Lean Six Sigma Refresher

15-LSSRefresh –PG4A

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USER AGREEMENT

OTHER COPYRIGHT INFORMATION

Topics

- Review of DMAIC
- Selected Tools used in DMAIC
  - MSA
  - Capability Measures (Cp, Cpk)
  - Sampling and Confidence Intervals
  - Hypothesis Testing
  - Control Charts
- Practice with SPC XL software
- Certification Process/Guidelines

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Goals

- Provide a summary of the key learning points from LSS GB training
- Build confidence in understanding and applying the DMAIC methodology and its tools
- Practice using SPC XL software for analyzing data

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Comfort Level with LSS / DMAIC Methods (Baseline)

- Using a scale of 0-10, rate your knowledge/comfort level with the tools of LSS (IPO, MSA, hypothesis testing, etc.)

0	1	2	3	4	5	6	7	8	9	10
Haven't used Not at all Comfortable					Moderate Comfort (Comfortable with about half of tools/methods)					Extremely Comfortable (Comfortable with all (almost all) aspects)

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Introductions

- Name
- Your Position/Role and Project Info
- Your Expectations (what would you like to get out of today's session?)

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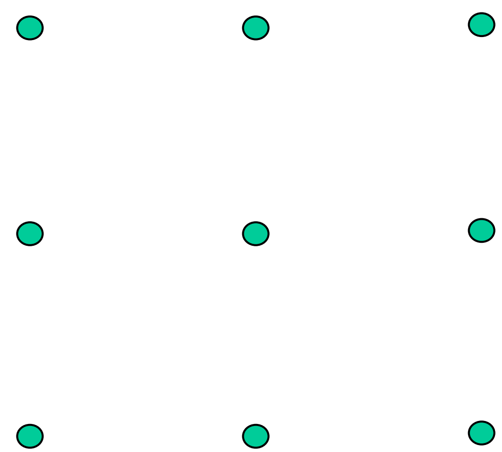
Warm Up Exercises

1. What comes next?

   58, 26, 16, 14, ___

2. Can you connect all 9 dots below, using 4 straight lines (or less), without lifting your pencil?



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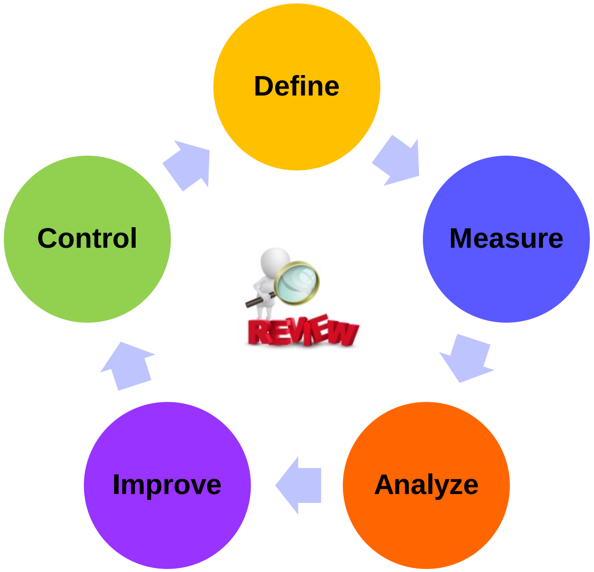
Review of DMAIC



The Define Phase

- **Define**
- Measure
- Analyze
- Improve
- Control

The Define Phase of Six Sigma involves defining the critical areas that need improvement.

In this phase, you define the project and goals, the process involved, the customers and stakeholders, and your team.

Phase	What	Tools
Define	✓ Define the problem and project (problem statement, goals, measures, etc.) ✓ Identify the team, roles and responsibilities, resources, stakeholders ✓ Understand the voice of the customer ✓ Create a high-level process map (IPO/SIPOC)	➢ Business case ➢ Project charter with S.M.A.R.T. goals ➢ Stakeholder Analysis ➢ IPO/SIPOC diagram ➢ Voice of the Customer (QFD) (HOQ) ➢ Value Stream Map

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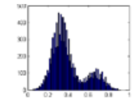
The Measure Phase



- Define
- **Measure**
- Analyze
- Improve
- Control

The Measure Phase of Six Sigma involves measuring the current performance of the process being studied.

In this phase, the team establishes a baseline of performance against which to measure progress and learns about the current “as-is” process.

Phase	What	Tools
Measure	✓ Map the current process ✓ Collect data and validate the measurement system ✓ Measure the current (“as-is”) capability ✓ Refocus/re-scope the project if necessary	➢ Process maps (physical, logical, time value, etc.) ➢ Data collection plan ➢ MSA ➢ Graphical analysis (histograms, run charts, control charts, etc.) ➢ Capability measures and analyses (Cp, Cpk, sigma capability, dpmo, etc.)

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The Analyze Phase

- Define
- Measure
- **Analyze**
- Improve
- Control

The Analyze Phase of Six Sigma involves analyzing the causes of poor performance and the sources of variation/waste.

In this phase, the team works toward finding the root cause(s) of the problems so that corrective action can be taken.

Phase	What	Tools
Analyze	✓ Analyze the waste and causes of poor performance ✓ Collect data and screen list of potential causes ✓ Prioritize the critical few causes/variables	➢ 7 wastes and Cost of Poor Quality ➢ Cause and Effect Diagrams (CE) with CNX ➢ Pareto charts ➢ Scatter diagrams ➢ voting, IPO matrix, Effort/Impact Analysis ➢ Hypothesis tests

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The Improve Phase

- Define
- Measure
- Analyze
- **Improve**
- Control

The Improve Phase of Six Sigma involves improving the process and implementing the necessary changes.

In this phase, the team generates solution alternatives, selects the best solution, makes changes to the process, and validates the improvements.

Phase	What	Tools
Improve	✓ Identify improvement opportunities ✓ Test/Screen solutions ✓ Pilot/measure/validate improvements ✓ Mistake proof the process ✓ Update process maps/SOPs	➢ IPO (prioritization) matrix ➢ Hypothesis Tests ➢ Charts and graphs (Run chart, box plots, histograms, Cp, Cpk, etc.) ➢ FMEA; poka yoke ➢ SOPs ➢ 5S

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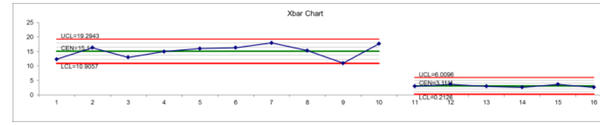
The Control Phase



- Define
- Measure
- Analyze
- Improve
- **Control**

The Control Phase of Six Sigma involves controlling and measuring the process improvements as well as implementing a plan to hold the gains.

In this phase, the team monitors the process, determines a plan for holding the gains, and summarizes their project work and key learnings.

Phase	What	Tools
Control	✓ Monitor new process ✓ Validate success ✓ Implement control plan for holding the gains ✓ Train team ✓ Summarize best practices / lessons learned; identify follow up actions and plans ✓ Hand off to process owner(s)	➢ control plan ➢ SOPs; standard work ➢ control charts ➢ FMEA ➢ project storyboard

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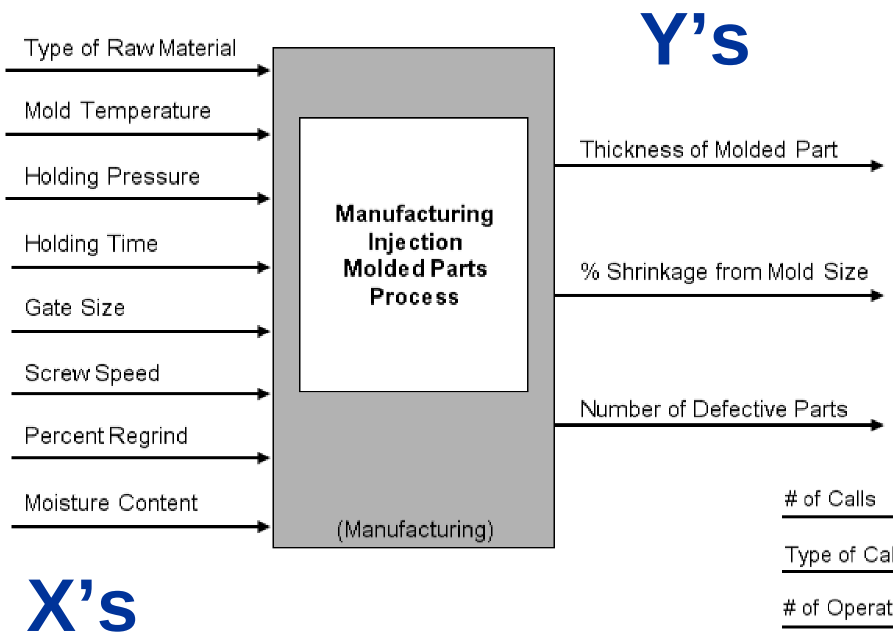
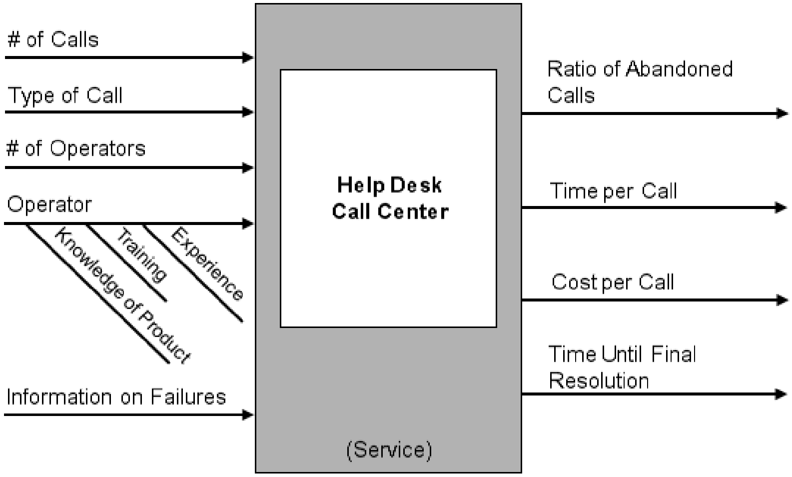
Input-Process-Output (IPO) Diagram

Processes are what we study and improve. A “process” is any blending of inputs to achieve desired outputs.



Y = f(X)



SIPOC Diagram (an extension of IPO)

Suppliers	Inputs	Process	Outputs	Customers
(providers of required resources)	(whats required)	(high level description of activity)	(deliverables, with measures)	(anyone who receives a deliverable)
Food Distributor Workforce NCR Customers Equipment Manufacturer AT&T Packaging Supplier	Ingredients Labor Cash Register Customer Orders Cooking Equipment Phone System Packaging Materials	Fast Food Pizza	Cooked Food * temperature of food * taste (survey) Change * error rate Packaged Order * order accuracy * cycle time	Hungry Customers

Take Order → Prepare Food → Package Food → Collect Payment → Deliver Food

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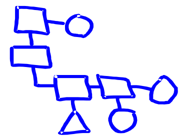
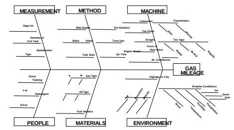
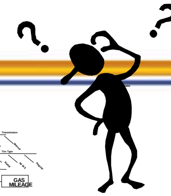
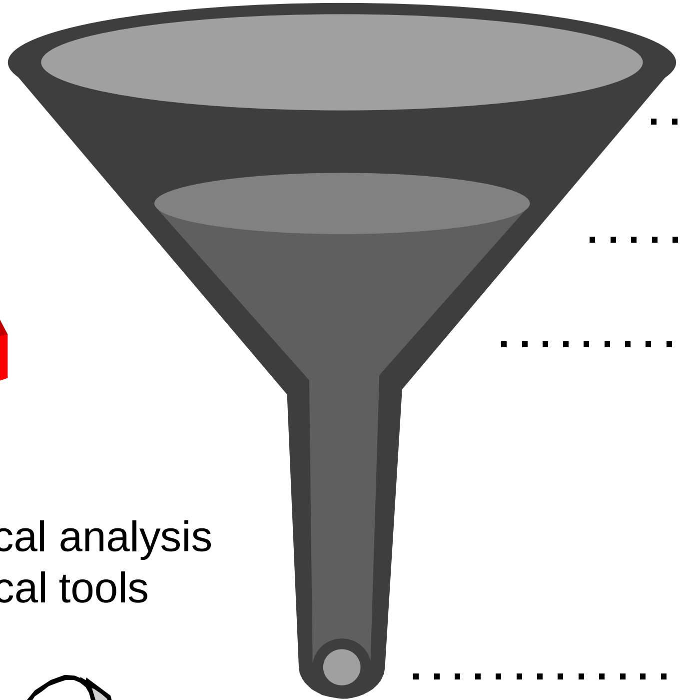
LSS is All About Drilling Down





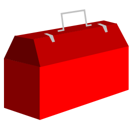




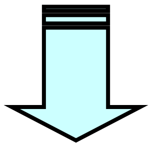
. . . .50 - 100 potential X’s

. . . . . . .30 - 50 potential X’s

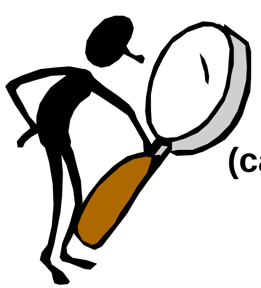
. . . . .10 - 30 potential X’s



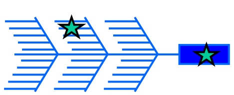
- DMAIC
- Data
- Graphical analysis
- Statistical tools



. . . . .the critical few (2 - 10)



Key inputs and Process steps (causing problems, affecting cost and/or performance, and generating waste)



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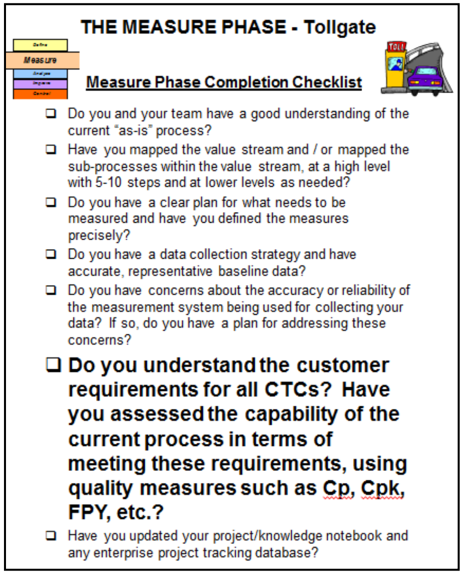
Capability Measures


THE MEASURE PHASE - Tollgate

Measure Phase Completion Checklist

- ❑ Do you and your team have a good understanding of the current "as-is" process?
- ❑ Have you mapped the value stream and / or mapped the sub-processes within the value stream, at a high level with 5-10 steps and at lower levels as needed?
- ❑ Do you have a clear plan for what needs to be measured and have you defined the measures precisely?
- ❑ Do you have a data collection strategy and have accurate, representative baseline data?
- ❑ Do you have concerns about the accuracy or reliability of the measurement system being used for collecting your data? If so, do you have a plan for addressing these concerns?
- ❑ **Do you understand the customer requirements for all CTCs? Have you assessed the capability of the current process in terms of meeting these requirements, using quality measures such as Cp, Cpk, FPY, etc.?**
- ❑ Have you updated your project/knowledge notebook and any enterprise project tracking database?

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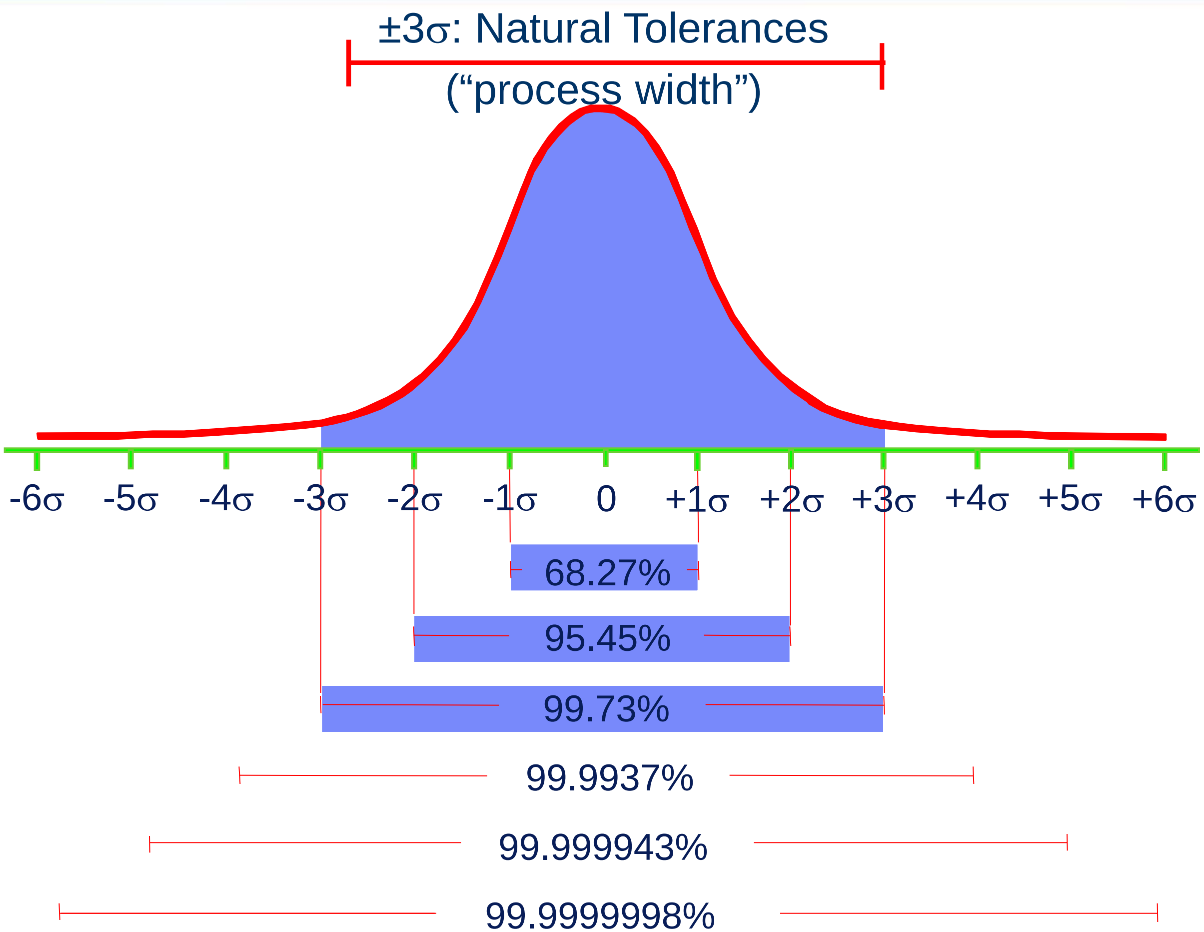
Graphical View of Variation



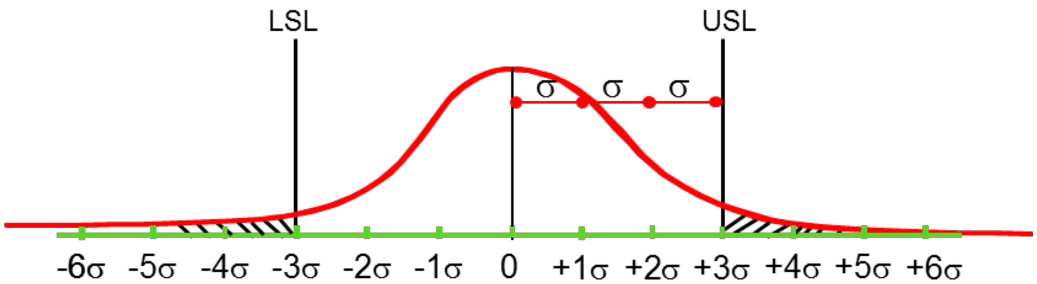
Typical Areas under the Normal Curve

Measure of Capability (Sigma Level)

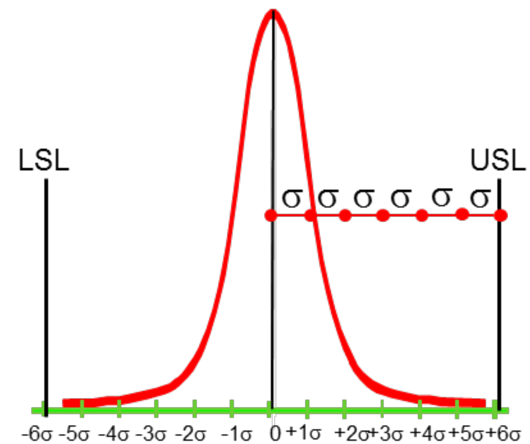
$$\text{Sigma level} = \text{minimum}\left(\frac{USL - \bar{y}}{\sigma} \text{ or } \frac{\bar{y} - LSL}{\sigma}\right)$$

Number of standard deviations that fit between the center of the process and the nearest spec limit

Example 1: $\sigma_{level} = 3$



Example 2: $\sigma_{level} = 6$



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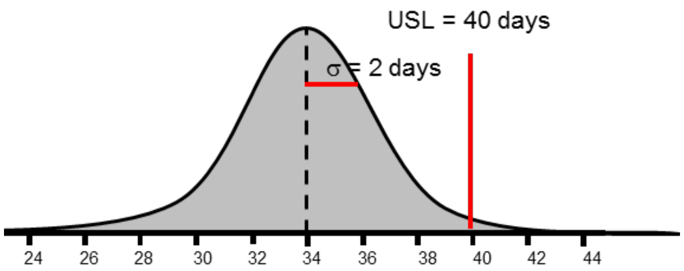
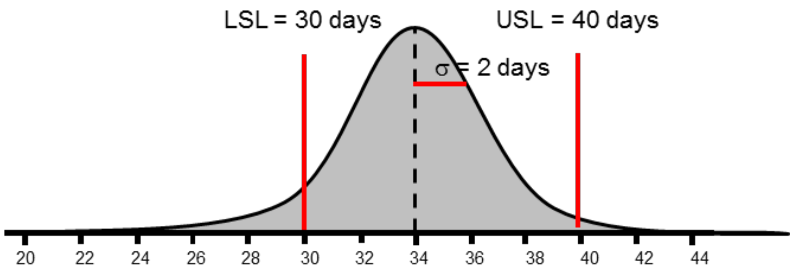
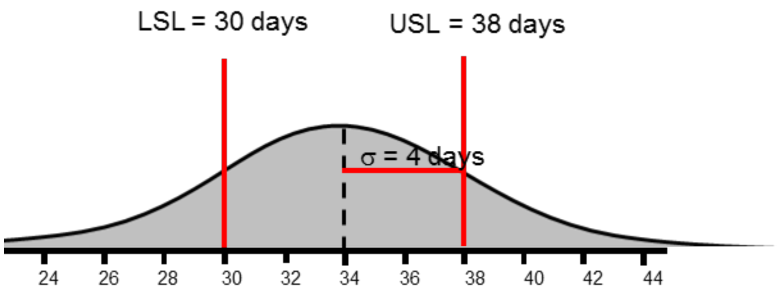
Practice (Sigma Level)



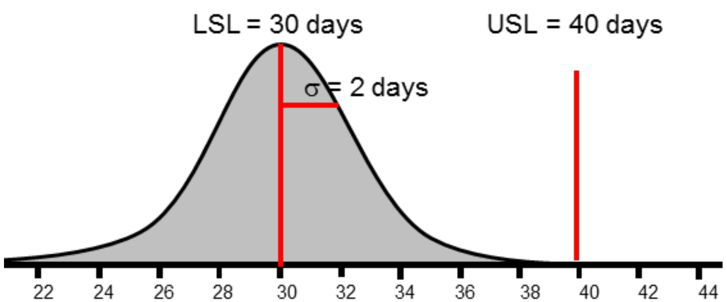
Sigma level = _____



Sigma level = _____



Sigma level = _____



Sigma level = _____

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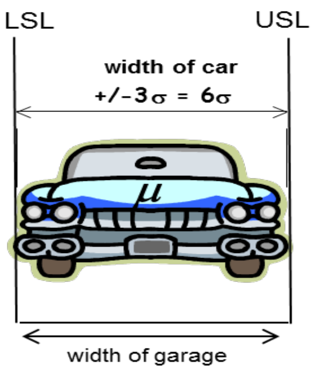
Measure of Capability (Cp)

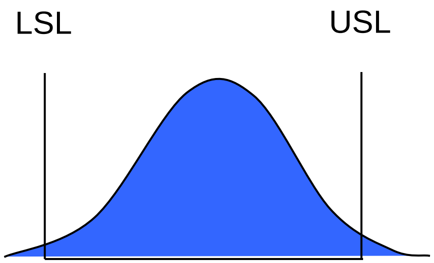
C_p: Process Capability (Potential)

$$C_p = \frac{USL - LSL}{6\sigma} = \frac{\text{Voice of the Customer}}{\text{Voice of the Process}} = \frac{\text{Spec Width}}{\text{Process Width}}$$

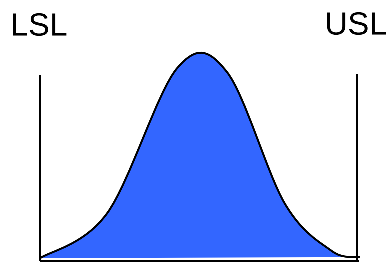


Examples:

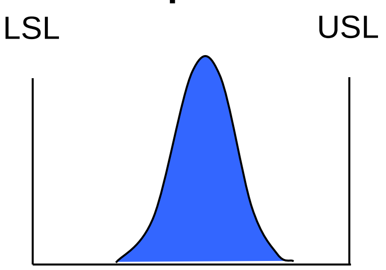
Cp = .9



Cp = 1



Cp = 2

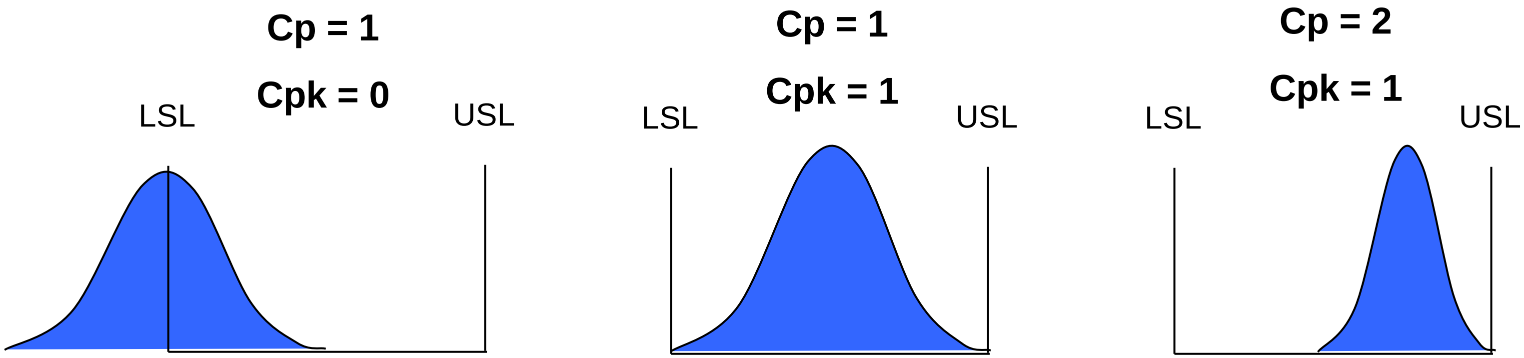


Measure of Capability (Cpk)

C_{pk}: Process Capability (Actual) (takes into consideration the center of the process)

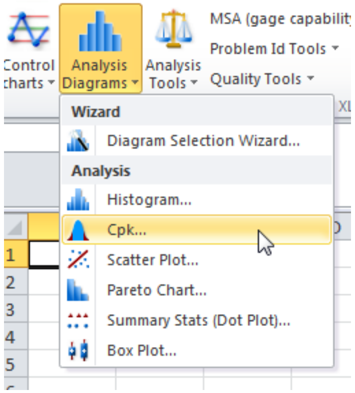
$$C_{pk} = \text{minimum}\left(\frac{USL - \bar{y}}{3\sigma} \text{ or } \frac{\bar{y} - LSL}{3\sigma}\right) = \frac{\text{sigma level}}{3}$$

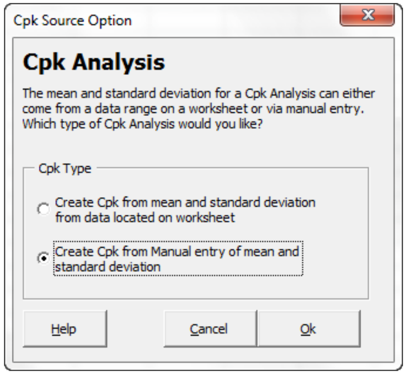
Examples:

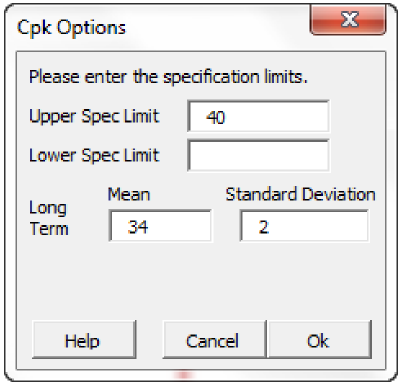


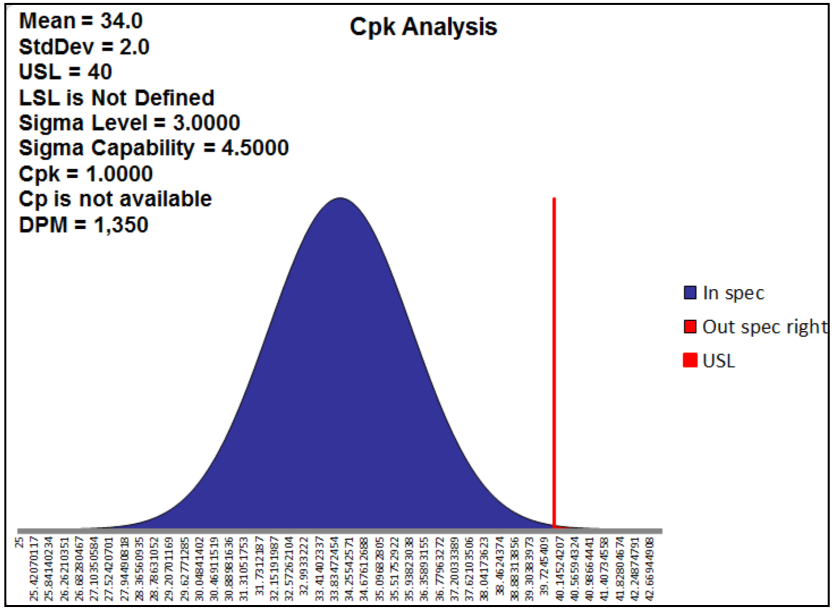
Using SPC XL for Capability Measures

SPC XL > Analysis Diagrams > Cpk

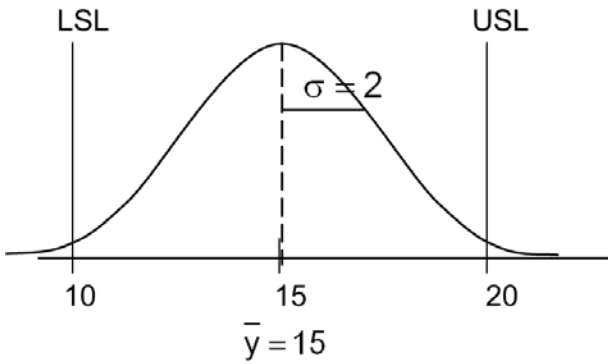








Practice (Capability Measures)

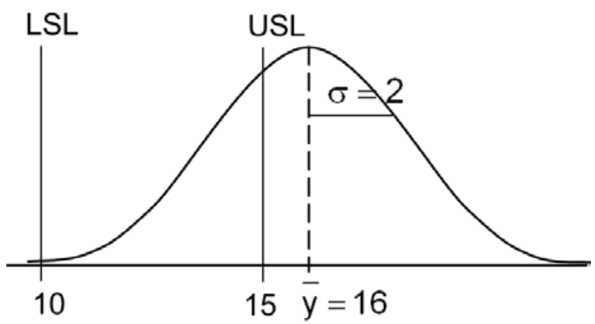


σ_{level} = ______

C_{pk} = ______

C_p = ______

dpm = ______

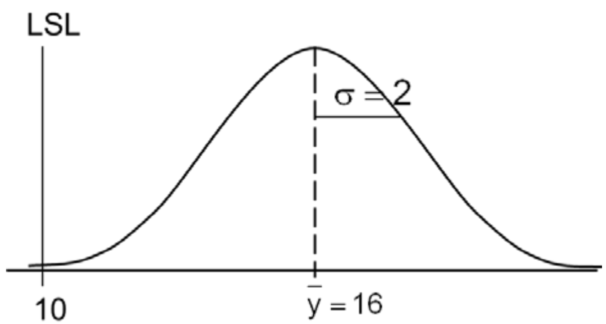


σ_{level} = ______

C_{pk} = ______

C_p = ______

dpm = ______



σ_{level} = ______

C_{pk} = ______

C_p = ______

dpm = ______

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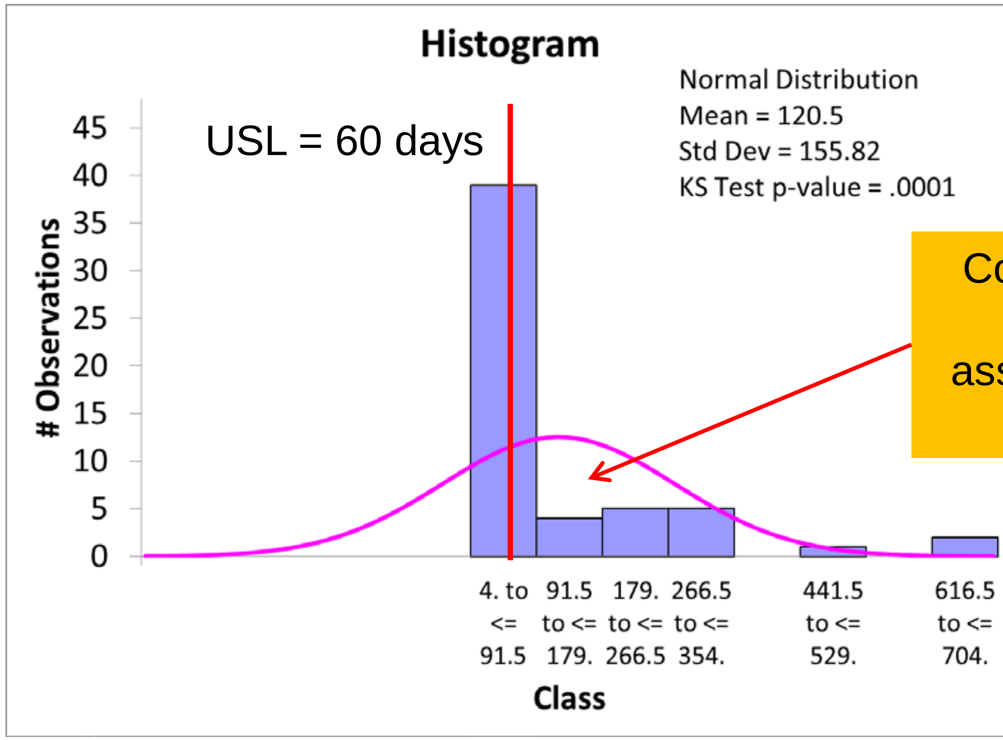
What if Data is Non-Normal?

SPC XL > Analysis Diagrams > Histogram



Could the dpm be overstated, assuming a normal distribution?

Days to Collect from Time Invoice Received (data in sorted order)

4	28	32	53	170	319
4	28	35	64	172	319
7	28	36	67	179	344
10	29	36	67	214	479
15	30	36	72	216	683
21	31	46	72	220	704
21	31	50	77	227	
25	31	50	80	266	
25	31	50	86	308	
25	31	51	95	318	

Data

Cpk non normal data.xls

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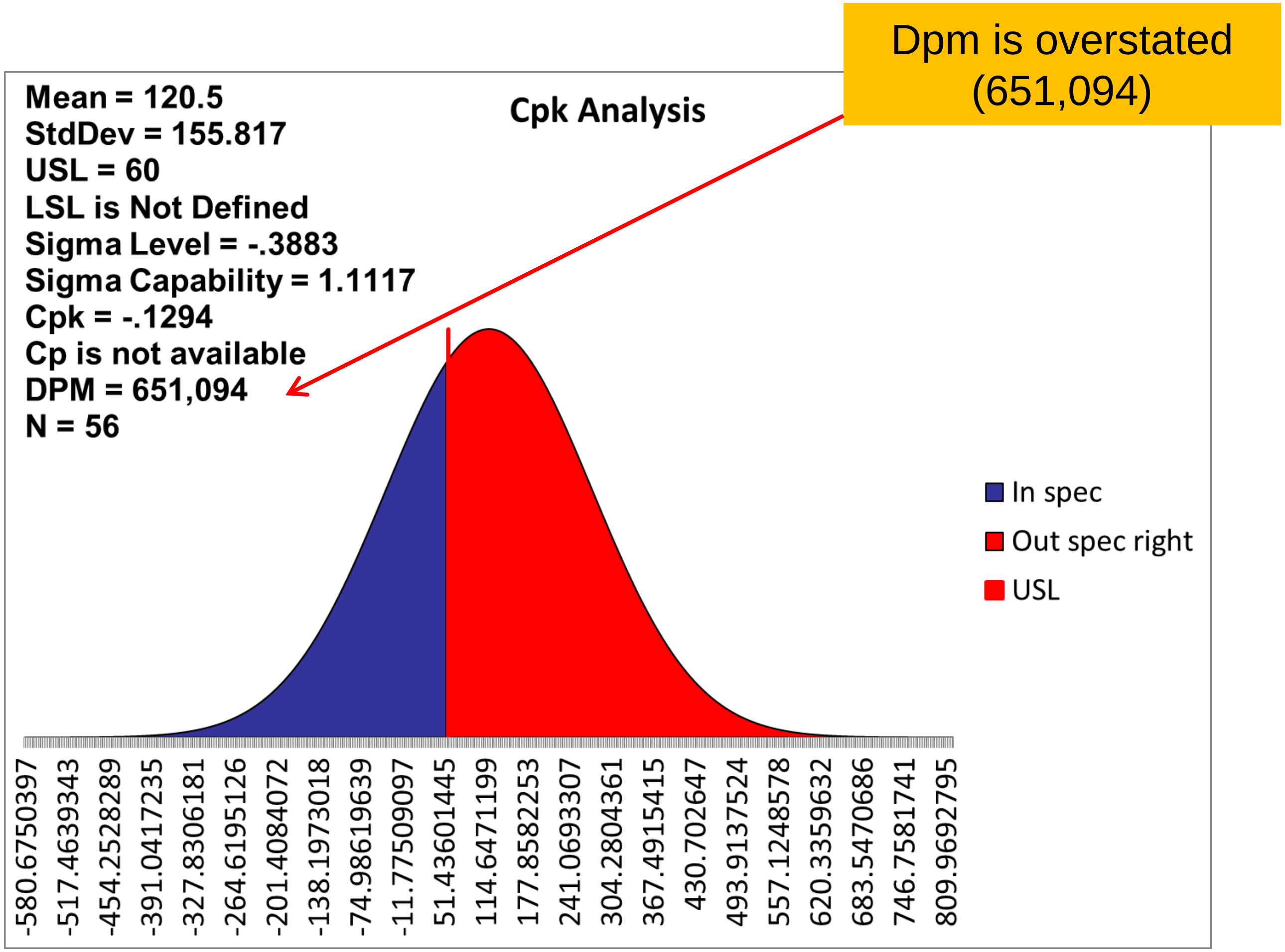
Cpk Analysis with Non-Normal Data

SPC XL > Analysis Diagrams > Cpk

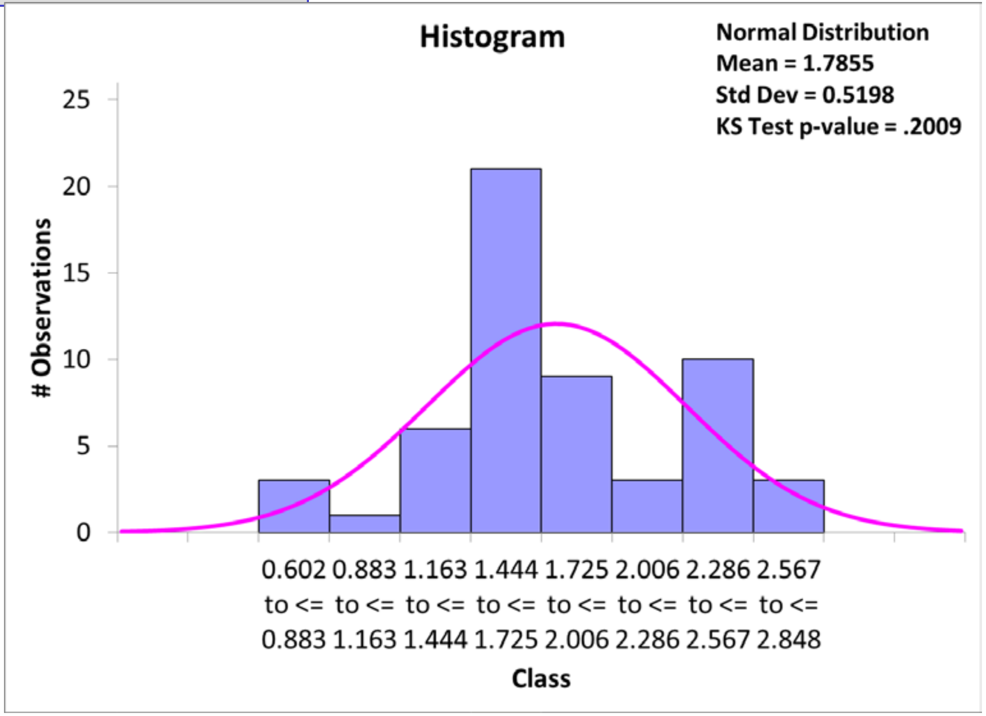


Trying a Data Transformation

Log (days)

Log(Days) (data in sorted order)					
.602060	1.447158	1.505150	1.724276	2.230449	2.503791
.602060	1.447158	1.544068	1.806180	2.235528	2.503791
.845098	1.447158	1.556303	1.826075	2.252853	2.536558
1.000000	1.462398	1.556303	1.826075	2.330414	2.680336
1.176091	1.477121	1.556303	1.857332	2.334454	2.834421
1.322219	1.491362	1.662758	1.857332	2.342423	2.847573
1.322219	1.491362	1.698970	1.886491	2.356026	
1.397940	1.491362	1.698970	1.903090	2.424882	
1.397940	1.491362	1.698970	1.934498	2.488551	
1.397940	1.491362	1.707570	1.977724	2.502427	

Some common data transformations to try include "log", "square root", and "inverse (1/y)"

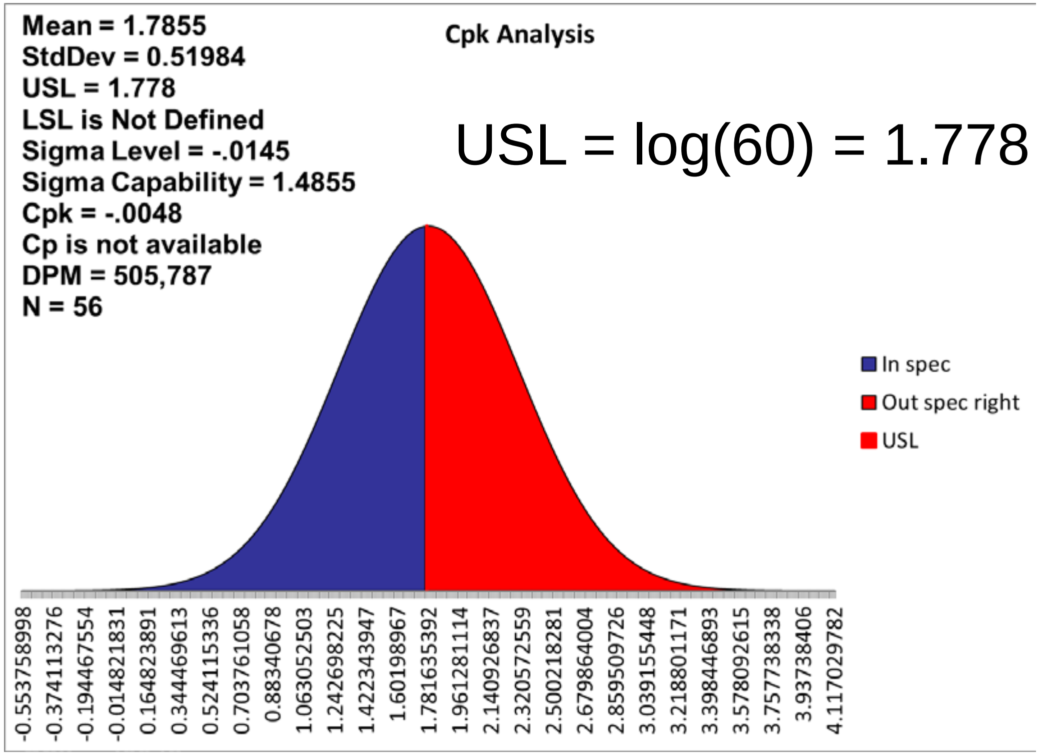


Trying a Data Transformation (cont.)

- Use transformed data for analysis (remember to use the same data transformation for the spec limits!)

SPC XL > Analysis Diagrams > Cpk

Better estimates of dpm and Cpk



USL = log(60) = 1.778

Non-Normal Data (Practice)

- LSL = 100 (no USL)

		Mohms		
154000	66400	77100	87700	62100
94700	79100	258000	74700	76500
87700	52200	61300	354000	330000
212000	85400	76500	86200	62200
74100	94700	76500	109000	199000
239000	88600	174000	252000	252000
112000	88500	265000	143000	167000
373000	107000	117000	114000	164000
74200	68300	208000	266000	137000
101000	76500	98600	107000	191000

Data

Cpk non normal data exercise.xls

- Perform a Cpk analysis with the raw (untransformed) data.
  Cpk = ______ dpm = _______
- Use a data transformation to normalize the data and perform a Cpk analysis with the transformed data.
  Cpk = ______ dpm = _______
- Which provides more realistic (better) estimates?

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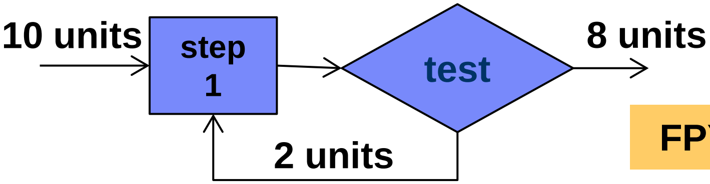
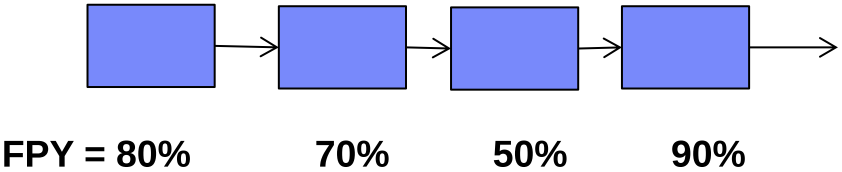
Measure of Capability (Attribute Data)

FPY = First Pass Yield



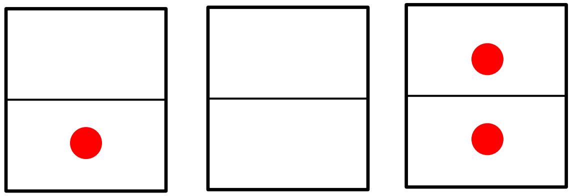
FPY = 80%

RTY = Rolled Throughput Yield



RTY = 25.2%

DPU = Defects per Unit



DPU = 3/3 = 1.0

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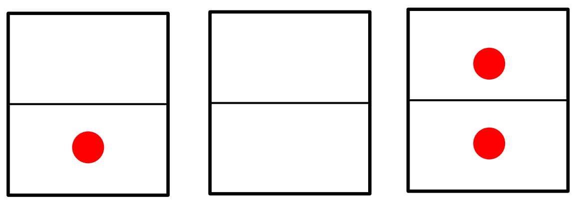
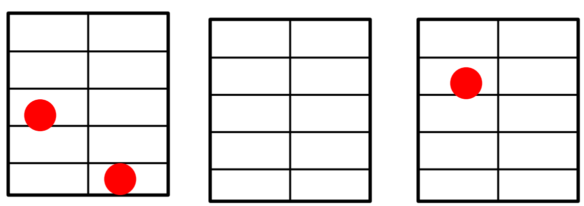
Measures of Capability (Attribute Data) (cont.)

DPMO = Defects per Million Opportunities

$$= \frac{\text{DPU} * 1{,}000{,}000}{\text{opportunity count}}$$



DPU = 3/3 = 1.0
DPMO = 1*1,000,000/2 = 500,000



DPU = 3/3 = 1.0
DPMO = 1*1,000,000/10 = 100,000

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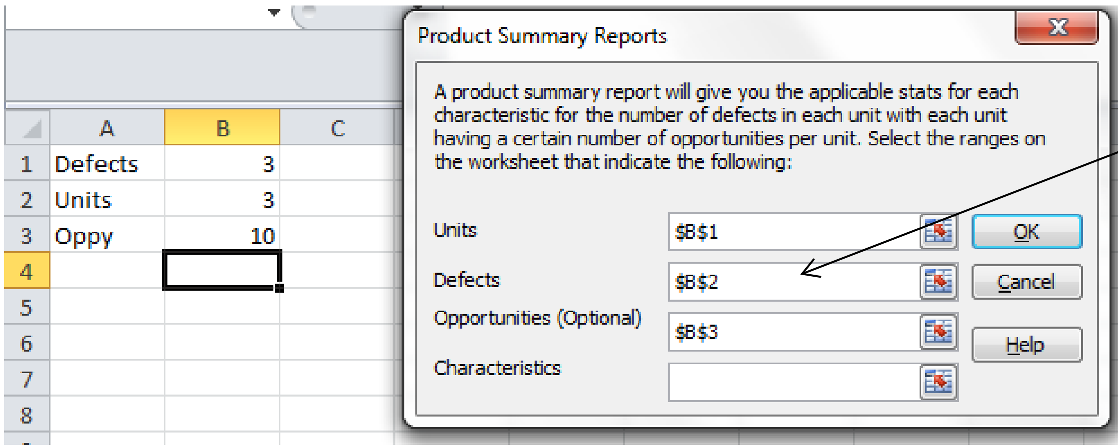
Analysis using SPC XL

SPC XL > Quality Tools > Product Capability



Must point to reference cells containing the data

Product Summary Report

Characteristic	Defects	Units	Opportunities	Total Opportunities	DPU	DPO	DPMO	Sigma Capability
1	3	3	10	30	1.00000	0.10000	100000.000	2.7816
Total	**3**		**0**	**30**		**0.10000**	**100000.000**	**2.7816**

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DPMO and Sigma Capability (Reference)

dpmo	sigma capability*
500,000	1.5
460,172	1.6
420,740	1.7
382,089	1.8
344,578	1.9
308,538	**2.0**
274,253	2.1
241,964	2.2
211,855	2.3
184,060	2.4
158,655	2.5
135,666	2.6
115,070	2.7
96,800	2.8
80,757	2.9
66,807	**3.0**
54,799	3.1
44,565	3.2
35,930	3.3
28,717	3.4
22,750	3.5
17,864	3.6
13,903	3.7
10,724	3.8
8,198	3.9

dpmo	sigma capability*
6,210	**4.0**
4,661	4.1
3,467	4.2
2,555	4.3
1,866	4.4
1,350	4.5
968	4.6
687	4.7
483	4.8
337	4.9
233	**5.0**
159	5.1
108	5.2
72	5.3
48	5.4
32	5.5
21	5.6
13	5.7
9	5.8
5	5.9
3.4	**6.0**

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Practice (Attribute Measures)

1. There are 3 steps in a process. 10 units pass through step 1 and only 7 units make it through with no rework. The FPY of step 1 is ________. Steps 2 and 3 each have a FPY of 90%. The RTY of the entire process is _________.

2. A product has 5 critical inspection points (opportunities for defects). 3,000 products were inspected and a total of 195 defects were found.

    a. What is the DPU for the product: __________

    b. What is the DPMO: ___________

    c. What is the sigma capability: ______________

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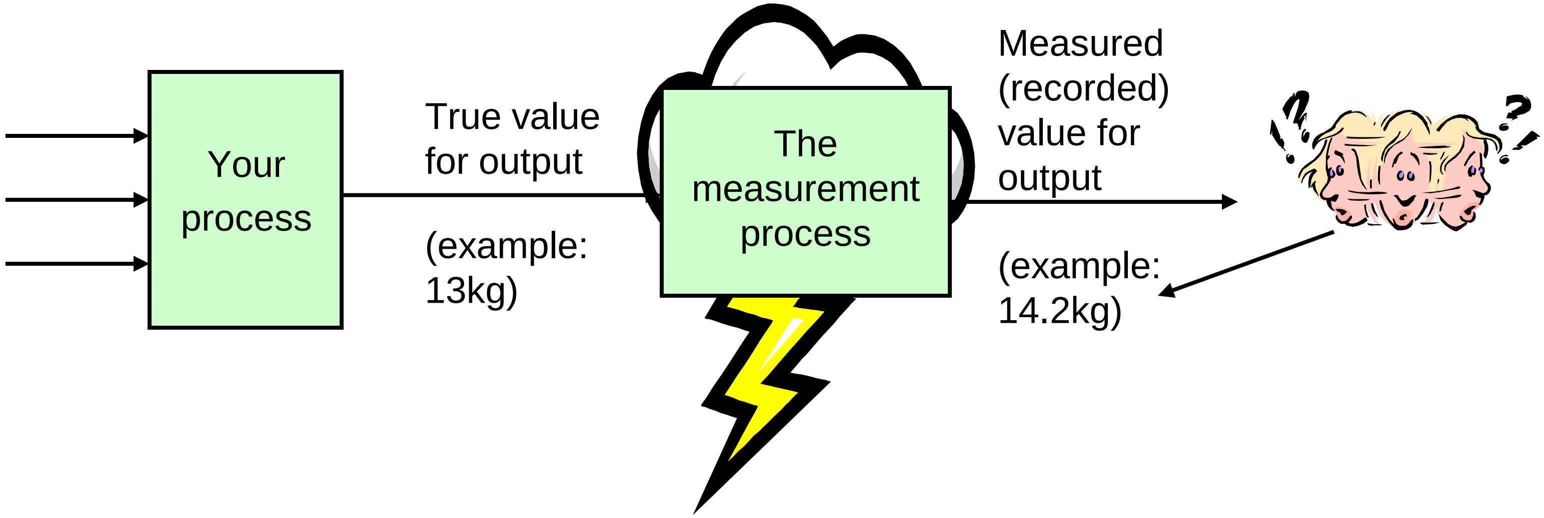
Measurement System Analysis (MSA)

Measurement Error

- We rely on data on a daily basis (projects, improvements, decision making). Measurement error can cause us to make bad decisions because our data may not be representative of the true process.



How much distortion does your measurement process add?

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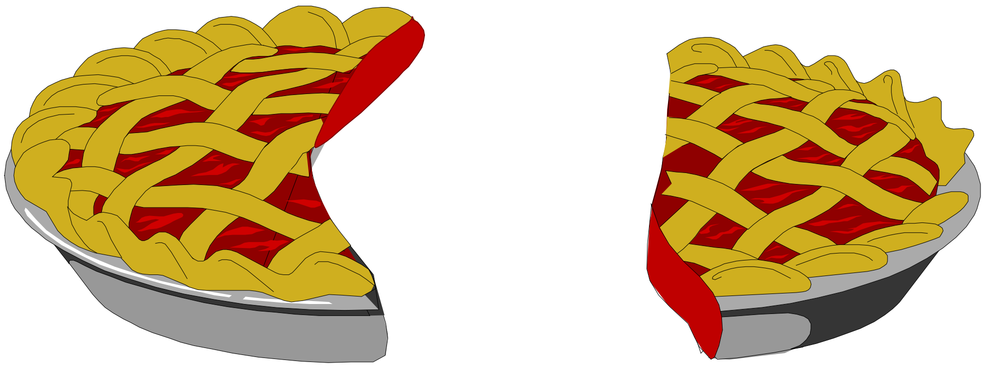
Measurement System Analysis (MSA)



Product or Service Variability | **Measurement Variability**

- MSA identifies and quantifies the different sources of variation that affect a measurement system.
- Variation in measurements can be attributed to variation in the product or service itself or to variation in the measurement system. The variation in the measurement system itself is measurement error.

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Guidelines for Conducting an MSA

- The strategy is to include people, SOPs, data recording devices, etc., that are (will be) the **usual elements** of the measurement process.
- A **random selection** of parts or items representing at least 80% of the total process variation should be made.
- The parts or items should be measured as **independently** as possible to avoid measurement bias. (blind marking)
- Each part or service item will be measured **multiple times** (at least twice) by each person or operator using the same procedure.
- **Rules of Thumb (ROT):**
  - Variables (continuous data)

    (Number of people) X (Number of parts) ≥ 20
  - Attribute (binary data)

    (Number of people) X (Number of parts) ≥ 60

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MSA for Attribute Data

- A Black Belt was tasked with studying the effectiveness of a visual inspection process used for examining cabinets for cosmetic defects such as scratches and dents.

- A cause and effect analysis surfaced several SOP issues related to the inspection process. The Black Belt decided to set up a measurement system analysis to look at the effectiveness of the process for identifying cosmetic defects such as scratches and dents.

- To conduct the study, 20 cabinets (“units”) were selected, half of which contained cosmetic defects and should have been written up as rejects (“R”); and half of which were acceptable according to company standards (“A”).

- Three (3) inspectors were selected, representative of the quality assurance inspectors who perform this inspection daily and must make the determination of reject vs. accept.   The units in the study were marked in a “blind” fashion. Each person was asked to inspect each of the 20 units over the course of the study to determine whether the unit was acceptable (in terms of cosmetic issues) or not.

- Data from the study is shown on the next page.

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MSA for Attribute Data (cont.)

R = Reject
A = Accept

1 = correct response
0 = incorrect response

Cabinet	True Standard	Op 1		Op 2		Op 3	
1	R	R	1	R	1	R	1
2	A	A	1	A	1	A	1
3	A	A	1	R	0	A	1
4	R	R	1	R	1	R	1
5	A	R	0	A	1	R	0
6	R	R	1	A	0	R	1
7	R	R	1	R	1	R	1
8	A	A	1	A	1	A	1
9	A	A	1	A	1	A	1
10	A	R	0	R	0	A	1
11	R	A	0	R	1	R	1
12	A	A	1	A	1	A	1
13	R	R	1	R	1	R	1
14	R	R	1	A	0	R	1
15	A	R	0	A	1	A	1
16	R	A	0	R	1	R	1
17	A	A	1	A	1	R	0
18	A	A	1	A	1	A	1
19	R	R	1	A	0	R	1
20	R	R	1	R	1	R	1
			15		15		18

Total Correct 48

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MSA – Attribute Measures

Effectiveness (E) is the ability of an individual to distinguish between good (accept) and bad (reject) parts or transactions.

$$E = \frac{\text{Number of transactions identified correctly}}{\text{Total number of opportunities to be correct}}$$

Probability of False Rejects (FR) is the likelihood of rating a good part or transaction as bad.

$$P(FA) = \frac{\text{Number of times bad transactions are accepted as good}}{\text{Total number of opportunities to rate bad transactions}}$$

Probability of False Acceptance (FA) is the likelihood of accepting a bad part or transaction as good.

$$P(FR) = \frac{\text{Number of times good transactions rated as bad}}{\text{Total number of opportunities to rate good transactions}}$$

Bias (B) is a measure of an individual's tendency to falsely classify a part or transaction as good or bad.

Parameter	Acceptable	Marginal	Unacceptable
E	$\geq$.90	.8 - .9	< .8
P(FR)	$\leq$.05	.05 - .10	> .10
P(FA)	$\leq$.02	.02 - .05	> .05
B	.8 - 1.20	.5 - .8 or 1.2 - 1.5	< .5 or > 1.5

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MSA Results

SPC XL > MSA (gage capability) > Attribute Analysis

Attribute MSA Analysis

Number and Type Mistake By Operator		OP 1	OP 2	OP 3	Total	
Truth	A	3	2	2	7	<-reject falsely
	R	2	3	0	5	<-accept falsely

Inspection Capability	OP 1	OP 2	OP 3	Total
Effectiveness	0.75	0.75	0.9	0.8
P(FR)	0.3	0.2	0.2	0.233333
P(FA)	0.2	0.3	0	0.166667
Bias	1.5	0.666667	NA	1.4

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Measurement System Study – Practice (Attribute Data)

- A Green Belt was tasked with improving a credit approval process. In the measure phase of her project, she wanted to look at the effectiveness of the current "measurement" (approval) process.
- Specifically, she wondered whether analysts, given the same sets of guidelines, would consistently make the same decision (approve vs. not approve) for various applicants and whether there was significant variation analyst to analyst.
- She decided to set up a measurement system analysis. Twenty six applications (only 13 of which should have been "approved" according to company guidelines) were used in the study. Four analysts each saw these "dummy" applications on 3 different occasions during the course of the study.
- The results (data) is given on the next page.

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Measurement System Study – Practice (Data)

see data file: ***MSA credit.xls***

		Operator 1			Operator 2			Operator 3			Operator 4		
Part #	**Reference**	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
1	A	R	R	R	A	A	A	A	A	A	A	A	A
2	A	A	A	A	A	R	A	A	A	A	A	A	A
3	A	A	A	A	A	A	A	A	A	A	A	A	A
4	A	R	A	A	R	A	A	R	R	R	A	A	A
5	A	A	A	A	A	A	A	A	A	A	A	A	A
6	A	A	A	A	A	A	A	R	R	R	A	A	A
7	A	A	A	A	A	A	A	A	A	A	A	A	A
8	A	A	R	A	A	A	A	A	A	A	A	A	A
9	A	A	A	A	A	A	A	A	A	A	A	A	A
10	A	R	A	A	A	A	A	A	A	A	A	A	A
11	A	A	A	A	A	A	A	A	A	A	A	A	A
12	A	A	A	A	A	R	A	A	A	A	A	A	A
13	A	A	A	R	A	R	A	R	R	A	A	A	A
14	R	R	R	R	R	R	R	A	A	A	R	R	R
15	R	R	R	R	R	R	R	R	R	R	R	R	R
16	R	R	R	R	R	R	R	A	A	A	R	R	R
17	R	R	R	R	R	R	R	R	R	R	R	R	R
18	R	R	R	R	R	R	R	R	R	R	R	R	R
19	R	R	A	R	R	R	R	R	A	A	R	R	R
20	R	R	R	R	R	R	R	R	R	R	R	R	R
21	R	R	R	R	R	R	R	R	R	R	R	R	R
22	R	R	R	R	R	R	R	A	R	A	R	R	R
23	R	R	R	R	A	R	R	R	R	R	R	R	R
24	R	R	R	R	R	R	R	A	A	A	R	R	R
25	R	R	R	R	R	R	R	R	R	R	R	R	R
26	R	R	R	R	R	R	R	R	R	R	R	R	R

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MSA Exercise (cont.)

- Analyze the data.
- Based on your analysis, what do you conclude about the overall effectiveness of the credit approval process in making the “correct” decision?

  ____

  ____

- Does there appear to be significant variability from analyst to analyst?

  ____

  ____

- Is there a bias toward either “good” applications being rejected or “bad” applications being approved?

  ____

  ____

- Any other observations or comments or recommendations?

  ____

  ____

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MSA - Variables Data

PURPOSE:

To assess how much variation is associated with the measurement system and to compare it to the total process variation or tolerances.

$$\sigma^2_{\text{total}} = \sigma^2_{\text{product}} + \sigma^2_{\text{measurement}}$$

$$\sigma^2_{\text{repeatability}} + \sigma^2_{\text{reproducibility}}$$

REPEATABILITY:

Variation obtained by the same person using the same procedure on the same product, transaction or service for repeated measurements (variability ***within*** operator).

REPRODUCIBILITY:

Variation obtained due to differences in people who are taking the measurements (variability ***between*** operators).

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MSA - Variables Data (example)

- 4 parts were measured by 2 operators, each twice

Difference = 2
(repeatability)

	Operator 1		Operator 2	
	Rep 1	Rep 2	Rep 1	Rep 2
Part 1	21	23	26	28
Part 2	19	18	24	24
Part 3	20	23	27	24
Part 4	19	22	21	20

Average = 21.5

Average = 25.5

Difference = 4
(reproducibility)

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MSA Measures (Variables Data)

1. **Precision-to-Tolerance Ratio (P/TOL)**

$$P/TOL = \frac{6\sigma_{meas}}{USL - LSL}$$ (Specification Limits are needed)

ROT**:** If P/TOL $\leq$ .10 : Very Good Measurement System

P/TOL $\geq$ .30 : Unacceptable Measurement System

2. **Precision-to-Total Ratio (P/TOT)**

$$P/TOT = \frac{\sigma_{meas}}{\sigma_{total}}$$

ROT: If P/TOT $\leq$ .10 : Very Good Measurement System

P/TOT $\geq$ .30 : Unacceptable Measurement System

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MSA Measures (Variables Data) (cont.)

3. **Discrimination or Resolution**

   (# of truly distinct measurements that can be obtained by the measurement system)

$$= \left(\frac{\sigma_{product}}{\sigma_{meas}} \right) \times 1.41$$

ROT: Resolution $\geq$ 5 represents an adequate measurement

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MSA Results (Variables Data)

SPC XL > MSA (gage capability) > ANOVA Analysis

Measurement variation is 83.7% of the total variation!

MSA ANOVA Method Results

Source	Variance	Standard Deviation	% Contribution	p Value
Total Measurement (Gage)	10.0625	3.172144385	83.71%	
Repeatability	2.3125	1.520690633	19.24%	
Reproducibility	7.75	2.783882181	64.47%	
Operator	5.79166667	2.40658818	48.18%	
Oper * Part Interaction	1.95833333	1.399404635	16.29%	0.1167
Product (Part-to-Part)	1.95833333	1.399404635	16.29%	
Total	12.0208333	3.467107344	100.00%	

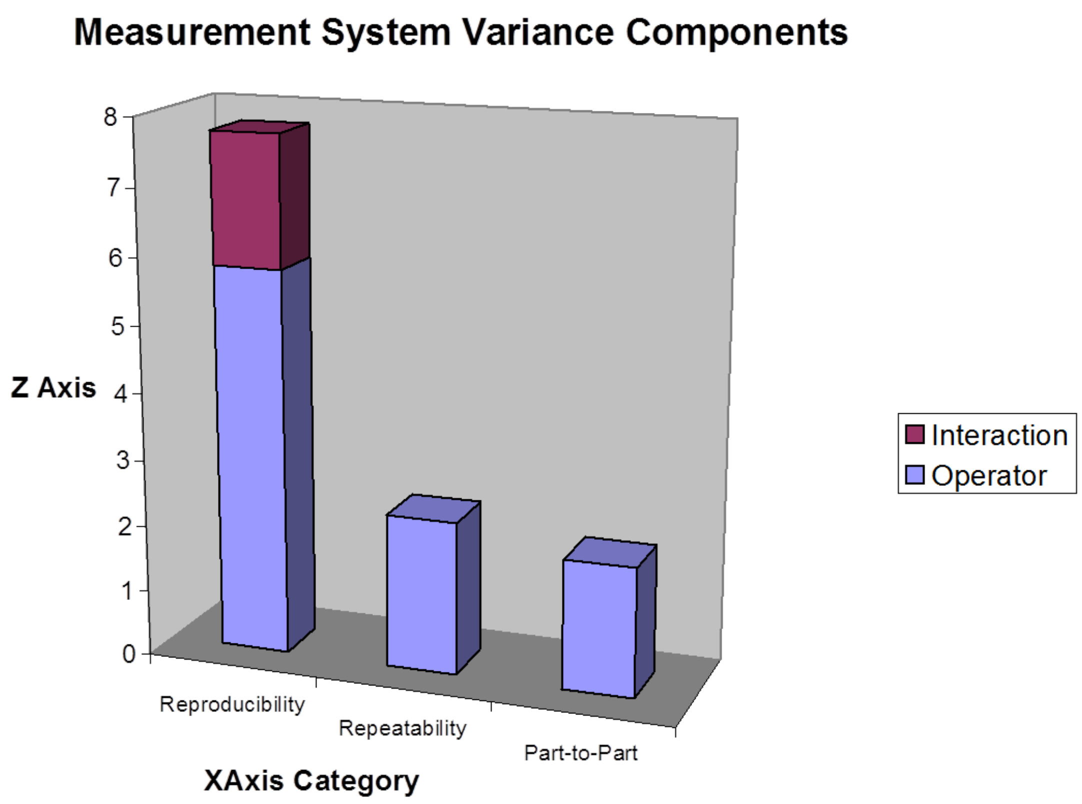
USL	35
LSL	10
Precision to Tolerance Ratio	0.76131465
Precision to Total Ratio	0.91492535
Resolution	0.6

The std deviation of the measurement process is 3.17. Reproducibility is a bigger problem than repeatability.

BIAS ANALYSIS	
Reference	Bias
Not Available	

P/Tol is too high
P/Tot is too high
Resolution is unacceptable

MSA Output – Pareto of Variance Comp.



- Displays the components of variation.
- Typically, we expect "part-to-part" variation to be the largest contributor, since most of the variation typically comes from the items we measure.
- Compare repeatability and reproducibility. In this example, we see that reproducibility is a bigger source of variation.

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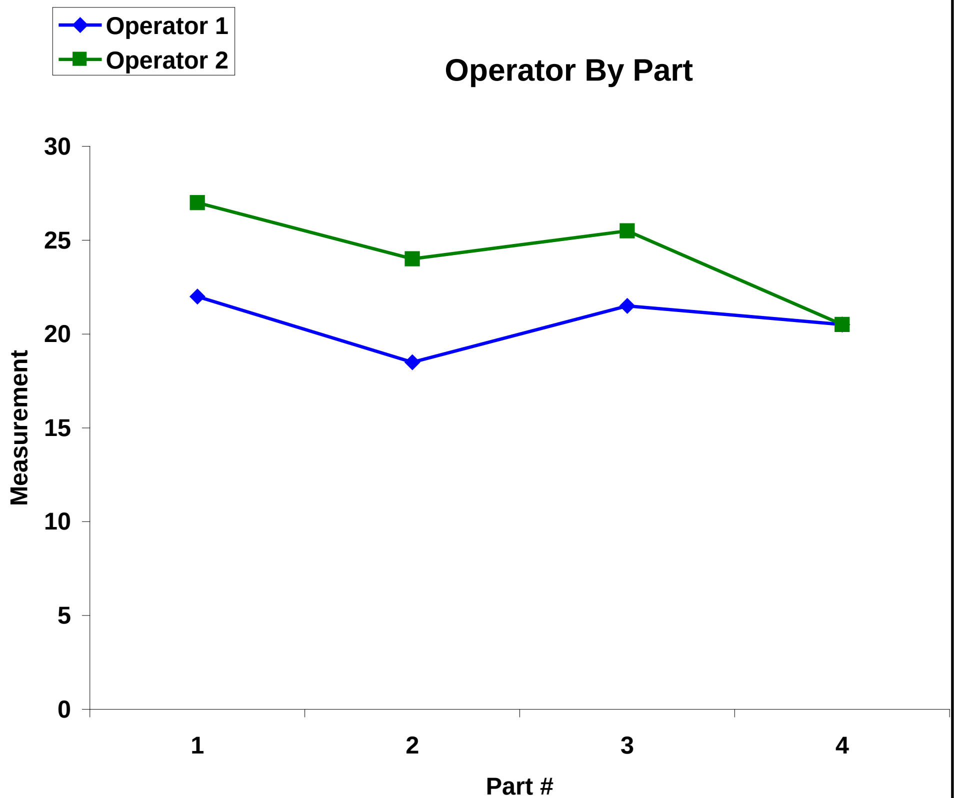
MSA Output – Operator by Part



- Displays the results from the study. Numbers plotted are averages.
- This graph helps to show any “reproducibility” issues, by comparing the difference in average measurements between operators
  - In this example, operator 1’s measurements are consistently lower than operator 2. Since we don’t have true reference values here, we aren’t sure which operator is more correct.
- “No Interaction” means that the differences between operators are consistent for all parts. (i.e., parallel lines) “Interaction” occurs when the lines are not parallel. In this example, there is a slight interaction.

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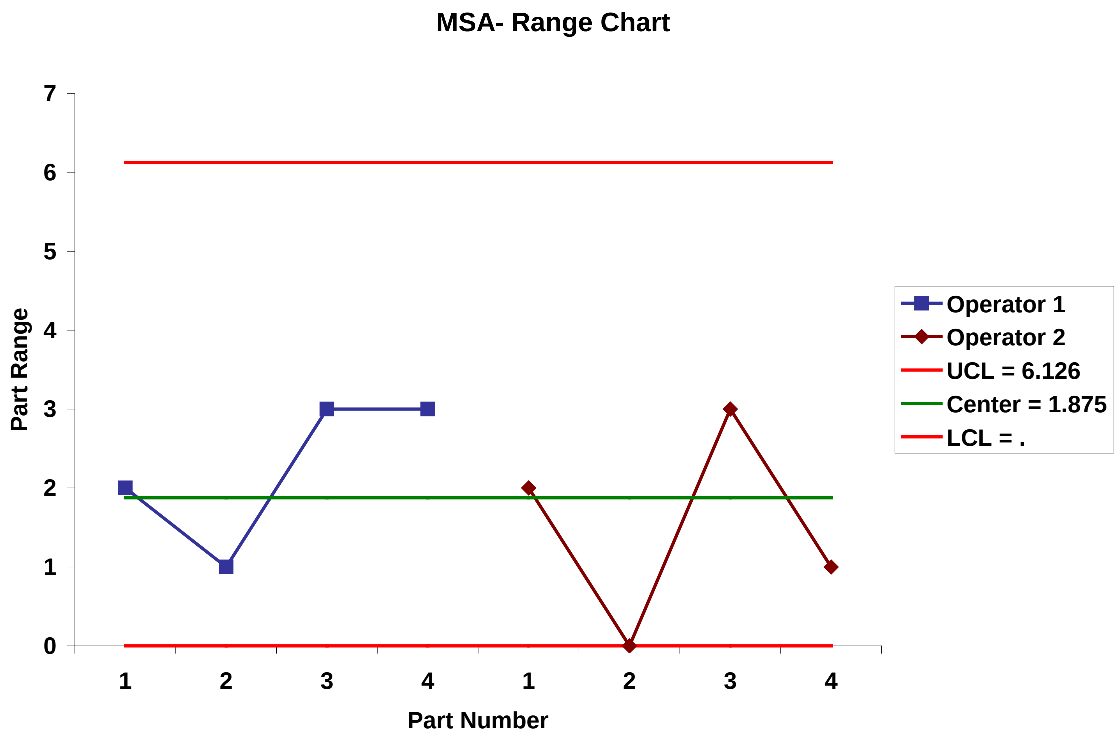
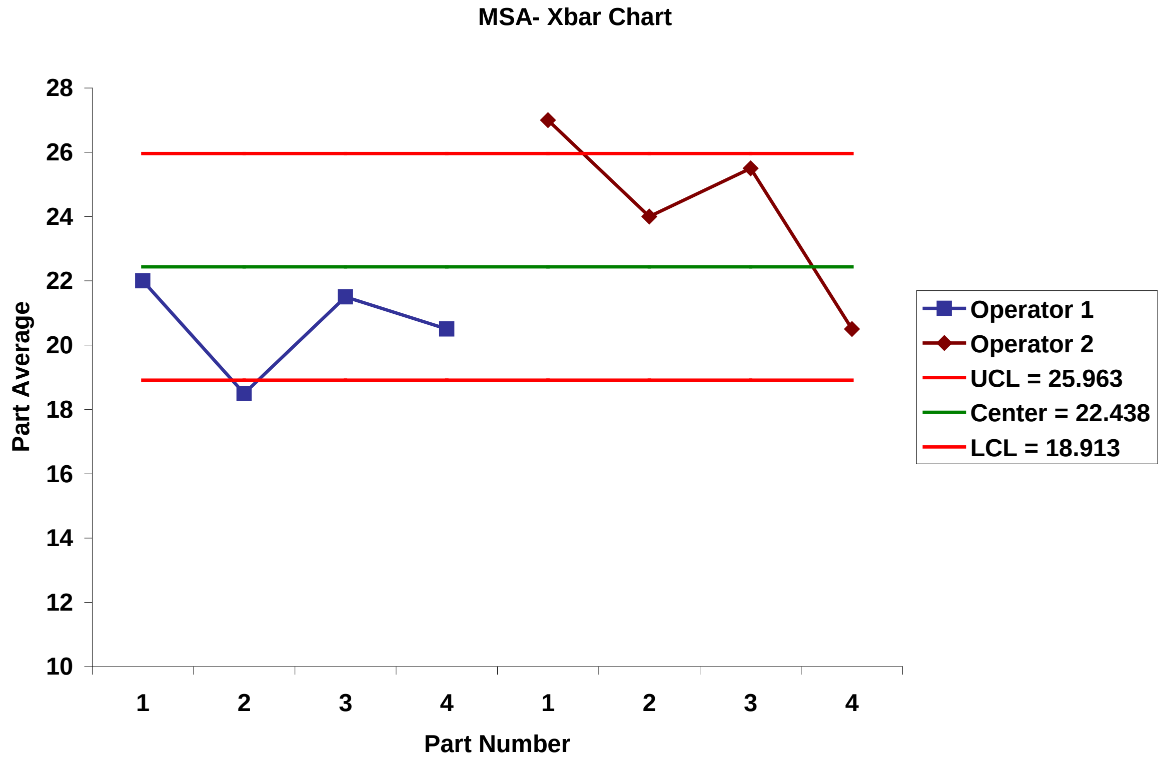
MSA Output – Range Chart



- Displays the differences in the measurements made by each operator for each part (sample).
- This graph helps to show any "repeatability" issues.
- Check to see whether the repeatability seems consistent between operators. In this example, the repeatability for both operators appears roughly the same.
- All of the points should fall within the control limits.

MSA Output – Xbar Chart



- Displays the average measurement made by each operator for each part (sample).
- This graph helps to show any "reproducibility" issues.
- ROT: At least half of the points should fall outside the control limits. If not, repeatability error is making it difficult to distinguish one part from another, since the control limits for this chart are based on the range chart (repeatability).

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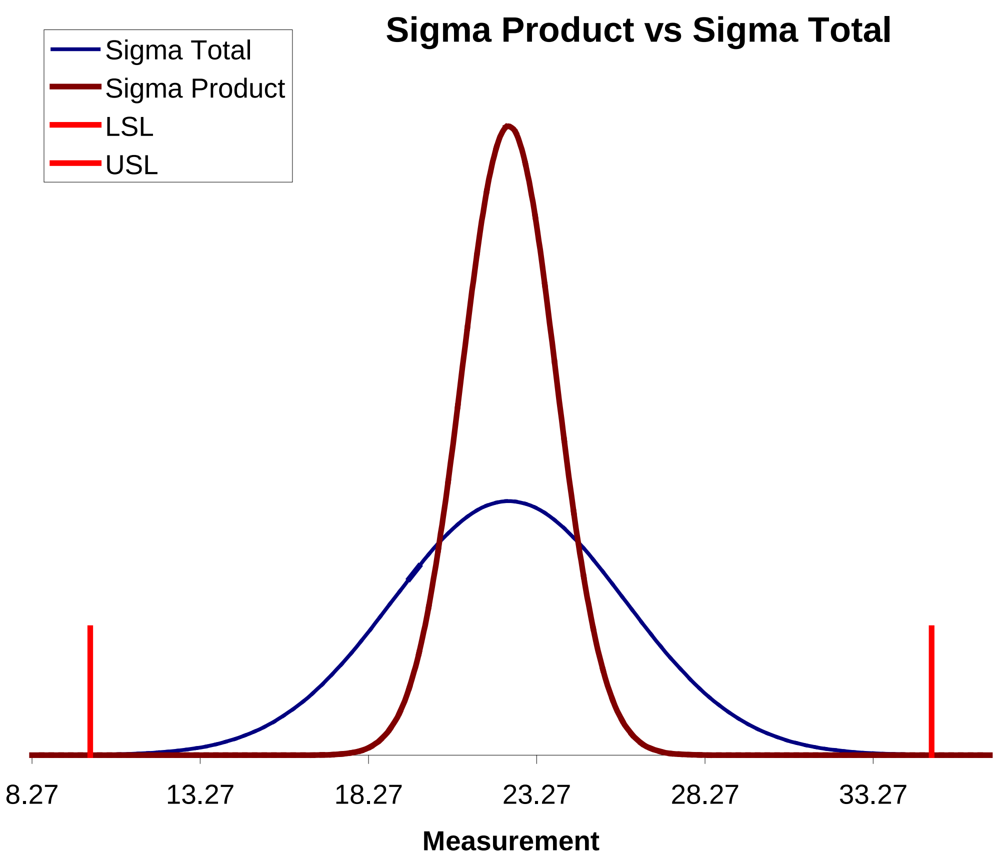
MSA Output – Sigma Product, Total



- Displays the effect of measurement error.
- The "sigma product" graph represents the part variation, while the " total" graph includes measurement error.
- The more different these graphs appear, the bigger the impact of measurement error.

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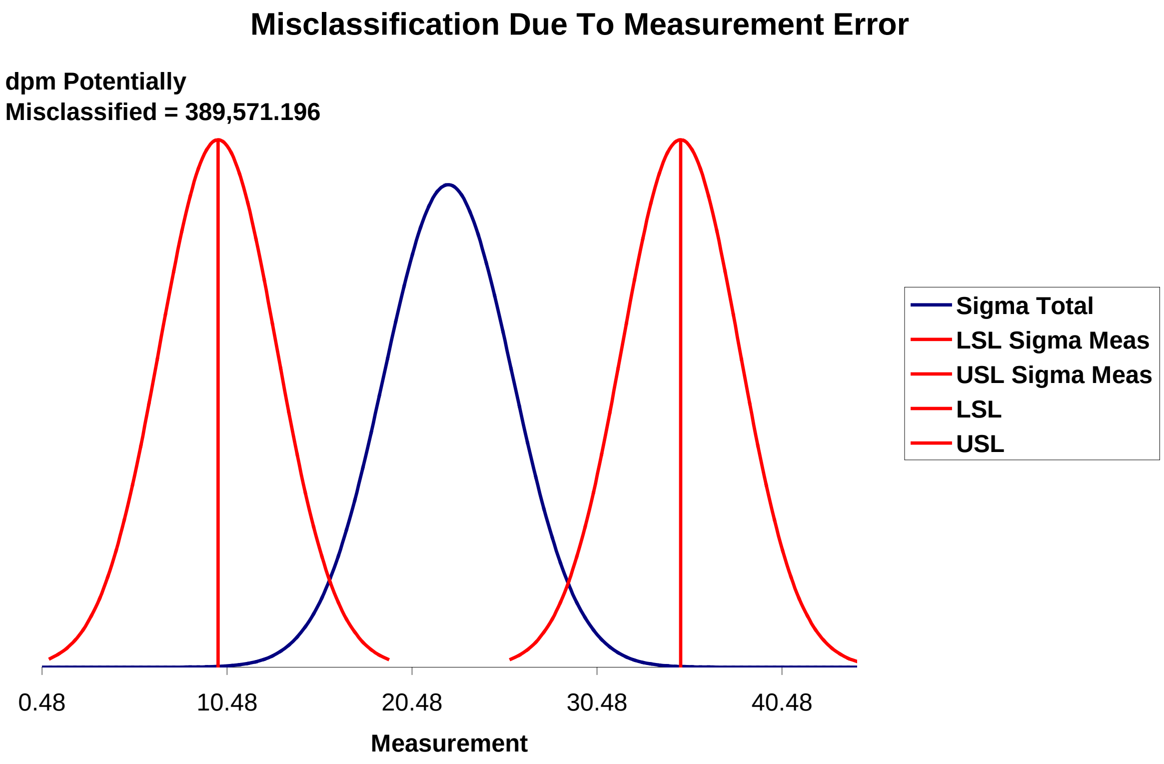
MSA Output – Misclassification



- Displays the measurement error at its worst-case scenario (when measuring a value right at the lower or upper spec limit). If the process produces values at the spec limit, then we have the biggest risk for mis-classifying parts (calling "good" parts "bad and vice versa)
- The dpm potentially misclassified gives an idea of the potential impact on COPQ due to the measurement system.

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MSA – Variables Data (Practice)

- A sample is measured at each of 3 laboratories. Data is shown below.

MSA Data Template

Date:	4/14/2015
Part Type:	
USL:	60.0
LSL:	20.0

see data file: ***MSA variables data exercise.xls***

		Lab 1		Lab 2		Lab 3	
Part #	**Reference**	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2
1		33	30	29	30	31	35
2		30	31	31	31	35	28
3		22	21	24	24	28	24
4		33	33	31	30	33	37
5		33	33	32	33	33	39
6		50	50	51	50	50	55
7		13	12	13	12	18	13
8		40	39	38	39	38	43
9		35	36	33	34	34	38
10		46	47	48	47	46	52

MSA – Variables Data Practice (cont.)

- Analyze the data.
- Based on your analysis, is there any concern about the measurement process? Why or why not?

  ____

  ____

- Is there more variation within a lab or between the labs?

  ____

  ____

- Which lab, if any, seems to have the biggest problem with repeatability?

  ____

  ____

- Any other observations or comments or recommendations?

  ____

  ____

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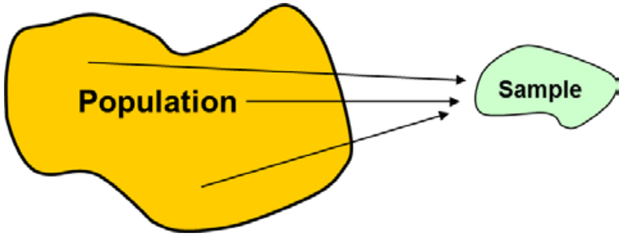
Sampling
Confidence Intervals
Sample Size



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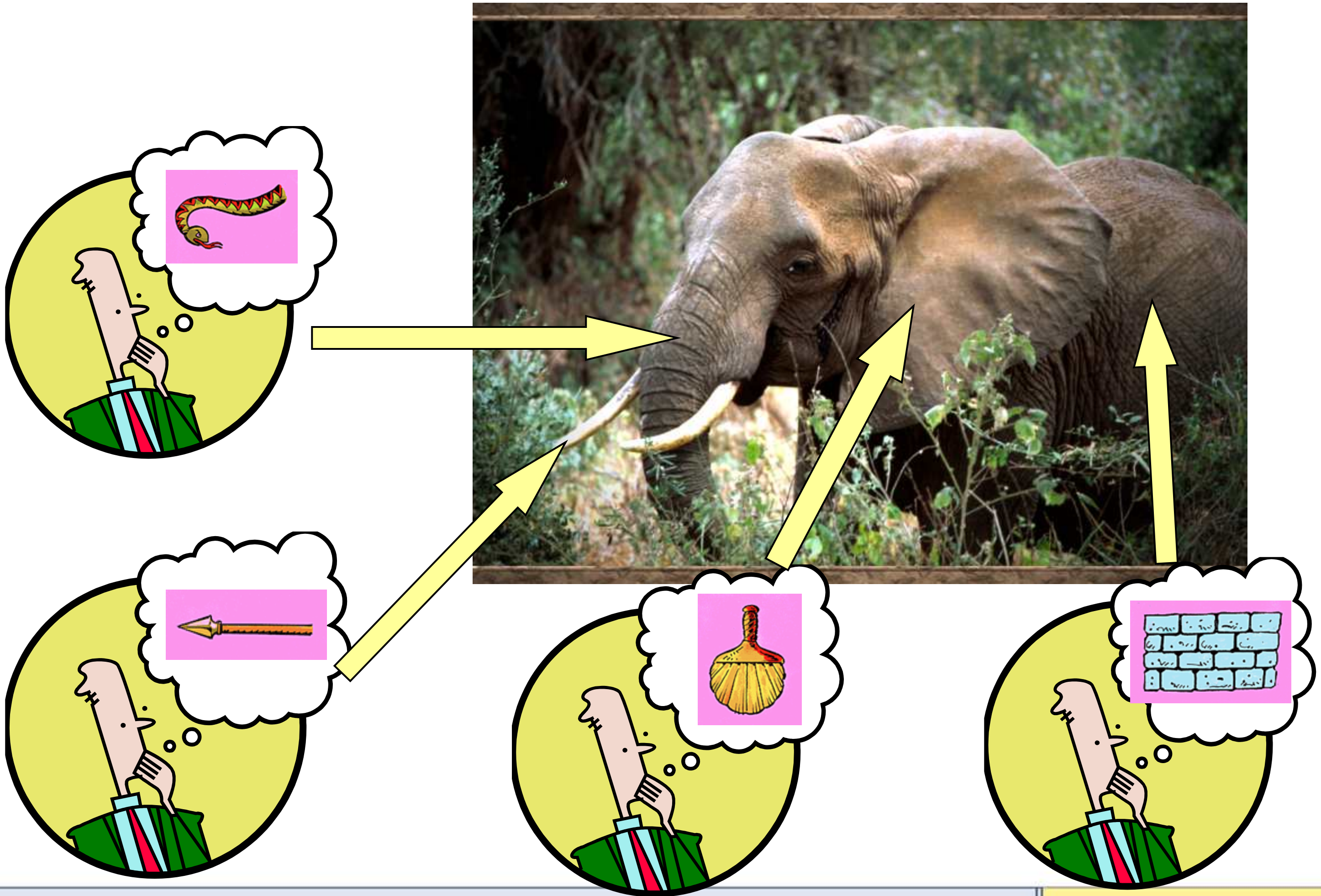
The Blind Men and the Elephant

Based on a fable told in India many years ago; Later adapted by others including American poet John Godfrey Saxe (1816-1887) in his poem "The Blind Men and the Elephant"



What Do These Things Have in Common?

Chicago Daily Tribune

DEWEY DEFEATS TRUMAN

G. O. P. Sweep Indicated in State; Boyle Leads in City

REPUBLICAN TICKET AHEAD OF 1944 VOTE

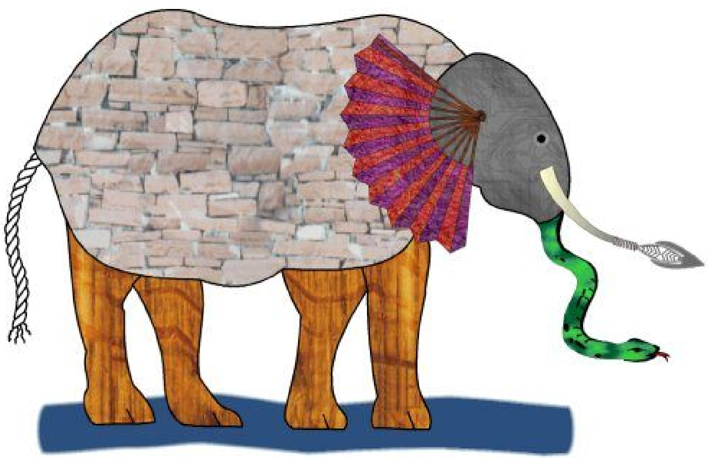
Tops Coghlan in Hot Race for Attorney

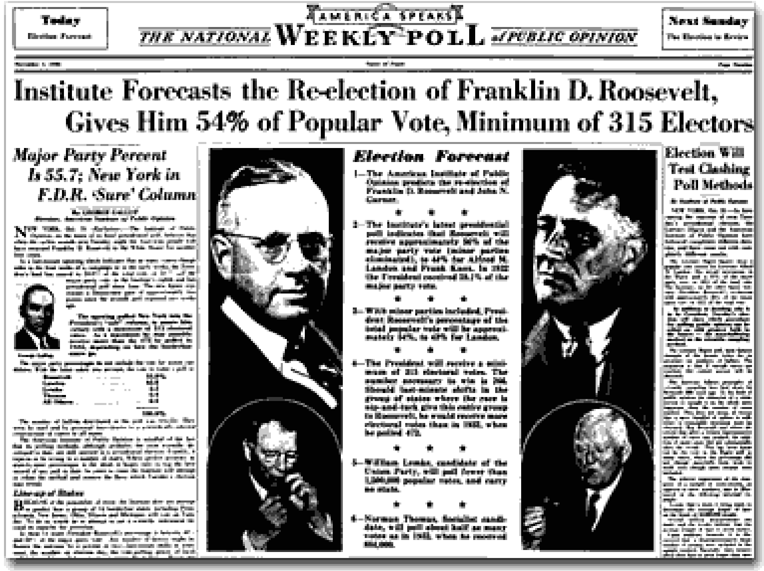
RECORD CITY VOTE SEEM IN LATE TALLIES

BULLETINS ON ELECTIONS

Early Count Gives G.O.P. Senate Edge

PUTS G.O.P. BACK IN THE WHITE HOUSE





Today

AMERICA SPEAKS

THE NATIONAL WEEKLY POLL of PUBLIC OPINION

Next Sunday

Institute Forecasts the Re-election of Franklin D. Roosevelt, Gives Him 54% of Popular Vote, Minimum of 315 Electors

Major Party Percent Is 55.7; New York in F.D.R. 'Sure' Column

Election Forecast

Election Will Test Clashing Poll Methods

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So True…….

“Not knowing the difference between opinion and fact makes it difficult to make good decisions.”

Marilyn Vos Savant
Parade Magazine

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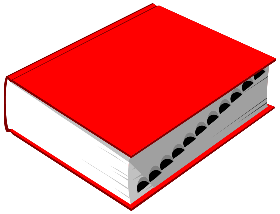
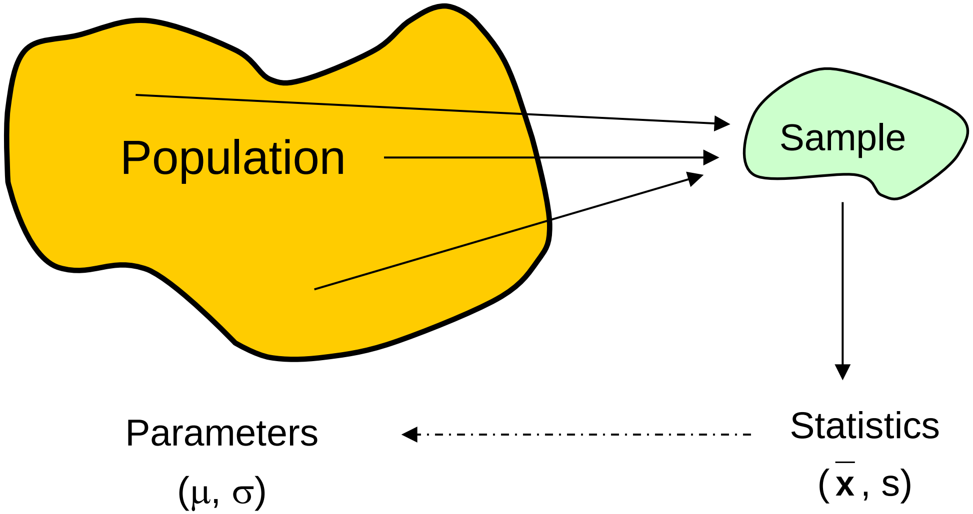
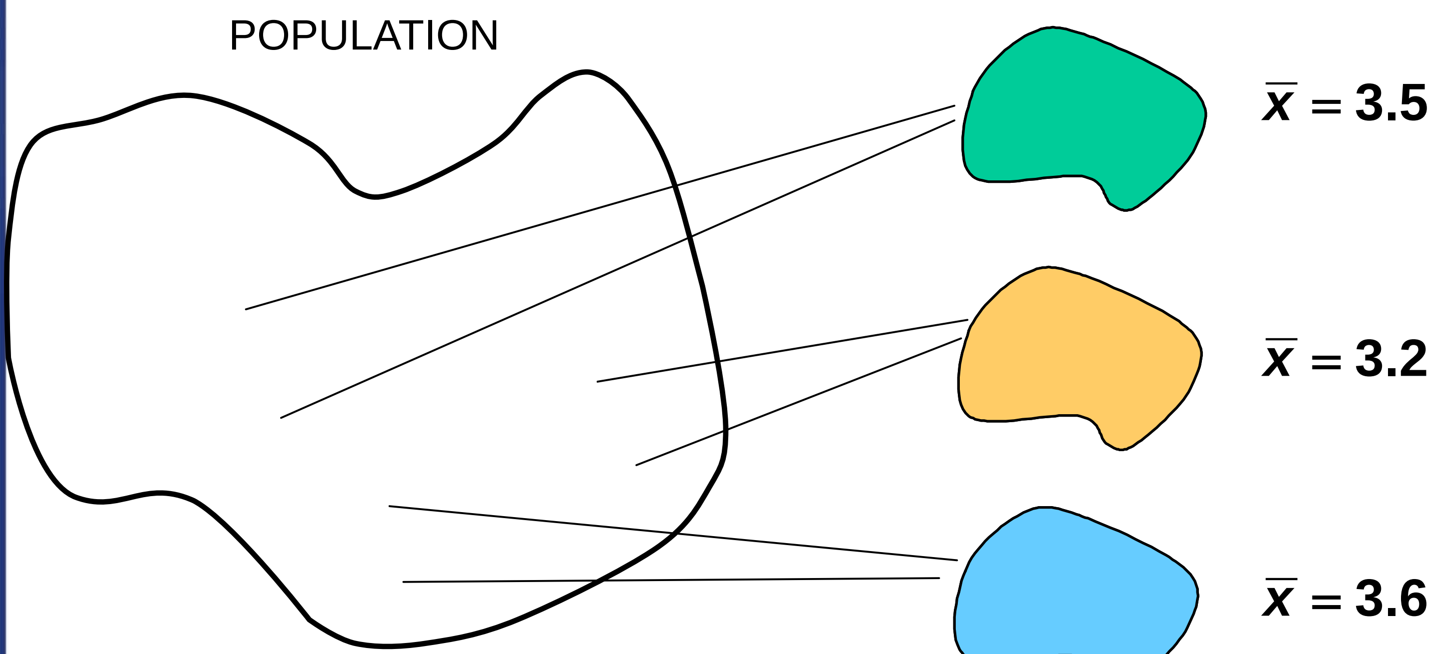
Sampling

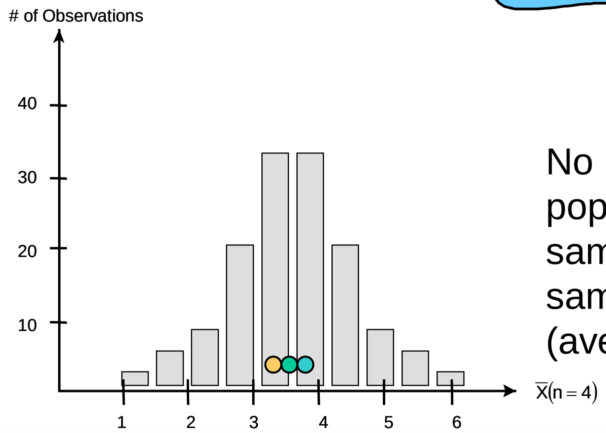


Sampling … "the act, process, or technique of selecting a suitable sample, or a representative part of a population for the purpose of determining parameters or characteristics of the whole population"



Distribution of Sample Averages (Central Limit Theorem)





No matter what kind of distribution (or population) we sample from, if the sample size is big enough, the sampling distribution of x-bar (averages) is approximately normal.

What is a Confidence Interval?

- Error bounds (margin of error) for an estimate
- Provides an estimate of uncertainty based on sample data

Confidence Interval =

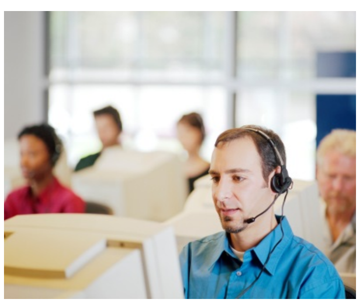
Sample Point Estimate ± Margin of Error

Confidence Interval Example (Estimating a Mean Value)

- Random sample of 10 customer service calls yielded the following response times (in minutes):

18, 25, 14, 22, 24, 20, 29, 15, 15, 27

Average time = 20.9 minutes
Standard deviation = 5.34 minutes



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Using SPC XL for Confidence Limits (Means)

- 2 options:
  - SPC XL / Analysis Tools / Confidence Interval / Normal

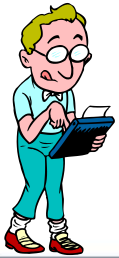
Normal Confidence Interval (Mean)	
User defined parameters	
Sample Size (n)	10
Sample Avg	20.9
Sample Standard Dev	5.34
Confidence Level	95.00%
Confidence Interval	
Lower Limit	Upper Limit
17.07999413	24.72000587

$$\begin{pmatrix} U \\ L \end{pmatrix} = \bar{x} \pm Z\left(\frac{s}{\sqrt{n}}\right)$$

20.9 +/- 3.82 minutes

  - SPC XL / Analysis Diagrams / Summary Statistics

Count	10
Mean	20.9
Median	21
Mode	15
Max	29
Min	14
Range	15
Std Dev (Pop)	5.068530359
Std Dev (Sample)	5.342700108
Variance (Pop)	25.69
Variance (Sample)	28.54444444
Skewness	0.085680584
Kurtosis	-1.439033279
95% Conf. Interval for Mean	
Upper Limit	24.72193741
Lower Limit	17.07806259



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Confidence Interval Example (Estimating a Proportion)

- Finance office processes travel vouchers.
- A random sample of 120 vouchers finds 12 with errors.
  - Estimated proportion of vouchers with errors = 12/120 = .10 (or 10%)

Confidence Interval Example (Estimating a Mean Value)

- SPC XL / Analysis Tools / Confidence Interval / Proportion (Binomial)

Binomial Confidence Interval (Proportion)

User defined parameters	
Sample Size (n)	120
Number Defective(x)	12
Confidence Level	95.00%

Lower Limit	< p <	Upper Limit
	Confidence Interval	
0.052747786	0.1	0.168165213

Between 5.27% and 16.8%

10% + 6.8%
10% - 4.73%

note: binomial distribution is not symmetric for all values of "p"

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How Much Data?

- The practical question of interest to Green Belts is often: “How much data do I need to get a good estimate”?

- Sample Size depends on 3 things:
  - What is the population variation? (for attribute data, variation is a function of “p”)
  - How much precision do you want in your estimate? (your desired margin of error, or width of the confidence interval)
  - What level of confidence do you desire?

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Sample Size Formulas (for reference only)

CAUTION

- For estimating a mean value

$$\begin{pmatrix} U \\ L \end{pmatrix} = \bar{x} \pm \underbrace{Z\left(\frac{s}{\sqrt{n}}\right)}_{=h} \Rightarrow n = \left[\left(\frac{Z\hat{\sigma}}{h}\right)^2\right]$$

SPC XL / Analysis Tools / Sample Size / Normal Conf. Interval (mean)

- For estimating a proportion

$$\begin{pmatrix} U \\ L \end{pmatrix} = p \pm \underbrace{Z\sqrt{\frac{pq}{n}}}_{=h} \Rightarrow n = \left[\frac{Z^2 pq}{h^2}\right]$$

SPC XL / Analysis Tools / Sample Size / Binomial Conf. Interval (proportion)

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Example: Sample Size for Estimating a Mean Value

- Suppose in our previous example with customer response times, we wanted to estimate the true mean response time to within +/- 2 minutes with 95% confidence (and our estimated std dev = 5.34)

20.9 +/- 3.82 minutes

previous result
with sample size of 10

SPC XL / Analysis Tools / Sample Size / Normal Conf. Interval (mean)

Sample Size to Estimate the Mean of a Normal Distribution	
User defined parameters	
Estimated Standard Dev	5.34
Half Interval Width	2
Confidence Level	95.00%
Results	
Estimated Sample Size (n)	28

n = 28

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How to Estimate the Standard Deviation?

- Historical data
- Data from a similar process
- Small pre-sample of data
- Make an Estimate
  - What range do you expect?
    - example: suppose we expect times as low as 5 minutes and as high as 30 minutes (95% of times expected in this range)
  - Use range/4 as an estimate of the standard deviation
    - example: $\hat{\sigma}$ = (30-5)/4 = 25/4 = 6.25 minutes

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Example: Sample Size for Estimating a Proportion

- Suppose in the previous example for travel vouchers, we wanted to estimate the true proportion of travel vouchers with errors to within +/- 3% with 95% confidence

SPC XL / Analysis Tools / Sample Size / Binomial Conf. Interval (Proportion)

Binomial Sample Size

User defined parameters	
Proportion defectives (p)	0.1
Half Interval Width	0.03
Confidence Level	95.00%
Results	
Estimated Sample Size (n)	385

From historical data, or a small pre-sample, or an estimate (if unknown, p=.5 can be used to produce a conservative (worst case) estimate of sample size)

n = 385

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Practice: Sample Size and Confidence Intervals

1. You want to estimate the true percentage of calibration orders submitted with no plan with 90% confidence to within +/- 4%. You think the actual percentage is around 10%. What size sample should you take?

2. During the measure phase of your project, you sampled data from 100 CARs (corrective action reports) processed at different times over the past 3 years. The average is 120 days and the standard deviation is 23.2 days. What is a 95% confidence interval for the true average time to process a CAR?

3. The distance of a statapult launch is a critical to customer measure. With the stop pin setting at 2, it is desired to predict the average launch distance to within +/- 0.5 inches with 95% confidence. The standard deviation is unknown, but it is estimated to be around 1 inch. What sample size is required? How would sample size change if the estimated std deviation were only .5 inches?

4. During the Measure phase of your project you review 700 documents (from a large number stored in a database) and find errors with 23 of them. What is a 99% confidence interval for the true % error rate?

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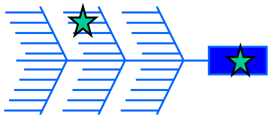
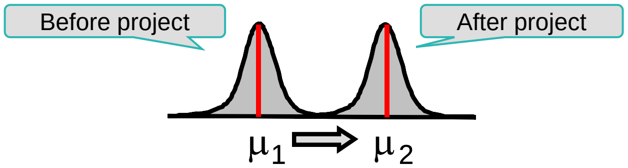
Hypothesis Testing

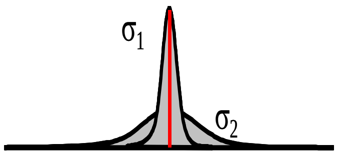
What is a Hypothesis Test?

- Hypothesis Tests are statistical tests used to:
  - Compare two (or more) sets of data (e.g., option A vs. option B, Region 1 vs. Region 2)
  - Identify the critical causes/variables having a significant effect on the process CTC



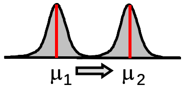
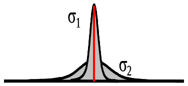
  - Validate a significant improvement or changes to a process





- Hypothesis tests help us make good decisions and not get fooled by random variation
  - in other words, is a difference we see REAL, or could it just be due to random variation in the data?

Hypothesis Tests

What do you want to compare?	Statistical Test
2 averages (are the means different?) 	t test
2 std deviations (are the std deviations different?) 	F test
2 proportions $\%_1$ vs $\%_2$	Test of Proportions
Count/classified data (relationship between “row” and “column”)	Independence Test (Chi Square)

	Defect Type A	Defect Type B	Defect Type C
Supplier 1			
Supplier 2			
Supplier 3			
Supplier 4			

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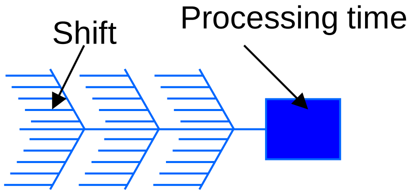
Hypothesis Test Example (Variables Data)

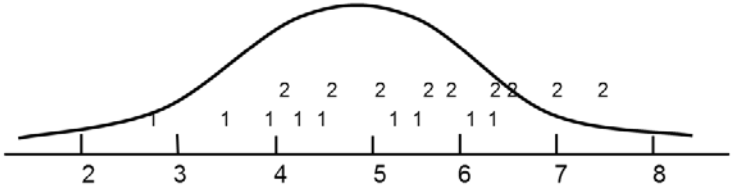


Shift	y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	$\bar{y}$	s
1	2.8	3.6	6.1	4.2	5.2	4.0	6.3	5.5	4.5	4.6889	1.17
2	7.0	4.1	5.7	6.4	7.3	4.7	6.6	5.9	5.1	5.8667	1.08

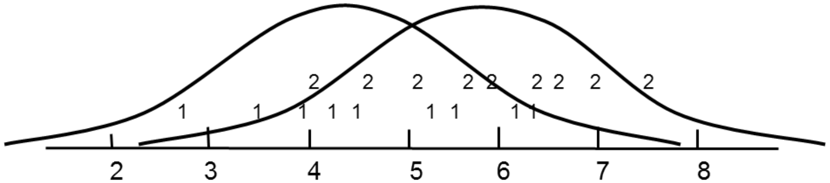
Total Processing Times (in hours)

Note: All times include wait time and approval times in addition to actual value added time spent completing the form

$H_0: \mu_1 = \mu_2$



$H_1: \mu_1 \neq \mu_2$



Rule of Thumb when Interpreting Hypothesis Test Results

- The result of the test is a p-value

- p-values represent the probability of making a type 1 error (concluding there is a difference (H1) when the null hypothesis (no difference) is really true)

- Rule of Thumb:
  - If p-value < .05, highly significant difference
  - If .05 < p-value < .10, moderately significant difference
  - If p-value > .10, no significant difference
  - (1 – p-value) • 100% is our percent confidence that there is a significant difference (H1)

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Testing for Differences in Average

SPC XL > Analysis Tools > t Test matrix (Mean)

t-Test Result		
Hypothesis Tested:	H0: Shift1 Mean = Shift2 Mean H1: Shift1 Mean not equal to Shift2 Mean	
	p-value (probability of Type I Error)	0.041
	Confidence that Shift1 Mean not equal to Shift2 Mean	95.9%

Summary Statistics	Shift1	Shift2
Mean	4.6889	5.8667
StDev	1.1731	1.0759
Count	9	9

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Testing for Differences in Std Deviation

SPC XL > Analysis Tools > F Test matrix (StdDev)

F-Test Result		
Hypothesis Tested:	**H0: Shift1 Variance = Shift2 Variance**	
	H1: Shift1 Variance not equal to Shift2 Variance	
	p-value (probability of Type I Error)	**0.813**
	Confidence that Shift1 Variance not equal to Shift2 Variance	**18.7%**

Summary Statistics	Shift1	Shift2
Mean	4.6889	5.8667
StDev	1.1731	1.0759
Count	9	9

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Hypothesis Test Example (Attribute Data)

- A sample of product produced at two different locations is tested. At location 1, 11 out of 65 samples were defective, and at location 2 there were 6 out of 60 samples defective

- Is there a significant difference in the proportion defective between locations 1 and 2?

  - Location 1: $p = 11/65 = 0.1692$ (16.92%)

  - Location 2: $p = 6/60 = 0.1000$ (10.0%)

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Testing for Differences in Proportions

SPC XL > Analysis Tools > Test of Proportions

Test of Proportions

Hypothesis Tested: H0: Group #1 Proportion = Group #2 Proportion
H1: Group #1 Proportion not equal to Group #2 Proportion

User defined parameters	
Number Defective Group #1 (x_1)	11
Sample Size of Group #1 (n_1)	65
Number Defective Group #2 (x_2)	6
Sample Size of Group #2 (n_2)	60

Results	
Sample Proportion Group #1 (p_1)	0.16923
Sample Proportion Group #2 (p_2)	0.10000
p-value (probability of Type I Error)	0.259
Confidence that Group #1 proportion is not equal to Group #2 proportion	74.1%

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Hypothesis Tests for Count/Classified Data (Example)

- A company has 4 product lines. Customers return the products for 3 basic reasons: cosmetic defects, hardware failures, and software incompatibility. Customer return data is summarized below:

Product Line \ Reason for Return	Cosmetic Defect	Hardware Failure	Software Incompatible	Total
1	125	43	12	**180**
2	136	55	8	**199**
3	186	75	20	**281**
4	78	33	10	**121**
Total	**525**	**206**	**50**	**781**

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Hypothesis Tests for Count/Classified Data (Example) (cont.)

- For each cell, an "expected" count is calculated:

Product Line \ Reason For Return	Cosmetic Defect	Hardware Failure	Software Incompatible	Total
1	125 (121.00)	43 (47.48)	12 (11.52)	**180**
2	136 (133.77)	55 (52.49)	8 (12.74)	**199**
3	186 (188.89)	75 (74.12)	20 (17.99)	**281**
4	78 (81.34)	33 (31.92)	10 (7.75)	**121**
Total	**525**	**206**	**50**	**781 (N)**

Expected count = (column total * row total) / N

= (525 * 180) / 781 = 120.998 ~ 121

In other words, in this case 525/781 = 67% of the returns are for cosmetic defects, so we would expect 67% * 180 = 121 cosmetic defects for product line 1 if there is no relationship between reason for return and product line.

Hypothesis Tests for Count/Classified Data (Example) (cont.)

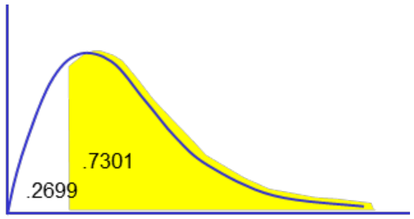
$$\chi^2 = \sum \frac{(\text{observed count} - \text{expected count})^2}{\text{expected count}}$$

$$= 3.604 \text{ (for this example)}$$

A p-value is computed using the Chi-Square distribution

Degrees of freedom: df = (r - 1)(c - 1)

= (4 - 1)(3 - 1) = 6



$\chi^2 = 3.604$

$p = .7301$

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Hypothesis Tests for Count/Classified Data (Example) (cont.)

SPC XL > Analysis Tools > Independence Test Matrix

	A	B	C	D
1	Company Product Lines vs. Reasons for I			
2				
3				
4				
5		Cosmetic Defect	Hardware Failure	Software Incompatible
6	Line1	125	43	12
7	Line2	136	55	8
8	Line3	186	75	20
9	Line4	78	33	10
10				

Independence Test Matrix

		Cosmetic Defect	Hardware Failure	Software Incompatible	Marginals
Line1	Actual	125	43	12	180
	Expected	121.0	47.5	11.5	
	Chi	0.1323	0.4223	0.0197	
Line2	Actual	136	55	8	199
	Expected	133.8	52.5	12.7	
	Chi	0.0371	0.1201	1.7636	
Line3	Actual	186	75	20	281
	Expected	188.9	74.1	18.0	
	Chi	0.0443	0.0105	0.2246	
Line4	Actual	78	33	10	121
	Expected	81.3	31.9	7.7	
	Chi	0.1370	0.0369	0.6556	
Marginals		525	206	50	781
p Value		.7301			
Chi Statistic		3.6040			
df		6			

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Hypothesis Testing (Practice)

1. Shear strength (in ksi) was measured for 2 types of fasteners. Is there a significant difference in the average shear strength when comparing the fasteners? Why or why not?

2. Two different methods for measuring iron concentration (in ppm) were evaluated (standard method, crush method) using 80 gr samples. Is there a significant difference in the average or standard deviation using the two different methods? Why or why not?

data file: *Hypothesis Testing practice.xls*

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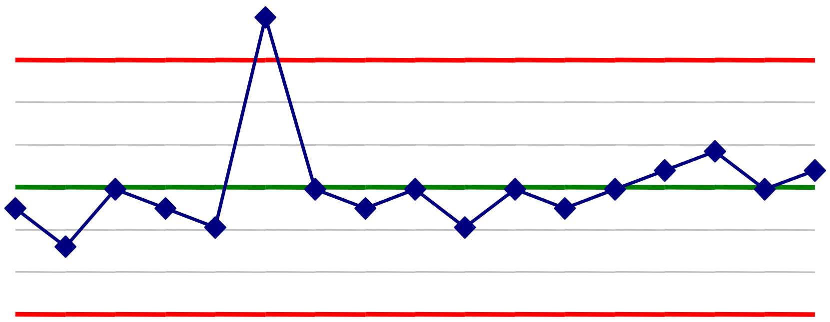
Hypothesis Testing (Practice)

3. Two different methods are used for processing paperwork. During a test, we observed 10 forms with errors out of 140 using method 1, and 14 forms with errors out of 130 using method 2. Is there a significant difference in the % error rates of the two methods? Why or why not?

4. Data was collected on the experience level of an employee (new, some experience, very experienced) and the type of errors made (A, B, C) when performing a particular task. Is there a significant relationship between the experience level and the type of errors made? If so, where are the biggest differences?

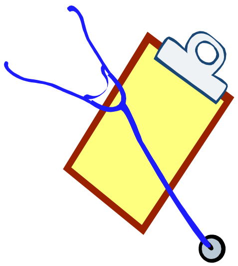
data file: *Hypothesis Testing practice.xls*

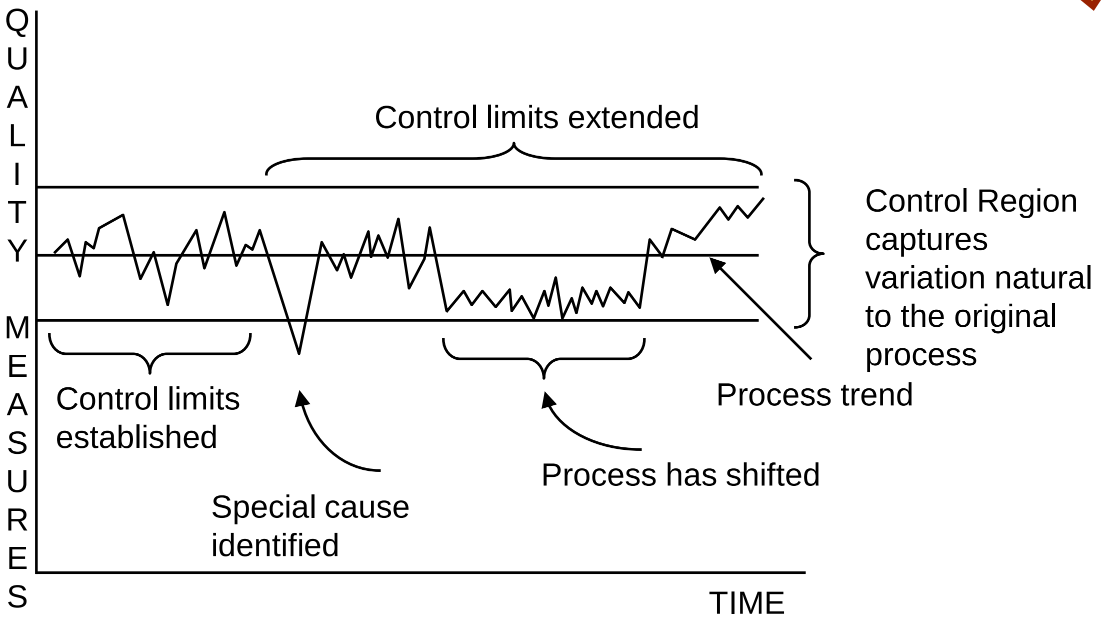
Control Charts



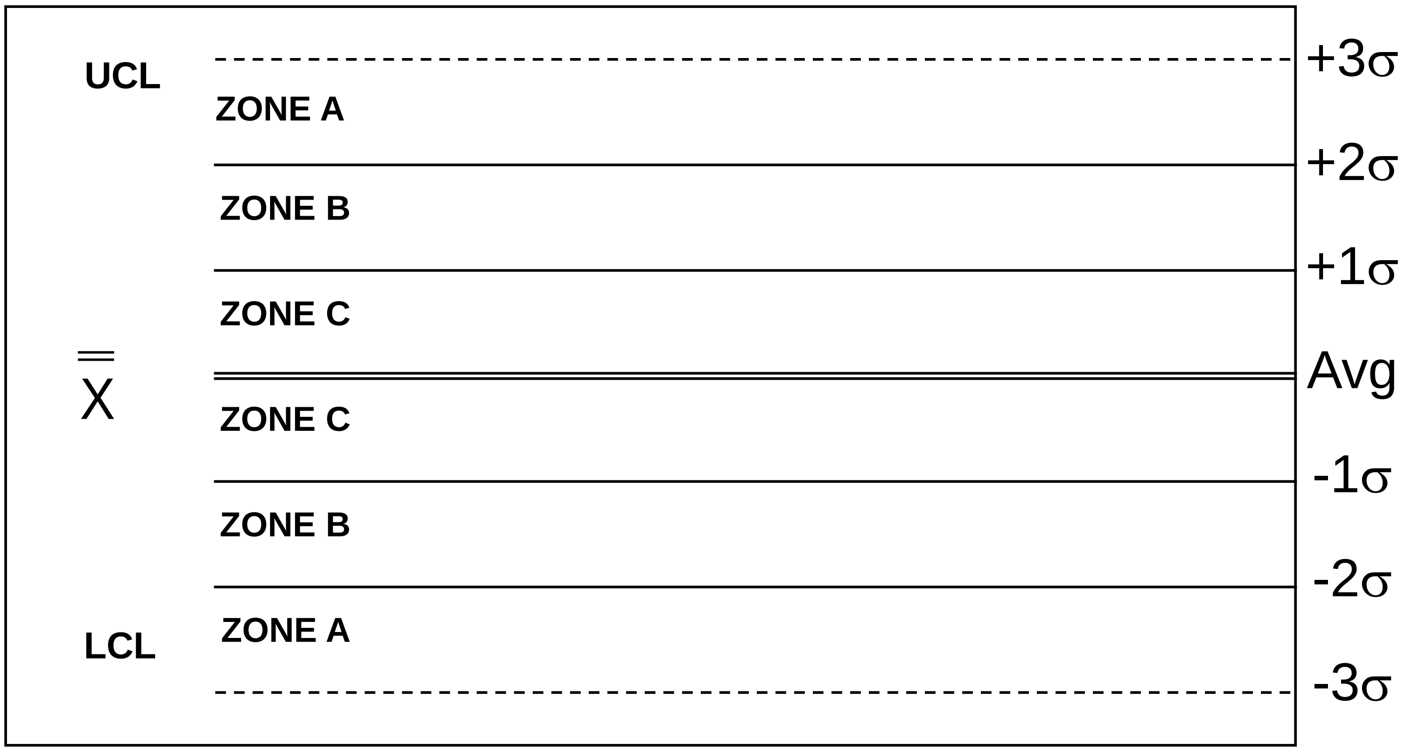
What is a Control Chart?

"Listening to the Voice of the Process"





Control Chart Broken into Zones



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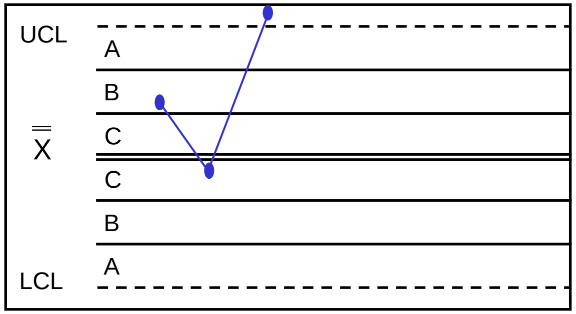
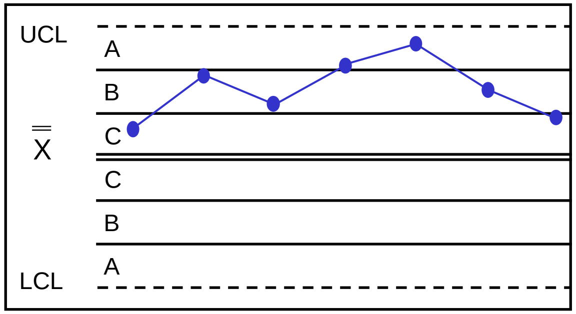
7 Out-of-Control Symptoms

Rule 1



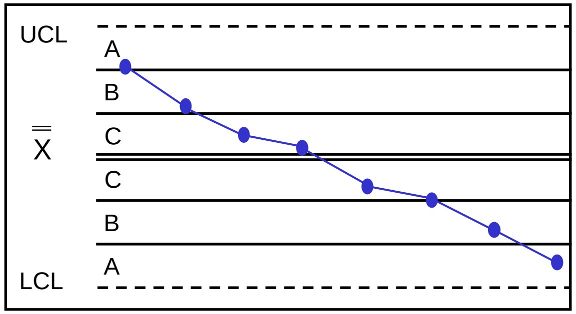
one or more pts are outside the control limits

Rule 2



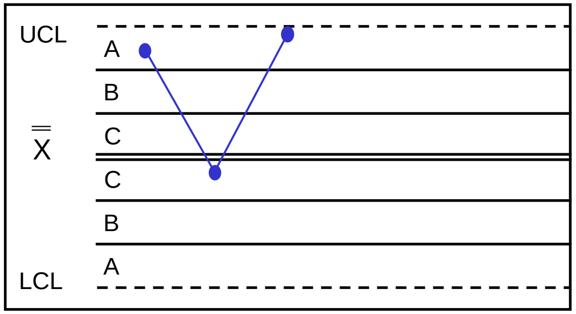
7 cons. pts are on one side of the centerline

Rule 3



7 cons. increasing or decreasing intervals

Rule 4



2 out of 3 cons. pts are in same Zone A or beyond

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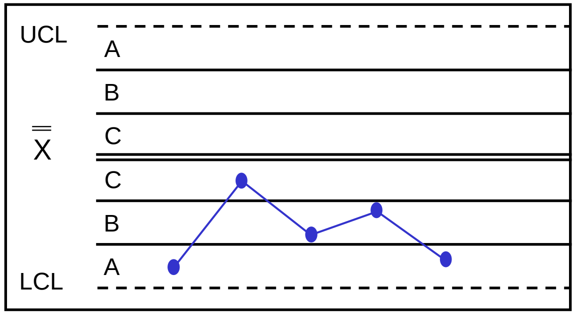
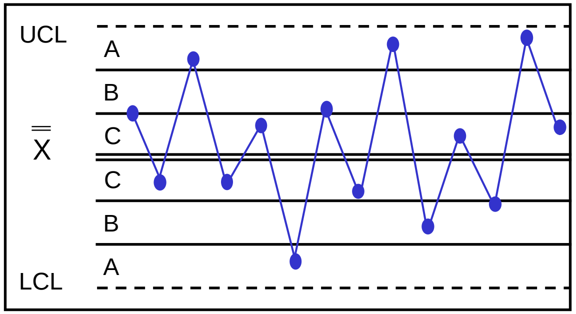
7 Out-of-Control Symptoms (cont.)

Rule 5



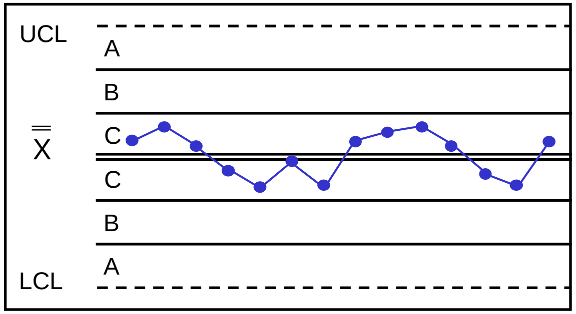
4 out of 5 cons. pts are in same Zone B or beyond

Rule 6



14 cons. pts that alternate up and down

Rule 7



14 cons. pts in either Zone C (i.e., in center third)

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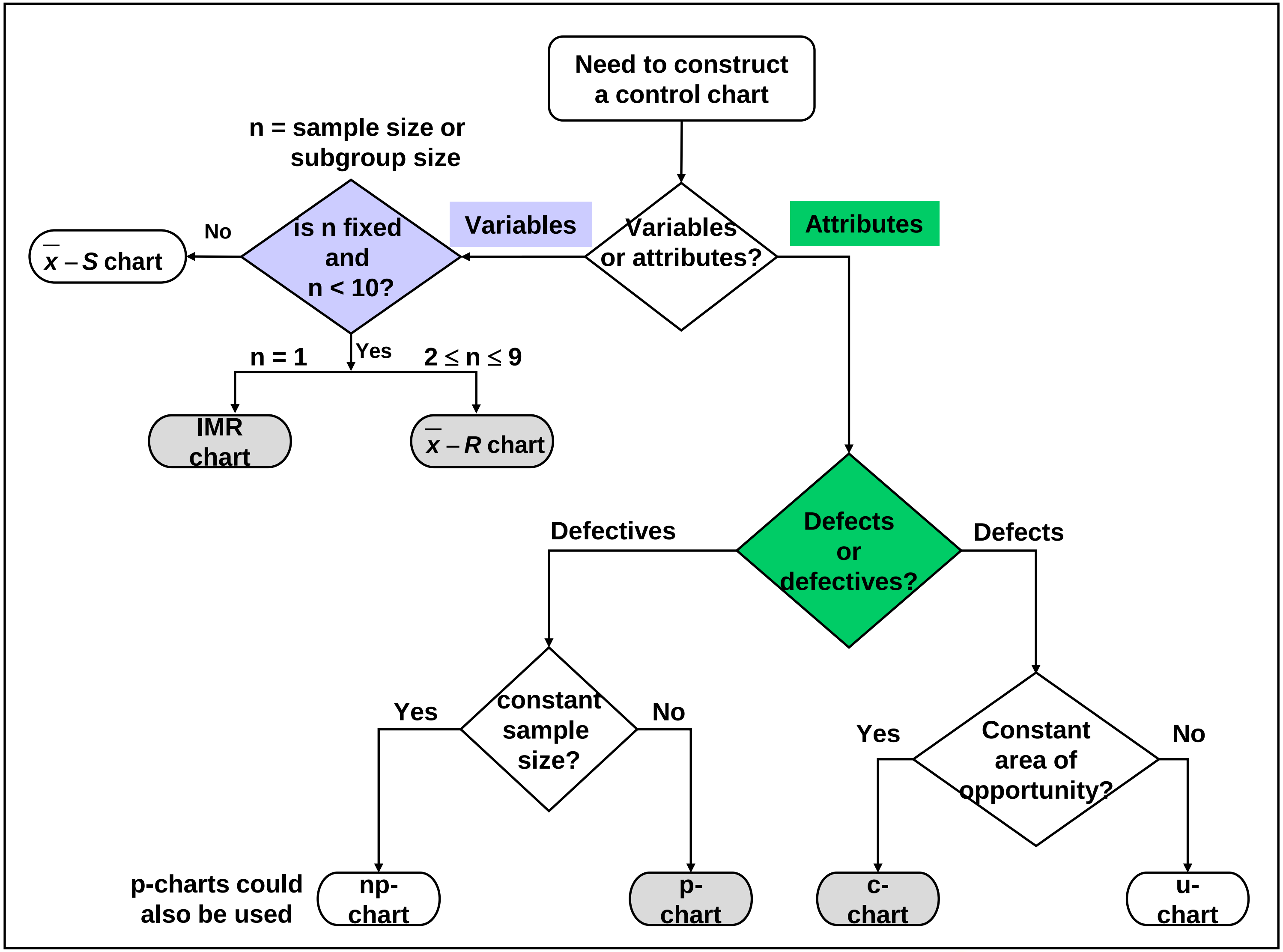
Selecting a Control Chart



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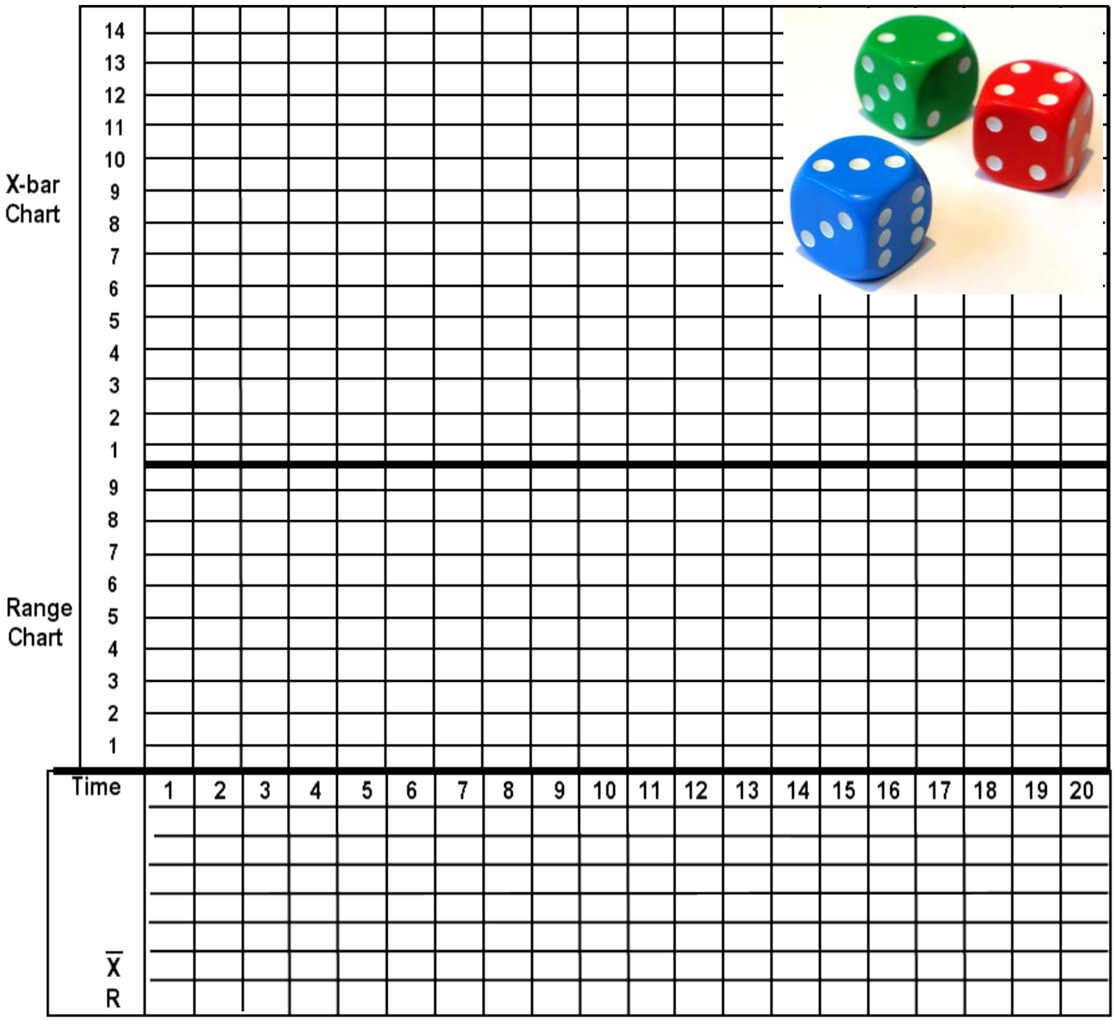
Illustrating an X-bar R Control Chart



- For each time period, roll 3 die and record the values. Plot the average of the 3 rolls on the X-bar chart, and the range of the 3 rolls on the Range chart.

- Use SPC XL to calculate the overall averages (center lines) for the X-bar and R charts, along with the control limits, to evaluate process stability.

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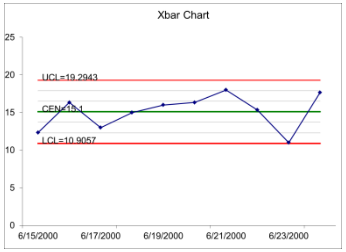
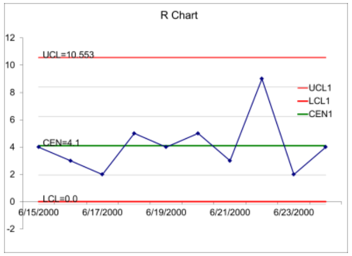
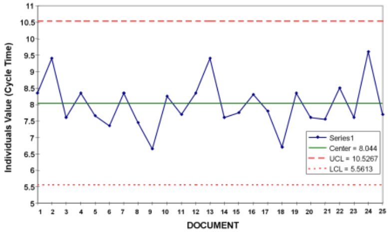
4 Most Common Charts

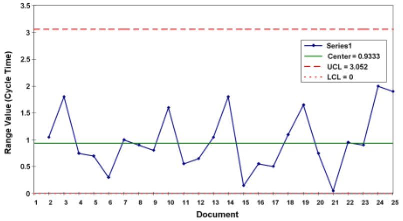
- X-bar R
  - subgroup averages & ranges



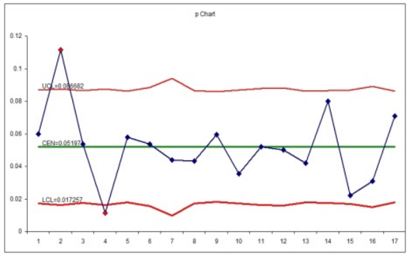


- IMR
  - individual values & moving ranges

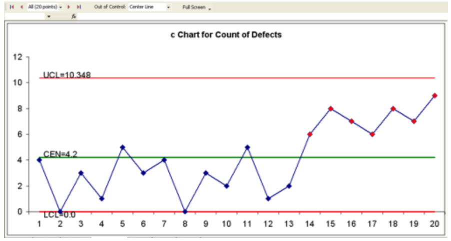




- p chart
  - proportions



- c chart
  - counts of defects



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Control Chart Practice

- For each situation, identify the appropriate control chart to use:

  1. The temperature in a furnace is recorded every 15 minutes. If temperature fluctuates too much, product quality is compromised. The team wants to monitor the temperature to ensure is remains stable.

  2. A product is inspected for scratches and other visual defects during final inspection. Every occurrence of a defect is written up and the total number of defects is recorded for each unit of product. The team wants to monitor the total defect rates.

  3. Each week, between 500 and 1,000 expense statements are processed. If any information is incomplete or incorrect, the expense statement is returned to the submitter for correction. The accounting department wants to monitor the percentage of returned requests, because they are concerned it has been increasing over time.

  4. The product weight of ingots varies with the batch. A sample of 5 ingots per batch is measured. The team wants to look at batch-to-batch and within-batch variation.

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Control Chart Practice (cont.)

5. Ingot weight (in kg) is measured for a sample of 5 ingots from each of 20 batches. Data is shown below. Evaluate and comment on the state of statistical control.

Batch 1	1.01	0.99	1.02	1	0.99
Batch 2	0.96	0.97	0.99	1.01	1
Batch 3	1.04	1.02	1.02	0.97	0.99
Batch 4	0.98	1.01	1	1	0.97
Batch 5	0.99	0.98	1.02	1.01	0.99
Batch 6	0.98	0.96	1.02	0.99	0.98
Batch 7	1.03	0.99	1	1.02	0.99
Batch 8	1.1	1.07	1.04	1.03	1
Batch 9	1	0.99	1.02	1	0.99
Batch 10	0.98	0.98	0.99	1.01	0.96
Batch 11	0.99	0.99	0.97	1.04	1.02
Batch 12	0.97	0.97	1.02	1.01	0.99
Batch 13	1.02	1.01	1.01	0.98	0.99
Batch 14	1.01	1.05	0.98	0.97	1
Batch 15	0.98	1.02	0.96	0.99	0.99
Batch 16	0.96	0.99	1.02	1.01	0.95
Batch 17	1.03	0.95	1.04	1.01	1.03
Batch 18	1.02	0.99	1.02	1	0.99
Batch 19	0.98	0.97	0.95	0.98	0.99
Batch 20	1.01	0.99	1.02	1.04	1.04

data file: *Control Chart practice.xls*

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Green Belt Certification

Certification Requirements

- Complete AAA 2-week Green Belt Training
- Pass AAA Lean Six Sigma Green Belt exam (online) (70%)
- Complete 2 projects (1 project if net hard benefits exceeds $25,000)
- Oral briefing of at least one project to a champion and member of the executive team, verified by signatures of attendees
- Written project report following AAA guidelines, documenting methodology, tools, and financial results

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Project Grading Criteria – Key Elements

- Candidate, Team members, and Champion documented
- Clear Problem statement
- Baseline (pre-improvement) metric given
- Evidence of DMAIC process used
- Project report outline used
- Tools Present
  - IPO diagram
  - PF/CE/CNX/SOP
  - FMEA (mistake proofing)
  - MSA
  - Proof of improvement (at least one from each group)
    - Capability Analysis (FPY, Cp, Cpk, dpm, etc.)
    - Graphical Analysis (Pareto, Histogram, run chart, control chart, box plots, etc.)
    - Statistical Analysis (t test, F test, Test of Proportions, confidence intervals, etc.)
  - Analyze phases uses at least 2 data analysis tools/methods
  - Control plan
  - Savings documented

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Certification Checklist

Certification Checklist

Student Name: ______________________
(as you would like it to appear on your certificate)

Email Address:________________________

Mailing Address: _____________________

Date

_______ Completed Air Academy Lean Six Sigma or Six Sigma Green Belt Training Program. (Please circle one)

_______ Passed Air Academy Green Belt Qualifying Exam with a grade of 70% or higher.

_______ Project Complete. Documentation must follow report guidelines. Project should produce savings in excess of $25, 000. If there are no quantifiable savings a second project should be completed.

_______ Second project complete (if required). Documentation must follow report guidelines.

_______ Oral Briefing Complete. Verified by signatures of Finance Executive and Champion (or Executive VP).

_______ Package prepared and sent to AAA:

- This completed checklist
- Written project reports
- Copy of training certificate
- Corporate certification of savings and oral briefing.
- Payment of project review fee

Note: The above package may be submitted electronically.

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Oral Briefing / Benefits Statement

Corporate Certification Statements

Project 1:

Company:

Green Belt Candidate:

Project Name:

Project Description:

Estimated Savings (annualized $):

Other Business Benefits:

This is to certify that the above Green Belt candidate has completed the required project through the control phase with savings and benefits as stated above. A satisfactory oral briefing was completed on ______ (date).

____________________ Champion

____________________ Finance Member

____________________ Executive Member (with title):

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Comfort Level with LSS / DMAIC Methods (Post-Session)

- Using a scale of 0-10, rate your knowledge/comfort level with the tools of LSS (MSA, hypothesis testing, etc.)

0	1	2	3	4	5	6	7	8	9	10
Haven't used Not at all Comfortable					Moderate Comfort (Comfortable with about half of tools/methods)					Extremely Comfortable (Comfortable with all (almost all) aspects)

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Thank You

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