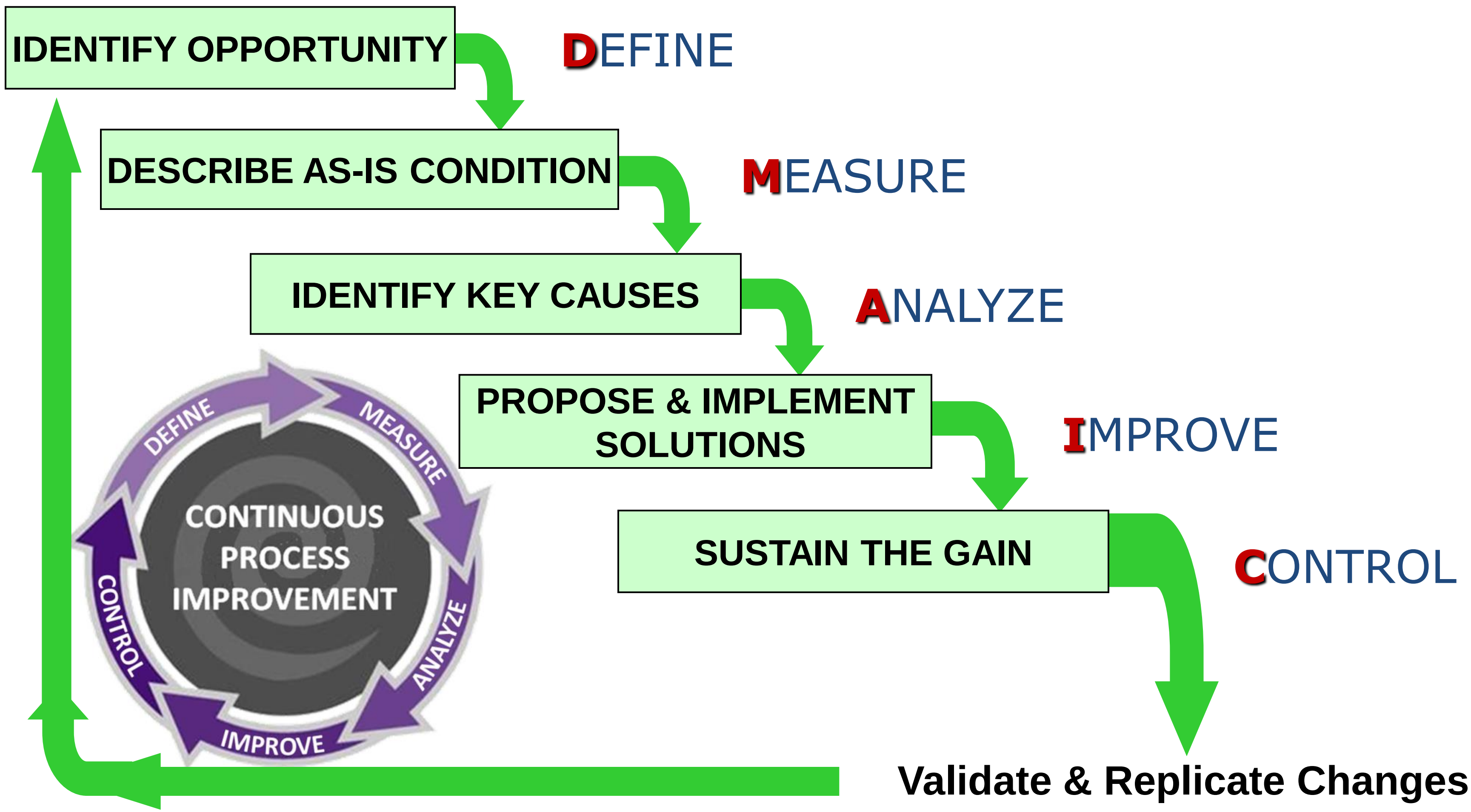
ANALYZE PHASE

Course Structure: DMAIC



Learning Objectives: Analyze Phase

At the end of this lesson you will be able to:

- Understand the tools necessary to complete the Analyze Phase.
- Create and interpret data analysis tools such as histograms, Pareto charts, fishbone diagrams, etc.
- Properly apply Root Cause Analysis to analyze process problems.
- Compute and interpret statistical results that measure location, variation, and shape.
- Identify and explain the objectives and benefits of statistical process control (SPC).

"If you can't describe what you are doing as a process, you don't know what you are doing." – Edward Deming

Data Tools

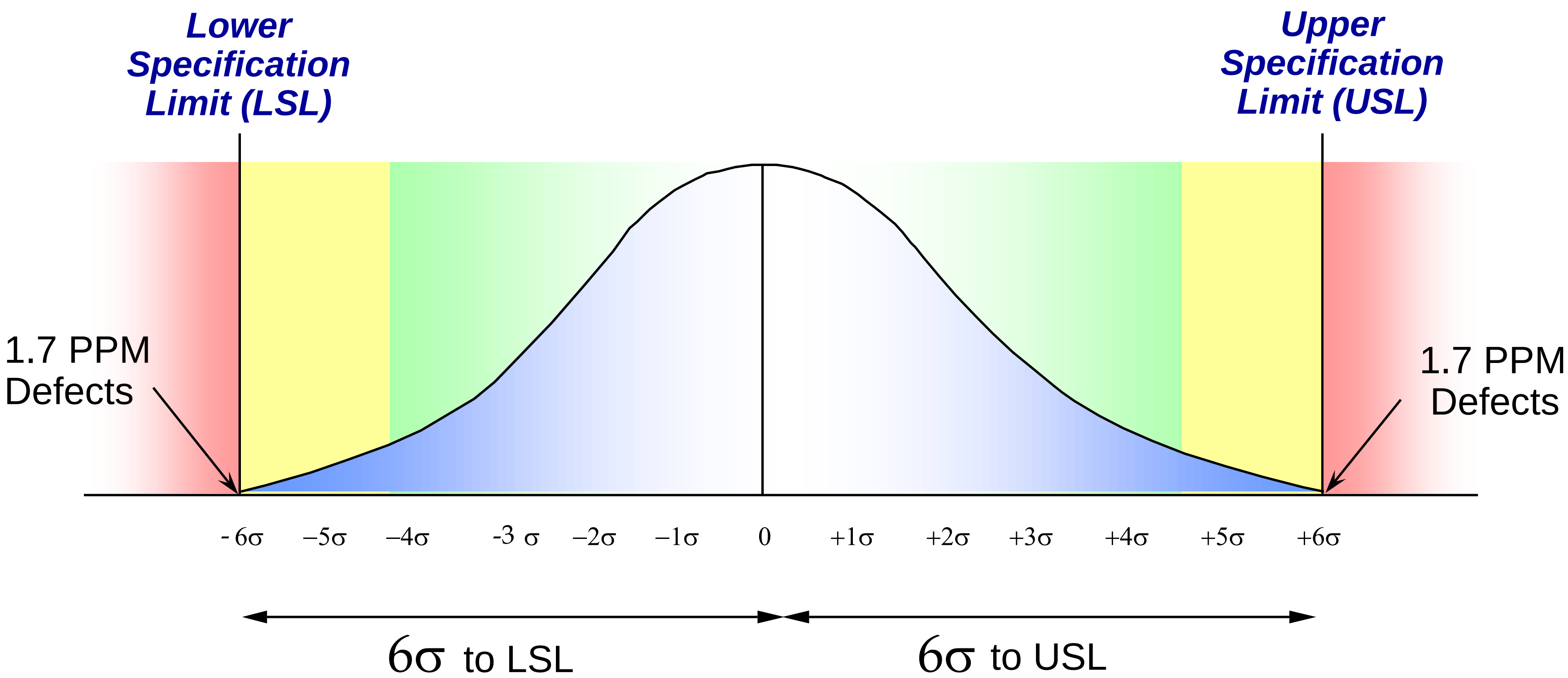

DEFINE
MEASURE
ANALYZE
IMPROVE
CONTROL
CONTINUOUS
PROCESS
IMPROVEMENT

Six Sigma as a Metric

- Benchmark for perfection.
- A Six Sigma process results in only 3.4 defects per million opportunities (DPMO).
  - A defect is anything that does not meet customer requirements.
- Manage process variation.
- Monitor Key Performance Indicators (KPI).
- Drive continuous improvement.

Adapted from Six Sigma as a Management System, McCarty, ASQ 2005

Six Sigma



Six Sigma is a fact based, data driven philosophy of improvement that values defect prevention. It drives customer satisfaction and bottom-line results by reducing variation and waste, thereby promoting a competitive advantage.

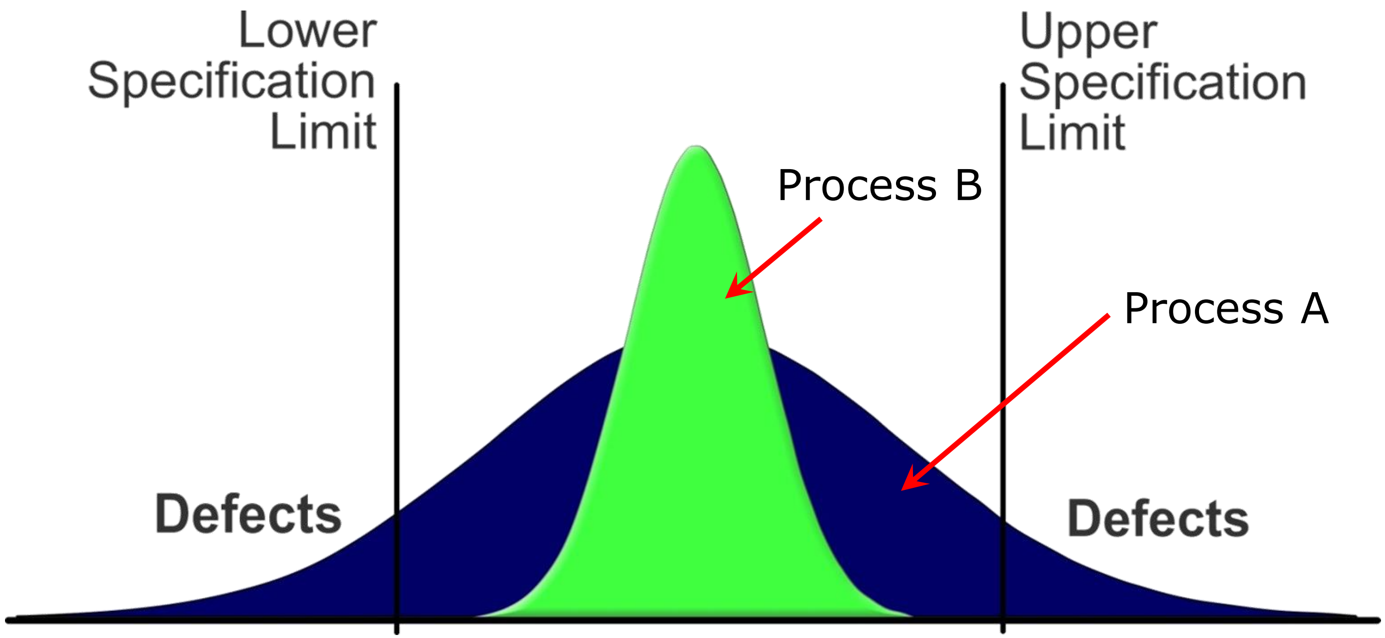
The Certified Six Sigma Black Belt Handbook, ASQ 2005

Variation in the Process

Based on Statistical Thinking

- All work is a series of processes.
- All processes have variation.
- Businesses improve when they reduce or eliminate variation.

"In God we trust, everyone else bring data."



Types of Variation

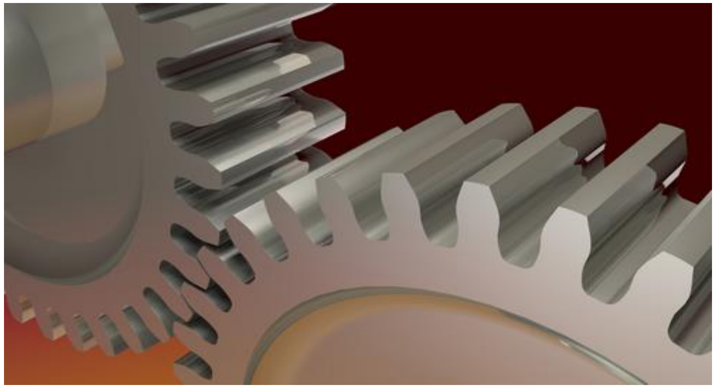
- **Common cause** (inherent) **variation** is always present in a process.
  - A process that exhibits only common cause variation is a stable process.
  - A stable process is predictable.
- **Special cause** (assignable) **variation** is some unusual, uncommon event.
  - A process that exhibits special cause variation is an unstable process.
  - An unstable process is unpredictable.

Common Cause Variation Overview

- Usually part of the process.
- Acting totally at random and independently.
- Root causes are in the key elements of the system.
  - Slight variations in raw materials
  - People
  - Slight machine vibration.
  - Environment

Special Cause Variation Overview

- Caused by a special abnormal activity resulting in an unexpected change in the process output.
  - Incorrect machine setup
  - Defects in materials
  - Untrained operator
  - Programming error

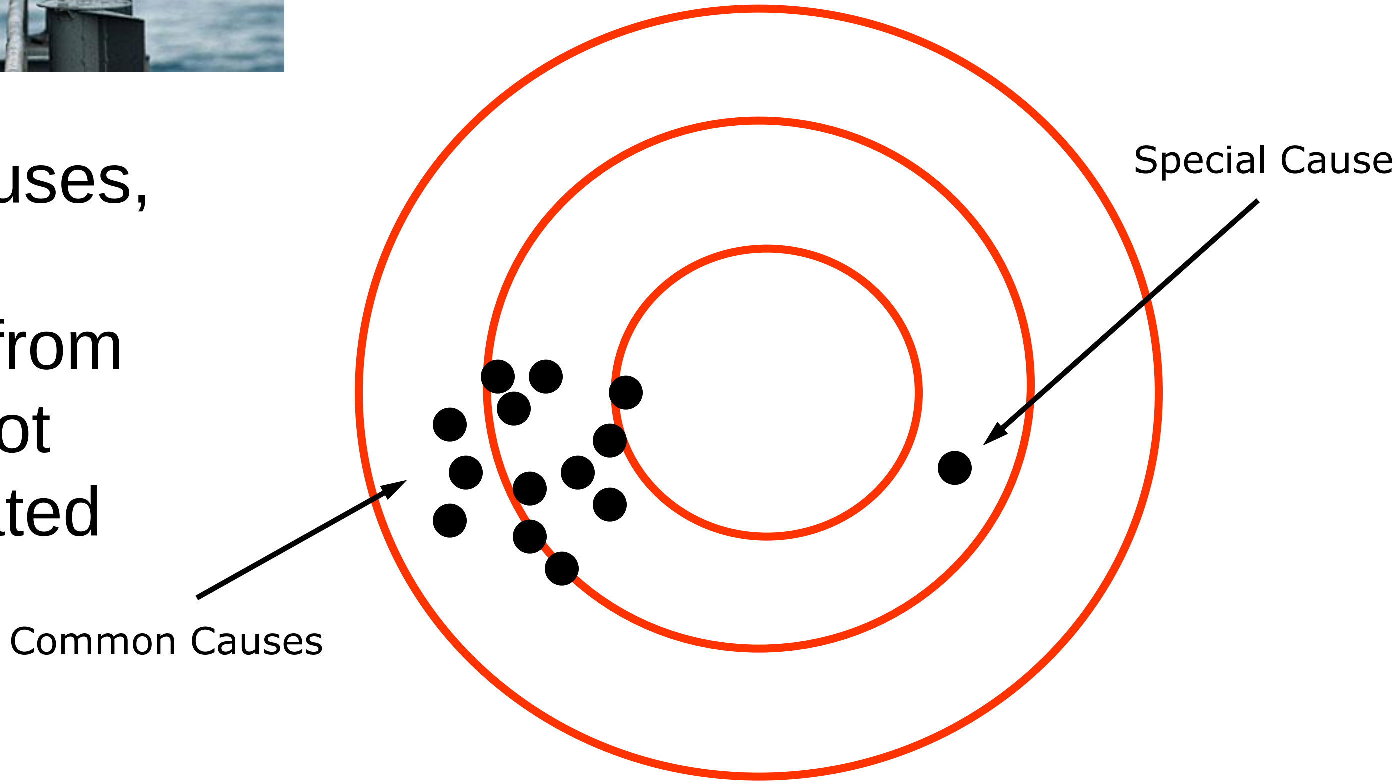


- The effects are intermittent and unpredictable.
- All processes must be brought into statistical control by first detecting and removing the special cause variation.

Comparison of Variation Types

Special causes, for example, could result from someone tripping over the shooter when the gun is fired.

Common causes, for example, could result from equipment not being calibrated properly.



Reducing Variation

The two types of variation require different approaches and tools to detect and attack them.

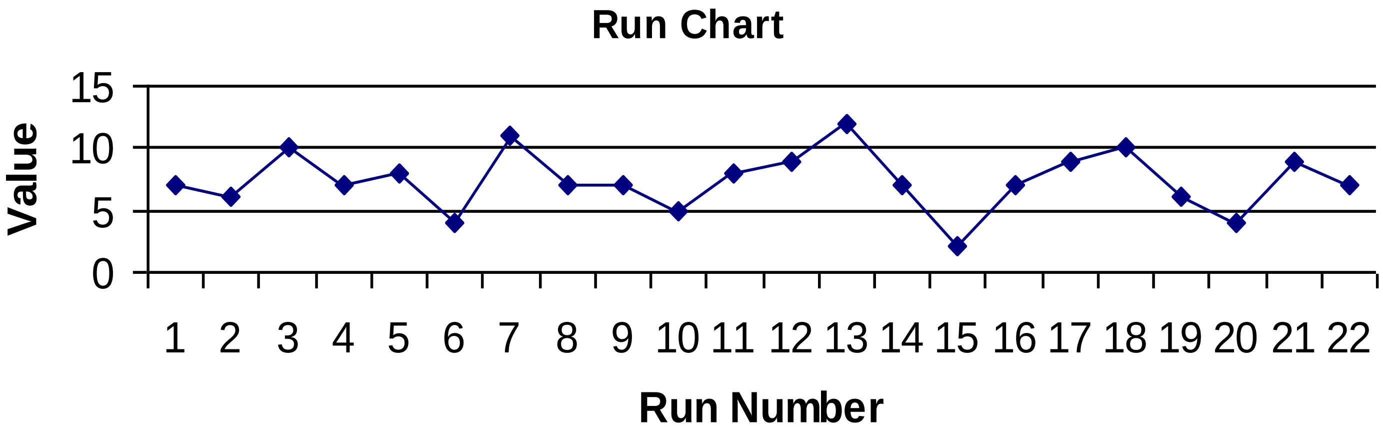
- **Eliminate special cause variation.**
  - By isolating root causes and controlling processes.
- **Reduce common cause variation.**
  - By improving the system.
- **Anticipate variation.**
  - By designing robust processes and products.

Time Series Plot (Run Charts)

- Plots of data arranged in time sequence.
- Used for preliminary analysis of data measured on a continuous scale.
  - Weight
  - Size
  - Distance
- Analysis of run charts shows:
  - Patterns can be attributed to common cause, or
  - If special causes of variation are present.

Run Charts - Example

- Collect and record data in the order they occur.
- Label vertical axis based on characteristic value (weight, size, distance, etc.).
- Plot the data points on the chart and draw a line connecting them in sequence.

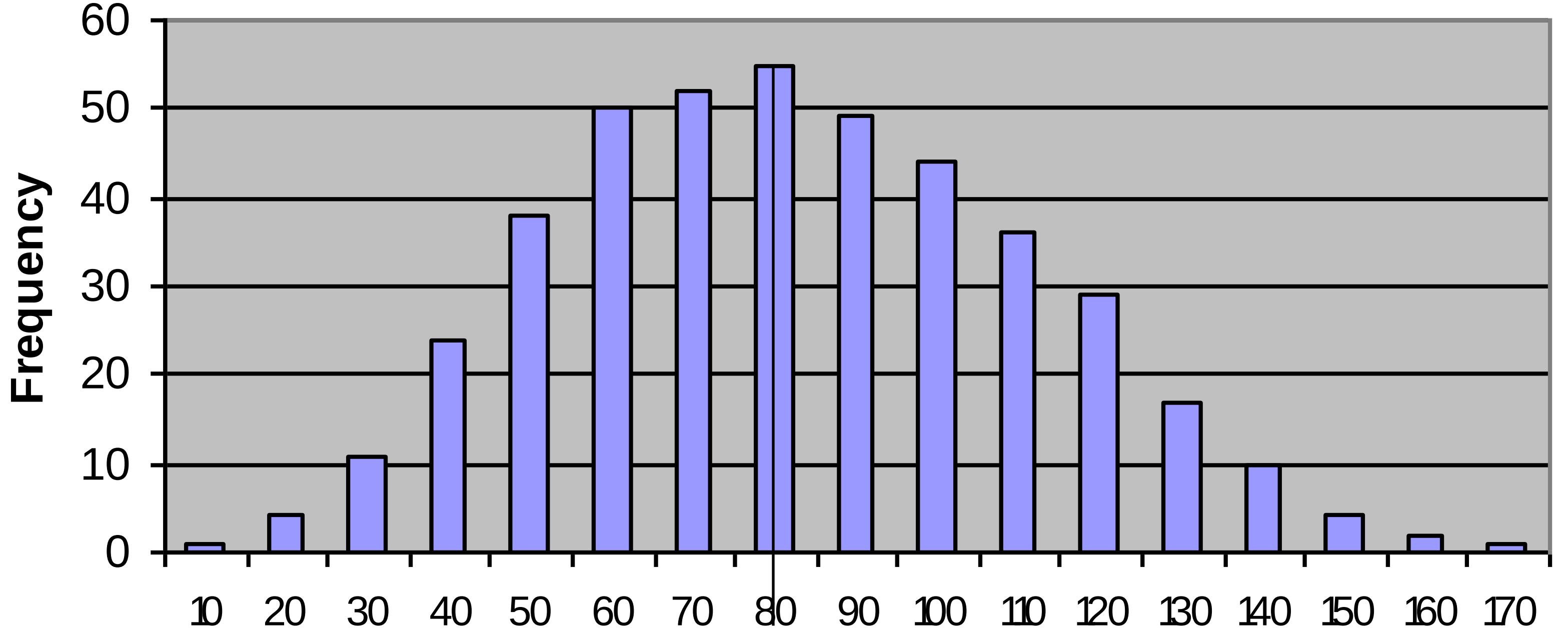


Histograms

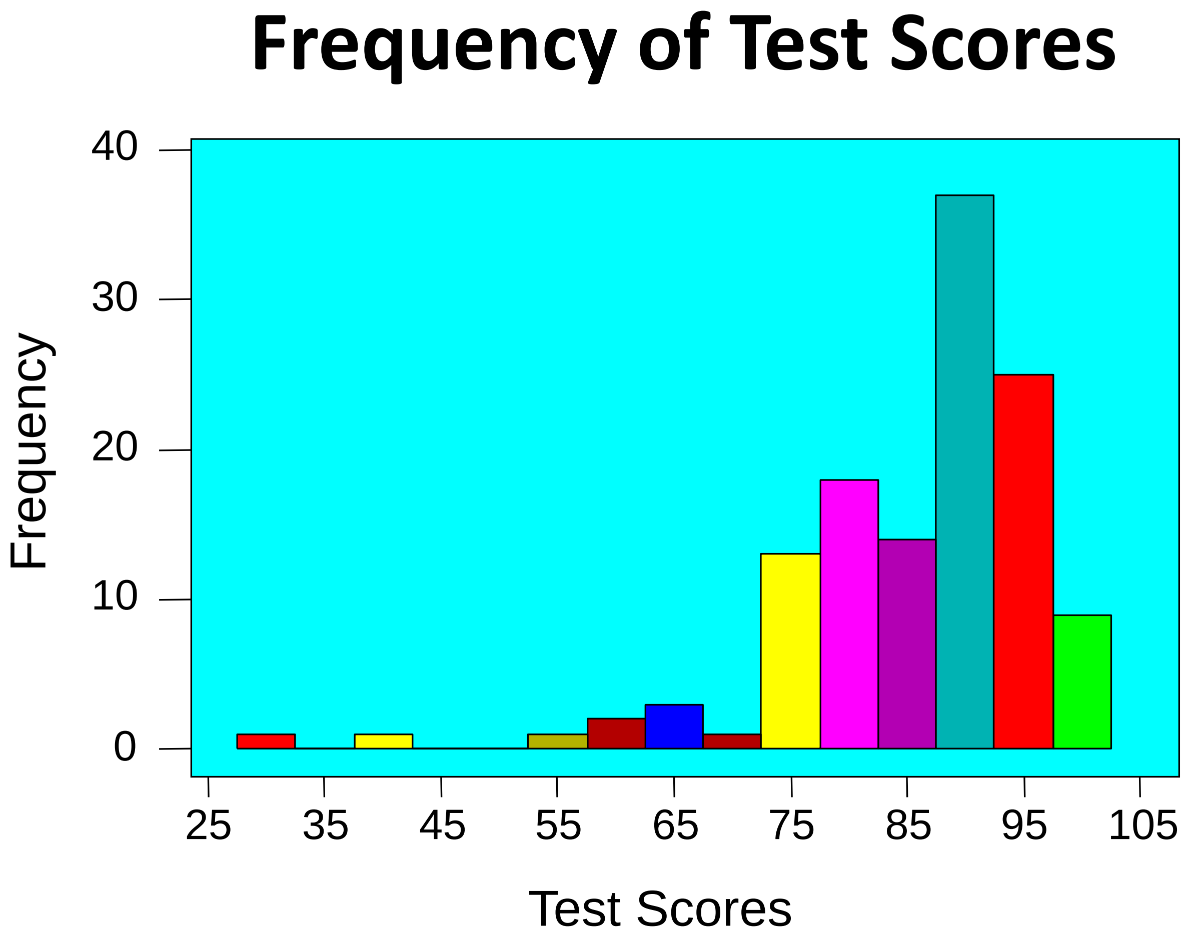
- A histogram is a useful way of graphically displaying data in groups.
- Divide the data into classes.
  - Classes may be attributes (e.g., Red, Yellow, Green, Blue, Brown, Orange).
  - For classes of variable data divide the data into ranges (e.g., Class 1 is between 0 and 10, Class 2 is between 10 and 20).
  - Count the number of occurrences in each class and chart on a bar graph.

Histograms Display

- Measure of central tendency (location).
- Measure of variation (spread).
- Measure of distribution (shape).



Histogram Example



Pareto Charts

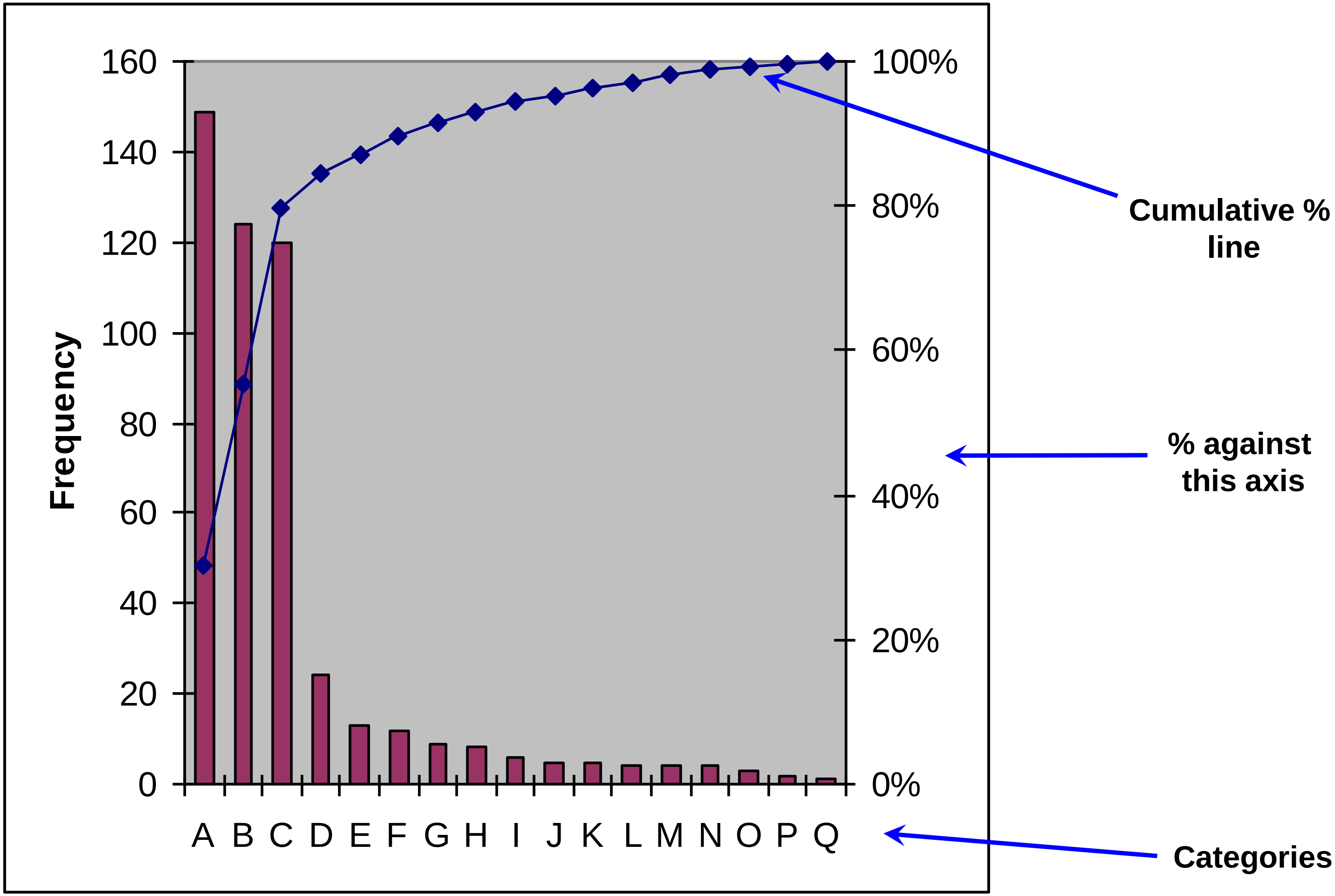
- Similar to histograms.
  - Aligns categories in descending order.
- The “80/20” Rule:
  - Pareto charts illustrate the concept that, for any given distribution of the results, the majority of the distribution (80%) is determined by a small part (20%) of the potential contributors or causes.

Construct a Frequency Table

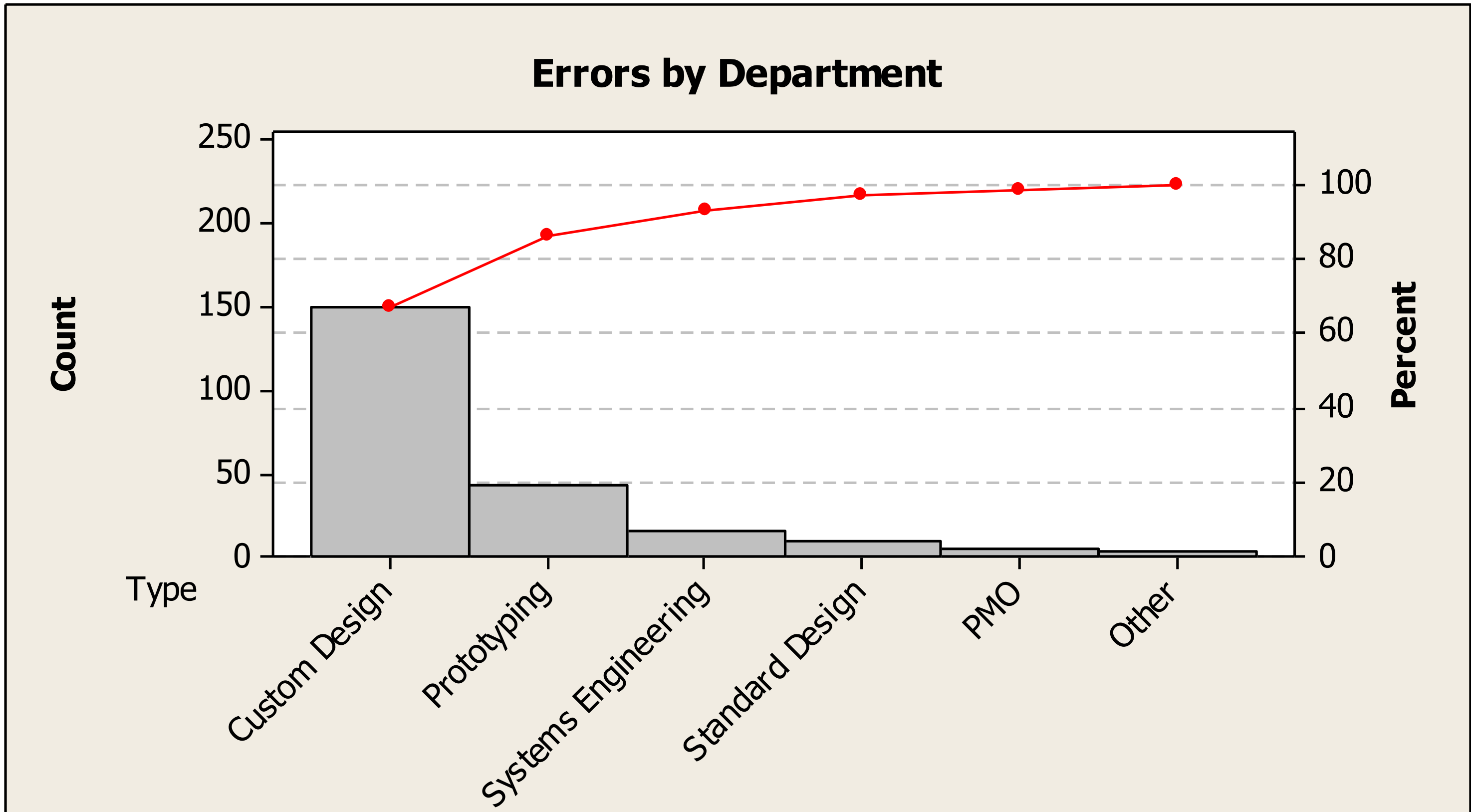
Category	Frequency	% of Total	Cumulative %
A	149	30.2%	30%
B	124	25.2%	55%
C	120	24.3%	80%
D	24	4.9%	85%
E	13	2.6%	87%
F	12	2.4%	90%
G	9	1.8%	91%
H	8	1.6%	93%
I	6	1.2%	94%
J	5	1.0%	95%
K	5	1.0%	96%
L	4	0.8%	97%
M	4	0.8%	98%
N	4	0.8%	99%
O	3	0.6%	99%
P	2	0.4%	100%
Q	1	0.2%	100%
Total	493		

Notice: "Frequency" column data arranged in descending order

Draw the Pareto Chart



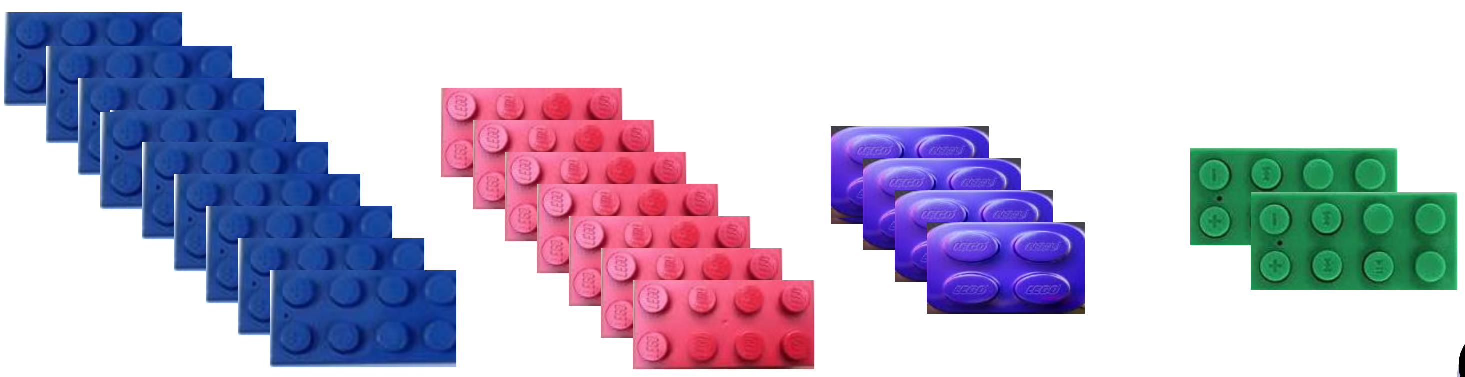
Pareto Charts - Example



Count	150	42	15	9	4	3
Percent	67.3	18.8	6.7	4.0	1.8	1.3
Cum %	67.3	86.1	92.8	96.9	98.7	100.0

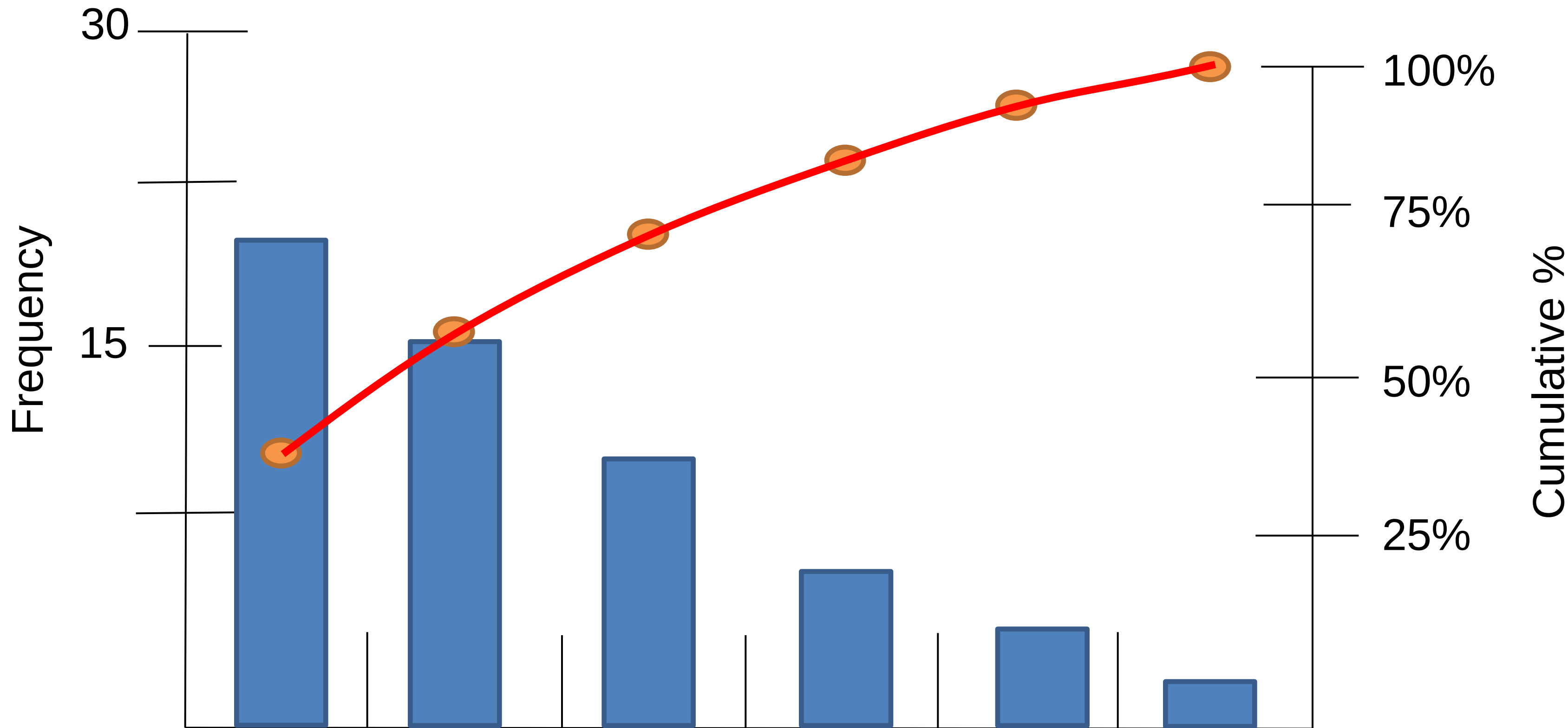
Pareto Chart Analysis Exercise

1. One Lego Bag per team.
2. Open Lego Bag.
3. Sort Lego's by color.
4. Highest number of Lego's on the Left.
5. Next Highest number of Lego's to the right.
6. Continue from highest to lowest until you reach the last color.
7. Plot the number of each color in descending order of magnitude.
8. Plot the number according to each color on the Occurrence Axis, from high to low.
9. Then plot the cumulative percent frequency showing the contributions from 0 to 100%.



15 minutes

Pareto Chart Analysis Exercise

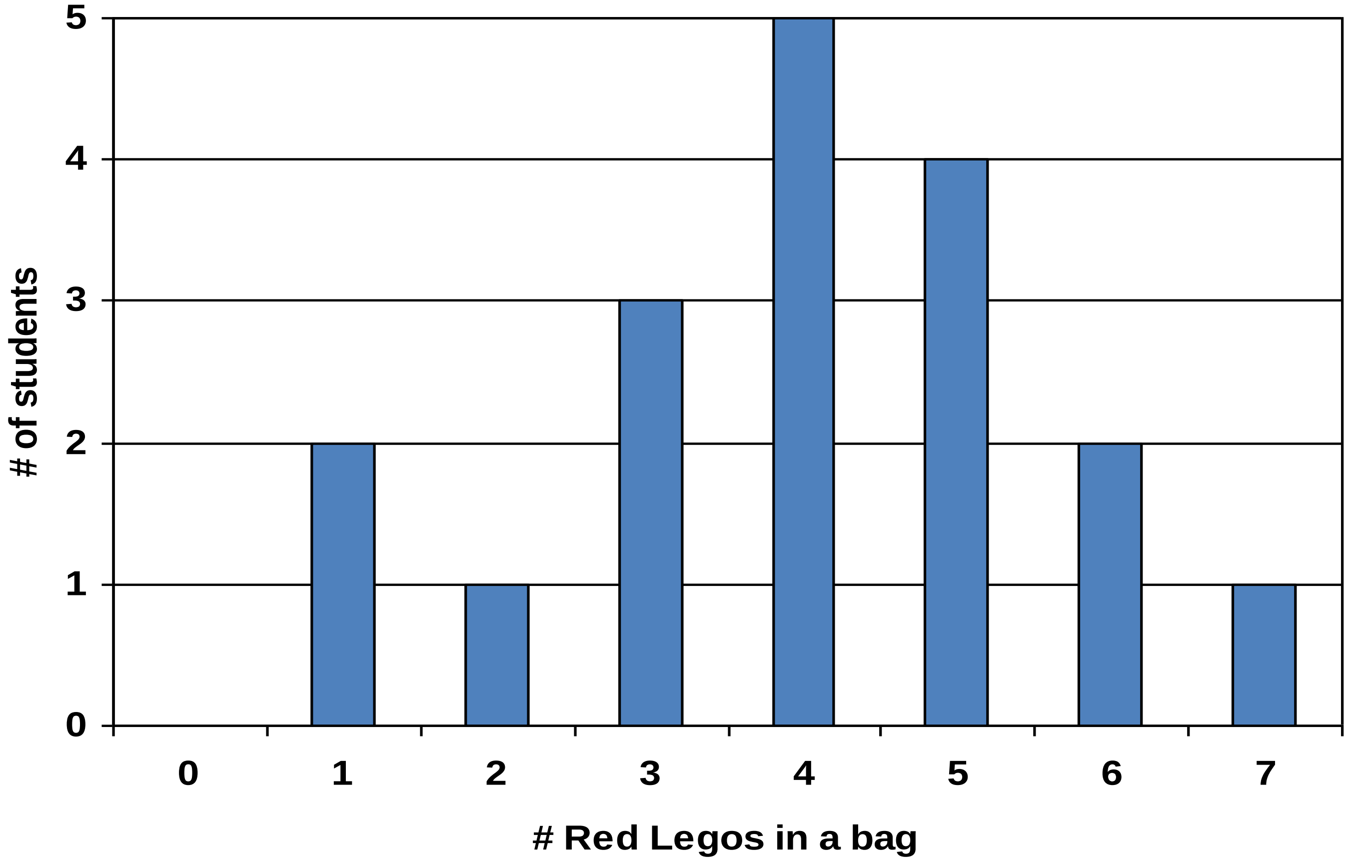


Categories Color of Lego's	Black	Red	White	Brown	Yellow	Green	
Lego Qty.	22	15	10	6	4	2	59
Cum %	37%	62%	79%	89%	96%	100%	
% of Total	37%	25%	17%	10%	7%	3%	

Exercise Review

- What does the chart tell you?
- Comparing your chart with the student next to you, is the chart the same?
- Which chart, you or your neighbor's accurately reflects the true population?

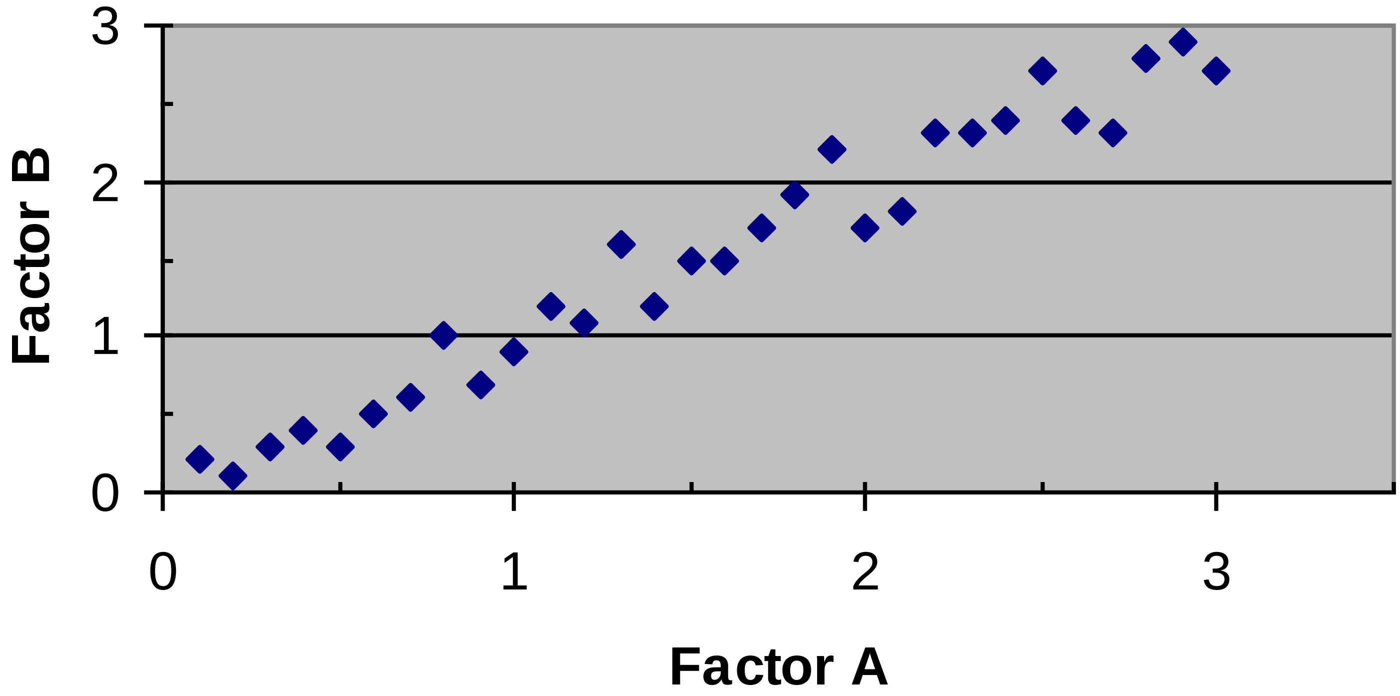
Histogram Example



Scatter Diagrams

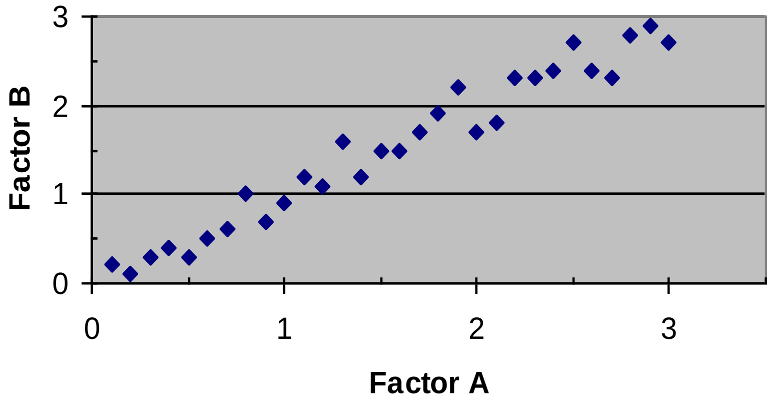
- Used to determine whether or not a relationship exists between two factors.
  - Will not prove that a cause-and-effect relationship exists.
- Enables teams to test hunches between two factors.
- Examples:
  - Ice Cream sales as they relate to outside temperature.
  - Demand for gasoline as it relates to the price at the pump.

Plot Paired Observations

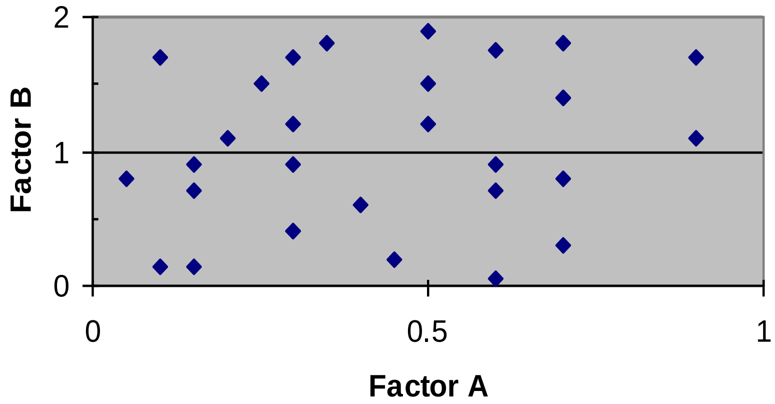


Interpret the Diagram

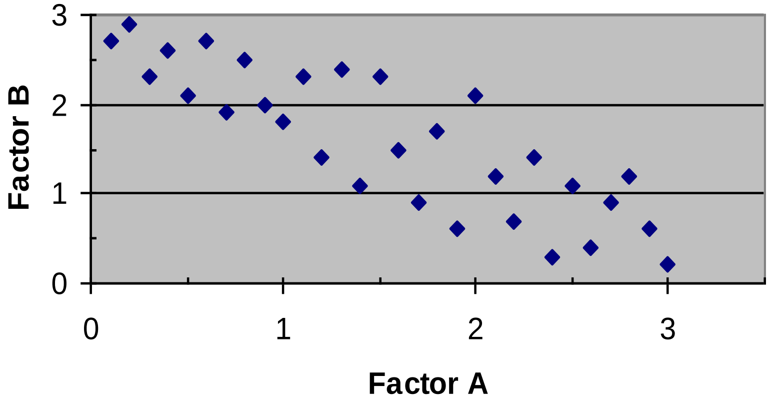
Narrow band, direct relationship



Circular, no relationship



Wide band, inverse relationship



Root Cause

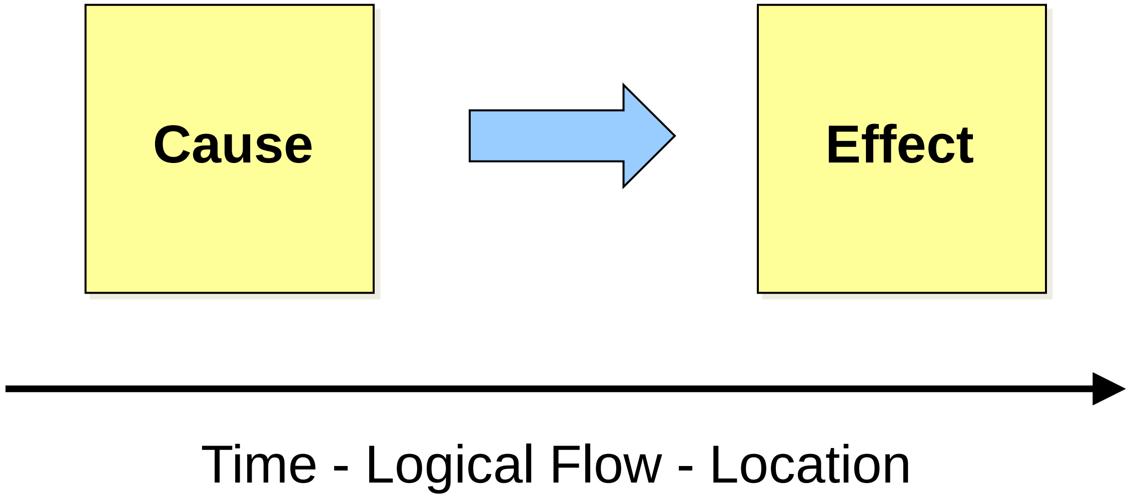
Why find the root cause of a defect?

- Eliminate the root cause, not the symptom.
- Problem doesn't reoccur.

- **Corrective action must:**
  - Ensure that the error is physically prevented from occurring again.
  - Prevents a defect loop.

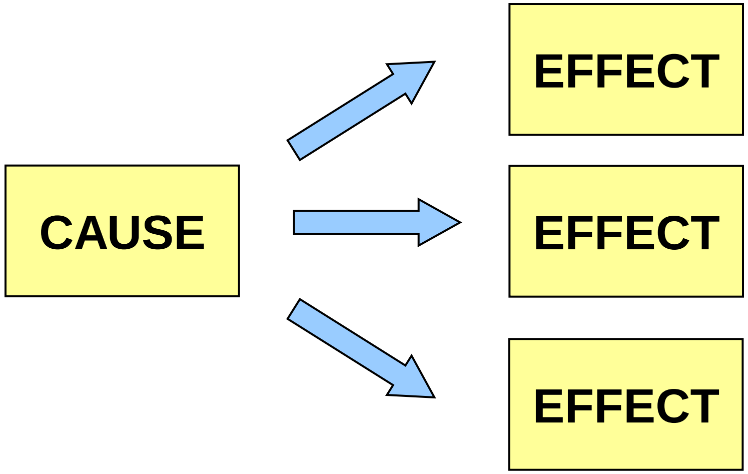
Root Cause Analysis

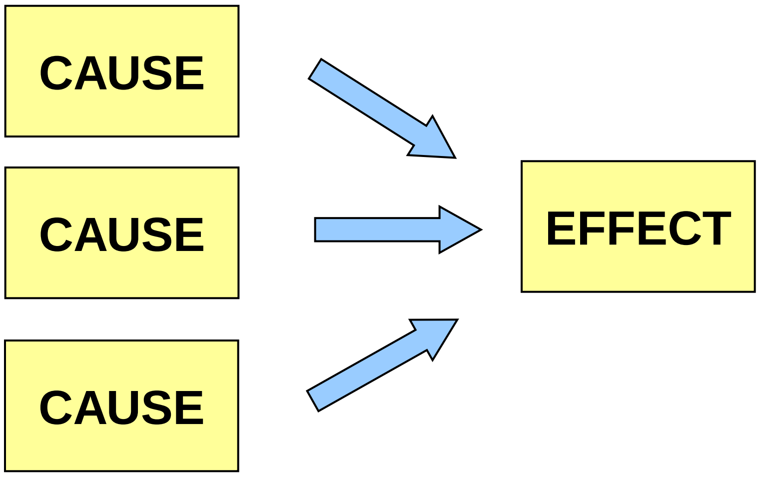
- Cause and Effect may be separated by Time, Logical Flow and Location.
- A Cause and Effect relationship is one-way.
- The Effect is not the Cause!



Root Cause Analysis

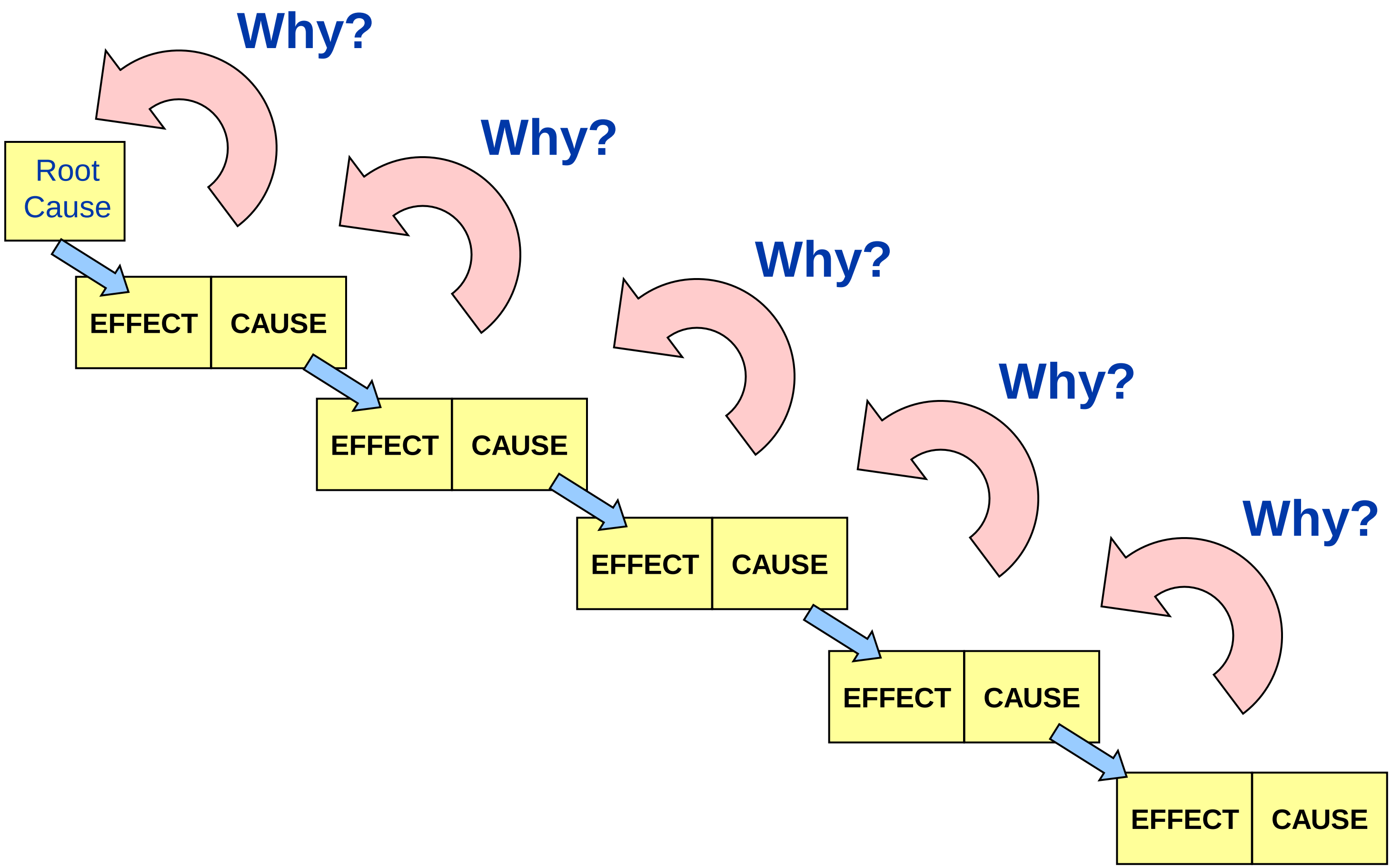
A single Cause can have multiple Effects.





A single Effect can have multiple Causes.

Root Cause Analysis – 5 Why's



Root Cause Analysis - Example

Granite on the Jefferson Memorial is deteriorating.

Why?

Use of harsh chemicals.

Why?

To clean pigeon droppings.

Why?

Lots of spiders at monument.

Why?

Lots of gnats to eat.

Why?

Gnats are attracted to the light at dusk.

Solution: Turn on the lights at a later time.

iSixSigma.com

Fishbone Diagrams

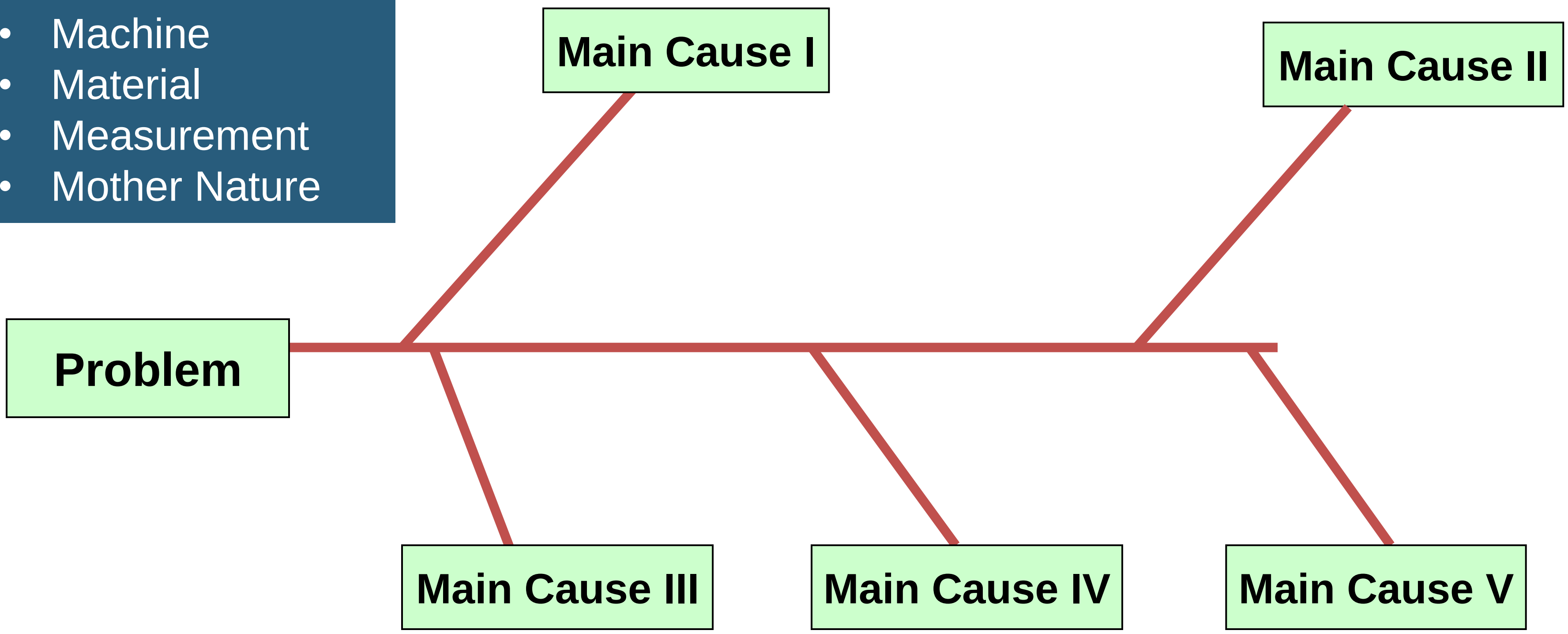
- Breaks problems down into bite-sized pieces.
- Displays many possible causes in a graphic manner.
- Shows how causes interact.
- Follows brainstorming rules when generating ideas.

Fishbone Diagrams

Define problem and determine the main causes (I,II,III, etc.).

Suggested Causes:

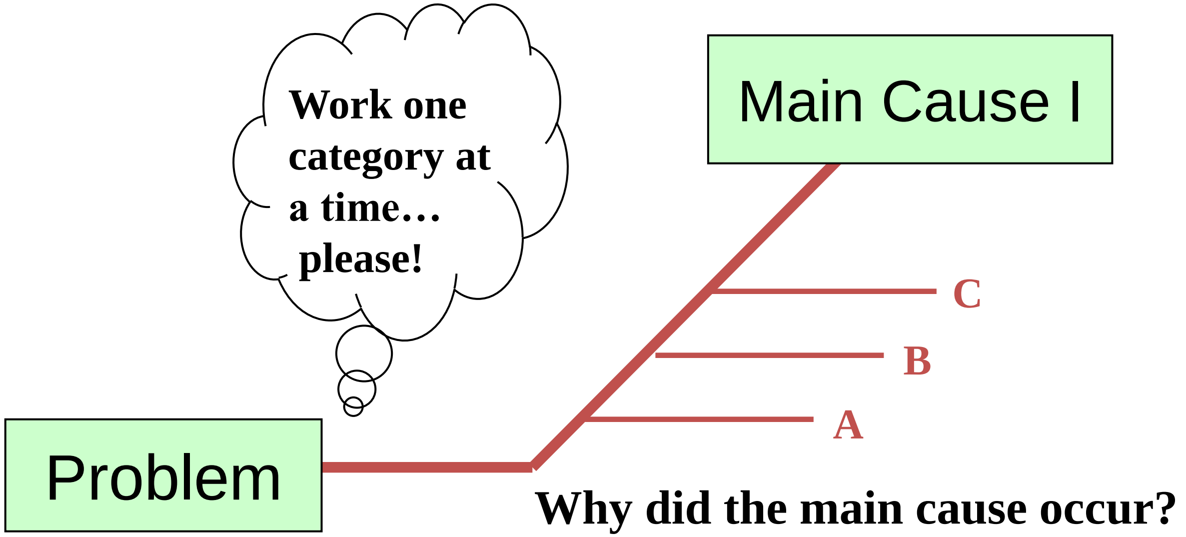
- Man
- Method
- Machine
- Material
- Measurement
- Mother Nature



Fishbone Diagrams – First Level

Pick one main cause and ask "Why did the main cause occur?"

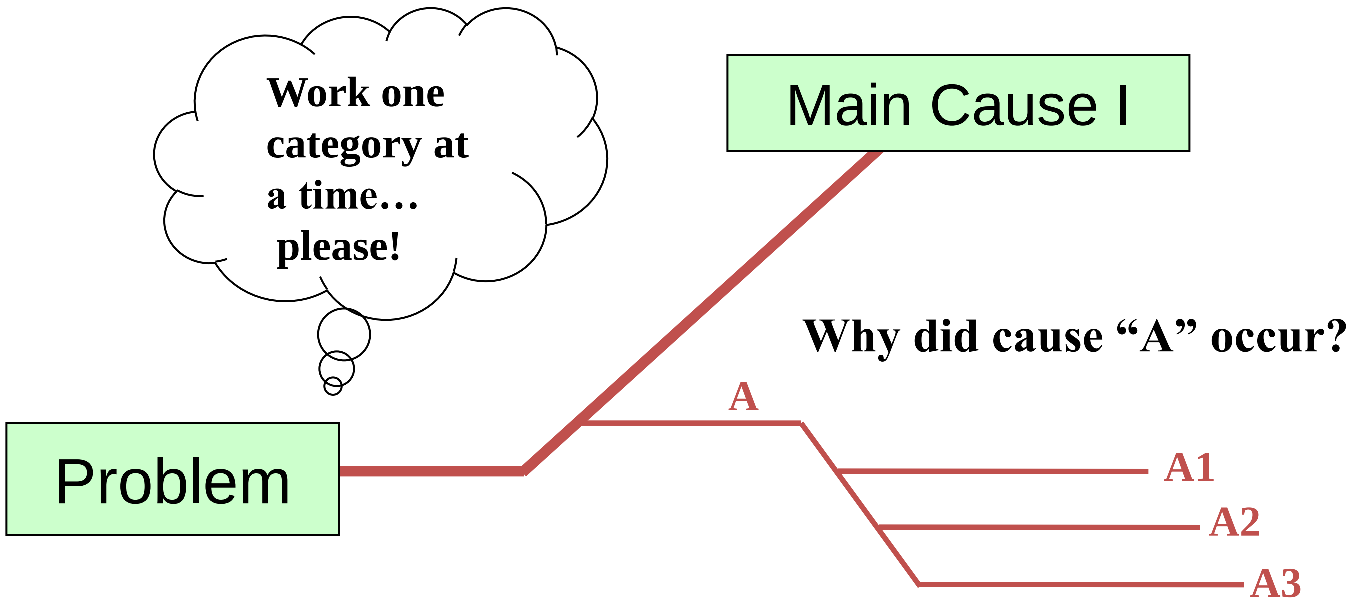
- Results in causes A, B, C, ...



Fishbone Diagrams – Second Level

Pick one main cause and ask "Why did cause A occur?"

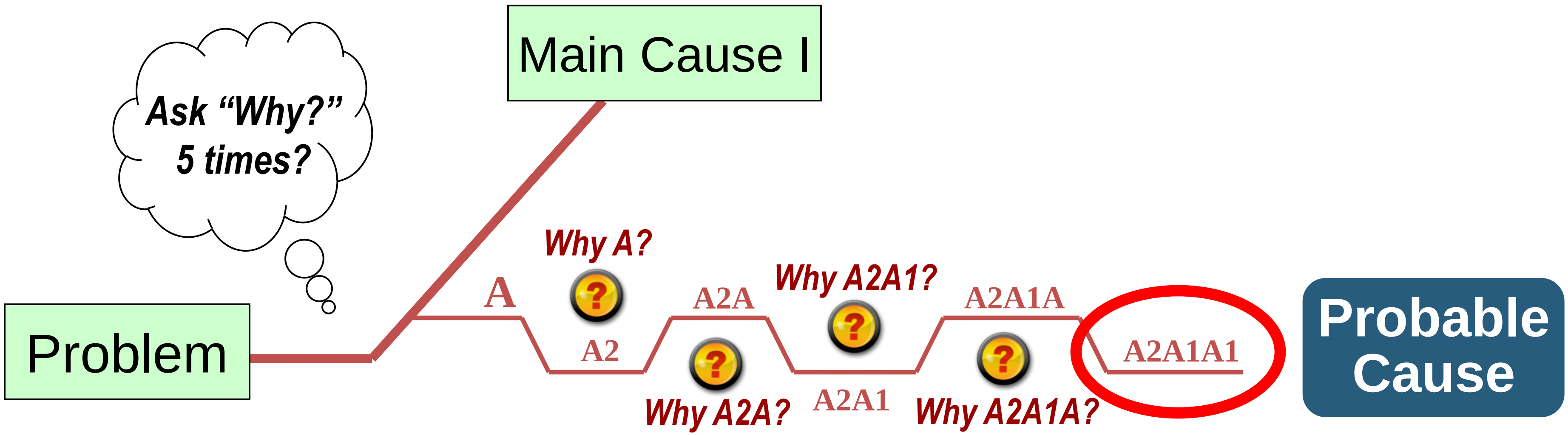
- Results in causes A1, A2, A3, etc.



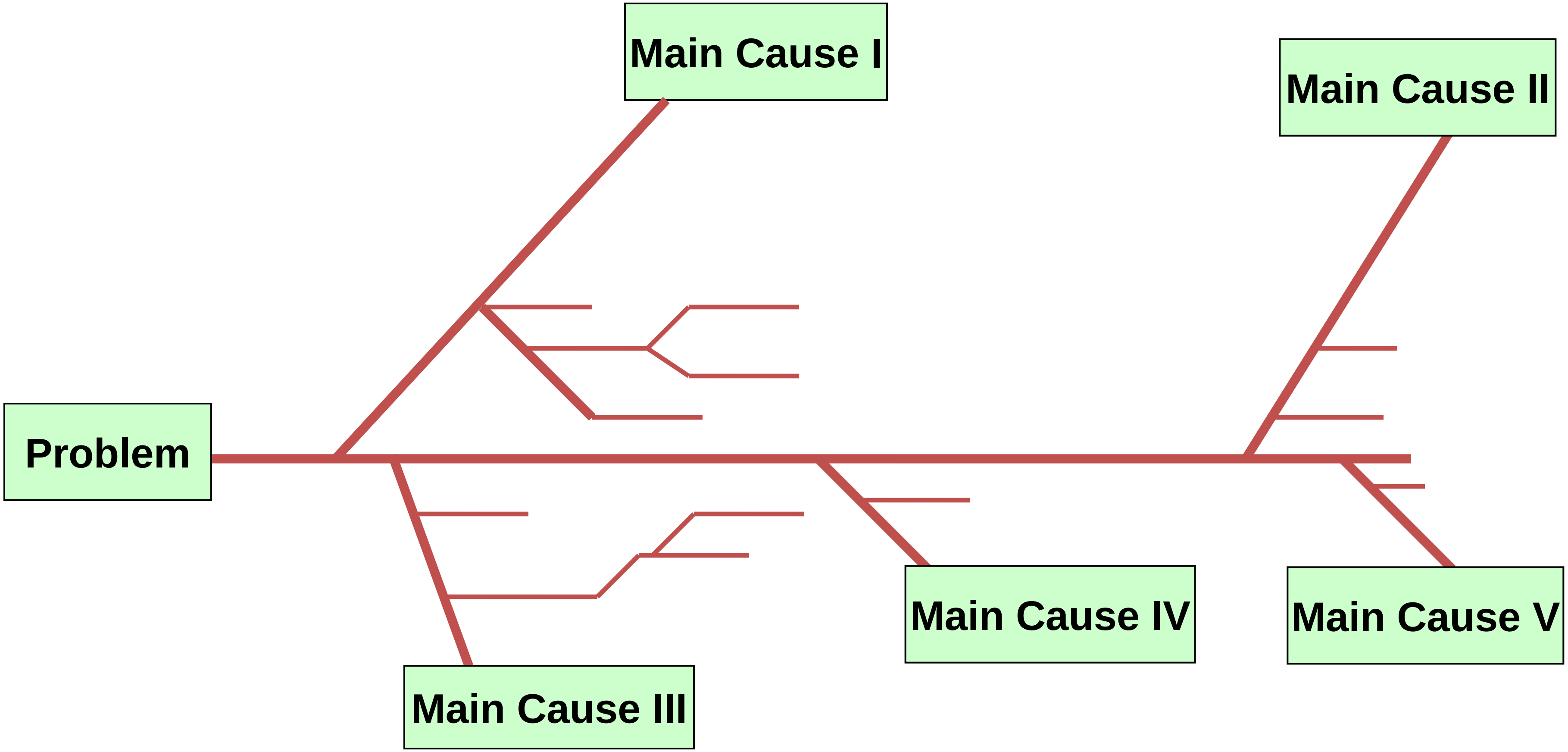
Fishbone Diagrams – Subsequent Levels

Pick one cause and ask "Why?" 5 times.

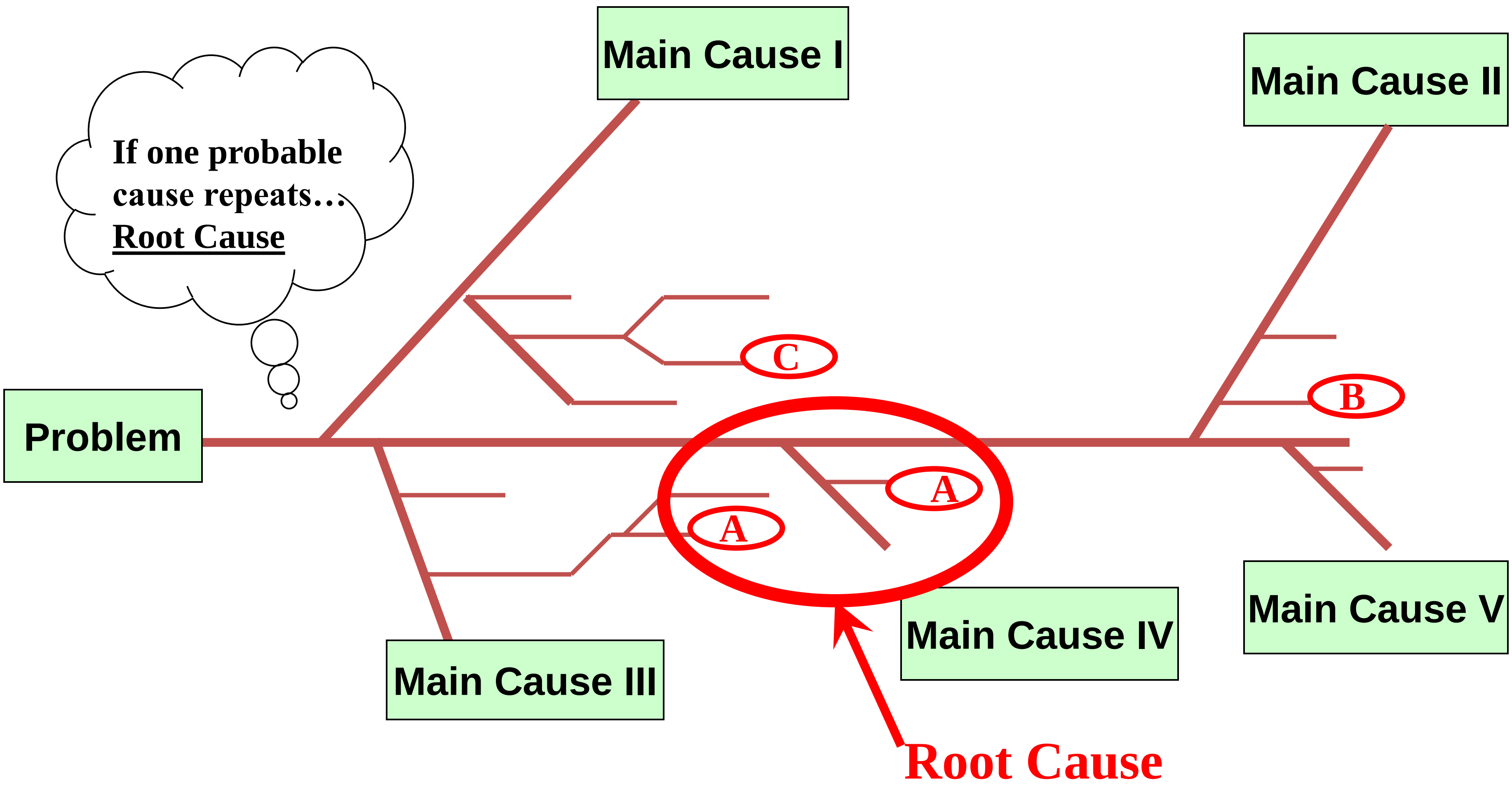
- End result is a probable cause.



Repeat for Each Main Cause

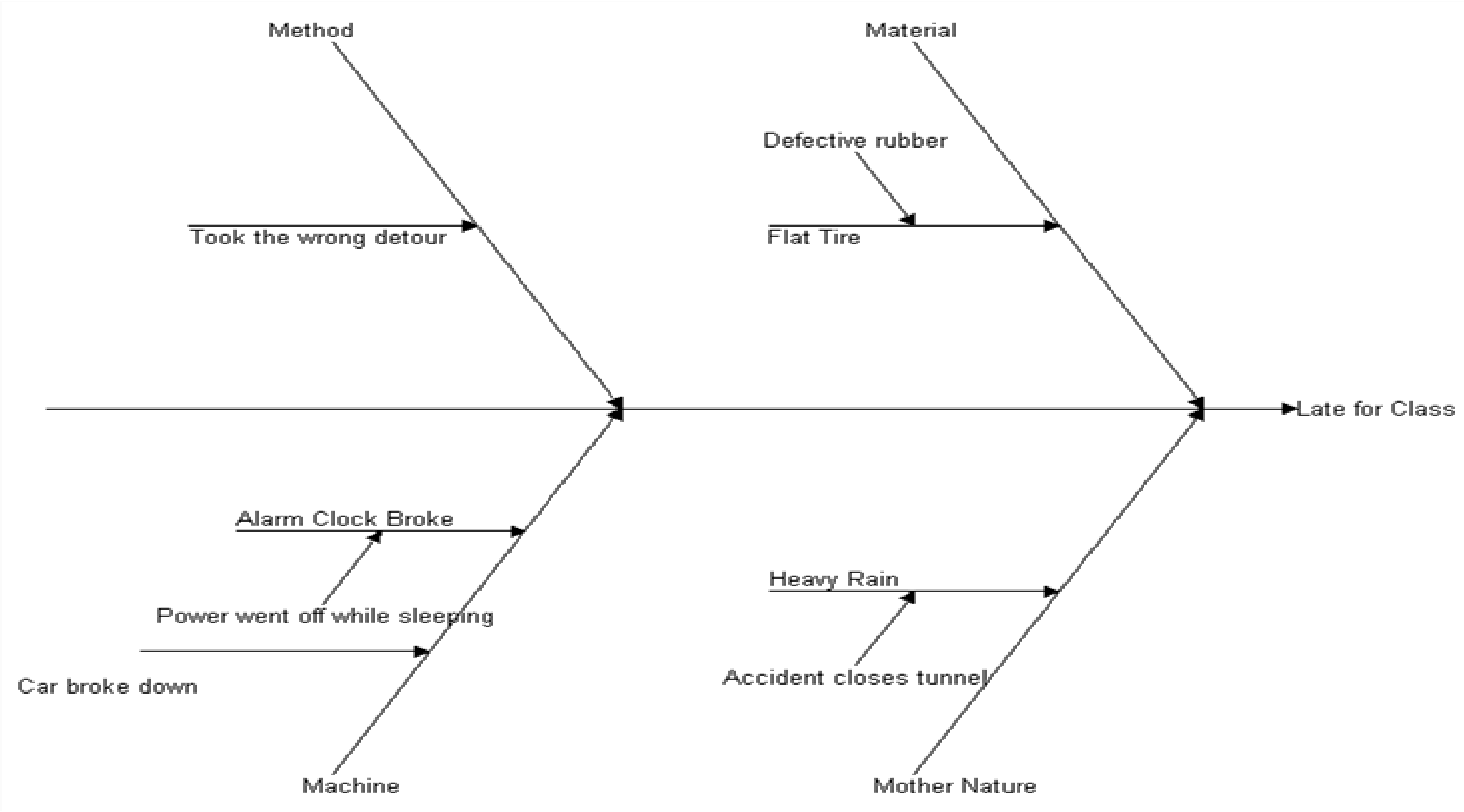


Fishbone Diagram - Identify Root Causes



Fishbone Diagram - Example

Late for Class

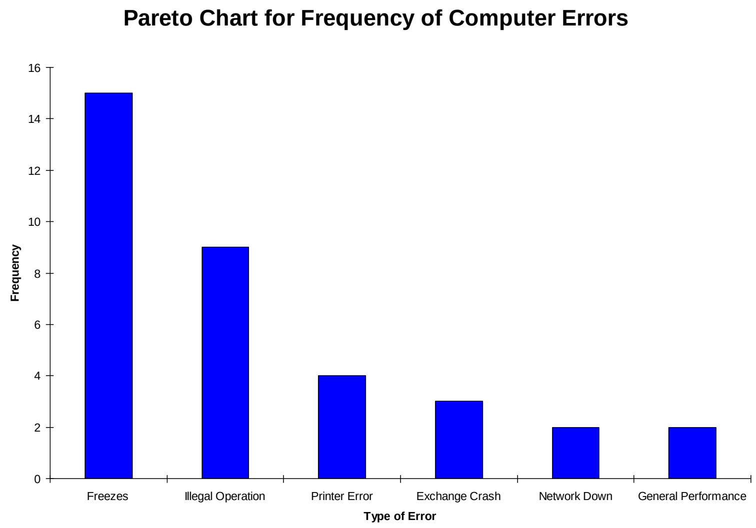


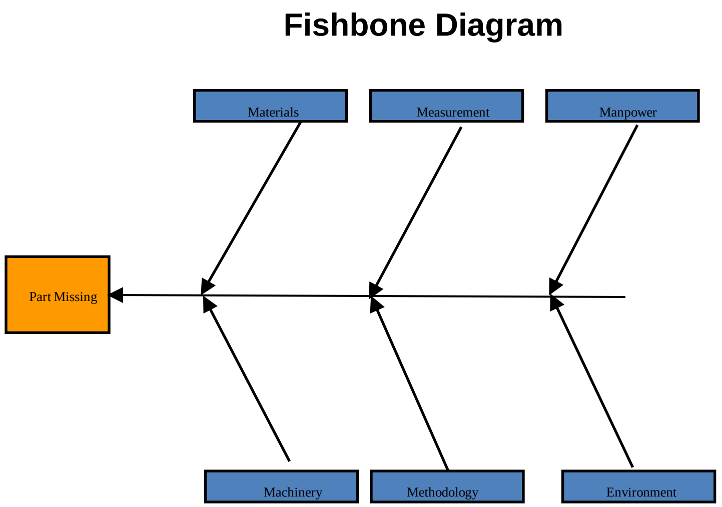
Exercise: Root Cause Analysis

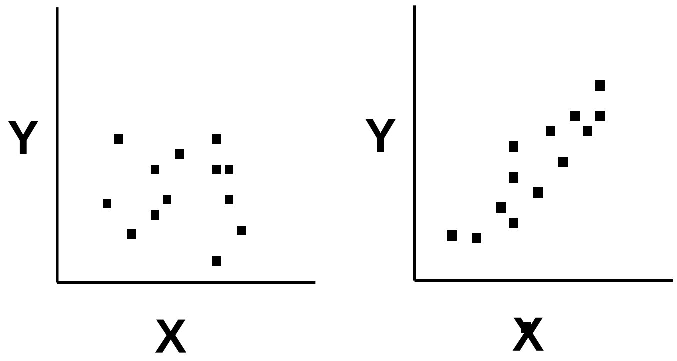
Break into Simulation groups and create a Fishbone Diagram for your Statapult process.

20 minutes

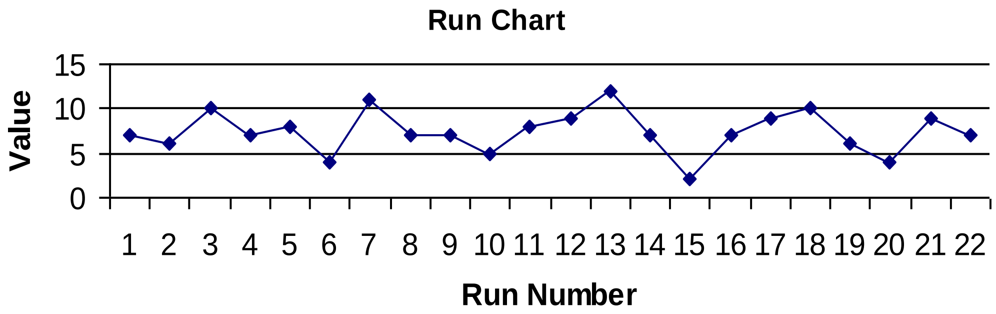
Root Cause Analysis Tools - Review







Scatter Plots



Failure Modes & Effects Analysis (FMEA)

- A risk assessment method to identify, analyze, prioritize and document potential failure modes, their effects on a process, product or system and the possible failure causes.
- It is a living document that needs to be reviewed and updated whenever a process is changed.
- FMEA Answers These Questions:
  - What the customer will experience if a key process input variable fails?
  - Which action needs to be taken to minimize risk?

Failure Modes & Effects Analysis (FMEA)

- Consider all failure modes of a system or process.
- Determine the effects of failure modes.
- Prioritize the failure modes based on:
  - Severity
  - Frequency of occurrence
  - Ability to escape detection

Prioritizing Failure Modes

- Severity, frequency of occurrence, and escaped detection are rated on relative scales.
- Generic scale is useful as starting point, but revision is necessary to fit the application.

Risk Priority Number (RPN) =
Severity X Frequency X Detection

Failure Mode and Effect Analysis - Example

FMEA of Building Elevators								
Item	**Failure mode**	**Failure effect**	**Severity**	**Causes**	**Occurrence**	**Controls**	**Detection**	**RPN**
Doors	Mis-alignment of plastic gib	Door will not close	10	Pushing or hitting door transversely	6	Proper use of elevators	5	300
	Foreign object on track	Door will not close	10	Daily use / poor housekeeping	7	Daily cleaning of track	5	350
	Electronic enter locks	Door will not close	10	Worn or tarnished contacts	6	Replace / clean contacts	1	60
	Hall door not closing properly	Door will not close	10	Failure of hall door retracting spring	2	Replace spring	1	20
	Micro scan failure	Door will not close	10	Dirty cover on scanner strips	9	Proper house keeping (i.e., no mop water allowed to get on sensor face plate)	8	720
Car	Door operator failure	Doors will not open/close	10	Motor failure	3	Replace motor	1	30
				V-belt failure	4	Replace belt	1	40
				Sheave failure	1	Replace sheave	1	10
				"Music box" resistors fail	5	Tune / replace resistors	1	50
	Door clutch failure	Hall doors will not open	10	Clutch spring fails	1	Replace spring	1	10
Buttons	Buttons Jam	Car constantly called to floor of stuck button	10	Dirt accumulation around button	2	Clean space around button	7	140

Severity Scale

1. No effect on performance.
2. Minor loss of performance with negligible effect on output.
3. Minor loss of performance.
4. Reduced performance.
5. Minor inability to meet customer requirements.
6. Inability to meet customer requirements.
7. Cause serious customer dissatisfaction.
8. Cause a failure.
9. Break regulations or other law.
10. Cause an injury.

Note: This is a sample scale and must be revised to fit your application of FMEA.

Occurrence/Probability Scale

1	Once every 5 - 10 years	Less than 2/1,000,000,000
2	Once every 3 - 5 years	Less than 3/10,000,000
3	Once every 1 - 3 years	Less than 6/1,000,000
4	Once per year	Less than 6/100,000
5	Once every 6 months	Less than 1/10,000
6	Once every 3 months	Less than 0.03%
7	Once per month	Less than 1%
8	Once per week	Less than 5%
9	Once every 3 - 4 days	Less than or equal to 30%
10	Once per day	Greater than 30%

Note: This is a sample scale and must be revised to fit your application of FMEA.

Detection Scale

1. Immediate detection.
2. Easily detected.
3. Moderately easy detection.
4. Quick detection by Statistical Process Control (SPC).
5. Detected by SPC.
6. Detected by inspection and error-proofing.
7. Detected by manual inspection.
8. Frequently undetected.
9. Very difficult to detect.
10. Cannot be detected.

Note: This is a sample scale and must be revised to fit your application of FMEA.

Knowledge Check: Fishbone

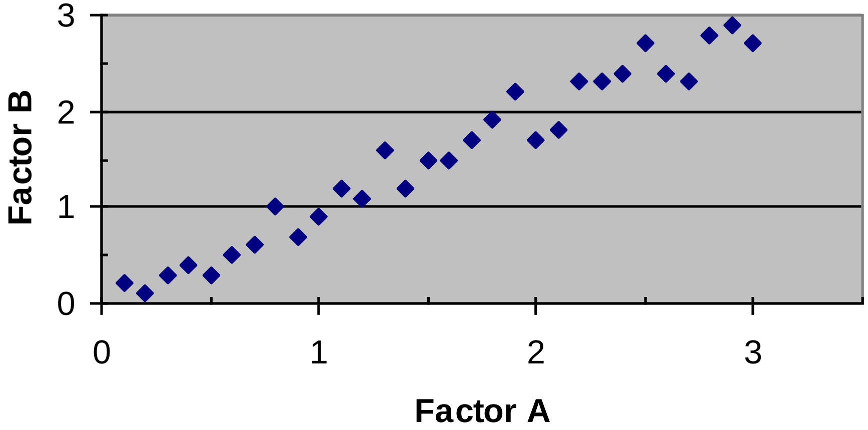
What is the purpose of the Cause and Effect Diagram (Fishbone/Ishikawa)?

Knowledge Check: Pareto Chart

What is the underlying principle of the Pareto Chart?

Knowledge Check: Scatter Diagram

What is the purpose of a Scatter diagram?



The diagram above shows that increasing Factor A causes Factor B to increase. True or false?

Knowledge Check: Risk

What basic tool is used to proactively identify, analyze, prioritize, and document risk?

Knowledge Check: Variation

Name the two types of variation?

Statistics


DEFINE
MEASURE
ANALYZE
IMPROVE
CONTROL
CONTINUOUS PROCESS IMPROVEMENT

The Role of Statistics

- **Descriptive Statistics**
  - Describing a set of data with graphs and a few summary numbers (central tendency, variation and distribution).
- **Inferential Statistics**
  - Using descriptive statistics to make educated guesses about the future (predictions).

Before we can go further with statistics we need to know something about data.

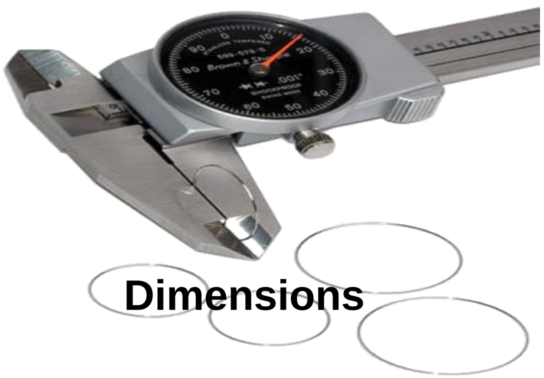
Data Types

- Much information comes to us in qualitative form (job is expensive or takes too long).
- Project information must be collected in quantitative form and can represent:
  - Whether something happened or not.
    - **Attribute** or discrete data – Counting data.
  - Specifics about what happened.
    - **Variable** or continuous data – Measurement data.

Data Types - Variable

Variable (continuous) Data - characterizes a product or process feature in terms of a parameter such as size, weight or time.

Time



Dimensions

Temperature

Weight

Variable data gives more information than just knowing if the part was good or bad.

Data Types - Attribute

Attribute (discrete) Data - the number of times something happens or fails to happen. It is measured as the ***frequency*** of occurrence. It is also data that falls into categories such as production line, operating shift and plant.

Examples of Attribute Data:	
Number of defects	**Pass/Fail**
Complaint Resolution	**Yield**
Line reject counts	**On time delivery**

Attribute data cannot be meaningfully subdivided into more precise increments.

Statistical Terminology

- **Population** - a complete set; all items of interest
  - The number of elements in a population is denoted by ***N.***
- **Sample** - a subset of elements from the population
  - The number of elements in the sample is denoted by ***n.***
- We can characterize a population or sample in 3 ways:
  - Measure of central tendency (location of center or middle).
  - Measure of variation (spread or width).
  - Measure of distribution (what does the set look like when viewed graphically (shape)).

Measures of Central Tendency (Location)

- **Mean** - the average of the population or sample.
  - Sum of all values divided by *N* or *n.*
- **Median** - the middle of the population or sample (***50% of all values fall on either side of this value***).
  - The middle value if *N* or *n* is odd.
  - The average of the two middle values if *N* or *n* is even.
- **Mode** – the most frequently occurring value.

Measures of Central Tendency - Mean

$$\text{Mean} = \frac{\sum_{i=1}^{N} x_i}{N} = \mu$$

Population

$$\text{Est. Mean} = \frac{\sum_{i=1}^{n} x_i}{n} = \overline{X} \text{ or } \hat{\mu}$$

Sample

Measures of Central Tendency – Mean Example

Salaries ($)
50,000
85,000
60,000
50,000
75,000
90,000
45,000

Mean (average):

1. Total the column of values. ($\sum \mathbf{X_i}$)
2. Divide by number of values. (n)

Measures of Central Tendency - Median

Salaries ($)
45,000
50,000
50,000
60,000
75,000
85,000
90,000

Median:

1. Place data in order from lowest to highest.

2. Find the middle point.

3. If middle point is between two numbers, average their values, otherwise it is the middle value.

Measures of Central Tendency - Mode

Salaries ($)
45,000
50,000
50,000
60,000
75,000
85,000
90,000

Mode:

1. Find the most frequently occurring value.

Measures of Variability (Spread)

- **Range** – the difference between the greatest value and the smallest value in the data set.
- **Percent variation** – when comparing frequencies, a normative way to describe variability.
- **Variance** – the average squared distance between an individual data point and the mean.
- **Standard deviation** – is the square root of variance.

Measures of Variability

Why do we care about variation?

Because just looking at the central tendency doesn't tell the whole story!

Process 1	Process 2
8	3
9	7
10	10
11	13
12	17

Measures of Variability – Percent Variation

- How do we compute percent variation?
  - How do you compare the number of blondes vs the number of brunettes in a population?
  - You can only compare based on a percentage.
  - If you have a room of people and 30% are blondes and 35% are brunettes, you can determine the percent variation (35% – 30% = 5%).

Thus the variability between those two hair colors is 5%.

Measures of Variability - Variance

$$\text{Variance} = \frac{\sum_{i=1}^{N}(x_i - \mu)^2}{N} = \sigma^2$$

Population

$$\text{Est. Variance} = \frac{\sum_{i=1}^{n}(x_i - \overline{X})^2}{n-1} = s^2 \text{ or } \hat{\sigma}^2$$

Sample

Measures of Variability – Standard Deviation

$$Std.Dev = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \mu)^2}{N}} = \sigma$$

Population

$$\text{Est.Std.Dev.} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{X})^2}{n-1}} = s \text{ or } \hat{\sigma}$$

Sample

Measures of Variability (Spread)

- How do we use Variance and Standard Deviation?
- Variance can be used to compare two processes to see if they are similar.
  - Example: Compare process time from 3 different factories to see if they are significantly different or the same. If one factory is different (i.e., worse), you start looking at that factory first.
- Standard Deviation can be used to determine how well your process is working.
  - Can be used to create a control chart.
  - Can be used to describe quality.

Exercise: Standard Deviation

Compute the variance & standard deviation of the sample: {8, 18, 12, 3, 9 }

Variance:

1. Determine the mean of the column of numbers.
2. Subtract the mean from each number in the column.
3. Square the difference.
4. Add the squares together, divide by n-1.

Standard Deviation: The square root of the variance.

i	x_i	$(x_i - \overline{x})$	$(x_i - \overline{x})^2$
1			
2			
3			
4			
5			
Totals			

Exercise: Central Tendency & Variance

n	Xi	Xi - $\bar{X}$	$(Xi - \bar{X})^2$
1	10		
2	9		
3	8		
4	11		
5	12		
6	6		
7	14		
∑			
n			
$\bar{x}$			

Variance S^2	Std Dev = S

Exercise: Central Tendency & Variance

n	Xi	Xi - $\bar{X}$	$(Xi - \bar{X})^2$
1	77		
2	65		
3	63		
4	90		
5	82		
6	92		
7	94		
8	98		
9	73		
10	96		
∑			
n			
X̄			

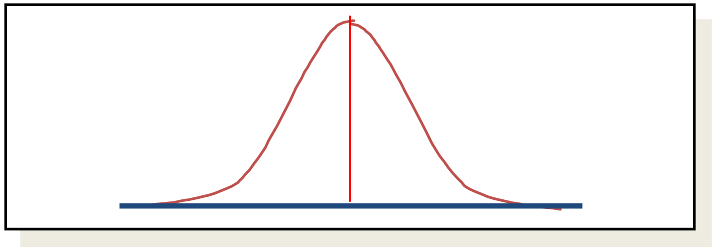
Variance S^2	Std Dev = S

Let’s Talk About Distribution (i.e., Shape)

- A graph of the data presents a visual of the data set, that can be more descriptive than just numbers.
- A graph provides a “snapshot” of the central tendency and variability of the data.
- Mapping the data – common graphs.
  - Histograms, Stem & Leaf plots, Boxplots.
  - Shows the data in relation to the scale.

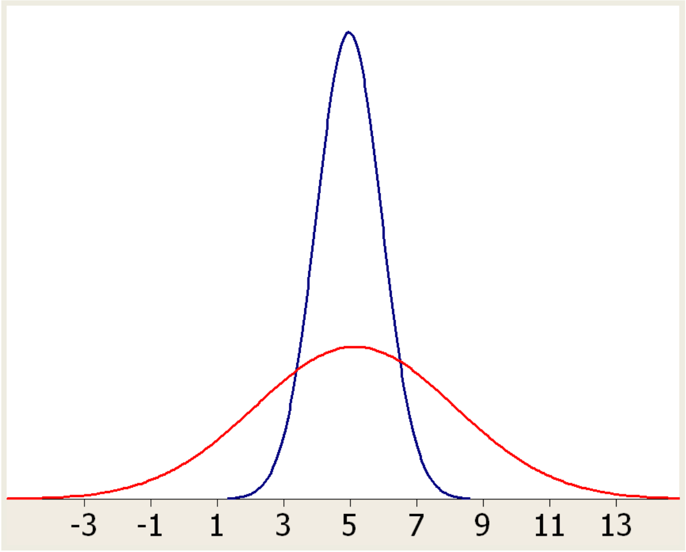
Defining Normal Distributions

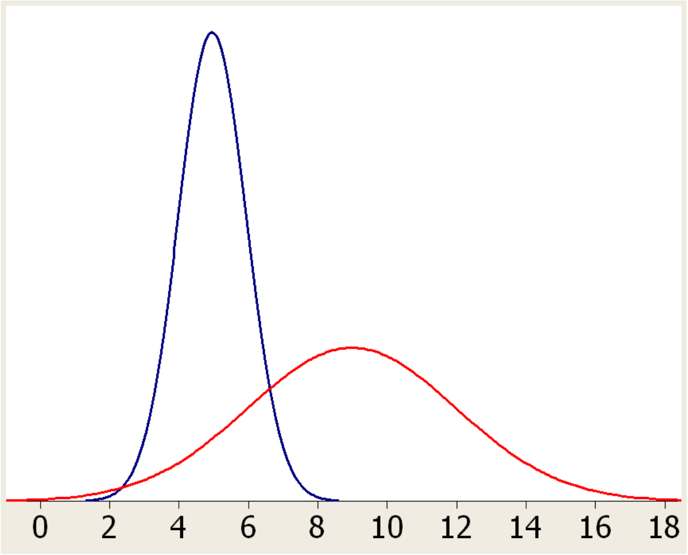
- The most common distribution is the normal distribution. It is a variable data distribution with a mean and a standard deviation as its primary measures.
- Normal distribution means that data values are evenly distributed about the mean, and the distribution is symmetric.
- Normal distribution is the most common shape.



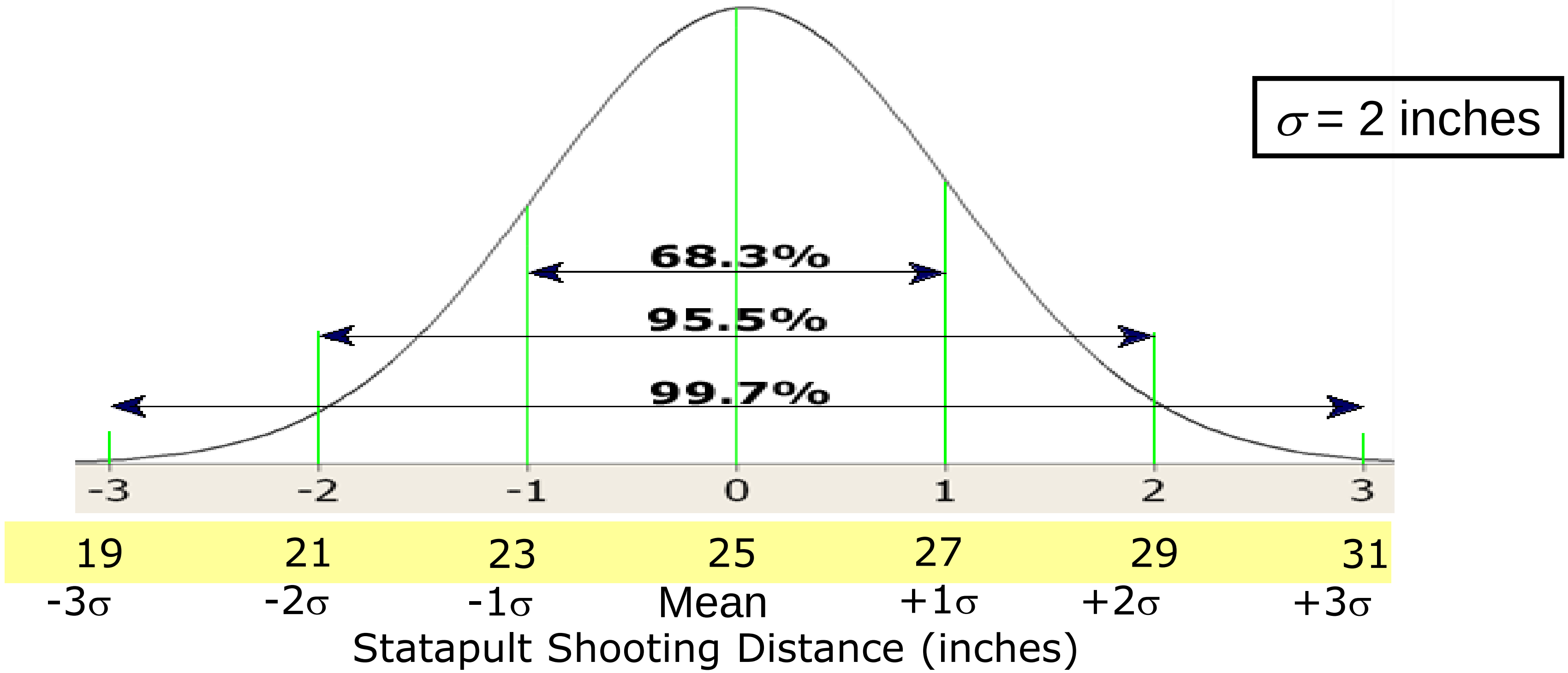
Defining Normal Distributions

- Normal distributions are described with two parameters:
  - The mean defines the central tendency (location).
  - Standard deviation defines variation (spread).
- Examine the following data distributions and compare the mean and standard deviation for each:





Distribution Characteristics



- 100% of the data is included underneath the curve.
- Certain percentages of data fall between the sigma divisions.
- If you fired the statapult 1,000 times, how many of the shots would fall between 19 and 31 inches?

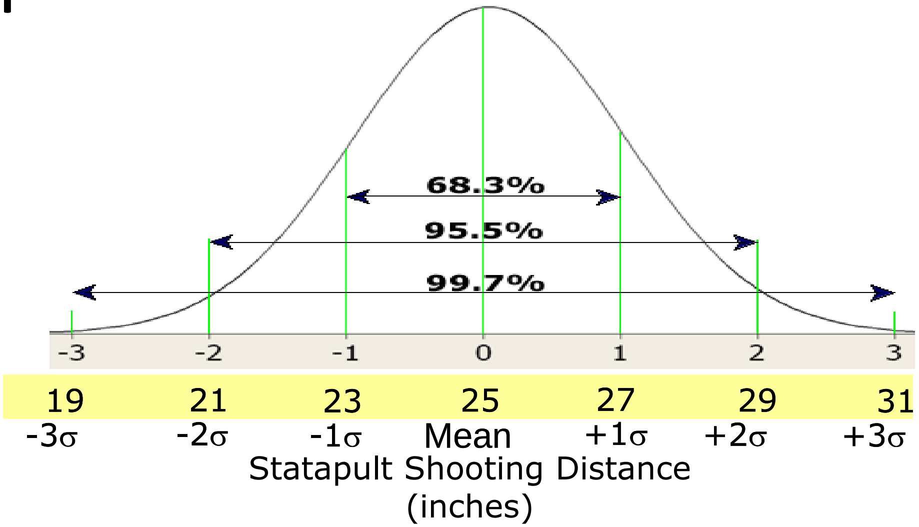
Answer = ______

The Role of Statistics – Inferential Statistics

- Types of data and measures of central tendency, variation and distribution are descriptive statistics.
- Inferential statistics can be used to infer, or make predictions, about processes based on the descriptive statistics.
- Inference is done by using the data for a normal distribution, and specific statistical tables.

The Role of Statistics – Inferential Statistics

- One hundred percent of data falls under the curve.

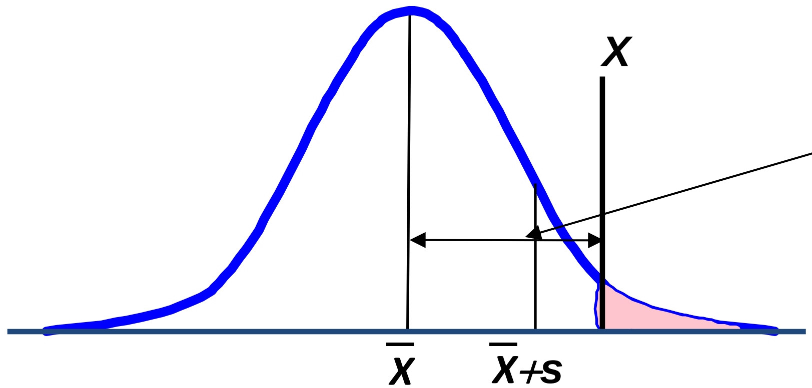


- A Z-table is used to compute the probabilities of data falling under a specific area of the curve.

You must have normal distribution to use a Z-table.

Convert Data to Standard Normal Distribution

- A Z-table is based on a "Standard Normal" data set – which has a mean of 0 and a standard deviation of 1.
- Since real data is not "Standard Normal", you need to transform your data in order to use the Z-table to predict a probability.



In this case, the Z score is the number of standard deviations between the mean ($\bar{X}$) and the performance limit (X).

$$Z = \frac{X - \bar{X}}{s}$$

Z

The X value is transformed by the formula, giving a z value. This allows you to look up probabilities on the z-table.

X = The value you are interested in predicting.

$\bar{X}$ = The mean of your data set.

s = The standard deviation of your data set.

Using Inferential Statistics (Z-table)

Scenario: You process travel claims. You have instituted a new process and collected data on processing time. It shows that you have a normal data set (distribution) with a mean of 32 minutes and a standard deviation of 1.89 minutes.

Your boss wants to know what are the odds (probability) that a travel claim will be processed in 37 minutes or less.

$$Z = \frac{X - \bar{X}}{s}$$

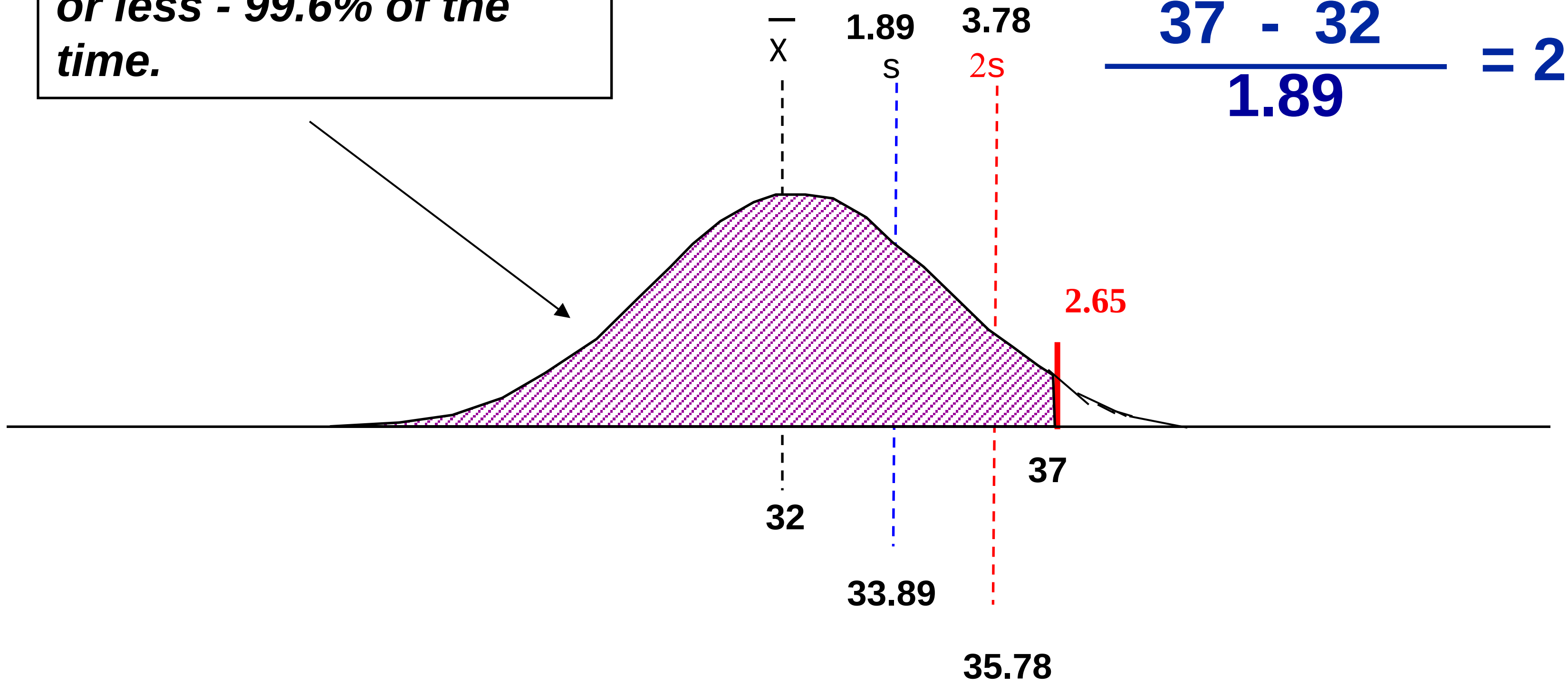
z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974

Z Table

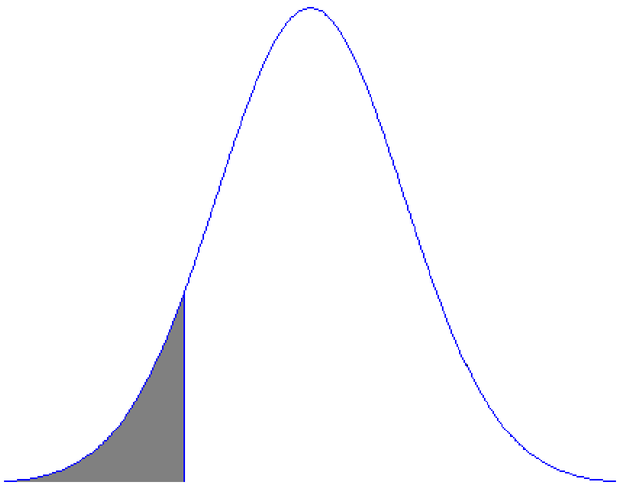
Using Inferential Statistics (Z-table)

The shaded area to the left represents the travel claims that will be processed in 37 minutes or less - 99.6% of the time.

$$\frac{37 - 32}{1.89} = 2.65$$



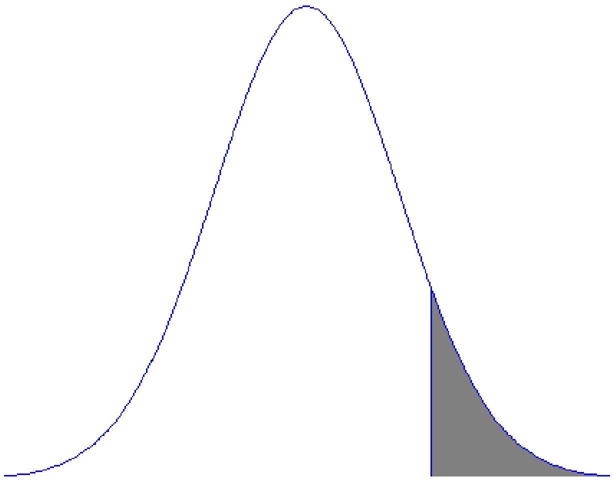
Z-Table Identification



X

Left Tailed Z-Table

Less than X



X

Right Tailed Z-Table

Greater than X

Typical Z-table always show probabilities less than X (Left Tailed Z-Table).

Right Table Z-Table Value = 1 – Left Tailed Z-Table Value

Exercise: Probability and Z Value

1. Complete the table for z value and probability:

$\bar{X}$	S	X	Z	Probability
120	40	<180		
28	4	<32		
85	5	>100		

2. A normally distributed process has output which is below the upper specification limit 99.7% of the time. How many standard deviations is the USL from the process mean? ___________

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974

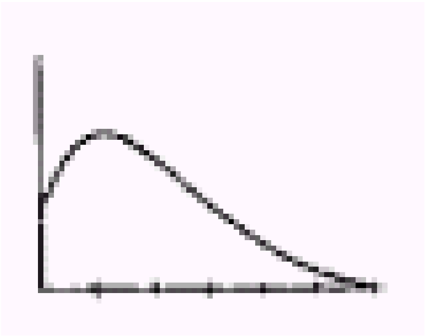
Z Table for Prob. 2

Central Limit Theorem

- Central Limit Theorem – the sampling distribution of the means tend to take the shape of a normal distribution curve.
  - If you have a data set.
  - You can take samples of the data and find the mean of those samples.
  - Then if you plot the means, you will a get a normal distribution.

Central Limit Theorem

- What if you don't have normal data?
  - If you collect a large enough sample over time, usually the data will take on a normal distribution.
  - There are some times, however, when the data will never be normal (Go get a Black Belt).



When would you see this type of distribution?

Knowledge Check: Statistics

What three things do you need to understand the performance of a process?

Knowledge Check: Statistics

How would we use the following formula:

$$Z = \frac{X - \bar{X}}{s}$$

Knowledge Check: Statistics

Assuming a normal distribution, no more than 95% of our data will fall in the range between

X_bar +/- 3 σ.

True or False?

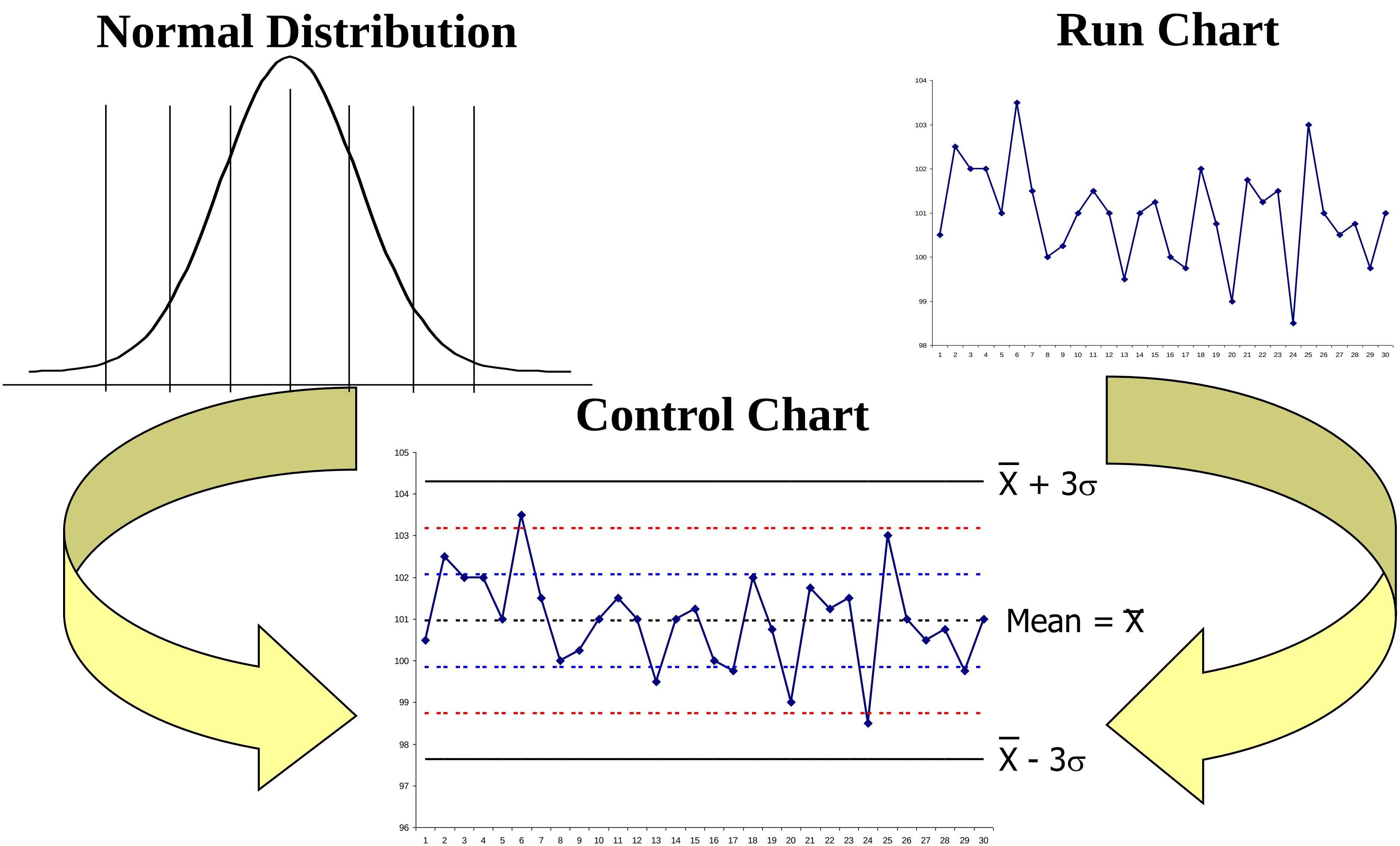
What is the relationship, if any, between Variance and Standard Deviation?

Statistical Process Control

Statistical Process Control

- Statistical Process Control (SPC) is the use of statistical methods to:
  - Detect the existence of special cause variation in a process.
  - Detect special cause and implement controls to eliminate future occurrences.
- Control charts are an important part of SPC.

Shewhart's Control Chart Philosophy



Control Charts

- Control charts are vary similar to Run Charts, but have additional information.
  - Centerline (mean)
  - Control Limits
- Used to analyze variation in a process.
  - Attribute (count) based.
  - Variable (measurement) based.
- Used to determine if variation is inherent to the system (common cause) or caused by an assignable event (special cause).

In Control Processes

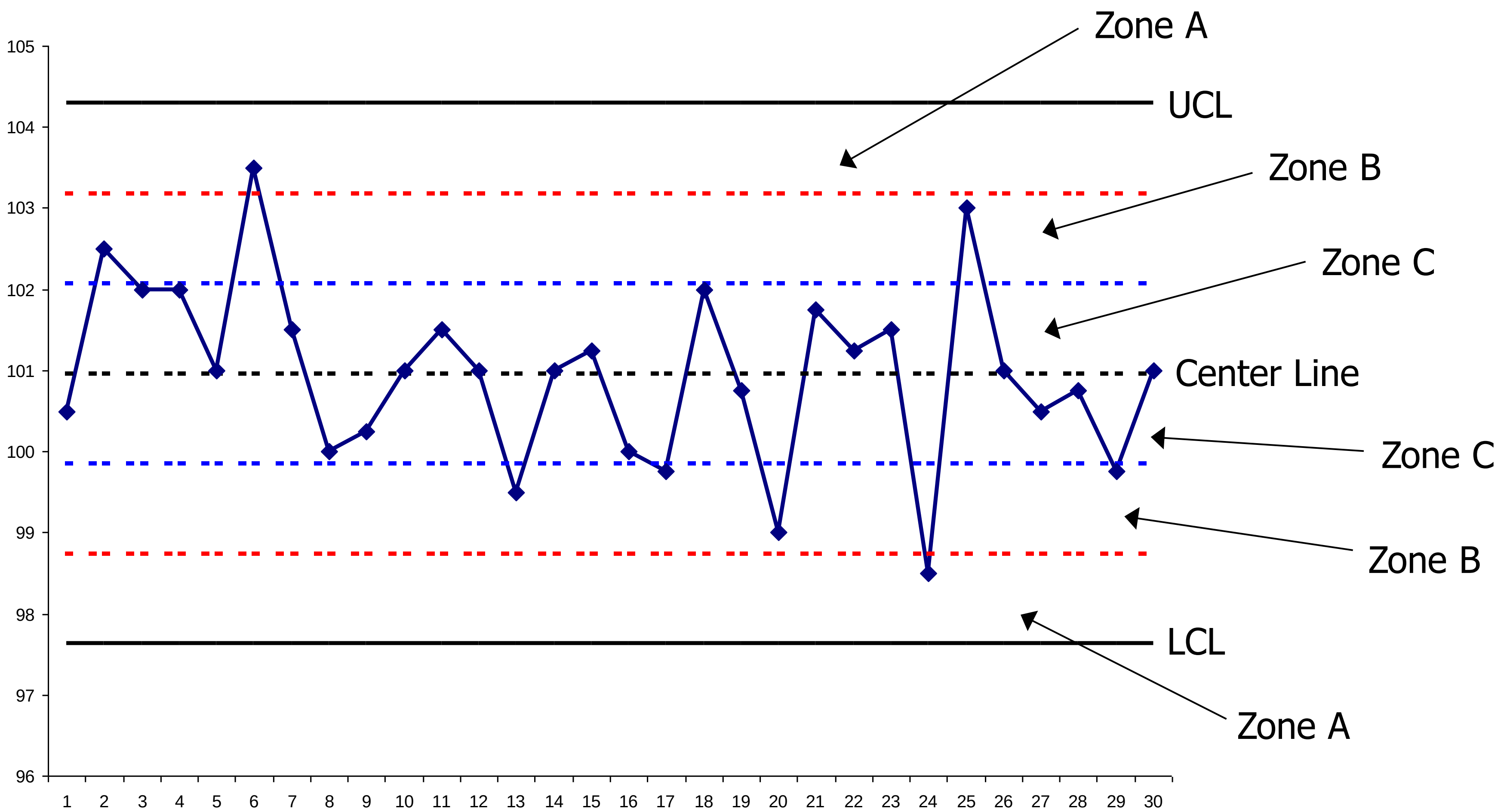
- If no out of control conditions exist, then the process is said to be in control.
- In control processes demonstrate common cause variation.
  - Normal variation.
  - Due to the nature of our universe.
- To reduce common cause variation you must change the system.
  - New equipment.
  - New methodologies.

Control Limits

- Control Limits
  - Calculated from the data as Upper Control Limit (UCL) and Lower Control Limit (LCL).
  - Shows the expected range of variation in a process.
  - Indicates how the process is actually performing
    - Specification Limits (USL, LSL) indicated how the customer wants the process to perform.
- Different kinds of data require different formulas for calculating the centerline and control limits.
  - Typically, +/- 3 standard deviations from the mean.
  - Unique equations used based on chart type.

Control Charts Zones

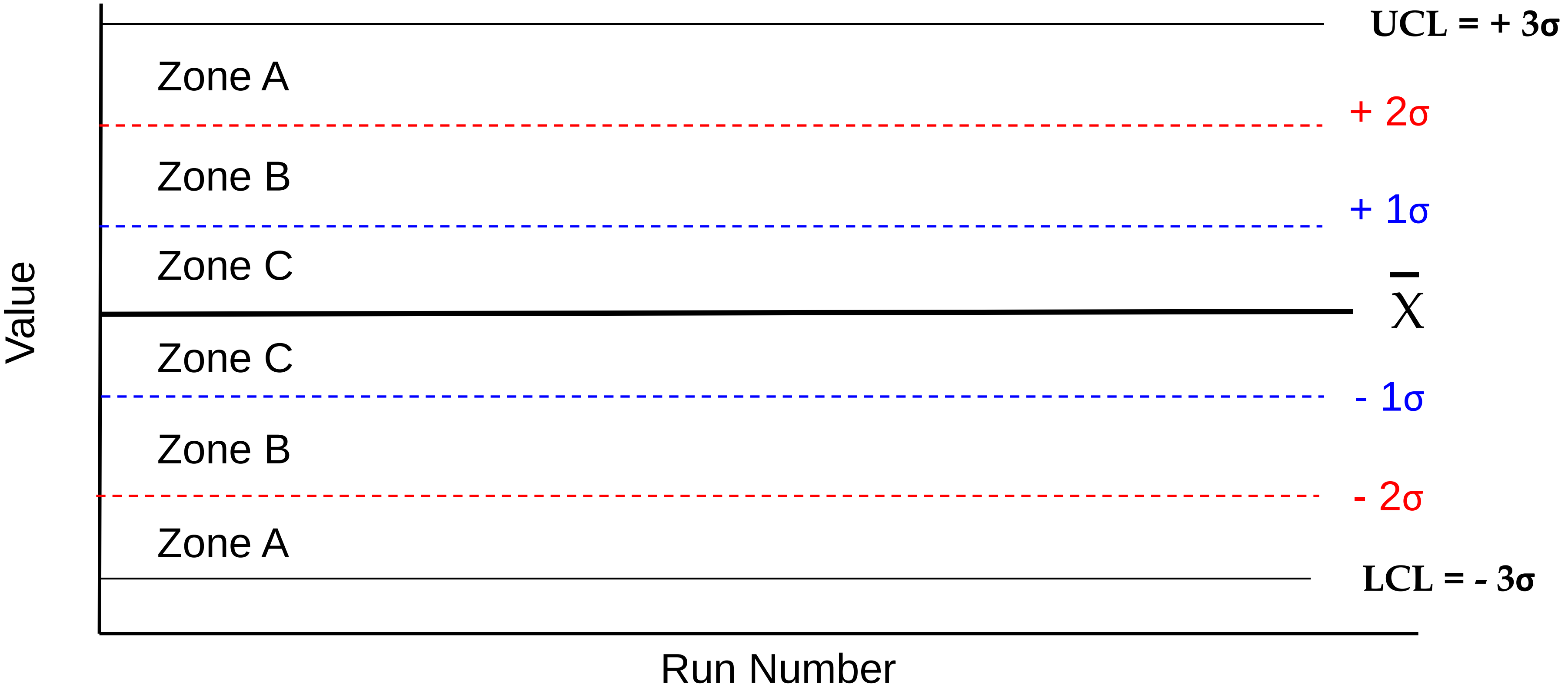
Control charts are simple run charts with statistically generated limits!



Control Chart Construction

Steps to create control and zones.

1. Calculate mean and standard deviation for baseline data set.
2. Plot centerline using mean.
3. Plot UCL and LCL using +/- 3 standard deviations.
4. Plot control chart zones A, B and C.



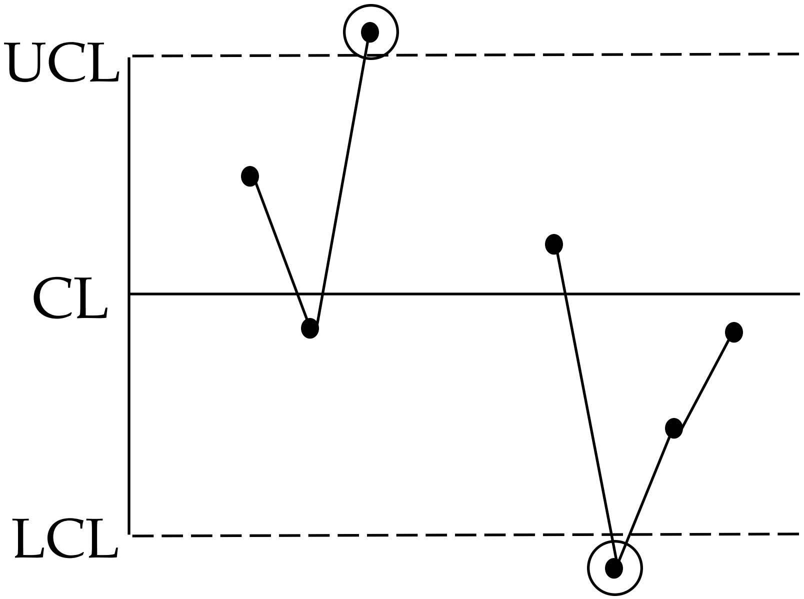
Out of Control Processes

- A control chart demonstrates special cause variation if:
  - Points are outside of control limits.
  - Increasing / decreasing trends.
  - Cycles
- To reduce special cause variation:
  - Find the assignable cause.
  - If appropriate, take action to prevent it from recurring.
    - Standard Work (Improve Phase)
    - Poka-Yoke (Improve Phase)

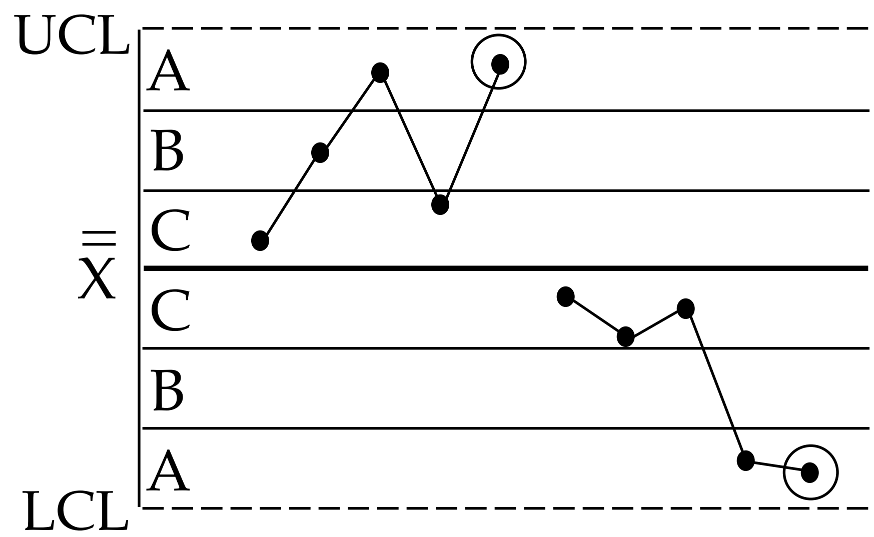
Out of Control Conditions: Extreme Points

- Out of control conditions are frequently detected by the extreme point condition.

Extreme Point (1 Point Beyond UCL or LCL)



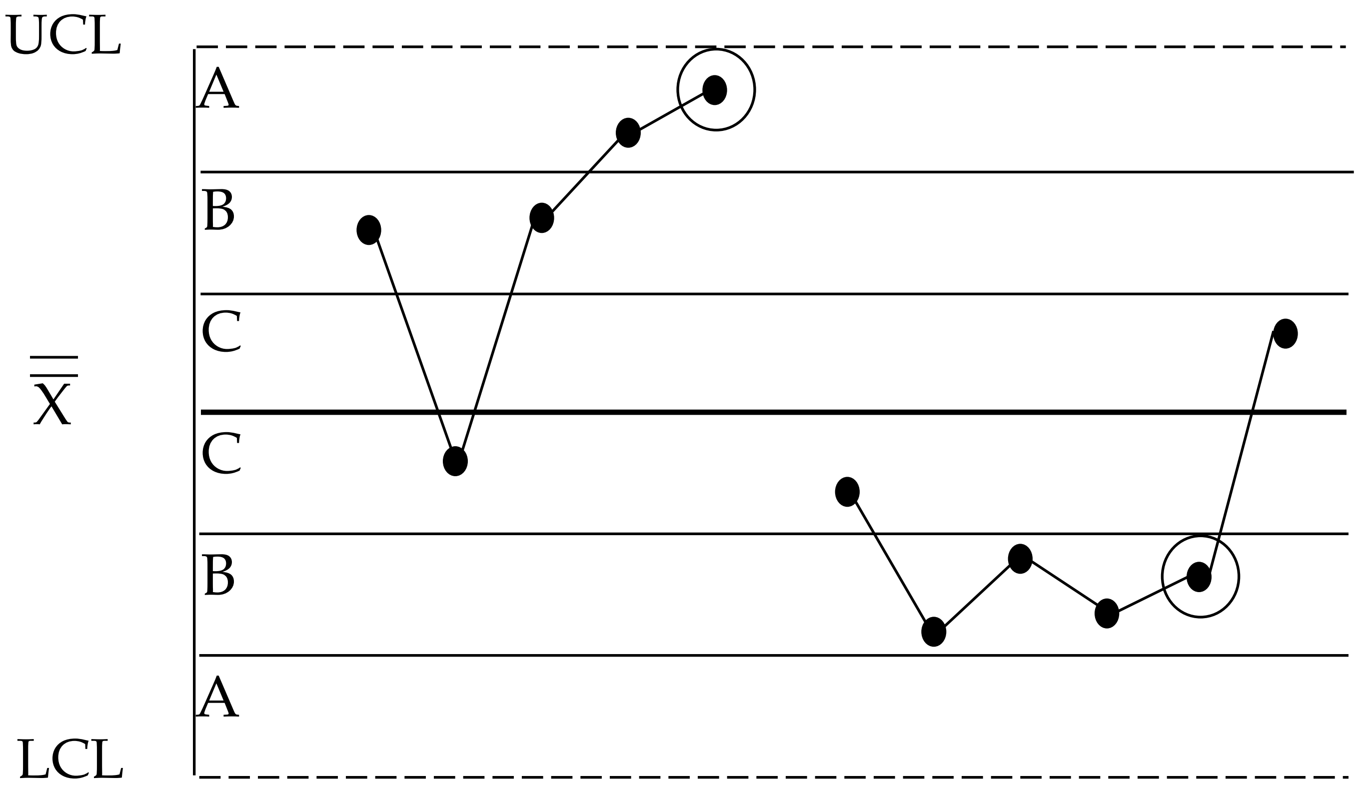
2 Out of 3 Points in Zone A or Beyond



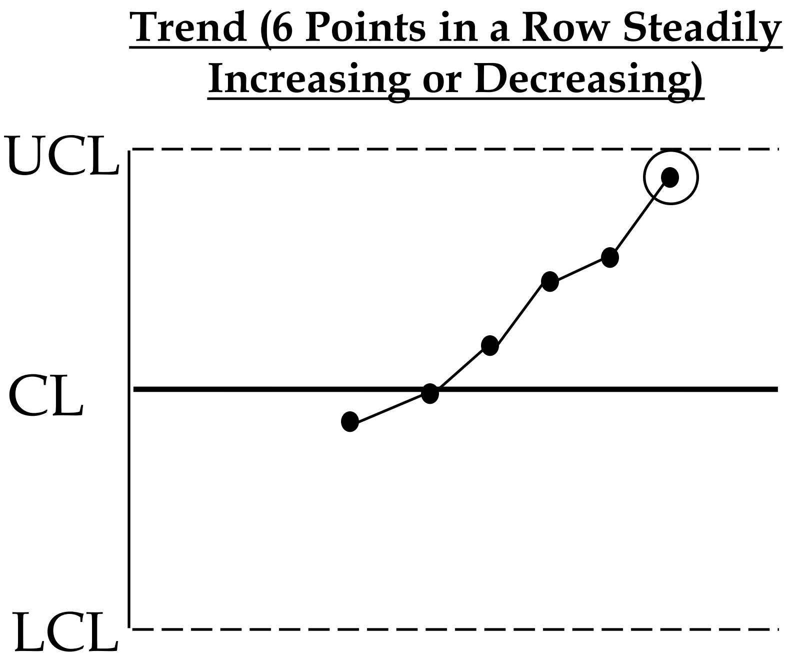
Note that the out of control point is always circled.

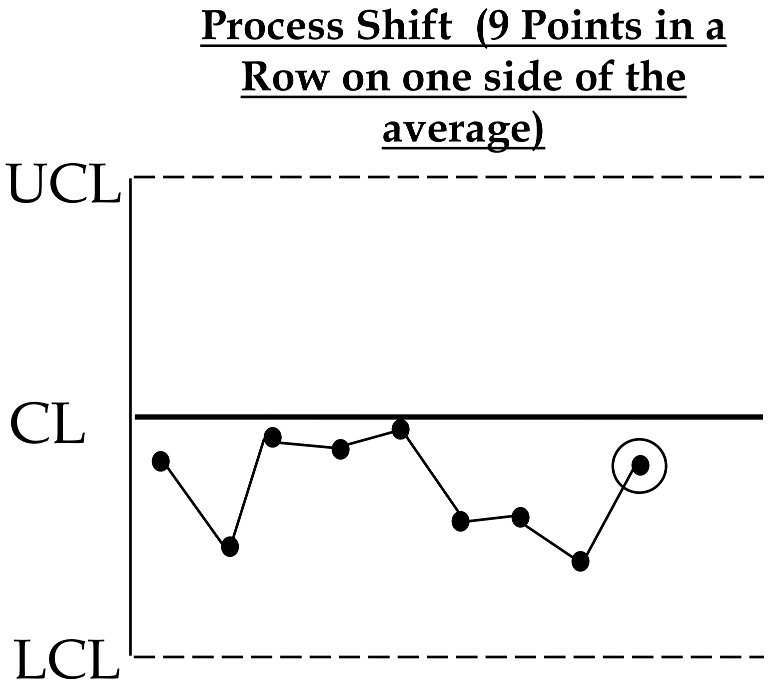
Out of Control Conditions: Extreme Points

4 Out of 5 Points in Zone B or Beyond



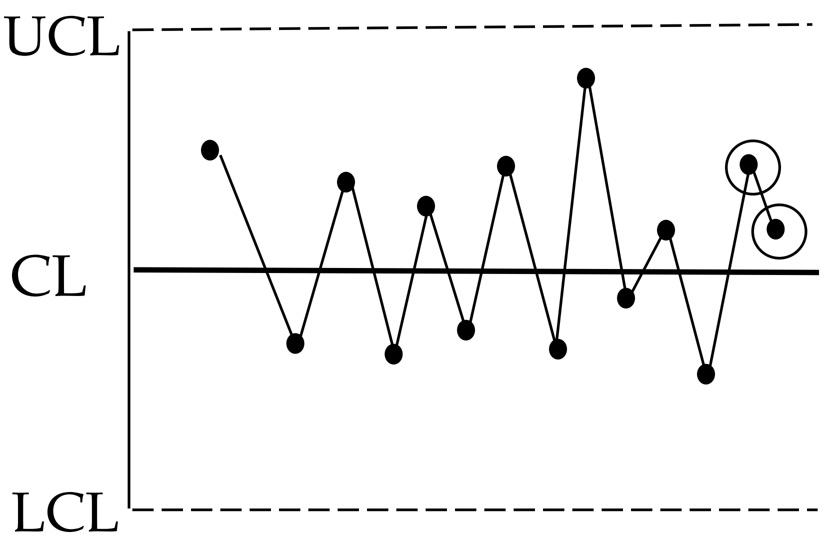
Out of Control Conditions: Trends & Shifts



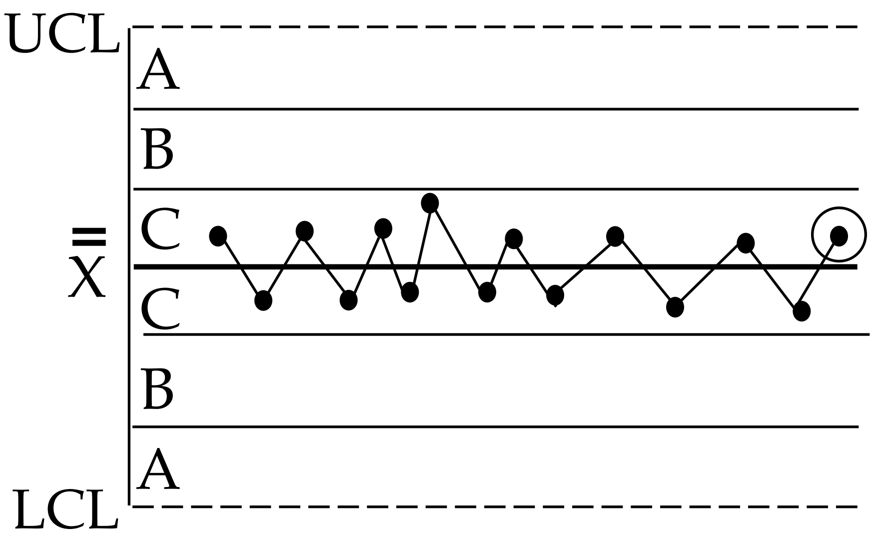


Out of Control Conditions: Oscillation

Oscillation
(14 Successive Points Alternating Up and Down)



15 Successive Points Alternating Up and Down in Zone C (above and below the average)



SPC Takeaways

- A stable, predictable, improved process is required to achieve and maintain product quality.
- Variation in processes may be due to either common causes or special causes.
- Control charts monitor the process so that we may act to eliminate or reduce variation.

Exercise: Control Charts

Create Control Chart with zones using the following data.

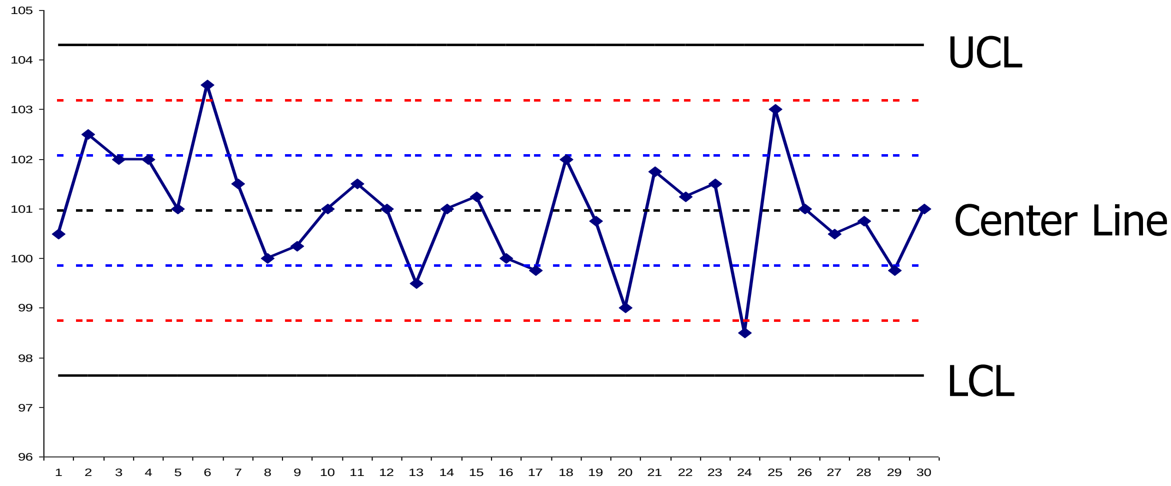
$$\bar{X} = 10$$

$$s = 2.64$$

10 minutes

Knowledge Check: Control Charts

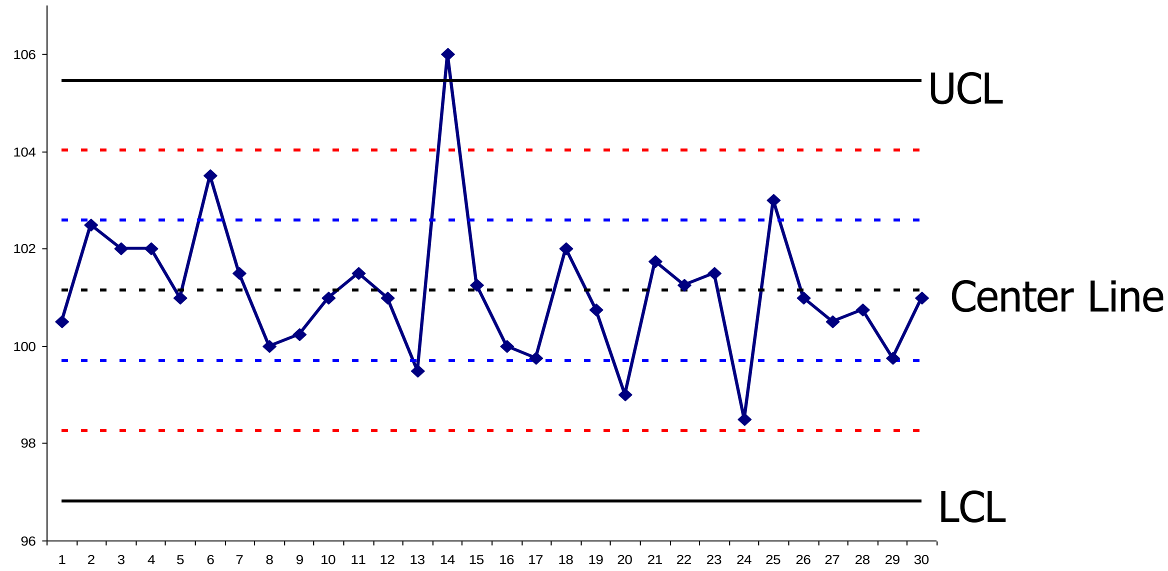
On the control chart shown below, how would we determine the center line, UCL, and LCL values?



Is this process in control or out of control and why?

Knowledge Check: Control Charts

Based on the control chart below, we can conclude that we are producing defects. True or False?



What We Have Covered: Analyze Phase

- General tools used within the Analyze Phase.
- Creation and interpretation of data analysis tools such as histograms, Pareto charts, fishbone diagrams, etc.
- Application of Root Cause Analysis to analyze process problems.
- Computation and interpretation of statistical results that measure location, variation, and shape.
- Identification and explanation of the objectives and benefits of statistical process control (SPC) with respect to:
    - Distinguish between common and special cause variation.
    - Identify and explain control charts.