EM384: Analytical Methods for Engineering Management

Lesson 30: Monte Carlo Simulation in Excel I

12 April 2023

Table of contents

Lesson Objectives

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- Understand Monte Carlo simulation.
- Create a Monte Carlo simulation in Excel.
- Interpret the results of a Monte Carlo Simulation using expected value, standard deviation, and a histogram.
- Find the probability of a result using the results of a Monte Carlo simulation

The Flaw of Averages

In-Class Exercise

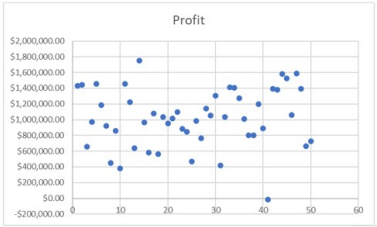
- Imagine you are ordering something to sell 6 months in advance of the Christmas selling season.
- The marketing department says demand is uncertain, but they give you the following:
  - Average Demand will be 100,000. So, in keeping with the forecast, you order 100,000 units.
  - Profit per unit is $10.
- If your boss asked you “what is the average profit going to be for the Christmas selling season?”...what do you tell him?
- Think. And write down your reply on a piece of paper.
- When told to do so, compare and discuss your answer with your neighbor.

In-Class Exercise

	A	B	C	D	E	F
1		Demand	Stocked	Sold	Unit Profit	Total Profit
2		108277.7652	100000	100000	10	1000000
3		112779.4694	100000	100000	10	1000000
4		95211.00847	100000	95211.01	10	952110.085
5		110797.5834	100000	100000	10	1000000
6		117186.3521	100000	100000	10	1000000
7		82111.22005	100000	82111.22	10	821112.2
8		64255.27907	100000	64255.28	10	642552.791
9		97274.30359	100000	97274.3	10	972743.036
10		100023.9463	100000	100000	10	1000000
11		126276.9325	100000	100000	10	1000000
12						
13						
14	AVG DEMAND	101419.386			AVG PROFIT	938851.811

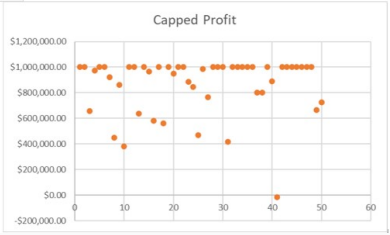
If actual demand is less than average, profit will drop. But if demand is greater than average, the sales are restricted by capacity. Thus there is a downside without an associated upside, and the average profit is less than the profit associated with the average demand.

The Flaw of Averages



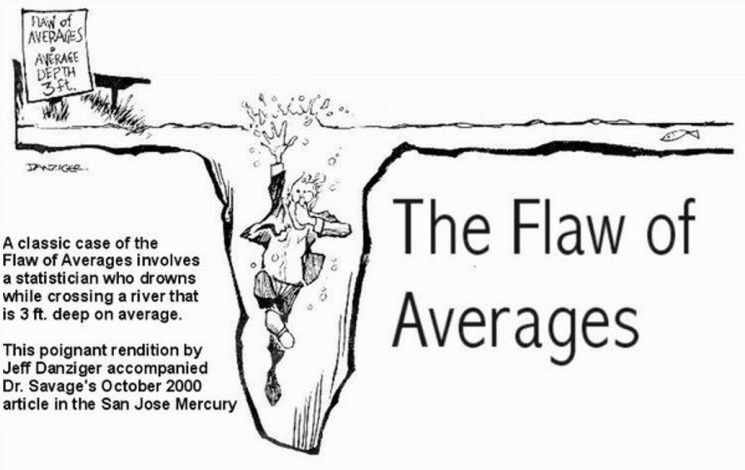
Average Profit: $1,022,133

Average Profit: $863,756



Simply using the average ignores the total distribution of possible outcomes and can lead one to greatly underestimate the risk of 'bad' outcomes.

The Flaw of Averages



http://www.youtube.com/watch?v=Oah03QcRxGY

Monte Carlo Simulation

What is Simulation?

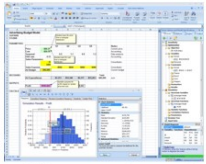
When do we prefer to develop a simulation model over an analytic model?

- When inputs and processes are uncertain
- When mathematical complexity makes it hard to provide “close form” results.
- When “good” solutions (not necessarily optimal) are satisfactory.

By estimating performance characteristics of the system, the best alternative from a set of alternatives under consideration can be identified.

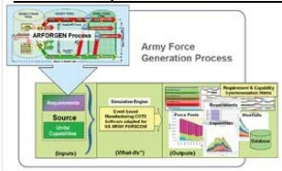
Simulation in DSE Courses

EM384 Monte Carlo (SE385, EM381)



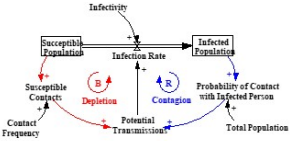
Monte Carlo simulation generates random inputs from input distributions and process distributions, processes the inputs, and generates distributions of the outputs. This course uses Excel and Python.

EM481 Systems Simulation



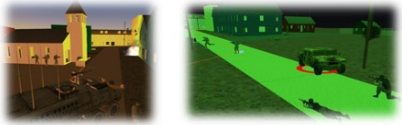
Systems Simulation uses Discrete Event Simulation, expanding the cadet's ability to model a large, complex, multi-disciplinary system using ProModel.

SM484 Dynamic Systems Analysis



System dynamics is a methodology for studying and managing complex feedback systems over time utilizing feedback loops, time delays, and stocks & flows. VENSIM is the modeling environment.

SE485 Combat Modeling

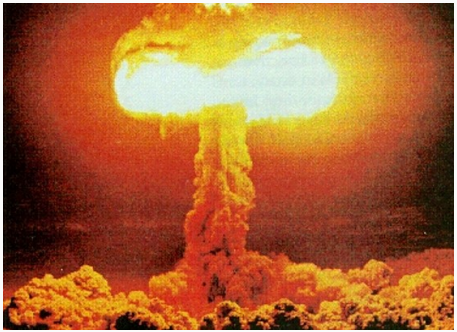


Cadets will learn and apply algorithms specific to combat modeling & simulation and design combat models in the Virtual Battlespace Simulator 3 (VBS3) and Infantry Warrior Simulations (IWARS) computer simulation environments.

Monte Carlo Simulation

Monte Carlo simulation generates random inputs from input distributions and process distributions, processes the inputs, and generates distributions of the outputs.

- The Monte Carlo method was coined in the 1940s by John Von Neumann, Stanislaw Ulam and Nicholas Metropolis, while they were working on nuclear weapon projects (Manhattan Project) in the Los Alamos National Laboratory.
- It was named after the Monte Carlo Casino, a famous casino where Ulam's uncle often gambled away his money.



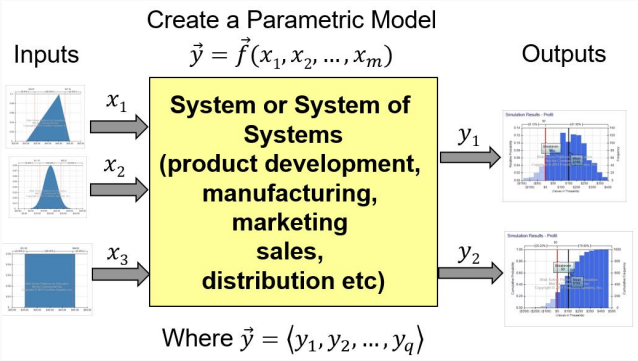
Monte Carlo Simulation

- We begin with a system model $\vec{y} = \vec{f}(x_1, x_2, ..., x_m)$ with inputs, processes, and outputs $x_1, x_2, ...x_m$.
- $\vec{y} =< y_1, y_2, ..., y_q >$ is a vector if there is more than one output from the model (e.g total sales, total returns, total wait time, etc.)
- Due to uncertainty, we assign distributions for the uncertain inputs $x_1, x_2, ..., x_m$.
- Monte Carlo simulation generates outputs for $\vec{y}$ from random variable inputs and logic/processes built into the parametric model.
- With more than one input, multiple random events interact. It's really the interaction of numerous random events that make such analyses interesting.
- **Each time we generate new random inputs $x_1, x_2, ..., x_m$ and calculate $\vec{y}$, we have completed one iteration of the Monte Carlo simulation.** We keep repeating this process for n iterations (consider using an n large enough to ensure your distribution of $\vec{y}$ converges).

Monte Carlo Simulation

Five steps:

1. Create a parametric model, $\vec{y} = \vec{f}(x_1, x_2, \ldots, x_m)$
2. Generate a set of random inputs, $x_1, x_2, \ldots, x_m$
3. Evaluate the model and store the outputs as $\vec{y}$.
4. Repeat steps 2 and 3 until n iterations are complete.
5. Analyze the results using frequency, cumulative, summary statistics, confidence intervals, etc.



Setting up your Excel Model

EM384 Standards for Monte Carlo in Excel

1. Fixed Parameters go at the top and are referenced using *absolute referencing*
2. Set up a column for each calculation or logic step
3. Set up a row for each iteration of the simulation
4. Random variable outcomes get generated in the columns where they are needed.
5. The last columns(s) of your model should be the outcomes you need to record for the problem (e.g. total profit, number of customers, etc)

	A	B	C	D	E	F
1	**Fixed Parameters**					
2	# of Cookies Bought (wholesale)	600				
3	Selling Price	1				
4						
5	Packaging Cost/Cookie	0.05				
6	Ingredient Cost/Cookie	0.3				
7						
8	Fixed Operating Cost	250				
9						
10						
11	**Monte Carlo Simulation**					
12	Cookie Demand	Cookies Bought (wholesale)	Cookies Sold (retail)	Gross Revenue	Gross Cost	Net Profit
13	571	=$B$2	=MIN(A13:B13)	=MIN($B$2,A13)*$B$3	=$B$2*($B$5+$B$6)+$B$8	=D13-E13
14	602	=$B$2	=MIN(A14:B14)	=MIN($B$2,A14)*$B$3	=$B$2*($B$5+$B$6)+$B$8	=D14-E14
15	573	=$B$2	=MIN(A15:B15)	=MIN($B$2,A15)*$B$3	=$B$2*($B$5+$B$6)+$B$8	=D15-E15
16	621	=$B$2	=MIN(A16:B16)	=MIN($B$2,A16)*$B$3	=$B$2*($B$5+$B$6)+$B$8	=D16-E16
17	587	=$B$2	=MIN(A17:B17)	=MIN($B$2,A17)*$B$3	=$B$2*($B$5+$B$6)+$B$8	=D17-E17

Conclusion

Next Class

Homework:

- Review Readings for Block 4

Next Lesson:

- Understand Monte Carlo simulation.
- Create a Monte Carlo simulation in Excel.
- Interpret the results of a Monte Carlo Simulation using expected value, standard deviation, and a histogram.
- Find the probability of a result using the results of a Monte Carlo simulation