

Project Quality Management

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Project Quality Management

Lecture 4

PMG354

Statistical Quality Control – part 1

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Lecture

04

Objectives



At the end of this lecture, we expect to acquire a knowledge about fundamentals for statistical quality control to use in project stages and assure the conformity of outcomes



Lecture
04

Contents

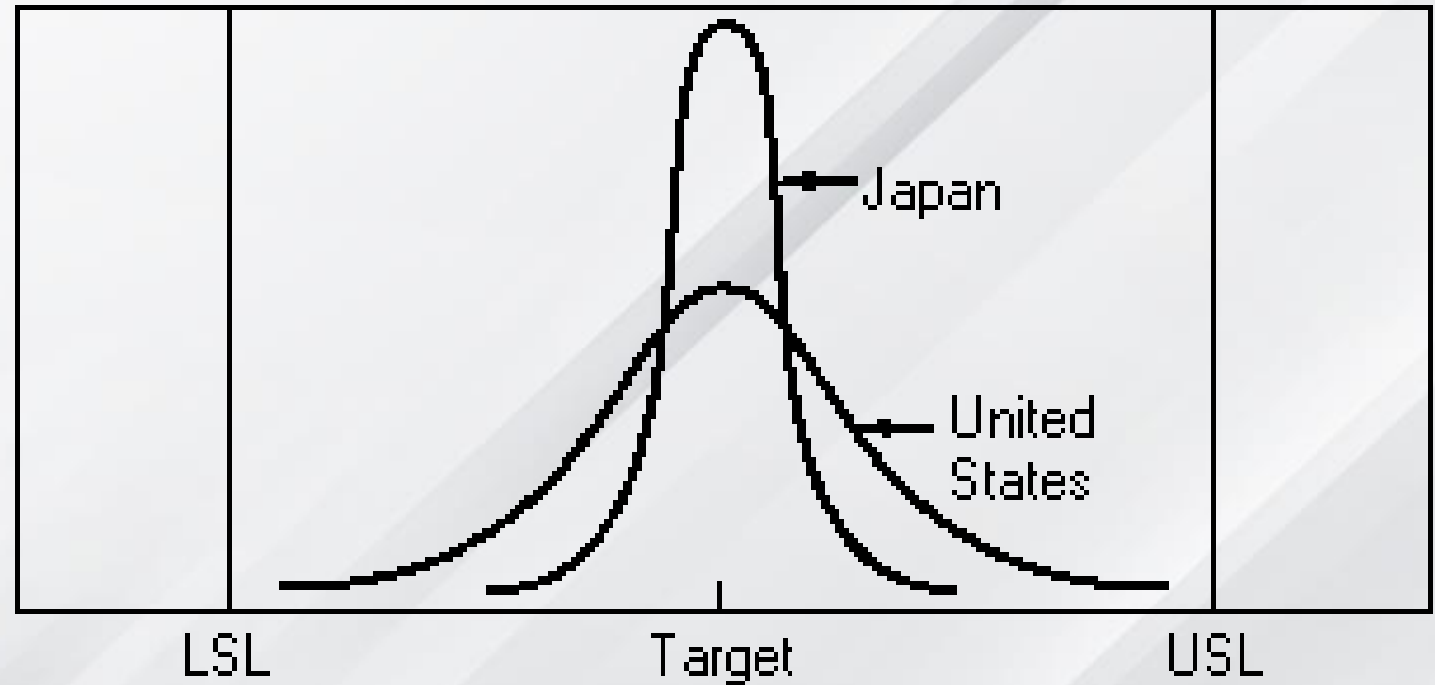
- Introduction
- Quality Engineering
- A Brief History of Quality Control and Improvement
- Statistical Methods for Quality Control and Improvement
- Statistical process control
- Process Improvement Using the Control Chart
- Procedure for Construction of X and R Control Chart
- Example

Introduction

- Quality means fitness for use
 - Quality of design
 - Quality of conformance
- Quality is inversely proportional to variability.
- Quality Improvement
 - Quality improvement is the reduction of variability in processes and products.
- Alternatively, quality improvement is also seen as “waste reduction”.

Introduction

Example



Distributions of critical dimensions for transmissions.

Types of quality characteristics

- **Physical** - length, weight, voltage, viscosity
- **Sensory** - taste, appearance, color
- **Time Orientation** - reliability, durability, serviceability

Quality Engineering

Is the set of operational, managerial, and engineering activities that a company uses to ensure that the quality characteristics of a product are at the nominal or required levels.



Quality Engineering Terminology

- Two types of data
 - Attributes Data - discrete data, often in the form of counts.
 - Variables Data - continuous measurements such as length, weight.

Quality Engineering Terminology

- Specifications
- Quality characteristics being measured are often compared to standards or specifications.
- Nominal or target value
- Upper Specification Limit (USL)
- Lower Specification Limit (LSL)

A Brief History of Quality Control and Improvement

- **Walter Shewhart (1924)** introduced statistical control chart concepts.
- The American Society for Quality Control formed in 1946 (now known as the **American Society for Quality (ASQ)**).
- **1950s and 1960s** saw an increase in reliability engineering, experimental design, and statistical quality control

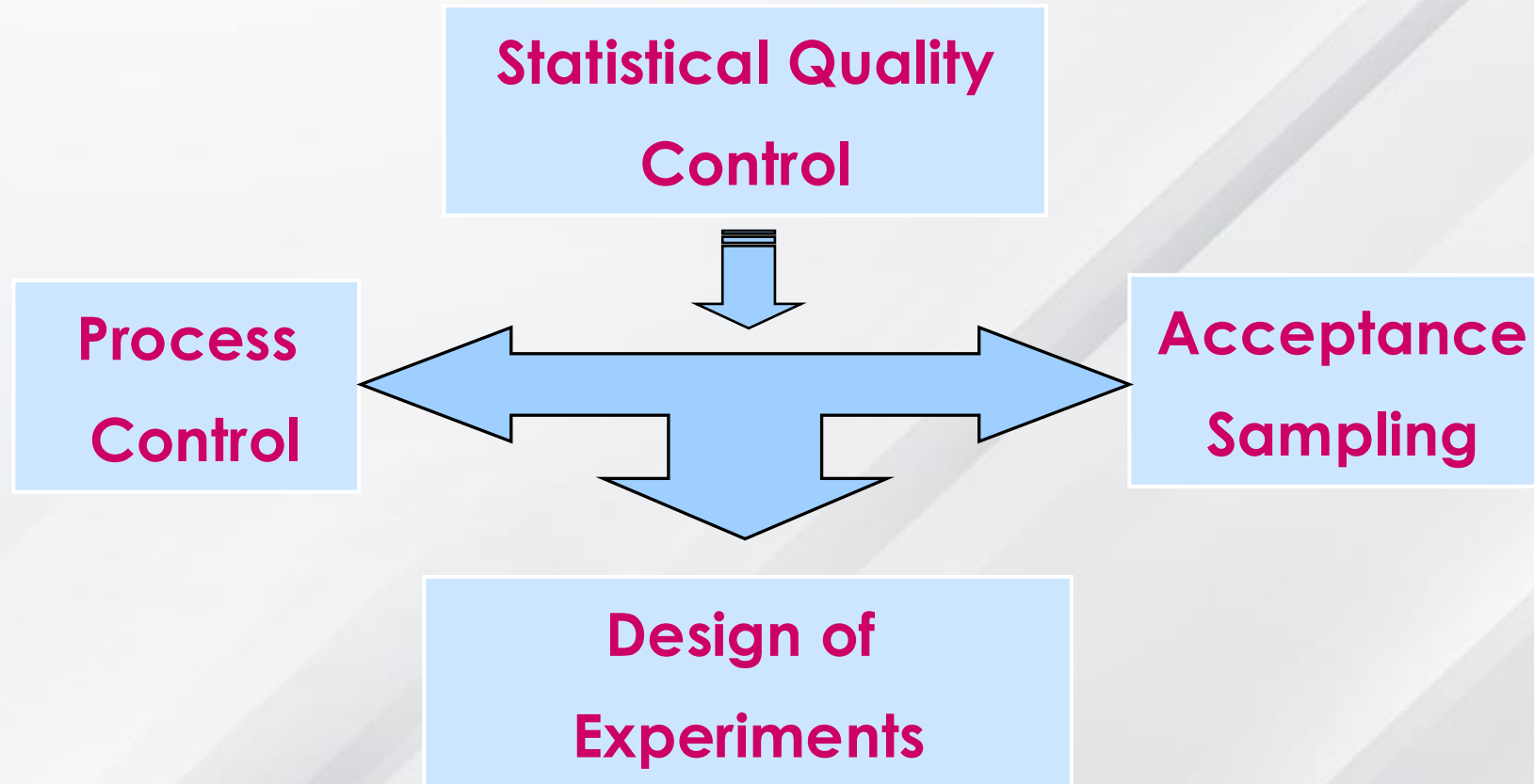
A Brief History of Quality Control and Improvement

- Competition from foreign industries (Japan) increases during the 1970s and 1980s.
- Statistical methods for quality improvement use increases in the United States during the 1980s
- **Total Quality Management (TQM)** emerges during 1970s and into the 1980s as an important management tool to implement statistical methods.

A Brief History of Quality Control and Improvement

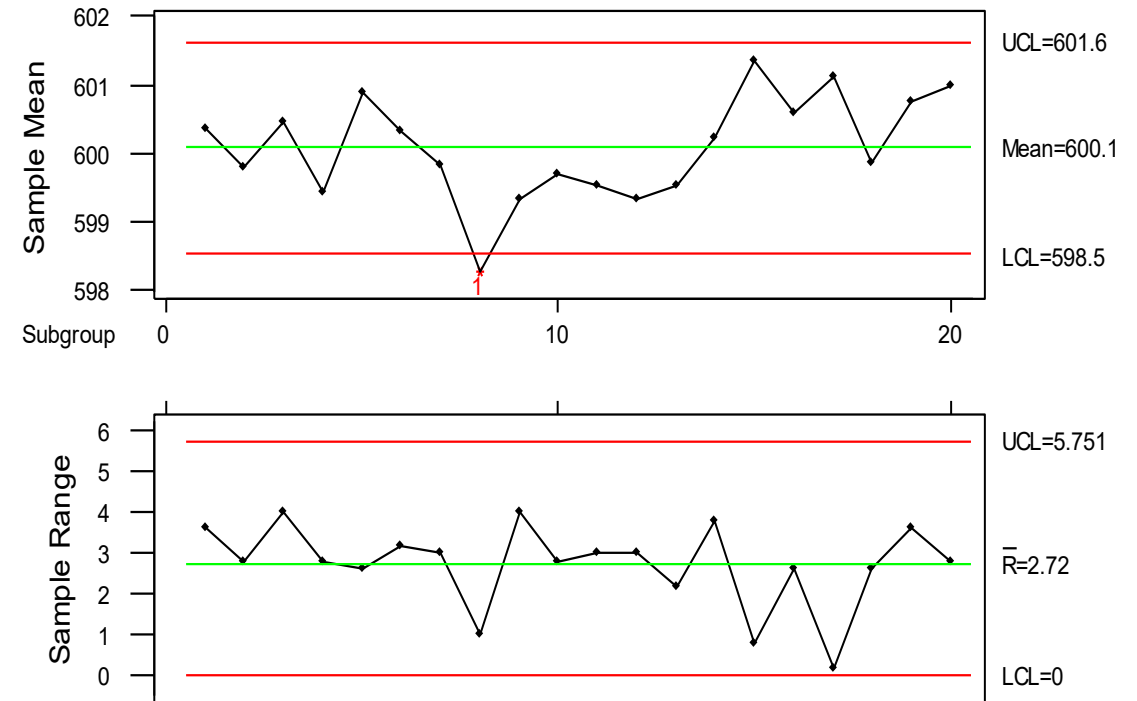
- **Malcolm Baldrige National Quality Award** is established in 1988.
- **ISO 9000 certification activities** increase in U.S. industry in the 1990s.
- **Applying Six-Sigma initiative** begins in the late 1980's thru 1992 till now.

Statistical Methods for Quality Control and Improvement



Statistical Process Control (SPC)

- **Control charts** are used for process monitoring and variability reduction.
- **SPC** is an on-line quality control tool.



Acceptance Sampling

- Acceptance sampling is the inspection and classification of a sample of the product selected at random from a larger batch or lot and the ultimate decision about disposition of the lot.
- Two types:
 1. **Outgoing inspection** - follows production
 2. **Incoming inspection** - before use in production

Design of Experiments

- Experimental design is an approach to systematically varying the controllable input factors in the process and determine the effect these factors have on the output responses.
- Experimental designs are off-line quality tools.
- Crucial for variability reduction.

Other Aspects of Quality Control and Improvement

- Total Quality Management (TQM)
- TQM is a managerial framework to accomplish quality improvement.
- Other names and related approaches:
 - Company-Wide Quality Control (CWQC)
 - Total Quality Assurance (TQA)
 - Six-Sigma-Black Belt Program

Statistical process control

- If a product is to meet customer requirements, it should be produced by a process that is stable or repeatable.
- Statistical process control is a collection of tools that when used together can result in process stability and variability reduction.



Statistical process control

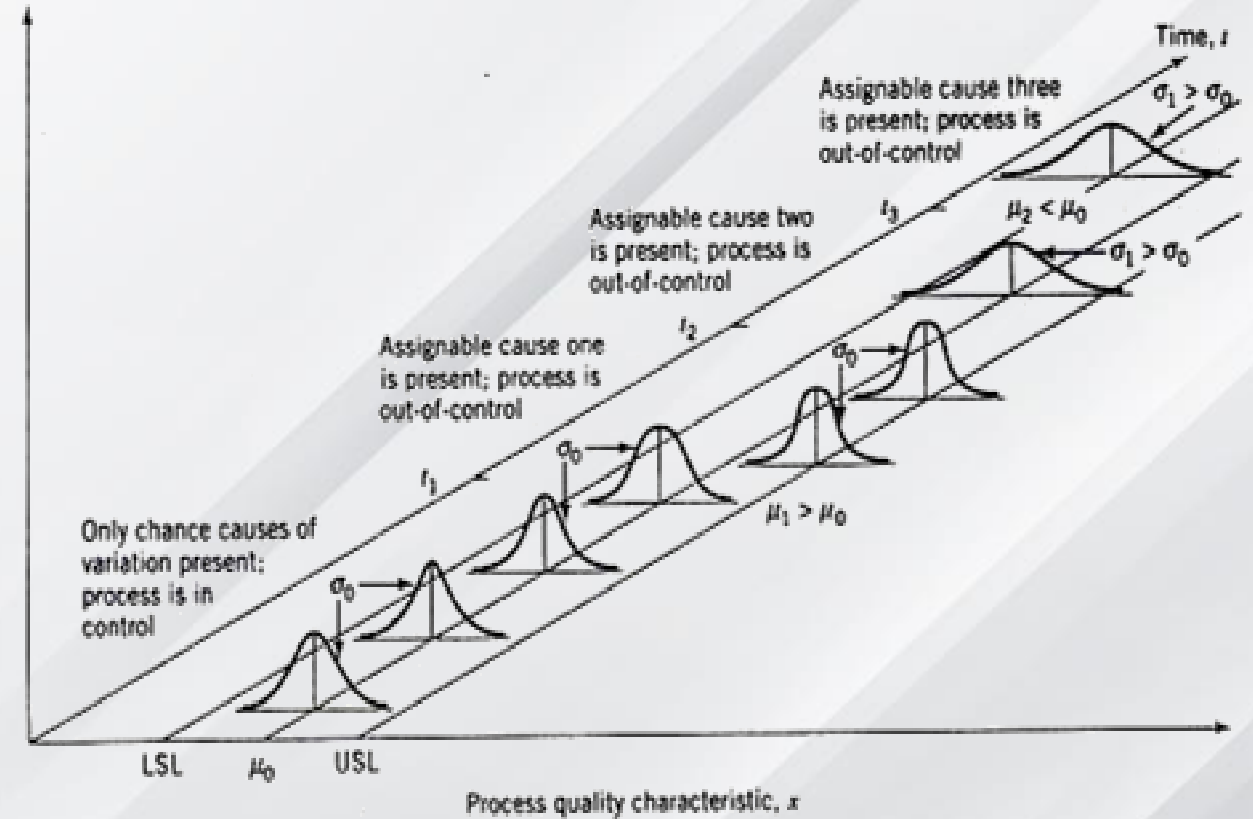
- A **process** that is operating with only chance causes of variation present is said to be in statistical control.
- A **process** that is operating in the presence of assignable causes is said to be out of control.
- The eventual goal of SPC is reduction or elimination of variability in the process by identification of assignable causes.

Statistical process control

- The terminology chance and assignable causes was developed by Dr. Walter A. Shewhart.
- Today, some writers or practitioners use the terminology common cause instead of chance cause and special cause instead of assignable cause.

Principle of the Control Chart

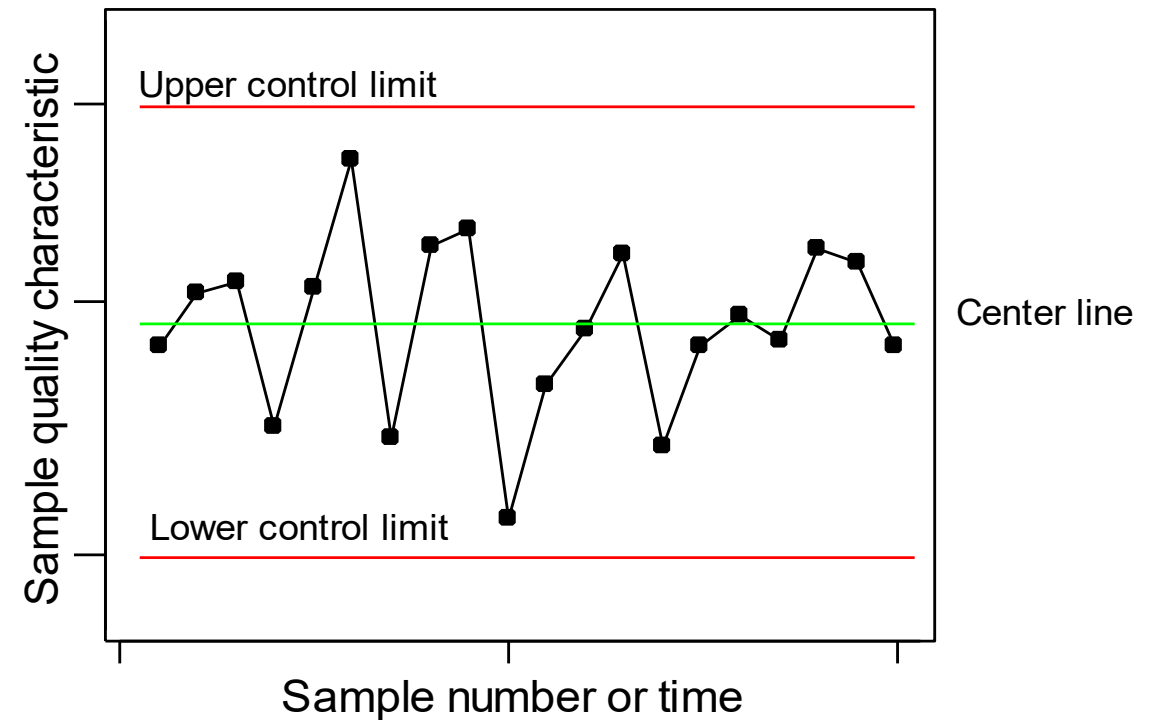
A typical **control chart** is a graphical display of a quality characteristic that has been measured or computed from sample versus the sample number or time.



Elements of A Control Chart

The chart contains a center line that represents the average value of the quality characteristic.

Also it has control limits set at values such that if the process is in control, nearly all points will lie between the upper control limit (UCL) and the lower control limit (LCL).



Control Situations

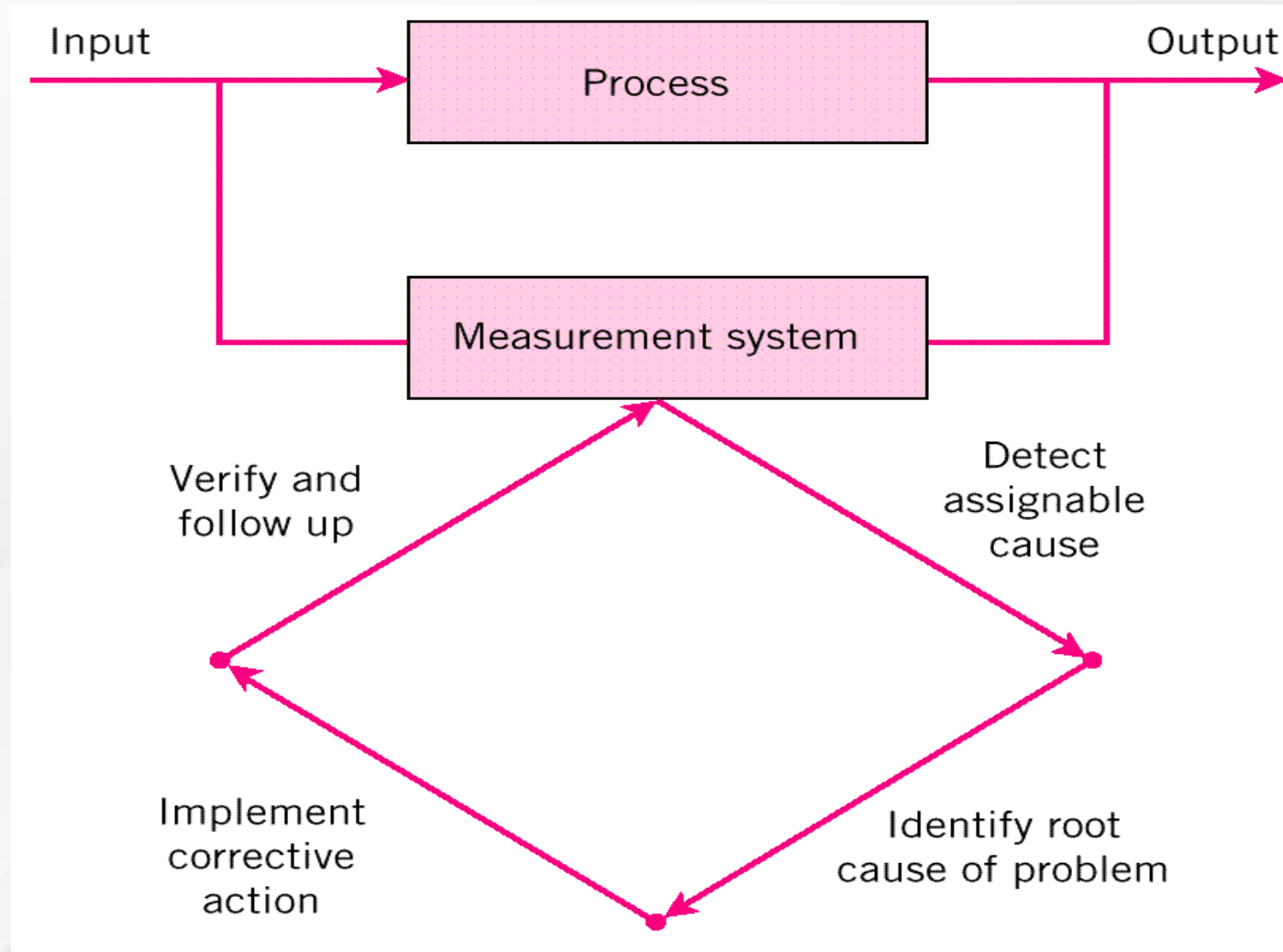
Out-of-Control

- If at least one point plots beyond the control limits, the process is out of control.
- If the points behave in a systematic or nonrandom manner, then the process could be out of control.
- Action is necessary.

In-Control

- As long as the points plot within the control limits, the process is assumed to be in control.
- No action is necessary.

Process Improvement Using the Control Chart



Benefits of control charts

- **Control charts** are a proven technique for improving productivity.
- **Control charts** are effective in defect prevention.
- **Control charts** prevent unnecessary process adjustment.
- **Control charts** provide diagnostic information.
- **Control charts** provide information about process capability.

Design of a Control Chart

- The important factors in the design of a control chart is selection of the following three parameters:
 - The width of the control limits (L)
 - The sample size (n)
 - The frequency of sampling (h)

Design of a Control Chart

$$UCL = \mu_W + L\sigma_W$$

$$\text{Center Line} = \mu_W$$

$$LCL = \mu_W - L\sigma_W$$

- **where** L = distance of the control limit from the center line, expressed in standard deviation units.

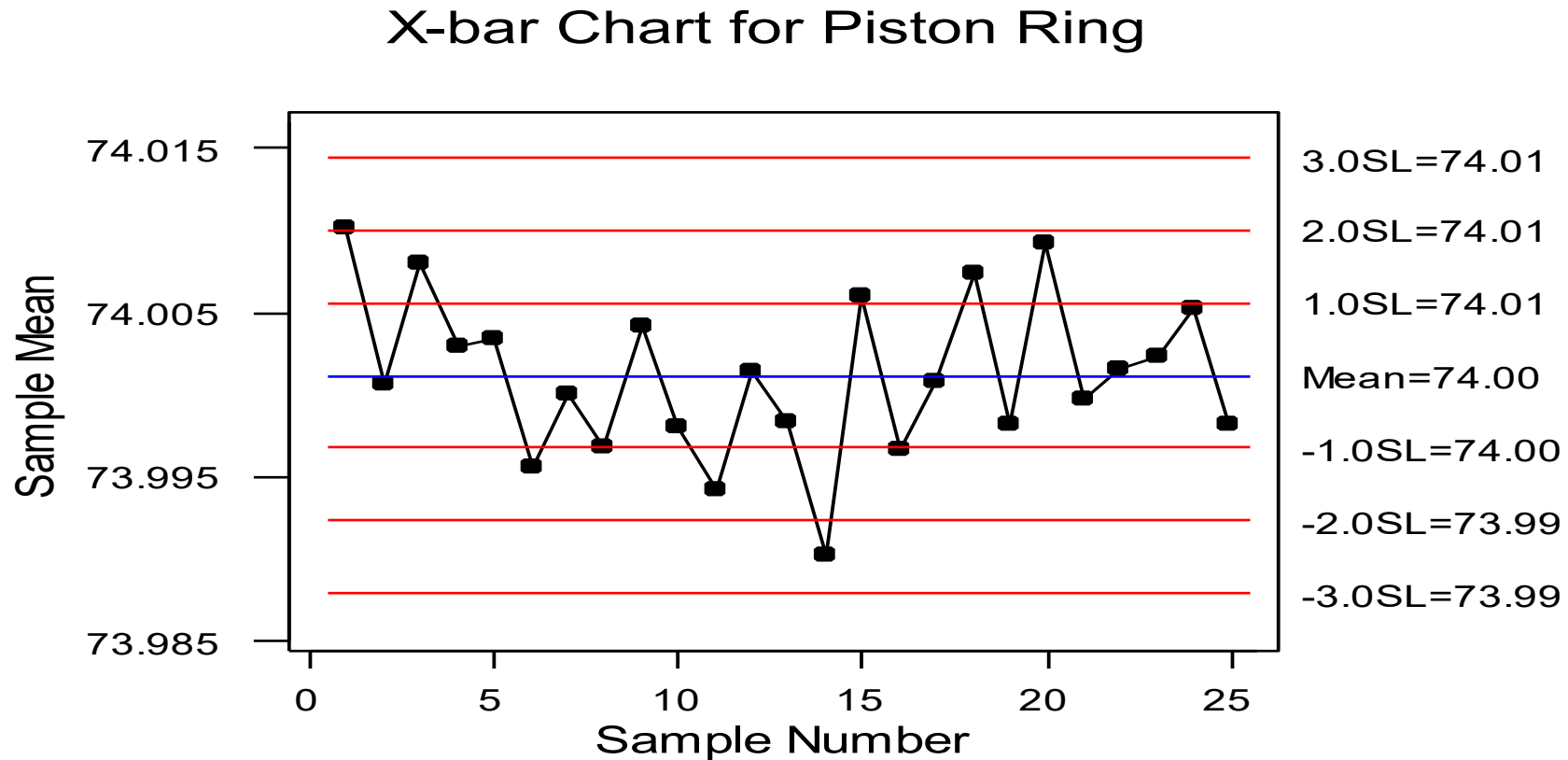
μ_W = mean of the sample statistic, w .

σ_W = standard deviation of the statistic, w .

Three-Sigma Limits

- The use of 3-sigma limits generally gives good results in practice.
- If the distribution of the quality characteristic is reasonably well approximated by the normal distribution, then the use of 3-sigma limits is applicable.
- These limits are often referred to as action limits.

Three-Sigma Limits



Warning Limits on Control Chart

- **Warning limits** (if used) are typically set at 2 standard deviations from the mean.
- If one or more points fall between the warning limits and the control limits, or close to the warning limits **the process may not be operating properly.**
- **Good thing:** warning limits often increase the sensitivity of the control chart.
- **Bad thing:** warning limits could result in an increased risk of false alarms.

Sample Size and Sampling Frequency

- In designing a control chart, both the sample size to be selected and the frequency of sampling must be specified.
- Larger samples make it easier to detect small shifts in the process.
- Current practice tends to favor smaller, more frequent samples.

Sample Size and Sampling Frequency

- Assume the **quality characteristic** of interest is normally distributed with mean μ , and standard deviation, σ .
- If $x_1, x_2, \dots, x_n$ is a sample of size n , then the average of this sample is

$$\bar{x} = \frac{x_1 + x_2 + \dots + x_n}{n}$$

- is normally distributed with mean, μ , and standard deviation,

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Sample Size and Sampling Frequency

- n - size of the sample (sometimes called a subgroup) chosen at a point in time
- m - number of samples selected (sample frequency)
- $\bar{x}_i$ = average of the observations in the i sample (where $i = 1, 2, \dots, m$)
- $\bar{\bar{x}}$ = grand average or “average of the averages” (this value is used as the center line of the control chart)

Sample Size and Sampling Frequency

- Assume the **quality characteristic** of interest is normally distributed with mean μ , and standard deviation, σ .
- If $x_1, x_2, \dots, x_n$ is a sample of size n , then the average of this sample is

$$\bar{x} = \frac{x_1 + x_2 + \dots + x_n}{n}$$

- $\bar{x}$ is normally distributed with mean, μ , and standard deviation,

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Control Limits for the X Chart

- **Process center** may be monitored by plotting values of the sample average on a control chart. The center line and control limits are as follows:

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

$$\text{Center Line} = \bar{\bar{x}}$$

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

$$\bar{\bar{x}} = \frac{\sum_{i=1}^m \bar{x}_i}{m}$$

- The constant A_2 is tabulated for various sample sizes.

Control Limits for the R Chart

- **Process variability** may be monitored by plotting values of the sample average on a control chart. The center line and control limits are as follows:

$$\begin{aligned}
 UCL_R &= D_4 \bar{R} \\
 \text{Center Line} &= \bar{R} \\
 LCL_R &= D_3 \bar{R}
 \end{aligned}$$

$$\bar{R} = \frac{\sum_{i=1}^m R_i}{m}$$

- The constant D_4 and D_3 is tabulated for various sample sizes.

Procedure for Construction of X and R Control Chart

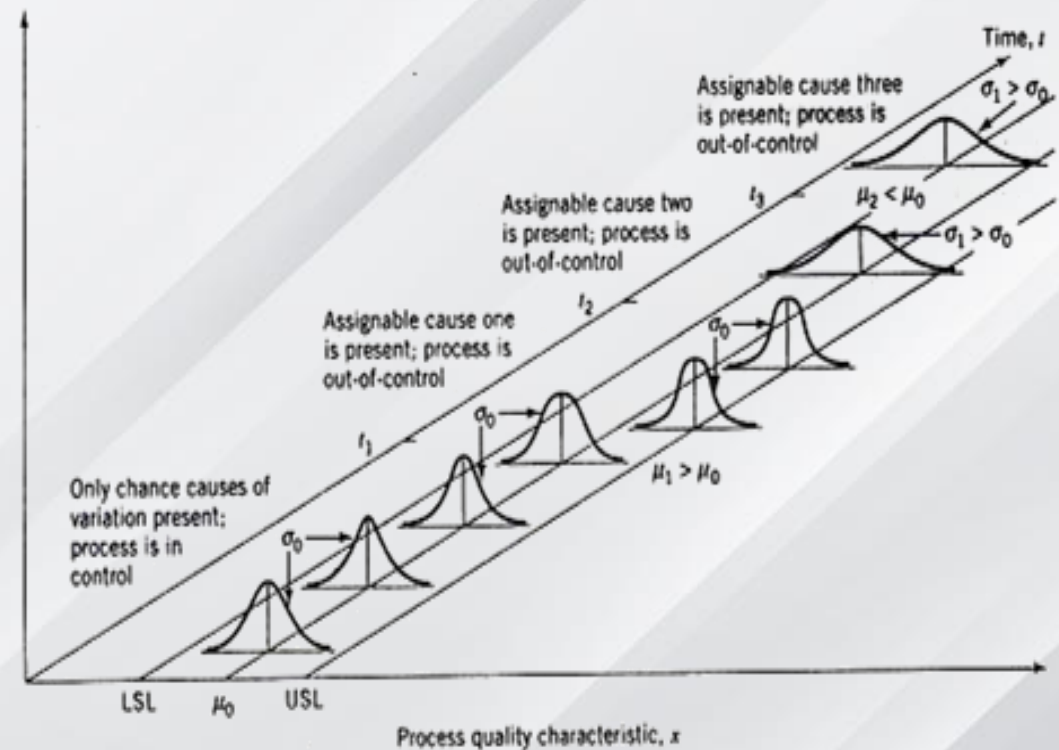
1. Select the **quality characteristic**.
2. Choose the **rational subgroup**.
3. Collect the **data**
4. Determine the **trial control limits**.
5. Establish the **revised control limits**
6. Achieve the **objective**



Procedure for Construction of $\bar{x}$ and R Control Chart

$\bar{x}$ chart monitors the *between* samples variability.

R chart monitors the *within* sample variability.



Example

- Piston rings for an automotive engine are produced by a forging process. We wish to establish statistical control of the inside diameter of the rings manufactured by this process using $\bar{x}$ and R charts. Twenty five samples, each of size 5, have been taken when we think the process is in control.
 - The inside diameter measurement data from these sample are shown in the next table.

Example

Sample Number	Observations					x_i	R_i
1	74.030	74.002	74.019	73.992	74.008	74.010	0.038
2	73.995	73.992	74.001	74.011	74.004	74.001	0.019
3	73.988	74.024	74.021	74.005	74.002	74.008	0.036
4	74.002	73.996	73.993	74.015	74.009	74.003	0.022
5	73.992	74.007	74.015	73.989	74.014	74.003	0.026
6	74.009	73.994	73.997	73.985	73.993	73.996	0.024
7	73.995	74.006	73.994	74.000	74.005	74.000	0.012
8	73.985	74.003	73.993	74.015	73.988	73.997	0.030
9	74.008	73.995	74.009	74.005	74.004	74.004	0.014
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
24	74.015	74.008	73.993	74.000	74.010	74.005	0.022
25	73.982	73.984	73.995	74.017	74.013	73.998	0.035
Sum						1850.028	0.581
						$\bar{x} = 74.001$	$R = 0.023$

Example

- Using the data from the previous table, we find that the center line for the R chart is

$$\bar{R} = \frac{\sum_{i=1}^{25} R_i}{25} = \frac{0.581}{25} = 0.023 \text{ mm}$$

- For samples of $n = 5$, and using the table we have
 - $D_3 = 0$
 - $D_4 = 2.115$

Example

The **trial control limits** for the ***R* chart** are

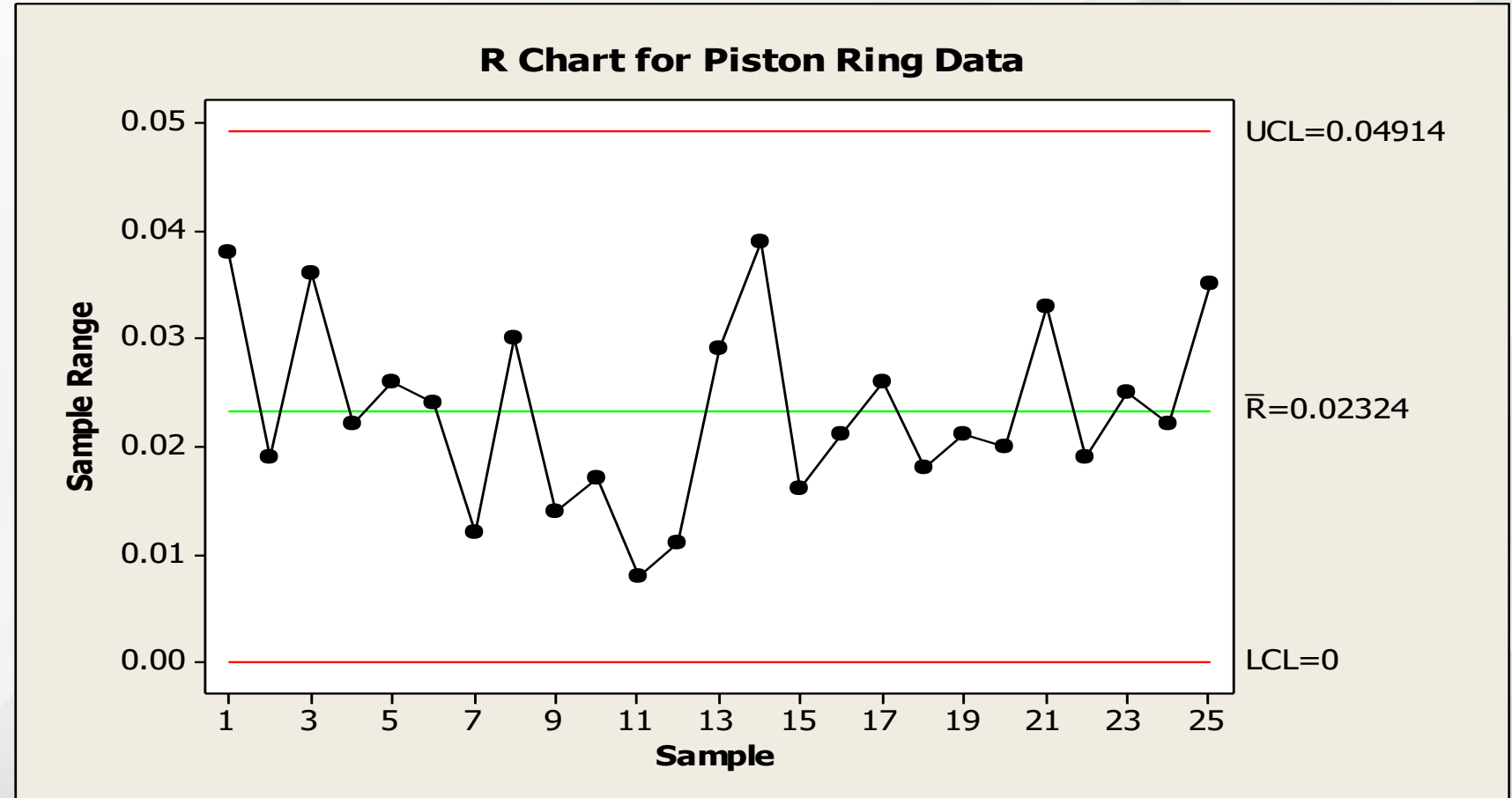
$$\begin{aligned}UCL_R &= D_4 \bar{R} \\&= (2.115)(0.023) \\&= 0.049 \text{ mm}\end{aligned}$$

$$\begin{aligned}LCL_R &= D_3 \bar{R} \\&= (0)(0.023) \\&= 0\end{aligned}$$



Example

- When the 25 sample ranges are plotted on the chart, there is no indication of an out-of-control condition.
- Since the R chart indicates that process variability is in control, we may construct the $\bar{x}$ chart.



Example

- The center line is

$$\bar{\bar{x}} = \frac{\sum_{i=1}^{25} \bar{x}_i}{25} = \frac{1850.028}{25} = 74.001 \text{ mm}$$

- To find the control limits, for sample of size $n = 5$ and using the table
 - $A_2 = 0.577$

Example

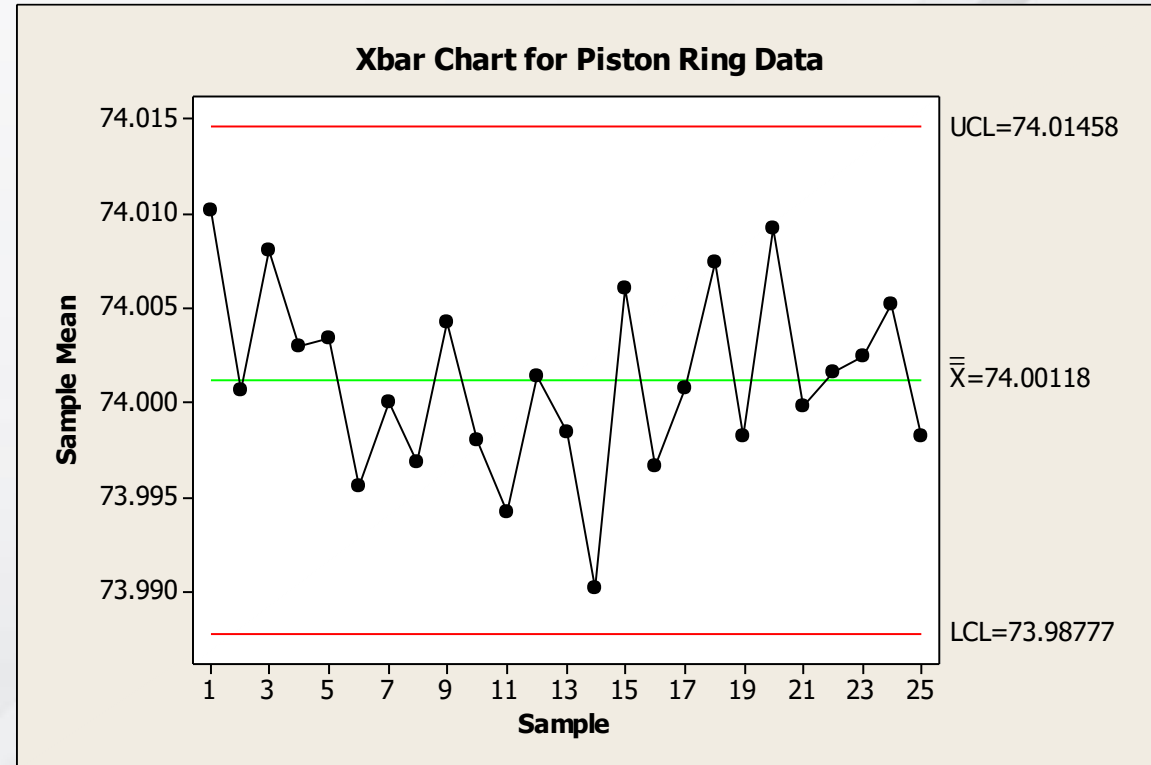
Therefore, the **trial control limits** for the **$\bar{x}$ chart** are

$$\begin{aligned}UCL_{\bar{x}} &= \bar{\bar{x}} + A_2\bar{R} \\&= 74.001 + (0.577)(0.023) \\&= 74.014 \text{ mm}\end{aligned}$$

$$\begin{aligned}LCL_{\bar{x}} &= \bar{\bar{x}} - A_2\bar{R} \\&= 74.001 - (0.577)(0.023) \\&= 73.988 \text{ mm}\end{aligned}$$

Example

- When preliminary sample averages plotted on the chart, no indication of an out-of-control condition is observed.

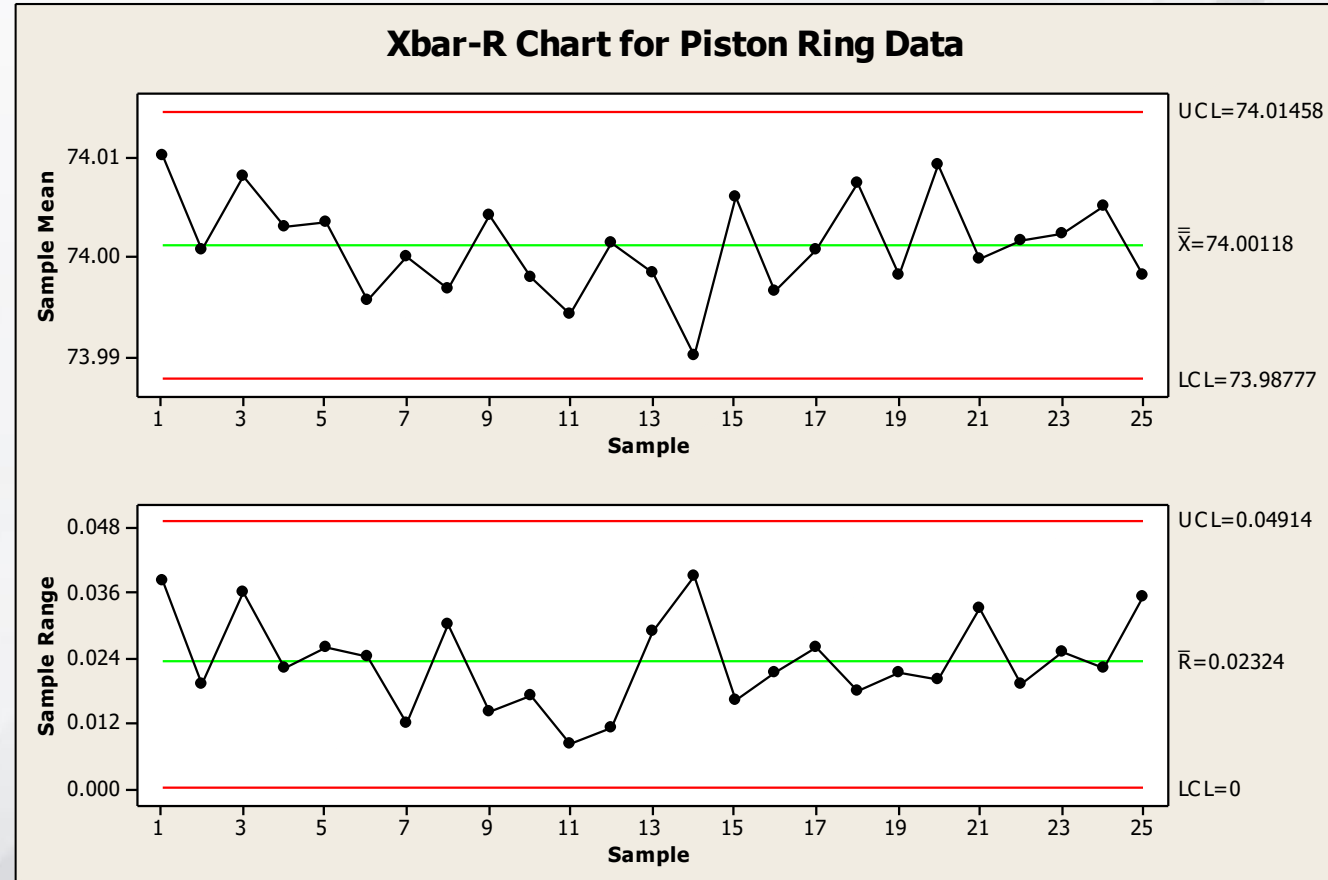


Example

- Since both the $\bar{x}$ and R exhibit control, we would conclude that the process is in control at the stated level.
- Adopt the trial control limits for use in on-line statistical process control.

Example

- In practice, it is common to use computer software packages in control chart construction.
- Minitab software will produce both chart at once.





Thank You