## Chapter 6. Introduction to Monte Carlo Simulation

A Simulation is an experiment in which we attempt to understand how some process will behave in reality by imitating its behavior in an artificial environment that approximates reality as closely as possible.

Simulation is typically used when

1) No formulae or good solution methods exist because assumptions in existing formulae/methods are violated.

2) Data does not follow standard probability distributions

3) Most importantly, to evaluate alternatives (e.g..., designs, systems, methods of providing service, etc.)

Examples include valuing options, evaluating overbooking policies for airplanes, evaluating work schedules, maintenance policies, financial portfolios, real estate salesperson planning, etc.

Advantage

1) It can be used to analyze large and complex real-world situations that cannot be solved by conventional operations management models.

2) Real-world complications can be included that most OM models cannot permit. For example, simulation can use any probability distribution the user defines; it does not require standard distributions.

3) "Time compression" is possible. The effects of OM policies over many months or years can be obtained by computer simulation in a short time.

4) Simulation allows "what-if?" types of questions. Managers like to know in advance what options will be most attractive. With a computerized model, a manager can try out several policy decisions within a matter of minutes.

5) Simulations do not interfere with real-world systems. It may be too disruptive, for example, to experiment physically with new policies or ideas in a hospital or manufacturing plant.

Disadvantage

1) Good simulation models can take a long time to develop.

2) It is a repetitive approach that may produce different solutions in repeated runs. It does not generate optimal solutions to problems (as does linear programming).

3) Managers must generate all of the conditions and constraints for solutions that they want to examine. The simulation model does not produce answers without adequate, realistic input.

4) Each simulation model is unique. Its solutions and inferences are not usually transferable to other problems.

**Session 1. Functions in Excel**

Introduce "IF function", "VLOOKUP function"

Normal Distribution

$= \text{NORMINV}(\text{RAND}(), \text{Mean}, \text{Std. Deviation})$

Uniform Distribution

$= \text{RANDBETWEEN}(\text{Min}, \text{Max})$

RANDBETWEEN can only generate random integers, if we want decimals, we can still use this function but we need some trick.

Suppose we want two-digit decimals between 1.00 and 10.00:

$= \text{RANDBETWEEN}(1 * 100, 10 * 100)/100$

Examples

1. Simulate 1000 observations from a Normal distribution with known mean and variance

2. Simulate 1000 observations from a Uniform distribution with known lower and upper limit

    - What if we only want integers?

3. Simulate 1000 observations from a Poisson distribution with known lambda

4. Simulate 1000 observations from a Binomial distribution with known parameter

5. How to simulate demand with cumulative probabilities

**Session 2. Simple Examples**

1) How to find Pi

2) Law of large number

3) Central limit theorem

**Session 3. What-if Analysis**

Robustness test, sensitivity analysis, competitive static (changing parameter)

but what-if is changing the decision variable

Data Table Introduction

1) Inventory with random demand

2) A newspaper vendor want to decide how many newspapers to order per day.

The unit cost of one newspaper is $20

The unit price of one newspaper is $40

If newspapers are not sold out, the rest can get a refund with unit price $10

The daily demand is normally distributed such that

N(100, 2500)

The vendor wants to maximize his profits. Meanwhile, he is risk-adverse, so he wants find a way to make the probability that the profits is less than $200 as small as possible.

Summary on Simulation

1) Simulation does not find you the optimal solution right away, but allows you to evaluate alternatives and pick the best one.

2) The number of iterations needed should be enough to stabilize your results. If your result bounces around, you need more iterations.

3) There is software available for Monte Carlo simulation, such as @Risk and Crystal Ball. These are easy to use, but Excel works perfectly fine as well.

4) Can you simulate continuous time processes using Monte Carlo simulation? Like the inventory simulation, entities (parts, orders) travel through the process in time. This is difficult to do using MC techniques, which are better for discrete time, static simulations. There are better software available for process simulation, such as Arena.

5) Using simulation software does not excuse you from modeling correctly. They only help you avoid the chore of keeping track of the accounting for various events happening simultaneously.