2.008

Process Control

Outline

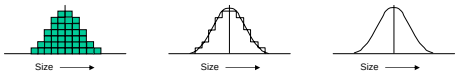
1. Optimization
2. Statistical Process Control
3. In-Process Control

What is quality?

Variation: Common and Special Causes

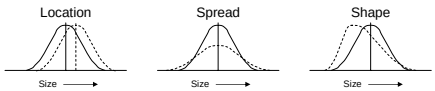
Pieces vary from each other:

But they form a pattern that, if stable, is called a distribution:



Common and Special Causes (cont'd)

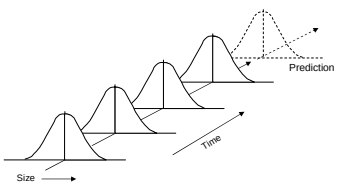
Distributions can differ in…



…or any combination of these

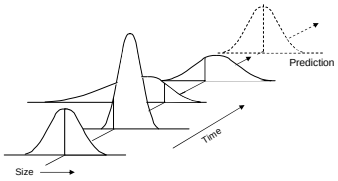
Common and Special Causes (cont'd)

If only common causes of variation are present, the output of a process forms a distribution that is stable over time and is predictable:

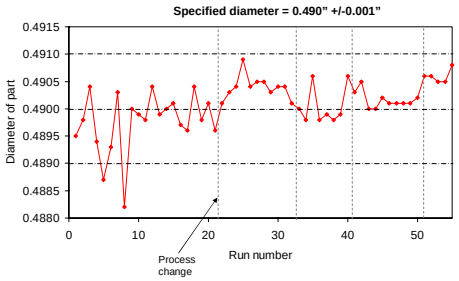


Common and Special Causes (cont'd)

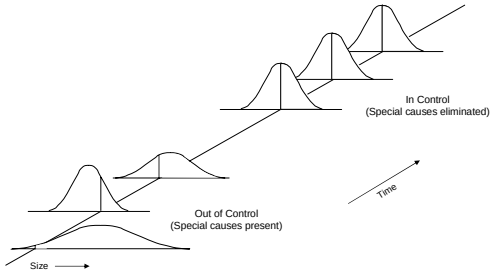
If special causes of variation are present, the process output is not stable over time and is not predictable:



Variation: Run Chart



Process Control



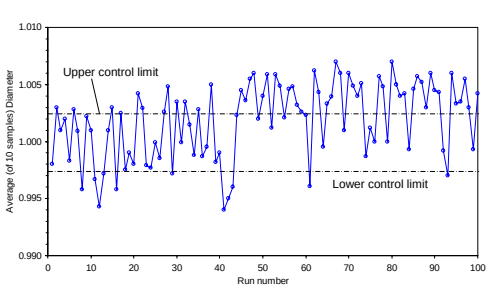
Statistical Process Control

1. Detect disturbances (special causes)
2. Take corrective actions

Central Limit Theorem

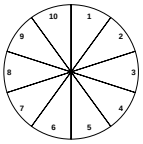
- A large number of independent events have a continuous probability density function that is normal in shape.
- Averaging more samples increases the precision of the estimate of the average.

Shewhart Control Chart



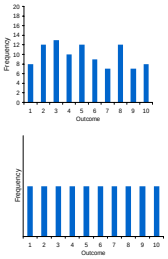
Sampling and Histogram Creation

Wheel of Fortune: Equal probability of outcome 1-10, P=0.1



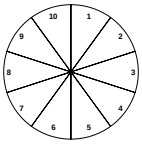
Taking 100 random samples, the resulting histogram would look like this

Taking ∞ random samples, the resulting histogram would look like this



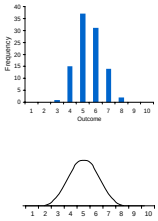
Sampling and Histogram Creation (cont'd)

Wheel of Fortune: Equal probability of outcome 1-10, P=0.1

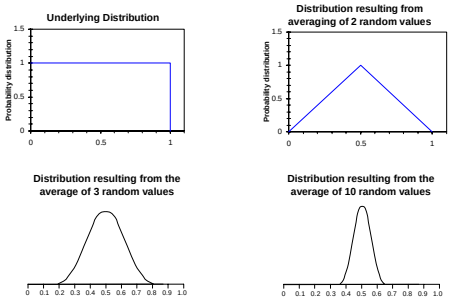


Take 10 random samples, calculate their average, and repeat 100 times, the resulting histogram would resemble

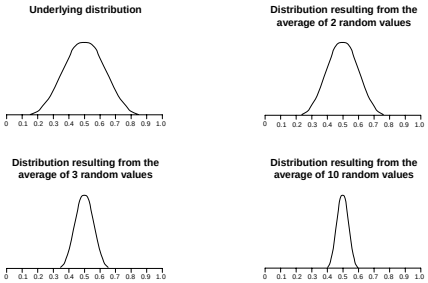
Take 10 random samples, calculate their average, and repeat ∞ times, the resulting histogram would approach the continuous distribution shown



Uniform Distributions



Normal Distribution



Precision

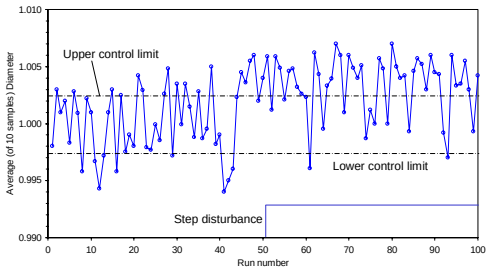
	Not precise	Precise
Not accurate		
Accurate		

Shewhart Control Chart

- Upper Control Limit (UCL), Lower Control Limit (LCL)
- Subgroup size ($5 < n < 20$)

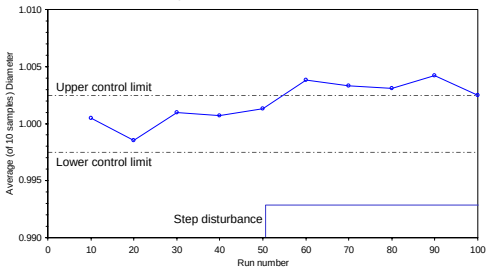
Shewhart Control Chart (cont'd)

Control chart based on 100 samples

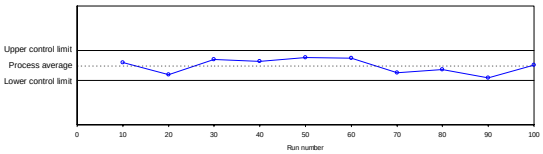


Shewhart Control Chart (cont'd)

Control chart based on average of 10 samples, note the step change that occurs at run 51



Control Charts



1. Collection:
   - Gather data and plot on chart.
2. Control:
   - Calculate control limits from process data, using simple formulae.
   - Identify special causes of variation; take local actions to correct.
3. Capability:
   - Quantify common cause variation; take action on the system.

These three phases are repeated for continuing process improvement.

Setting the Limits

Idea: Points outside the limits will signal that something is wrong- an assignable cause. We want limits set so that assignable causes are highlighted, but few random causes are highlighted accidentally.

Convention for Control Charts:

- Upper control limit (UCL) = $\bar{\bar{x}} + 3\sigma_{sg}$
- Lower control limit (LCL) = $\bar{\bar{x}} - 3\sigma_{sg}$

(Where σ_{sg} represents the standard deviation of a subgroup of samples)

Setting the Limits (cont'd)

Convention for Control Charts (cont'd):

$$\sigma_{\text{sub group}} = \sigma_{sg} \neq \sigma_{\text{process}}$$

$$\sigma_{\text{subgroup}} = \sigma_{\text{process}}/\sqrt{n}$$

$$\text{UCL} = \bar{\bar{x}} + 3\sigma_{\text{process}}/\sqrt{n}$$

$$\text{LCL} = \bar{\bar{x}} - 3\sigma_{\text{process}}/\sqrt{n}$$

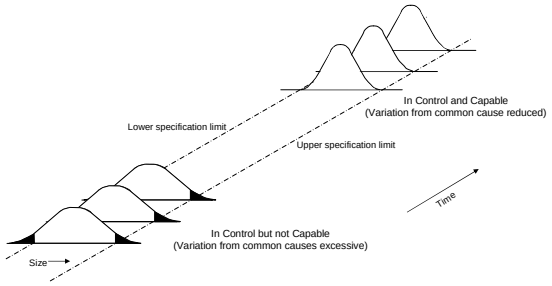
As n increases, the UCL and LCL move closer to the center line, making the control chart more sensitive to shifts in the mean.

Benefits of Control Charts

Properly used, control charts can:

- Be used by operators for ongoing control of a process
- Help the process perform consistently, predictably, for quality and cost
- Allow the process to achieve:
  - Higher quality
  - Lower unit cost
  - Higher effective capacity
- Provide a common language for discussing process performance
- Distinguish special from common causes of variation; as a guide to local or management action

Process Capability

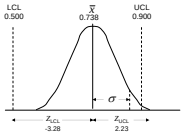


Process Capability Index

1. Cp = Range/6σ
2. Cpk

Process Capability

- Take an example with:
  Mean = .738
  Standard deviation, σ = .0725
  UCL = 0.900
  LCL = 0.500
- Normalizing the specifications:



$$Z_{UCL} = \frac{UCL - \bar{x}}{\sigma} = \frac{0.900 - 0.738}{0.0725} = 2.23$$

$$Z_{LCL} = \frac{LCL - \bar{x}}{\sigma} = \frac{0.500 - 0.738}{0.0725} = -3.28$$

Z_{MIN} = 2.23 (on an absolute basis)

Process Capability (cont'd)

- Using the tables of areas under the Normal Curve, the proportions out of specification would be:

  P_{UCL} = 0.0129

  P_{LCL} = 0.0005

  P_{total} = 0.0134
- The Capability Index would be:

  $C_{PK} = Z_{min}/3 = 2.23 / 3 = 0.74$

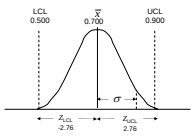
Process Capability (cont'd)

- If this process could be adjusted toward the center of the specification, the proportion of parts falling beyond either or both specification limits might be reduced, even with no change in Standard deviation.
- For example, if we confirmed with control charts a new mean = 0.700, then:

$$Z_{UCL} = \frac{UCL - \bar{x}_{new}}{\sigma} = \frac{0.900 - 0.700}{0.0725} = 2.76$$

$$Z_{LCL} = \frac{LCL - \bar{x}_{new}}{\sigma} = \frac{0.500 - 0.700}{0.0725} = -2.76$$

Z_{min} = 2.76



Process Capability (cont'd)

- The proportions out of specification would be:

  P_{UCL} = 0.0029

  P_{LCL} = 0.0029

  P_{total} = 0.0058
- The Capability Index would be:

  $C_{PK} = Z_{min}/3 = 2.76 / 3 = 0.92$

Improving Process Capability

- To improve the chronic performance of the process, concentrate on the common causes that affect all periods. These will usually require management action on the system to correct.
- Chart and analyze the revised process:
  - Confirm the effectiveness of the system by continued monitoring of the Control Chart