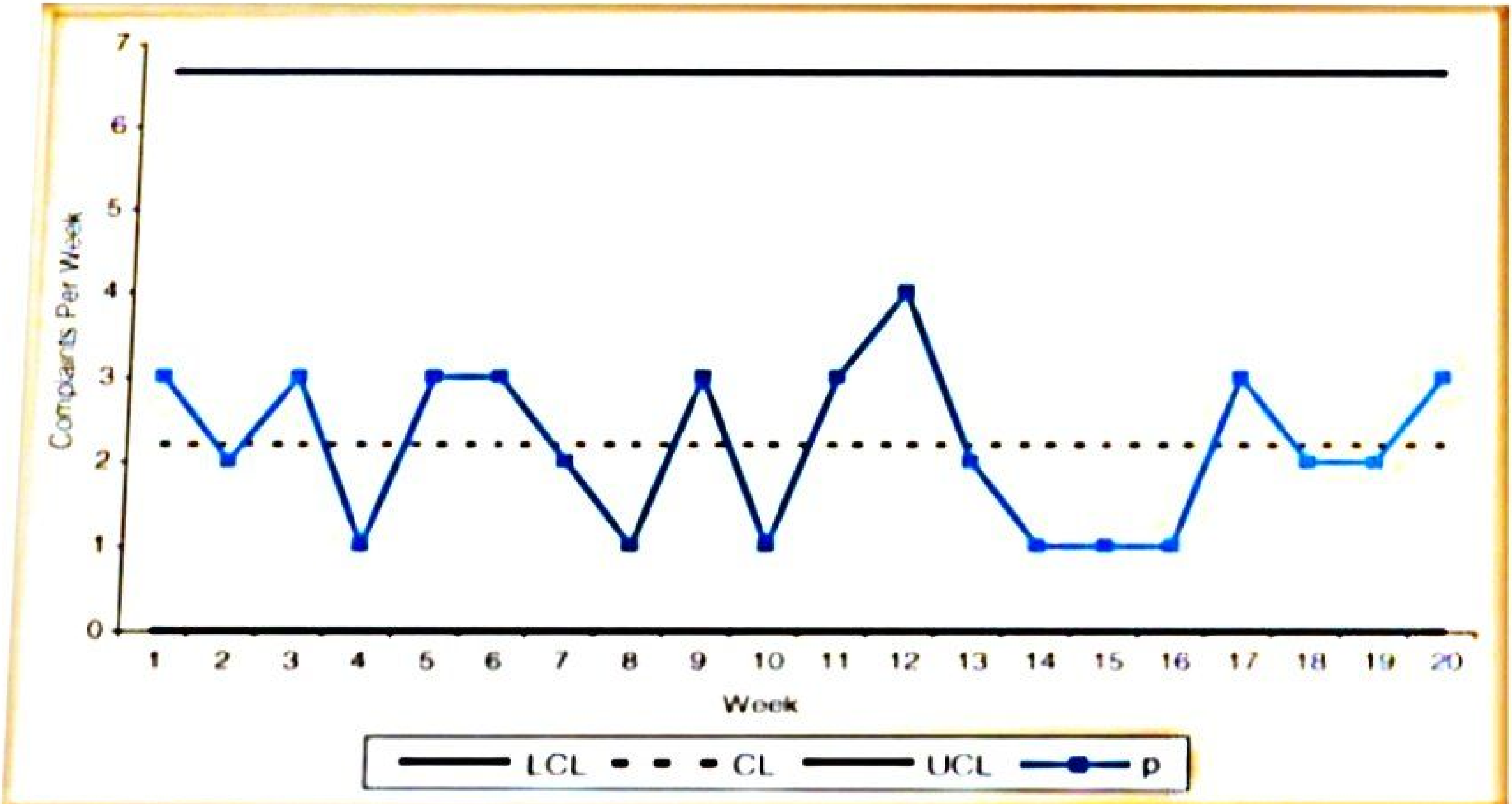
Solution:

$$CL = \frac{\#\text{complaints}}{\#\text{of samples}} = \frac{22}{10} = 2.2$$

$$UCL_c = \bar{c} + z\sqrt{\bar{c}} = 2.2 + 3\sqrt{2.2} = 6.65$$

$$LCL_c = \bar{c} - z\sqrt{\bar{c}} = 2.2 - 3\sqrt{2.2} = -2.25 = 0$$

C- Control Chart



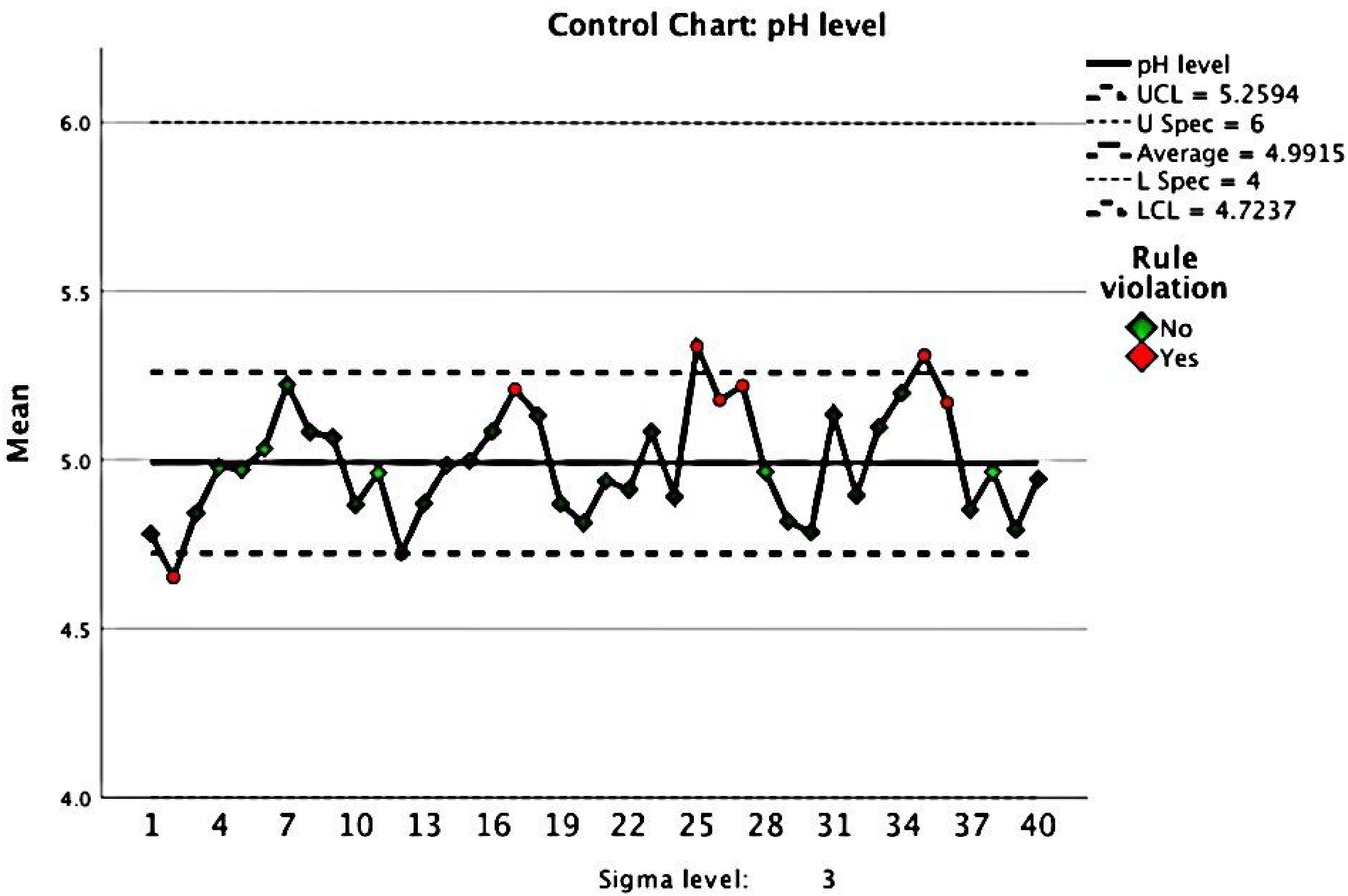
x-bar chart

The x-bar and R-chart are quality control charts used to monitor the **mean and variation** of a process based on samples taken in a given time. The control limits on both chats are used to monitor the mean and variation of the process going forward. If a point is out of the control limits, it indicates that the mean or variation of the process is out-of-control; assignable causes may be suspected at this point. On the x-bar chart, the y-axis shows the grand mean and the control limits while the x-axis shows the sample group. Let's take a look at the *R* code using the *qcc* package to generate a x-bar chart.

R-chart

In order to use the R-chart along with the x-bar chart, the sample size *n* must be greater than 1 and less than 11. For bigger samples, the *s*-chart must be used instead to monitor the standard deviation of the sample rather than its range. On the R-chart, the y-axis shows the range grand mean and the control limits, while the x-axis shows the sample group. Once you have created a x-bar chart, you will only need to add the following lines of code to generate the R-chart.

Figure 1. X-bar chart



Mean Chart

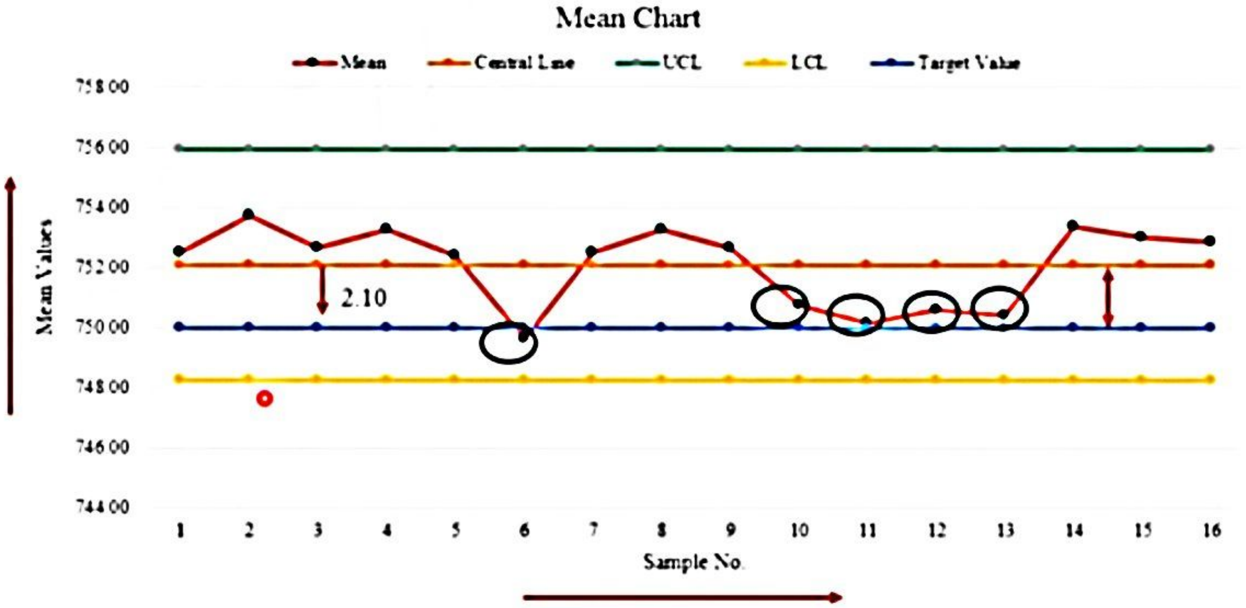
Target Value for the volume of an Item = 750ml ± 7

Table 1					
Sample No.	Item No.				Sample Mean $\overline{X_i}$
	1	2	3	4	
1	752.5	748	756.5	753	752.50
2	754	755.5	753	752.5	753.75
3	752	753	754	751.5	752.63
4	757	753	753	750	753.25
5	751	753.5	755	750	752.38
6	755.5	746	748.5	748.5	749.63
7	757	751	752.5	749.5	752.50
8	756	754	748	755	753.25
9	748.5	761.5	747	753.5	752.63
10	751	752.5	750.5	749	750.75
11	754	750.5	744	752	750.13
12	751.5	750	754	747	750.63
13	750.5	752.5	752	746.5	750.38
14	760.5	750.5	748	754.5	753.38
15	754	756	754.5	747.5	753.00
16	754.5	746.5	754	756.5	752.88
				Average ($\bar{\bar{X}}_i$)	752.10

$$(\sigma_p) = \sqrt{\frac{\Sigma(\overline{X_i} - \bar{\bar{X}}_i)^2}{n}} = 1.28$$

$$UCL = \bar{\bar{X}}_i + 3\sigma_p = 755.95$$

$$LCL = \bar{\bar{X}}_i - 3\sigma_p = 748.25$$

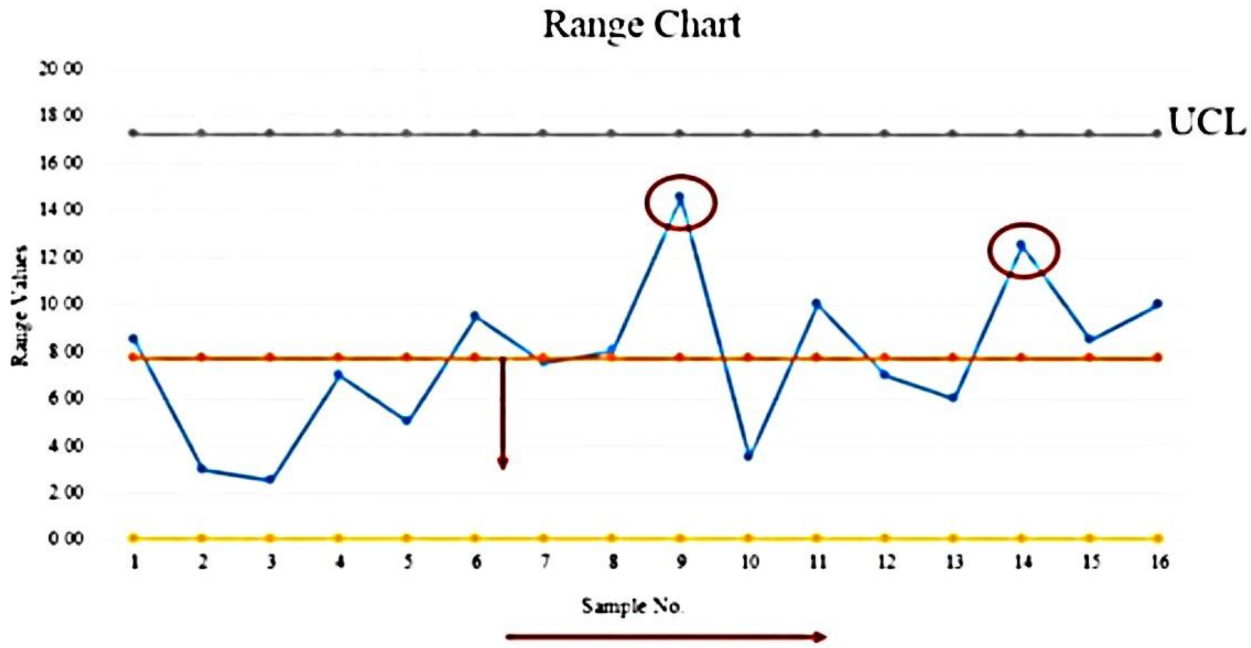


Range Chart

Table 2					
Sample No.	Item No.				Sample Range (R_i)
	1	2	3	4	
1	752.5	748	756.5	753	8.50
2	754	755.5	753	752.5	3.00
3	752	753	754	751.5	2.50
4	757	753	753	750	7.00
5	751	753.5	755	750	5.00
6	755.5	746	748.5	748.5	9.50
7	757	751	752.5	749.5	7.50
8	756	754	748	755	8.00
9	748.5	761.5	747	753.5	[illegible].50
10	751	752.5	750.5	749	3.50
11	754	750.5	744	752	10.00
12	751.5	750	754	747	7.00
13	750.5	752.5	752	746.5	6.00
14	760.5	750.5	748	754.5	12.50
15	754	756	754.5	747.5	8.50
16	754.5	746.5	754	756.5	10.00
Average ($\overline{R_i}$)					7.69

$$\sigma_p = \sqrt{\frac{\sum(R_i - \overline{R}_i)^2}{n}} = 3.19$$

$$UCL = \overline{R_i} + 3\sigma_p = 17.25$$



X-bar and R Control Charts

X-bar and R charts are used to monitor the mean and variation of a process based on samples taken from the process at given times (hours, shifts, days, weeks, months, etc.). The measurements of the samples at a given time constitute a subgroup. Typically, an initial series of subgroups is used to estimate the mean and standard deviation of a process. The mean and standard deviation are then used to produce control limits for the mean and range of each subgroup. During this initial phase, the process should be in control. If points are out-of-control during the initial (estimation) phase, the assignable cause should be determined and the subgroup should be removed from estimation. Determining the process capability (see R & R Study and Capability Analysis procedures) may also be useful at this phase.

Once the control limits have been established of the X-bar and R charts, these limits may be used to monitor the mean and variation of the process going forward. When a point is outside these established control limits it indicates that the mean (or variation) of the process is out-of-control. An assignable cause is suspected whenever the control chart indicates an out-of-control process.