Data Analytics in Business

Operations Management

Bob Myers
Lecturer
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Quality

Learning Objectives

At the end of this lesson, you should be able to:

- Explain Quality and its meaning
- List the dimensions of product and service quality
- Assess the use of analytics to ensure quality

What is Quality?

- Meeting or exceeding customers expectations

Garvin's 8 Dimensions of Product Quality

1. Performance
2. Functionality
3. Durability
4. Reliability
5. Conformance to Specifications
6. Serviceability
7. Aesthetics
8. Perceived Quality

Dimensions of Service Quality

- Consistency
- Courtesy
- Convenience/Availability
- Communication
- Accuracy/Reliability
- Timeliness/Responsiveness
- Credibility/Trustworthy
- Security

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How Could Analytics be Used with Respect to Quality?

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Summary

1. Quality – meeting or exceeding customers expectations
2. It can mean different things to different people
3. Analytics can be used to improve quality

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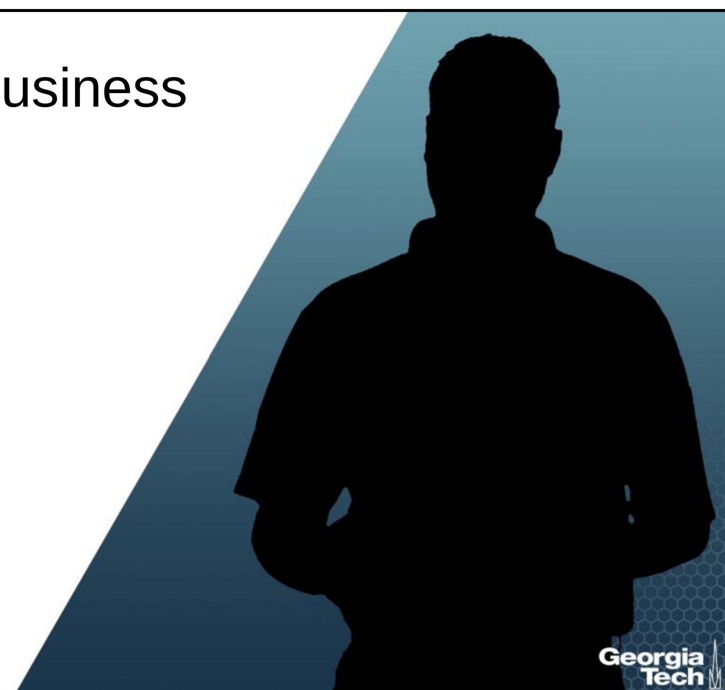
Costs of Quality



Learning Objectives

At the end of this lesson, you should be able to:

- Describe Juran’s Cost of Quality

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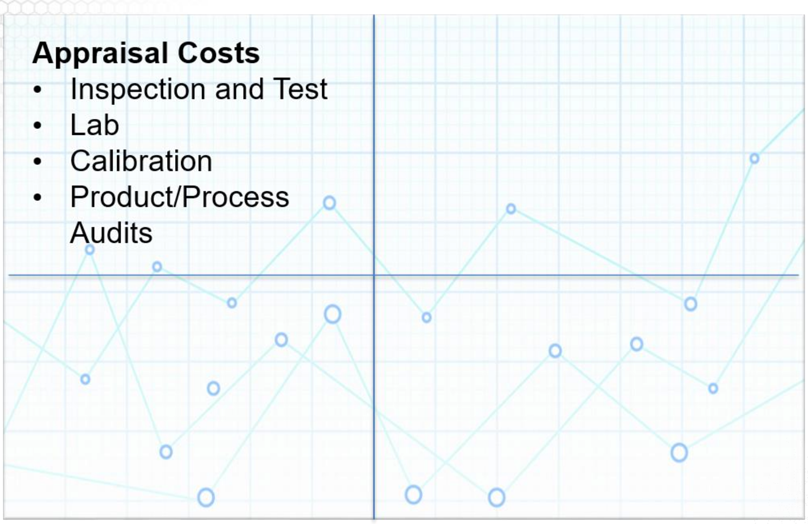
What are the Costs of Quality?



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What are the Costs of Quality?

Appraisal Costs
- Inspection and Test
- Lab
- Calibration
- Product/Process Audits

Prevention Costs
- Training
- Quality Improvement
- Quality Audits
- Quality Planning

What are the Costs of Quality?

Appraisal Costs
- Inspection and Test
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- Product/Process Audits

Prevention Costs
- Training
- Quality Improvement
- Quality Audits
- Quality Planning

Internal Failure Costs
- Scrap
- Rework
- Re-testing

What are the Costs of Quality?

Appraisal Costs • Inspection and Test • Lab • Calibration • Product/Process Audits	**Prevention Costs** • Training • Quality Improvement • Quality Audits • Quality Planning
Internal Failure Costs • Scrap • Rework • Re-testing	**External Failure Costs** • Warranty • Reputation • Returns • Litigation

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What are the Costs of Quality?

Appraisal Costs • Inspection and Test • Lab • Calibration • Product/Process Audits	**Prevention Costs** • Training • Quality Improvement • Quality Audits • Quality Planning	← Costs of GOOD Quality
Internal Failure Costs • Scrap • Rework • Re-testing	**External Failure Costs** • Warranty • Reputation • Returns • Litigation	← Costs of POOR Quality

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Summary

1. 4 Costs of Quality

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Variation

Learning Objectives

At the end of this lesson, you should be able to:

- Outline the types of variation
- Explain the use of statistics in analyzing variation

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What is Variation (From Webster's Dictionary?

- The extent to which, or the range in which, a thing varies
- A measure of the change in data, a variable, or a function

VARY

- To make a partial change in**:** make different in some attribute or characteristic
- To make differences between items

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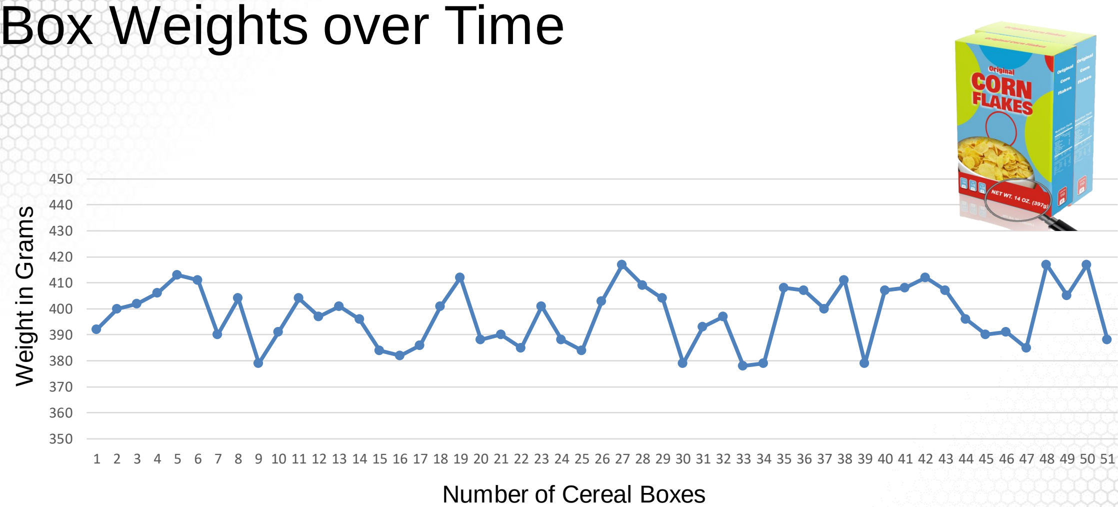
Consider Making Cereal

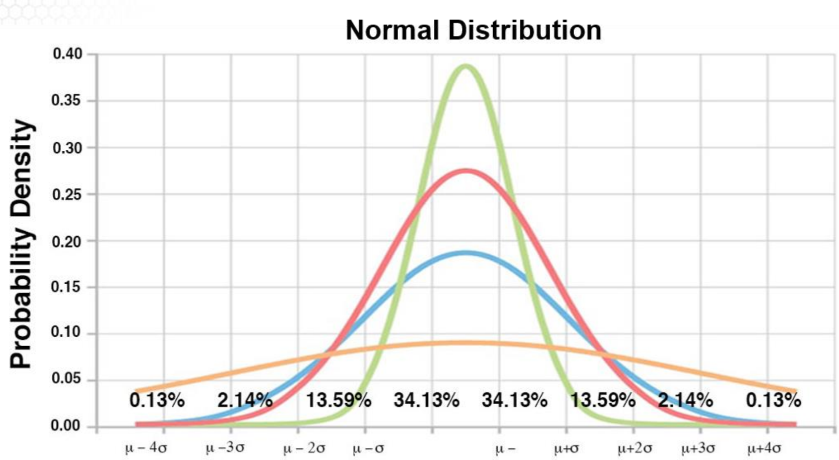
Box Weights over Time



What Can Cause the Weight to Vary?

- **Random/Common Causes**
  - Inherent in the process used
  - Unavoidable with current process
  - Can do nothing about this
- **Assignable/Special Causes**
  - Can be identified
  - Can be corrected/fixed (ex: new operator error)

What Would Distribution of Weights Look Like with Only Common Causes of Variation?



μ = mean
σ = standard deviation

Summary

1. Common vs Assignable causes of variation

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Control Chart Basics

Learning Objectives

At the end of this lesson, you should be able to:

- Explain the basics of a control chart
- Explain what indicates assignable causes of variation in a control chart

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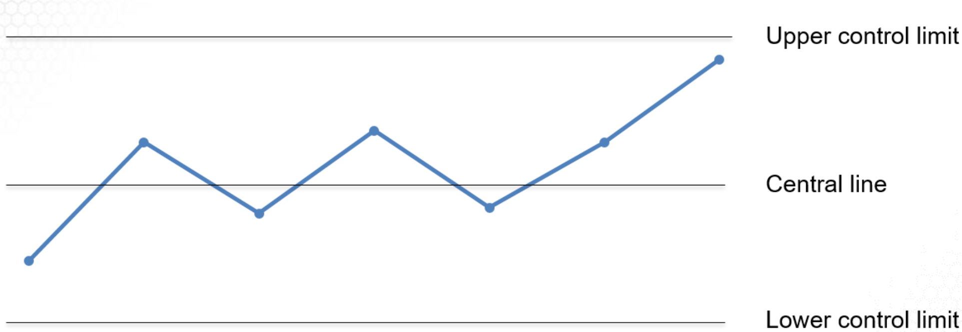
What is a Control Chart?



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How Does This Relate Back to Types of Variation?

- Upper and Lower control limits are set based on Common/Random causes of variation for the process (we know these will lead to a normal distribution)
- Data plotting and monitoring is to watch for Assignable/Special causes of variation (these are causes of variation we can do something about)

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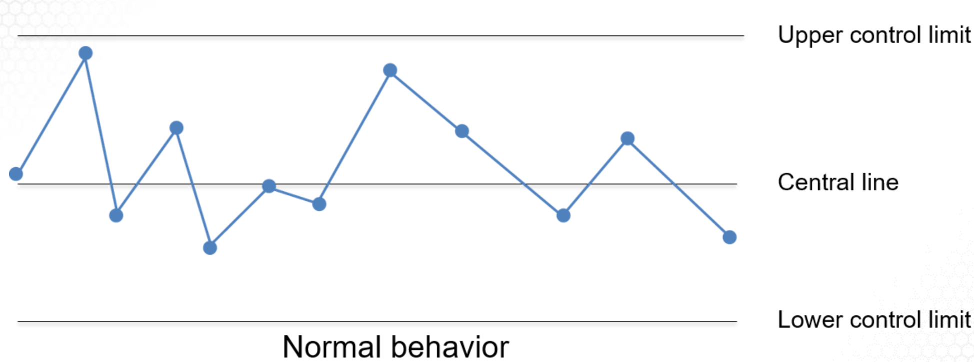
Sample Control Chart



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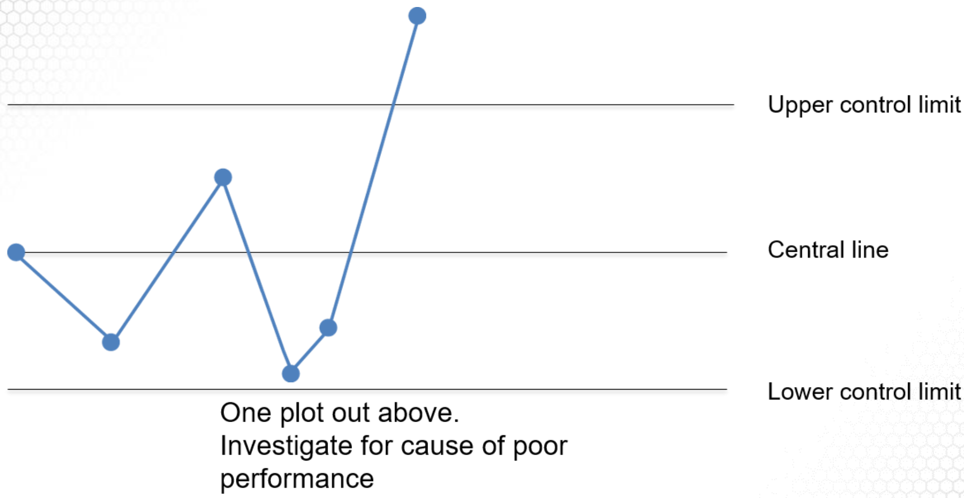
Sample Control Chart



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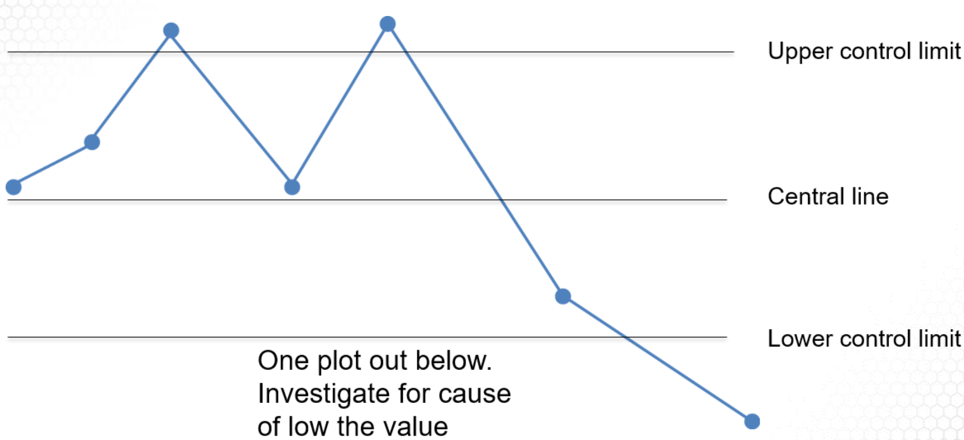
Sample Control Chart



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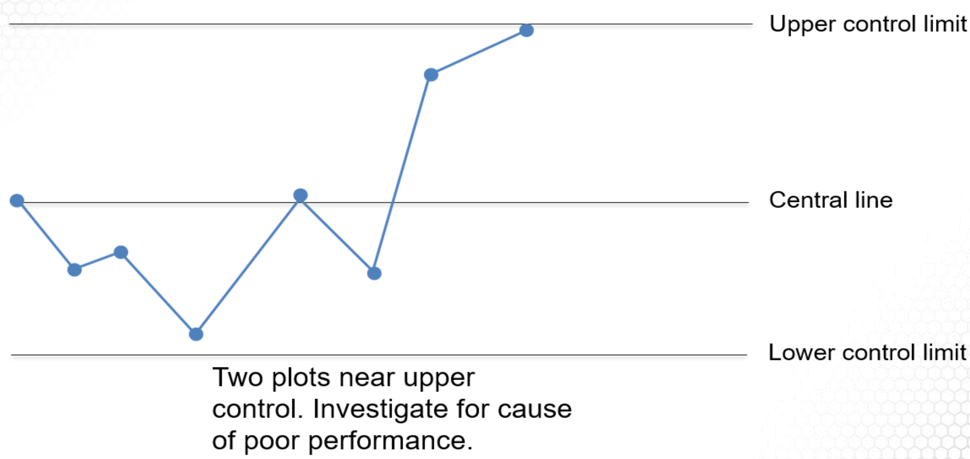
Sample Control Chart



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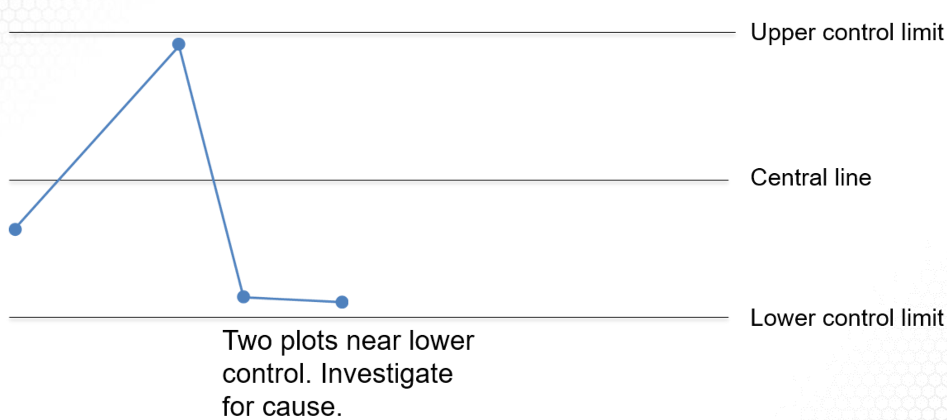
Sample Control Chart



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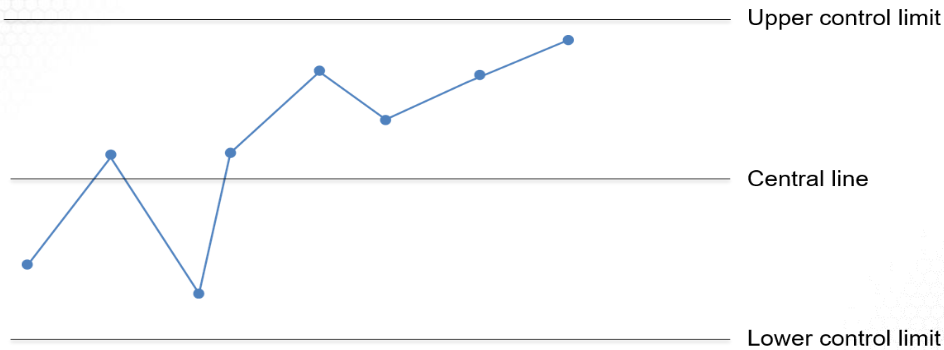
Sample Control Chart



Run of five above central line. Investigate for cause of sustained poor performance.

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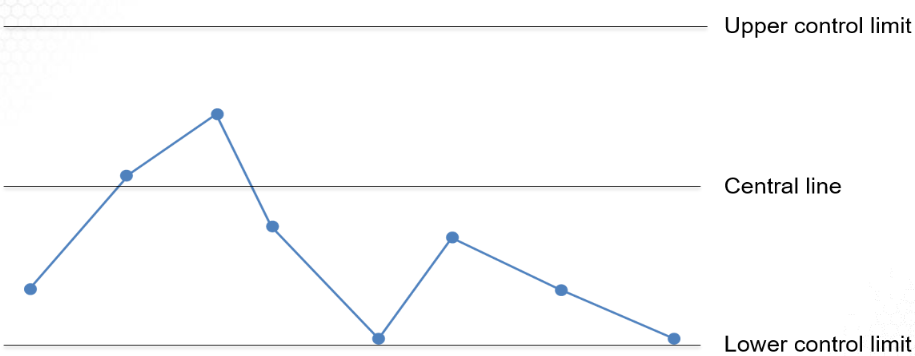
Sample Control Chart



Run of five below central line. Investigate for cause of progressive performance.

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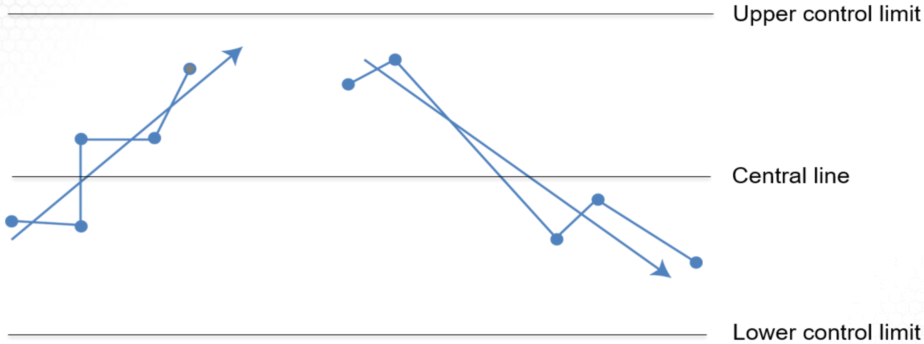
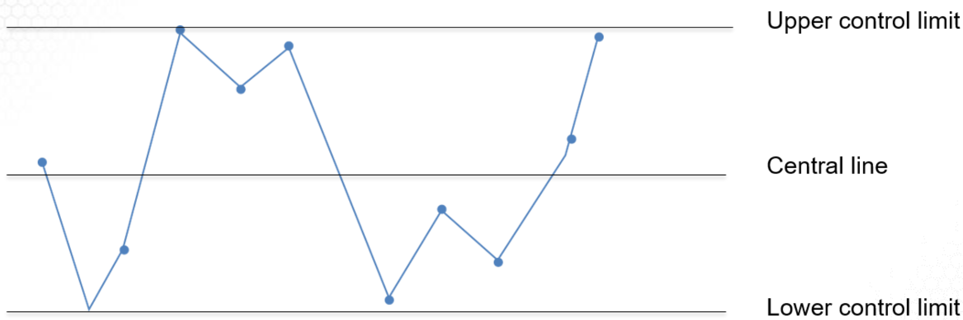
Sample Control Chart



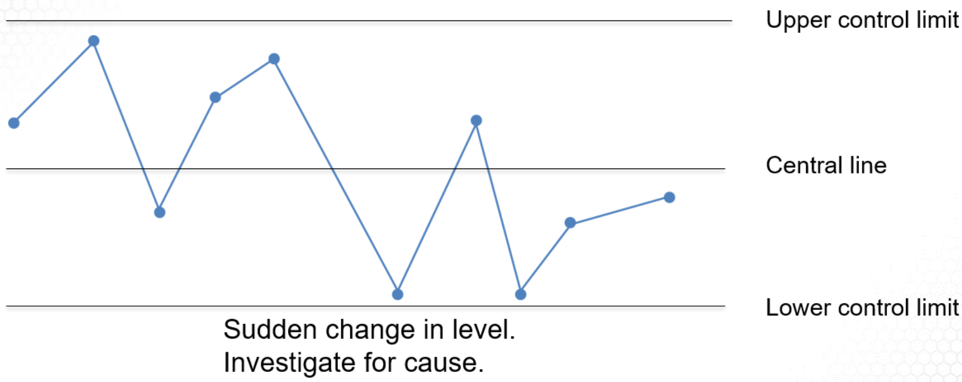
Trend in either direction five plots. Investigate for cause of progressive change.

Sample Control Chart



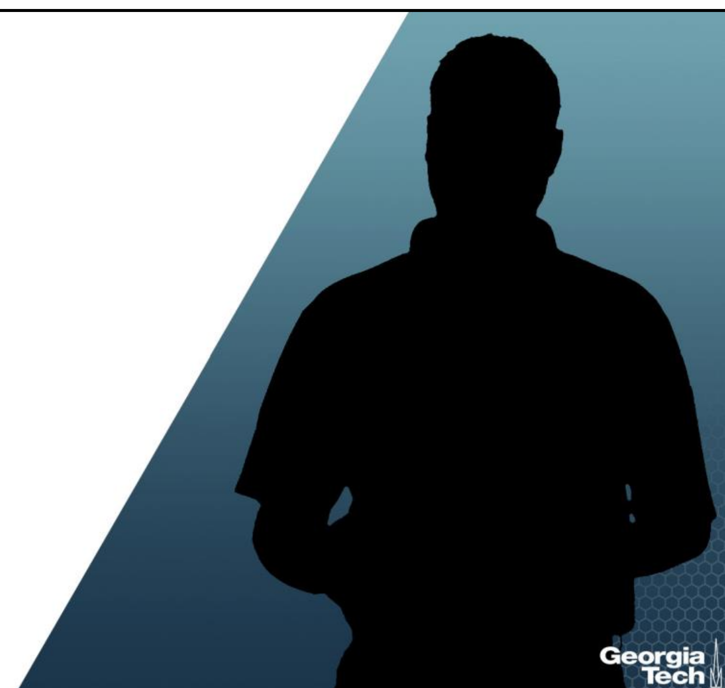
Erratic behavior. Investigate.

Sample Control Chart



Summary

1. Control Charts are used to identify assignable causes of variation



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Control Charts for Variables

Learning Objectives

At the end of this lesson, you should be able to:

- Discuss control charts for continuous values (variables)
- Explain how to setup and evaluate control charts for variables

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The Central Limit Theorem

From Merriam Webster: “any of several fundamental theorems of probability and statistics that state the conditions under which the distribution of a sum of independent random variables is approximated by the normal distribution”

Translation: Take a sample of 5 boxes of cereal, weigh each and calculate the average weight for the sample. Do this 20-30 times and plot the averages. You will get a normal distribution.

Thinking More…

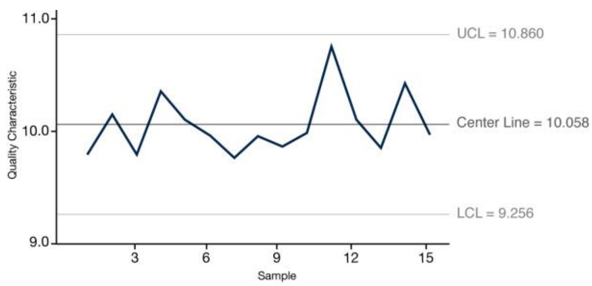
- We should be able to take periodic samples and use the information from the samples to represent the population as a whole
  - This is great news for measurements that would be cost prohibitive to conduct on all items
- Recall from a normal distribution that 99.73% of all values should fall within 3 standard deviations of the mean
  - If a average or mean falls outside of 3 standard deviations, it is 99.73% likely that an assignable cause of variation has occurred
- A Normal Distribution has 2 parts: its Mean and Standard Deviation
  - We will use 2 control charts to monitor these: $\overline{x}$ and r Chart

$\overline{x}$ Chart (Monitors the mean)

Assuming 3σ limits:

UCLx = $\bar{\bar{X}} + A_2 * \bar{R}$

LCLx = $\bar{\bar{X}} - A_2 * \bar{R}$



Sample Size	Mean Factor A_2
2	1.880
3	1.023
4	.729
5	.577
6	.483
7	.419
8	.373

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R Chart (Monitors the spread)

Assuming 3σ limits:

UCLr = $D_4 * \bar{R}$

LCLr = $D_3 * \bar{R}$

Sample Size	Upper Range D_4	Lower Range D_3
2	3.268	0
3	2.574	0
4	2.282	0
5	2.115	0
6	2.004	0
7	1.924	0.076
8	1.864	0.136

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Steps for Statistical Process Control Monitoring a Variable

1. Collect Data
2. Calculate $\bar{R}$
3. Calculate UCLr and LCLr
4. Plot R-chart
5. Calculate $\bar{x}$
6. Calculate UCLx and LCLx
7. Plot X-chart

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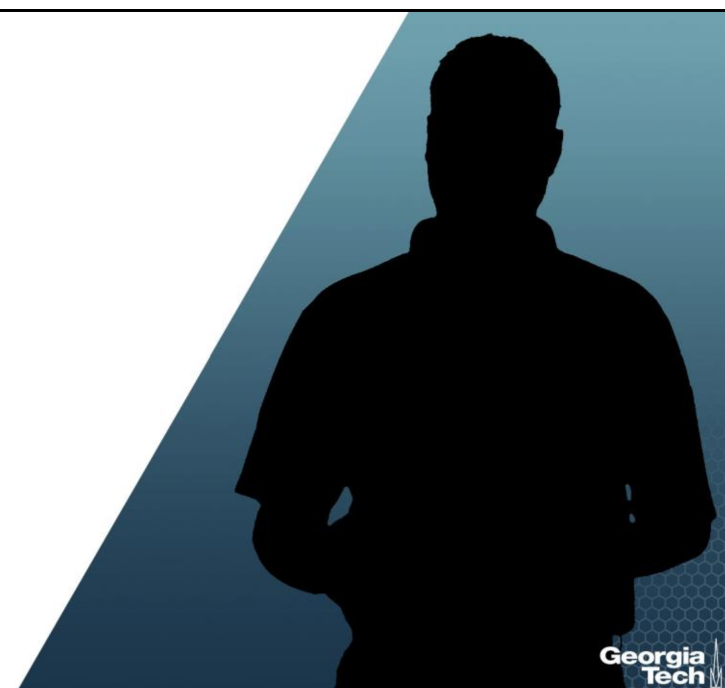
Summary

1. Control Charts look to identify assignable causes of variation.
2. Can be used to reduce defects.



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Sample Problem

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Learning Objectives

At the end of this lesson, you should be able to:

- Outline the use Statistical Process Control to monitor a proc

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Making Bottles for a Beverage

- You are the plant manager for a plant that make bottles for Co… se bottles are sent on to a bottling plant to get filled and capped
- You want to be able to use analytics to monitor the perfor… ottle making plant
- The bottleneck diameter is critical. It needs to be c… bottle will cause spillage. Also, if not consistent, th… another company) will not fit or will fall off
- You decide to implement Statistical Process Co… performance of the bottle making line

Steps for Statistical Process Control Monitoring a Variable

1. **Collect Data**
2. Calculate $\bar{R}$
3. Calculate UCLr and LCLr
4. Plot R-chart
5. Calculate $\bar{\bar{x}}$
6. Calculate UCL$\bar{x}$ and LCL$\bar{x}$
7. Plot $\bar{x}$-chart

Step 1 – Collect Data

- Decide on the variable to use
  - We will pick the bottleneck diameter
- Decide on Sample size and frequency
  - We will pick a sample size of 4 and take a sample every hour
- Take Data

	Bottle			
SAMPLE	1	2	3	4
1	.604	.612	.588	.600
2	.597	.601	.607	.603
3	.581	.570	.585	.592
4	.620	.605	.595	.588
5	.590	.614	.608	.604
6	.585	.583	.617	.579

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Steps for Statistical Process Control Monitoring a Variable

1. Collect Data
2. **Calculate $\bar{R}$**
3. Calculate UCLr and LCLr
4. Plot R-chart
5. Calculate $\bar{\bar{x}}$
6. Calculate UCL$\bar{x}$ and LCL$\bar{x}$
7. Plot $\bar{x}$-chart

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2. Calculate $\bar{R}$

	Bottle				
SAMPLE	1	2	3	4	R
1	.604	.612	.588	.600	.024
2	.597	.601	.607	.603	.010
3	.581	.570	.585	.592	.022
4	.620	.605	.595	.588	.032
5	.590	.614	.608	.604	.024
6	.585	.583	.617	.579	.038

$\bar{R}$ = .025

Steps for Statistical Process Control Monitoring a Variable

1. Collect Data
2. Calculate $\bar{R}$
3. **Calculate UCLr and LCLr**
4. Plot R-chart
5. Calculate $\bar{\bar{x}}$
6. Calculate UCL$\bar{x}$ and LCL$\bar{x}$
7. Plot $\bar{x}$-chart

3. Calculate UCLr and LCLr

UCLr = $D_4 * \bar{R}$
UCLr = 2.282 * .025
UCLr = .057

LCLr = $D_3 * \bar{R}$
LCLr = 0 * .025
LCLr = 0

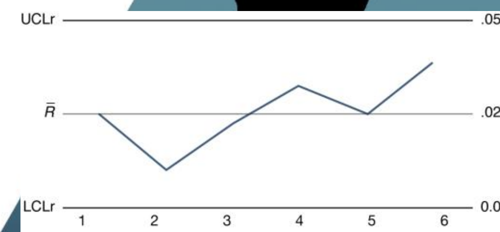
Sample Size	Upper Range D_4	Lower Range D_3
2	3.268	0
3	2.574	0
4	2.282	0
5	2.115	0
6	2.004	0
7	1.924	0.076
8	1.864	0.136

Steps for Statistical Process Control Monitoring a Variable

1. Collect Data
2. Calculate $\bar{R}$
3. Calculate UCLr and LCLr
4. **Plot R-chart**
5. Calculate $\bar{\bar{x}}$
6. Calculate UCL$\bar{x}$ and LCL$\bar{x}$
7. Plot $\bar{x}$-chart

4. Plot R chart

	Bottle				
SAMPLE	1	2	3	4	R
1	.604	.612	.588	.600	**.024**
2	.597	.601	.607	.603	**.010**
3	.581	.570	.585	.592	**.022**
4	.620	.605	.595	.588	**.032**
5	.590	.614	.608	.604	**.024**
6	.585	.583	.617	.579	**.038**



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Steps for Statistical Process Control Monitoring a Variable

1. Collect Data
2. Calculate $\bar{R}$
3. Calculate UCLr and LCLr
4. Plot R-chart
5. **Calculate $\bar{\bar{x}}$**
6. Calculate UCL$\bar{x}$ and LCL$\bar{x}$
7. Plot $\bar{x}$-chart

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5. Calculate $\bar{\bar{x}}$

	Bottle				
SAMPLE	1	2	3	4	$\bar{x}$
1	.604	.612	.588	.600	.601
2	.597	.601	.607	.603	.602
3	.581	.570	.585	.592	.582
4	.620	.605	.595	.588	.602
5	.590	.614	.608	.604	.604
6	.585	.583	.617	.579	.591

$\bar{\bar{x}}$ **= .597**

Steps for Statistical Process Control Monitoring a Variable

1. Collect Data
2. Calculate $\bar{R}$
3. Calculate UCLr and LCLr
4. Plot R-chart
5. Calculate $\bar{\bar{x}}$
6. **Calculate UCL$\bar{x}$ and LCL$\bar{x}$**
7. Plot $\bar{x}$-chart

6. Calculate UCL$\bar{x}$ and LCL$\bar{x}$

UCL$\bar{x}$ = $\bar{\bar{x}}$ + A2 * $\bar{R}$
UCL$\bar{x}$ = .597 + .729 * .025
UCL$\bar{x}$ = .615

LCL$\bar{x}$ = $\bar{\bar{x}}$ - A2 * $\bar{R}$
LCL$\bar{x}$ = .597 - .729 * .025
LCL$\bar{x}$ = .579

Sample Size	Mean Factor A_2
2	1.880
3	1.023
4	.729
5	.577
6	.483
7	.419
8	.373

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Steps for Statistical Process Control Monitoring a Variable

1. Collect Data
2. Calculate $\bar{R}$
3. Calculate UCLr and LCLr
4. Plot R-chart
5. Calculate $\bar{\bar{x}}$
6. Calculate UCL$\bar{x}$ and LCL$\bar{x}$
7. **Plot $\bar{x}$-chart**

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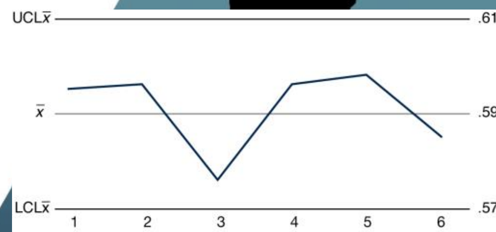
7. Plot $\bar{\bar{x}}$ chart

	Bottle				
SAMPLE	1	2	3	4	$\bar{x}$
1	.604	.612	.588	.600	**.601**
2	.597	.601	.607	.603	**.602**
3	.581	.570	.585	.592	**.582**
4	.620	.605	.595	.588	**.602**
5	.590	.614	.608	.604	**.604**
6	.585	.583	.617	.579	**.591**



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Summary

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Process Capability

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Learning Objectives

At the end of this lesson, you should be able to:

- Discuss how to determine if a process is actually capable of meeting a desired specification

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Process Capability

- SPC tells us if a process is showing signs of an assignable cause of variation but there is another important aspect to a given process:

Is the process capable of meeting a necessary requirement?

- Parts are often given design tolerances
  - Ex: 15 inches +- .5
- 2 common measurements are the Process Capability Ratio and Process Capability Index

Process Capability Index (Cp)

Cp = (Upper specification – Lower Specification)/6σ

- Cp >=1.0 indicates process is capable
- Six Sigma equates to a Cp >=2.0
- This value only looks at spread, not how well a process is centered on its target value

Process Capability Index (Cpk)

Cpk = Minimum of [{upper specification-$\bar{\bar{x}}$/3σ} , {$\bar{\bar{x}}$-lower specification/3σ}]

- Gives the proportion of variation between the center of the process and the nearest specification limit
- Cpk = 1 means process meets specifications
- Cpk < 1 Process does NOT meet specifications
- Cpk > 1 Process is better than the specification requires

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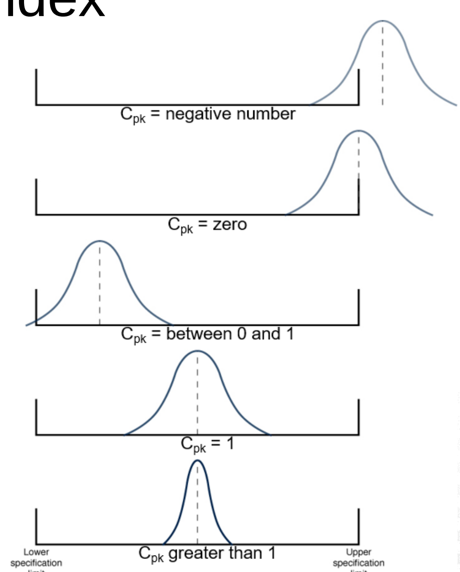
Process Capability Index



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Lets Apply to Prior Problem

Say the requirement given by Coke is the bottleneck diameter must be .600 +- .050. Above the tolerance and cap will not fit. Below the tolerance and the cap will fall off. Assume the standard deviation is .012

Cpk = Minimum of [{upper specification-$\bar{\bar{x}}$/3s} , {$\bar{\bar{x}}$-lower specification/3s}]

Cpk = Minimum of [{(.650-.597)/(3*.012)} , {(.597-.550)/(3*.012)}]

Cpk = Minimum of [{1.306} , {1.472}]

Cpk = 1.306 (Capable as Cpk>1)

Summary

- SPC only indications presence of assignable causes of variation
- Process Capability refers to the ability of a process to meet a given requirement (or specification)
- Cpk is more often used

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SPC Recap

Learning Objectives

At the end of this lesson, you should be able to:

- Explain Statistical Process Control
- Describe how this analytical technique is used in reducing defects

Recap

- Processes are central to creating products and services
- How could we use data and analytics to asses quality?
- Assignable vs. Common Causes of Variation
- SPC monitors for the presence of assignable variation
  - Still requires company to investigate
  - Not all assignable variation is bad (may want it to continue)
- P and C charts for Attributes (good/bad, pass/fail)