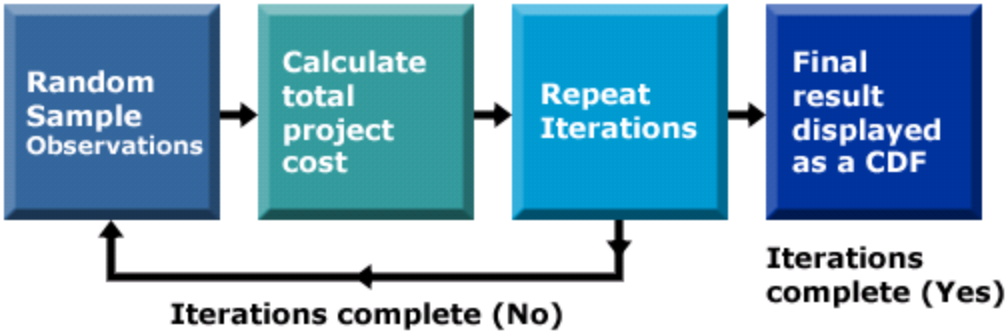
Lesson Objectives

This lesson provides an overview of the statistical process of calculating specific numerical values used to estimate the cost involved in acquiring and developing a weapon system.
Objectives covered in the lesson are:

- Explain the Monte Carlo Simulation process
- Explain the concept of correlation between cost elements
- State the rule of thumb for the coefficient of correlation



Monte Carlo Simulation

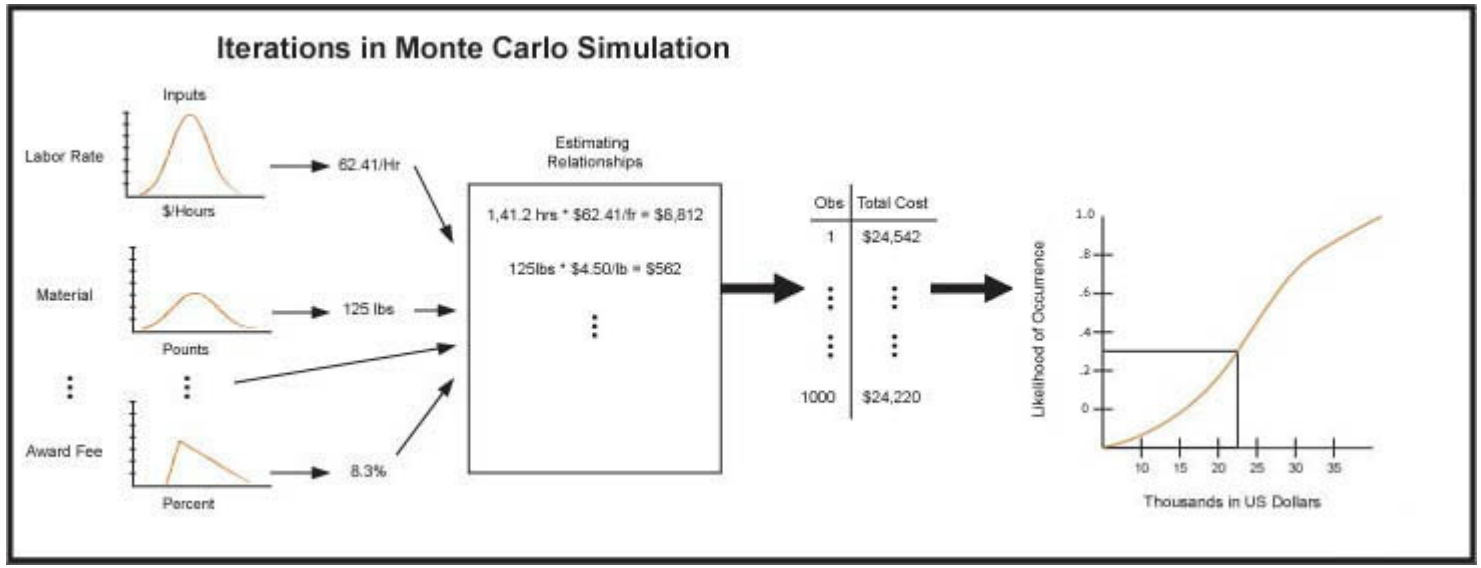
The Monte Carlo Simulation Process is outlined below:

- Draw one observation from each input distribution:
  - Each cost element is defined with a distribution
  - Each distribution is treated as a population from which a random sample is drawn
- Calculate total project cost with the set of input (sample) values:
  - The number of sample values depends on the number of cost elements of the project
  - Store the value of the total project cost
- Repeat this process:
  - 1000-10000 iterations is usually sufficient
  - The more iterations calculated, the better the accuracy of the total cost distribution
- Final result:
  - A distribution of total cost described by its mean and standard deviation
  - Portrayed as a Cumulative Distribution

Click here to view an illustration of the Monte Carlo Process from beginning to end.

Popup Text

Monte Carlo Process



Cost Element Correlation

Modeling total project costs gives a better perspective of how individual cost elements may or may not correlate. Correlation means the degree to which two or more cost elements or parameters tend to vary together.

In other words, there are independent and dependent cost elements.

Let's take the airframe structure of an aircraft. Weight of an airframe is directly correlated to its engine thrust. The heavier the airframe, the more thrust is required. The second element, engine thrust, varies with the first element, airframe weight.

Issue:

Monte Carlo Simulation requires that all inputs be statistically independent. One element should not affect another element.

Solution:

Dependent elements must be identified and the degree of correlation estimated.

Reality:

There will be dependencies among cost elements and variables in a cost estimate. All will not be independent.

How:

Monte Carlo Simulation tools have the capability to account for correlation among cost elements and variables. Estimated correlation coefficients are entered into the Monte Carlo Simulation and are modeled. Modeling results then account for some of the correlation among elements.

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Long Description

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Coefficient of Correlation

To measure the strength and direction (upward/positive or downward/negative) of the correlation (relationship) between two variables, the coefficient of correlation (Pearson correlation coefficient) is calculated.

The Greek letter ("rho") or **R** (upper case) and **r** (lower case) represents the correlation coefficient. We will use R.

Sample Correlation

R (sample correlation) has a range value of -1 to +1.

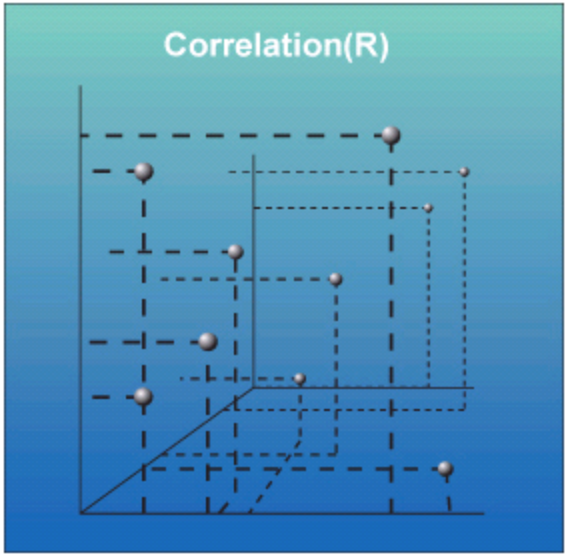
If **R = 1**, then the **slope** (of the line) is positive and the values of cost elements move together. For instance, if cost element *x* is a high value so is cost element *y*.

If **R = -1**, then the **slope** is negative and the values of cost elements move in the opposite direction. For instance, if cost element *x* is a high value, then cost element *y* is a low value.

If **R = 0**, then there is **no slope** and both cost element values (*x* and *y*) are independent of each other. This is also referred to as having statistical independence.

Coefficient of Correlation, Cont.

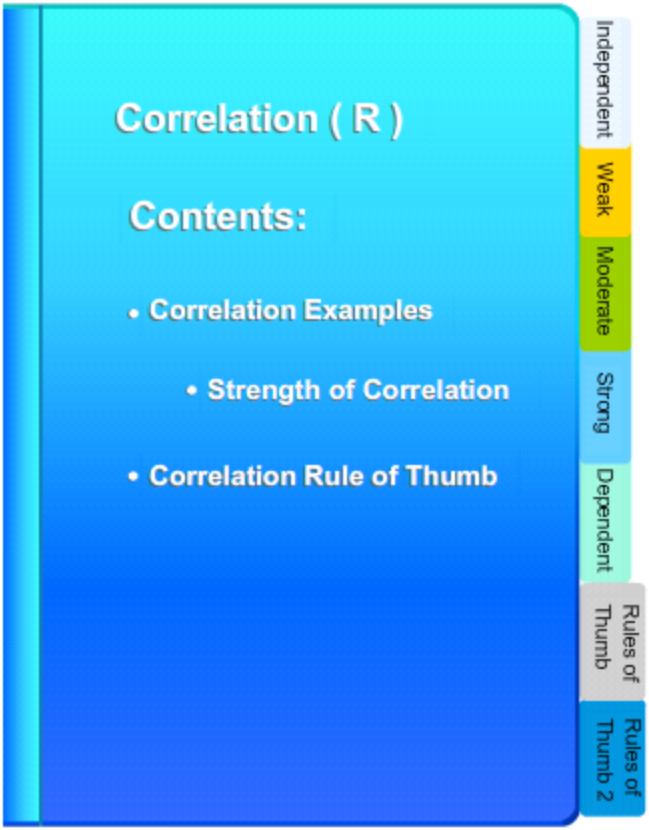
There are several rules of thumb that can be used to provide an indication of the degree of correlation based on the value of R.



Select the "next" button to view the 'rules of thumb' for the coefficient of correlation

Correlation Rules of Thumb

Click each selectable tab in the graphic to learn more about correlation(R).



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Long Description

Rules of Thumb Long Description

Tabbed Book that allows user to view seven examples of correlation strengths.

Book Cover: Title: Correlation (R)
Subtitle: Contents

- Correlation Examples
- Strength of Correlation
- Correlation Rule of Thumb

Tab Labels:

Tab One (White): Independent
Tab Two (Gold): Weak
Tab Three (Green): Moderate
Tab Four (Blue): Strong
Tab Five (Green): Dependent
Tab Six (Grey): Rules of Thumb
Tab Seven (Blue): Rules of Thumb 2

Tab One:

Independent: Individual WBS cost elements have no relationship to each other. The value of one cost element does not change the value of another.

- **Rule of Thumb: R = 0 (R must be 0 to be considered independent)**

Tab Two:

Weak: The number of individual WBS cost elements that have a relationship to each other is low in occurrence; henceforth a weak correlation.

- **Rule of Thumb: $0 < R \leq +0.3$ Rule of Thumb: $-0.3 \leq R < 0$**

Long Description

Tab Three:

Moderate: The number of Individual WBS cost elements that have a relationship is more frequent; henceforth a moderate correlation.

- **Rule of Thumb: + 0.3 < R ≤ + 0.7 Rule of Thumb: - 0.7 ≤ R < - 0.3**

Tab Four:

Strong: The number of individual WBS cost elements that have a relationship to each other is high in occurrence; henceforth a strong correlation.

- **Rule of Thumb: + 0.7 < R < + 1.0 Rule of Thumb: - 1.0 < R < - 0.7**

Tab Five:

Dependent (Perfect): The number of individual WBS cost elements that have a relationship to each other is continuous; henceforth a Dependent or Perfect correlation.

- **Rule of Thumb: R = + 1 Rule of Thumb: R = - 1**

Long Description

Tab Six:

Rules of Thumb

Correlation Coefficient	Correlation Strength
R = + 1	Perfect Positive Correlation (upward slope) **Perfect**
+0.7 < R <+ 1.0	Strong Positive
+0.3 < R ≤ +0.7	Moderate Positive
0 < R ≤ +0.3	Weak Positive
R = 0	**None – Indicates statistical Independence No slope**
- 0.3 ≤ R < 0	Weak Negative
- 0.7 ≤ R < - 0.3	Moderate Negative
- 1.0 < R < - 0.7	Strong Negative
R = - 1	Perfect Negative Correlation (downward slope) **Perfect**
Correlation Coefficient	**Correlation Strength**

Long Description

Tab Seven:

Rules of Thumb2: Correlation (R) Graphical Representation Degree of Correlation between individual WBS Cost Elements

Real Number Line of R values: - 1, - 0.7, - 0.5, -0.3, 0, +0.3, +0.5, +0.7, +1

Correlation Strength along the real number line: Strong, Medium, Weak, None, Weak, Medium, Strong

Correlation Direction along the real number line: Negative Slope, Slope = 0, Positive Slope

Correlation and Causality

Definition of Correlation: the degree to which two or more attributes or measurements on the same group of elements show a tendency to vary together.

Question: Does correlation imply causation?

Answer: No – although cost element *y* depends on cost element *x*, it does not mean that cost element *x* is the cause of cost element *y*. There is no implication of cause-and-effect.

- It is possible for correlation to exist when there is no causality
  - Statistical interpretation: R = a large (high) value **Example:** R = .992
- The correlation between variables may be indirect, a third variable to which both cost element *x* and cost element *y* are related may be the common cause of affect.
- It is possible to have strong causality with low R values
  - Statistical interpretation: R = a small (low) number **Example:** R = .234
- R measures the degree of linear correlation
- If the causality is non-linear, it will not be presented in R

Contingency and the Point Estimate

A typical weapon system cost estimate (the point estimate) is between the 15-35 percentiles of the total cost distribution developed from the cost risk analysis.

The amount of funding a program requires above the point estimate is sometimes called the ***contingency funding level*** (also called **risk dollars**). This funding level is normally the **budgeted amount**.

A manager can determine from the cost risk analysis (by using the total system cost distribution) the amount of contingency funding required based on some acceptable level of risk (probability of having sufficient funds).

Knowledge Review

Which of the following steps of the Monte Carlo process are in their correct order?

- [ ] 1st - Combine all the costs into a total cost distribution
  2nd - Calculate total cost with sample values
  3rd - Calculate additional costs by repeating the sampling process
  4th - Draw a single observation from each input distribution

- [ ] 1st - Draw a single observation from each input distribtion
  2nd - Calculate additional costs by repeating the sampling process
  3rd - Combine all the costs into a total cost distribution
  4th - Calculate additional costs by repeating the sampling process

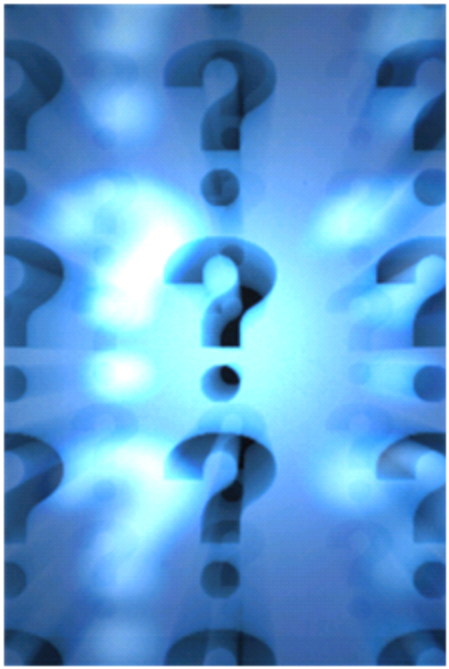
- [x] 1st - Draw a single observation from each input distribution
  2nd - Calculate associated costs with the sample observations
  3rd - Calculate additional costs by repeating the sampling process
  4th - Combine all the costs into a total cost distribution

Check Answer

The correct order is: **1st - Draw a single observation from each input distribution**; **2nd - Calculate associated costs with the sample observations**; **3rd - Calculate additional costs by repeating the sampling process**; and **4th - Combine all the costs into a total cost distribution**.

Knowledge Review

The Monte Carlo Simulation process has an objective to build a probability distribution reflecting the total range of costs with all uncertainties considered.



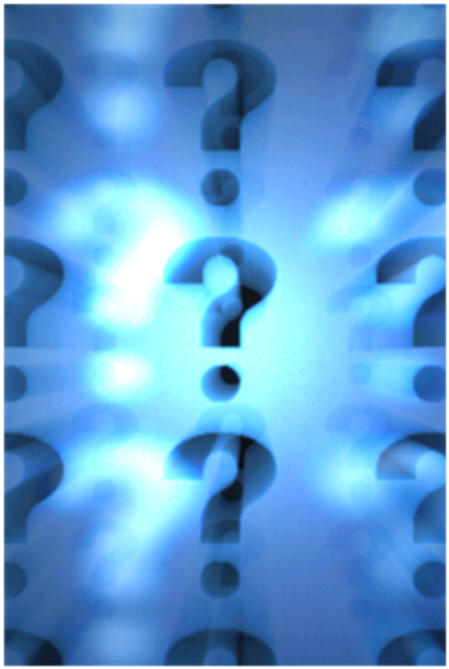
- [x] True
- [ ] False

Check Answer

This is a **True** statement. The Monte Carlo Simulation process has an objective to build a probability distribution reflecting the total range of costs with all uncertainties considered.

Knowledge Review

R = + 0.95 means there is a strong positive correlation.



- [x] True
- [ ] False

Check Answer

This is a **True** statement. R = + 0.95 means there is a strong positive correlation.

Summary

The Monte Carlo Simulation process is:

- **Step 1** – Draw one observation from each input distribution.
- **Step 2** – Calculate total cost with the set of input (sample) values.
- **Step 3** – Repeat Step 1 and Step 2.
    - 1000-10000 iterations is usually sufficient
- **Step 4** – Final Result
    - A Cumulative Distribution
- Correlation is the degree to which two or more attributes (cost elements) from the same group (Work Breakdown Structure) show a tendency to vary together.
- Monte Carlo Simulation assumes that all inputs are statistically independent until told different.
- Correlation coefficient is represented by R.

Lesson Completion

You have completed the content for this lesson.

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If you have closed or hidden the Table of Contents, click the Show TOC button at the top in the Atlas navigation bar.