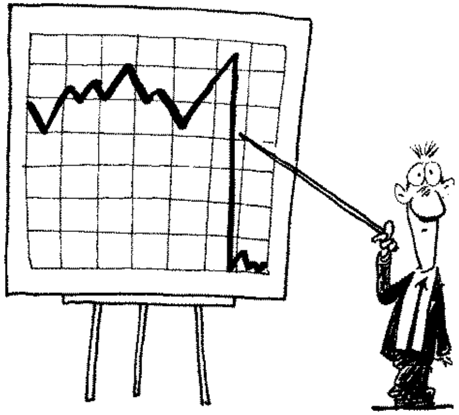
# Continuous Improvement Toolkit

## **Hypothesis**

$H_0$ $H_1$


Managing Risk
PDPC
FMEA
RAID Logs
Fault Tree Analysis
Risk Assessment*
Traffic Light Assessment
Deciding & Selecting
Pros and Cons
Importance-Urgency Mapping
Break-even Analysis
Cost -Benefit Analysis
Force Field Analysis
Voting
Pugh Matrix
Decision Tree
TPN Analysis
QFD
Matrix Diagram
Prioritization Matrix
Kano Analysis
Paired Comparison
Critical-to Tree
Planning & Project Management*
RACI Matrix
Stakeholders Analysis
PEST
PERT/CPM
Activity Diagram
SWOT
Roadmaps
Project Charter
Gantt Chart
PDCA
Control Planning
Gap Analysis
Hoshin Kanri
Kaizen
How-How Diagram
Tree Diagram**
Standard work
Identifying & Implementing Solutions***
Simulation
TPM
Mistake Proofing
Pull Systems
JIT
Ergonomics
Work Balancing
Automation
Bottleneck Analysis
Visual Management
Flow
Value Analysis
5S
SMED
Lean Measures
KPIs
OEE
Capability Indices
MSA
RTY
Descriptive Statistics
Cost of Quality
Reliability Analysis
Understanding Performance
Benchmarking
Cause & Effect Matrix
Pareto Analysis
Confidence Intervals
Understanding Cause & Effect
Probability Distributions
ANOVA
Hypothesis Testing
Design of Experiments
Graphical Analysis
Scatter Plot
Correlation
Regression
Run Charts
5 Whys
Chi-Square Test
Multi-Vari Charts
Control Charts
Relations Mapping*
Fishbone Diagram
TRIZ***
Sampling
Focus groups
Interviews
Brainstorming
Analogy
SCAMPER***
Photography
Check Sheets
Nominal Group Technique
Mind Mapping*
Measles Charts
Surveys
Affinity Diagram
Attribute Analysis
Data Collection
Critical Incident Technique
Lateral Thinking
Visioning
Observations
Creating Ideas**
Wastes Analysis
Time Value Map
Process Redesign
IDEF0
Value Stream Mapping
SIPOC
Flow Process Chart
Process Mapping
Flowcharting
Service Blueprints
Designing & Analyzing Processes

# - Hypothesis Testing



- Statistic is the science of describing, interpreting and analyzing data.
- **Statistics Types:**
  - **Graphical Statistics:**
    Makes the numbers visible.
  - **Inferential Statistics:**
    Makes inferences about populations from sample data.
  - **Analytical Statistics:**
    Uses math to model and predict variation.
  - **Descriptive Statistics:**
    Describes characteristics of the data (central tendency, spread).

# - Hypothesis Testing

$H_0$ $H_1$

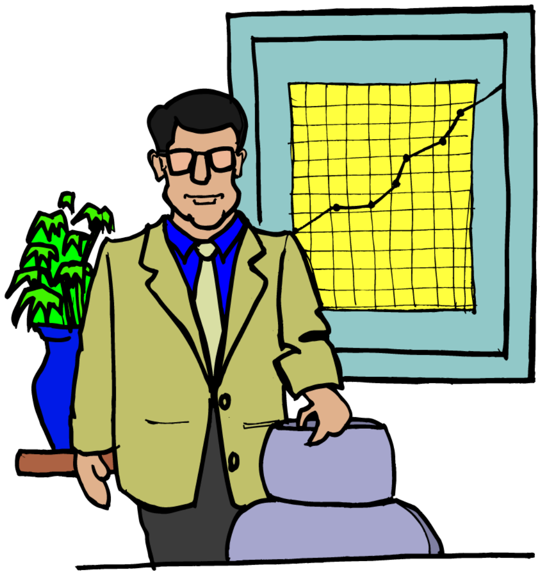
- A statistical hypothesis is a claim about a population parameter.
- It is a test that would find **statistical answers** to questions about our processes, products or services.
- Hypothesis testing can tell us:
  - How certain / confident we can be in our decision.
  - Our risk of being wrong.
- There is always a chance of being wrong.
- We have now the way of measuring this risk.

# - Hypothesis Testing

**It Should Be Based On:**

- **Our knowledge of the process:**
  - Such as how a process has performed in the past.

- **The customers expectations:**
  - Such as how the customer would expect the performance of the product.



# - Hypothesis Testing

**The Hypothesis Will Help Answer Questions Such As:**

- Is there is a difference between the process waiting line across different regions?
- Is there is a difference between the customer satisfaction levels for different products.
- Is there is a difference between the expensive software packages that the company will invest in?
- Is there is a difference between the suppliers of a specific material?

# - Hypothesis Testing

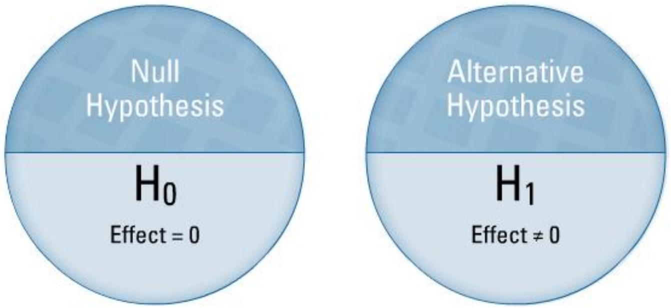
**Hypothesis Flow:**

| | |
|---|---|
| What are you Testing? | Define your 2 hypothesis |
| How confident do you want to be in your decision? | Set Alpha level |
| Select the test | Select the right technique |
| Run the test | Calculate p-value |
| Check if your theory was right or not | Accept or reject your hypothesis |

Decision Making

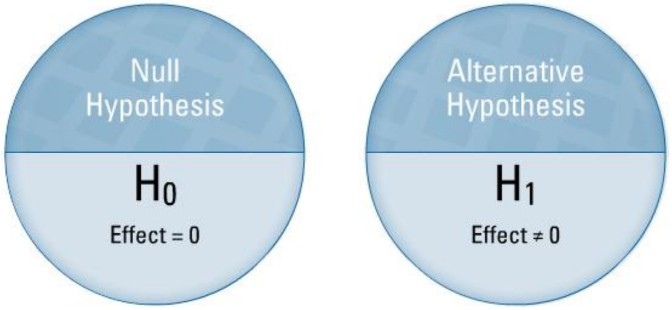
# - Hypothesis Testing

- In inferential statistics, we have two hypotheses:
  - **The null hypotheses.**
  - **The alternative hypotheses.**
- The null hypotheses is a hypotheses
  that usually states that a population parameter **equals** a specified value or a parameter from another population.



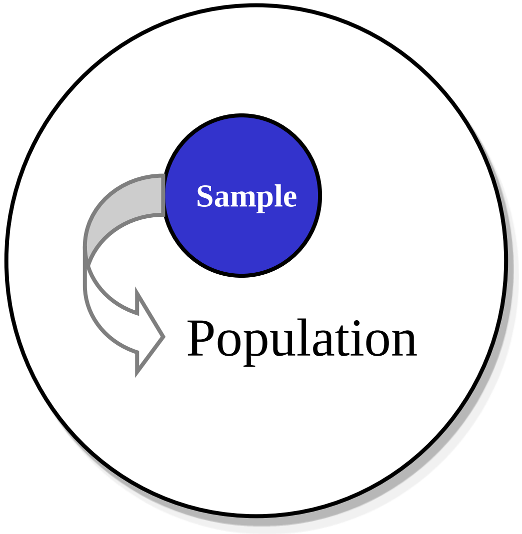
# - Hypothesis Testing

- The Alternative Hypotheses is the opposite of null hypothesis.
- Sometimes the Alternative Hypothesis is greater than or less than some value.
- A hypothesis test does not tell how big that difference is, but only that it is there.
- Remember, we are not proving the Alternative Hypothesis, we are just seeking enough evidence to disprove the Null Hypothesis.



# - Hypothesis Testing

- **We can make two possible conclusions after analyzing our data:**
  - **Reject the null hypothesis** and claim statistical significance.
  - **Fail to reject the null hypothesis** and conclude that we do not have enough evidence to claim that the alternative hypothesis is true.
- We are making our decision using sample data rather than the entire population, therefore, we can never accept the null hypothesis because we can never be absolutely certain whether it is true.



# - Hypothesis Testing

**Example:**

- A researcher want to evaluate the effectiveness of their product by comparing it against the industry standard elasticity of 3.10.

- Their **Null Hypothesis** is that the **mean elasticity is equal to 3.10**.
- The **Alternative Hypothesis** is opposite, that the **mean elasticity is not equal to 3.10**.
- We might say the alternative hypothesis to be greater than 3.10 ($\mu > 3.10$).

# - Hypothesis Testing

**Example:**

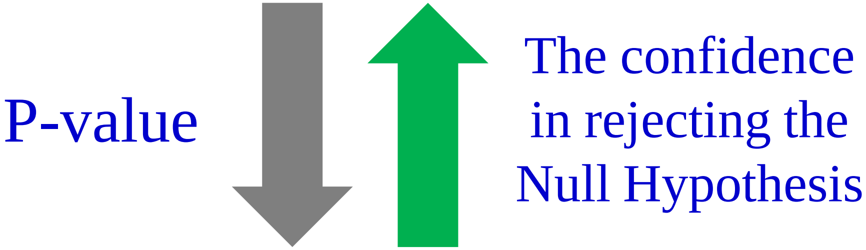
- A plant has just receive a shipment of **6,000** timing belts.

- Before sending these belts into production, a quality technician wants to examine them to see whether they meet the required specification (*The width of the belts of one inch*).
- **What is the null and the alternative hypotheses?**

**The Null Hypothesis →** The width of the belts equals one inch.
**The Alternative Hypothesis →** The width does not equal one inch.

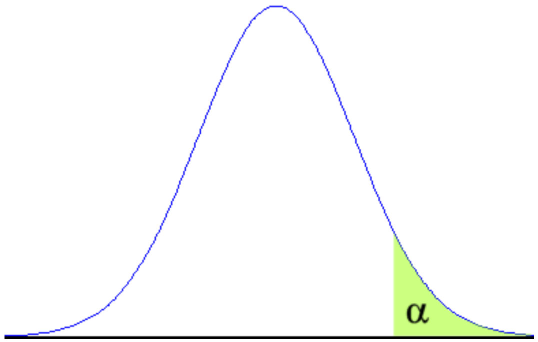
# - Hypothesis Testing

- When we conduct a hypothesis test, our results include a **test statistic** and a **p-value**.
- The p-value is used to determine if we should reject or fail to reject the null hypothesis.
- **A practical definition:** p-value is your confidence in the Null Hypothesis.
- When it's low, 'reject the null'.
- As the p-value comes down, the confidence in rejecting the Null Hypothesis goes up.



# - Hypothesis Testing

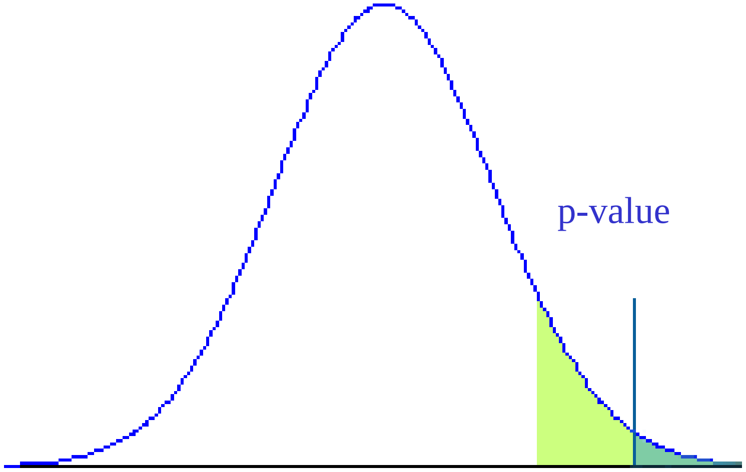
- The green shaded region represents the probability of rejecting a null hypotheses that is true.
- This probability is called **alpha (α)**.
- We should always select **alpha (α)** before performing the test.
- **Alpha (α)** is the probability of rejecting a null hypothesis that is true.
- It's the level that the p-value must drop below if you are to 'reject the null' and decide there is a difference.




**One-sided test**

# - Hypothesis Testing

- To make a decision about the null hypothesis, we compare the **p-value** to **alpha (α)**.
- **P-value** is the area to the right of the test statistic.
- If **p-value** is less that or equal **alpha (α):**
  - Reject the null hypothesis.
  - The results are statistically significant.

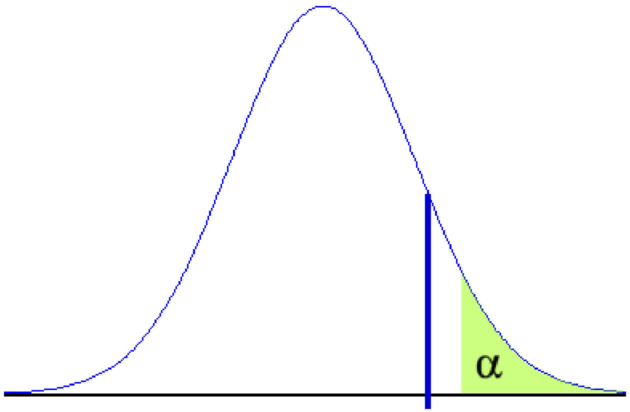


# - Hypothesis Testing

**Example:**

- Suppose alpha (α) is 0.05 and the p-value is 0.091? Would we reject or fail to reject the null hypothesis?

- We would fail to reject $H_0$ as **p-value** > **alpha (α)**.




***p-value = 0.091***

# - Hypothesis Testing

**How Do You Decide the Required Confidence?**

- Consider the rusks of making the wrong decision.
- This will often depend on the environment you are working in.
- This will also depend on the decision you are trying to make.
- Working in a safety critical environment such as a hospital or a chemical factory would require a higher confidence in your decision.

# - Hypothesis Testing

- What are the consequences of a wrong decision?

| Decision | Defendant is Innocent | Defendant is Guilty |
|---|---|---|
| Acquit | Correct decision | Type II error |
| Convict | Type I error | Correct decision |

| Decision | $H_0$ is True | $H_0$ is False |
|---|---|---|
| Fail to Reject $H_0$ | Correct decision | Type II error ($\beta$) |
| Reject $H_0$ | Type I error ($\alpha$) | Correct decision |

# - Hypothesis Testing

- **A type I error – (α)** is the probability of rejecting a null hypothesis that is true.
- **A type II error – (β)** is failing to reject a false null hypothesis.
- We can increase the chances of making the right decision by increasing the **power** of the hypothesis test.
- **Power** is the likelihood that we will find a significant effect when one exists.

**Power = 1- β**

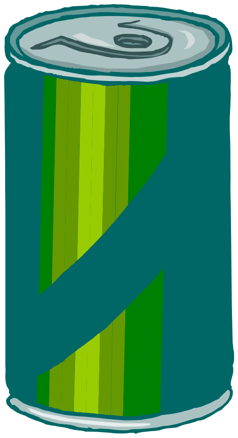
# - Hypothesis Testing

- The factors that will affect the **power** of the test are:
  - Sample size.
  - Population differences.
  - Variability.
  - Alpha level.

# - Hypothesis Testing

**Statistical vs. Practical Significance:**

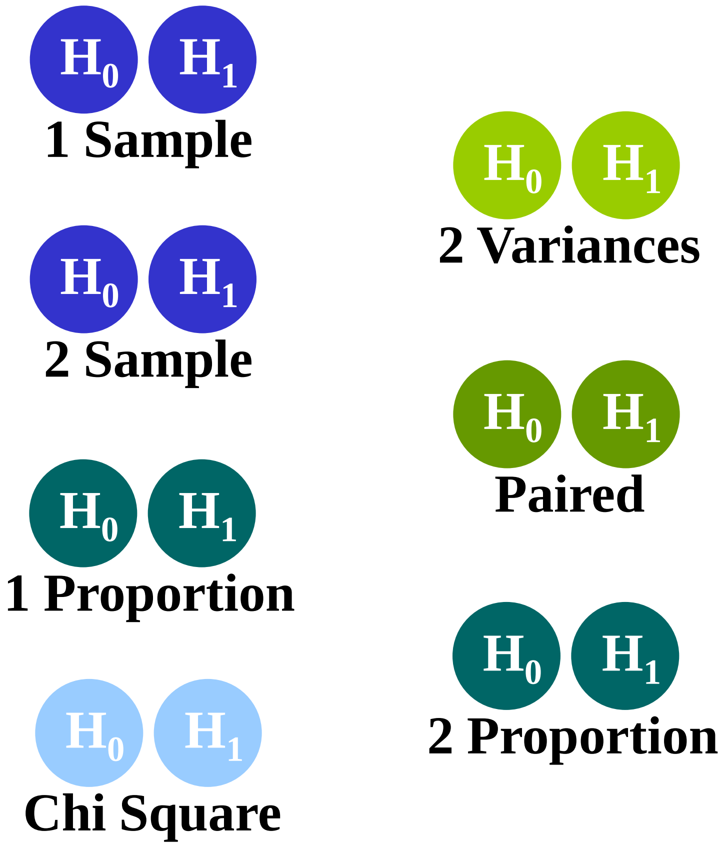
- A production line manager attempts to reduce production time by modifying the process.
- He compares the production time of the old process with the production time of the new process.
- If the difference between the two times is five seconds, is it worth the cost of implementing the process change?
- Just because our results are statistically significant doesn't mean that they are practically significant.
- Always consider the **practical significance** of the results and your knowledge of the process before reaching a conclusion.



# - Hypothesis Testing

**Hypothesis Testing Techniques:**

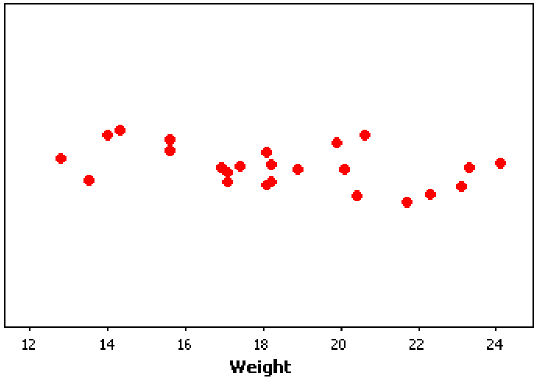
- 1-sample t-test.
- 2 Variances test.
- 2-sample t-test.
- Paired t-test.
- 1 Proportion test.
- 2 Proportion test.
- Chi-Square test.



# - Hypothesis Testing

**1-Sample t-test:**

- Used to determine whether the population mean is equal to a hypothesized value.
- Data are numeric, random and from a normally distributed population.
- **Example:** Determine if a call center is meeting its average resolution time goal.

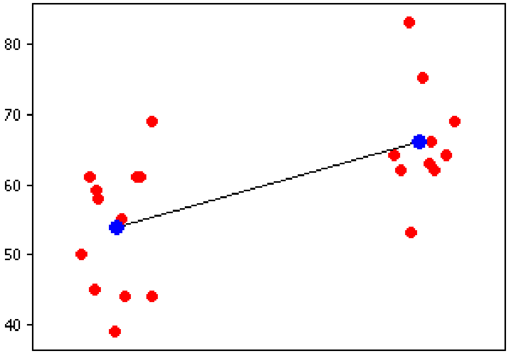



- **Approach:**
  1- Establish the Null and Alternative Hypothesis.
  2- Collect a random sample data from the population.
  3- Conduct the t-test and interpret the results.

# - Hypothesis Testing

**2-Sample t-test:**

- Used to determine whether two population means are equal.
- It require two independent random samples of numeric data from normally distributed populations.
- **Example:** Compare the durability of a new supplier's relay switches to the durability of the old supplier.




- **Approach:**
  1- Establish the Null and Alternative Hypothesis.
  2- Collect random data sample from the 2 populations.
  3- Conduct the 2-sample t-test and interpret the results.

# - Hypothesis Testing

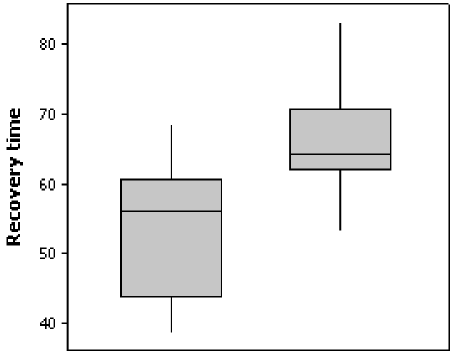
**2 Variances Test:**

- Determine if 2 population have equal variances.
- Requires tow independent, random samples of numeric data.
- We use **F-test** for normally distributed population, if not, we use **Levene's test**.
- **Example:** Determine if the variability in delivery times for 2 companies is the same.
- **Approach:**

  1- Establish the Null and Alternative Hypothesis.

  2- Collect random data samples from the 2 population.

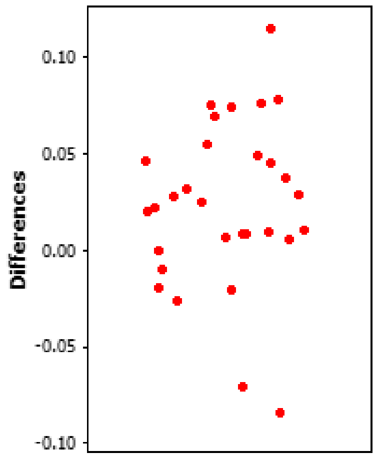
  3- Conduct the 2 variances test and interpret the results.



# - Hypothesis Testing

**Paired t-test:**

- Used to compare the means of 2 dependent population.
- Data should be paired, numeric, come from random samples and are from a normally distributed population.
- **Example:** The power output of the same engines before and after being treated with a fuel additive.
- **Approach:**
  1- Establish the Null and Alternative Hypothesis.
  2- Collect random samples of data from the two dependent populations.
  3- Conduct the test & interpret the results.



# - Hypothesis Testing

**1 Proportion Test:**

- Used to determine whether a population proportion is equal to a hypothesis value.
- The 1 proportion test requires that we have binary data which can only take one of two values, such as "Pass" or "Fail", "Male" or "Female", or "Yes" or "No".
- **Example:** Determine if a company is losing market share in specific demographic.
- **Approach:**

  1- Establish the Null and Alternative Hypothesis.

  2- Collect a random data sample from the population.

  3- Conduct the 1 proportion test & interpret the results.

# - Hypothesis Testing

**2 Proportion Test:**

- Used to determine whether the proportion of one population is equal to the proportion of another one.
- The 2 proportion test also requires that we have binary data which can only take one of two values, such as “Pass" or "Fail “.
- We assume the data are random, binary and independent, and the proportion of interest is constant.
- **Example:** Compare the defect rates of 2 machines.
- **Approach:**

  1- Establish the Null and Alternative Hypothesis.

  2- Collect random sample from each population.

  3- Conduct the 2 proportion test & interpret the results.

# - Hypothesis Testing

**Chi-square Test:**

- Used to determine whether the levels of one categorical variable are related to the levels of another.
- Each trial must have the same number of possible outcomes.
- Two test statistics: The Pearson chi-square and the likelihood ratio chi-square.
- **Example:** Compare the defect rates for production of four different products at three different locations.
- **Approach:**

  1- Establish the null and alternative hypothesis.

  2- Collect random sample from the population.

  3- Conduct the Chi-square test & interpret the results.

# - Hypothesis Testing

**Example:**

- A Gas Filler company wants to evaluate whether gas tanks are being filled properly.
- As gas liquid expands once heated, the tanks must be filled to only **80%** capacity to allow room for possible liquid expansion in hot days.
- When the tank is **80%** full, it holds **20** pounds of gas.
- We want to test the null hypothesis that the mean weight of gas tanks is **20** pounds.
- **What Hypotheses test to be used?**

# - Hypothesis Testing

**Example:**

- We will used the 1-Sample t-test.
- The null hypothesis: **Mean weight = 20 pounds.**
- The alternative hypothesis: **Mean weight <> 20 pounds.**

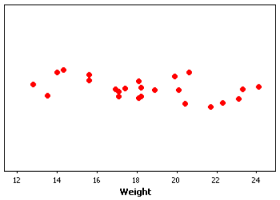
**1.**

- We will collect a random data.

| Weight | 24.1 | 18.9 | 15.6 | 16.9 | 20.6 |
|---|---|---|---|---|---|

**2.**

- We'll interpret the results, suppose that **alpha (α) = 0.05**




**One-Sample T: Weight**

```
Test of mu = 20 vs not = 20
Variable   N     Mean    StDev   SE Mean         95% CI              T       P
Weight    25  18.0560   3.5294    0.7059   (16.5991, 19.5129)   -2.75   0.011
```

- **We should reject the null hypothesis.** There is sufficient statistical evidence to claim the population mean is not equal to **20** pounds.

**3.**