**Part 1: Computer Simulation**

Focusing on discrete-event systems and model design:

Step 1: Generation of input data using random number generation

Step 2: Development of system simulation based on our knowledge of the system and inputs while considering the order of occurrence of the events in the system

Step 3: Output statistical analysis and model validation.

**Simulation:** Imitation of the operations of a real-world process or system over time

Generation of an artificial history of a system

Observation of the artificial history to deal with the operating characteristics of the real system.

**Morden simulation is a computer program that mimics the behaviour of a real-world “system” over time, including its inputs and outputs.**

Applications of simulation:

* Manufacturing applications
* Construction engineering
* Military applications
* Transportation, Distribution Applications
* Climate and weather forecast
* Design of communication networks

Systems:

**System**:

* A group of objects or components that interact together towards the accomplishment of some logical goals.

**Entity**:

* Any object or component in the system that requires explicit representation, e.g., a server, a customer, a machine
* - Attributes are the properties of entity.
* - Attributes are represented by state variables.

**Activity:**

* Set of actions, e.g., check balance at the bank, serve a customer

**State of a system:**

* Collection of variables and their values necessary to describe the system at a particular time.

**Discrete vs Continuous:**

* **Discrete**: State variables change instantaneously at separated points in time (e.g., bank model only changes when a customer arrives or departs)
* **Continuous**: State variables change continuously as a function of time (e.g., airplane model with state variables such as position, velocity change continuously).

**Models:**

Mathematical model:

* Uses symbolic notation and mathematical equations to represent a system.

Physical model:

* Are the models whose physical characteristics resemble those of the actual system. It looks or feels like the real thing.

Analytical Solution:

* If the model is simple enough, mathematical approach is feasible , e.g., calculus, algebra, probability theory.

Use analytical model whenever possible due to its efficiency and low-cost.

Use simulation when:

* Modelling complex dynamic systems theoretically needs too many simplifications and thus the resulting analytical models may not be valid. Simulation does not require that many simplifying assumptions.
* Complete mathematical formulation does not exist, or an analytical solution cannot be developed;
* Analytical methods are available, but the mathematical procedures (e.g., partial differential equations) are so complex that simulation provides a simpler solution;

However, the problems with simulation are:

* Simulations are often complex error-prone pieces of software
* Simulations can take a LONG time to execute
* Simulation only produces approximate answers.
* Analytical models are less flexible, but they are exact and efficient.

**Simulation Models: stochastic vs deterministic**

**Deterministic:**

* No probabilistic component or random variable in the system.
* Have a known set of fixed inputs
* Example: deterministic arrivals would occur at a dentist’s office if all patients arrived at the scheduled appointment time

**Stochastic:**

* Has one or more random variables as inputs
* Random inputs lead to random outputs
* Random outputs are the estimates of the true characteristics of a model
* Example: queueing systems.

**Simulation Models: Static vs Dynamic:**

**Static Simulation:**

* Time plays no role
* Example: Monte Carlo Method: calculating value of Pi.

**Dynamic Simulation:**

* Represents a system as it evolves over time
* Example: Simulation of a bank from 9am to 4pm

**Steps in a simulation study:**1: Problem formulation:

* Understand the problem to be addressed by simulation clearly.
* Agree the problem formulation between the policy maker and the analyst.

2: Setting of the objectives and overall project plan:

* The objectives indicate the questions to be answered by simulation.
* What to do with the simulation?
* Determine whether simulation is the appropriate methodology
* Form the project plan

3: Model conceptualisation (constructing the model)

* Model: an abstract representation of the system.
* What should be included in model? What can be left out?
* Appropriate choice depends on the purpose of the model.
* What abstractions should be used? What is the level of details?

4. Data collection ▪ The more data you have→ the more complete information you get→ the more precise model you can build→ the better solution you would get.

5. Model translation (Developing a computer program):

- Program the model into a computer language from a computational model,

- OR: Use special-purpose simulation software.

6. Verified?:

- Is the computer program prepared for the simulation model correct?

- Are the input parameters and logical structure of the model correctly represented in the computer?

- Is the computer program performing properly?

7. Validated?:

- Determine if the model is an accurate representation of the real system.

- Validation is an iterative process of comparing the model to actual system

- Helps to improve the model.

8. Experimental design: Decide on

- The length of the initialisation period,

- The length of simulation runs, and

- The number of replications to be made of each run.