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Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Department of Defense Lean Six Sigma

-Overview-

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Overview

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Lean Six Sigma and Why
- Principles and Tools
- OSD CPI/LSS Charter
  - DepSecDef memo of 11 May 2006
  - DepSecDef memo of 30 April 2007
  - DoDD 5010.42 15 May 2008
- Performance Excellence… A Lean Six Sigma World-Class Methodology
- Where to Start…Voice of the Customer
  - Projects Prioritized to Strategic Plan

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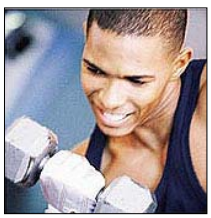
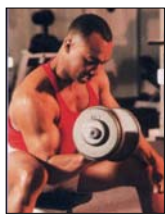
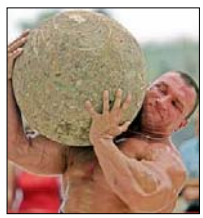
Right Training. Right Attitude.

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Lean Six Sigma is not rocket science… you can do this
- Lean Six Sigma is not “easy”… it requires dedication and effort



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Foundation to Lean 6 Sigma

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

If you cannot express what you know in numbers,
you don’t know much about it;

If you don’t know much about it,
then you can’t control it;

If you can’t control it,
you are at the mercy of chance.

-Dr. Mikel Harry
Motorola

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Foundation to Lean 6 Sigma

Lean Six Sigma

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Definitions of Insanity:

Doing the same thing over and over and expecting a different outcome!

AND

Using the same logic to get out of the trouble that got you there in the first place!

-Albert Einstein

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Continuous Improvement

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Define | Measure | Analyze | Improve | Control

- A framework for constantly improving organizational performance
- Provides steady, incremental improvement in everything we do to meet/exceed changing expectations:
  - Better quality
  - Faster turnaround
  - Lower costs
  - More responsive service
- A relentless, never-ending process
- Requires that we **all** change the way we think, talk, work, and act

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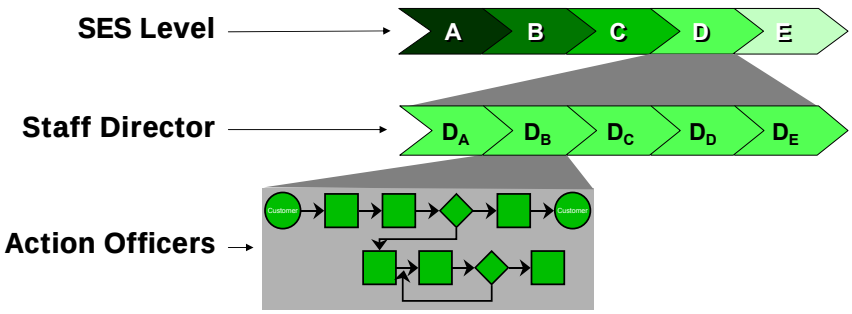
What is Lean?

Lean Six Sigma

Define | Measure | Analyze | Improve | Control



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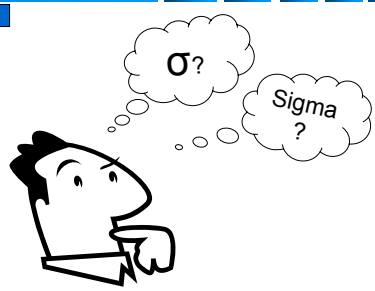
What Is Six Sigma?

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Sigma (or σ) is a statistical concept that represents how much variation there is in a process *relative to customer specifications*



Too much variation	Hard to produce output within customer requirements (specifications)	Low sigma values (0–2)
Moderate variation	Most output meets customer requirements	Middle sigma values (2–4.5)
Very little variation	Virtually all output meets customer requirements	High sigma values (4.5–6)

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Why Aim as High as 6 Sigma?

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Even at 99% quality (equivalent to a sigma level of 3.8), there would be:

- At least 200,000 wrong drug prescriptions per year

- Unsafe drinking water almost 10 hours each month

- Two short or long landings at O'Hare airport each day

- Over 90,000 wrong felony convictions per year

- 20,000 lost or incorrectly delivered articles of mail per hour

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The Look of 6σ Performance

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Define | Measure | Analyze | Improve | Control

		99% Good	99.99966% Good
	Lost articles of mail per hour	20,000	7
	Incorrect surgeries per wk	5,000	1.7
	Wrong prescriptions each yr	200,000	68
	Hours without electricity	7 hr per month	1 hr per 34 years

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Measures of Performance

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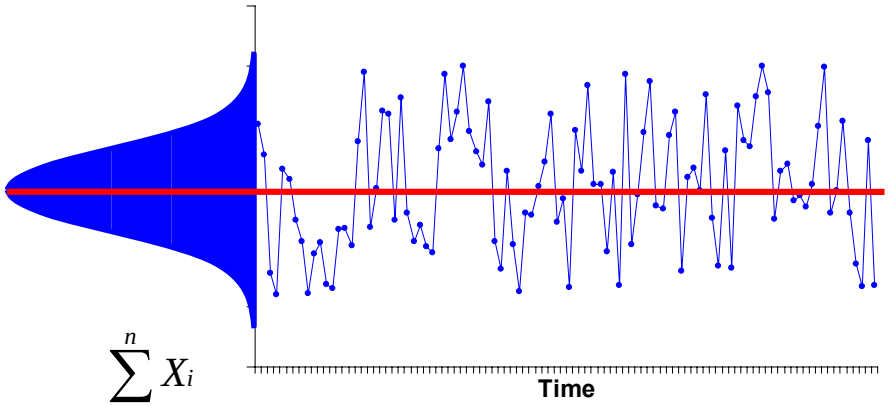

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n}$$

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Standard Deviation

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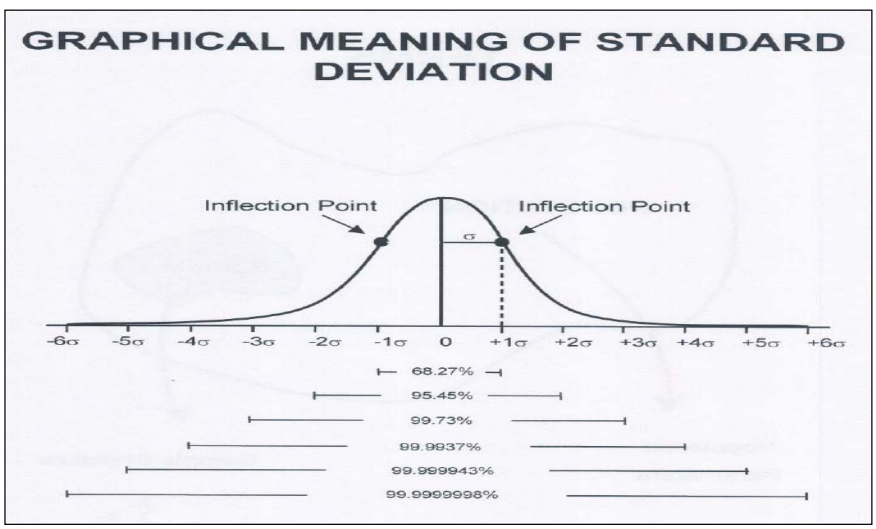

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Exercise 1A

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

What can we say about the performance of these two Services with respect to their means?

Purchase Requests Processed		
	Army	Navy
Mon	89	91
Tue	70	102
Wed	100	103
Thur	121	105
Fri	120	99
$\bar{X}$		

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Exercise 1A

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

The Services are equal in performance, but is there more to the story?

Purchase Requests Processed		
	Army	Navy
Mon	89	91
Tue	70	102
Wed	100	103
Thur	121	105
Fri	120	99
$\bar{X}$	100	100

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Exercise 1B

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

What can we say about the performance variation of these two Services?

Purchase Requests Processed		
	Army	Navy
Mon	89	91
Tue	70	102
Wed	100	103
Thur	121	105
Fri	120	99
σ		

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Exercise 1B

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Army is much more varied. What are the implications?

Purchase Requests Processed		
	Army	Navy
Mon	89	91
Tue	70	102
Wed	100	103
Thur	121	105
Fri	120	99
σ	21.6	5.5

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Sigma Level

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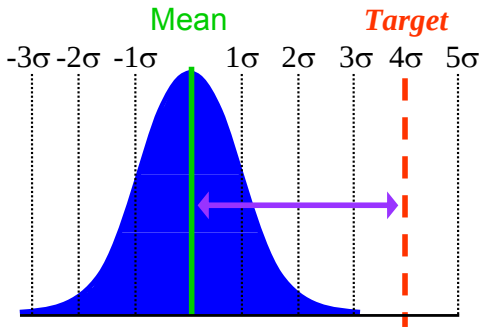
- **Sigma Level** (or Z-value): the number of Sigma between the process mean and the nearest specification limit
  - If we know:
    - The Mean of the process +
    - The σ of the process +
    - The Specifications set by the customer
  - Then:
    - We can determine the Sigma Level of the process



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A 3σ Process

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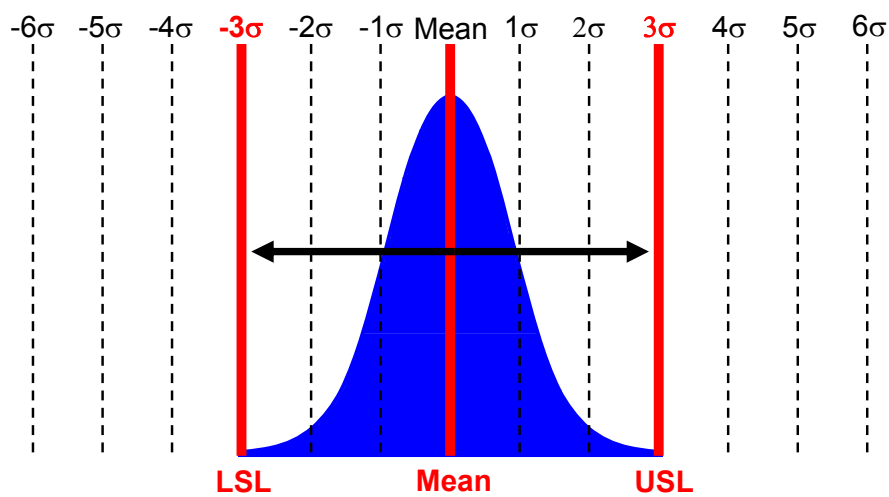

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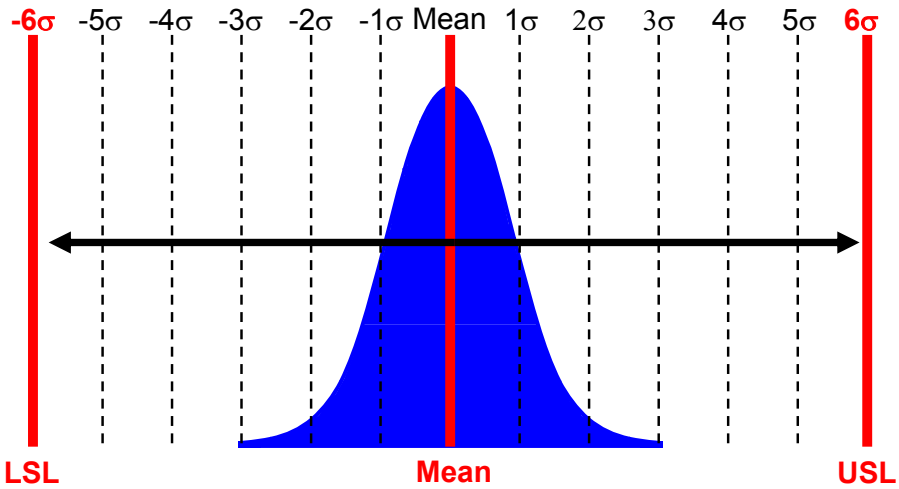
A 6σ Process

Lean Six Sigma

Define | Measure | Analyze | Improve | Control



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Example

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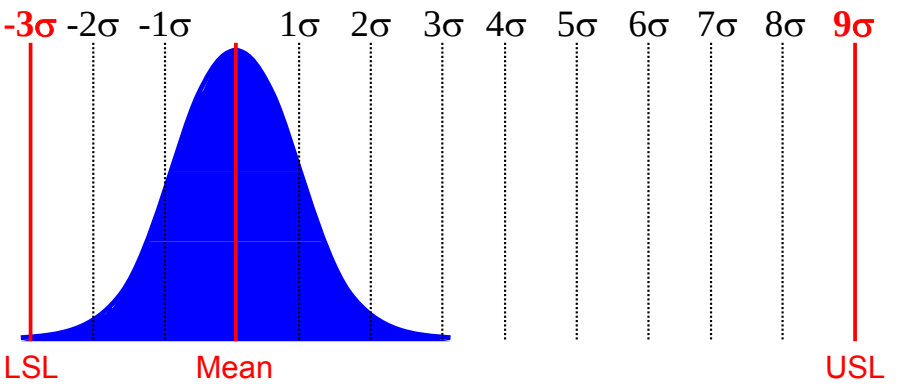
Define | Measure | Analyze | Improve | Control

- What is the sigma level of this process?



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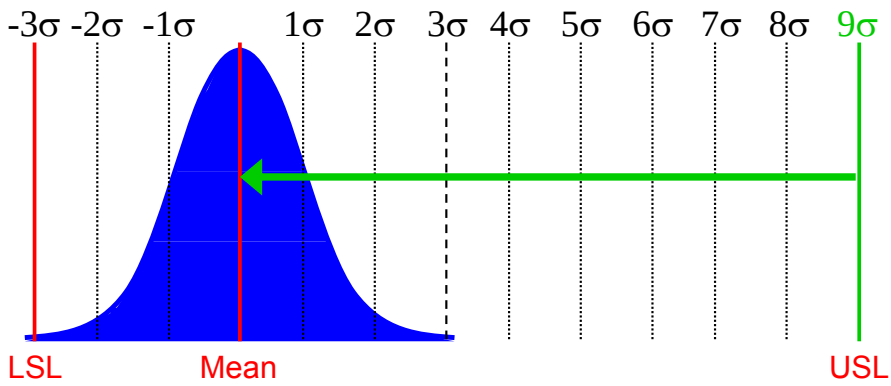
Example

Lean Six Sigma

Define | Measure | Analyze | Improve | Control



USL - Mean = 9σ

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Example

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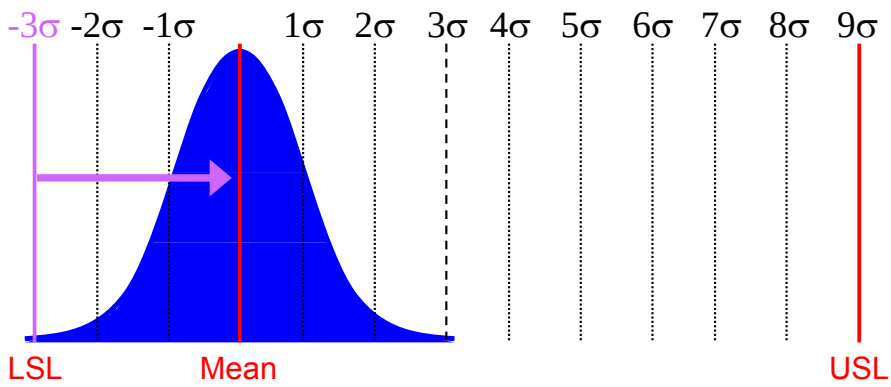

Mean - LSL = 3σ

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Example

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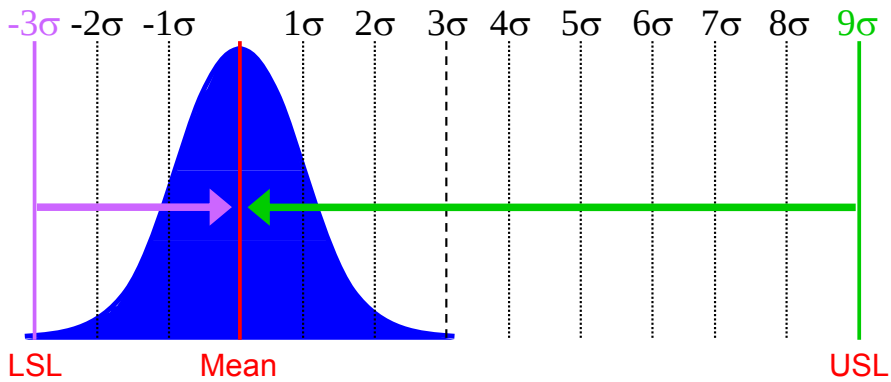

- The "Process Sigma" is:
  - The lesser of (USL-Mean) & (Mean-LSL) stated in units of σ

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Sigma Level Formula

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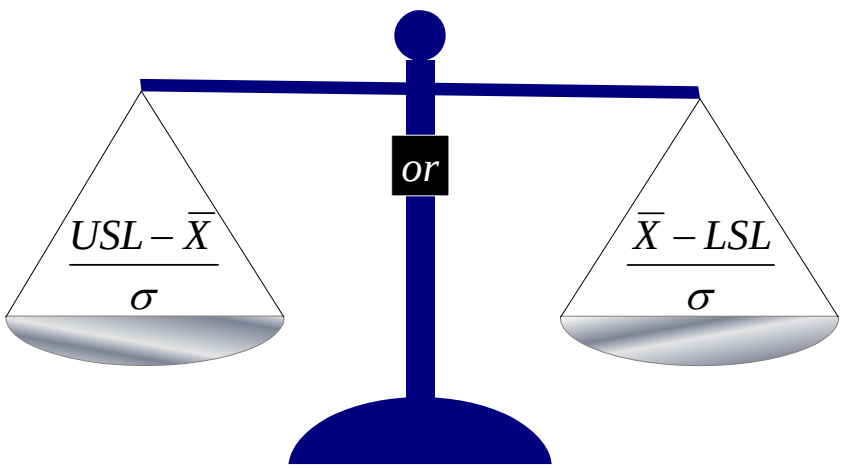
Define | Measure | Analyze | Improve | Control

- The Sigma level of a process is the lesser of:



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Measures of Performance

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Recall the Army and Navy processing rates
  - Assume:
    - LSL = 70 documents per day
      - to keep up with incoming rate
    - USL = 130 documents per day
      - To keep from "overfeeding" the processor which would result in a higher error rate
  - What are the sigma levels for each of these?
  - What are the implications?

Purchase Requests Processed		
	Army	Navy
Mon	89	91
Tue	70	102
Wed	100	103
Thur	121	105
Fri	120	99
σ	21.6	5.5

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Measures of Performance

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

ARMY

Upper Sigma Level:

$$\frac{USL-\overline{X}}{\sigma}=\frac{130-100}{21.6}=1.4$$

Lower Sigma Level:

$$\frac{\overline{X}-LSL}{\sigma}=\frac{100-70}{21.6}=1.4$$

Sigma Level: 1.4

NAVY

Upper Sigma Level:

$$\frac{USL-\overline{X}}{\sigma}=\frac{130-100}{5.5}=5.5$$

Lower Sigma Level:

$$\frac{\overline{X}-LSL}{\sigma}=\frac{100-70}{5.5}=5.5$$

Sigma Level: 5.5

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Which would you prefer?

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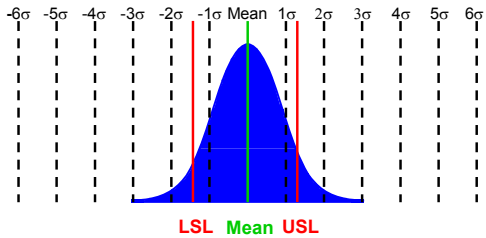
Define | Measure | Analyze | Improve | Control

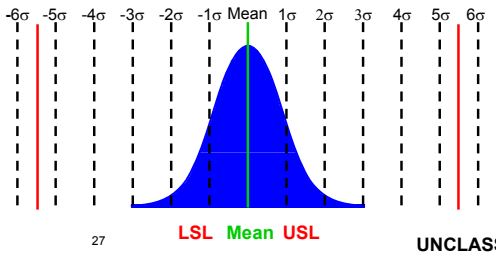
A R M Y

The target is missed more than 15% of the time



N A V Y

The target is usually never missed?



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A Program of Process Improvement

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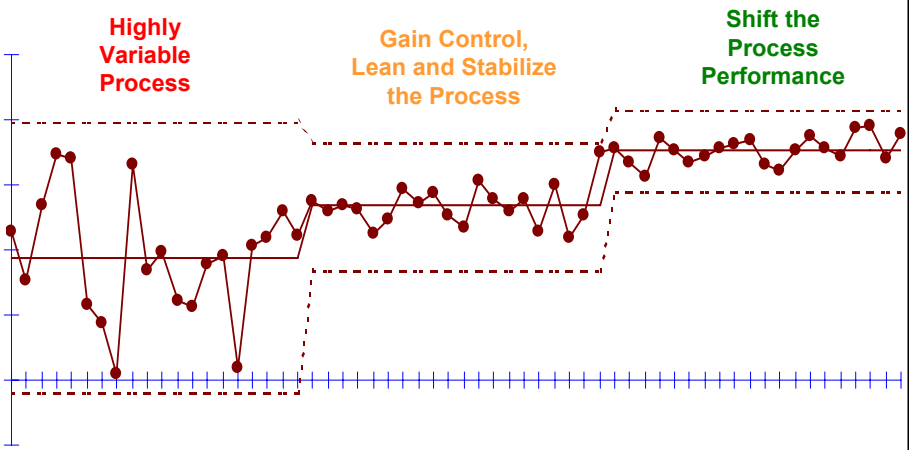
Define | Measure | Analyze | Improve | Control

- Continuous Process Improvement (CPI) is a deliberate change in Process Performance



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Customer Specifications

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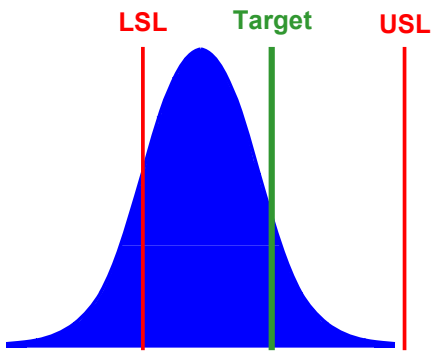
Define | Measure | Analyze | Improve | Control

- The specification limits represent the parameters of performance desired by the customer.
- The Upper Spec Limit (USL) & Lower Spec Limit (LSL) represent the level of tolerance around this desired target.
- Together, they represent what the customer **wants**! Not what the process **does**.



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Different Sigma Process Levels

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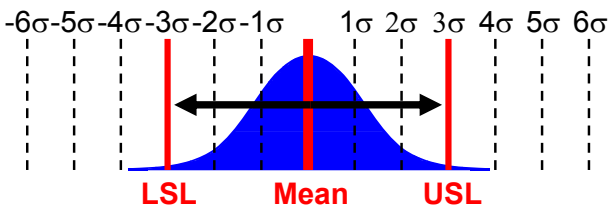
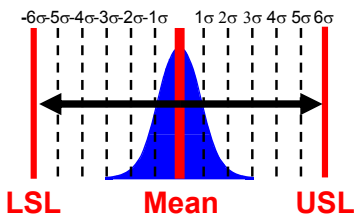
Define | Measure | Analyze | Improve | Control

3σ Process



6σ Process



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Importance of Reducing Variation

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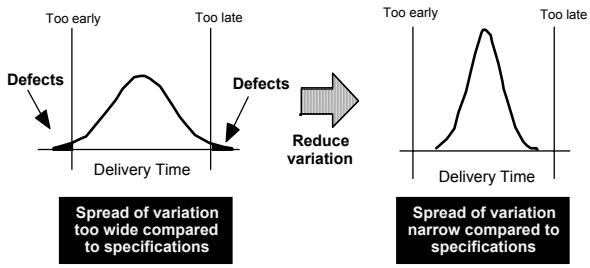
Define | Measure | Analyze | Improve | Control

- To increase a process sigma level, you have to decrease variation.



- Less variation provides:
  - Greater reliability in the process
  - Less waste and rework, which lowers costs
  - Products and services that perform better and last longer
  - Happier customers

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Measures of Performance

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- If we know the process mean and the process sigma, then we can describe the performance of the process.

- But:
  - How do we know if the process performance is good or bad?
  - Who should determine if performance is good enough?

?

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Additional Metrics of Six Sigma

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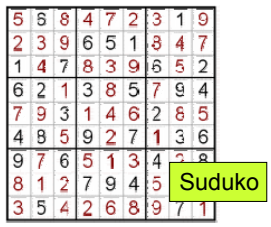
- In addition to Sigma Level, four other performance metrics are of interest:
  - Defects Per Unit (DPU)
  - Process Capability
  - Defects Per Million Opportunities (DPMO)
  - Yield

- If you know one…

  you can determine the others



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Objectives

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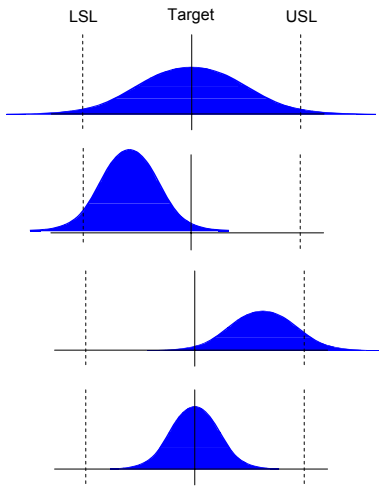
Current State	Objective
The mean is on target, but the spread is wider than the specification range.	Focus on reducing process variation while maintaining the mean at target.
The mean is not centered, but the spread is narrower than the specification range.	Focus on shifting the mean to target, while maintaining or reducing process variation.
The mean is not centered and the spread is wider than the specification range.	Focus on shifting the mean to target AND reducing process variation.
The mean is centered and the spread is narrower than the specification range.	Use control procedures to maintain the mean and process variation.



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Foundation to 6 Sigma

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

$$Y = f(x)$$

Y is:	Xs are:
Output	Inputs
Dependent	Independent
Observed	Controlled
Effect	Causes
Result	Reason

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Improvement-Focused Scale

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Define | Measure | Analyze | Improve | Control

Increase in Sigma requires exponential defect reduction

"trim the fat"

DPMO	σ
308,537	2
66,807	3
6,210	4
233	5
3.4	6
Defects per Million Opportunities	Process Capability

(distribution shifted ±1.5s)

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Why Use Six Sigma As a Metric?

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- **Focuses on defects**
  - Even one defect reflects a failure in your customer's eyes
- **Using a common metric makes comparisons easier**
  - For instance, which of the following processes performed best?

Process	# of Transactions per month	Performance
Calls handled	14,000	10% require transfers
Credits processed	75	Avg. cycle time of 3 days
Installation of new service	2500	94% first-time through rate
Daily reports	28-31	9 errors per day

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The History of CPI/Lean Six Sigma

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Frederick W. Taylor in 1880s and early 1900s
  - Taylor's systematic study of workers' use of time and motion prefigured Walter Shewhart's application of statistical methods to control manufacturing quality
- World War I
  - Application of mathematics to problems of production and quality control helped decrease failure rate
  - Management became interested in continuing quality control programs after the war
- W.E. Deming and Joseph Juran took quality control to Japan in 1953. The 1960s saw a surge in the growth of quality in Japan
- In the 1980s, the NBC White Paper *"If Japan Can… Why can't We"* sparked increased interest in quality and total quality management

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The History of 6 Sigma

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Mid-1980s Motorola started "6 Sigma"
  - Focused on creating strategies to reduce defects in own products
  - Discovered that problems with high first-pass yield (the amount of products that make it through defect-free) seldom failed in use
  - Won Baldrige Award 1988
- Led by Mikel Harry, Motorola partnered with IBM, ABB (Asea Brown Boveri), Texas Instruments, Allied Signal, and Kodak to found the "Six Sigma Research Institute"
  - Late 1990s, Mikel Harry began commercializing 6 Sigma and successfully applied its techniques to a non-manufacturing environment
- Current popularity due in part to publicity of General Electric's former CEO Jack Welch's commitment to achieving 6 Sigma capability

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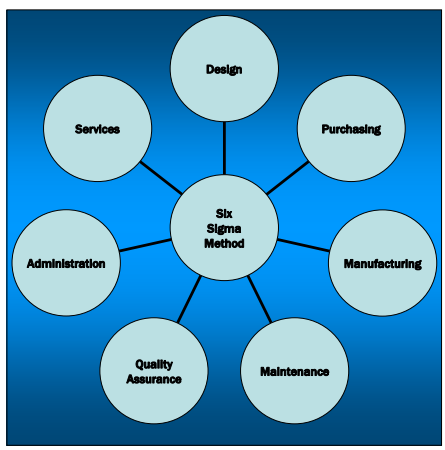
Versatility

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- **Applicable to EVERY Business Function**
  - **Traditional manufacturing**
  - **Transactional processes**
- **Any process that produces an output has downstream "customers" (external or internal)**



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Why Use Lean Six Sigma

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- **LSS is the CPI industry standard**
  - ✓ Increase throughput
  - ✓ Shorten cycle times
  - ✓ Reduce defects
  - ✓ Lower costs

1992: Motorola, ABB, TI, IBM, DEC, Kodak, AlliedSignal, GE

1995: Siebe Foxboro, Lockheed Martin, Bombardier, John Deere, Whirlpool, GenCorp, Nokia, Sony

2000: Siemens, Compaq, Seagate, PACCAR, Toshiba, DuPont, Dow Chemical

Today: Maytag, Praxair, Ford, Air Products, Honeywell, Johnson Controls, Johnson & Johnson, Fannie Mae, Bank Of America, Intuit, AXA Equitable, United Health Group, Cardinal Health, Blue Cross, Providence Health, Home Depot, US DoD, Wells Fargo, Robert Half, Fifth Third Bank, CitiGroup

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Where Are Businesses Today?

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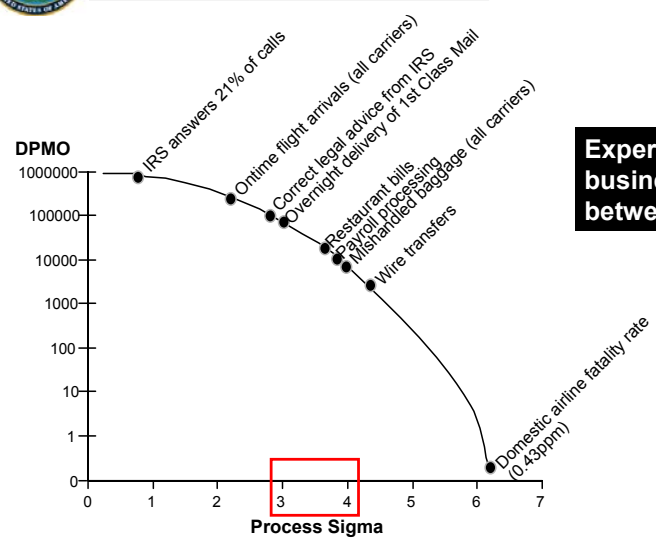

Experts think most businesses fall between 3 - 4 sigma

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Lean Six Sigma Principles

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Identify value in the eyes of the Customer
  - Learn to see your processes from the perspective of your customer
- Identify the value stream and eliminate waste/variation
- Make value flow at the pull of the customer
- Involve, align, and empower employees
  - Develop solutions using the people who are currently working in the process
- Continuously improve knowledge in pursuit of perfection

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Identify & Control the Xs

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

process output | is | a function of | key process and input factors that cause variation in the output

$$y = f(x_1, x_2, \ldots)$$

- In Improvement…
  - identify the key Xs to reduce variation in the Y
- In Design…
  - carefully set specifications on the Xs so that we get the desired Y
- In Process Management…
  - monitor and control the Xs to assure we will get the desired Y

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Overview of DMAIC

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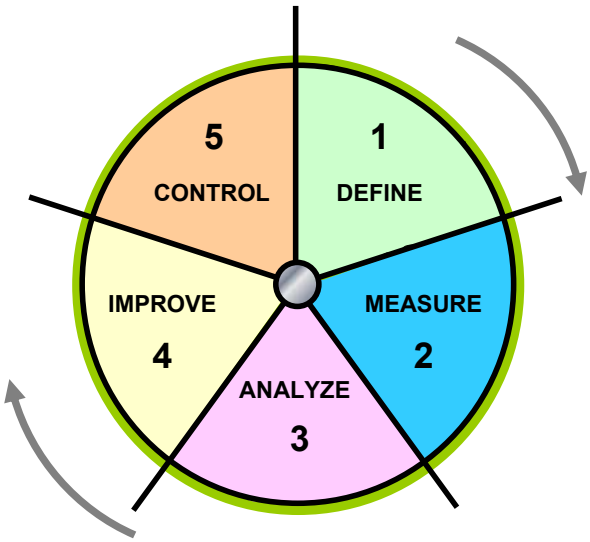

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The Six Sigma Tollgate

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Define	Measure	Analyze	Improve	Control
❑ Project Charter • Problem Statement • Defined Benefits • Business Case	❑ Process Map	❑ Potential Xs	❑ "To Be" Process Map	❑ Transition Plan
❑ Measurable Y • Customer Specs/VOC	❑ Data Collection Plan • Data Collected	❑ Critical Xs	❑ Improvement Strategy • Improvement Model • "X" Improvement Target	❑ QC Chart
❑ Cross Functional Team	❑ Data Presentation • Run Chart; Histogram; Mean/Stand. Dev.	❑ Required Data Display: • **Pareto Charts; Fish Bone / C&E; Histograms;**	❑ Mistake-Proofing	❑ Communication to Impacted Areas
❑ Timeline	❑ Updated CTQs/CTPs	❑ Optional Data Display: • **Descriptive Stats.; Time Series Plots; Control Charts; Box Plots**	❑ FMEA	❑ Project Documentation
❑ SIPOC	❑ "Y" Performance Target	❑ XY Matrix	❑ Risk Analysis & Risk Mitigation Plan	
I accept the Define Tollgate. Signed: _____ *(Sponsor)* _____ *(Process Owner)* _____ *(MBB)* _____ *(Finance Owner)*	I accept the Measure Tollgate. Signed: _____ *(Sponsor)* _____ *(Process Owner)* _____ *(MBB)*	I accept the Analyze Tollgate. Signed: _____ *(Sponsor)* _____ *(Process Owner)* _____ *(MBB)* _____ *(Finance Owner)*	I accept the Improve Tollgate. Signed: _____ *(Sponsor)* _____ *(Process Owner)* _____ *(MBB)*	I accept the Control Tollgate. Signed: _____ *(Sponsor)* _____ *(Process Owner)* _____ *(MBB)* _____ *(Finance Owner)*

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The Role of Performance Management

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Change Agents for the way we do business
- OSD's full-time CPI/LSS Program Office
  - Lean Six Sigma methodology
  - OSD training, testing, and certifying Green Belts and Black Belts
  - In-house capability, ownership
- Reporting and Metric Development
  - Centralized oversight for reporting and metrics
- Regularly scheduled updates to the Senior Steering Committee
- Assist and Support OSD Performance Management efforts
  - Habitual relationship with CPI/LSS personnel

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The Lean Six Sigma Cadre

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Green Belt
  - Researcher, Data Analyzer, Team leader
- Black Belt
  - Works Lean Six Sigma Full-time
- Master Black Belt
  - Manages deployment of several Black Belts and mentors Black Belts/ Green Belts
- Champion
  - Executive-level Sponsor/Supporter
- Senior Steering Committee
  - OSD, Service, Agency, Activities Reps

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Six Sigma Certification Requirements

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

	Training	Testing	Projects	Mentoring	Other
Green Belt	• 40 hrs GB classroom instruction	• Pass GB test	• Complete 1 GB project with measurable improvement results • Signed Tollgates	• None	• Approval from Certification Review Board
Black Belt	• 160 hrs BB classroom instruction (includes previous GB instruction plus 120 hrs DoD BB instruction)	• Pass BB test	• 2 BB level projects with measurable improvement results • Signed Tollgates	• Mentor 2 GBs to project completion	• Instruct GB Course • Approval from Certification Review Board
Master Black Belt	• Black Belt Certification	• None	• Complete 2 high-impact projects with measurable improvement results • Signed Tollgates	• Mentor 5 GBs to project completion • Mentor 4 BBs to project completion	• Instruct BB Course • Approval from Certification Review Board

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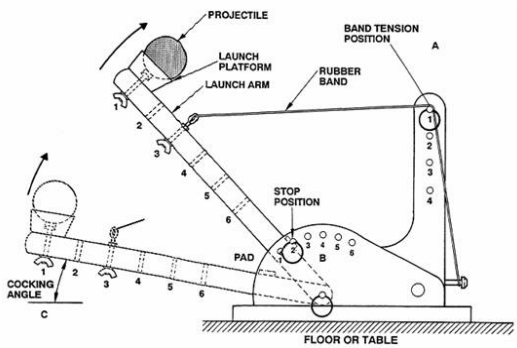
Exercise: Catapult

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Break up into teams of approx. 5 members
- Assemble and fire catapult
- Record results
- Time limit: 5 minutes



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Exercise: Catapult Performance

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Group #	Name			
Test Launch				
Distance 1				
Variance from Center 1				
Distance 2				
Variance from Center 2				
Distance 3				
Variance from Center 3				
Distance 4				
Variance from Center 4				
Distance 5				
Variance from Center 5				
Total				
Mean/Average				
Median				
Sigma				

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Exercise: Catapult

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Did any team perform exactly alike?
- Note any differences among teams
- Discuss possible reasons for differences

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Lean Six Sigma

Define | Measure | Analyze | Improve | Control

The harvest is plentiful but the workers are few

Questions?

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Lean Six Sigma

Define | Measure | Analyze | Improve | Control

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Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Define

Measure

Analyze

Improve

Control

Define

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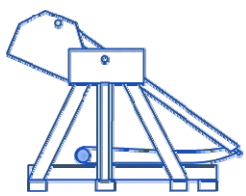
Catapult Customer

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Who is the customer of the catapult you just fired?
- Will your catapult meet customer spec's?
  - What does the customer want?
  - What is the objective?
  - What might the customer have wanted the catapult to do?
- Might knowing this information give you ideas on how you should have fired your catapult?



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Define

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Who is the customer for your project?
  - Are they Internal, External, or Both?
- What is required of you for your project?

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Problem Statement

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- OSD Policy:
  - Financial benefit yielded from project remains with the process owner
  - Project benefit is determined by the Champion
    - ***Benefit must be measurable***
- The problem statement should:
  - Focus everyone involved on the deficiency at hand
  - Quantify the deficiency in terms of performance or customer satisfaction

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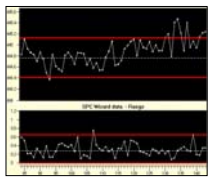
Project Benefits

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Project benefits can come in many forms:
  - Financial savings
  - Cost Avoidance
  - Productivity Improvements
  - Throughput improvement
  - On Time Delivery
  - Labor reductions
  - Customer Satisfaction
  - Defect Elimination
  - Accuracy Improvement
  - Error Reduction



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Problem Statement: Example 1

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

In 2006, 70% of all purchase requests submitted contained errors.

Update your problem statement as you uncover more details about the problem

In 2006, 70% of all purchase requests submitted contained errors.

Errors result in double-processing that adds work hours (cost) and processing delays.

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Define The Project

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Often people think tackling a broad problem can make big improvements
  - *"Let's tackle the elephant"*
  - *"Solve world hunger"*
  - *"Boil the ocean"*

- This usually backfires because it's easy to get bogged down taking on too much at once
- It is more effective to focus on a specific component of a problem

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Define the Project

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- A poorly focused problem statement does not answer as many questions as a well focused problem statement
- Focus a problem statement by answering *who*, *what*, *where*, *when*, and *which*

Poor service at the Pentagon

Broad or Vague		Somewhat Focused		Narrow Focus
X				

What: poor service

Poor service at the Pentagon Badge Office in the afternoon

Broad or Vague		Somewhat Focused		Narrow Focus
		X		

What: poor service
Where in the Pentagon: Badge Office
When: afternoon

Slow service obtaining CAC cards between 2pm and 4pm on weekdays at Pentagon Badge Office

Broad or Vague		Somewhat Focused		Narrow Focus
				X

What: Poor service
What type of service: CAC card
What about the service: It is slow
When is the problem the greatest: Between 2pm and 4pm on weekdays

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Charter & Timeline

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Charter	
Problem Statement:	
Business Case:	
Unit:	
Defect:	
Customer Specifications:	
Measure Start:	
Measure Stop:	
Scope:	

Take away message goes here (impact of problem)

Timeline			
Phase	Planned	Actual	Status
Define	**dd mm yy**	**dd mm yy**	
Measure	**dd mm yy**		
Analyze	**dd mm yy**		
Improve	**dd mm yy**		
Control	**dd mm yy**		

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Charter & Timeline

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Charter	
Problem Statement:	**What is the problem**
Business Case:	• **What benefits will be achieved as a result of the project**
Unit:	**How is an action identified -**
Defect:	• **Describes an unacceptable unit**
Customer Specifications:	**Defines what the customer considers to be good/poor performance**
Measure Start:	**Defines when a unit starts**
Measure Stop:	**Defines when a unit is considered complete**
Scope:	**Defines the organization or area where process resides.**

Take away message goes here (impact of problem)

Timeline			
Phase	Planned	Actual	Status
Define	**dd mm yy**	**dd mm yy**	
Measure	**dd mm yy**		
Analyze	**dd mm yy**		
Improve	**dd mm yy**		
Control	**dd mm yy**		

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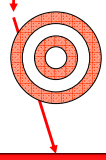
Define the Project - QFR Response Process

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Charter	
Problem Statement:	**Questions For the Record (QFRs) from Congress are not being answered in a timely manner.**
Business Case:	**As a result of this project, we will:** ○ **Decrease QFR response time to within 30 days** ○ **Streamline the current QFR/IFR (Question for the Record/Insert for the Record) process and promulgate a written procedure that can be effectively used by all component organizations** ○ **Ensure coordination chops are obtained at the optimal steps in the process**
Customer Specs:	**DoD has 30 days from receipt of QFR/IFR to return a response to Congress.**
Defect:	**Responses that exceed 30 days**
Unit:	**Individual QFRs. For the purposes of this review, only QFRs will be evaluated, as they are the bulk of the actions being tracked.**
Start:	**Upon receipt by DoD Legislative Affairs**
Stop:	**Upon LA transmission of response back to Congress**
Scope:	**All LA-processed QFRs submitted in Calendar Year 2007 up to and including those sent to committee as of 30 November 2007, with detailed tracking of QFRs assigned to AT&L and Policy.**



Faster responsiveness to Congressional QFRs will improve our relationship with Congress

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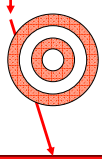
Define the Project – PRD/PRS Congressional Reply Process

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Charter	
Problem Statement:	**Replies to letters from Congressmen/Senators for DEPSECDEF and SECDEF signature (PRD/PRS) are not being answered in a timely manner.**
Business Case:	**As a result of this project, we will:** ○ **Decrease PRD/PRS Congressional response time to 7 days** ○ **Establish PRD/PRS Congressional standard processing business rules that can be effectively used by all component organizations** ○ **Ensure coordination chops obtained at optimal steps in the process**
Customer Specs:	**Per SECDEF, DoD has 7 days from receipt of a PRD/PRS Congressional to return a response to Congress.**
Defect:	**Responses that exceed 7 days**
Unit:	**Individual PRD/PRS Congressional replies. For the purposes of this review, only QFRs will be evaluated, as they are the bulk of the actions being tracked.**
Start:	**Upon receipt by DoD Executive Services Division (ESD)**
Stop:	**Upon ESD delivery to Congress**
Scope:	**All PRD/PRS Congressional replies generated in Calendar Year 2007 up to and including 30 September 2007, with detailed tracking of QFRs to AT&L and Policy.**



Faster responsiveness to Congressional letters will improve our relationship with Congress

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Define Tools

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- **Customer Research** such as interviews, focus groups, surveys

- **Pareto Chart (s)** depicting why the project is important to the customer

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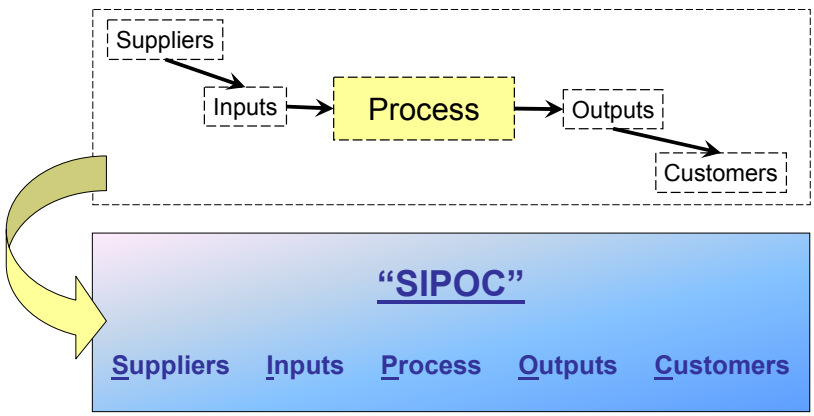
Define

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Before we stumble around someone's sandbox,
…shouldn't we *know* something about the sandbox?



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SIPOC

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- A SIPOC is a framework used to construct a high-level map of a process

S	*upplier:*	A person or organization that provides the inputs to your process.
I	*nput:*	Materials, resources, and data required to execute your process.
P	*rocess:*	A collection of activities that takes one or more kinds of input and creates one or more kinds of output that is of value to the customer.
O	*utput:*	Tangible products or services that result from the process -should satisfy customer need.
C	*ustomer:*	A person or organization who receives the outputs of your process -internal or external.

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Elements of a SIPOC

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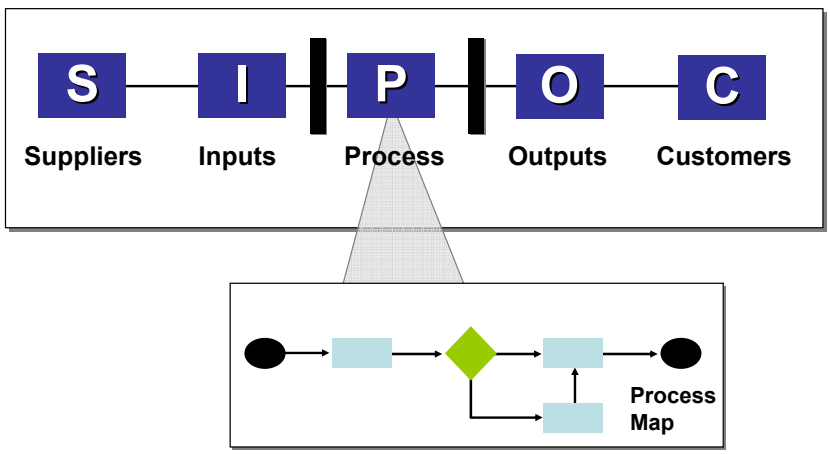
Define | Measure | Analyze | Improve | Control



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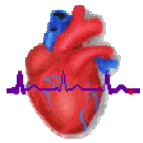
What are CTQs?

Lean Six Sigma

Define | Measure | Analyze | Improve | Control



- CTQ = "Critical To Quality" characteristics
  - Measurable characteristics of a product or process
  - Imply performance standards that **must be met** to satisfy the customer
- Role of CTQs in your project
  - Ensure that your project is directly linked to a critical issue affecting customer satisfaction
  - Typically focus on 1 or 2 CTQs
  - The basis for project success

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Other SIPOC Uses

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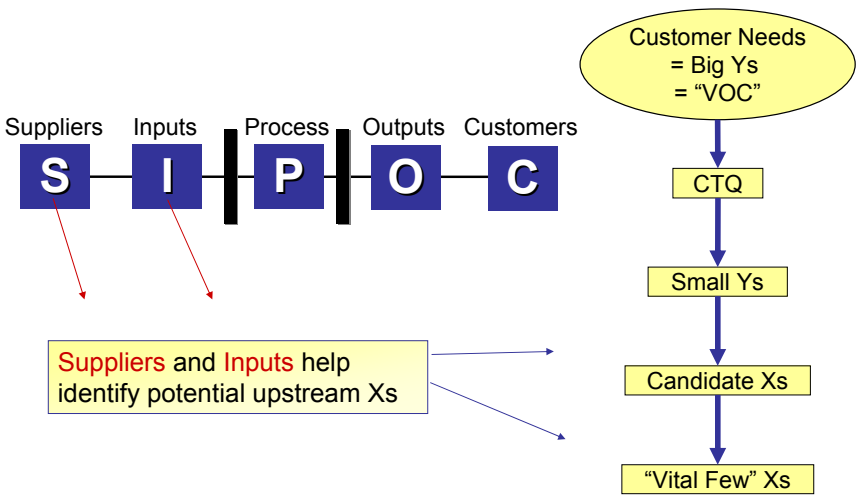
Define | Measure | Analyze | Improve | Control



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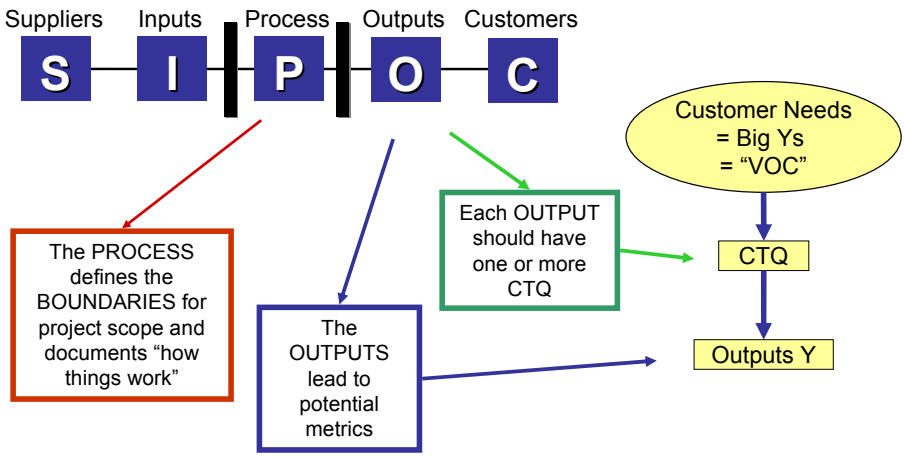
Why develop a SIPOC in the DEFINE Phase?

Lean Six Sigma

Define | Measure | Analyze | Improve | Control



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Steps to Build a SIPOC Map

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

1. Name the Process
   - Agree on beginning and end (boundaries)
2. Specify primary **O**utputs and the **C**ustomers receiving them
   - Use nouns for outputs (e.g., Intel report, training, etc.)
   - Use adjectives for CTQs (e.g., timely, knowledgeable, accurate, etc.)
3. Document the steps in the **P**rocess
   - Brainstorm with the whole team
   - Write each process step on a separate post-in note and post on wall
     - Begin all steps with a verb
     - Don't try to establish order yet
     - Don't get lost in the details of each step
4. Identify critical **I**nputs which affect the quality of the process
5. Identify the **S**upplier who provides each input
6. Validate that the map represent how things **actually work today**
   - Not how you *think* it is
   - Not how it *should* be

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High Level Process Map

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

S — I (Use Nouns) — P (Use Verbs) — O (Use Nouns) — C

Family
- Requirements
- Family needs
- Budget

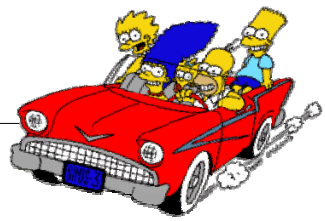
Dealers
- Specs
- Prices
- Availability

Bank
- Loan details

Determine purchase options
↓
Visit dealers; identify best deals
↓
Review data
↓
Agree on best option
↓
Secure loan
↓
Negotiate w/dealer
↓
Pick up car

- Purchased car
- Secured Loan

- Me
- Family



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CTQ Flow Down

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Begin with customer needs and "flow down" to Xs

Customer Needs = Big Ys = "VOC" — **"Voice of the Customer" (VOC)**

↓

CTQ — **CTQ = "Critical to Quality"**
Key measurable characteristics that must be met in order to satisfy the customer

↓

Small Ys — Process outputs that directly relate to the CTQ. (Specifications for these outputs determine "defects")

↓

Candidate Xs — Process inputs, controls, and factors that potentially impact the Project Y

↓

"Vital Few" Xs — Xs that can be adjusted to achieve Six Sigma performance

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Determining Customer Needs

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Customer Interview
  - Important information gathering technique to identify and understand customer needs
  - Able to ask follow-up questions to gather more complete and useful feedback
  - Fosters cooperative working relationships between customer and supplier
  - Must be well planned
  - Customers can be internal or external

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Customer Interview Procedure

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Before the Interview:
  - Gather background information
  - Outline areas to be covered and major questions to be asked:
    - Open-ended questions
    - Who, What, Where, When, Why, and How
  - Choose a comfortable meeting place

- During the Interview:
  - Help interviewee feel comfortable
  - Tell interviewee the purpose and proposed length of the interview
  - Remain analytical and objective
  - Take notes
  - Summarize and reflect back answers to verify what you learned

- After the Interview:
  - Thank the interviewee
  - Review and interpret data as soon as possible

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Interview Suggestions

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- **Ask:**
  - "What barriers do you face in doing …?"
  - "What issues do you encounter when …?"
  - "What are the main issues as they relate to …?"
  - "In an ideal world, what would you improve?"
  - "Why is that true?"
  - "Tell me more about that."
  - "Give me an example."
  - Open-ended questions
- **Listen!**
  - Conduct the interview so that the interviewee feels like the customer

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Likert Scale

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- **Likert Scale**
  - A rating scale measuring the strength of agreement with a clear statement
  - Often administered in the form of a questionnaire used to gauge attitudes or reactions
  - Example:

"I found the software easy to use..."

A. Strongly disagree
B. Somewhat disagree
C. Neither disagree nor agree
D. Somewhat agree
E. Strongly agree

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Surveys

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- In these 2 examples, information is being obtained in different ways
  - Providing response options in varying degrees will allow you to stratify your responses

1. You are a:
___ a. supervisor
___ b. agency head
✓ c. administrative assistant
___ d. other employee

2. How many times in the past 12 months did you order supplies?
___ a. Once a week or less
✓ b. More than once a week
___ c. Never

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Define Recap

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- How to determine who the customer is:
  - SIPOC
- How to set project/process boundaries:
  - SIPOC
- How to determine what the customer wants:
  - CTQs
  - Customer Interviews

- Do we have everything we need to define our project with a narrow scope?
- Do we know how we will measure success?

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Problem Statement

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- The problem statement should:
  - Focus everyone involved on the deficiency at hand
  - Specify exactly:
    - …what the problem or issue is
    - …who owns the problem or issue
    - …where the problem or issue is
    - …what the time frame is

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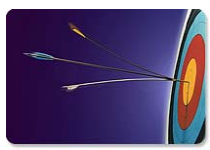
Problem Statements

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Quantify the deficiency
  - …lost efficiency
  - …over spending
  - ...customer dissatisfaction

- Quantify a <u>concrete</u> target
  - What is your expected improvement target?



- Identify the timing to meet the target
  - When do you expect to complete your project?

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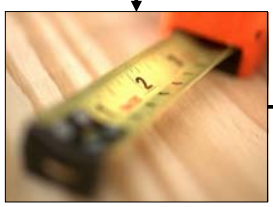
Primary Metrics

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- How the output/product of the process is measured
- Must be consistent with the Problem Statement
- Must be objectively measured
- Creates the yardstick used to measure the success of the project!



EXAMPLES
• Total Head Count
• Employees Trained
• On Time Delivery
• Customer Satisfaction
• Total Cycle Time

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Secondary Metrics

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- The measures that will "keep the process honest"
- They prevent process members/project team from taking a problem from one area and moving it to another
  - Therefore, any associated secondary metrics should be defined and tracked to prevent process sub-optimization

EXAMPLES	
Primary Metrics	Secondary Metrics
• Total Head Count	• # of Contractors Used
• Employees Trained	• # Employees completing
• On Time Delivery	• Number of Extensions
• Customer Satisfaction	• Reworked Processes
• Total Cycle Time	• Total Head Count

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Change Isn't Easy

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

"One of the difficulties in bringing about change in an organization is that you must do so through the persons who have been most successful in that organization, no matter how faulty the system or organization is.

To such a person, you see, it is the best of all possible organizations, because look who was selected by it and look who succeeded most within it. Yet these are the very people through whom we must bring about improvements."

George Washington
Second Inaugural Address

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Human Factors

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Stagnation

- May or may not be working hard, but they have no sense of threat- which indicates a delusional state
- Can only end with a forceful demand for change from someone in a position of power and authority

- **Preparation**
  - People feel anxious, jittery, hopeful, threatened, excited, betrayed…WIFM
  - Lack of Leadership alignment – most common cause of failure…NOT lack of commitment by middle management
- **Implementation**
  - People feel confusion, apathy, resentment, inadequacy, and volatility
  - It is up to the Leaders to help the employees understand the plan, persuade them it will work, motivate them and work with them.

"For a change initiative to succeed, the emotional and behavioral aspects must be addressed as thoroughly as the operational issues"

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Human Factors

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- **Determination**
  - Workers are likely to revert to their old ways, or leave, or worse, stay in place but not engage.
  - Organization starts to experience change fatigue
  - Retreat
    - Disguised as apathy, hopelessness, or cynicism
    - "We need a little breathing space before we begin" "We just need a little period of normalcy". Because the halt is supposedly temporary, the apparent failure doesn't have to be recognized or addressed.
- **Fruition**
  - Confident, optimistic and energized
  - Stop and acknowledge the people and broadly share the rewards
  - Distill and assimilate the benefits and lessons learned

"Change can be exhilarating and bring about the best work of a lifetime"

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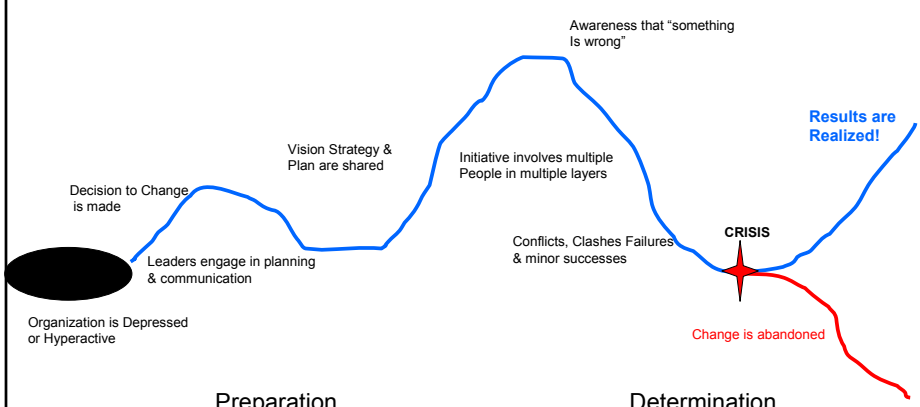
Change Curve

Lean Six Sigma

Define | Measure | Analyze | Improve | Control



"Change unfolds in a reasonably predictable and manageable series of dynamic phases, known as the Change Curve"

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The 6 Sigma Team

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Four major roles need to be filled for your project to be successful:

- Team Leader (You)
- Team Members (Subject Matter Experts [SME])
- Project Sponsor (Champion)
- MBB

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Definition of a Team

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Define | Measure | Analyze | Improve | Control

To be a team, you must have…

- Common purpose, shared goals
- Shared outcomes (risk and rewards)
- Specific roles for each member
- Interdependency (must collaborate to accomplish goals)
- Structure and rules

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What Teams Need to be Successful

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Define | Measure | Analyze | Improve | Control

- Agreement on and commitment to goals
- Clearly defined roles and accountabilities
- Good processes for getting work done
- Opportunity to learn from mistakes
- Clear understanding of what each team member needs from the others
- Commitment to the principles of equality

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Facilitation Skills

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Define | Measure | Analyze | Improve | Control

- Manage group conflict
- Create a collaborative environment for participants
- Help generate ideas
- Maintain the focus of group discussion
- Clarify and communicate meeting expectations
- Enable agreement through consensus

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Roles and Responsibilities

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Prepare

- Ensure appropriate team members are included
- Talk to subject matter experts about the purpose of the project
- Reserve meeting space
- Prepare any materials

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Roles and Responsibilities

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Conduct / Facilitate

- Develop ground rules
- Assign roles (i.e. scribe, timekeeper)
- Reiterate / clarify purpose of event
- Ensure group maintains focus
- At the conclusion of the event, review outcomes and get agreement
- Record action items

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DACI Chart

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

D = Driver – *The person who is responsible for the action/task.*

A = Approver – *Process owner: Responsible for area impacted by project.*

C = Contributor – *Who should be consulted regarding changes in the process.*

I = Informed – *The person(s) who is informed after performing the action/task.*

Step	Action/Task	Driver	Approver	Contributor	Informed
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

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Team Roles and Responsibilities

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

	Before Project	During Project	After Project
Team Leader	• Review draft Charter with Sponsors • Develop Charter further • Help Select Team Members	•Manage schedules •Lead meetings •Coordinate communication •Liaison between coach, sponsor(s), and stakeholders •Keep records •Do team's work	•Ensure that documents are completed and lessons captured •Monitor implementation (if appropriate) •Use improved methods
Team Members	• Assist with team definition and recruiting	•Participate in meetings •Complete assignments •Help with team tasks and logistics •Contribute knowledge and expertise •Learn necessary methods and acquire needed skills	•Use improved methods

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Team Roles and Responsibilities

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

	Before Project	During Project	After Project
MBB	• Assist Team Leader • Help develop Charter	•Provide expert guidance and coaching on skills and methods •Help team gather and interpret data •Help prepare for sponsor reviews	•Provide guidance as needed
Process Owner	•Reviews draft Charter with Sponsor	•Approve Tollgates •Contribute knowledge and expertise	•Use improved methods
Sponsor (guidance team)	•Identify goals •Select Team Leader and Members •Assign coach •Approve Draft Charter	•Provide direction and guidance •Review team progress •Run interference •Control budget	•Provide ongoing support for implementation •Ensure monitoring •Preserve lessons learned

Project Sponsor may not always be the process owner.

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Team Member Selection

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Work with your project Champion and/or process Stakeholder(s) to determine team composition
  - What departments will need to be represented?
  - How many ?
- Review your team composition with your MBB

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Before the Project

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Hold a “Pre-Meeting" to verify a common understanding and agreement on project scope
- Ensure Champion and Process Owner (s) participate
- Documented agreement in a "Project Charter"

Charter	
Problem Statement:	DIA lacks a standardized process to allocate space within the NCR
Business Case:	• Using LSS to standardized space allocation will produce: – Mission-driven allocation – Equitable distribution of space – Reduce missing or conflicting information • Satisfies DA objective 1.1.2 “Implement new processes for allocating and reviewing space requirements to effectively manage DIA space challenges”
Customer Specs:	A consistent, transparent, equitable, and future-oriented space allocation process
Scope:	Space requirements for all DIA employees (Gov/Mil/CNTR) in the NCR
Start:	Space requirement identified
Stop:	Space requirement satisfied
Unit:	Individual space requirement
Defect:	Process variation

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The Meeting Process

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Plan Meeting → **Conduct Meeting** → **Follow Up**

- Distribute agenda
- Determine objectives
- Plan the process
- Define roles/ responsibilities
- Set time/location

- Start on time
- Set ground rules
- Follow the agenda
- Ensure all contribute
- Assign accountability
- Determine timetables
- Discuss concerns
- Summarize due outs
- End on time

- Debrief
- Publish minutes
- Next steps
- Include benefits & concerns in next meeting

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Plan the Meeting

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Select appropriate time and location to maximize participation
- Prepare and distribute agenda beforehand
- Create an environment that ensures success
- Agreement on how team members will work and interact with one another

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Conduct the Meeting

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Define | Measure | Analyze | Improve | Control

1. Team leader reviews progress towards goals
2. Team identifies, analyzes, and solves problems
3. Team records action items
   - Including who is responsible and when the task should be complete
4. Team provides input for the next meeting's agenda
5. Meeting minutes are recorded

TIPS
All ideas are valuable
Generate first
Evaluate second
"Build" on others ideas
Be open
One person at a time

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Guidelines for Achieving Consensus

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Involve everyone in the discussion
- Explore alternative choices
- Listen to others
- Identify actual problems, not symptoms
- Be wary of quick solutions
- Encourage differences to help clarify issues
- Do not compete
- Allocate time carefully
- Strive for the best answer
- Avoid conflict reducing techniques (e.g., majority vote, averaging, coin flip, etc.)
- Yield only to positions that have objective and sound foundations

Consensus helps a decision survive!

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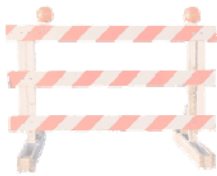
Meeting Follow-up

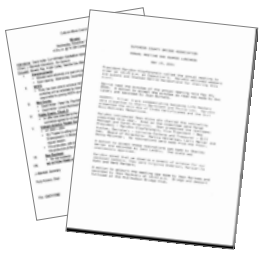
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Discuss roadblocks and barriers



- Distribute the meeting minutes as soon as possible after the meeting to:
  - Managers
  - Supervisors
  - Other interested parties



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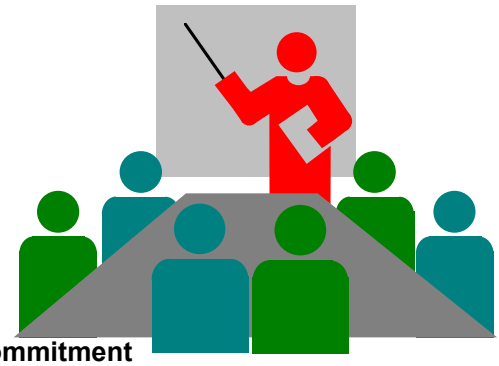
First Meetings

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Team building

- Intros
- Ice Breakers
- Ground rules
  - Attendance
  - Promptness
  - Participation
  - Chores
  - Breaks
  - Work assignments
- Expected level of commitment



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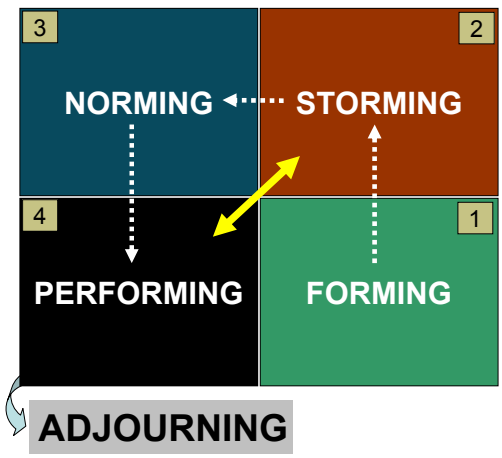
Stages of Team Growth

Lean Six Sigma

Define | Measure | Analyze | Improve | Control



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Verbal Communication

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Verbal communication is frequently abused in meetings and team environments.

- *What are some examples of negative verbal communication?*
- *What effect can negative verbal communication have on a team?*
- *What are some examples of positive verbal communication?*

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Non-Verbal Communication

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

It's important to observe your body language (non-verbal communication) for the impact it has on the team.

The team members will tend to read your body language, interpret it, and react to it.

Positive cues

- Eye contact (positive interest)
- Smiling (encouragement)
- Leaning forward (positive interest)
- Nodding yes (Agreement)

Negative cues

- Evasive glances (discomfort)
- Slouching (disinterest)
- Shaking head no (disagreement)

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Overcoming Roadblocks - Influence

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Influence

Use of personal energy to change an outcome or make an impact on a situation

- I can't get the data I need!
- *My team is stalled!*
- The process owner wants to steer us in another direction!
- *Nobody will make a decision!*

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Position vs. Interest

Lean Six Sigma

Define

Position…

We don't have the $$$ to make that change

I can't get the data you're requesting

… vs. Interest

I'm afraid to make the change – something might go wrong

If someone starts investigating my process, I could lose billets

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ID and Address the Interest

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

First try to discover the *interest*

Might be different from position

Second, use your *influence* to deal with the *interest*

Influence styles
Involvement
Negotiation
Persuasion
Appealing
Dictating

Social Power
Reward – you can provide something
Coercive – you can punish
Legitimate – you have authority
Expert – you're the acknowledged SME
Informational – you have desired info
Reverent – charisma, natural leadership

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Case Study 1

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

It's the first day of your project and one of your key team members, Sally, has hardly spoken a word. She sits silently, with her arms crossed and won't make eye contact. You are depending on her expertise and need her ideas.

As the facilitator, what can you do to encourage her participation?

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Case Study 2

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Team member, Ben, has been a valuable asset. He's always the first to volunteer and speaks up at every opportunity, but doesn't listen to others' ideas. He sometimes speaks forcefully in an attempt to exert control and even takes the lead on group activities without being asked.

How can you ensure a good team process and team member involvement?

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Case Study 3

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Things were going smoothly until the team began the process map of the current state. Now they're jumping to solutions and the group is disintegrating into smaller sub-teams with no focus for the work.

What needs to be done to get the team back on track?

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Case Study 4

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

It's day three and tension is high. Lou and Robin are not listening to each other. Both are frustrated and the unproductive debates have led to sarcasm and personal attacks. The other team members are hopeful that you, the Green Belt, can help the group come to a consensus and implement a strategy.

How can you get this team to commit and take ownership?

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Define Phase Review Questions

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Have you defined the problem to be addressed by the project?
- Who is the customer (internal or external)?
- What is the expected process impact?
- When do you expect to complete the project?
- Does this project have applications in other areas?

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Define Phase Review Questions

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Have you completed the Problem Statement?
- Have you selected a project team?
- Is your Project Charter complete?
- Have you consulted with your Master Black Belt?
- Use Tollgate to determine next steps

Based on your answers… what do you think your next steps will be for completing the Define Phase of the DMAIC process?

?

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Lean Six Sigma

Define | Measure | Analyze | Improve | Control

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Lean Six Sigma

Measure

Define

Measure

Analyze

Improve

Control

Measure

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Data Collection

Lean Six Sigma

Measure

- Critical to validity of conclusions
- Generally not readily available or accessible
- Often not in a user-friendly format
- Forms the foundation for your project!

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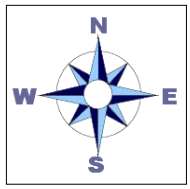
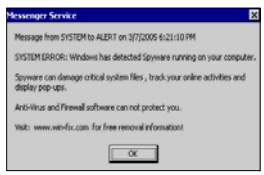
Things We Measure

Lean Six Sigma

Measure

- Throughput
- Customer
- Time of Day
- Employee
- Location
- Size
- Cycle Time
- Schedule Attainment
- Waste or Spoilage
- Cost
- Number of employees
- Proportion defective
- Number of errors





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Types of Data

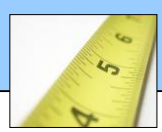
Lean Six Sigma

Measure

Quantitative

Numeric in nature
Expressed as
AMOUNT of something

- Time
- Distance
- Money



Qualitative

Non-Numeric by nature
Expressed as a CATEGORY

- Pass/Fail
- Type of Department
- Name of Branch

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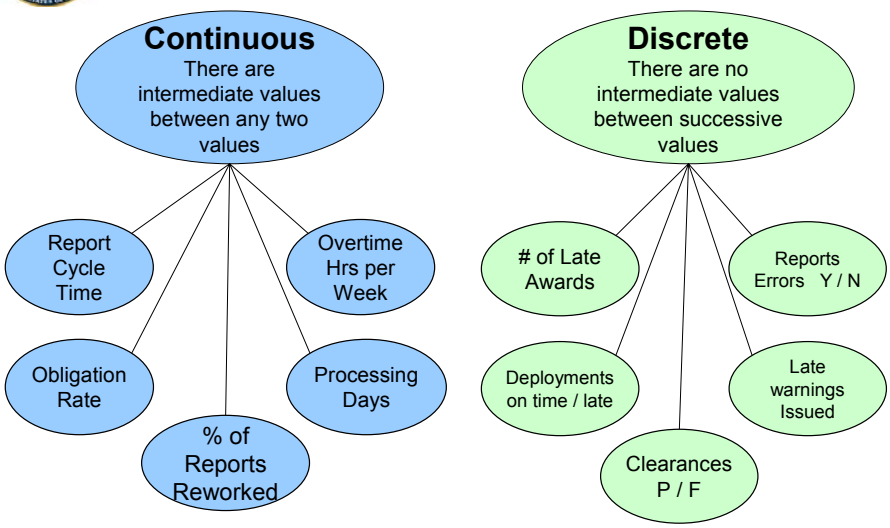
Examples of Types of Measurement

Lean Six Sigma

Measure



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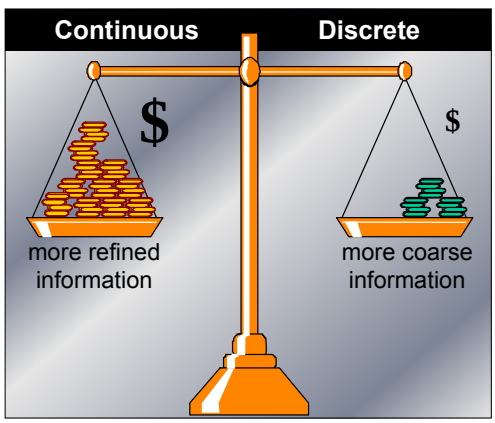
Continuous vs. Discrete

Lean Six Sigma

Measure

Which is a better metric… continuous or discrete?

- Depends on the problem!
- Often you will not have a choice. Your process dictates the type of measure you will have
- If a continuous metric is feasible… it is preferred



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Types of Measurements

Lean Six Sigma

Measure

Data	Type
Lateness of Delivery	*Continuous*
Defective Weapons Parts	*Discrete*
Overdue Shipments	*Discrete*
Pounds of MREs Shipped	*Continuous*
Tons of Body Armor	*Continuous*
Equipment Breakdowns	*Discrete*
Production Cycle Time	*Continuous*
Lost Customers	*Discrete*
Errors on Reports	*Discrete*
Changes to Plan	*Discrete*
% Rework	*Continuous*

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Pop Quiz

Lean Six Sigma

Measure

- List the categories below by the measure type :

	Data Characteristic	Measure Type	
		Continuous	Discrete
1	Student's grade in a class		
2	Time to Get to Work		
3	Today's Temperature		
4	Automobile Type		
5	Gender		
6	Age		
7	Cycle Time		
8	Pass Fail		
9	# of People on a Bus		
10	Quality Inspection		

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Cycle Time

Lean Six Sigma

Measure

- The actual time needed to complete a step and move on to the next step in the process

B

Package arrives at Step A at 8 am.

Package arrives at Step B at 9 am.

Cycle Time = 1 hour

Caution: Operationally define start and stop times BEFORE collecting data!

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Defectives & Defects

Lean Six Sigma

Measure

- A defective unit is that which fails to meet customer requirements or standards
  - Late order, incorrect invoice, short-count, etc.
- A defect is any reason for such a failure
  - Not filed correctly, incorrect line item, transposed numbers, etc.
- A defective unit can have more than one defect

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Defects Per Unit (DPU)

Lean Six Sigma

Measure

- Defects Per Unit (DPU) – the average number of defects, of all types, over the total number of units produced
  - Unit is the item being processed
    - (order, invoice, form, plate, etc.)

$$\text{DPU} = \frac{\text{Total Number Defects}}{\text{Total Number Units Processed}}$$

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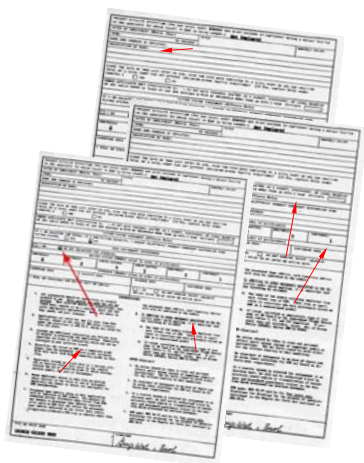
DPU Example

Lean Six Sigma

Measure

- In one month, 220 reports were sampled after being sent to customers
- Among the 220 reports, 344 line items were found incorrect (defects)

Unit = Report
DPU = 344 incorrect line items / 220 Reports
= 1.56



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How Many Samples do I Need?

Lean Six Sigma

Measure

- Depends on 4 factors:
  - The type of data (discrete or continuous)
  - The objective of the sampling process
    - Describe a characteristic for a whole group (mean or proportion), within a certain confidence interval (+- ___units)
    - Compare a group of characteristics (find difference between group means or proportions; at what power – the probability of detecting a certain difference)
  - What estimate of σ will be
  - How confident you want to be when you state your conclusion about the overall performance

There is typically a trade-off between:

- **Accuracy**
- **Cost**
- **Sample Size**

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Sampling

Lean Six Sigma

Measure

- **Sampling**
  - That part of statistical practice concerned with the selection of individual observations
  - Intended to yield knowledge about a population for the purpose of statistical inference
- **The sampling process consists of** :
  - Definition of population of concern
  - Specification of a sample frame
    - …a set of items or events that can be measured
  - Specification of sampling method for selecting items or events from the frame
  - Determine the sample size
  - Implement the sampling plan
  - Sampling and data collecting
  - Review of sampling process

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Sample Plans

Lean Six Sigma

Measure

It is not always possible or feasible to gather and analyze 100% of the data from a process

- The purpose of a sample:
  - To gain the ability to draw statistical conclusions about the population of data
- A Sample Plan:
  - The process by which the Sample will be obtained
- Determining the correct MINIMUM sample size is a very important issue.
  - Samples that are too large may waste time, resources, and money
  - Samples that are too small may lead to inaccurate results

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Population vs. Sample

Lean Six Sigma

Measure

Population

- An entire group of objects containing a characteristic of interest
- Highly unlikely we can ever know the true population parameters
  - The average days to bill all customers
  - All registered voters in the U.S.

Sample

- A sample is usually a subset of the population of interest
- The group of objects actually measured in a statistical study
  - The average days to bill customers this year
  - A survey of 1,000 voters

"Population Parameters" (Greek Symbol)

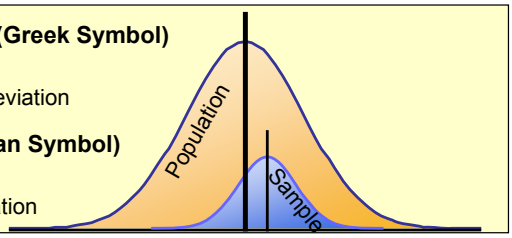
μ = Population mean

σ = Population standard deviation

"Sample Statistics" (Roman Symbol)

$\bar{X}$ = Sample mean

s = Sample standard deviation



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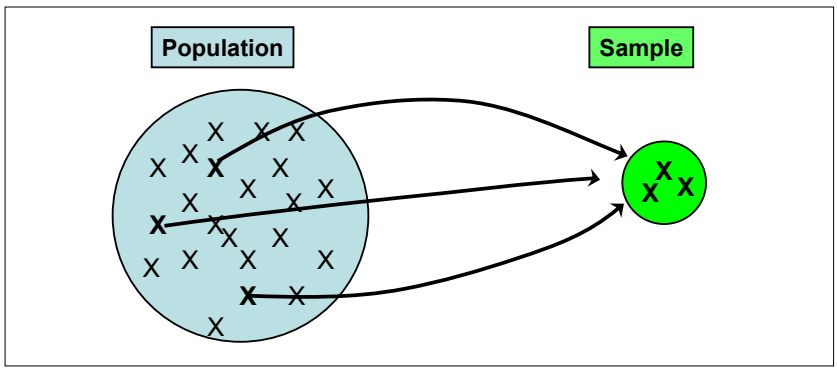
Sampling

Lean Six Sigma

Measure

- Collecting only enough individual data points from a process to determine the sources of variation
- A fast, low cost way to describe a process



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When Sampling Works

Lean Six Sigma

Measure

Random… Each unit/transaction has an equal likelihood of being selected

Independent… Selecting one unit/transaction does not influence the likelihood of another unit/transaction being selected

No Bias… There are no significant differences between those selected and those that are not

Frequency… Your sample is large enough to see what you are looking for

NOTE: If what you are looking for is *rare* or you want to be very precise, you will need a very LARGE sample

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Sampling Plans

Lean Six Sigma

Measure

- A Sampling Plan is a method of inspecting a prescribed portion of the production run.
- Quality cannot be inspected into a product; it must be produced that way.
- The Sample Inspection Process is used for:
  - Obtaining an estimate of how good, or bad, the rest of the run might be.
  - Ensuring that production quality guidelines and specifications are followed.
  - Determining inspection criteria whether a product should be shipped or not.
  - Determining incoming material inspection criteria for accepting or rejecting shipments
  - Providing an estimate of performance

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Sampling Plans

Lean Six Sigma

Measure

- For conclusions to be valid, samples must:
  - Be representative of the whole
  - Consider what groups to sample, and the proportion of each group
  - Consider when to sample
  - Consider where to sample
- Sampling Approaches
  - Random Sampling – Each unit has the same chance of being selected
  - Stratified Random Sampling – Randomly sample a proportionate number from each group
  - Systematic Sampling – Sample every n^{th} one, (i.e every 3rd)
  - Subgroup Sampling – Sample n units every n^{th} time (i.e. 3 units every hr) Then calculate the mean of each subgroup

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Examples of Sampling Plans

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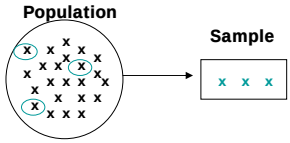
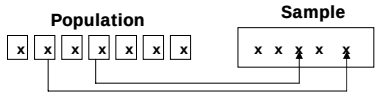
Measure

Random Sampling

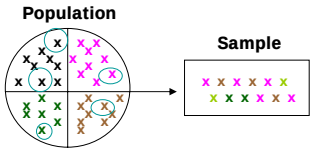


Systematic Sampling

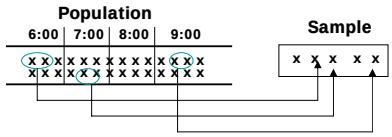


Preserve Time Order!

Stratified Random Sampling



Subgroup Sampling



Preserve Time Order!

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Mitigating the Risk of Sampling

Lean Six Sigma

Measure

- Risk of making a wrong decision
  - Decrease risk, Increase Sample
- Variation in measurements
  - Larger variation, Increase Sample
- Difference to be detected
  - Difference decreases, Increase Sample
- Consider cost, practicality, representation

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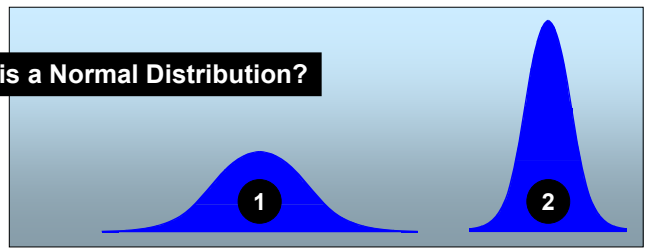
Normal Distributions

Lean Six Sigma

Measure

- Normal Distributions are a family of distributions
  - They are symmetric, with data points concentrated more in the center than in the tails.
- Normal Distributions are defined by two parameters
  - Mean
  - Standard Deviation

Which is a Normal Distribution?



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Empirical Rule for Normally Distributed Data

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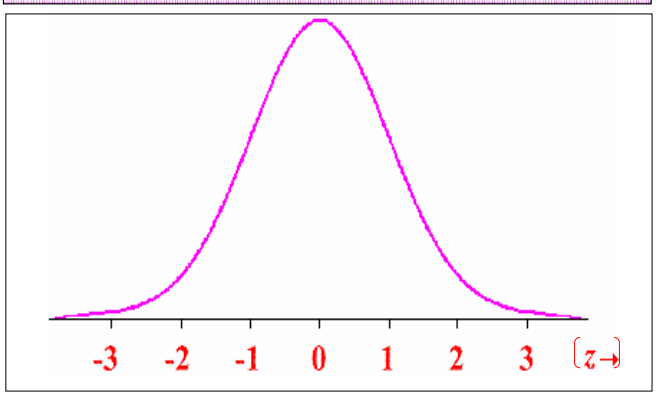
Measure

The means of samples from a population will tend to be normally distributed around the population mean

Central Limit Theorem



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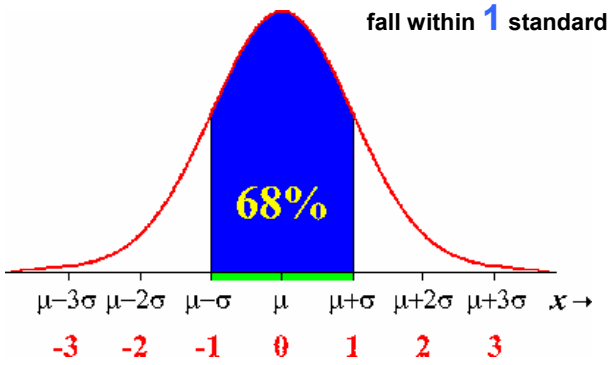
Empirical Rule for Normally Distributed Data

Lean Six Sigma

Measure

Approximately **68%** of the observations fall within **1** standard deviation of the mean



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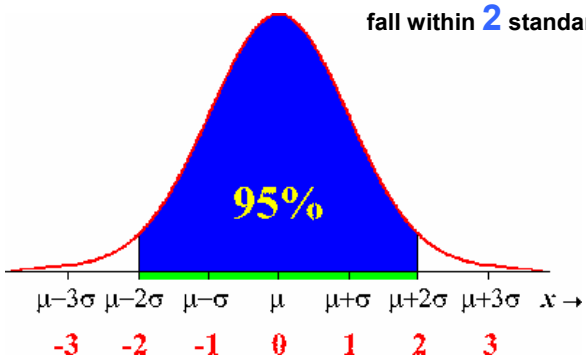
Empirical Rule for Normally Distributed Data

Lean Six Sigma

Measure

Approximately **95%** of the observations fall within **2** standard deviations of the mean



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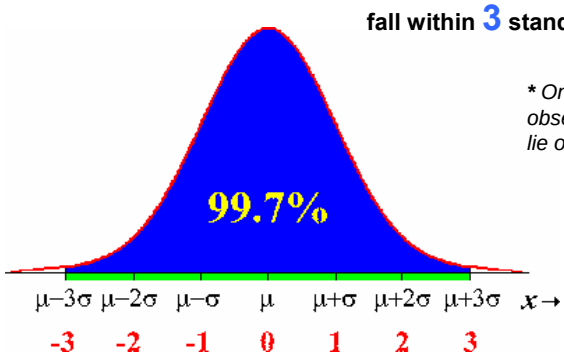
Empirical Rule for Normally Distributed Data

Lean Six Sigma

Measure

Approximately 99.7% of the observations fall within 3 standard deviations of the mean

** Only a small fraction of observations (1 out of 333 or 0.3%) lie outside this range*



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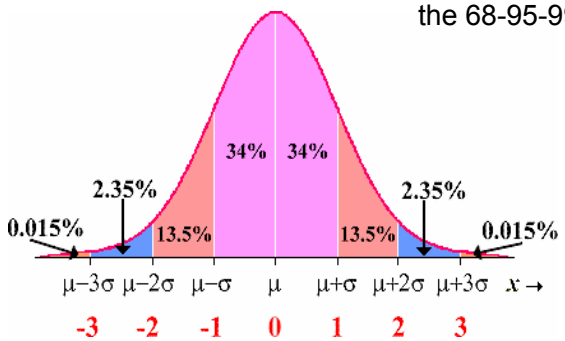
Empirical Rule for Normally Distributed Data

Lean Six Sigma

Measure

- Another way of looking at it
- This is merely a consequence of the 68-95-99.7 rule



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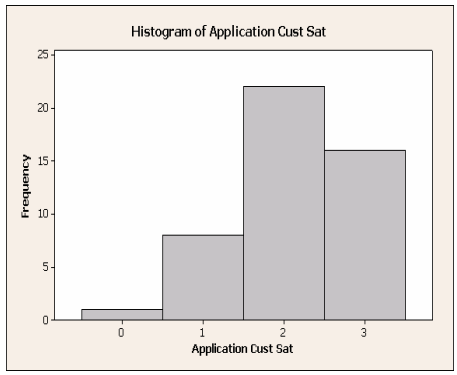
Issues of Non-Normality

Lean Six Sigma

Measure

- **Non-normal data**
- **Tests for normality**
  - **Minitab, graphical/visual**
- **Impact: statistical tests may provide less valid results**
  - **May be improved by collecting more data**
  - **Must consider costs of data collection**



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Describing Variation

Lean Six Sigma

Measure

Test Scores
99
95
92
88
83
76
65
55
55
54
53
41
40
39
33

Mean or Average
Tells you where the center point of the process is located

Median
Tells you where the center point of the data is located

Range
The distance between the highest and the lowest points (Indicates spread)

Standard Deviation
A more descriptive measure of spread

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Mean

Lean Six Sigma

Measure

Test Scores
99
+ 95
+ 92
+ 88
+ 83
+ 76
+ 65
+ 55
+ 55
+ 54
+ 53
+ 41
+ 40
+ 39
+ 33
=968

$$\text{Mean} = \frac{\text{Sum of all data points}}{\text{Number of data points}}$$

- Indicates location of process
- Reflects all the data values
- Influenced by extreme values
- Also known as "Average"

$$\frac{968}{15} = 64.5$$

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Median

Lean Six Sigma

Measure

Test Scores
99
95
92
88
83
76
65
55
55
54
53
41
40
39
33

- The center number after the data has been sorted in *ascending* order
  - If even number of data points, the Median is the *average* of the two middle data points
- The 50% rank of the data
- Indicates the location of the data
- Does not use all values in the calculation
- "Robust" to extreme values

Median

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Range

Lean Six Sigma

Measure

Test Scores
99
95
92
88
83
76
65
55
55
54
53
41
40
39
33

Range = Highest Value — Lowest Value

- The distance between the extreme values in the data
- Only uses two data points

99 – 33 = 66

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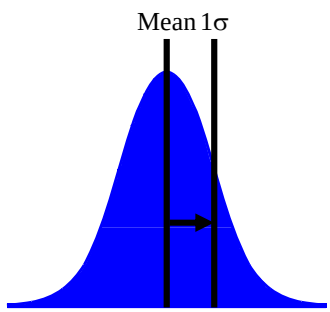
Standard Deviation

Lean Six Sigma

Measure

- A more descriptive measure of spread than range
- Takes into account the difference of each data point from the mean
- Uses all the data
- Smaller is better

$$\sigma \approx s = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}{n-1}}$$



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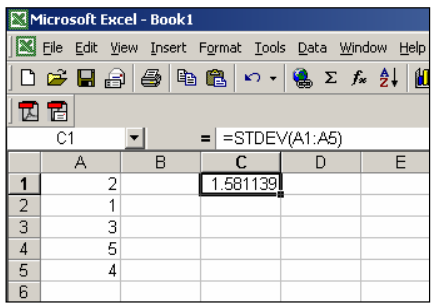
Standard Deviation Calculation

Lean Six Sigma

Measure

	X	$X-\bar{X}$	$(X-\bar{X})^2$
1	2	-1	1
2	1	-2	4
3	3	0	0
4	5	2	4
5	4	1	1
Sum	15		10
Mean	3		
Median	3		
σ			1.58



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Exercise: Catapult

Lean Six Sigma

Measure

- Each person in team fires the catapult 5 times
- Measure performance by:
  - total length of flight
  - Distance of landing from center line
- Record the data:
  - Using handout
  - Bombardier (Name)

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Exercise: Catapult

Lean Six Sigma

Measure

Group #	Name			
Test Firing				
Distance 1				
Distance from Center 1				
Distance 2				
Distance from Center 2				
Distance 3				
Distance from Center 3				
Distance 4				
Distance from Center 4				
Distance 5				
Distance from Center 5				
Total				
Mean/Average				
Median				
Sigma				

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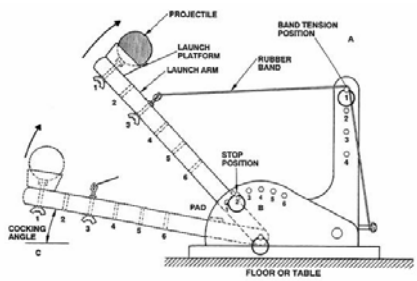
Exercise: Catapult

Lean Six Sigma

Measure

- What did you learn from firing the catapult?
- Can you draw any conclusions?
  - Are your conclusions proven or speculation?
- What would you suggest as the next step in the process?



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Data

Lean Six Sigma

Measure

- Think about your project:
  - Do you know if data already exists?
  - If it does, what do you know about it?
  - Is it any good?
  - Can you trust it?
  - How was it collected?
  - Is there an SOP for collecting the data?
  - What is the training level of the persons collecting the data?
  - If equipment is used, what is the integrity of the collection process?

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Data Integrity

Lean Six Sigma

Measure

Thorough data collection and validation can be tedious,
but the consequences of not doing it right
are invalid conclusions, wasted time, wasted money, and
inefficient use of resources.

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Total Variation

Lean Six Sigma

Measure

Total Variation

Due to the way the <u>process</u> works

Due to the way we <u>measure</u> our process

Total Variation = Process Variation + Measurement Variation

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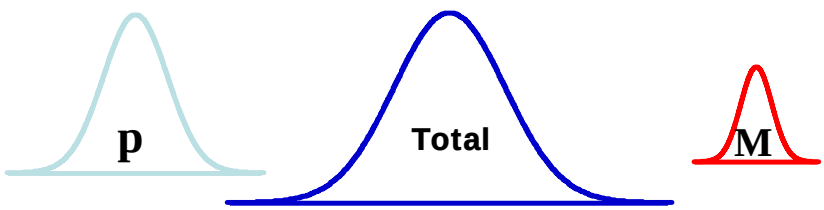
Total Variation

Lean Six Sigma

Measure

Process Variation | **Total Process Variation** | **Measurement Error**



$$\sigma^2_{total} = \sigma^2_p + \sigma^2_M$$

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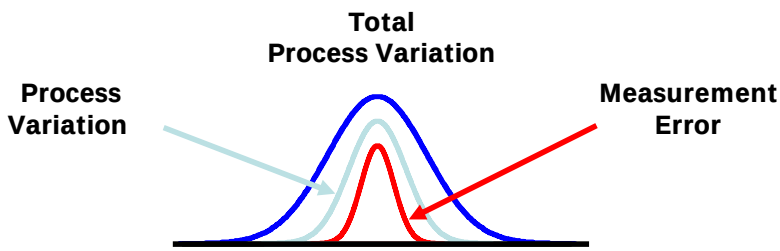
Total Variation

Lean Six Sigma

Measure

- **If a significant portion of the variation in your process is a result of the data collection process, what might your first step be?**



$$\sigma^2_{total} = \sigma^2_p + \sigma^2_M$$

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Reasons for Measurement Variation

Lean Six Sigma

Measure

- Data Unavailable, Gaps in Collection
- Recording/Judgement Errors
- Keying Errors
- Legibility Errors
- Undefined and/or Poor Instruction
- Poorly Designed Forms

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Measurement System Analysis

Lean Six Sigma

Measure

- Measurement System Analysis, aka "MSA"
- MiniTab refers to MSA as a **Gage R&R**
- Gage R&R studies are used to:
  - Determine the capability of the measurement system across the range of process output
  - Assess repeatability, or whether the same operator (or measurement system) can achieve the same measure multiple times
  - Assess reproducibility… or whether two different operators (or measurement systems) get the same answer when measuring the same sample

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Gage R&R (MSA)

Lean Six Sigma

Measure

Continuous Data

- Components
  - Discrimination
  - Accuracy
  - Repeatability
  - Bias Effects
  - Stability

Discrete Data

- Components
  - Uniformity
  - Effectiveness
  - Bias
  - Miss
  - False Alarm

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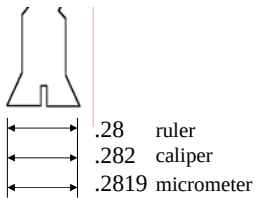
Gage R&R: Continuous Data

Lean Six Sigma

Measure

- Discrimination: The technological ability of the measurement system to adequately differentiate between values of a measured parameter

1.0 pounds
1.09 pounds
1.1 pounds



- A poor performing Gage may give you different readings each time you measure the same object

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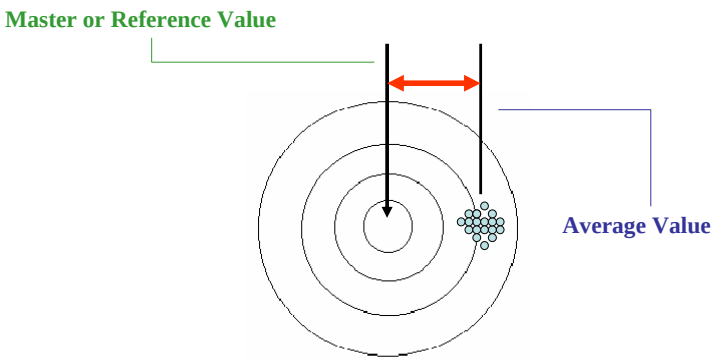
Gage R&R: Continuous Data

Lean Six Sigma

Measure

- Accuracy: The difference between the observed average value of the measurements and the master value



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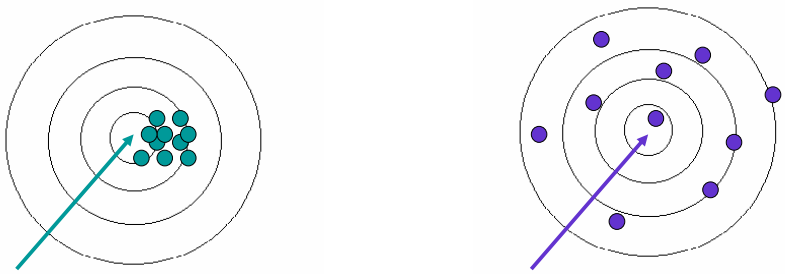
Repeatability

Lean Six Sigma

Measure

- **Repeatability: the variation between successive measurements of the same part preformed:**
  - **with the same gauge**
  - **by the same person**
  - **doing it the same way (an estimation of short term variation)**



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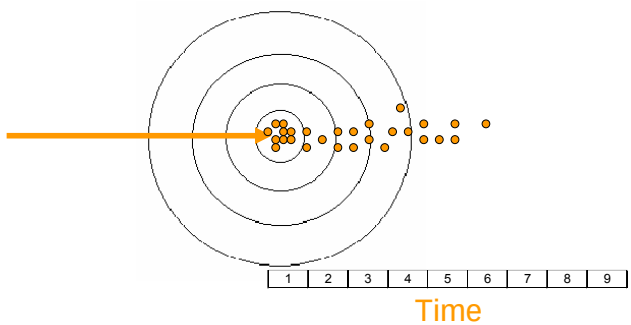
Stability

Lean Six Sigma

Measure

- **Stability:** (or drift) is the total variation in the measurement system on the same part when measuring the same characteristic over an extended period of time



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Gage R&R: Continuous Data

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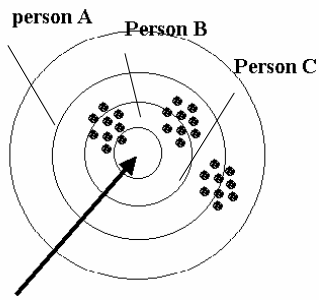
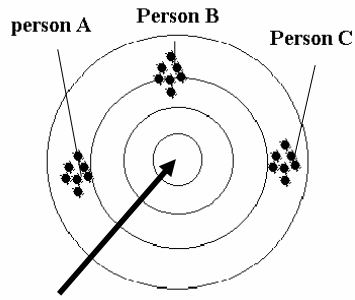
Measure

- Reproducibility: The difference in the average of the measurements made by different people using the same or different gauge but measuring the same characteristic





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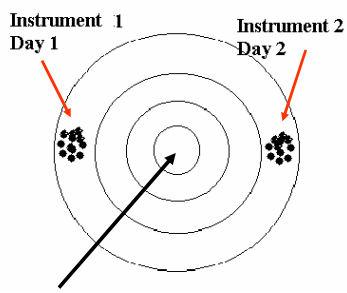
Gage R&R: Continuous Data

Lean Six Sigma

Measure

- Reproducibility
- The average measurements are different by fixed amounts from the reference value
- Bias effects include
  - Operator bias (operators look at the same image and draw a different conclusion)
  - Machine bias (detection sensitivity may be set differently for detection of the same trigger)



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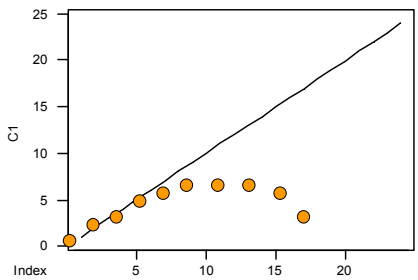
Linearity

Lean Six Sigma

Measure

- **Linearity:** the consistent ratio of output (measurement) to input (measured quantity) through the expected operating range of the gauge



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Gage R&R: Discrete Data

Lean Six Sigma

Measure

- **Uniformity** refers to the overall agreement within and among operators. This is similar to the repeatability (within operator) and reproducibility (between operators) aspects of a variable measurement gage
- **Effectiveness** (E) is the operators ability to detect good and bad units
- **Miss** occurs when a bad unit is accepted as good
- **False Alarm** means a good unit is rejected

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What do you know about the Measurement Process?

Lean Six Sigma

Measure

- Written inspection/measurement procedure?
- Do the measurement points show up on the process map?
- What is the training level of the operators?
- Do our measurements correlate to other known sources?
- Are there measurement specifications?
- Is there a gauge?
- Does the gauge being used meet the needs of the process?

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Process

Lean Six Sigma

Measure

- Think about your project:
  - Do you know what your process looks like?
  - Do you know if data already exists?
  - If it does, where is it being collected?
  - If there is no data, where should you collect it?
  - How do you determine the correct location(s) for data collection/process measures?

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Process Map or Flowchart

Lean Six Sigma

Measure

- A Pictorial Representation of a Process
  - Identifies Inputs (X) and Outputs (Y)
  - Identifies Current Data Collection Points
  - Categorizes Inputs (X)
- Defines Process Boundaries
  - Identifies customers and suppliers
- Points out discrepancies in the process
- Points out inefficiencies in the process
  - Determines Value-Added and Non-Value-Added Steps
- Initiates standardization of procedures

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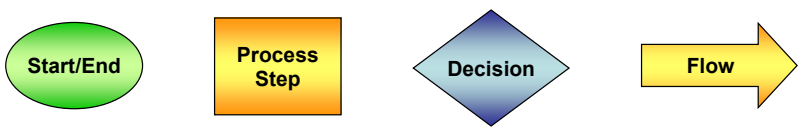
Process Map Procedure

Lean Six Sigma

Measure

- Symbols to know:



- Determine the start and finish of the process you are charting
- Define how the process actually works, step by step, in detail
- Use observation, recorders, etc.
- Add inputs and outputs

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High-Level Process Map

Lean Six Sigma

Measure

- 50,000 foot view of the process
- Identifies customers and suppliers
- Identifies products and / or services of the process
- Identifies Key Measures

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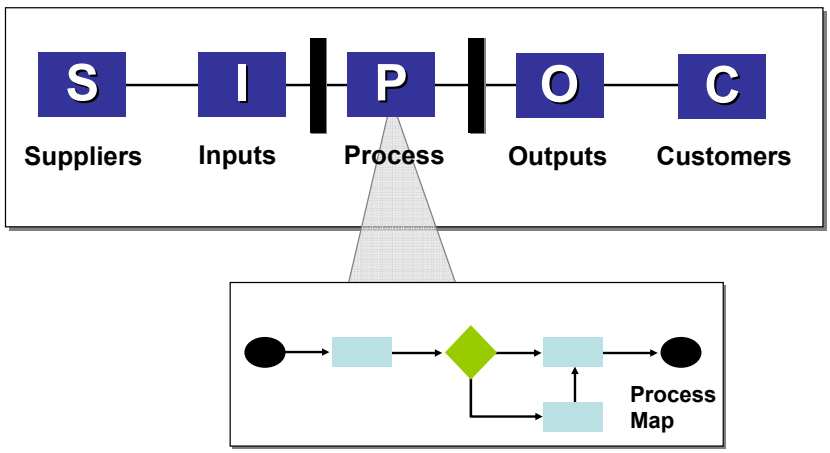
SIPOC

Lean Six Sigma

Measure

SIPOC: The starting point for any process map



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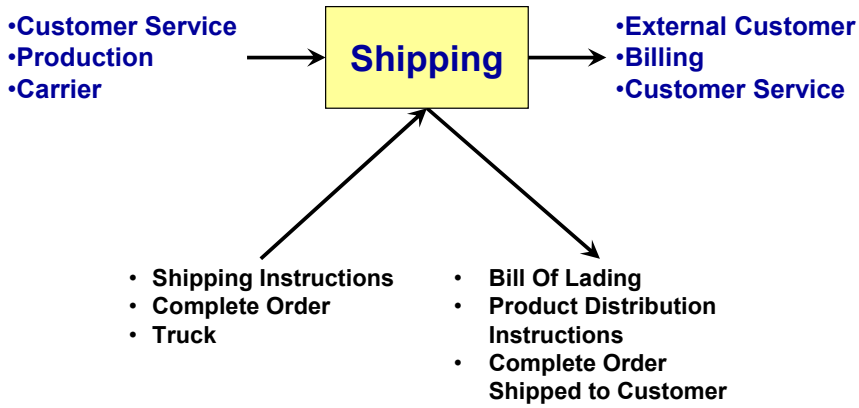
Example High-Level Process Map

Lean Six Sigma

Measure



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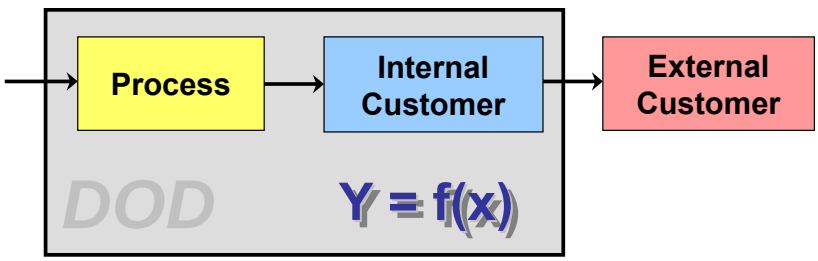
Who is the Customer?

Lean Six Sigma

Measure

- Customers are recipients of products and/or services
  - Internal Customers use our outputs for their processes.
  - External Customers pay our bills



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Who is the Supplier?

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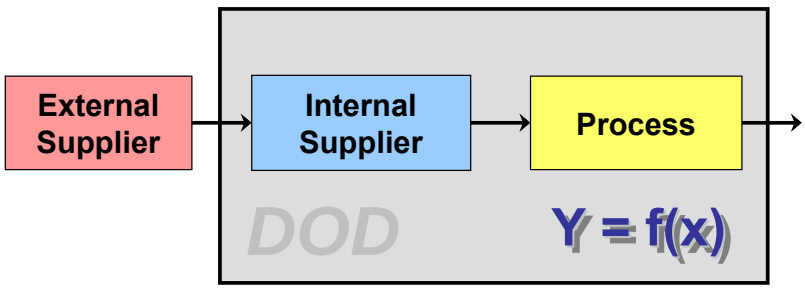
Measure

- Suppliers provide products and/or services
  - Outputs of “internal suppliers” are inputs to our process
  - We pay “external suppliers”



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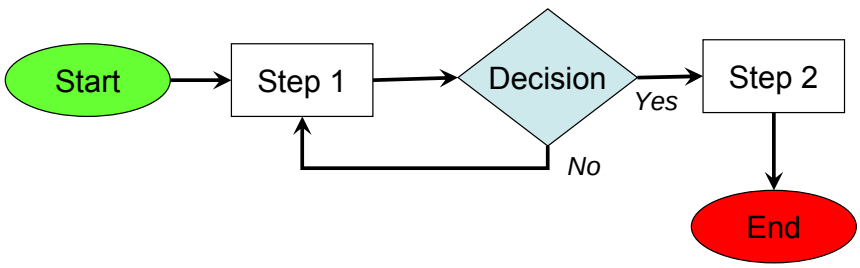
Simple Process Map

Lean Six Sigma

Measure

- Describes the high-level steps followed day in and day out



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Process Map

Lean Six Sigma

Measure

- Process mapping is a technique to make work visible
  - A pictorial representation of a process
- A process map shows:
  - The sequence of events
  - Where decisions are made
  - Who is doing what
    - with whom
      - when
        - for how long
  - Wait times or delays inherent to the process

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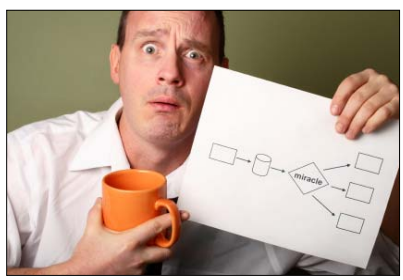
Process Map

Lean Six Sigma

Measure

- There probably has never been a process map developed where someone has not said:
  - "Do we still do that?"
  - "Why does X happen there?"
  - "Why do we do it that way?"
  - "I did not realize...."
- Identify opportunities to
  - Reduce cycle time
  - Avoid rework
  - Eliminate inspection steps
  - Prevent errors



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How to Analyze a Process Map

Lean Six Sigma

Measure

- Look at each process step for:
  - Errors being fixed instead of prevented (rework)
  - Role ambiguity (we didn't know who...) Bottlenecks
  - Sources of delay
  - Duplications
  - Unnecessary steps
  - Cycle time

- Look at each decision point for:
  - Sequence (are the decisions needed at this point?)
  - Authority ambiguity (two or more people get to decide...)

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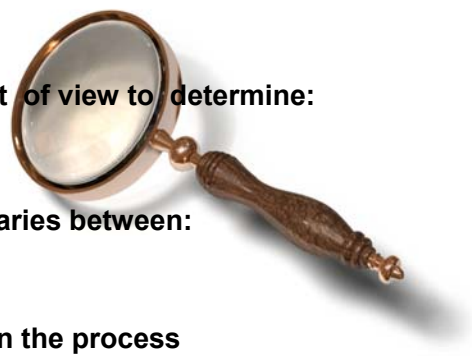
How to Analyze a Process Map

Lean Six Sigma

Measure

- **Look at each rework loop to:**
  - Eliminate steps
  - Reduce time
  - Prevent rework
- **Use the customer's point of view to determine:**
  - Value-added
  - Non-value-added steps
- **Confirm Process Boundaries between:**
  - Customers
  - Suppliers
- **Look for discrepancies in the process**
- **Determine if procedures are standardized**



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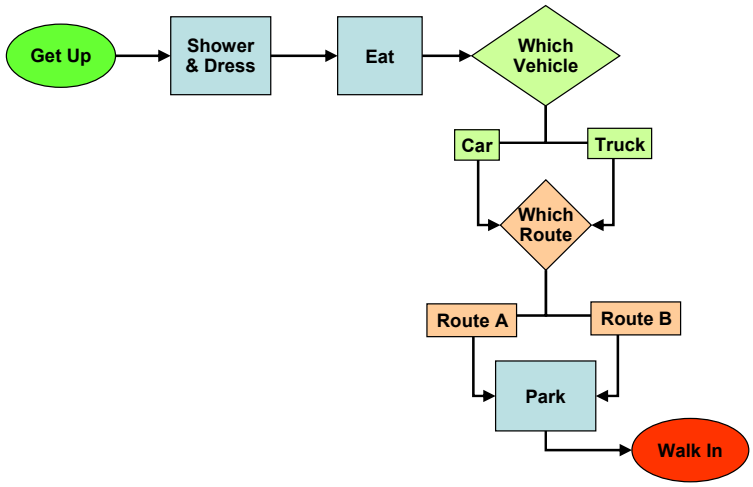
Process Map: Example

Lean Six Sigma

Measure



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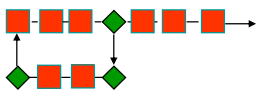
Always Keep in Mind…

Lean Six Sigma

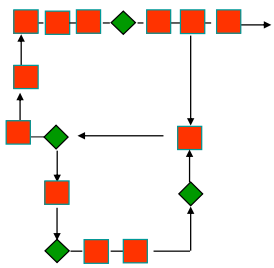
Measure

There are usually 3 versions of each Process Map

What you *Believe it is...*



What it *Actually is...*



What you *Want it to be...*

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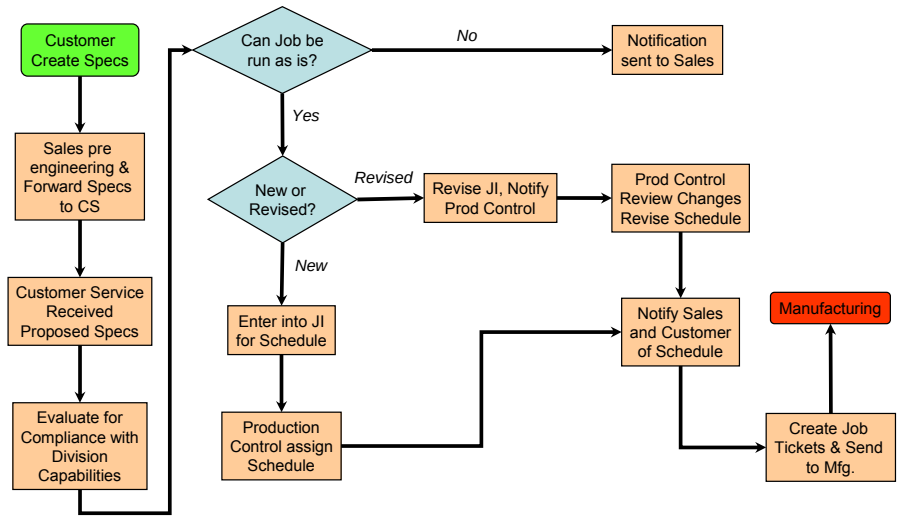
Process Map Example

Lean Six Sigma

Measure



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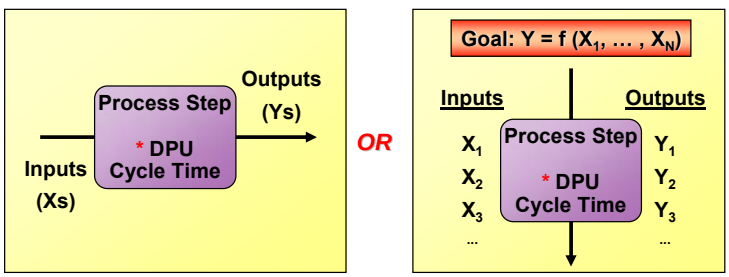
Elements of Process Improvement

Lean Six Sigma

Measure

- **X**s are the inputs that impact the ability to achieve the Ys of that process step
- **Y**s are the results of completing the process step
- A "**Y**" from one process can be an "**X**" for a later process
- Note: The DPUs of each process step are the DPUs introduced by the materials added or the processes performed at that step



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Creating a Useful Process Map

Lean Six Sigma

Measure

Step 1: At an actionable level, define the boundaries of the process you need to improve

Step 2: Identify all operations needed in the production of a product or service. At each step include:

- Cycle time
- Quality levels

Step 3: Identify each operation above as value-added or non-value-added. A value-added operation "transforms the product in a way meaningful to the customer"

Step 4: List both internal and external Ys at each process step

(continued)

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Creating a Useful Process Map

Lean Six Sigma

Measure

Step 5: List both internal and external Xs at each process step

Step 6: Classify all Xs as one or more of the following:

- Controllable (C): Inputs you can adjust or control while the process is running
  - Examples: Speed, feed rate, temperature, pressure
- Standard Operating Procedures (SOPs): Common sense things you always do because they make sense
  - Just because it is in a procedure --does not mean it is an SOP
  - Procedures can be used to specify set-points of controllable parameters
  - Examples: Cleaning, safety, loading components, setup
- Noise (N): Things you cannot control or do not want to control (too expensive or too difficult)
  - Examples: Ambient temperature, humidity, operator

(continued)

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Creating a Useful Process Map

Lean Six Sigma

Measure

Step 7: Document any known operating specification for each input and output

- What are the operational requirements of the process?
- Examples: Obligation Rate 8% per month

  EOD (End of Day) +/- 1 day

  Recon Imagery Resolution +/- 1 meter

Step 8: Clearly identify all process data collection points

- What are the DPUs of the various process steps?
- What is the Rolled Throughput Yield (RTY) of the Process?

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Example: Value-Added Analysis

Lean Six Sigma

Measure

Air Travel from NYC to Chicago

Arrive Airport 1 hr before departure	=	60 minutes
Taxi from gate to runway	=	10 minutes
Flight to from NY to Chicago	=	**121 minutes**
Taxi from runway to gate	=	10 minutes
Wait at baggage carousel	=	15 minutes
Elapsed Time	=	**216 minutes**

Value-Added = 121/216 = 56%

Non-Value-Added activity reduces speed

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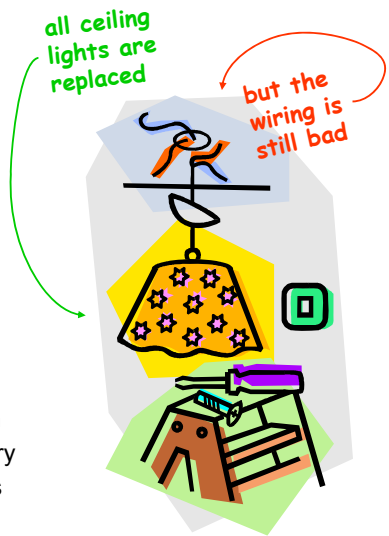
Value-Added Analysis

Lean Six Sigma

Measure

- Value-Added Steps
  - Customers are willing to pay for it
  - It physically changes the product
  - It's done right the first time
- Non-Value-Added Steps
  - Not essential to produce output
  - Does not add value to the output
  - Includes:
    - Defects, errors, omissions
    - Preparation/setup, control/inspection
    - Overproduction, processing, inventory
    - Transporting, motion, waiting, delays



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Process Map: Red Flags (1 of 4)

Lean Six Sigma

Measure

- **Assumptions**
  - Challenge all assumptions
  - It's easy to forget that a process step was based on assumptions and not fact
- **Changes**
  - Changes made to be creative or for some other reason that are NOT linked to the business plan or a business need
- **Flexibility**
  - Can the process respond to changes in customer/technology requirements?
- **Duplication**
  - Duplicate data entry
  - Duplication of efforts/steps in another group

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Process Map: Red Flags (2 of 4)

Lean Six Sigma

Measure

- **Forgot how or too complex**
  - Mistakes due to a complex procedure or because people forgot what to do
  - Consider job aids: list, check-sheet, flowchart, picture
- **Intermediaries**
  - Question "coordinate," "pass it by me first," "expedite", and "liaison" for value-added
- **Lack of consequences**
  - No consequence or negative feedback for not following standards

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Process Map: Red Flags (3 of 4)

Lean Six Sigma

Measure

- **Quality control**
  - Prevention instead of detection is the desired process
  - Can the work be mistake-proofed to make it impossible for the defect to be passed on?
  - QC of work when the "supplier" could have delivered 100% QC input
  - Is the QC check really needed? What is the defect rate?
- **Resistance**
  - Someone saying this won't work… we tried that already… we can't make any changes
    - Be neutral. Remind all involved that process improvement is why we are here!!
  - Do they claim there is no standard because they did not agree to it?
- **Repetition**
  - Can repetitive work be automated?

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Process Map: Red Flags (4 of 4)

Lean Six Sigma

Measure

- **Scalability**
  - Is the process limited to the current workload?
  - Is it scalable to handle a larger volume of work?
- **Specifications**
  - Treat every time like the first
    - Developing specifications <u>each time</u> something is done instead of only the first time as a standard or template
- **Supplier Input**
  - Input supplier sends inaccurate/incorrect input
    - Ask if they know what to do
- **Old ways**
  - People have not or won't get trained on new tools/software
  - Old ways in new tools… lots of steps in software that just replicate the old manual process

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Value Analysis Matrix

Lean Six Sigma

Measure

- Helps clarify not only what types of waste are present in the process, but also the percentage of the overall process each non-Value-Added step adds

Process Step	1	2	3	4	5	6	7	8	9	10	Total	%Total
Time (Hours)	12	10	1	10	20	6	10	1	10	20	100	100%
Value-added			✓					✓			2	2%
Non-value-added												
Fixing errors									✓		10	10%
Prep/Set-up												
Control/Inspection						✓					6	6%
Delay	✓				✓					✓	52	52%
Transporting/Motion		✓		✓			✓				30	30%
Total											100	100%

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Example : Catapult

Lean Six Sigma

Measure

- In your group, create a process map for firing the catapult
- Make sure that you clearly define your
  - Inputs
  - Outputs
  - Data collection points
  - Equipment / suppliers
- The process for building it must be written down
- Test your process following your Process Map steps

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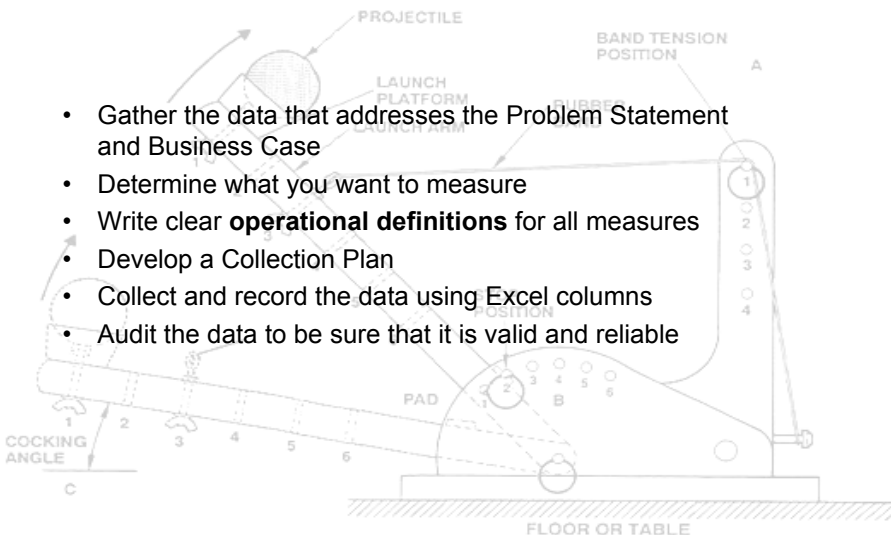
Data Collection Planning

Lean Six Sigma

Measure



- Gather the data that addresses the Problem Statement and Business Case
- Determine what you want to measure
- Write clear **operational definitions** for all measures
- Develop a Collection Plan
- Collect and record the data using Excel columns
- Audit the data to be sure that it is valid and reliable

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Check Sheet

Lean Six Sigma

Measure

- Check Sheets can also be used to cross reference events with time or other dimensions or see emerging patterns

	Jim	Jackie	Tom	Total
Key errors	20	24	16	**60**
Spelling Errors	11	23	9	**43**
Late Completion	75	26	34	**135**
Wrong Sequence	12	2	6	**20**
Layout	4	0	5	**9**
Late Delivery	7	14	9	**30**
Unknown	5	2	19	**26**
	135	**93**	**101**	**323**

Resist the natural urge to focus on the individual performance.

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Check Sheet

Lean Six Sigma

Measure

- Check Sheets can also be used to cross reference events with time or other dimensions or see emerging patterns

	Jim	Jackie	Tom	Total
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Layout	4	0	5	**9**
Late Delivery	7	14	9	**30**
Unknown	5	2	19	**26**
	135	**93**	**101**	**323**

Improving the process, will improve the overall performance for everyone.

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Check Sheet

Lean Six Sigma

Measure

- Improvement of the process, improved overall performance

	Jim	Jackie	Tom	Total
Key errors	20	24	16	**60**
Spelling Errors	11	23	9	**43**
Late Completion	17	13	19	**49**
Wrong Sequence	12	2	6	**20**
Layout	4	0	5	**9**
Late Delivery	7	14	9	**30**
Unknown	5	2	19	**26**
	59	**78**	**83**	**276**

How many people wanted to fire Jim?

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Data Collection Procedure

Lean Six Sigma

Measure

- Make a list of categories to measure or draw a map of the process components
- Decide who will gather data and how
- Design an Excel spreadsheet to record the data
- Review and act on the information!
- Did the data represent the problem?
- Adjust collection plan and continue to collect as needed

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Measure Phase Review Questions

Lean Six Sigma

Measure

- What is the purpose of the Measure Phase?
- What are the Ys or outputs?
  - How did you determine them?
  - How are you measuring them?
- What are the Xs or inputs?
  - How did you determine them?
  - How are you measuring them?
- Is data already being collected?
  - If yes, does the data pass a Gage R&R?
  - Is the data being collected in the areas of interest?
- If no data exists, do you know where you want to collect data?

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Measure Phase Review Questions

Lean Six Sigma

Measure

- What Xs have been identified as potentially having an impact?
  - Have you assessed the impact of these Xs with data?
  - If not, what is your plan to do so?
    - What tools do you think you will be effective for the type of data you have?
- Is the problem you face concerned with moving the mean or shrinking the variance, or both?
- Do you have adequate resources to complete the project?
  - Are there any issues or barriers?

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Lean Six Sigma

Analyze

Define

Measure

Analyze

Improve

Control

Analyze

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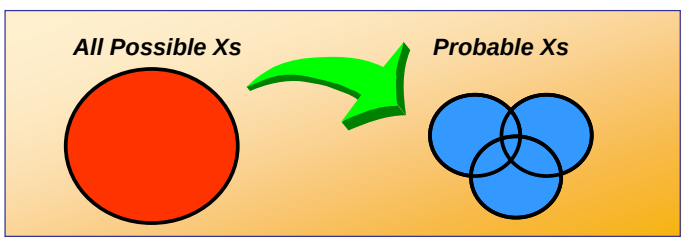
Searching for Xs

Lean Six Sigma

Analyze

- The primary focus of the analyze phase is to separate the Critical Few from the Trivial Many
- In short: What is driving our deficiency or variation?



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Prioritize Problems

Lean Six Sigma

Analyze

- Prioritization will:
  - Provide a priority list of the sources of variation
  - Guide team activities
  - Guide the tracking of those activities
  - Give a starting point of questions to ask and answers to find first
- The Failure Modes and Effects Analysis (FMEA) tool helps us prioritize

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Brainstorming

Lean Six Sigma

Analyze

- Display the question the group is considering
- Ask the group to answer the question with silent writing
- Collect the ideas from each group member, one at a time
  - No criticism or discussion
  - Do not interrupt others
  - Any individual may pass on any turn
- Record the ideas *as stated* for all to see
- When everyone passes on the same turn, discuss the ideas
  - Clarify
  - Combine similar ideas
  - Identify common themes or categories

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Brainstorming Guidelines

Lean Six Sigma

Analyze

- Don't critique ideas
- Use freewheeling imagination
- Build on other's ideas
- Aim for quantity
- Record each idea as stated

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Brainstorming Example

Lean Six Sigma

Analyze

Entitlements Problems: late / incorrect pay

- Data errors in application
- Application not submitted
- Incomplete information
- Missed deadline
- Forms lost in mail
- Paperwork misfiled
- E-mail latency
- Faxed to wrong number
- Data entry error
- Incorrect exchange rate

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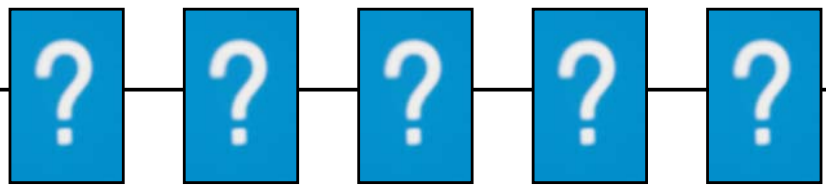
5 Whys

Lean Six Sigma

Analyze

- Technique to get from symptom to root cause
- Asking “Why?” as many as five times to get to root cause
- By identifying root cause we can take action to prevent recurrence



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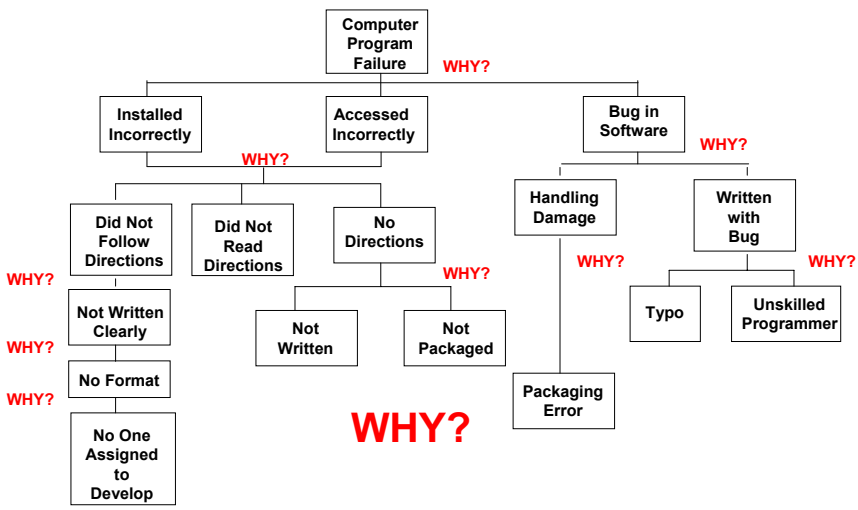
5 Whys: Computer Failures

Lean Six Sigma

Analyze



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Multi-voting

Lean Six Sigma

Analyze

- Narrows the number of choices
- Based on individual opinion, experience
- Must be followed up with data (Analyze tools)

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Multi-voting

Lean Six Sigma

Analyze

- Give each team member 10 points and let them distribute across the options, OR
- Give each team member 3 multi-colored dots (red, blue, green) to represent high, medium, and low to distribute across the options
- Focus next steps on the item(s) with the highest number of votes and / or score
- Obtain data to validate

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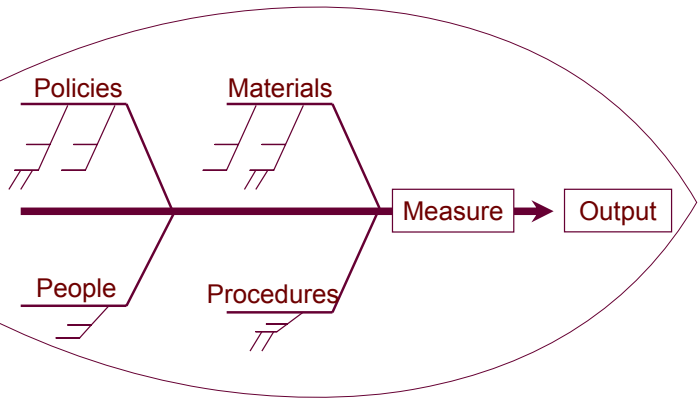
Fishbone Diagram

Lean Six Sigma

Analyze

- Used to categorize problems and/or possible solutions
- Very useful for finding the root cause (s) of a problem
- Also known as Cause-and-Effect Diagram



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Fishbone Diagram Procedure

Lean Six Sigma

Analyze

- Write the problem (effect or "Y") in a box on the right side with an arrow entering from the left
- Generate a list of causes that potentially create the problem
- Organize the causes into categories
  - Place causes on the fishbone by category
- Breakdown the causes into smaller components by asking "Why?"
  - Add to fishbone
- Examine for patterns, root causes, data needs

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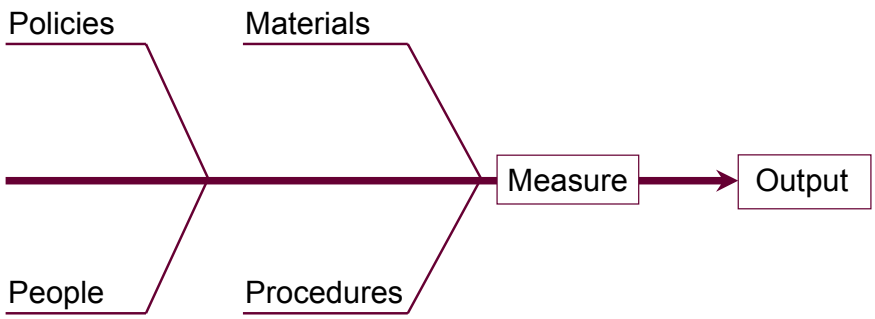
What's the Biggest Source?

Lean Six Sigma

Analyze



Not using standard operating procedures
is often the single largest source of variation!

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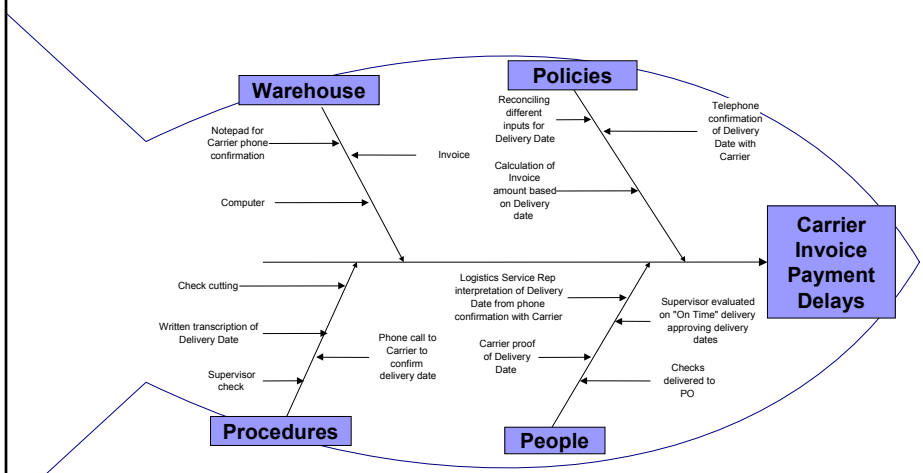
Fishbone Example

Lean Six Sigma

Analyze



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XY Matrix

Lean Six Sigma

Analyze

XY matrix is used to:

- Identify and subjectively rank "sub-Ys"
- Relate Xs to Ys
- Take the first crack at: Y = f(X)

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Why Do We Need an XY Matrix?

Lean Six Sigma

Analyze

- To allow everyone involved with a process to agree on outputs critical to the product and/or customer
- Through numerical ranking, an XY matrix enables your team to assign a level of importance to each output variable
- Through association, an XY matrix enables a team to numerically assess the effect of each X on each Y
- It provides the team its first stab at determining Y = f(X)
- It leads the way to an area of focus on the process “Failure Modes and Effects Analysis” (FMEA)

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How to Create a Useful XY Matrix

Lean Six Sigma

Analyze

Step 1: Use available information sources like process maps to aid you in your identification of inputs and outputs.

Step 2: List the output variables (Ys) along the top section of the matrix. These are outputs that the team and/or customer deem important. These may be a subset of the list of Ys identified on the process map.

Step 3: Rank each output numerically using an arbitrary scale (possibly 1 to 10). The most important output receives the highest number. Enter these rankings in the Output Ranking row of the matrix.

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How to Create a Useful XY Matrix

Lean Six Sigma

Analyze

Step 4: Identify all potential inputs or causes (Xs) that can impact the various Ys and list these along the left side of the matrix.

Step 5: Numerically rate the effect of each X on each Y within the body of the matrix.

Step 6: Use the results page to analyze and prioritize where to focus your effort when creating the preliminary FMEA. The XY matrix is a great team brainstorming tool. It can also facilitate future team activities.

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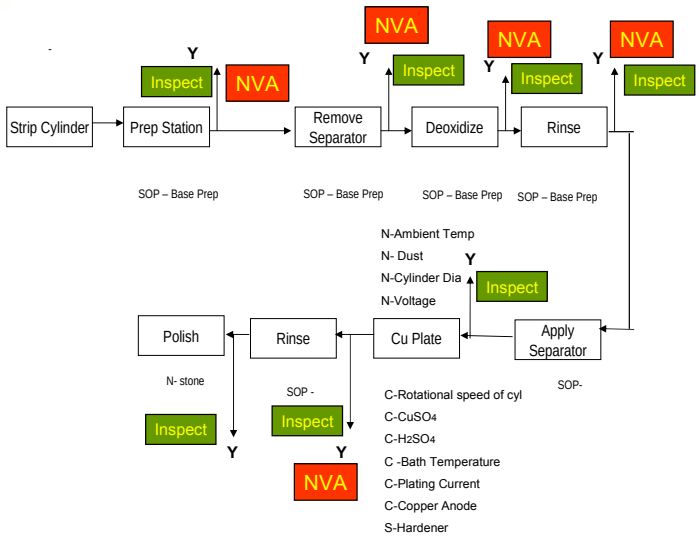
Revisit your Process Map

Lean Six Sigma

Analyze



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Example

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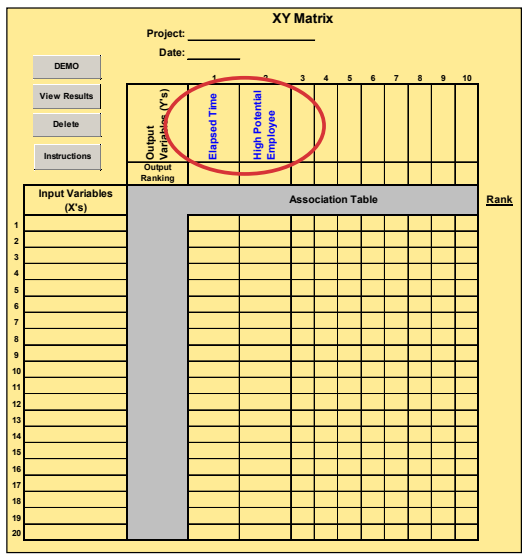
Analyze

Step 2:
List the important output variables along the top section of the matrix.



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Example

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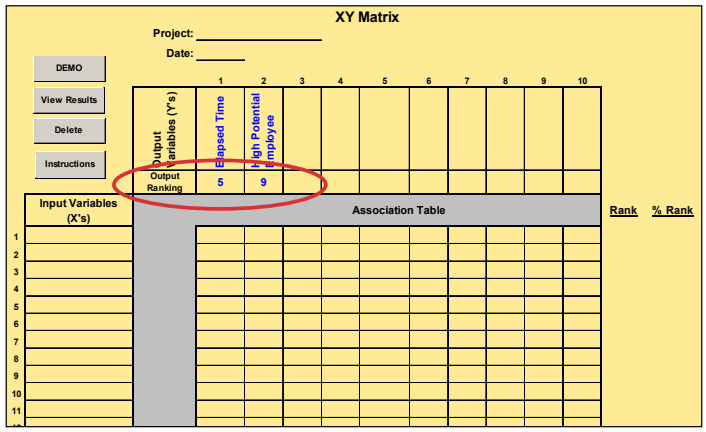
Analyze

Step 3:
Rank each output numerically using an arbitrary scale. A scale of 1 to 10 is often used.



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Example

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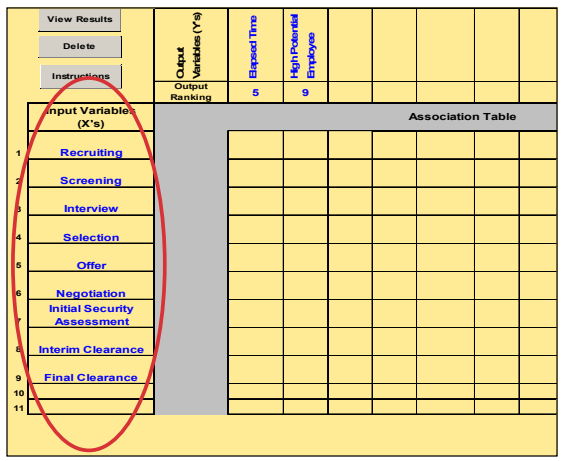
Analyze

Step 4: Identify potential causes (failed Xs) that can impact various outputs, and list each one along the left side of the matrix.



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Example

Lean Six Sigma

Analyze

Step 5: Numerically rate the effect of each X on each Y within the body of the matrix.

Note: This captures what is known so far about the process.

Date: _____

DEMO | View Results | Delete | Instructions

	Output Variables (Y's)	1 Elapsed Time	2 High Potential Employee	3	4	5	6	7	8	9	10		
	Output Ranking	5	9										
	Input Variables (X's)	Association Table										Rank	% Rank
1	Recruiting	3	8									87	13.26%
2	Screening	2	9									91	13.87%
3	Interview	7	9									116	17.68%
4	Selection	6	7									93	14.18%
5	Offer	2	7									73	11.13%
6	Negotiation	6	6									84	12.80%
7	Initial Security Assessment	2	1									19	2.90%
8	Interim Clearance	6	1									39	5.95%
9	Final Clearance	9	1									54	8.23%
10													
11													
12													

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Example

Lean Six Sigma

Analyze

Step 6: Use the resulting ranks to analyze and prioritize future team activities.

If no FMEA exists, the highest-ranking inputs from the XY matrix should be addressed first.

Input Variables	Rank	%
Recruiting	87	13.26%
Screening	91	13.87%
Interview	116	17.68%
Selection	93	14.18%
Offer	73	11.13%
Negotiation	84	12.80%
Initial Security Assessment	19	2.90%
Interim Clearance	39	5.95%
Final Clearance	54	8.23%

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In-Class Exercise

Lean Six Sigma

Analyze

- Break into your groups
- Use your catapult Process Map
- Use the 6-step methodology to create an XY matrix (XYMatrix.xls) for the process
- Use the Xs and Ys from your process map as key information
- Be prepared to report your results
- You have 20 minutes for this exercise

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FMEA Defined

Lean Six Sigma

Analyze

- Failure Modes and Effects Analysis (FMEA) is a detailed document that identifies ways a process or product can fail to meet critical customer requirements (Ys)
- A *living* document that lists all possible causes (Xs) of failure
  - From this, list of items for the control plan can be generated
- A document that allows the team to track and prioritize the actions required to improve the process
- In short, a FMEA will:
  - Ultimately capture the entire process
  - Identify ways the product or process failed because of these Xs
  - Facilitate the documentation of a plan to prevent those failures

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Example: Entitlements Project FMEA

Lean Six Sigma

Analyze

	what should happen	*what goes wrong*	*the result*		*potential causes*		*preventative actions*		
Process Step	Action (e = Employee, n = NSA, c = CBES	Failure Mode	Effect	Sev	Cause	Occ	Controls	Det	RPN
17	(e) Employee applies for TQSA via CBES	App. not received by CBES	TQSA Advance not paid	9	Employee fails to submit application	7	CBES inquires about application when employee arrives OCONUS	5	315
				9	Application lost in transit	5	Communications procedures	3	135
				9	Application lost at CBES or NSA	4	Internal SOPs	3	108
		App. received late by CBES	TQSA advance paid late	8	Employee submits application late	6	CBES inquires about application when employee arrives OCONUS	5	240
				8	Transit delays	5	Communications Procedures	3	120
				8	Filing delays	4	Internal SOPs	3	96
		Erroneous app. received by CBES	Wrong TQSA amount paid, potential reconciliation problems later	7	Employee submits erroneous application	7	CBES internal review	4	196

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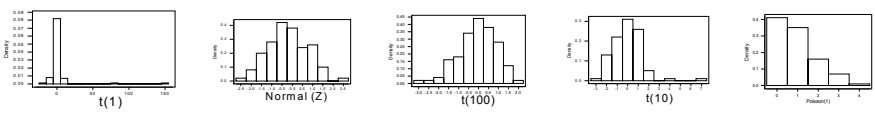
Distributions: Purpose

Lean Six Sigma

Analyze

- Is the basis for inferential statistics
  - We go from what we know to what we don't know
  - We know we have sample data
  - We deduce that our data fits an appropriate population
  - We make assumptions based on each distribution
- We draw conclusions based on the shapes of these distributions
  - Construct a confidence interval
  - Test for differences in samples
  - Examine associations between samples



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What Good are Distributions?

Lean Six Sigma

Analyze

- Distributions depict the probability of a random effect occurring
- We use customer specifications to determine significance when compared to our observed values
- Significant events happen somewhere in the tails

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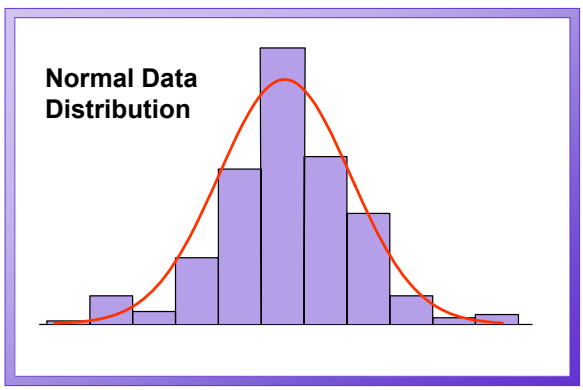
Data Distributions

Lean Six Sigma

Analyze



One of the most frequently used graphic views of a data set

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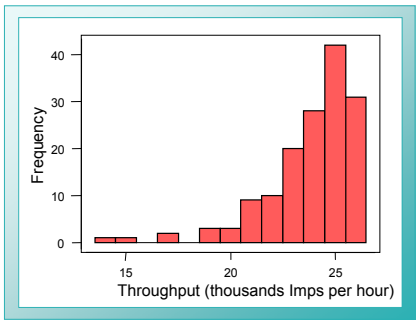
Non-Normality

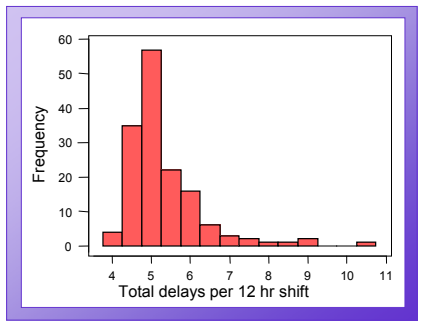
Lean Six Sigma

Analyze

Left Skew



Right Skew



Potential Causes (In Hierarchical Order)

1. Natural Limits
2. Artificial Limits (Sorting/Selecting/"Tweaking")
3. Mixtures
4. Non-Linear Relationships
5. Interactions
6. Non-Random Patterns across Time

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Discrete Distributions

Lean Six Sigma

Analyze

- Discrete distributions differ from continuous
  - Data consists of counts instead of measurements
    - No intermediate values
    - Well-defined area of opportunity
      - Must have equal area of opportunity for comparison
  - Distributions are more 'theoretical'
    - Standard deviations are a function of the means
    - Violates the constant variance assumption within subgroups

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Graphical Tools

Lean Six Sigma

Analyze

- The primary graphical tools available to help characterize and learn about the process are:
  - Pareto Charts
  - Histograms
  - Time Series Plots
  - Control Charts
  - Box Plots
  - Cause & Effect Diagrams

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Pareto Chart

Lean Six Sigma

Analyze

- The Pareto Chart is used to:
  - Separate the critical few areas from the trivial many
  - Focus and refine the problem statement
- Pareto Effect: 80% of the problem is due to 20% of the potential causes

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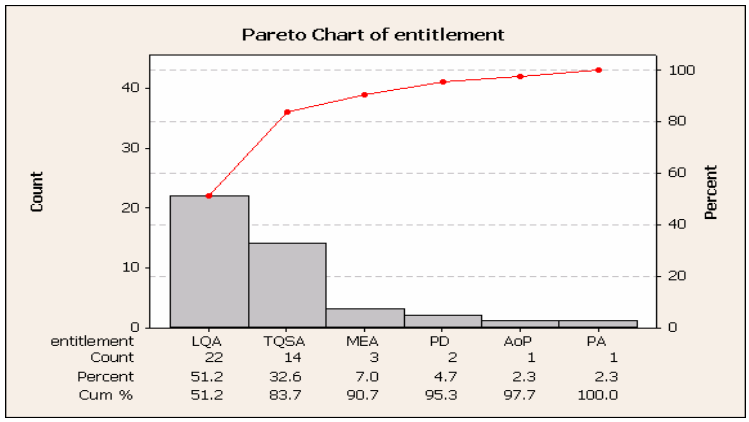
Pareto Chart

Lean Six Sigma

Analyze



LQA – Living Quarters Allowance
TQSA – Temporary Quarters Subsistence Allowance
MEA – Miscellaneous Expense Allowance

PD - Per Diem
AoP - Advice of Payment
PA - Per Annum

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Histogram

Lean Six Sigma

Analyze

- Provides a snapshot of overall or average process performance
- Reveals variation around the average
- Measures the output against specifications or targets
- Provides some initial clues for improvement

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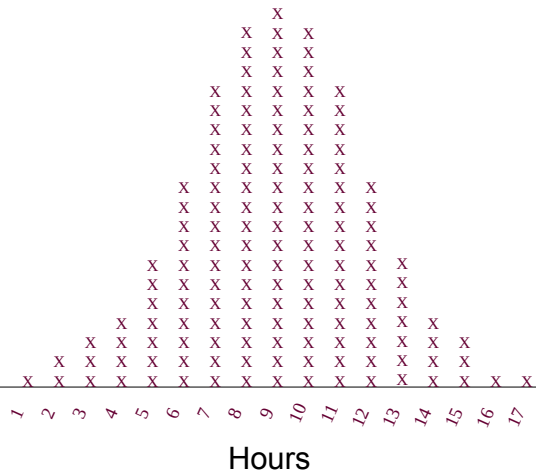
Histogram

Lean Six Sigma

Analyze



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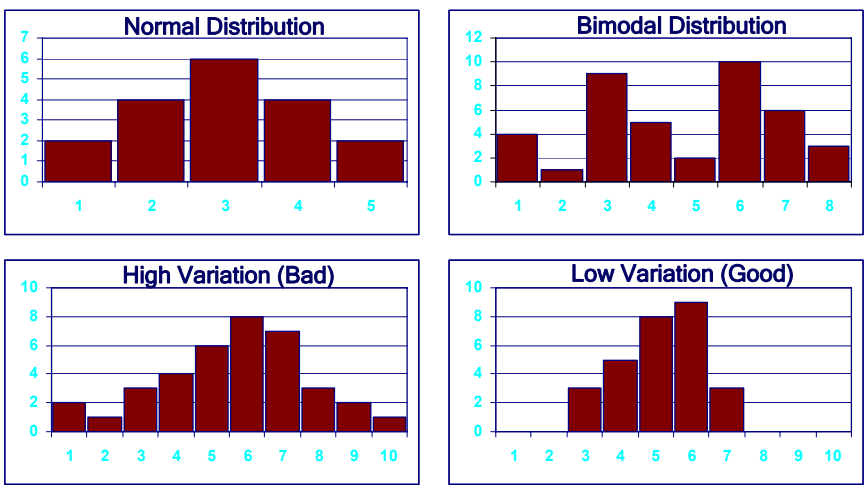
The Shape of Variation

Lean Six Sigma

Analyze



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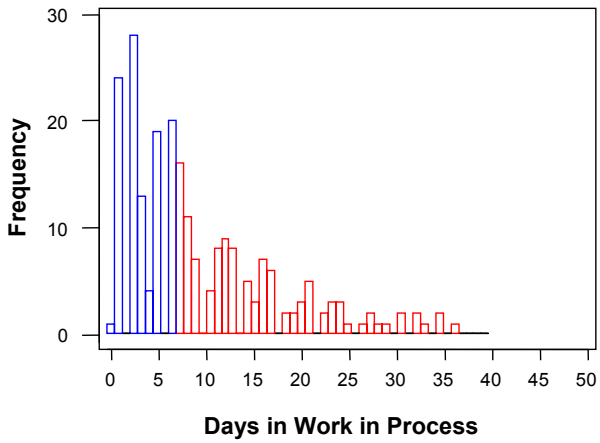
Example: Histogram

Lean Six Sigma

Analyze



Median = 7

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Time Series & Control Charts

Lean Six Sigma

Analyze

- Time Series Plots/Run Charts and Control Charts are used to:
  - To observe the stability of Xs and Ys over time
  - Look for patterns in the data
  - Identify and take action on special cause variation

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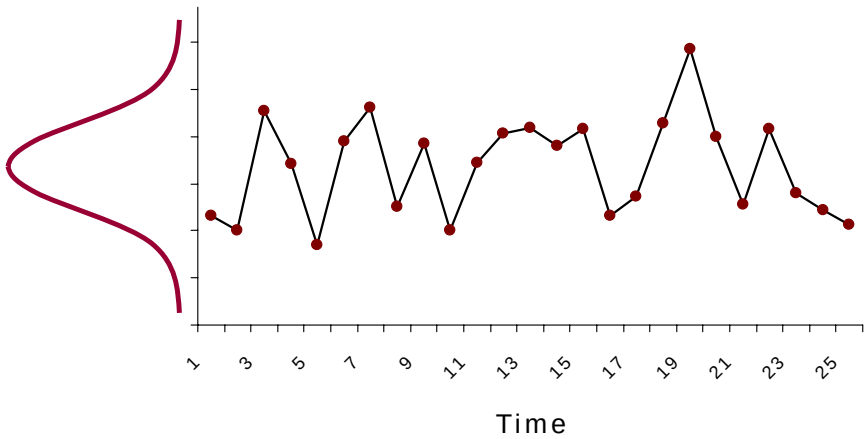
Run Chart

Lean Six Sigma

Analyze



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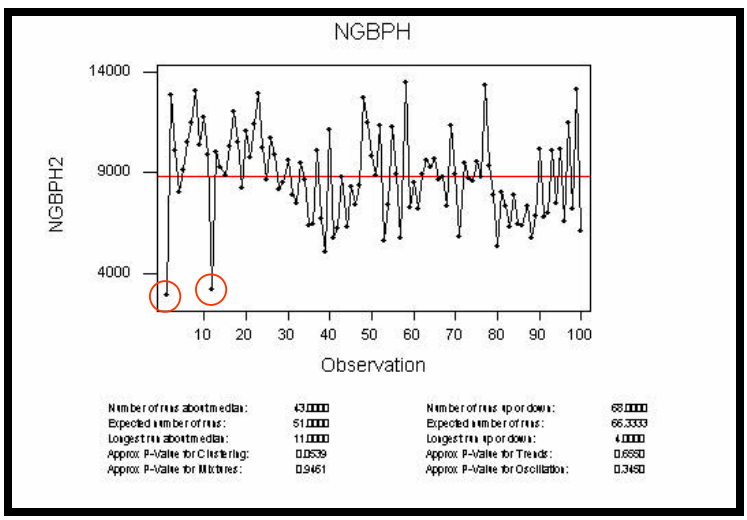
Time Series or Run Chart

Lean Six Sigma

Analyze



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Run Chart

Lean Six Sigma

Analyze

- Shows how the process varies over time
- Shifts, trends, intermittent problems and cyclic patterns can be detected
- Vertical-axis is the unit of measure; horizontal-axis is time
- A baseline average or current average line can be used as a point-of-reference to detect process changes

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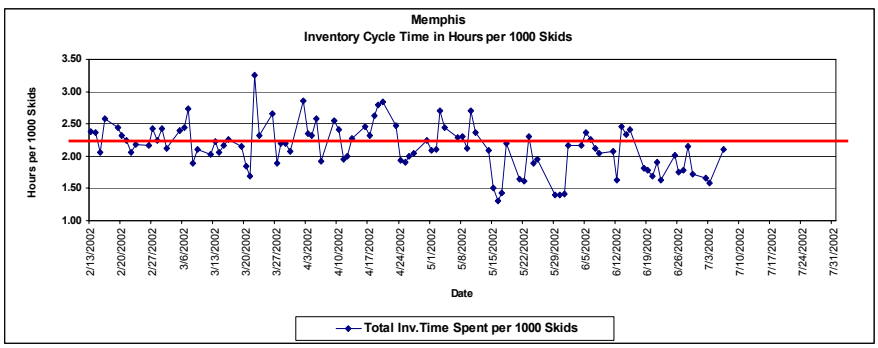
Example: Time Series Chart

Lean Six Sigma

Analyze



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Run Chart Procedure

Lean Six Sigma

Analyze

- Gather data over time in sequence
- Create a graph with a vertical line and a horizontal line
  - The vertical line should cover the full range of measurements
  - The horizontal line should cover the time period which the data was collected
  - Add a baseline (using prior data) or average (current data) line to indicate process location (mean)
- Plot the data on the graph connecting the points
- Interpret the chart
  - Look for trends, patterns and/or unusual data points

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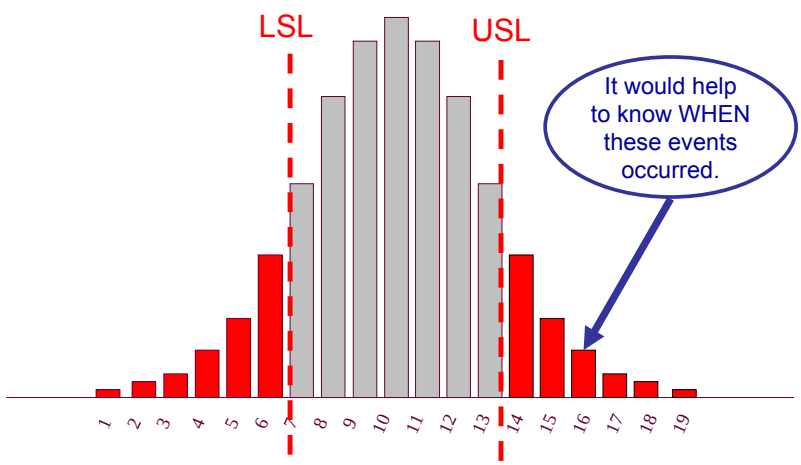
Histogram

Lean Six Sigma

Analyze



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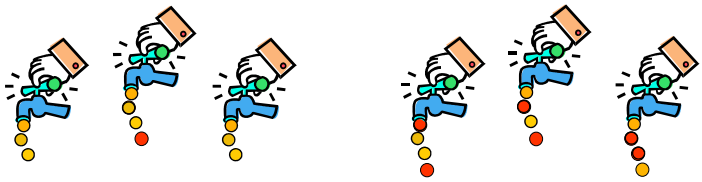
Two Types of Variation

Lean Six Sigma

Analyze

- Two types of variation are visible in a Run Chart:



Special Cause
Something different happening at a certain time and place

Common Cause
Always present to some degree in the process

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Causes of Variation

Lean Six Sigma

Analyze

Common Cause

- Predictable
- Inherent
- Part of the Process
- Must change the process to reduce

Special Cause

- Surprising
- Uncontrolled
- Often outside the process
- Must identify the source and eliminate

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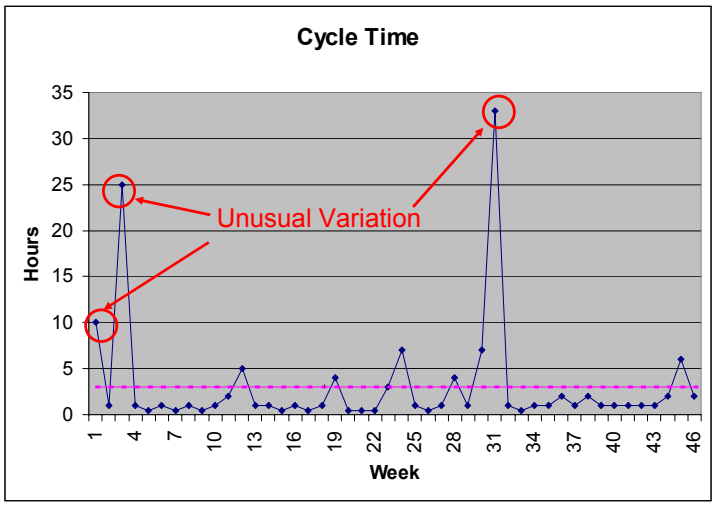
Run Chart of Cycle Time

Lean Six Sigma

Analyze



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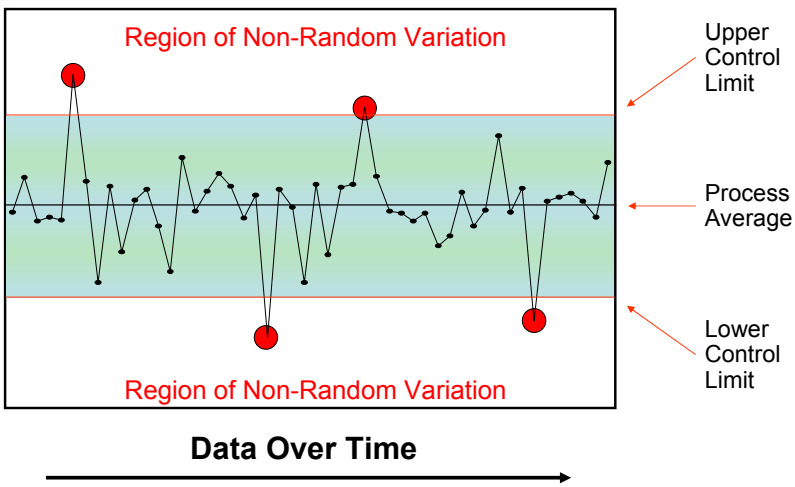
Control Charts

Lean Six Sigma

Analyze



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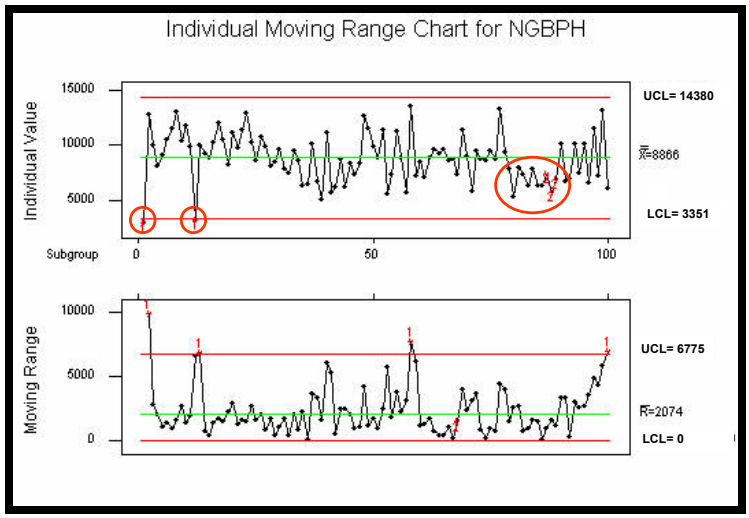
Control Chart

Lean Six Sigma

Analyze



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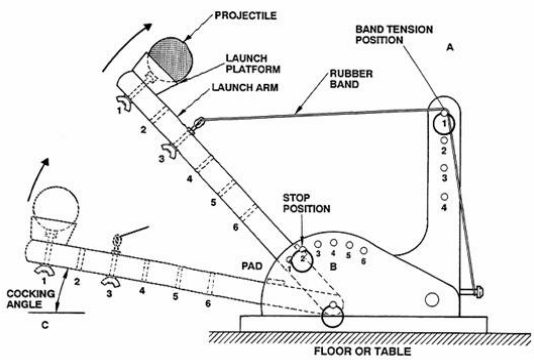
Catapult Exercise: Run Chart

Lean Six Sigma

Analyze

- Using the data from your Histogram …create a Run Chart of your catapult data
  - Total Distance
  - Azimuth Variation



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Correlation

Lean Six Sigma

Analyze

- Identify dependency relationships between two or more variables (Xs and Y).
- It is customary to call X the input variable (independent) and Y the output variable (dependent).

(Response)	(Factor)
Y	X
y_1	x_1
y_2	x_2
y_3	x_3
y_4	x_4
y_5	x_5
y_nth	x_nth

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Scatter Diagram

Lean Six Sigma

Analyze

- Good for finding and/or confirming relationships between measures
- Can assist in identifying which process inputs impact the process output
- Add evidence to opinion regarding cause and effect
- Can identify clues for improvement

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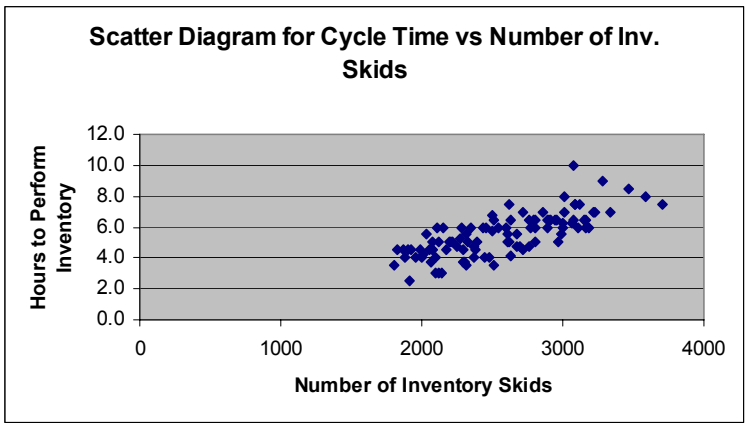
Scatter Diagram

Lean Six Sigma

Analyze



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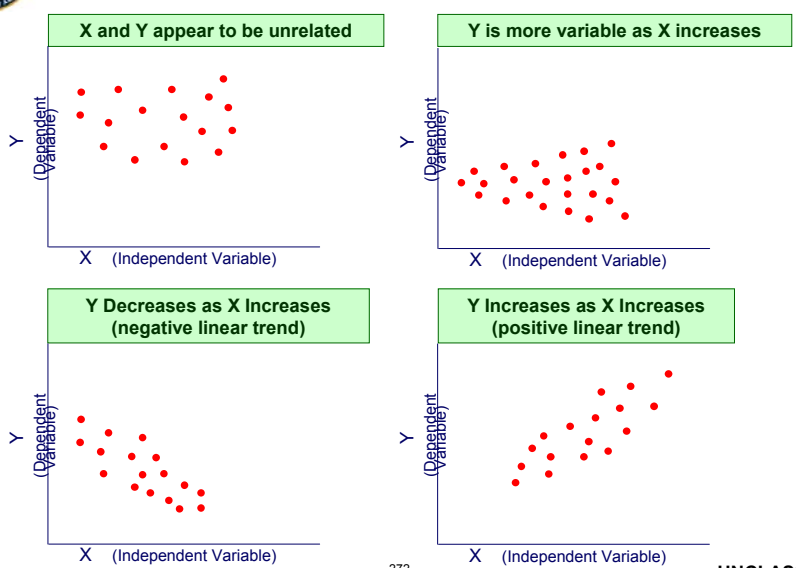
Scatter Diagrams Patterns

Lean Six Sigma

Analyze



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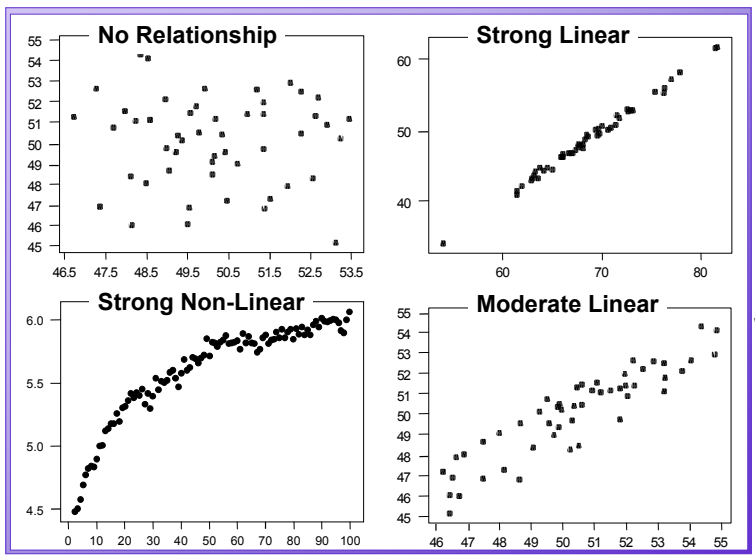
Examples of Variable Relationships

Lean Six Sigma

Analyze



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Abuse & Misuse of Correlation

Lean Six Sigma

Analyze

- If we establish a correlation between X_1 and Y, that does NOT necessarily mean variation in X_1 caused variation in Y
- A third variable that is associated with both X_1 and Y may be "lurking."
- Relationship could be coincidental
- To conclude that there is a relationship between two variables does NOT mean that there is a cause and effect relationship.

Correlation Does NOT Determine Causation!

A study conducted in New York indicated there was a proportional rise in ice cream sales and murder rates during summer months.
Correlation or coincidence?

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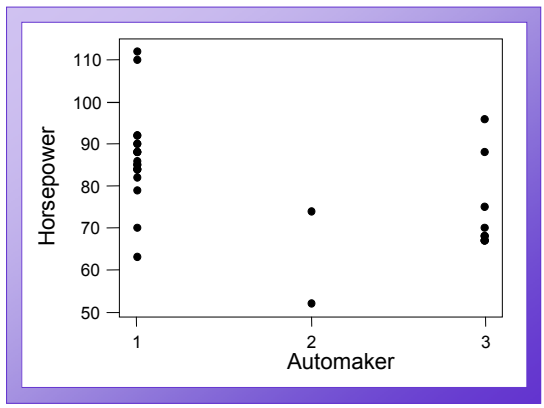
Scatter Plots with a Discrete X Variable

Lean Six Sigma

Analyze

- Scatter plots with a discrete X variable can display the data in a useful way

- Since the data are both continuous (horse power) and discrete (automaker) it will stratify based on the categorical data



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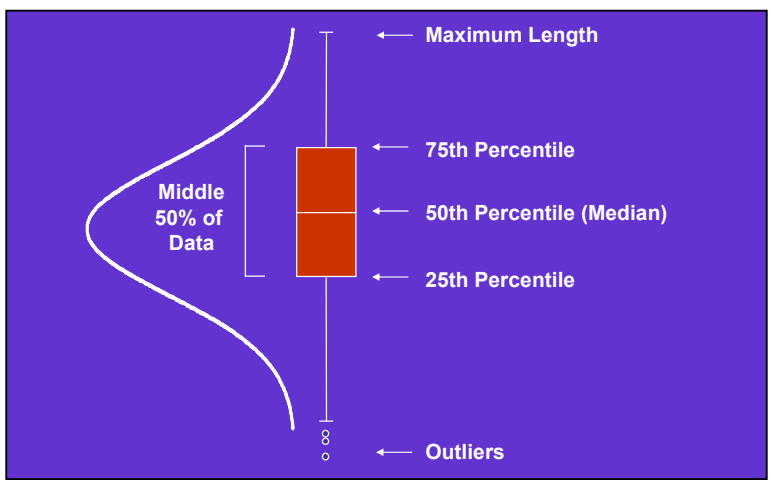
Boxplot Distribution

Lean Six Sigma

Analyze



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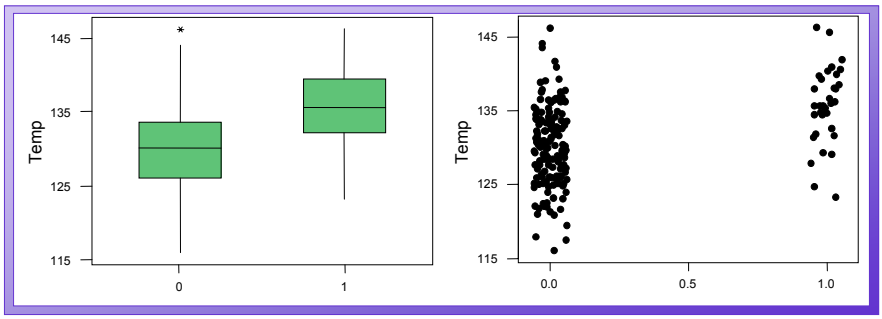
Analyzing Discrete Outputs with Continuous Inputs

Lean Six Sigma

Analyze

- If you have a discrete process output (i.e. pass or fail) *and* more than one continuous input variable, you can apply many of the graphs that have been discussed here by switching the axes on graph specification.
- Graphs especially suitable for this application are boxplots and jittered scatter plots (note: input is on vertical axes below).



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Summary

Lean Six Sigma

Analyze

- **Brainstorming** captures potential root causes through open-ended discussion
- **Fishbone Diagram** organizes potential root causes by source or category
- **XY Matrix** prioritizes root causes via their relationship to the output
- **FMEA** prioritizes root causes analytically by investigating all potential failure mechanisms; forms basis for control plan
- **Pareto Charts** show the relative magnitude of a problem
- **Histograms** provide a view of the process performance (location & spread)
- **Run Charts** provide a view of the process performance over time
- **Scatter Diagrams** identify or confirm relationships between measures

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Analyze Review Questions

Lean Six Sigma

Analyze

- Based on your analyses, should you refine the project definition?
  - If so, address why and communicate to the team
- Do you have an idea of what Xs may be critical to your Y?
- Are those Xs controllable?
  - What Xs can be changed or addressed based on the data you currently have?
  - Which will require further investigation?
- Have you communicated your findings?
- What issues and barriers exist?
  - Have you documented these on the action item list?
  - Are there any action items from Measure still not complete?

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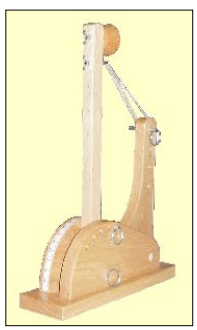
Exercise: Catapult Performance

Lean Six Sigma

Analyze



- Identify and eliminate variation in the catapult operation
  - Standardize the setup and firing process
  - Create a NEW Process Map
- Eliminate variation in the launching technique
  - Create a NEW Process Map of the launching technique

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Catapult Customer

Lean Six Sigma

Analyze

- What does the catapult customer want?
- What is their objective?
- Might knowing this give you any ideas on what you should measure?
- Might knowing this give you any ideas on how you should set up and launch your catapult?

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Lean Six Sigma

Analyze

UNCLASSIFIED

Lean Six Sigma

Improve

Define

Measure

Analyze

Improve

Control

Improve

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Improve

Lean Six Sigma

Improve

- Recap:
  - Define
    - You have defined the problem
  - Measure
    - You have determined the size of the problem
  - Analyze
    - You have analyzed the data to determine the root causes where the improvement opportunities are
  - Improve
    - Now it's time to take action in order to CHANGE the process and improve performance
    - Just DO IT!

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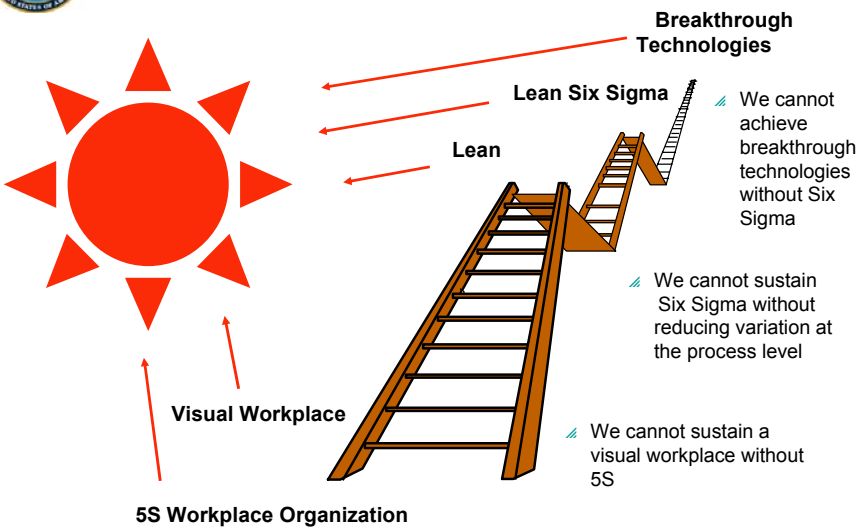
What is Lean?

Lean Six Sigma

Improve



- We cannot achieve breakthrough technologies without Six Sigma
- We cannot sustain Six Sigma without reducing variation at the process level
- We cannot sustain a visual workplace without 5S

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5 Lean Principles

Lean Six Sigma

Improve

1. Specify what creates value from the customers perspective
2. Identify all the steps along the process chain
3. Make those processes flow
4. Make only what is pulled by the customer
5. Strive for perfection by continually removing wastes

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Lean Principles

Lean Six Sigma

Improve

- The goal of Lean is to compress the process time period
- This is achieved by attacking the "8 areas of Waste":
  1. Overproduction
  2. Wasted Capital
  3. Poor Quality
  4. Wasted Motion
  5. Idle Time
  6. Processing
  7. Transportation
  8. Inventory

The first step toward waste elimination is waste identification!

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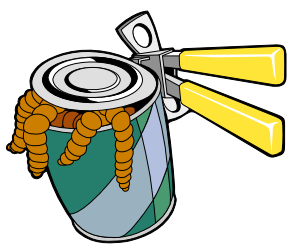
Rework/Correction

Lean Six Sigma

Improve

- Correcting or repairing a defect in materials or parts adds unnecessary costs because of additional equipment and labor expenses
- Example:
  - The labor costs associated with scheduling employees to work overtime to re-work defects



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Overproduction

Lean Six Sigma

Improve

- Two types of overproduction:
  - Producing *more* products than are necessary
  - Producing products at a rate *faster* than is required
- Example:
  - DIA Bi-Weekly Metrics

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Processing

Lean Six Sigma

Improve

- Processing work that is unnecessary because it has no connection with advancing the process or improving the quality of the deliverable
- Examples:
  - Printing a document to be faxed which could be forwarded as e-mail
  - Review steps without decision authority

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Conveyance/Transportation

Lean Six Sigma

Improve

- Conveyance does not directly contribute added value to a product. It is an incidental required action.
- It is vital to avoid conveyance *unless* it is supplying items when and where they are needed (JIT)
- Example:
  - Stove pipes between collection and analysis (collectors – analysts-warfighters)

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Inventory

Lean Six Sigma

Improve

- Inventory is a drain on an organization's overhead. The greater the inventory, the higher the overhead costs become.
- If quality issues arise and inventory is not minimized, defective material is hidden in finished goods.
- To remain flexible to customer requirements and to ensure control of product variation, we MUST minimize inventory.
- Excess inventory covers up unacceptable setup times, excessive downtime, operator inefficiency, and lack of organizational sense of urgency to produce product.

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Motion

Lean Six Sigma

Improve

- Movement of people or machinery that does NOT contribute added value to the product
- Examples:
  - Centralized printer/fax locations
  - Excessive walking distance between operations
  - Key office personnel scattered around various locations

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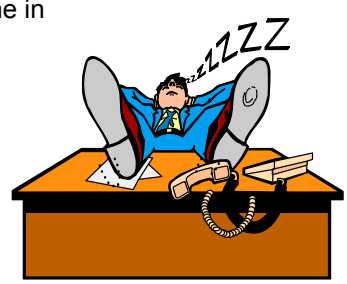
Waiting

Lean Six Sigma

Improve

- Idle time between operations or events
- Examples:
  - An operator waiting for a machine to finish cycling
  - A machine waiting for an operator to load new parts
  - Dead time in the engineering development cycle
  - LSAs waiting for trouble tickets to come in



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Unnecessary Capital Investment

Lean Six Sigma

Improve

- Investment in plant, equipment, and systems without justification of need or ability to deliver
- Examples:
  - Building a warehouse to store extra inventory
  - Developing computer applications for dysfunctional manual processes without fixing it first

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The Goal

Lean Six Sigma

Improve

- Don't forget the goal:
  - ELIMINATION OF WASTE!
    - With this in mind, we will introduce each of the concepts of lean manufacturing.
    - Within each phase, our goal remains the same!

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5S Workplace Organization

Lean Six Sigma

Improve

- To ensure sustainable gains, start with a firm foundation
  - 5S standards are the foundation that supports all phases of lean manufacturing
  - A system can only be as strong as the foundation upon which it is built
- The foundation of a production system is a CLEAN, SAFE, and SECURE work environment
  - Its strength depends upon the employees committed to maintaining it
- Each operator must understand that maintaining these standards is a CONDITION of his/her employment
- As a Green Belt, you must set high goals and accept nothing less

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1S: Sort

Lean Six Sigma

Improve

- Sort through and remove clutter
- Red tag unneeded items
- Move red tagged items to a holding area
- Evaluate red tagged items
- Dispose or relocate red tagged items

Benefits

- Reduce cycle time; clear/label workspace
- Discover hidden supplies/tools
- Reveal and remove hazards
- Remove damaged or worn parts

Metrics

- Process delays
- Run time delays
- Supply expense
- Recordable accidents
- Speed
- Make-ready time

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2S: Set in Order

Lean Six Sigma

Improve

- Review workplace flow
- Decide where and how to keep things
- Arrange items in neat and organized patterns
- Use label, home addresses, visuals
- Make it obvious where things belong

Benefits

- Reduced movement through labeling
- Cycle time reduction
- Reduce potential hazards
- Design in ergonomics compliance requirements

Metrics

- Process delays
- Run time delays
- Recordable accidents
- Make-ready time

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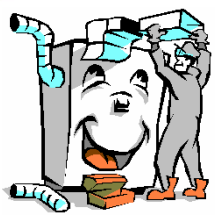
Defining Final Solution

3S: Shine

Lean Six Sigma

Improve



- Create a cleanup work plan - top to bottom
- Thoroughly clean entire area, including equipment
- Identify potential safety hazards
- Identify potential mechanical problems

Benefits

- Remove debris / increase safety
- Minimize fire and spill hazards
- Preventative maintenance

Metrics

- Recordable accidents
- Delays
- Make-ready time

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4S: Standardize

Lean Six Sigma

Improve

- Establish guidelines for 5S conditions
- Establish cleanliness housekeeping standards
- Use SOPs, Checklists, Audits

Benefits

- Cleanliness
- Standards for new hires
- Daily rules
- SOP for training

Metrics

- Throughput
- Latent capacity

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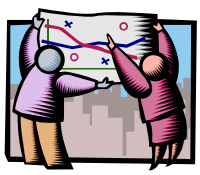
5S: Sustain

Lean Six Sigma

Improve



- Make 5S part of daily routine
- Establish discipline
- Maintain consistency with standards
- Make it part of the culture

Benefits

- Sustained improvements in work environment

Metrics

- Throughput
- Latent capacity

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Keys to Success for 5S

Lean Six Sigma

Improve

1. Get everyone involved
2. Get commitment and authorization
3. Set expectations
4. Establish standards
5. Establish daily routines
6. Keep it simple
7. Ensure resources are made available

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Overall benefits of 5S

Lean Six Sigma

Improve

- Energizes the workforce
- Improves safety (could be 6S)
- Improves efficiency
- Improves quality
- Establishes workplace control
- Lays the foundation for autonomous maintenance

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Visual Workplace

Lean Six Sigma

Improve

- A visual technique for process management aids in sustaining gains
- Types of Visual Management Systems:
  - White Boards
  - Postings of daily activities
  - Indicator lights
  - Posted process flow chart with post-its to indicate position of key jobs
  - Posted control charts and check sheets

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The Visual Workplace

Lean Six Sigma

Improve

- The first steps of the visual workplace are the 5S standards.
- Next, the team should ask, Can we readily identify:
  - Downtime issues?
  - Scrap issues?
  - Setup problems?
  - Line balancing opportunities?
  - Excessive inventory levels?
  - Extraneous tools and supplies?

- If you CANNOT readily identify these opportunities through a VISUAL glance of the area, the team should establish a means of immediate identification.

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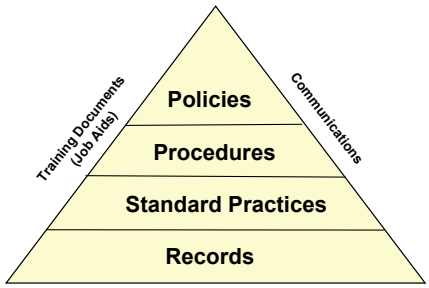
Standardized Work

Lean Six Sigma

Improve

- Types of documentation
  - Policies: give general guidance in how to handle given situations
  - SOPs / Standard Practices: more specific and focus on a given process, event, or activity. These documents provide the "How to"
  - Training Documentation: operation method sheets and job aids with instructions structured for effective training



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Prerequisites for Standardized Work

Lean Six Sigma

Improve

- **Availability of required tools (5S):**
  - Operators cannot be expected to maintain standard work if they are required to locate needed tools.
- **Consistent flow of raw material:**
  - Operators cannot be expected to maintain standard work if they are hunting down needed parts.
- **Visual alert of variation in the process (visual workplace):**
  - Operators and material handlers need visual signals to keep "standard work" a standard. If they can identify new lots of material or other variation, they can identify potential changes in the process. This visual check will assist in defect identification and reduction.
- **Identified and labeled in-process stock (5S):**
  - As inventory levels of in-process stock decrease, a visual signal should be sent to the material handlers to replenish this stock. Operators cannot maintain standard work without this.

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Breakthrough Process Strategies

Lean Six Sigma

Improve

- **Just-in-time (JIT)**
  - The necessary components of production arrive in the necessary quantity at the necessary time
  - Eliminates inventory
- **Pull production systems**
  - Component supply triggered by signal (e.g. Kanban card)
  - Replaces central planning (push system)
  - Essential mechanism for JIT
- **Production smoothing**
  - Mix of units produced based on sales proportions
  - Production sequence based on unit cycle times
  - Goal: "production at the velocity of sales"
- **General purpose, flexible machines**
  - Specialized tools instead of specialized machines
  - Enables production smoothing and quick response to variation in sales

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More Process Strategies

Lean Six Sigma

Improve

- **Shortened setup time**
  - Perform setup operations in advance of machine stop (external setup)
  - Convert as many setup operations to external as possible
  - Reduce time requirement for internal setup operations
- **Process layout for shortened lead times (cell manufacturing)**
  - Sequential processing machines laid out in a "multi-process holding line" - often U-shaped
  - Multi-function workers process units through multiple operations (v. multiple single function "departments")
  - Tends to increase productivity, decreases WIP, balances production, reduces conveyance
- **Autonomous defects control**
  - Machines stop automatically when process is out of spec
  - Prevents mass production of defects

Source: Toyota Production System, Yasuhiro Monden, Engineering and Management Press, 1998

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Summary of Lean Six Sigma

Lean Six Sigma

Improve

- A relentless process of identifying and eliminating waste
- An environmental framework that aids in sustaining gains
- It is comprised of 5 building concepts
  - Kaizen: Philosophy of Continuous Improvement
  - 5S: A systematic method to organize, order, clean, and standardize a workplace… and keep it that way
  - Visual Workplace: A visual technique for real-time process management
  - Standardize: Use of documented, standardized work procedures to reduce variation
  - Breakthrough manufacturing strategies: application of relevant learning from other organizations to eliminate waste

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Building on Lean Six Sigma

Lean Six Sigma

Improve

Once techniques for sustaining the gains are selected … it's time to prepare for implementation.

The control plan assists with the implementation of:

- Documentation
- Communication
- Control methods
- Confirmation of compliance

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Areas of Focus

Lean Six Sigma

Improve

- **Lean the process:**
  - Cycle time
  - Redundancy
  - Streamline
  - Consolidate
  - Sources of Consternation
- **Reduce the variation:**
  - Attack sources of variation
  - Attack sources of error
  - Attack sources of rework
- **Together these will:**
  - Reduce effort
  - Increase consistency
  - Makes resources available for other needs

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Process Streamlining: Identify "To Be"

Lean Six Sigma

Improve

ASK	ACT	IMPACT
What	Eliminate	
Where When Who	Combine Rearrange	Places Sequences Persons
How	Simplify	

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Lean the Process

Lean Six Sigma

Improve

- Validate Process Map with a “walkthrough”
- Identify Value-Added and necessary steps
  - Ask: “If we no longer did this, what would happen?”
  - For process steps that, if stopped, would negatively impact the process, mark “TENATIVELY” as Value-Added
  - For steps you are unsure of, mark “TENTATIVELY” as Non-Value-Added
  - Identify streamlining activities to improve process flow
  - Can any steps be re-routed, eliminated or combined?
- Develop “To-Be” Process Map
- Validate “To-Be” Process Map
- Develop Implementation Plan
- Implement changes (*careful, you may find some unexpected things!*)

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Lean the Process

Lean Six Sigma

Improve

- Non-Value-Added
  - Which activities are non-value-adding?
  - Which activities are not needed?
  - Which activities can be combined?
  - Which activities can be made simpler?
- Long Queues and Pauses
  - Where is there a long chain of tasks?
  - Which activities can start sooner than currently shown?
- Critical Resources
  - Which activities center around key functions / people?
  - Where are hand-offs between functions / people?
  - How many hand-offs?

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Lean the Process

Lean Six Sigma

Improve

- Wasted Space / Cycle Time
  - Where is wasted space?
  - Where are long cycle times?
- Rework or Poor Timing
  - Are there activities that are done more than once?
  - What percent of the desk-space is allocated to rework?
- Done More Than Once?
  - Where are similar tasks done by more than one function?
- Distances
  - Can distances be reduced?
- Decision Points
  - Due to incomplete or erroneous work / information in previous steps?
  - Can they be eliminated?

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Lean the Process

Lean Six Sigma

Improve

- Add cycle times to Process Map. Include:
  - Run Time – time to actually perform the step
  - Wait Time – time unit sits waiting for movement to next step
  - Queue Time – time unit sits waiting for processing
  - Changeover Time – time to change from one unit to next unit
- Look for opportunities to reduce cycle time by:
  - Eliminating steps
  - Changing the sequence of steps
  - Eliminating/minimizing movement between steps
  - Etc.

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Necessary Steps

Lean Six Sigma

Improve

- A step may be non-value-added but *necessary* if:
  - Required by law, regulation, or contract
  - Required for safety, health, environmental, or ethical considerations

EPA
DFAR
EEOC
OSHA
FISMA

Environmental Protection Agency
Defense Federal Acquisition Regulation
Equal Employment Opportunity Commission
Occupational Safety and Health Administration
Federal Information Security Management Act

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Mistake-Proofing Agenda

Lean Six Sigma

Improve

Mistake-proofing: using knowledge and ingenuity to create devices that allow you to do your job 100% defect/error free 100% of the time

- The relationship between errors and defects
- Types of errors
- The arguments for mistake-proofing
- Mistake-proofing versus inspection
- Mistake-proofing concepts
- Mistake-proofing techniques or devices
- Exercise

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Examples of Everyday Mistake-Proofing

Lean Six Sigma

Improve

- **Home**
  - Automated shutoffs on electric coffee pots
  - Ground fault circuit breakers for bathroom inside or outside electric circuits
  - Pilotless gas ranges and hot water heaters
  - Child-proof caps on medications
  - Butane lighters with a safety button
- **Factory**
  - Dual palm buttons and other guards on machinery
- **Office**
  - Spell check in word processing software
  - A “Do you want to delete?” message after you press the “Delete” button on your computer
- **Automobile**
  - Seat belts
  - Air bags
  - Car engine warning lights
- **Retail**
  - Tamper-proof packaging

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Mistake-Proofing

Lean Six Sigma

Improve

- Forgetfulness (not concentrating)
- Errors due to misunderstanding (jumping to conclusions)
- Errors in identification (viewing incorrectly- too far away)
- Errors made by untrained workers
- Willful errors (ignoring rules)
- Inadvertent errors (distraction, fatigue)
- Errors due to slowness (delay in judgment)
- Errors due to lack of standards (written and visual)
- Surprise errors (equipment malfunctions)
- Intentional errors (sabotage- least common)
- Errors due to fatigue

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Mistake-Proofing Methods

Lean Six Sigma

Improve

- There are an infinite number of methods to mistake-proof a process including:
  - Performance Step Techniques
  - Fixed-value Techniques
  - "Make it easy to do it right" Techniques
- Be creative and imaginative!

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Mistake-Proofing Methods

Lean Six Sigma

Improve

- **Performance Step Techniques**
  - Require "monitoring" the process to insure the proper steps are followed, and triggering an outcome if the step is not performed correctly.
  - Examples:
    - eZHR Appraisal System
    - Online expense reporting systems

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Mistake-Proofing Methods

Lean Six Sigma

Improve

- **Fixed-value Techniques**
  - Involve setting conditions for a process step (input) and counting to that value
  - Triggers can occur when the count is not achieved (over or under) or the trigger can't occur unless or until the count is achieved
  - Examples:
    - Paying for a fixed amount of gasoline before pumping
    - Debit cards

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Mistake-Proofing Methods

Lean Six Sigma

Improve

- **"Make it easy to do it right"**
  - True process mistake-proofing techniques are hard to put in place due to cost or effort associated
  - In such cases, mistake-proofing "aids" can be used to "*make it easy to do it right*"
  - These techniques are not truly 100% mistake-proofing but they can prevent mistakes from occurring
  - Examples include:
    - Color coding
      - Tire wear stripe
    - Shapes
      - Different shaped electrical plugs for different voltages
      - Tool shapes on a tool board
    - Operator-initiated "auto-detection" systems
      - Sheet scanners for density and/or register with triggers
      - Control charts for inputs and outputs

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Mistake-Proofing

Lean Six Sigma

Improve

- What kinds of mistake-proofing do you see here?

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Transactional Mistake-Proofing

Lean Six Sigma

Improve

- Other Tools
  - Checklists
  - Forms
  - Posted SOPs and/or schematics
  - Simplified workflow
- Keep them simple and short (1 page) or they will not be used
- Simplified workflow is always a more desired state
- A picture is worth a thousand words

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Implementation Plan

Lean Six Sigma

Improve

- An organizational tool that allows a Black/Green Belt to lay out their thoughts, leading to an efficient flow of action
  - Compiling initial concept questions leads to both parallel and serial activities
  - Include all necessary action items that can aid in the success of the project
  - Graphically represent your approach in a manner that others can follow

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Goal of Implementation Plans

Lean Six Sigma

Improve

- Imbed sequential work within a parallel thought process
- Resolve questions prior to developing solutions
- Identify necessary items on a “Macro” level
- Assign responsibility for completing and monitoring to the correct individuals

Focus on parallel tasking!

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Implementation Plan

Lean Six Sigma

Improve

- Changes cannot be made until there is a plan
  (We do not plan to fail, we fail to plan, which often results in Failure)
- Implementation plans -
  - Includes timing, responsibility, involvement of key stakeholders, and key milestones
  - Large tasks are divided into subtasks and outcomes defined for each subtask
  - Includes regular status reviews of the plan
  - Entire implementation team involved in creating the plan
  - Tools include: Action Item Register

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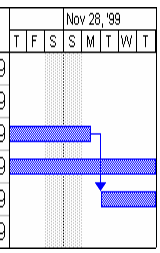
Project Plans

Lean Six Sigma

Improve

- Several tools can help you create a project plan
- If you are not familiar with Microsoft Project, use Excel

ID	Task Name	Duration	Start
1	Determine Practical & Statistical Problem	11 days	Mon 11/1/99
2	Complete DOE Factor Selection	15 days	Mon 11/1/99
3	Evaluate Practicality of DOE plan	5.5 days	Mon 11/22/99
4	Complete Development of the Measurement System	11 days	Fri 11/19/99
5	Coordination and planning for Running 1st DOE	14 days	Tue 11/30/99
6	Running of 1st DOE subject to Material and Equipment Availability	3 days	Mon 12/20/99



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Implementation Plan

Lean Six Sigma

Improve

- Responsibility, involvement, and key stakeholders
  - **D = Driver**
    - Change agent
    - Drives process improvement via Lean Six Sigma
  - **A = Approver**
    - Process owner
    - Responsible for area impacted by project
  - **C = Contributor**
    - Who should be consulted regarding changes in the process
  - **I = Informed**
    - Who needs to be informed regarding process changes

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Implementation Plan

Lean Six Sigma

Improve

- Organize your implementation plan to ensure the correct people are assigned to the right tasks

Task	Which groups or individuals should be…			
	Driver	Approver	Contributor	Informed
Identifying solutions				
Selecting Solutions				
Planning the implementation				
Handling potential problems				
Implementing the solution				
Monitoring results				

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Implementation Plan Procedures

Lean Six Sigma

Improve

- Identify what you want to accomplish
- Identify the actions needed
- Estimate the time and resources required
  - For each action
  - For people, equipment, supplies, money
- Identify measures of progress
  - Is the plan working?
  - Are we getting the desired results?
- Identify potential problems and how to deal with them
- Create a document that captures the plan

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Action Item Register (AIR)

Lean Six Sigma

Improve

- An action plan to help us link:

Problem → Analysis of Problem → Root Cause of Problem → Corrective Action → Evidence of Improvement → Control

- Helps prioritize and track problems and issues
- Ties to Pareto Charts (especially 2nd level) on reports
- Basis for Customer Scorecard, Action Plans, and Forecasted Improvements
- Helps define resource requirements
- Identifies responsible person(s)

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AIR Problem Type

Lean Six Sigma

Improve

Type 1 Problem within the immediate control of the Process Supervisor and Team

Type 2 Problem not within the immediate control of the Process Supervisor and Team but can be resolved with help from resources inside the division

Type 3 Problem for which Team or internal resources cannot identify the true root cause or permanently fix

- 6 Sigma Green Belt projects
- Involve outside suppliers/equipment vendors

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AIR Example

Lean Six Sigma

Improve

	Date Task Complete	Task	Action Date	Due Date	Week Day	+/- 0	Team Member(s)	Check Complete	Notes
A1	08/24/06	Update Action Register	08/23/06	08/23/06	Wed	21	Rollins	08/24/06	Update Action Register and post on group share
								08/24/06	Email notification to CS3 Team informing them of Action Register update:
								08/24/06	Outlook:\\Public Folders\All Public Folders\DIA\CS-3\CS-3 Contacts
A2		Room Reservation	08/23/06	08/23/06	Wed	21	Rollins	08/29/06	Enough seats to accommodate **60** people at DIAC
								08/29/06	Ensure room has JWICS and NIPERNET connectivity
								08/26/06	Ensure room has laptop connectivity
								08/29/06	Ensure Room Access Code
A3		Invite Green Belts	08/30/06	08/30/06	Wed	14	Johnson		Schedule out for next 12 months (see attached schedule for course dates)
									Determine agenda (GB Briefers, GB Learning Session, Group Dialogue)
									Confirm invitee list
									Confirm briefers (2 per MBB suggestion)
									Confirm facilitator for learning session
							Rollins	09/05/06	Contact briefers and associated MBBs via telephone or in person
								09/05/06	Email GB Calibration notice (date, time, place, and briefing template attachment):
								09/05/06	Outlook:\\Public Folders\All Public Folders\DIA\CS-3\CS-3 Contacts
A4		GB Brief Prep	08/31/06	09/08/06	Fri	13	Acton Cantwell DeLaroderie		Work with briefers in preparation for GB Calibration meeting

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Improve Phase Review Questions

Lean Six Sigma

Improve

- Do your improvements address the root causes of the problem?
- Have you mistake-proofed your improvements?
- Do you need to run a pilot?
- Did your team contribute to the improvements?
- What is the implementation plan?

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Improve Exercise

Lean Six Sigma

Improve

TO: Product Calibration Teams
FROM: Mr. Topper, DD4, 007 Projects Division
CC: Performance Management Group
SUBJECT: Cat-A-Pult Working Instructions for Acme Weapons, LLC

- Acme Weapons LLC, a long-time customer, uses our product as part of its ongoing mission and relies on us to provide an accurate and reliable product every time. After extensive interviews and coordination efforts with Acme, we have identified specific customer demands regarding the functionality of our Cat-A-Pult product.
- Because we have to be responsive to customer demands, we will insure that our product arrives at the customer meeting the following defined operational parameters:
  - **Set-up:** Rubber band must connect from catapult launch arm, over the tension adjustment pin, connecting to the anchor pin connecting to the bottom of the catapult.
  - **Accuracy:** Customer must be able to achieve an impact within 3" of a target that is 60"-120" from launch site. Vendors will be required to demonstrate their catapult five (5) times and achieve an 80% or greater success rate to be deemed successful.

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Lean Six Sigma

Control

Define

Measure

Analyze

Improve

Control

Control

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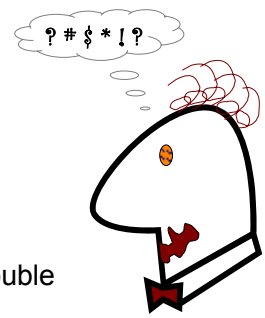
Change

Lean Six Sigma

Control

Definitions of Insanity:



"Doing the same thing over and over and expecting a different outcome!"

…and

"Using the same logic to get you out of trouble that landed you there in the first place!"

-Albert Einstein

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How to Sustain the Gains

Lean Six Sigma

Control

- **Change**
  - Remember Albert? Don't Be Insane
  - Change is uncomfortable for most people
  - Change takes time to take hold and become routine
- **New Instructions**
  - Ensure there are clear SOPs where accountability has been assigned
  - Ensure there are clear work instructions
- **Identify Measures**
  - Measures must now be converted to Metrics and monitored
  - Ensure you have a **response process** should performance dip
- **Training**
  - Ensure everyone is informed and trained on the changes

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Control Plans

Lean Six Sigma

Control

1. Define the Solution
2. Document the Standard Practice
   - Who, What, When, Where, Why, How
3. Established Data Collection Process
4. Determine Control Tools
5. Create Training Documentation
6. Communication & Training Plan
   - Communicate & Train
   - Who, What, When, Where, Why, How
7. Audit Procedures
8. Corrective Action Reports
9. Project Documentation
10. Translation of Learning (s)

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Control Plans

Lean Six Sigma

Control

- A critical piece of a control plan is the process of monitoring the process output
- Control Charts are ideally suited for data monitoring because they tell us:
  - If a process is stable
  - The level of variability from data-point to data-point, over time, relative to the central limit theorem
  - About process trends
  - Special Cause occurrence

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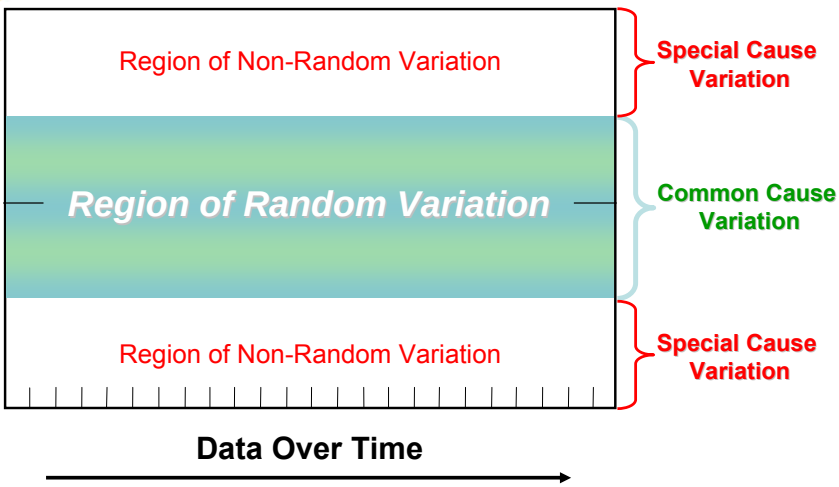
Concept of a Control Chart

Lean Six Sigma

Control



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Control Charts

Lean Six Sigma

Control

- Center Line
  - Average or Mean
  - Median
  - Other
- Upper Control Limit
  - A boundary 3σ above the center line
- Lower Control Limit
  - A boundary 3σ below the center line

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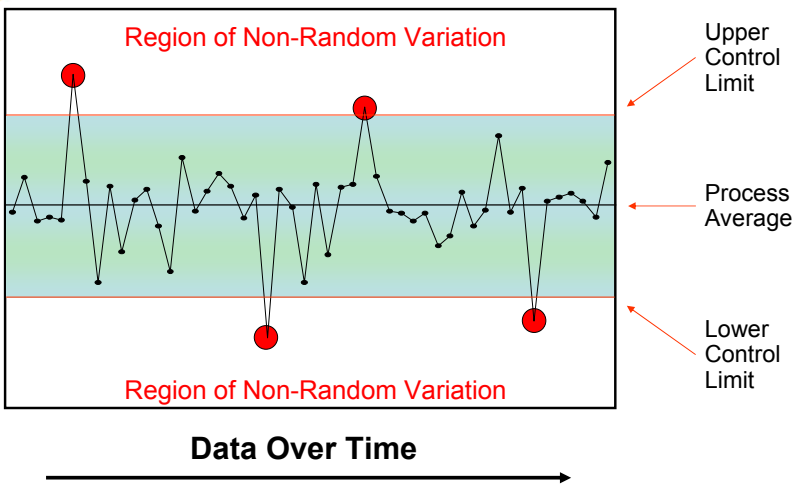
Control Charts

Lean Six Sigma

Control



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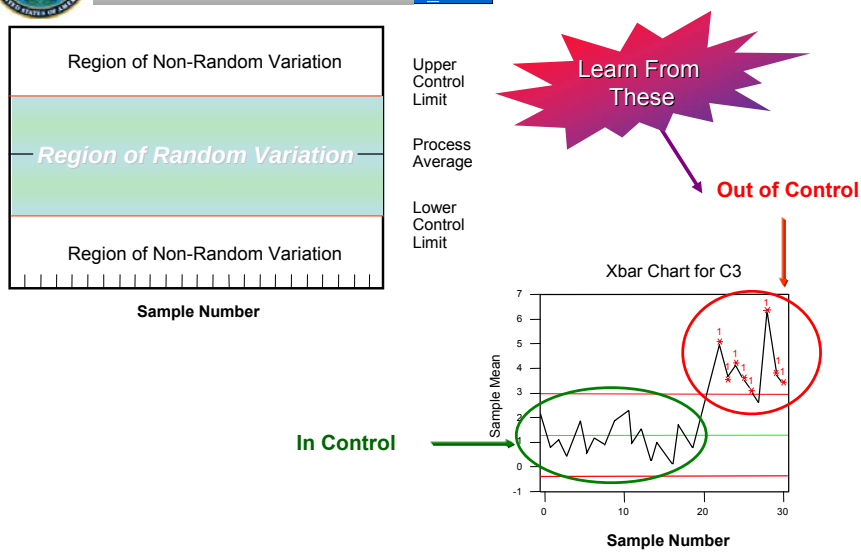
Control Charts

Lean Six Sigma

Control



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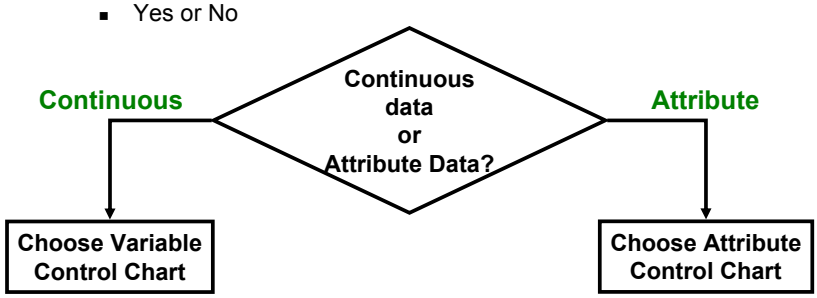
Control Charts

Lean Six Sigma

Control

- The type of control chart used depends on the nature of the data being charted:
  - Variable or Continuous Data
    - Measures
  - Attribute Data
    - Counts
    - Yes or No



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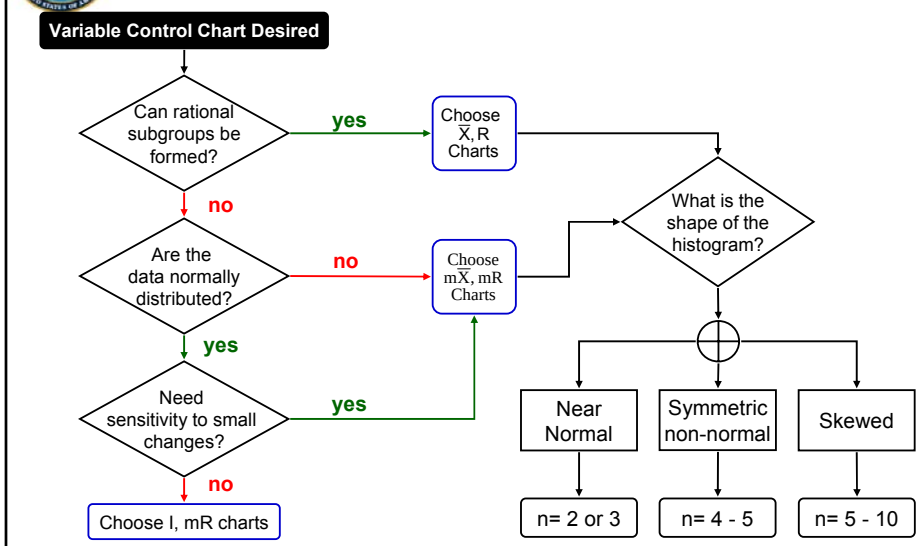
Control Charts

Lean Six Sigma

Control



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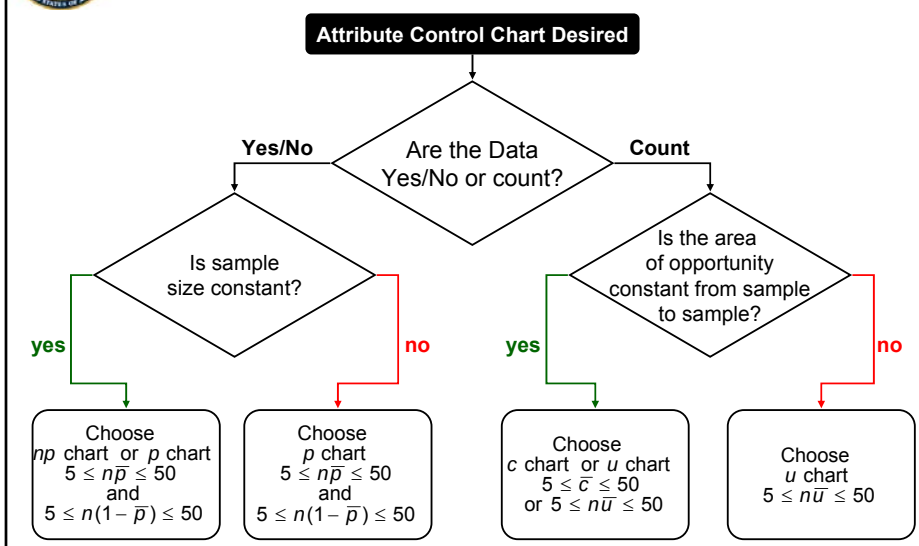
Control Charts

Lean Six Sigma

Control



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Control Charts

Lean Six Sigma

Control

- For Variable data, three basic *pairs* of charts exist:
  1. I,MR: Individual and Moving Range
  2. Xbar,R: Average and Range
  3. mXbar, mR: Moving Average and Moving Range

- For Attributes data, four basic charts exist:
  1. nP: Number chart
  2. P: Proportions chart
  3. C: Count chart
  4. U: Rate

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Project Action Item Register

Lean Six Sigma

Control

PROJECT DESCRIPTION	LEAD	RESOURCES	PROBLEM STATEMENT	NATURE OF DEFECT	CORRECTIVE ACTION PLAN	DUE DATE	PROGRESS	DATE UPDATED
Calibrate temperature control system on all units.	John Doe	Supplier Ellen Technician	Independent measures of ink temperature do not match those on the consol. Each is off by different amounts.	Variant temps between the units causing print defects.	John will contact supplier re: problem, Ellen will use manual to attempt to reset control system and calibrate.	12/14/1999	Completed 11/29/99	11/29/1999

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AIR Example

Lean Six Sigma

Control

- Your AIR will serve as the foundation of your Control Plan

Define The Problem	FMEA Results	Type	Measure	Analyze		Action Start Date	Action End Date	Improve	Control Plan
				Root Cause Analysis	What Action Who (Name)				
Mis ship pallets - outbound skids left in rack	2500	1	Physical inspection of warehouse,Que detail report, Inventory Error messages	scanning pallets before loading, 8125 or postage issues, could not find pallets	Frank gives counseling on individual basis, discuss topics in pre shift meetings	3/12/2002	3/20/2002	Number of Mis-shipped pallet sreduced by 15%	PRESHIFT MEETING ON THE IMPORTANCE OF SCANNING PRODUCT AS YOU LOAD THE TRUCK.
Improper scanning - not watching screen of scanner- incorrect manual input - manual keying	1892	1	excessive error messages	drive by scanning, skids not in active inventory	Supervisor (Greg) discussed porper ways of scanning in daily Pre-shift meeting	3/21/2002	3/21/2002	Improper scanning and manual input decreased	supervisor is monitoring to make sure employees are not scanning inventory on forklifts, unless they are in the cage scanning the upper levels
Not following procedures - product in rack not scanned - Lack of training	1620	1	inventory not scanned report/Inventory error messages, manual keying	Lack of training/Improper checking of product	Sal will conduct pre-shift meeting on the importance of scanning anything that is moved out of location	4/1/2002	4/17/2002	SOP helped new emoployees identify the process	preshift meeting on the proper way to put away product, manual keying prohibited.

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Control Plans: Data Collection/Documentation

Lean Six Sigma

Control

- What data needs to be gathered?
  - Primary metrics
  - Secondary metrics
  - X data
- What form should the data take?
  - Paper
  - Electronic
- How often should each measure be assessed (Gage R&R)?

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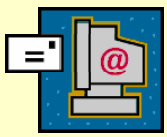
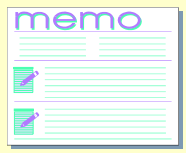
Control Plans: Communicate & Train

Lean Six Sigma

Control

- Utilize ANY and ALL communication vehicles:
  - Memo
  - E-Mail
  - Town Hall Meetings
  - Small Group Meetings
  - Newsletter
  - Flyer
  - Video/DVD
  - Web Page





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Control Plans: Audit

Lean Six Sigma

Control

Auditing is a process for evaluating compliance to written requirements and the effectiveness of those requirements in meeting basic management controls. The evaluation compares reality to requirements.

- Effective audits must be a function used by management
  - The purpose for the audit should be well defined
- Auditors must be qualified to perform their tasks
  - Confirm auditor can perform audit without bias
  - Auditor must understand importance of CPI and Standardization
- Measure against a defined standard
  - Audit is to be performed against written standard operating procedure
- Contain conclusions based on fact
  - Utilization of an effective checklist assures scope and content of audit
- Provide reports that focus on the control system
  - The audit should confirm or refute the control systems work

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Control Plans: Audit

Lean Six Sigma

Control

- Review the Standard Practice
- Create a checklist to confirm the process is being followed and includes:
  - Review of Training Records
    - Including maintenance of Training Records
  - Questions/Observations that encompass the entire scope of the standard practice
    - Use as many open-ended questions as possible
  - Specifics on what to observe
    - This could include yes/no answers to observations
  - Data collection procedures

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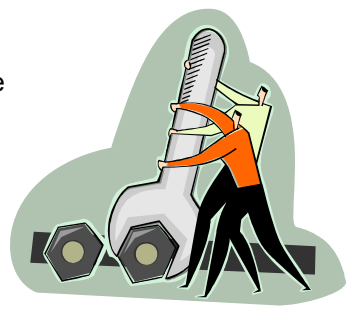
Control Plans: Corrective Action

Lean Six Sigma

Control

Objectives:

- Document significant non-conformities
- Identify a problem and isolate the underlying cause
- Find a solution for the cause of the problem and develop a plan to implement the solution
- Document the Corrective Action Plan
- Establish a schedule of when actions are to be initiated and completed



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Control Plans: Corrective Action

Lean Six Sigma

Control

- Corrective Actions represent systematic issues or conditions
- The following always result in a Corrective Action:
  - Customer Complaints
  - Failure to meet Customer expectations
  - Significant internal or third party audit findings
  - Deviation from documented Standard Practices or Procedures
  - Statistical data or trends indicate the need

- An effective Corrective Action is:
  - Timely
  - Effective
  - Prevents the recurrence of a problem!

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Control Plans: Corrective Action

Lean Six Sigma

Control

- Implement immediate containment solution
- Create an intervention step as a short term solution:
  - Allows problem to be managed during investigation
  - Appropriate steps may be inspection and/or increased supervisor involvement
  - Stop-gap measures ensure the problem does not reoccur

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Control Plans: Translate & Document

Lean Six Sigma

Control

- Next, **Transfer** ownership of the project to the Process Owner
- Ensure Division Director is aware of the transfer data
- Ensure the Process Owner:
  - is aware of the transfer data
  - has been fully trained on all aspects of the control plan
  - is completely aware of his/her responsibility to maintain the control plan going forward
  - is aware of the reporting responsibilities going forward

Leave NO question in ANYONE'S mind
that project and process ownership have changed!

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Example: Project Control Plan Document

Lean Six Sigma

Control

- Creative applications of tools used in other ways during the process

Control Plan #	SIX SIGMA CONTROL PLAN						Date (Original):	Prepared by:
	Black Belt	Key Contact	Equipment / Process					
Control Plan for:							Date (Revised):	Process Manager
	Audit Details						Champion Approval:	
Division:	Audit Frequency	By Supervision	By Dept Manager	By CIM	By Corp CIM		Stakeholder Approval:	
	Date of First Audit						CI Manager Approval:	
							Division Director Approval:	
Process		Measurement		Sample			Audit	
Process	Process Step	Required Action	Process Specification (LSL, USL, Target)	Measurement Technique	Sample Size	Sample Frequency	Control Method	Reaction Plan

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Example: Process Control Plan Document

Lean Six Sigma

Control

Process Control # (Issued #)	Process Name: Metric Review	Process Owner: Director of Continuous Improvement	Original Date: May 21, 2003	Date Revised
		Division Director Approval:	CI Approval/Date: BlackBelt and or CI Mgr.	Hand Off Date:
		Department Manager Approval:	MBB Approval - Jesse Johnson	

Process Control Items						Target Specification - UCL/LCL, Target etc.	Action Item Control					
Process, Machine, Equipment	Machine Number or Equipment I.D.	Process Step	Reference of Process Item (Exhibit, Work Instruction, SOP, Etc.)				Operational Measure	Sample		Control Chart	Audit Frequency	Audit Date
			SOP #	SOP DISC	Metric			Size	Freq.			
Any Special Tools required or needed	Actual Item of Control (WHAT)	Specific to Item	ISO Format	Explanation of ISO #	Key Variation of product	Spec of Item being controlled	Specifics for data measurement	#	#	Type of Control Chart used	Specify the Audit Freq of each line item	Date of last Audit
Obtain Strategic Plan from COO	Catelog Retail Business Unit	Strat Plan Review	CW-1222	ID CTB Objectives	BU Specific	.05 % of Target	EBIT	4	1per QTR	I-MR	QTRLY Report	1st week of each new QTR
Metric Review	Catelog Retail Business Unit	Establish metrics	SW-567	Tie CTB Objectives to KPIs	BU Specific	0.05%	EBIT	4	per QTR	I-MR	Monthly Report	2nd week of each new QTR

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Example: Process Control Plan Document

Lean Six Sigma

Control

Control Plan # 704-1	KE 704 SIX SIGMA CONTROL PLAN	Glasgow Division, R.R.Donnelley & Sons	
Product: KE 704 Strapper/Stacker Stops		Date (Original):	Prepared by:
Key Contact: Jerry Springer (ext. 138) Stan Mills (ext. 257)			Jerry Springer
Core Team: Donnie Bunch, Mike Chapman, Wes Gentry, Bobby Jessie, J.T. Mitchell, Wayne Smith, Sanford Syra, Steve Webb		Date (Revised):	
Champion: Marlin Harker Stakeholder: Drew Coxhead			
Control Plan for:	Attachments: SOP - 015	Champion Approval:	
KE 704 Oval Strapper #1 Performance Level	SOP - 025	Stakeholder Approval:	
		CI Manager Approval:	Jesse Johnson
		Key Facilitator Approval:	

Process	Process Step	Recommended Action	Process Specification (LSL, USL, Target)	Measurement Technique	Sample Size	Sample Frequency	Control Method	Reaction Plan
Binding	Makeready	Set up strapper using settings established as result of DOE	Strapper settings listed on daily strapper stop checksheet and in KE 704 SOP - 015	Key Facilitator measure adherence per PVR audit	N/A	Each Makeready	PVR Audit	Key Facilitator document and review with Craft person involved in non-adherence
Binding	Makeready	Set up cardfeeder using settings established as result of DOE	Cardfeeder settings listed in KE 704 SOP - 025	Key Facilitator measure adherence per PVR audit	N/A	Each Makeready	PVR Audit	Key Facilitator document and review with Craft person involved in non-adherence
Binding	Run	Record all strapper stops (cause and delay time involved) on shift strapper stop checksheets	Procedure outlined in strapper stop manual at Assistant Operator desk	Key Facilitator measure adherence per visual audit	N/A	Shift	Visual audit for compliance	Key Facilitator document and review with Craft person involved in non-adherence
Training	Crew Training	Train new 704 Craft on standard MR strapper settings.	Strapper settings listed on daily strapper stop checksheet and in KE 704 SOP - 015	Key Facilitator measure adherence per PVR audit	N/A	Each Makeready	PVR Audit	Key Facilitator document and review with Craft person involved in non-adherence
Training	Crew Training	Verify all Vacation/Overtime coverage Assistant Operators (non 704) of standard strapper settings	Strapper settings listed on daily strapper stop checksheet and in KE 704 SOP - 015	Key Facilitator measure adherence per PVR audit	N/A	Each Makeready	PVR Audit	Key Facilitator document and review with Craft person involved in non-adherence

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Example: Process Control Plan Document

Lean Six Sigma

Control

Control Plan Product Name: Plant Damage	**Process Owner:** Name/Phone Person assigned by Dept. Mgr. Responsible for overseeing plan **Gail Millward** Ext. 3850	**Date:** Original 1.30.2001	**Date:** Revised
Control Plan Number: ISO format CP-029-30-001A	**Core Team Members:** Reference for future of Team know ledge & Involvement Dario Cruz, Skeeter Dominguez, Dar - Meredith, Dennis Lancaster, Troy Valentine	**CI Approval**/Date: BlackBelt and or CI Mgr. Rob Wenning 1.30.2001	
		Department Mgr. Approval/Date: Ultimately responsible person for comp Gail Millward 1.30.2001	
Approved By - Jesse Johnson	**Black Belt:** Name/Phone Rob Wenning Ext. 3844 / **Champion:** Name/Phone Gail Millward Ext. 3850	**Other Approval**/Date: As needed, Example DD, HR, ENG.	

Action Item						Target Specification	Action Item Control					
Process Name/ Operation Description	Machine, Device, Tools For Mfg.	Reference of Process Item (Exhibit, Work Instruction, SOP, Etc.)			Responsibility: Name/Phone		Measurement	Sample		Control Method	Responsibility: Name/Phone	Date
		No.	Product	Process				Size	Freq.			
Actual Item of Control	Specific to Item	ISO Format	Explanation of ISO #	Key Variation of product	person assigned	Spec of Item being controlled	Specifics for data measurement	#	#	Specifics for data Control	person assigned	
1) Train Operators on SOP'S	Clamp truck	01,02,03, 04,05	WI-029-30-..	Damage Prevention	Monica Campbell Ext. 3894	Every Hoist Operator	Receipt of Train-ing document			Sign form before leaving class	Rob Wenning Ext. 3844	1.26.01
Coordinator Create Audit Text	Clamp truck	01,02,03, 04,05	WI-029-30-..	Damage Prevention	Rob Wenning 3844	Written & Visual criteria	Check-Off List				Allan Fairchild Ext. 3738	2.9.01
3) Text created for DLS Audit	Clamp truck	01, 03	WI-029-30-..	Transport Roll TD Inspection	Allan Fairchild Ext. 3737	Written & Visual criteria	Check-Off List				Allan Fairchild Ext. 3739	2.16.01
4) Leads Audit	Clamp truck	AU-001 ,2,3,,4,5	Audit WI-029-30-001,2,3,4,5	Audit Form	Dar Meredith Ext. 3952	Leads, Coordinator & Receiver	Check-Off List			Pass / Fail	Allan Fairchild Ext. 3738	2.23.01
5) Hoist Operator Audit	Clamp truck		Audit WI-029-30-001,2,3,4,5	Audit Form	Materials Dept. Leads	Every Hoist Operator	Check-Off List			Pass / Fail	Allan Fairchild Ext. 3738	2.28.01
6) DLS Driver Audit	Clamp truck	01, 03	WI-029-30-..	Transport Roll TD Inspection	Allan Fairchild *days* Leads *nights*		Check-Off List			Pass / Fail	Allan Fairchild Ext. 3739	3.12.01

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Summary

Lean Six Sigma

Control

Control plans must identify:

- What we are measuring
- How we monitor
- What we do when the process is out of control

> "I have been impressed with the urgency of doing.
> Knowing is not enough; we must apply.
> Being willing is not enough; we must do."
>
> **Leonardo da Vinci**

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UNCLASSIFIED

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Define

Measure

Analyze

Improve

Control

Analyze

MINITAB

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Agenda

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Introduction to Minitab window and icons
- Time Plots
  - Stratified Time Plots
- Run Charts
- Histograms and Dot Plots
- Box Plots
- Scatter Plots
- Pareto Charts
- Individual Control Charts

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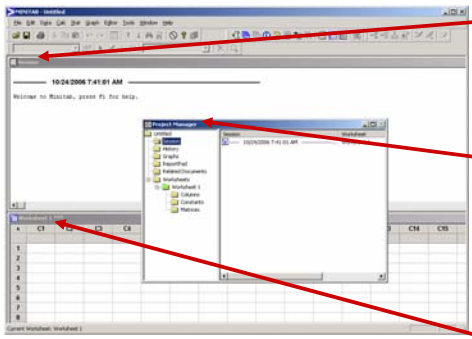
Minitab Windows

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Minitab opens three windows when launched:



- Session
  - Only shows text.
  - It shows log of work performed including commands and graphs, and data analysis results.
- Project Manager
  - Lists all Worksheets, Sessions, and Graphs in the current Project.
  - Can be used to re-name any window within the Minitab Project (graphs, worksheets, etc.).
- Worksheet 1
  - Looks like MS Excel.
  - Data goes in this window.
  - Data MUST be in column format.
  - Columns should be labeled on first row (shaded row).

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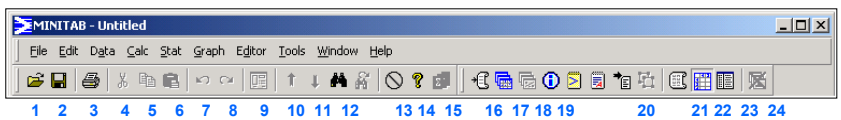
Minitab Icons

Lean Six Sigma

Define | Measure | Analyze | Improve | Control



1. Open Project (not a worksheet)
2. Save Project (not worksheet)
3. Print (contents of Active Windows)
4. Cut
5. Copy
6. Paste
7. Undo
8. Redo
9. Bring up last dialog box (repeats last request or command)
10. Move up in the Session window
11. Move down in the Session window
12. Find or look-up (similar to search in MS Office)

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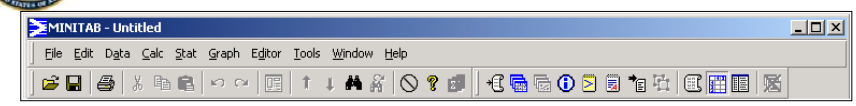
Minitab Icons

Lean Six Sigma

Define | Measure | Analyze | Improve | Control



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

13. Cancel Command (useful when Minitab locks up during calculation or takes too long to come up with analysis)
14. Help
15. Statistical Guide (explains statistical concepts related to the last command or calculation preformed)
16. Session icon (brings the Session window to front)
17. Worksheet icon (brings the active Worksheet to front)
18. Plot icon (brings the Graphs to front)
19. Show Information (describes contents of current Worksheet)
20. Related Documents icon (stores related links)
21. Go to Session Window (goes to the Session window)
22. Go to Data Window (toggles between all Worksheets)
23. Project Manager Window (goes to Project Manager view)
24. Close All Graphs (deletes all graphs in current Minitab Project)

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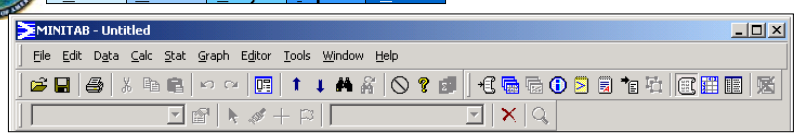
Graph Editing Toolbar

Lean Six Sigma

Define | Measure | Analyze | Improve | Control



1 2 3 4 5 6 7 8

1. Select Graph Element (i.e. axis label, graph title, etc.).
2. Edit Select Graph Element (allows user to edit the graph element).
3. Select Mode (user can point-and-click to select graph elements).
4. Brush Mode (to identify points on a graph [identification shows in the *Brushing* window]).
5. Crosshair Mode (shows coordinates of any point in a graph).
6. Add List (adds elements to a graph i.e. reference line, etc.).
7. Delete (deletes selected graph element).
8. Zoom (zoom on graph).

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Importing Data

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Open catapult Excel worksheet *Wave_7_Catapult.xls*.

Catapult Teams

Time Stamp	Team 1 T1-Distance	T1-Variation	T1-Pass/Fail	Pass/Fail Conversion	Time Stamp	Team 2 T2-Distance	T2-Variation	T2-Pass/Fail	Team 3 T3-Distance	T3-Variation	T3-Pass/Fail	Team 4 T4-Distance	T4-Variation	T4-Pass/Fail	Team 5 T5-Distance	T5-Variation	T5-Pass/Fail
3/1/2006	121		P	1	10/1/2006	22		F	101		F	104		F	136		
3/2/2006	121		P	1	10/2/2006	21		F	96		F	104		F	127		
3/3/2006	120		P	1	10/3/2006	21		P	99		P	104		F	127		
3/4/2006	112		P	1	10/4/2006	21		F	79		F	103		F	130		
3/5/2006	120		P	1	10/5/2006	21		F	96		F	104		F	132		
3/6/2006	144		F	0	10/6/2006	20		F	75		F	103		F	114		
3/7/2006	144		P	1	10/7/2006	20		P	76		P	103		F	130		
3/8/2006	153		P	1	10/8/2006	20		P	94		P	103		F	123		
3/9/2006	147		P	1	10/9/2006	20		P	88		P	102		F	123		
3/10/2006	152		P	1	10/10/2006	20		F	43		F	103.5		F	123		
3/11/2006	120		F	0	10/11/2006	18		F	104		F	102		F	97		
3/12/2006	137		F	0	10/12/2006	18		F	97		F	102		F	115		
3/13/2006	117		P	1	10/13/2006	19		F	100		F	91		F	119		
3/14/2006	118		P	1	10/14/2006	19		F	94		F	100		F	123		
3/15/2006	128		P	1	10/15/2006	19		F	89		F	79		F	121		
3/16/2006	126		P	1	10/16/2006	19		F	93		F	90		F	120		
3/17/2006	156		F	0	10/17/2006	19		F	93		F	92		F	124		
3/18/2006	132		P	1	10/18/2006	19		F	96		F	96		F	125		
3/19/2006	136		F	0	10/19/2006	19		F	93		F	94		F	128		
3/20/2006	152		P	1	10/20/2006	19		F	88		F	88		F	117		
3/21/2006					10/21/2006												
3/22/2006					10/22/2006												
3/23/2006					10/23/2006												
3/24/2006					10/24/2006												
3/25/2006					10/25/2006												
3/26/2006					10/26/2006												
3/27/2006					10/27/2006												
3/28/2006					10/28/2006												
3/29/2006					10/29/2006												
3/30/2006					10/30/2006												
Total	2675	0				384	0		1788	0		1967.5	0		2466	0	
Mean	133.75	#DIV/0!				19.20	#DIV/0!		89.40	#DIV/0!		98.38	#DIV/0!		123.30	#DIV/0!	
Std. Dev.	14.07	#DIV/0!				1.68	#DIV/0!		12.41	#DIV/0!		7.68	#DIV/0!		8.87	#DIV/0!	

- Notice:
  - Data on screen may not match current Wave data.

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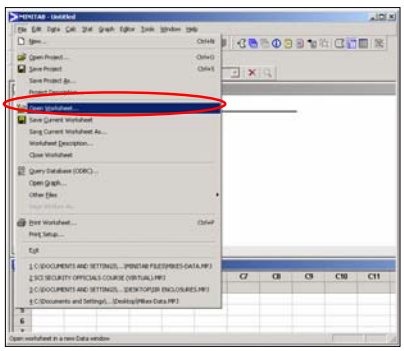
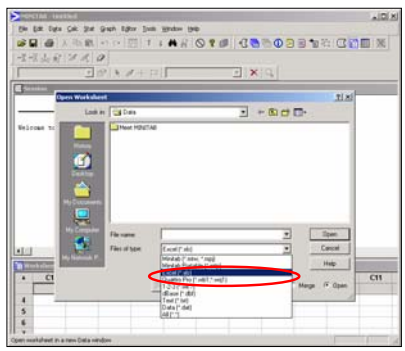
Importing Data

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Start Minitab and open Excel worksheet *Wave_7_Catapult.xls:*
  - Go to *File* > *Open Worksheet*.
  - Change “Files of type:” to Excel(*.xls).
  - Search and open file.





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Importing Data

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

	C1	C2-T	C3-T	C4-T	C5-T	C6-T	C7-T	C8-T	C9-T	C10-T	C11-T
1		Catapult Teams									
2											
3			Team 1					Team 2			Team 3
4		Time Stamp	T1-Distance	T1-Variation	T1-Pass/Fail	Pass/Fail Conversion	Time Stamp	T2-Distance	T2-Variation	T2-Pass/Fail	T3-Distance
5		38961	121		P	1	38991	22		F	101
6		38962	121		P	1	38992	21		F	96
7		38963	120		P	1	38993	21		P	98
8		38964	112		P	1	38994	21		F	78
9		38965	128		P	1	38995	21		F	86
10		38966	144		F	0	38996	20		F	75
11		38967	144		P	1	38997	20		P	76
12		38968	153		P	1	38998	20		P	94
13		38969	147		P	1	38999	20		P	88
14		38970	152		P	1	39000	20		F	49
15		38971	120		F	0	39001	18		F	104

- Notice:
  - The Title Row (gray row) is empty
  - Column 1 is empty
  - In Columns 2 and 7 the dates are not in the proper format
  - When you scroll down you can find the *Total*, *Mean*, and *Std. Dev.* values
  - This worksheet is NOT USABLE for analysis in Minitab!

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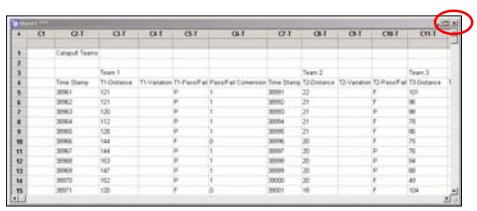
Importing Data

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Rules to Remember when importing data from Excel:
  - Data should be in “column” order
  - Place column titles on the first row (don’t repeat titles!)
  - Do not use special format numbers ($, %, etc.). Minitab will assume that the numbers are “text.” Also, don’t have multiple rows of titles (e.g. *C3-T*)
  - Do not use cells to calculate *Total*, *Mean*, and *Std. Dev.*, etc. Minitab will assume they are just one more data point (and skew your data!)
  - If you use formulas, realize that Minitab will only copy the calculated value -not the formula

- Close worksheet *Sheet1*:
  - Click on the “X” button on the top-right corner of the worksheet
  - If asked to save the worksheet click on “No”
  - A new worksheet should automatically appear (*Sheet2*)



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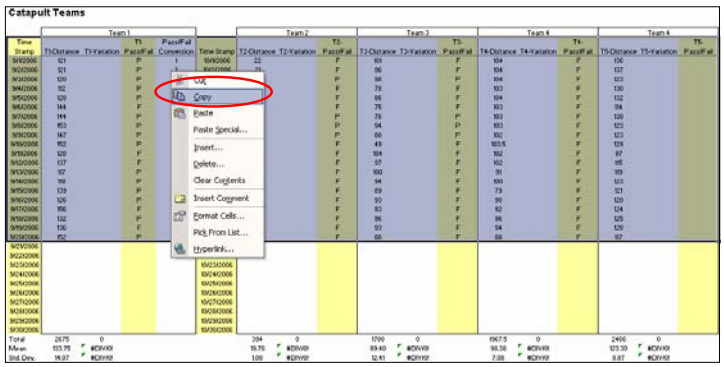
Importing Data

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Go to the catapult Excel worksheet *Wave_7_Catapult.xls*
- Highlight the cells containing the groups data
- *Copy* only the "relevant data"



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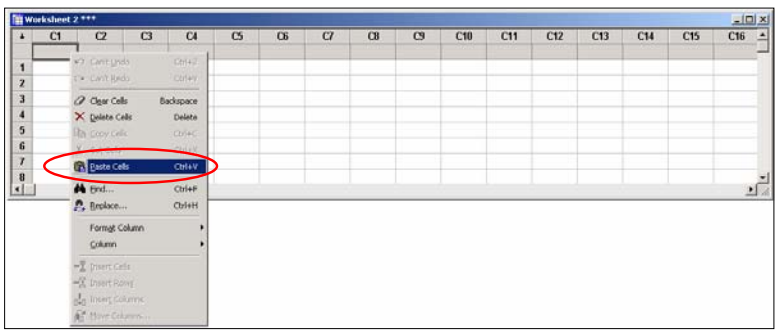
Importing Data

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Go to Minitab and paste the Excel data
  - Paste starting on the top-left corner gray cell
    - Right-mouse click on the cell and select "*Paste Cells*"



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Importing Data

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Excel data should now appear in the Minitab worksheet

Worksheet 2 ***

	C1-D	C2	C3	C4-T	C5	C6-D	C7	C8	C9-T	C10	C11
	Time Stamp	T1-Distance	T1-Variation	T1-Pass/Fail	Pass/Fail Conversion	Time Stamp_1	T2-Distance	T2-Variation	T2-Pass/Fail	T3-Distance	T3-Variation
1	9/1/2006	121		P	1	10/1/2006	22		F	101	F
2	9/2/2006	121		P	1	10/2/2006	21		F	96	F
3	9/3/2006	120		P	1	10/3/2006	21		P	98	P
4	9/4/2006	112		P	1	10/4/2006	21		F	78	F
5	9/5/2006	128		P	1	10/5/2006	21		F	86	F
6	9/6/2006	144		F	0	10/6/2006	20		F	75	F
7	9/7/2006	144		P	1	10/7/2006	20		P	76	P
8	9/8/2006	153		P	1	10/8/2006	20		P	94	P

- Notice:
  - Columns 1 and 6 end with "-D" which stands for *date*
  - Columns 4 and 9 end with "-T" which stands for *text*
  - Other columns (C2, C3, etc.) end with the column number which means that they are *numerical* columns
  - Minitab re-titled Column C6-D as *Time Stamp_1*

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Data Format

Lean Six Sigma

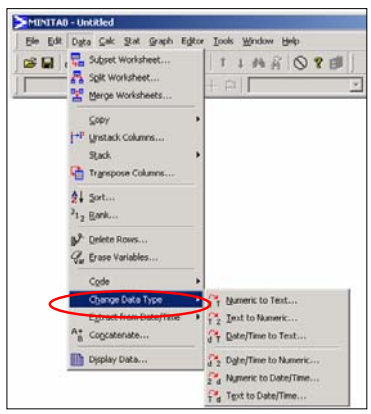
Define | Measure | Analyze | Improve | Control

The only THREE data formats are:

- **Numerical**
  - Positive or negative numbers expressed in decimal format
- **Date**
  - Calendar dates that can be expressed in various formats (i.e. mmm-yy, dd-mm-yy, etc.)
- **Text**
  - Any combination of letters and numbers
  - Minitab will not recognize these cells as having numerical values

To change data format:

- *Data>Change Data Type*



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Time Plot

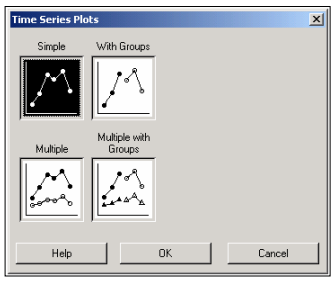
Lean Six Sigma

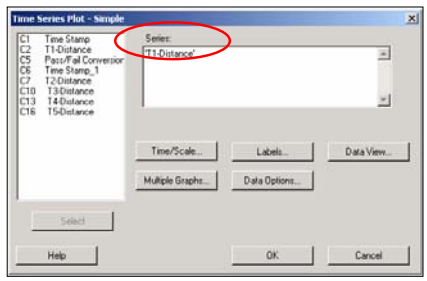
Define | Measure | Analyze | Improve | Control

DEFINITION: Graph of data in time order

TASK: Create a Time Plot of *T1-Distance*:

- *Graph>Time Series Plot>Simple*
- Select *Simple* plot - Click *OK*
- Click inside the *Series* box - *Select T1-Distance*
- Click *OK*





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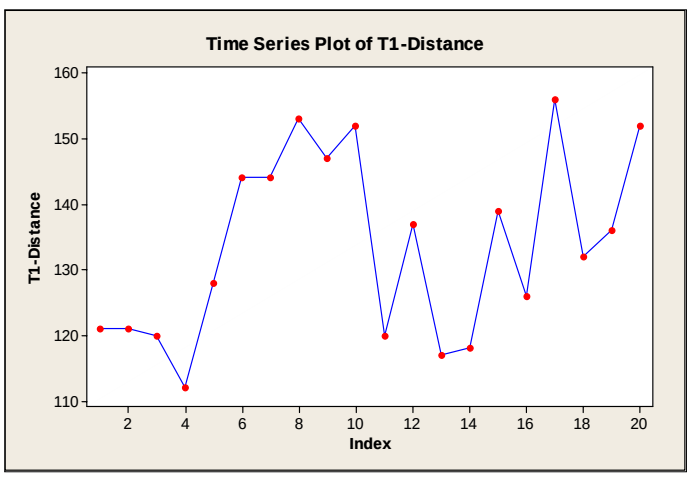
Time Plot

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



UNCLASSIFIED

Time Plot: Date Labels

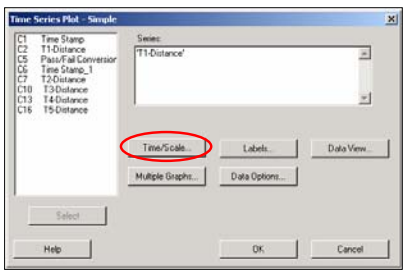
Lean Six Sigma

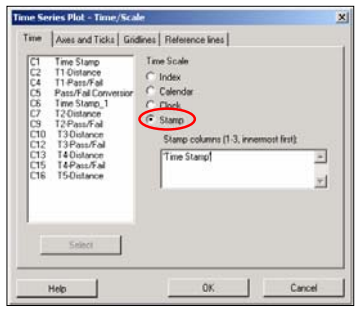
Define | Measure | Analyze | Improve | Control

TASK: Re-generate Time Plot with date labels:

- On the toolbar click the icon "Bring up last dialog box" (#9) or use "Control-E"

- Click *Time/Scale* button>*Time* tab>*Stamp* button
- Click inside the *Stamp* dialogue box>on the left, double click *Time Stamp* column to make it appear in "*Stamp columns*" dialog box
- Click *OK* twice to generate the graph





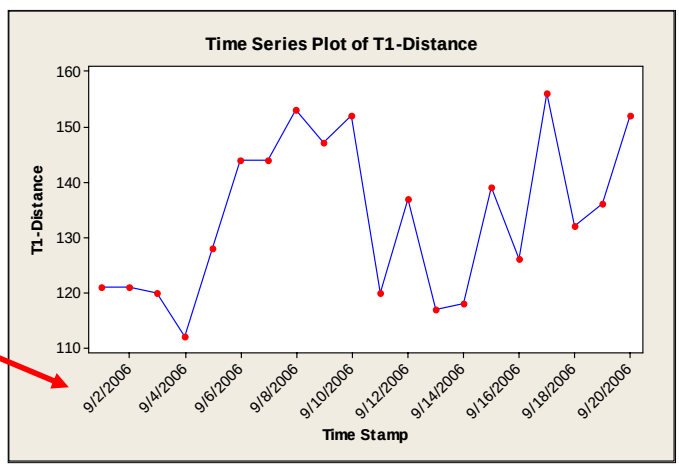
UNCLASSIFIED

Time Plot: Date Labels

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



dates

UNCLASSIFIED

Time Plot: Chart Points

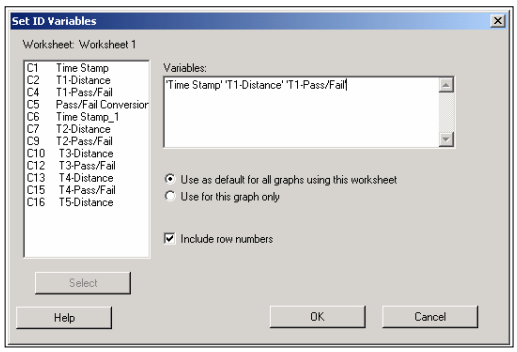
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

TASK: Get Time Plot with chart points information:

- From the Graph Editing Toolbar select *Brush Mode*

- Click *Editor>Set ID Variables…>Select Columns*>OK



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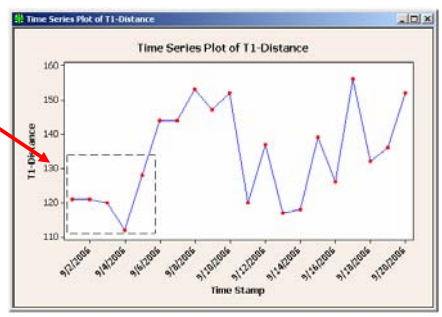
Time Plot: Chart Points

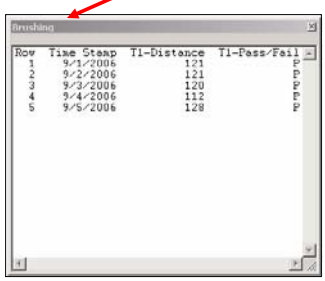
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:

- Select the first five data points on graph by dragging mouse and creating box over them
- Data points information will appear in the *Brushing* window





UNCLASSIFIED

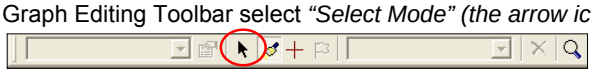
Time Plot: Stratified

Lean Six Sigma

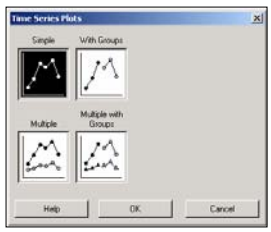
Define | Measure | Analyze | Improve | Control

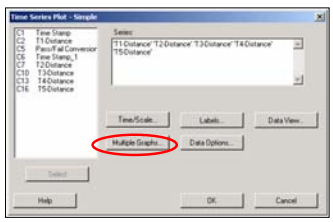
TASK: Plot all five teams distance data in the same graph:

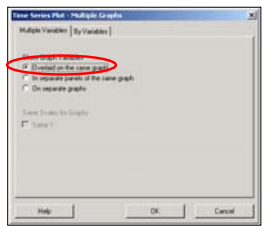
- From the Graph Editing Toolbar select *"Select Mode" (the arrow icon)*



- Click *Graph>Time Series Plot>Simple*
- Click inside *Series* box. Select *T1-Distance*, *T2-Distance*, *T3-Distance*, *T4-Distance*, and *T5-Distance*
- Click the *Multiple Graphs* button and select the *Multiple Variables* tab. Select "*Overlaid on the same graph*." Click *OK* twice







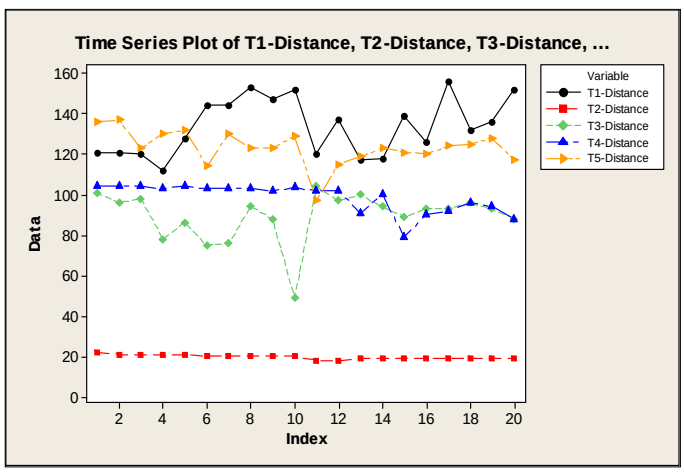
UNCLASSIFIED

Time Plot: Stratified

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



UNCLASSIFIED

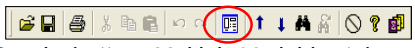
Time Plot: Stratified

Lean Six Sigma

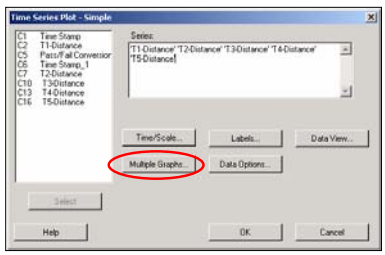
Define | Measure | Analyze | Improve | Control

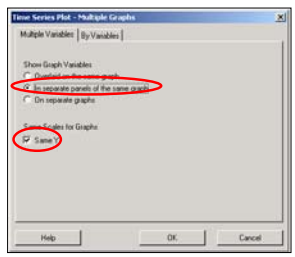
TASK: Make Stratified Time Plot with separate lines for each team in separate panels:

- On the toolbar click the icon "Bring up last dialog box" (#9) or use "Control-E"



- Select *Multiple Graphs* button>*Multiple Variables* tab
- Select "*In separate panels of the same graph*" and check "*Same Y*"
- Click *OK* twice





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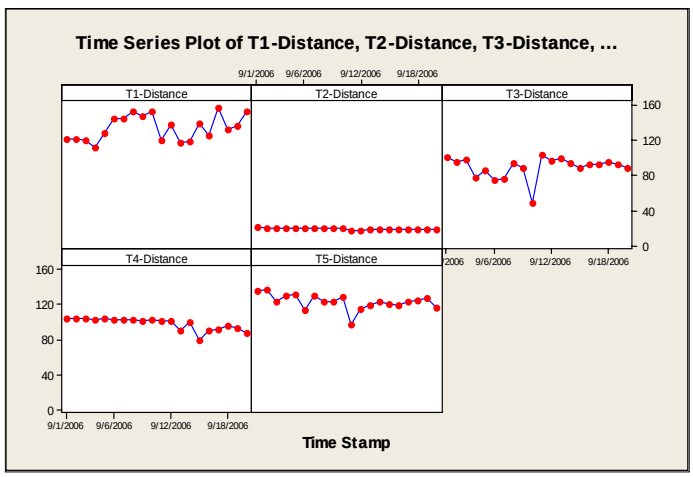
Time Plot: Stratified

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



UNCLASSIFIED

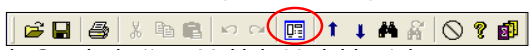
Time Plot: Stratified

Lean Six Sigma

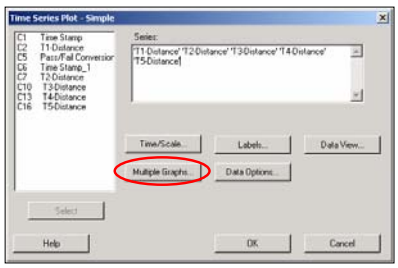
Define | Measure | Analyze | Improve | Control

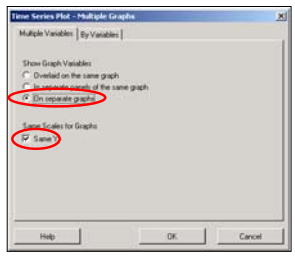
TASK: Make Stratified Time Plot with separate graphs for each team:

- On the toolbar click the icon “Bring up last dialog box” (#9) or use “Control-E”



- Select *Multiple Graphs* button>*Multiple Variables* tab
- Select “*On separate graphs*” and check “*Same Y*”
- Click *OK* twice





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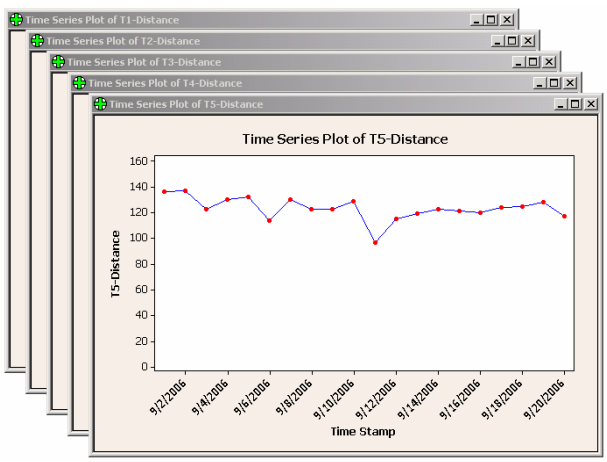
Time Plot: Stratified

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



UNCLASSIFIED

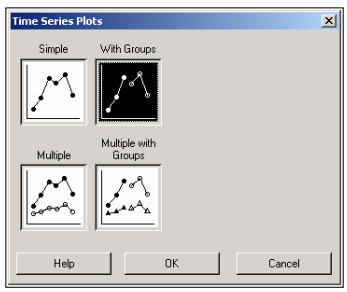
Time Plot: Stratified

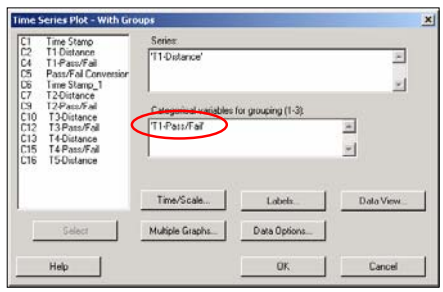
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

TASK: Stratify *T1-Distance* by *T1-Pass/Fail:*

- Click *Graph>Time Series Plot>With Groups*
- Select *T1-Distance* as *Series*
- Select *T1-Pass/Fail* as *Categorical Variables for Grouping*
- Click *Time/Scale* tab - Select *Time Stamp* for *Stamp*
- Click *OK* twice





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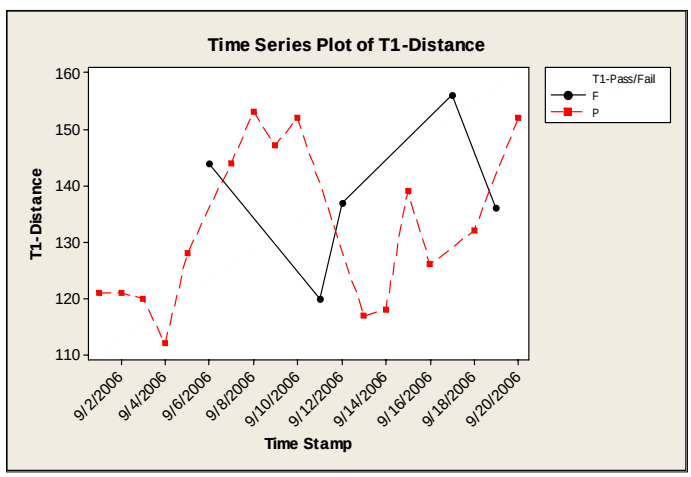
Time Plot: Stratified

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



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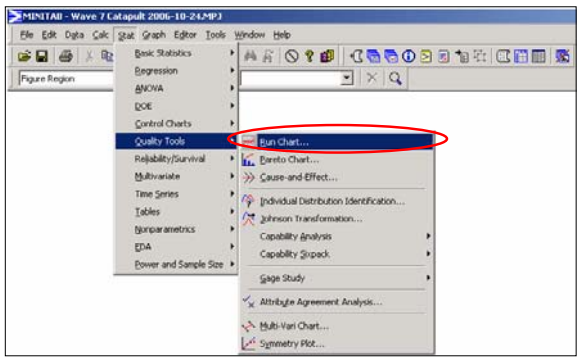
Run Chart

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Alternate to Time Series Plots

- Go to the *Stat* menu:
  - Go to *Quality Tools*
    - Select *Run Chart*



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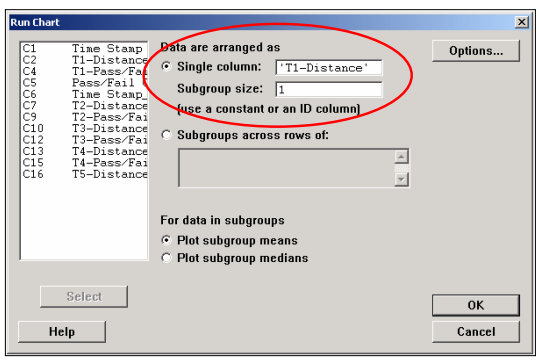
Run Chart

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

TASK: Create Run Chart for *T1-Distance*:

- Select *T1-Distance* as *Single column* box
- Set *Subgroup Size* to 1
- Click *OK*



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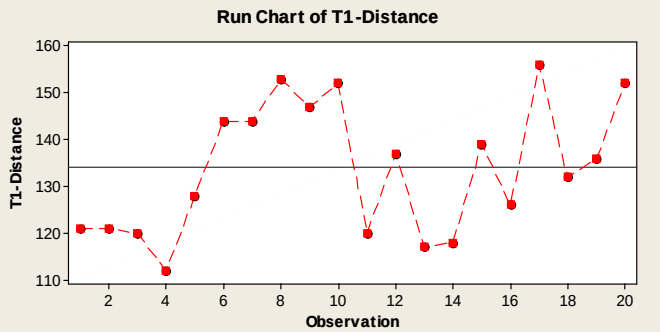
Run Chart

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



Number of runs about median:	10
Expected number of runs:	11.00000
Longest run about median:	5
Approx P-Value for Clustering:	0.32295
Approx P-Value for Mixtures:	0.67705

Number of runs up or down:	14
Expected number of runs:	13.00000
Longest run up or down:	3
Approx P-Value for Trends:	0.71094
Approx P-Value for Oscillation:	0.28906

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Histograms & Dot Plots

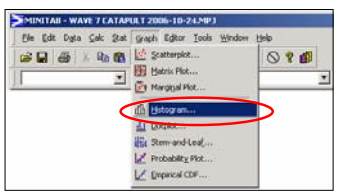
Lean Six Sigma

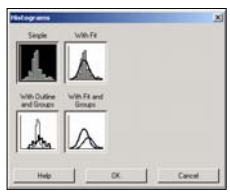
Define | Measure | Analyze | Improve | Control

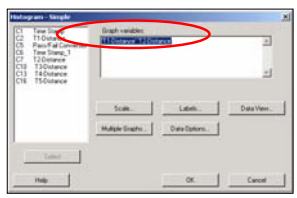
DEFINITION: Histograms and Dot Plots are "Frequency Plots." They are used to show the average, spread, and shape of the data distribution.

TASK: Create histograms for *T1-Distance* and *T2-Distance*

- *Go to Graph* menu > *Histogram* >Select *Simple*
- *Click in the Graph variables box and select T1-Distance* and *T2-Distance as the variables to plot*







OSD, Business Transformation L6σ Green Belt Training

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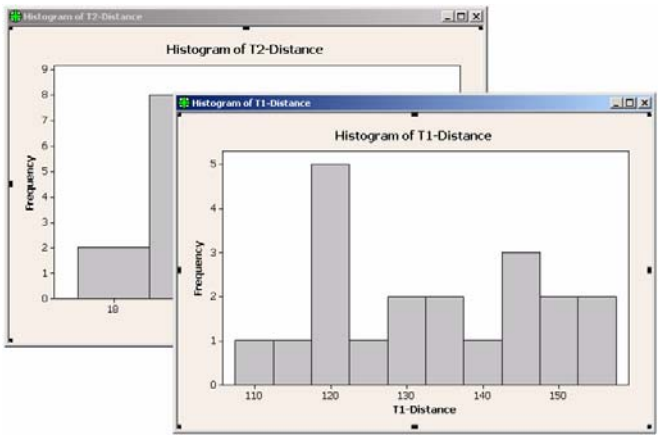
Histograms & Dot Plots

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



UNCLASSIFIED

Histograms

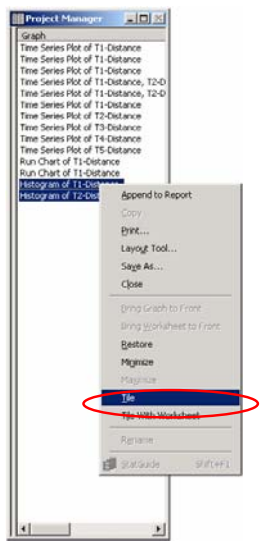
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

TASK: View the graphs side-by-side

- Select the *Show Graphs* Button

- Select both histogram charts in the *Project Manager* window
- Right mouse click and select *Tile*



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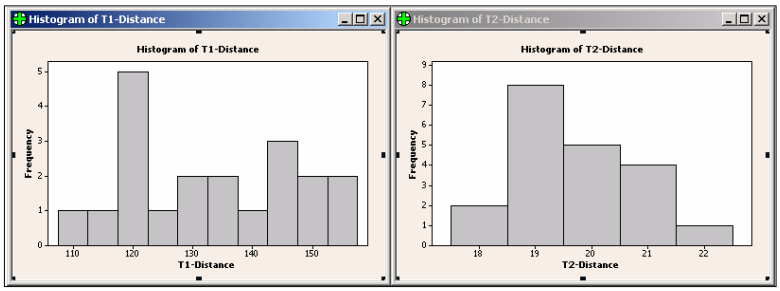
Histograms

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



UNCLASSIFIED

Histograms

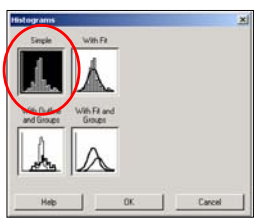
Lean Six Sigma

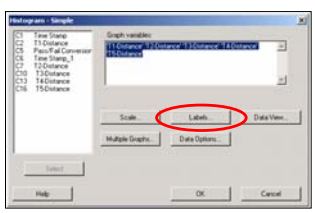
Define | Measure | Analyze | Improve | Control

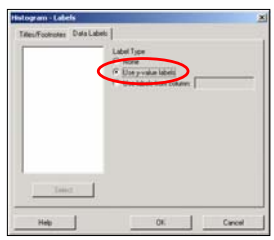
TASK: Plot all five histograms on a single chart:

- Click the *Show Graphs* button until the Project Manager is shown without graphs.

- Go back to the *Graph* menu and select *Histogram*
- Select *Simple*
- Click inside the *Graph Variables* dialog box > select *T1-Distance, T2-Distance, T3-Distance, T4-Distance, and T5-Distance*
- Click the *Labels* button. Select the *Data Labels* tab and check *Use y-value labels*
- Click *OK* twice







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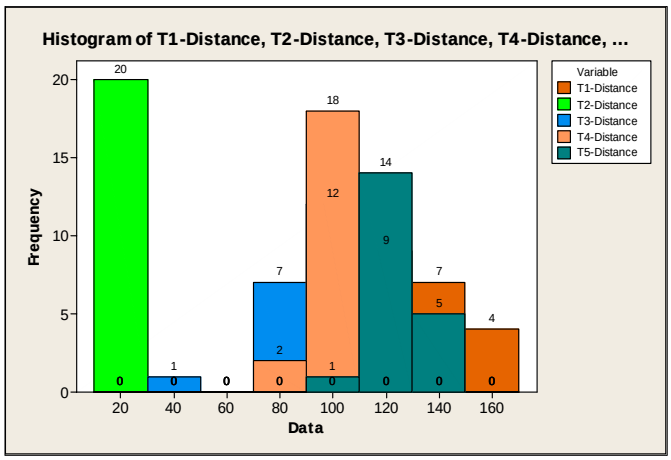
Histograms

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



UNCLASSIFIED

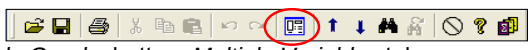
Time Plot: Stratified

Lean Six Sigma

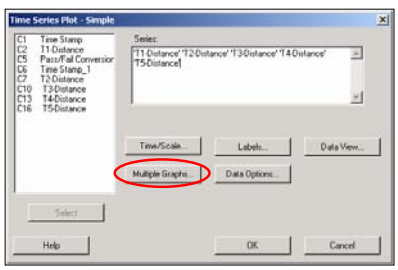
Define | Measure | Analyze | Improve | Control

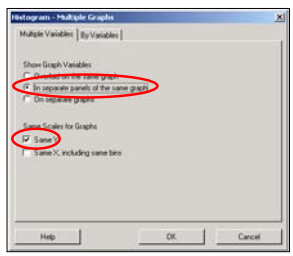
TASK: Plot all five histograms in separate panels of a single chart:

- On the toolbar click the icon "Bring up last dialog box" (#9) or use "Control-E"



- Select *Multiple Graphs* button>*Multiple Variables* tab
- Select "*In separate panels of the same graph*" and check "*Same Y*"
- Click *OK* twice





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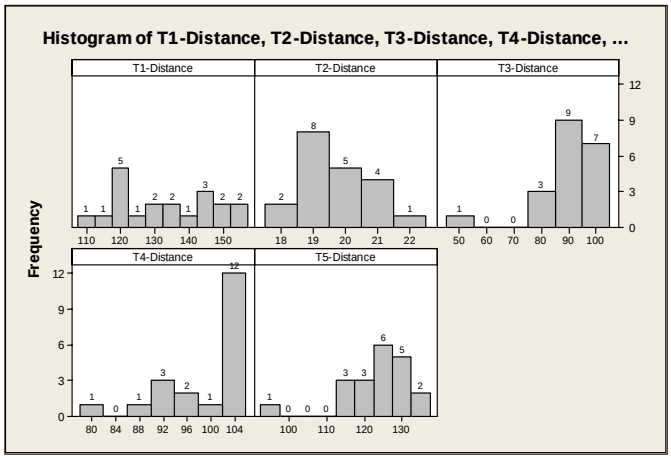
Histograms

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



UNCLASSIFIED

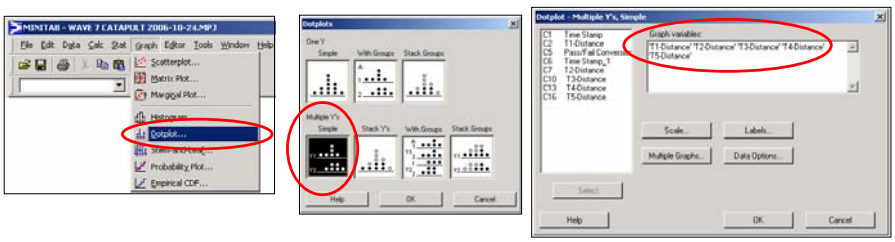
Dot Plots

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

TASK: Make Dot Plots of all five teams distances:

- Go to *Graph* menu > *Dotplot*
- Select *Multiple Ys Simple* - Click *OK*
- Click inside the *Graph Variables* dialog box. Select *T1-Distance, T2-Distance,T3-Distance, T4-Distance,* and *T5-Distance*
- Click *OK*



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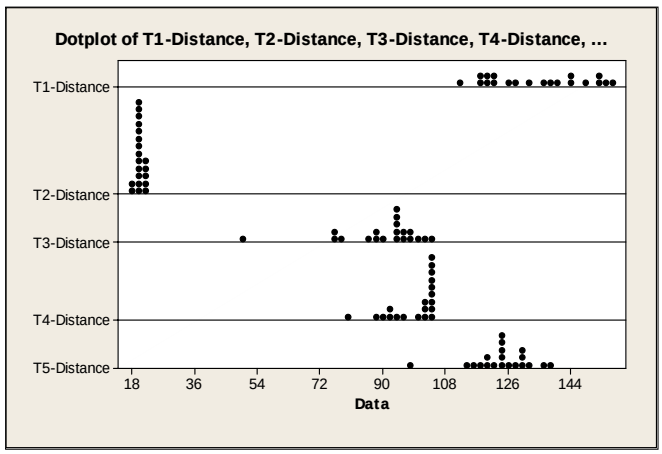
Dot Plots

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



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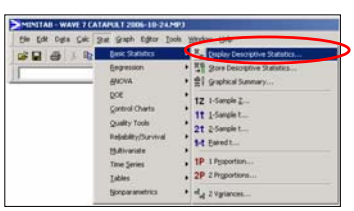
Histograms and Dot Plots

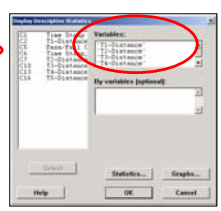
Lean Six Sigma

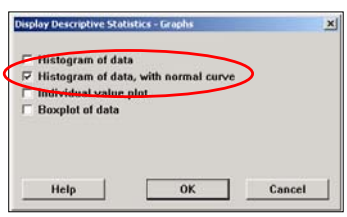
Define | Measure | Analyze | Improve | Control

TASK: Alternate way to get histograms and dot plots in Minitab:

- Go to *Stat* menu > *Basic Statistics* > *Display Descriptive Statistics*
- Click in the *Variables* box and select *T1-Distance, T2-Distance, T3-Distance, T4-Distance,* and *T5-Distance*
- Click on *Graphs*. Check *Histograms of data, with normal curve*
- Click *OK* twice
- Minitab displays the descriptive statistics in the Session window and the graphs in their own windows







UNCLASSIFIED

Histograms and Dot Plots

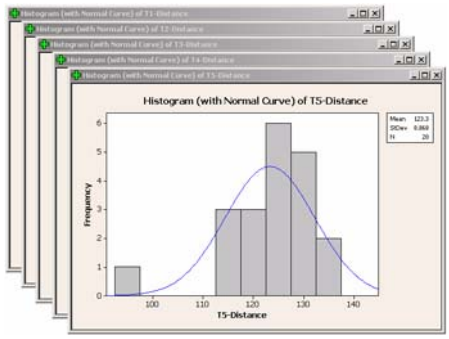
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
T1-Distance	20	0	133.75	3.15	14.07	112	120.25	134	146.25
T2-Distance	20	0	19.7	0.242	1.081	18	19	19.5	20.75
T3-Distance	20	0	89.4	2.77	12.41	49	86.5	93	96.75
T4-Distance	20	0	98.38	1.58	7.08	79	92.5	102	103.38
T5-Distance	20	0	123.3	1.98	8.87	97	119.25	123	129.75

Variable	Maximum
T1-Distance	156
T2-Distance	22
T3-Distance	104
T4-Distance	104
T5-Distance	137



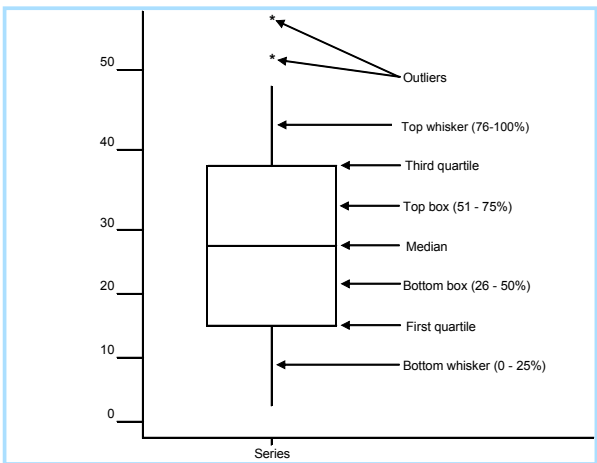
UNCLASSIFIED

Boxplots

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Definition: Box plots summarize data in percentages (%) using the Median (not the Mean!)



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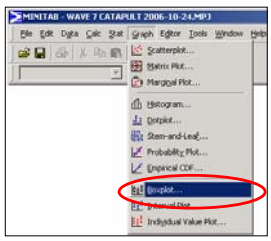
Boxplots

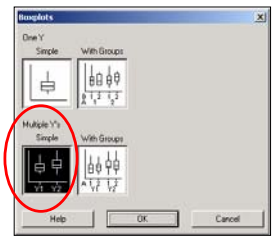
Lean Six Sigma

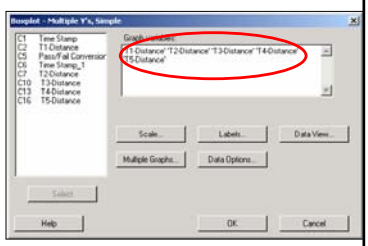
Define | Measure | Analyze | Improve | Control

TASK: Make Dot Plots of *T1-Distance, T2-Distance, T3-Distance, T4-Distance,* and *T5-Distance*:

- Go to *Graph* menu > *Boxplot*
- Select *Multiple Ys Simple* > Click *OK*
- Click in the *Variables* box and select *T1-Distance, T2-Distance,T3-Distance, T4-Distance,* and *T5-Distance*
- Click OK twice







OSD, Business Transformation L6σ Green Belt Training

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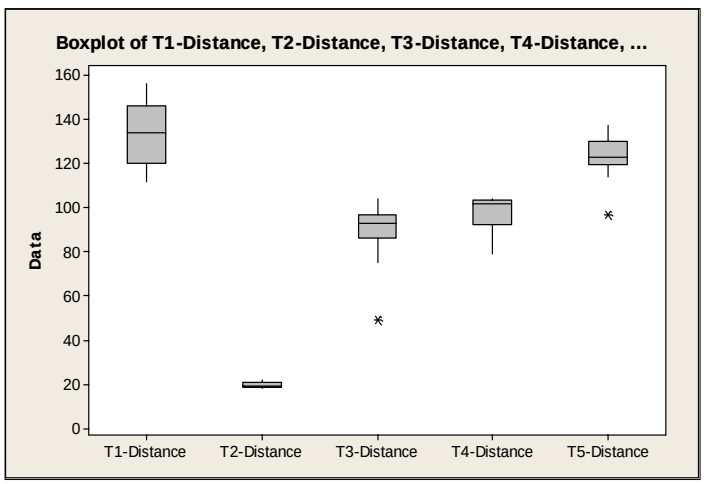
Boxplots

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



OSD, Business Transformation L6σ Green Belt Training

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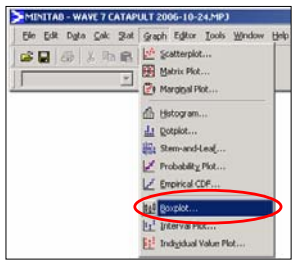
Boxplots

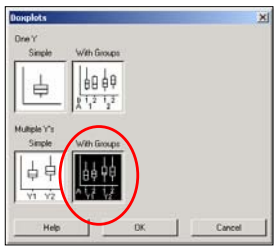
Lean Six Sigma

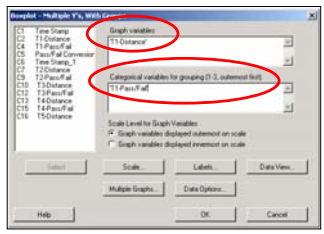
Define | Measure | Analyze | Improve | Control

TASK: Display difference between the *pass* (P) and *fail* (F) for T1-Distance:

- Go to *Graph* menu > *Boxplot*
- Select *Multiple Ys with Groups*
- Click in the *Variables* box and select *T1-Distance*
- Click inside *Categorical variables for grouping* > select *T1-Pass/Fail*
- Click *OK*







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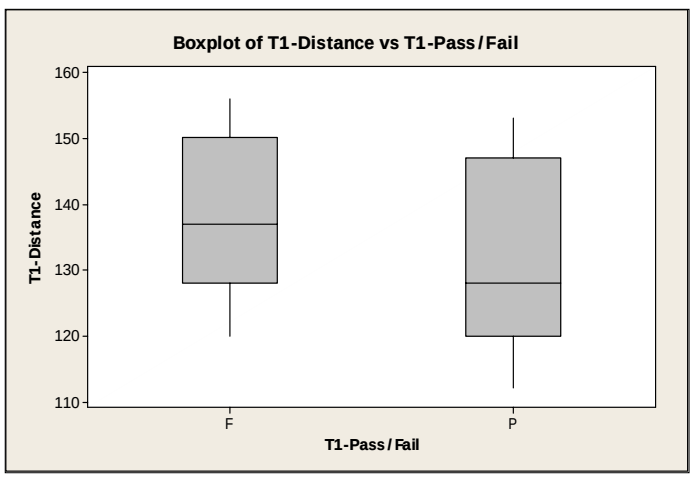
Boxplots

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



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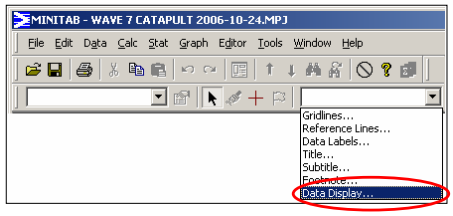
Boxplots

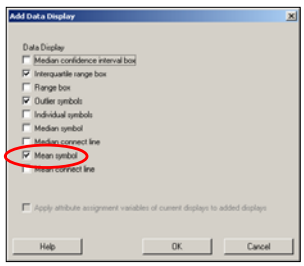
Lean Six Sigma

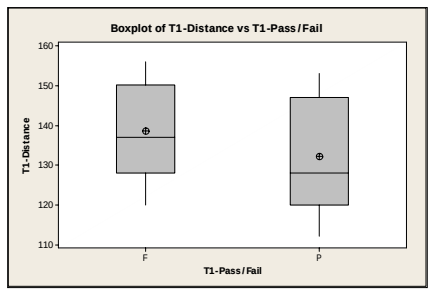
Define | Measure | Analyze | Improve | Control

TASK: Display the mean symbol on the boxplots

- Go to the *Add List* selector in the *Graph Editing Toolbar*
- Select *Data Display*
- Check the *Mean Symbol* box
- Click *OK*







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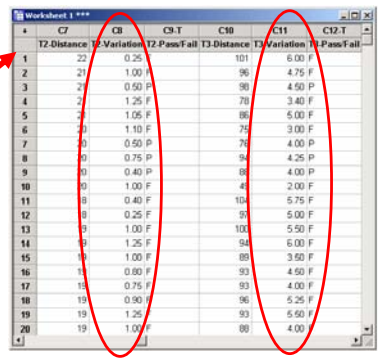
Scatter Plots

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Definition: Shows relationships between numerical variables
(NOT non-numeric variables!)

- To create scatter plots we need to related numerical variables. Therefore we need to add the *Variation* data for Teams 2 and 3:
  - Go to the worksheet and click on the first cell of column *C8* (*T2-Variation*)
  - Input the data as shown in the picture to the right
  - Do the same for column *C11* (*T3-Variation*)



	C7	C8	C9-T	C10	C11	C12-T
	T2-Distance	T2-Variation	T2-Pass/Fail	T3-Distance	T3-Variation	T3-Pass/Fail
1	22	0.25		101	6.00	F
2	21	1.00	F	96	4.75	F
3	21	0.50	P	98	4.50	P
4	2	1.25	F	78	3.40	F
5	20	1.05	F	86	5.00	F
6	20	1.10	F	75	3.00	F
7	20	0.50	P	76	4.00	P
8	20	0.75	P	94	4.25	P
9	20	0.40	P	88	4.00	P
10	20	1.00	F	4	2.00	F
11	18	0.40	F	104	5.75	F
12	18	0.25	F	97	5.00	F
13	19	1.00	F	100	5.50	F
14	19	1.25	F	94	6.00	F
15	19	1.00	F	89	3.50	F
16	19	0.80	F	93	4.50	F
17	19	0.75	F	93	4.00	F
18	19	0.90	F	96	5.25	F
19	19	1.25		93	5.50	F
20	19	1.00	F	88	4.00	F

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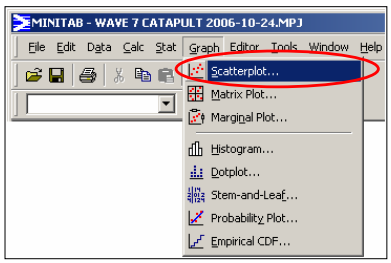
Scatter Plots

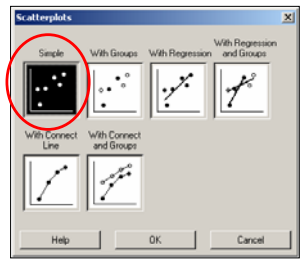
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

TASK: Create a graph showing the relationship between the *Distance* and the *Variation* for Teams 2 and 3:

- Go to *Graph* menu > *Scatterplot*
- Select *Simple*





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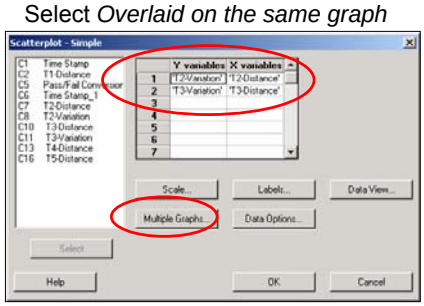
Scatter Plots

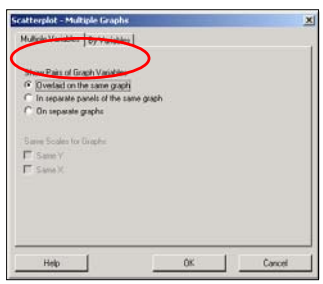
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

(Cont...)

- Select *T2-Variation* for the 1st Y variable
- Select *T2-Distances* Volume for the 1st X variable
- Select *T3-Variation* column for the 2nd Y variable
- Select *T3-Distance* Volume column for the 2nd X variable
- Click on *Multiple Graphs*
- Select *Overlaid on the same graph*





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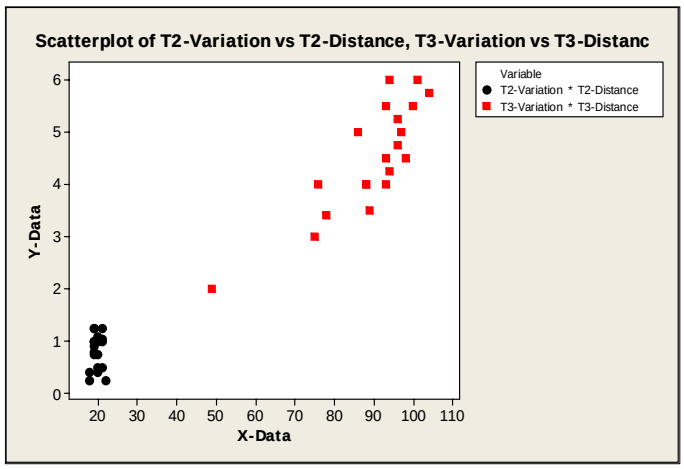
Scatter Plots

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



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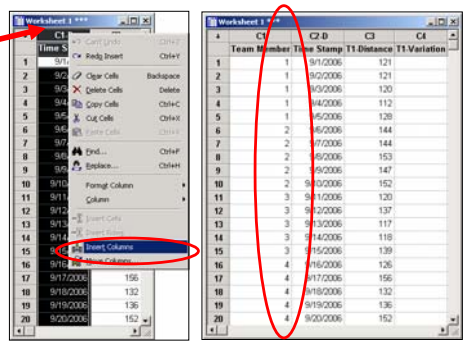
Scatter Plots

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

TASK: Create a stratified graph showing the relationship between the Distance and the Variation for Teams 2 and 3 for each "Team Member":

- Assume each team has four (4) members and that each team member performed five (5) launches:
  - Go to the worksheet and right mouse click on the title cell of column *C1-D*
  - Select *Insert Columns*
  - Title the new column "*Team Member*"
  - Input the data as shown in the picture to the right



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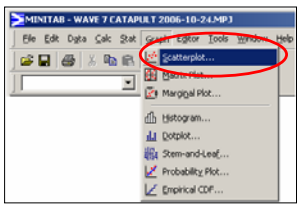
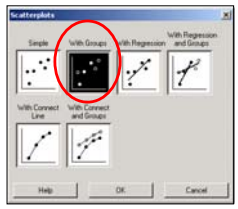
Scatter Plots: Stratified

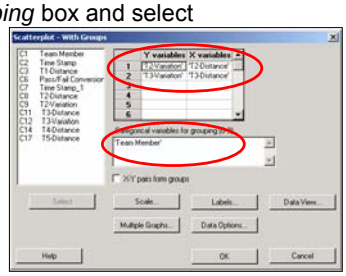
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

- Go to *Graph* menu > *Scatterplot*
- Select *With Groups*
- Select *T2-Variation* for the 1st Y variable
- Select *T2-Distances* Volume for the 1st X variable
- Select *T3-Variation* column for the 2nd Y variable
- Select *T3-Distance* Volume column for the 2nd X variable
- Click inside the *Categorical variables for grouping* box and select *Team Member* column *(C1)*







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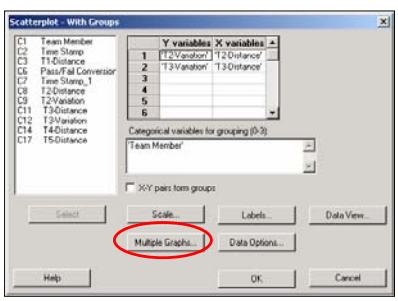
Scatter Plots: Stratified

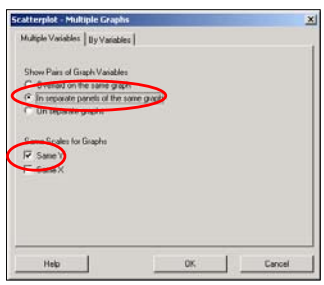
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

(Cont...)

- Click on *Multiple Graphs*
- Select *Overlaid on the same graph*
- Check *Same Y*
- Click *OK* twice





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Scatter Plots: Stratified

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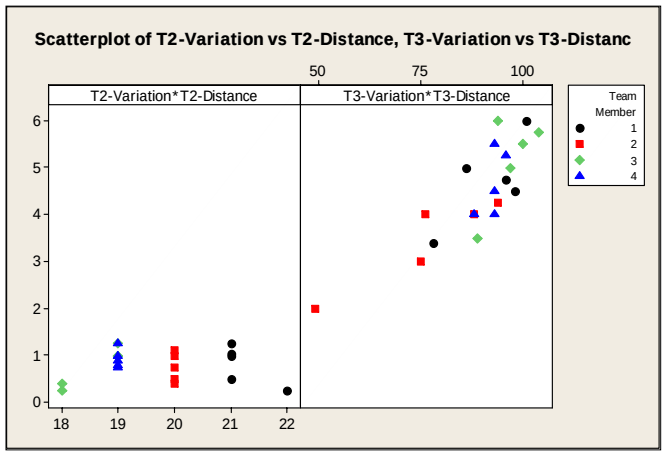
Define | Measure | Analyze | Improve | Control

RESULTS:



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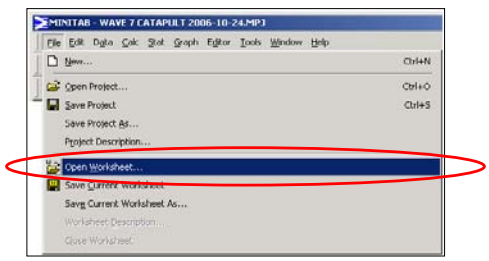
Pareto Charts

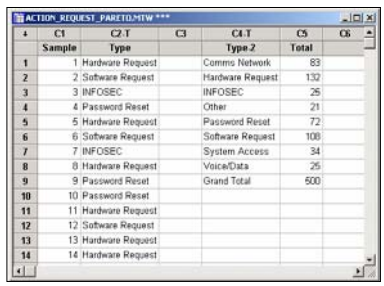
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Definition: A bar chart that shows number of occurrences in descending order as well as the cumulative percentage of the data

- Open *ACTION_REQUEST_PARETO.MTW* worksheet
  - Go to File > Open Worksheet
  - Search for file and open it
- This worksheet contains 500 trouble ticket requests by category





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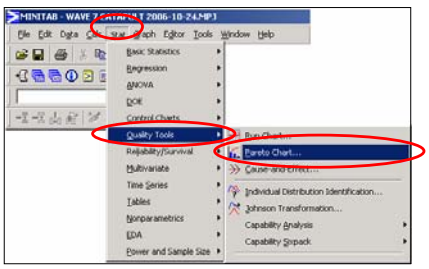
Pareto Charts

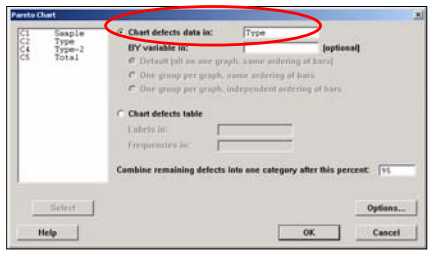
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

TASK: Create a Pareto Chart using the *Type* data in column C2-T:

- Go to Stat menu > Quality Tools > Pareto Chart
- Click inside the "*Chart defects data in*:" selection box and select the *Type* column
- Click *OK*





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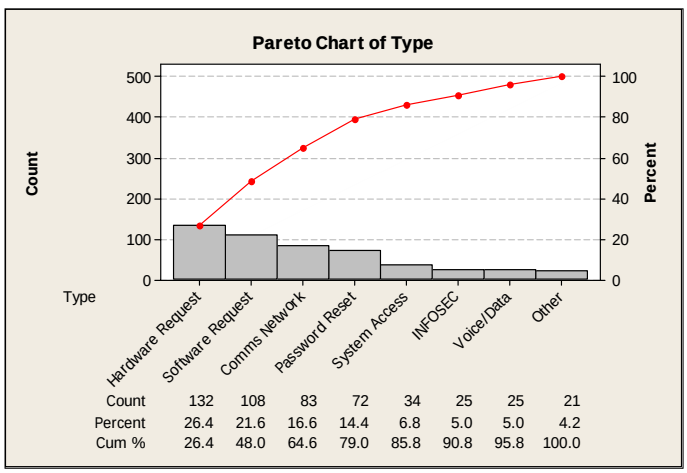
Pareto Charts

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



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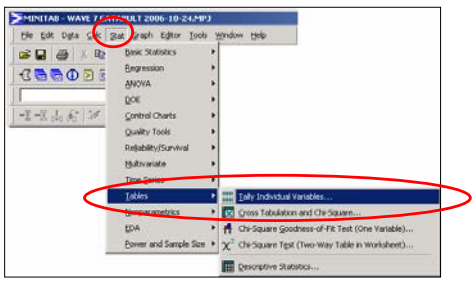
Pareto Charts

Lean Six Sigma

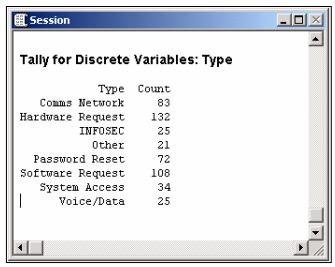
Define | Measure | Analyze | Improve | Control

TASK: Get a summary table of the Types and Counts:

- Go to *Stat* menu > *Tables* >*Tally Individual Variables*



RESULTS:



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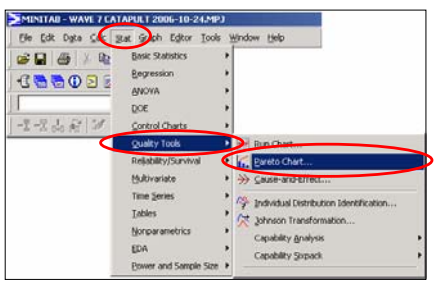
Pareto Charts

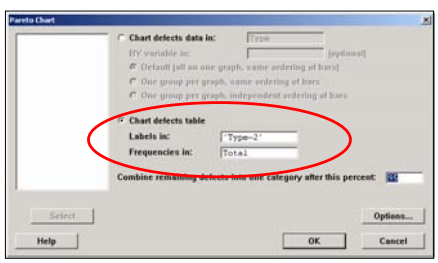
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

TASK: Get a Pareto from the table in columns *C4-T* and *C5*:

- Go to *Stat* menu > *Quality Tools* > *Pareto Chart*
- Click the "*Chart defects table*"
- Select *Type-2* for *Labels* and *Total* for *Frequencies*





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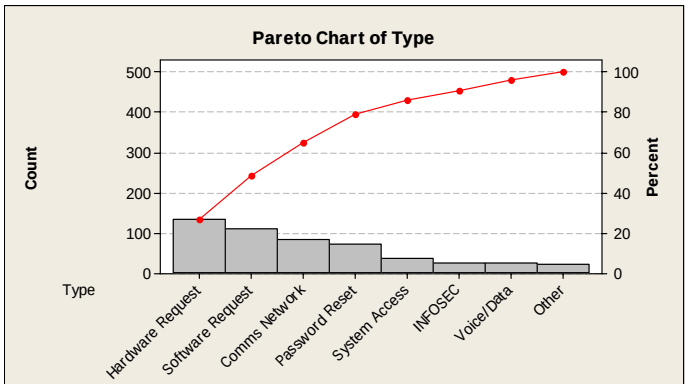
Pareto Charts

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



Count	132	108	83	72	34	25	25	21
Percent	26.4	21.6	16.6	14.4	6.8	5.0	5.0	4.2
Cum %	26.4	48.0	64.6	79.0	85.8	90.8	95.8	100.0

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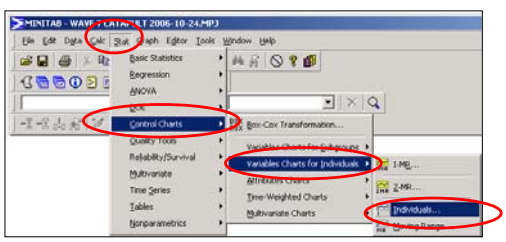
Control Charts

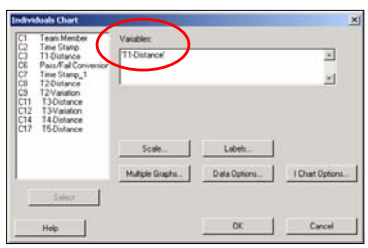
Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Definition: A Time Series plot that shows control limits at both +3σ and -3σ from the mean

- Go back to the catapult data worksheet
- Go to *Stat* menu > *Control Charts* > *Variables Charts for Individuals* > *Individuals*
- Click inside the *Variables* dialog box > select *T1-Distance*





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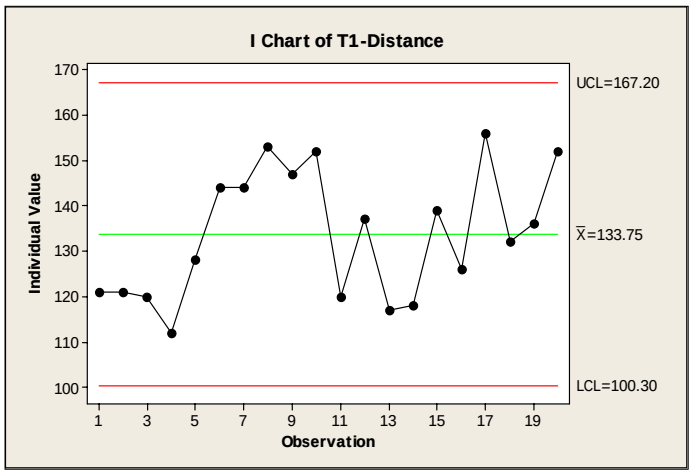
Control Charts

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



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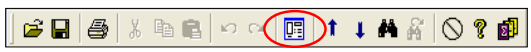
Control Charts

Lean Six Sigma

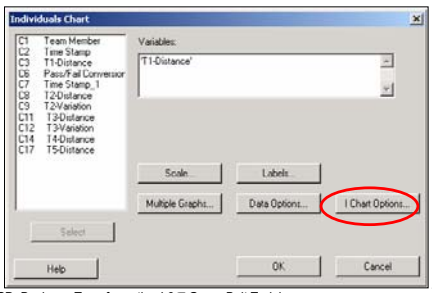
Define | Measure | Analyze | Improve | Control

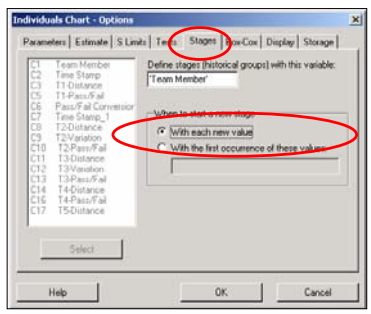
TASK: Remake plot with separate control limits for each team member:

- On the toolbar click the icon “Bring up last dialog box” (#9) or use “Control-E”



- Click on *I Chart Options* > Go to *Stages* tab
- Click on the *Define Stages* box > select *Team Member*
- Click *OK* twice





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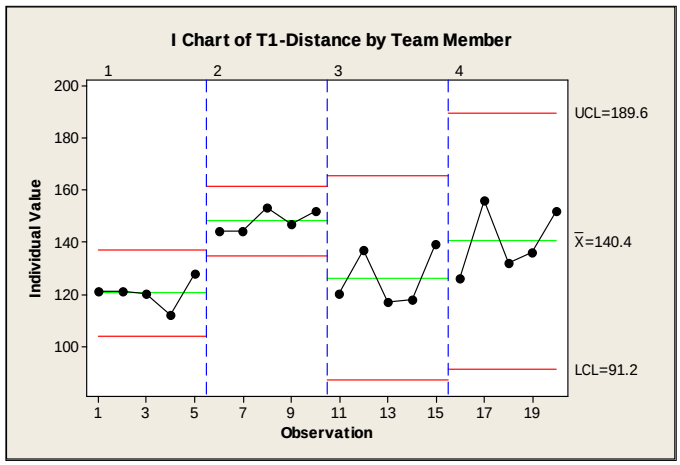
Control Charts

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

RESULTS:



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Define | Measure | Analyze | Improve | Control

Work Sheets

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The Six Sigma Tollgate Tool

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Define	Measure	Analyze	Improve	Control
❑ Project Charter • Problem Statement • Defined Benefits • Business Case	❑ Process Map	❑ Potential Xs	❑ "To Be" Process Map	❑ Transition Plan
❑ Measurable Y • Customer Specs/VOC	❑ Data Collection Plan • Data Collected	❑ Critical Xs	❑ Improvement Strategy • Improvement Model • "X" Improvement Target	❑ QC Chart
❑ Cross Functional Team	❑ Data Presentation • Run Chart; Histogram; Mean/Stand. Dev.	❑ Required Data Display: • **Pareto Charts; Fish Bone / C&E; Histograms;**	❑ Mistake-Proofing	❑ Communication to Impacted Areas
❑ Timeline	❑ Updated CTQs/CTPs	❑ Optional Data Display: • **Descriptive Stats.; Time Series Plots; Control Charts; Box Plots**	❑ FMEA	❑ Project Documentation
❑ SIPOC	❑ "Y" Performance Target	❑ XY Matrix	❑ Risk Analysis & Risk Mitigation Plan	
I accept the Define Tollgate. Signed: _____ *(Sponsor)* _____ *(Process Owner)* _____ *(MBB)* _____ *(Finance Owner)*	I accept the Measure Tollgate. Signed: _____ *(Sponsor)* _____ *(Process Owner)* _____ *(MBB)*	I accept the Analyze Tollgate. Signed: _____ *(Sponsor)* _____ *(Process Owner)* _____ *(MBB)* _____ *(Finance Owner)*	I accept the Improve Tollgate. Signed: _____ *(Sponsor)* _____ *(Process Owner)* _____ *(MBB)*	I accept the Control Tollgate. Signed: _____ *(Sponsor)* _____ *(Process Owner)* _____ *(MBB)* _____ *(Finance Owner)*

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Charter & Timeline

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Charter	
Problem Statement:	
Business Case:	
Unit:	
Defect:	
Customer Specifications:	
Measure Start:	
Measure Stop:	
Scope:	

Take away message goes here (impact of problem)

Timeline			
Phase	Planned	Actual	Status
Define	**dd mm yy**	**dd mm yy**	●
Measure	**dd mm yy**		○
Analyze	**dd mm yy**		○
Improve	**dd mm yy**		○
Control	**dd mm yy**		○

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Project Action Item Register

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

PROJECT DESCRIPTION	LEAD	RESOURCES	PROBLEM STATEMENT	NATURE OF DEFECT	CORRECTIVE ACTION PLAN	DUE DATE	PROGRESS	DATE UPDATED
Calibrate temperature control system on all units.	John Doe	Supplier Ellen Technician	Independent measures of ink temperature do not match those on the consol. Each is off by different amounts.	Variant temps between the units causing print defects.	John will contact supplier re: problem, Ellen will use manual to attempt to reset control system and calibrate.	12/14/1999	Completed 11/29/99	11/29/1999

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Exercise: Catapult Performance

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Group #	Name			
Test Launch				
Distance 1				
Variance from Center 1				
Distance 2				
Variance from Center 2				
Distance 3				
Variance from Center 3				
Distance 4				
Variance from Center 4				
Distance 5				
Variance from Center 5				
Total				
Mean/Average				
Median				
Sigma				

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Exercise: Catapult Performance

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Group #	Name			
Test Launch				
Distance 1				
Variance from Center 1				
Distance 2				
Variance from Center 2				
Distance 3				
Variance from Center 3				
Distance 4				
Variance from Center 4				
Distance 5				
Variance from Center 5				
Total				
Mean/Average				
Median				
Sigma				

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Implementation Plan

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

Task	DACI			
	Driver	Approver	Contributor	Informed
Identifying solutions				
Selecting Solutions				
Planning the implementation				
Handling potential problems				
Implementing the solution				
Monitoring results				

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GREEN BELT ACRONYMS

Lean Six Sigma

Define | Measure | Analyze | Improve | Control

μ	Population mean (mu)
5S	Sort - Set in Order - Shine - Standardize - Sustain
6Ms	Manpower, Machines, Materials, Measurements, Methods, Mother Nature
6S	Sort - Set in Order - Shine - Safety - Standardize - Sustain
AIR	Action Item Register
C Chart	Count (control) Chart
CPI	Continuous Process Improvement
CTQ	Critical to Quality
DACI	Driver Approver Contributor Informed
DMAIC	Define, Measure, Analyze, Improve, Control
DPMO	Defects Per Million Opportunities
DPU	Defects Per Unit
FMEA	Failure Modes and Effects Analysis
Gage R&R	Gage Repeatability & Reproducibility
GB	Green Belt
I/MR Chart	Individual / Moving Range
JIT	Just-in-time
KPI	Key Process Indicator
LCL	Lower Control Limit
LSL	Lower Specification Limit
LSS	Lean Six Sigma
MBB	Master Black Belt
mR Chart	Moving Range
MSA	Measurement Systems Analysis
mXbar Chart	Moving Average
nP Chart	Number (control) chart
NVA	Non-Value-Added
P Chart	Proportions (control) chart
PPM	Parts per million
r	Correlation Coefficient
RPN	Risk Priority Number. The product of Sev*Occ*Det. Used in FMEA.
RTY	Rolled throughput yield
s	Sample standard deviation. Estimate of the true σ.
SOP	Standard Operating Procedures
SIPOC	Suppliers Inputs Process Outputs Customers
U Chart	Rate (control chart)
UCL	Upper Control Limit
USL	Upper Specification Limit
VA	Value-Added
VOC	Voice of Customer
X-bar	Sample mean
X_i	Individual data point
Y=f(x)	Outputs (Y) are a function of the Inputs (x).
σ	Population standard deviation (sigma)

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