# Modeling and Simulation

Dr. Pushpender Kumar Dhiman

# Books

- A.M. Law and W.D. Kelton, “Simulation Modeling and Analysis”, McGraw-Hill.
- Geoffrey Gordon, “System Simulation”, Prentice Hall of India.

# What Is A Model ?

A Representation of an object, a system, or an idea in some form other than that of the entity itself.

(Shannon

# What is modeling

- Modeling is the process of producing a model; a model is a representation of the construction and working of some system of interest.
- A model is similar to but simpler than the system it represents. One purpose of a model is to enable the analyst to predict the effect of changes to the system. A model should be a close approximation to the real system and incorporate most of its salient features.
- Model should not be so complex that it is impossible to understand and experiment with it.
- Simulation practitioners recommend increasing the complexity of a model iteratively.
- An important issue in modeling is model validity. Model validation techniques include simulating the model under known input conditions and comparing model output with system output.
- Generally, a model intended for a simulation study is a mathematical model developed with the help of simulation software.
- Mathematical model classifications include deterministic (input and output variables are fixed values) or stochastic (at least one of the input or output variables is probabilistic); static (time is not taken into account) or dynamic (time-varying interactions among variables are taken into account). Typically, simulation models are stochastic and dynamic.

# What is Simulation

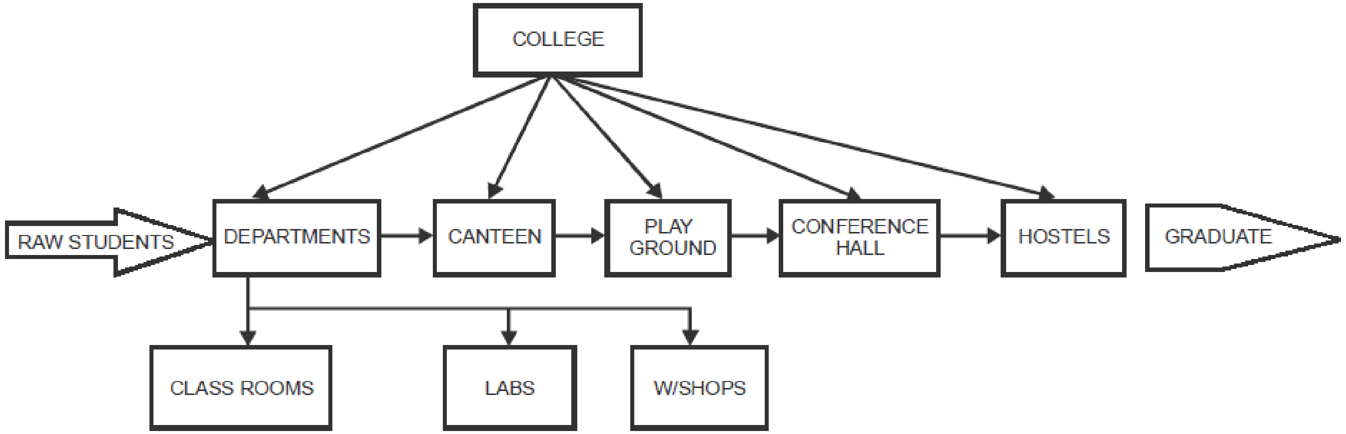
- Simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose of either understanding the behavior of the system and/or evaluating various strategies for the operation of the system

# What is simulation

- A simulation of a system is the operation of a model of the system. The model can be reconfigured and experimented with desired input and get pre calculated outputs.
- The operation of the model can be studied, and hence, properties concerning the behavior of the actual system or its subsystem can be inferred.
- Simulation is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time.
- Simulation is used before an existing system is altered or a new system built, to reduce the chances of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over-utilization of resources, and to optimize system performance.

# Basic Definition

- ***Exogenous****:* The system which are effected by the environment.
- ***Endogenous:*** The system which are not effected by the environment
  - The economic model of a country is effected by the world economic conditions and is exogenous model. Aircraft flight is exogenous, as flight profile is effected by the weather conditions, but static model of the aircraft is endogenous. A class room in the absence of students, is *endogenous*.
- ***Entity:*** Any object which has some action to perform and is dependent on number of objects called entities, is a system.
- ***Attribute:*** Properties of interest of the entity.
- **Activity:** The process, which causes the change in any attribute of an entity of a system.


COLLEGE
RAW STUDENTS
DEPARTMENTS
CANTEEN
PLAY GROUND
CONFERENCE HALL
HOSTELS
GRADUATE
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W/SHOPS

- ***Queue:*** It is a situation, where entity wait for some thing to happen. It may be physical queue of people or of objects or list of tasked performed.
- ***Creating:*** it is causing an arrival of new entity to the system at some point in time.
- ***Scheduling:*** scheduling is  a process of assigning events to the exiting entities, like the service begin and service and times.
- ***Random Variable:*** it is a variable with uncertain magnitude i.e quantitative value changes at random like life of bulbs.
- ***Random Variate:*** it is a variable generated by using random numbers along with the probability density function.
- ***Distribution:*** It is a mathematical law which governs and define probability feature of random variables. Also called probability density function

# Lets us consider the example patrol pump

- Entities: all vehicle entered petrol pump of various type two three, four
- Events are arrival of vehicles, service beginning, service ending, departure of vehicle
- State are number of vehicle in the system at particular time, no of worker busy, no of vehicle in waiting, etc.
- Attributes are type, size of fuel tank
- Random variable are arrival time of vehicle, service time, billing time

# Few more Examples

| ***System*** | ***Entities*** | ***Attributes*** | ***Activities*** |
|---|---|---|---|
| Banking | Customers | Maintaining accounts | Making deposits |
| Production unit | Machines, workers speed, | Capacity, | Break-down welding, Manufacturing |
| College | Teachers, Students | Education teaching, | Games |

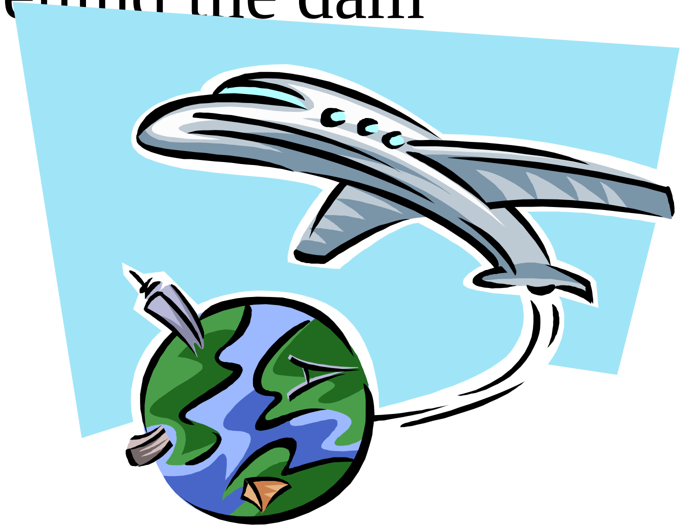
# Goal of modeling and simulation

- A model can be used to investigate a wide verity of “what if” questions about real-world system.
  - Potential changes to the system can be simulated and predicate their impact on the system.
  - Find adequate parameters before implementation
- So simulation can be used as
  - Analysis tool for predicating the effect of changes
  - Design tool to predicate the performance of new system
  - It is better to do simulation before Implementation.

# Two Types of Systems

- Discrete – is one for which the state variables change instantaneously at separated point in time. eg. Number of customer waiting in a line

- Continuous – is one for which the state variables change continuously with respect to time. eg. Head of water behind the dam



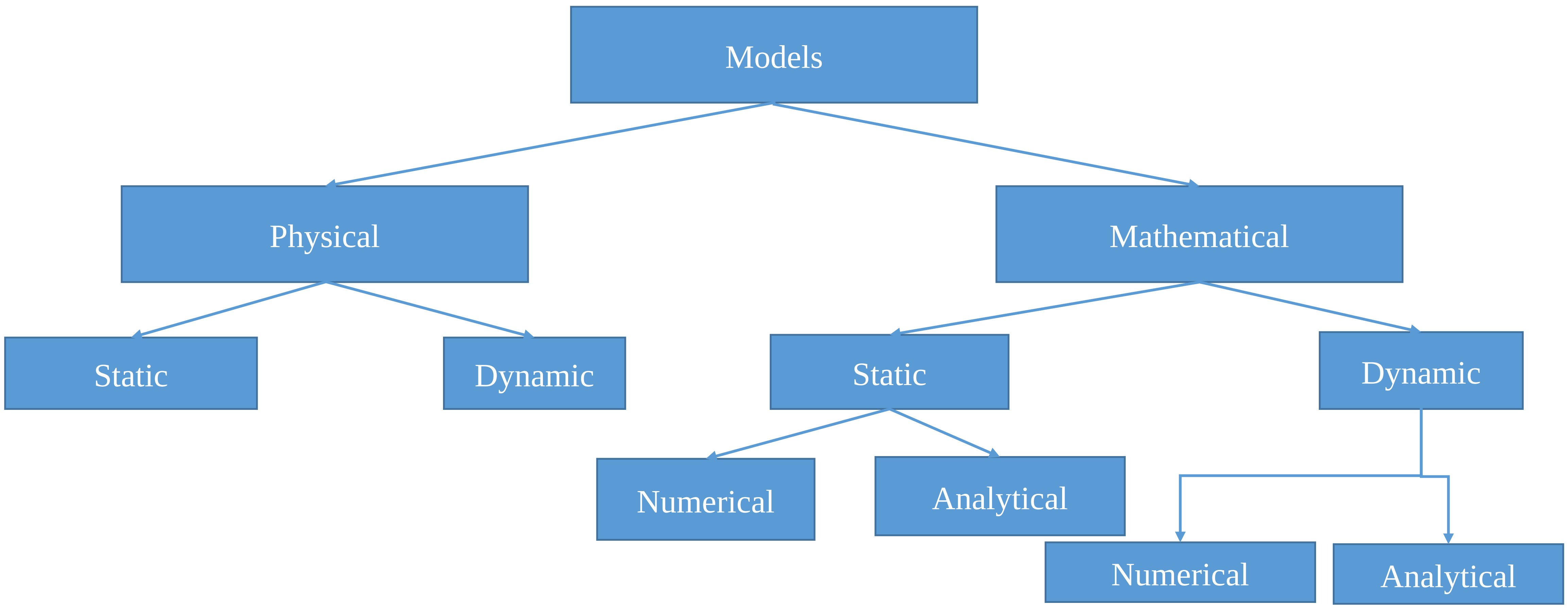
# When simulation is the appropriate tool

- Simulation enable the study of internal interaction of a subsystem with complex system
- Informational, organizational and environmental changes can be simulated and find their effects
- A simulation model help us to gain knowledge about improvement of system
- Finding important input parameters with changing simulation inputs
- Simulation can be used with new design and policies before implementation

# Cont….

- Simulating different capabilities for a machine can help determine the requirement
- Simulation models designed for training make learning possible without the cost disruption
- A plan can be visualized with animated simulation
- The modern system (factory, wafer fabrication plant, service organization) is too complex that its internal interaction can be treated only by simulation

# Types of models



# Types of models

- Physical and Mathematical
- Static and Dynamic Model
- Analytical and Numerical Model
- Deterministic and Stochastic model

# Steps involved in developing a simulation model

- **Step 1. Identify the problem:**
  - Enumerate problems with an existing system. Produce requirements for a proposed system
- **Step 2. Formulate the problem:**
  - Select the bounds of the system, the problem or a part thereof, to be studied.
  - Define overall objective of the study and a few specific issues to be addressed.
  - Define performance measures - quantitative criteria on the basis of which different system configurations will be compared and ranked.
  - Identify, briefly at this stage, the configurations of interest and formulate hypotheses about system performance.
  - Decide the time frame of the study, i.e., will the model be used for a one-time decision (e.g., capital expenditure) or over a period of time on a regular basis (e.g., air traffic scheduling).
  - Identify the end user of the simulation model, e.g., corporate management versus a production supervisor.
  - Problems must be formulated as precisely as possible.
- **Step 3. Collect and process real system data**
  - Collect data on system specifications (e.g., bandwidth for a communication network), input variables, as well as Altered System
  - Study Simulation Experiment Simulation Analysis Conclusions performance of the existing system.
  - Identify sources of randomness in the system, i.e., the stochastic input variables. Select an appropriate input probability distribution for each stochastic input variable and estimate corresponding parameter(s).
  - Software packages for distribution fitting and selection include Expert Fit, Best Fit, and add-ons in some standard statistical packages.

- **Step 4. Formulate and develop a model:**
  - Develop schematics and network diagrams of the system (How do entities flow through the system?).
  - Translate these conceptual models to simulation software acceptable form.
  - Verify that the simulation model executes as intended. Verification techniques include traces, varying input parameters over their acceptable range and checking the output, substituting constants for random variables and manually checking results, and animation.
- **Step 5. Validate the model:**
  - Compare the model's performance under known conditions with the performance of the real system.
  - Perform statistical inference tests and get the model examined by system experts.
  - Assess the confidence that the end user places on the model and address problems if any.
- **Step 6. Document model for future use**
  - Variables of a simulation model so that we may observe and identify the reasons for changes in the performance measures.
  - The number of experiments in a simulation study is greater than or equal to the number of questions being asked about the model (e.g., Is there a significant difference between the mean delay in communication networks A and B?, Which network has the least delay: A, B, or C? How will a new routing algorithm affect the performance of network B?).
  - Design of a simulation experiment involves answering the question: what data need to be obtained, in what form, and how much? The following steps illustrate the process of designing a simulation experiment.
- **Step 7. Select appropriate experimental design**
  - Select a performance measure, a few input variables that are likely to influence it, and the levels of each input variable.
  - When the number of possible configurations (product of the number of input variables and the levels of each input variable) is large and the simulation model is complex, common second-order design classes including central composite, Box-Behnken, and full factorial should be considered.
  - Document the experimental design.
- **Step 8. Establish experimental conditions for runs:**
  - Address the question of obtaining accurate information and the most information from each run.
  - Determine if the system is stationary (performance measure does not change over time) or non-stationary (performance measure changes over time).
  - Select the run length. Select appropriate starting conditions (e.g., empty and idle, five customers in queue at time 0).
  - Select the length of the warm-up period, if required.
  - Decide the number of independent runs - each run uses a different random number stream and the same starting conditions - by considering output data sample size.

- **Step 9. Perform simulation runs**
  - Perform runs according to steps 7-8 above Most simulation packages provide run statistics (mean, standard deviation, minimum value, maximum value) on the performance measures, e.g., wait time (non-time persistent statistic), inventory on hand (time persistent statistic).
- **Step 10. Interpret and present results:**
  - Compute numerical estimates (e.g., mean, confidence intervals) of the desired performance measure for each configuration of interest.
  - To obtain confidence intervals for the mean of auto correlated data, the technique of batch means can be used.
  - In batch means, original contiguous data set from a run is replaced with a smaller data set containing the means of contiguous batches of original observations. The assumption that batch means are independent may not always be true; increasing total sample size and increasing the batch length may help.
- **Step 11. Recommend further course of action:**
  - This may include further experiments to increase the precision and reduce the bias of estimators, to perform sensitivity analyses, etc.

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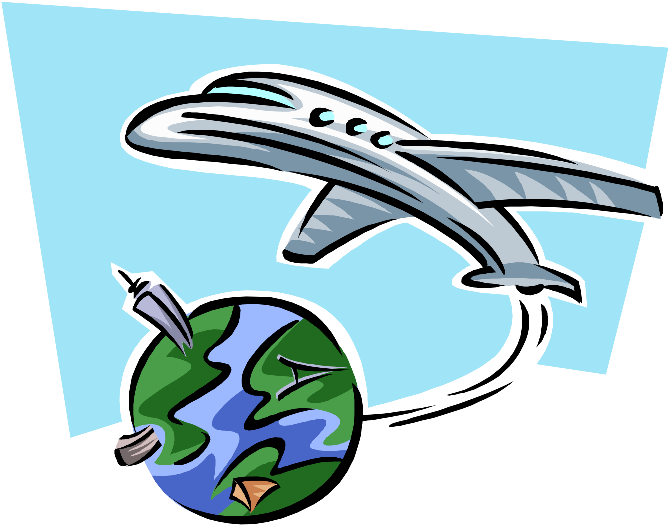
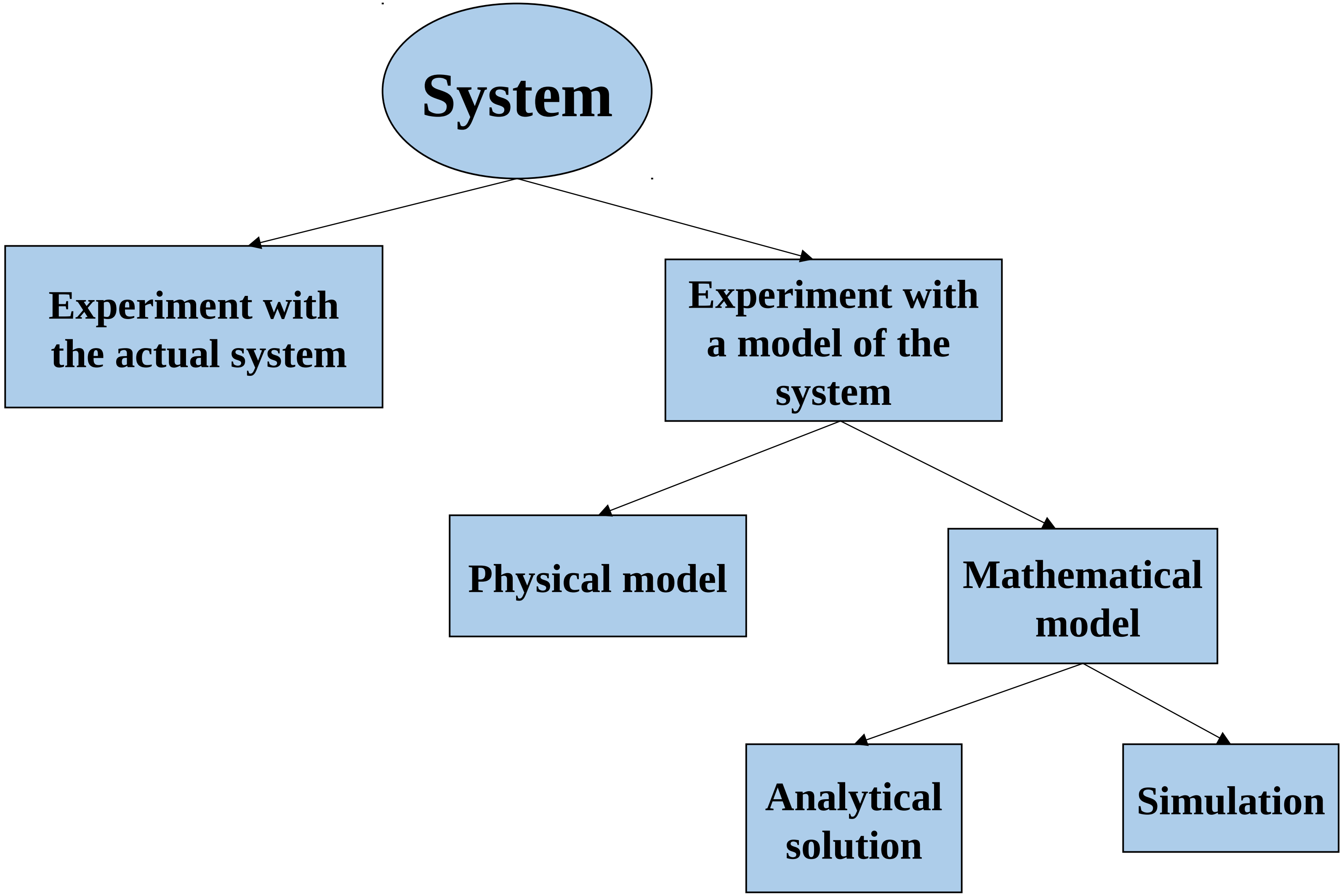


# Ways to study a system



# Discrete-Event Simulation

- Discrete-event simulation concerns the modeling of a system as it evolves over time by a representation in which the state variables change instantaneously at separate points in time. These points in time are the ones at which an event occurs, where an "***event***" is defined as an instantaneous occurrence that may change the state of the system.

**Example**

- Consider a service facility with a single server-e.g., a one-operator barbershop or an information desk at an airport—for which we would like to estimate for (expected) average delay in queue (line) of arriving customers, where the delay in queue of a customer is the length of the time interval from the instant of his arrival at the facility to the instant he begins being served.

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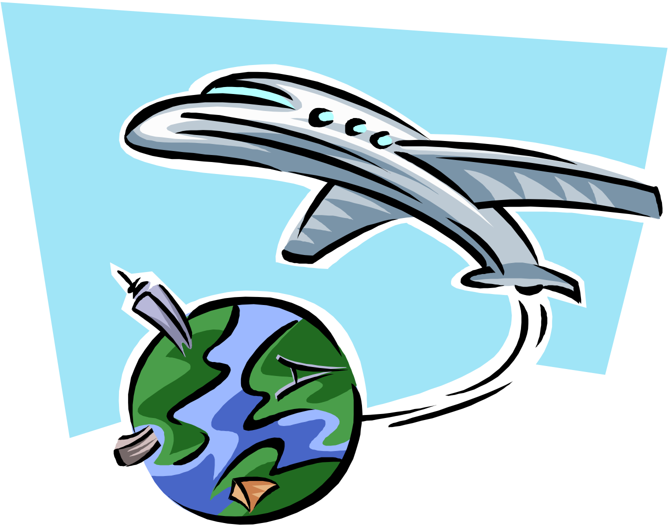

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