LEANOhio

# Transforming the Public Sector

## Green Belt

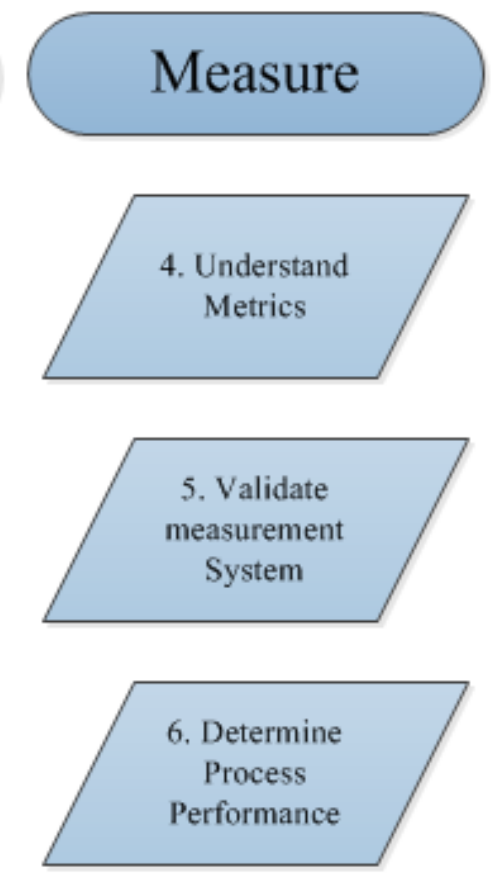
# Intro to Measurement

SIMPLER. FASTER. BETTER. LESS COSTLY.

| Define | Measure | Analyze | Improve | Control |
|---|---|---|---|---|
| 1. Identify CTQ | 4. Understand Metrics | 7. ID potential Sources of Variation | 10. Establish level for X's | 13. Evaluate Process Performance |
| 2. Develop PAF | 5. Validate measurement System | 8. Characterize the X's | 11. Develop Solutions | 14. Develop Control Plan |
| 3. Visualize the Process | 6. Determine Process Performance | 9. Determine Significant X's | 12. Pilot and Implement | 15. Transition to Project Owner |
| **Purpose:** To identify and prioritize the business improvement opportunity, define critical customer requirements, document the processes and build effective teams | **Purpose:** To determine what to measure, manage the measurement data collection, develop and validate measurement systems and determine process performance | **Purpose:** To determine the root causes, estimate population parameters with confidence intervals and to construct hypothesis about the data and test them to determine significance. | **Purpose**: To develop and quantify potential solutions, improve/optimize the process, evaluate and select final solution and implement the pilot. | **Purpose**: Implement final solution, maintain process improvements, ensure new process problems are identified & quickly corrected, disseminate lessons learned. Identify areas for replication & standardization. |
| **Deliverables**: Project Approval Form; Project Team – TRAIL; CT Flow Down (CTs); SIPOC; Process map (current process) ; Project benefits; Project plan major milestones; Data Collection Plan; Data Integrity Audit (if applicable) | **Deliverables**: TRAIL Chart – updated; Detailed Process Map; Cause & Effect Matrix; FMEA; Decision Tree; Operational Definitions; MSA Evaluation; Data Collection Plan; Capability Study with Control Charts; Project Status | **Deliverables**: Data Collection Plan- updated; Hypothesis Testing; Decision Tree; MSA Analysis; Capability Analysis- updated; Executive Summary- updated; TRAIL- updated; Analysis Summary; Control Charts- updated | **Deliverables**: DOE; Lean Analysis; Simulation; Optimal settings for X's; Executive Summary- updated; TRAIL- updated; Implementation plan; Control Charts- updated; Capability Analysis- updated | **Deliverables**: Control Plan; Transition Plan; Capability Analysis- updated; Executive Summary- updated; TRAIL- updated; Control Charts- updated |

# DMAIC Flow

- Measure:
  - Understand Metrics
  - Validate Measurement System
  - Determine Process Performance



# Measure Purpose

- To determine what to measure
- Manage the measurement data collection
- Develop and validate measurement systems
- Determine process performance.

# Measure Deliverables

- TRAIL Chart Updated (Week One)
- Detailed Process Map (Week One)
- **Cause and Effect Matrix (Week Two)**
- **FMEA (Week Two)**
- **CT Flowdown (Week Two)**
- Operational Definitions (Week One)
- **MSA Evaluation (Week Two)**
- Data Collection Plan (Week One)
- **Capability Study (Week Two)**
- **Control Charts (Week Two)**

# The Fundamental Principle of Six Sigma

- Variation is Evil!
  - But…
- These causes of variation can be identified, measured, prioritized, and then controlled

# Why Measure

- Our Processes:
  - Can be chronically off target
  - Can be occasionally off target
- Measure to see if it is a systematic problem or exception

# Remember our first Mantra…

$$Y = f(X_1, X_2, X_3 \ldots)$$

***"Y is a function of X"***

# How do Statistics Relate to Six Sigma?

- Statistics deals with the study of variation
- Statistical tools will allow us to quantify the problem, investigate the root causes, develop a solution, and confirm the improvements over time.
- **Let the Data Take You There!**

# First Lets Take a Moment and Think about Data

- Define your Primary Metric for your Project
  - What was the Primary Metric for the DOP example?
- Define your Secondary Metrics
  - What are the Secondary Metrics for the DOP example?

Be intentional when you collect data:
Think it through

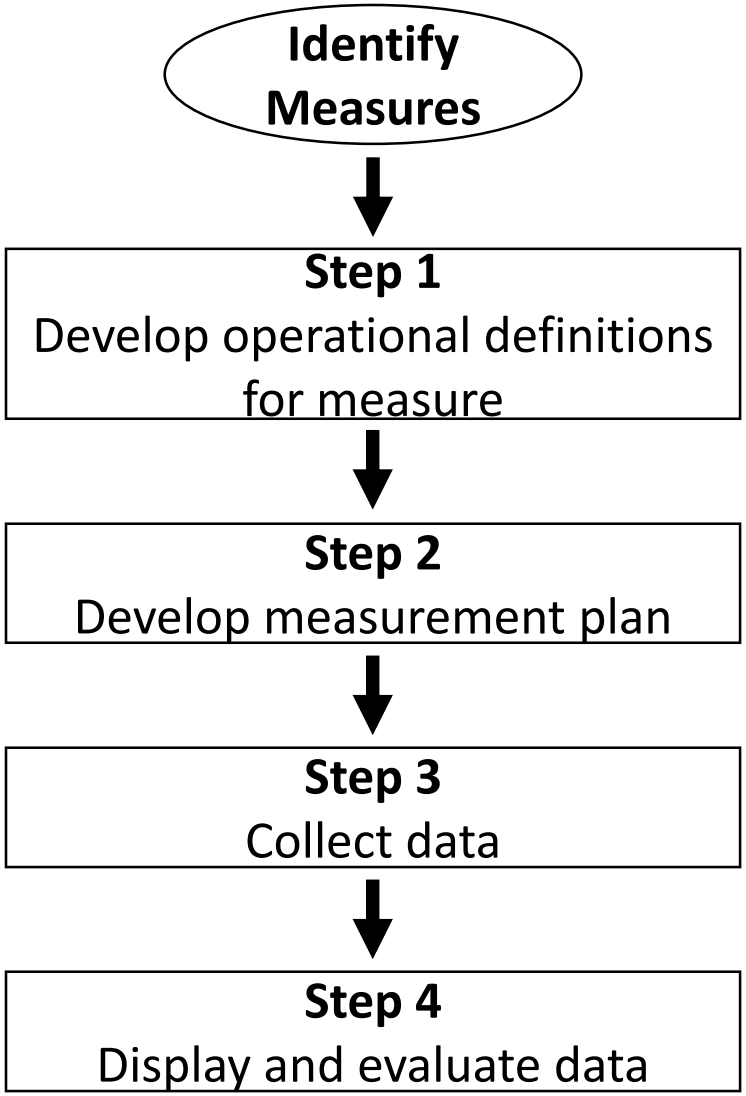
# Secondary Metrics

***Keep Me Honest!***

***Helps avoid sub-optimization!***

# Data Collection Method

Measurement management starts with a data collection methodology.



# Develop a Measurement Plan - Types of Data

- Before data collection starts, classify the data into different types: continuous or discrete.

- This is important because it will:
  - Provide a choice of data display and analysis tools
  - Dictate sample size calculation
  - Provide performance or cause information
  - Determine the appropriate control chart to use
  - Determine the appropriate method for calculation of Sigma Level

# Types of Data

# Two Basic Types of Data

**Discrete** (Categories)

**Ordinal**
- Count defects
- # approved
- # of errors
- Rank

**Nominal**
- Yes/No
- Group A, B..
- Good/Bad
- Pass/Fail

**Continuous** (Measured on a continuum)

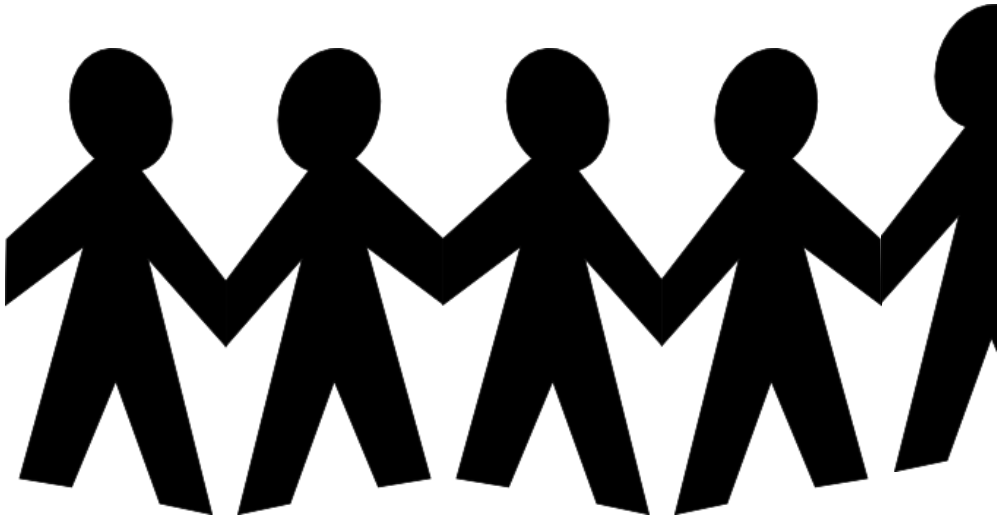
- Time
- Money
- Weight
- Length
- Speed
- Temperature

# Types of Data

- It's important to know what type(s) of data you're collecting… Different types of data require different types of tests

| Discrete | Continuous |
|---|---|
| Discrete Data can be Qualitative AND Quantitative | Continuous Data is Quantitative ONLY |
| ↓ | ↓ |
| Finite Numbers<br>No Fractions Here! | Usually Associated with Measurements & Fractions Work Here! |
| ← Weakest | Strongest → |

# Discrete Data



JOB APPLICA

PLEAS

Name (Last, First Middle)

Address

City State

For which job are you applying?

What will you do if hired?

Previous job experience:

Have you ever been fired from a job? I

YES NO

Signature of applicant

Do not write in

Date hired: Daily rate of pay:

Immediate supervisor: Teacher

Can only have the values
2, 3,4,5,6,7,8,9,10,11,and 12

# Discrete Data

| Discrete Variable | Possible values for the variable |
|---|---|
| The number of defective needles in boxes of 100 diabetic syringes | 0,1,2, …, 100 |
| The number of individuals in groups of 30 with a Type A personality | 0,1,2, …, 30 |
| The number of surveys returned out of 300 mailed in a customer satisfaction study. | 0,1,2, … 300 |
| The number of employees in 100 having finished high school or obtained a GED | 0,1,2, … 100 |
| The number of times you need to flip a coin before a head appears for the first time | 1,2,3, … |

# Continuous Data

Time

Height

# Continuous Data

| Continuous Variable | Possible Values for the Variable |
|---|---|
| The length of prison time served for individuals convicted of first degree murder | All the real numbers between ***a*** and ***b***, where ***a*** is the smallest amount of time served and ***b*** is the largest. |
| The household income for households with incomes less than or equal to $30,000 | All the real numbers between ***a*** and $30,000, where ***a*** is the smallest household income in the population |
| The blood glucose reading for those individuals having glucose readings equal to or greater than 200 | All real numbers between 200 and ***b***, where ***b*** is the largest glucose reading in all such individuals |

# Identify Discrete or Continuous Data

- Classify each set of data as discrete or continuous

| | |
|---|---|
| 1. The number of suitcases lost by an airline | |
| 2. The height of corn plants | |
| 3. The number of ears of corn produced | |
| 4. The number of green M&M's in a bag | |
| 5. The time it takes for a car battery to die | |
| 6. The weight of luggage on an airplane | |

# Types of Data

- It's important to know what type(s) of data you're collecting… Different types of data require different types of tests

| Discrete | | Continuous | |
|---|---|---|---|
| Discrete Data can be Qualitative AND Quantitative | | Continuous Data is Quantitative ONLY | |
| Nominal | Ordinal | Interval | Ratio |
| Finite Numbers<br>No Fractions Here! | | Usually Associated with Measurements & Fractions Work Here! | |
| Weakest | | Strongest | |

# Characteristics of Discrete Data

| **Discrete Data** | |
|---|---|
| *Discrete Data can be Qualitative AND Quantitative*<br>*Finite Numbers – No Fractions Here!* | |
| Nominal | Ordinal |
| - The weakest level of data.<br>- Made up of values that are distinguished by name only.<br>- There is no standard ordering scheme. | -Stronger than nominal data, but not as strong as Continuous data.<br>- Like nominal data, also made up of values that are rank ordered values or ranked groups.<br>- Different than nominal data because there is an ordering scheme. |

# Discrete: Nominal Data

Counties

Nominal: Name Only
You can’t perform arithmetic operations, like addition or subtraction.

# Nominal Scale

| Qualitative Variable | Possible nominal level data values for the variable |
|---|---|
| Blood Types | A, B, AB, O |
| State of Residence | Alabama, …, Wyoming |
| Country of Birth | United States, China, other |

Time to weigh in!

# Examples of Discrete Data

| Discrete Data | |
|---|---|
| *Discrete Data can be Qualitative AND Quantitative*<br>*Finite Numbers – No Fractions Here!* | |
| Nominal | Ordinal |
| The colors of M&M candies is an example of nominal level data. This data is distinguished by name only. There is no agreed upon order of this data to distinguish between colors and determine which color is "better". | Movies are classified as 2 thumbs up, 1 thumb up, or 0 thumbs up. There is an order here. A movie that receives 2 thumbs up is better than a movie that receives 1 thumb up. How much better is a movie that receives 2 thumbs than 1 thumb? Ordinal data tells you there is an order to distinguish between classes but does not tell you the distance between "good, better and best". |

# Discrete: Ordinal Data

| Very Interested | Somewhat Interested | Neutral | Not Very Interested | Not at All Interested |
|---|---|---|---|---|
| 5 | 4 | 3 | 2 | 1 |

Likert Scale

BIG 10 Conference Football

Revenue Premium Based Brand Equity Rankings

| University | Rank |
|---|---|
| The Ohio State University | 1 |
| Pennsylvania State University | 2 |
| University of Michigan | 3 |
| University of Nebraska | 4 |
| Michigan State University | 5 |
| University of Wisconsin | 6 |
| University of Iowa | 7 |
| University of Illinois | 8 |
| Purdue University | 9 |
| University of Minnesota | 10 |
| Indiana University | 11 |
| Northwestern University | 12 |

Ordinal: Implied Order

Cannot state whether the intervals between each value are equal

# Ordinal Scale

| Qualitative Variable | Possible Ordinal level data values |
|---|---|
| Automobile Sizes | Subcompact, compact, intermediate, full size, luxury |
| Product rating | Poor, good, excellent |
| Baseball team classification | Class A, Class AA, Class AAA, Major League |

# Characteristics of Continuous Data

| **Continuous Data** | |
|---|---|
| *Continuous Data is Quantitative ONLY* | |
| Interval | Ratio |
| Interval data has an ordering scheme, but unlike ordinal data, the differences between data is meaningful and can be measured. Arithmetic operations are possible. However, interval data lacks a zero starting point, a characteristic unique to Ratio data. | Ratio data has an ordering scheme, has differences that are meaningful, can be measured, and arithmetic operations are possible. Ratio data has a natural starting point and can identify absolute zero. |

# Continuous: Interval Data

Interval: Like Ordinal except we can say the intervals between each value are equally split. No natural zero point.
Without a true zero, it is impossible to compute ratios

# Interval Scale

| Interval Variable | Possible Scores |
|---|---|
| IQ scores of students in Green Belt Training | 100…<br>(the difference between scores is measurable and has meaning but a difference of 20 points between 100 and 120 does not indicate that one student is 1.2 times more intelligent ) |

# Examples of Continuous Data

| Continuous Data | |
|---|---|
| *Continuous Data is Quantitative ONLY* | |
| Interval | Ratio |
| Boiling temperatures of different liquids vary. We can tell whether a temperature is higher or lower than another, so we can put them in order. If water boils at 212 degrees and another liquid boils at 284 degrees, the differences between data are measurable and meaningful. However, because there is no natural starting point, ratios between 2 data values are meaningless. Is 75 degrees 3 times as hot as 25 degrees? No, because the ratio of 75 to 25 is meaningless here. | Four people are randomly selected and asked how much money they have with these results: $21, $50, $65 and $300. Is there an order to this data? Are the differences between the data values meaningful? Can we calculate ratios based on this data? |

# Continuous: Ratio Data

Ratio: Interval data with a zero starting point.

# Data Summary

# Data Summary

- Nominal data used to “name,” or label a series of values
- Ordinal data provide good information about the order of choices, such as in a customer satisfaction survey
- Interval data give us the order of values + the ability to quantify the difference between each one
- Ratio data give us the ultimate–order, interval values, plus the ability to calculate ratios since a “true zero” can be defined

# Data Summary ✓

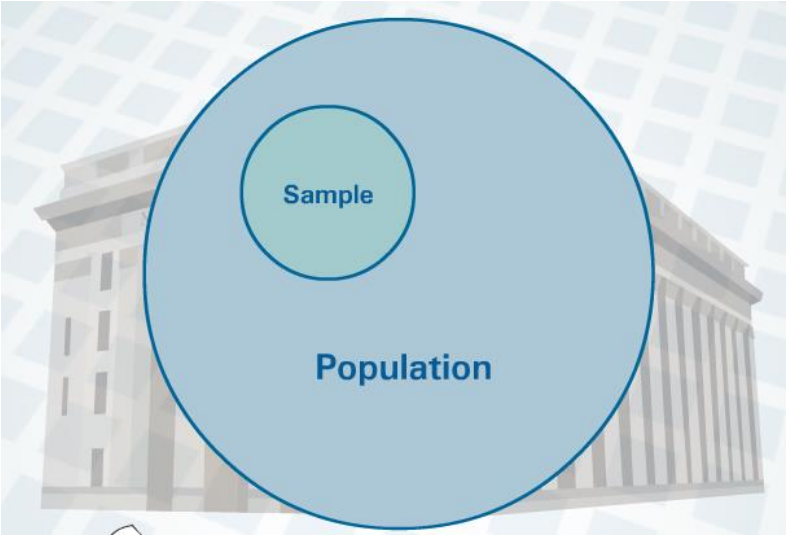
| Provides: | Nominal | Ordinal | Interval | Ratio |
|---|---|---|---|---|
| "Counts," aka "Frequency of Distribution" | ✓ | ✓ | ✓ | ✓ |
| Mode, Median | | ✓ | ✓ | ✓ |
| The "order" of values is known | | ✓ | ✓ | ✓ |
| Can quantify the difference between each value | | | ✓ | ✓ |
| Can add or subtract values | | | ✓ | ✓ |
| Can multiple and divide values | | | | ✓ |
| Has "true zero" | | | | ✓ |

# Samples vs. Populations

# Samples vs. Populations

# Sample vs. Population

- A sample is a portion of the population from which it is selected
- If selected properly, the sample will display characteristics similar to the parent population



# Why Sample?

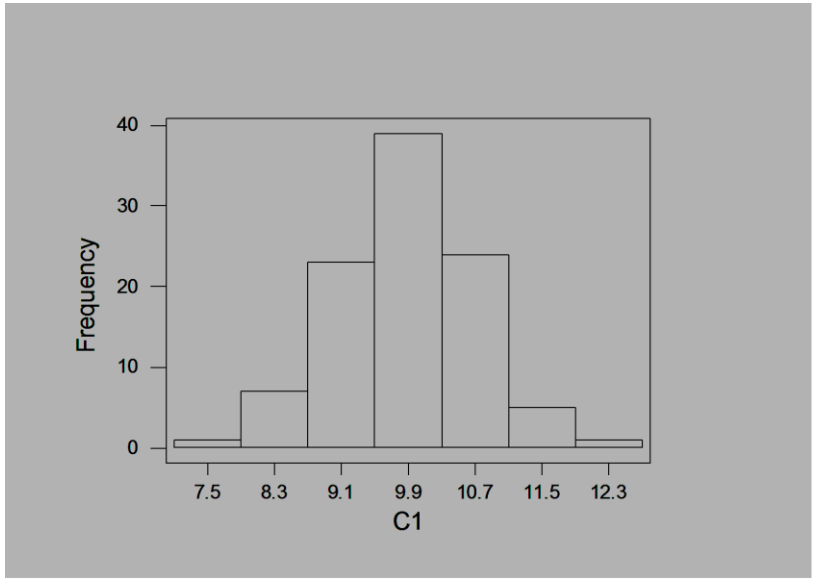
- Resource Constraints - Due to resource constraints (e.g., time and money) we often cannot measure everything in a given population
- Conclusion Validity - After a point, additional measurements will not have a meaningful return to the validity of the conclusion

# Sampling Strategies

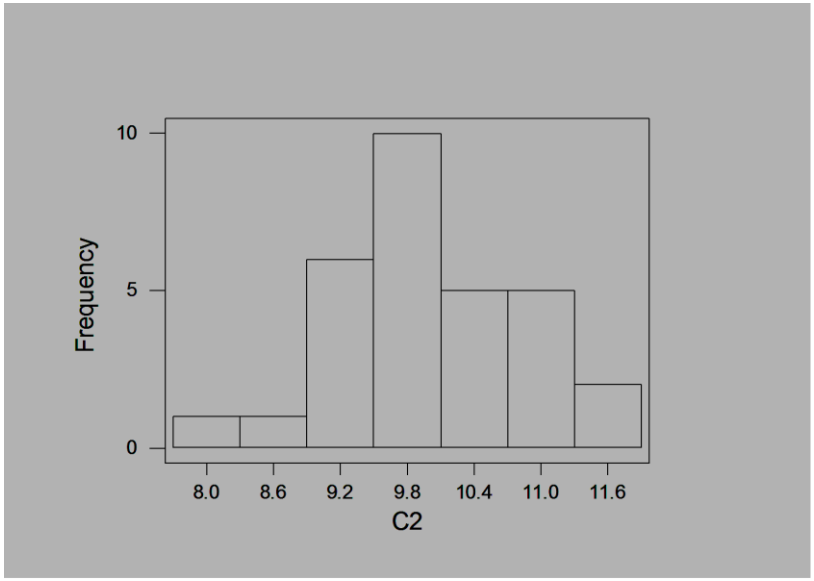
- Random
- Systematic-nth
- Stratified

# Sample Information

- Population (100 Items)




- Sample (30 Items)




*The Sample distribution should mirror the population distribution.*

# One Sample Calculator - Continuous Data

- Note that this calculator uses the Standard Deviation from the population in place of proportion
- If the standard deviation is unknown, use Range/5

**Calculation for Sample Size - Continuous Data**

| | | |
|---|---|---|
| **Population Size (N)** | **1,000** | |
| **Confidence Level (1-alpha)** | **0.95000** | (Percent expressed as decimal) |
| **Power Level (1-beta)** | **0.80000** | (Percent expressed as decimal) |
| **Standard Deviation (s)** | **0.50000** | (Best prior estimate or Range/5) |
| **Required Precision (+/- delta)** | **0.10000** | (Margin of Error) |
| **Initial Sample Size** | **197** | (Assumes infinite population) |
| **Corrected for Population** | **165** | (Correction for finite population) |
| **Recommended Sample Size** | **165** | |

# Central Limit Theorem

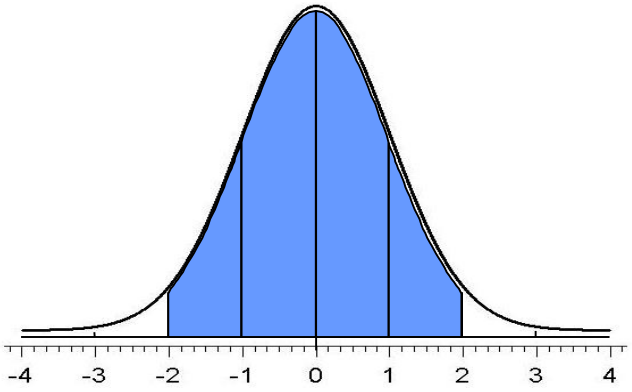
- When studying averages, as the sample size gets larger, the distribution of averages more closely approximates normality
- The average of the sample averages is approximately equal to the population average

# Confidence Intervals

- Confidence intervals tell us how confident we can be that a sample is representative of the population.
- If independent samples are taken repeatedly from the same population, and a confidence interval calculated for each sample, then a certain percentage (confidence level) of the intervals will include the unknown population parameter.

# Why Worry About Confidence Intervals

- Statistics such as the mean and standard deviation are only estimates of the population mean and standard deviation, and are based on one sample only.
- Because there is variability in these estimates from sample to sample, we can quantify our uncertainty using statistically based Confidence Intervals (C.I.'s)



# Confidence Intervals

- In order to estimate confidence intervals, we need to know the population distribution.
  - While we never know the exact distribution, we know through experience and theory that certain mathematical distributions can be safely used to represent any conceivable situation.
- There are a dozen or so of these most common distributions, we almost always rely on just a small handful of them.

# Confidence Intervals

- Confidence intervals are usually calculated so that this percentage is 95%, but we can produce 90%, 99%, 99.9% (or whatever) confidence intervals for the unknown parameter.

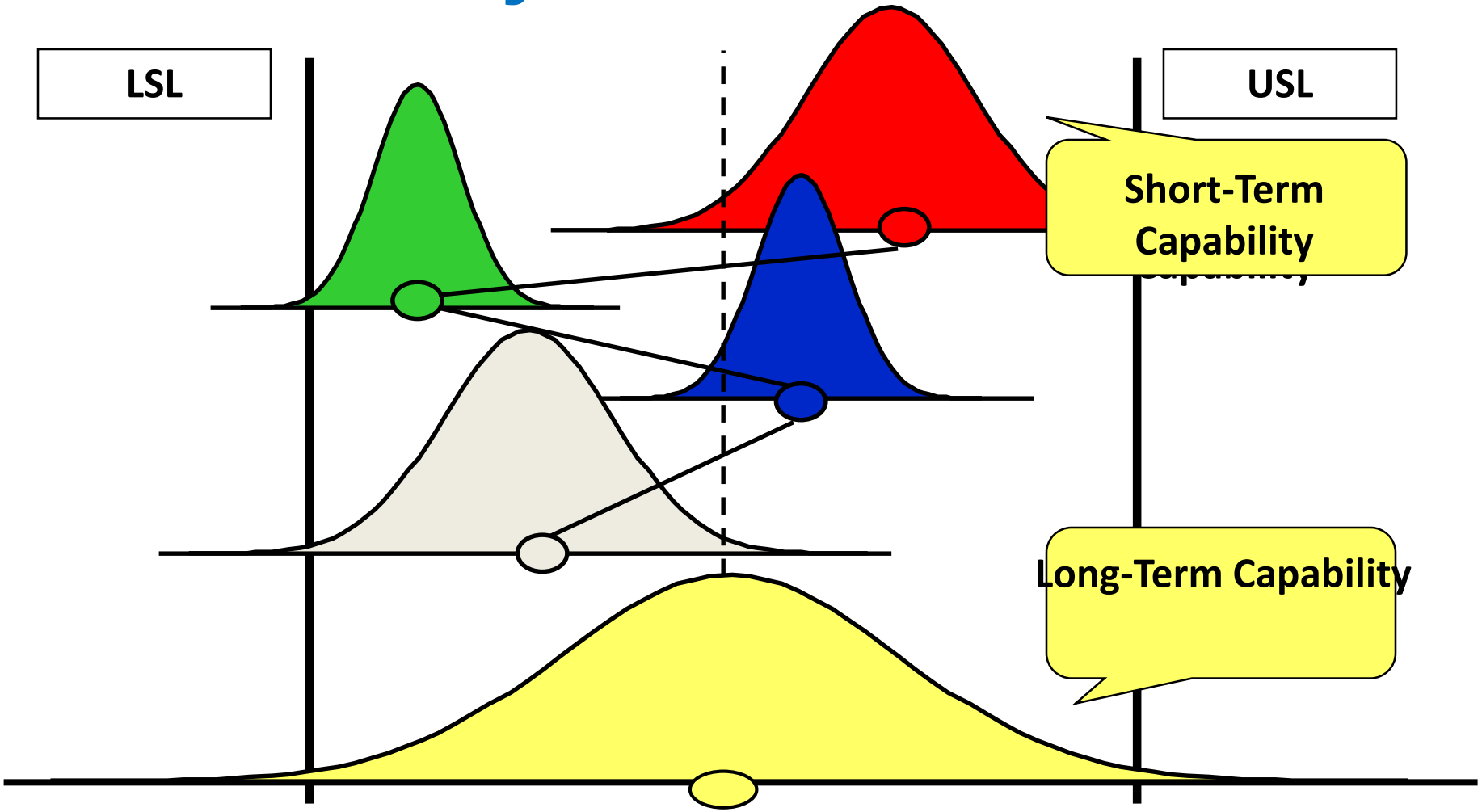
# Another Mantra

- Why is data so important?

SHIFT Happens

  – http://www.youtube.com/watch?v=FdTOFkhaplo

# The Dynamic Process



# Questions