Computer Modeling and Simulation (CS 233)

Lecture Notes (Theory)

Chapter 1
Introduction to Modeling & Simulation

System: A system is any set of interrelated components acting together to achieve a common objective. It means a system requires some inputs to process and produce desired outputs. The diagram is shown below:

Figure1.1: System

It is also defined to be a collection of entities, e.g., people or machines, which act and interact together toward the accomplishment of some logical end.

Example: **Banking System**

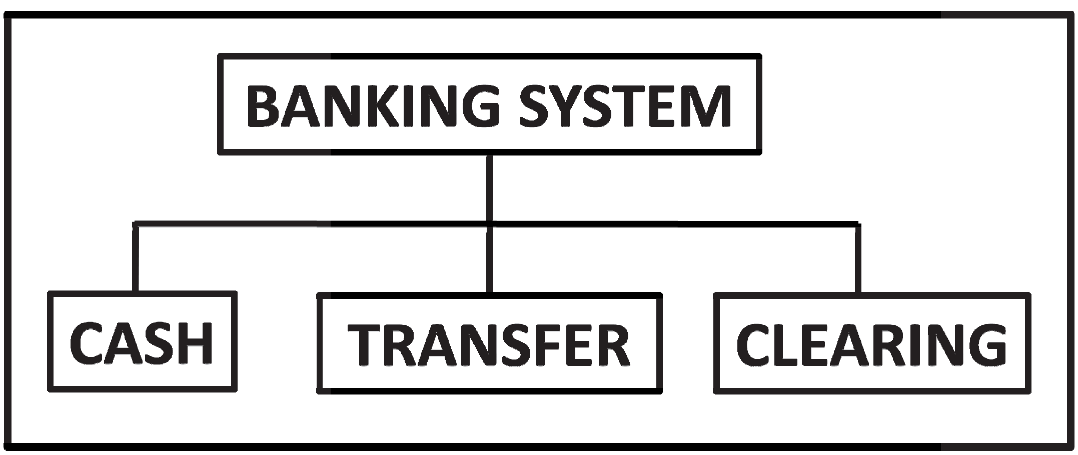

Figure 1.2: Banking System

More Examples: Queuing System, Inventory System, Email System, Traffic System, Supermarket System

Components of a System: A system has mainly five components.

Entity: An **entity** is an object of interest in the system.

Attribute: An **attribute** is a property of an entity. A given entity can possess many attributes.

Activity: An **activity** represents a time period of specified length.

State of a System: The **state of a system** is defined to be that collection of variables (e.g. entities, attributes, activities) necessary to describe the system at any time, relative to the objectives of the study.

Event: An **event** is defined as an instantaneous occurrence that may change the state of the system.

Example 1: Let us **c**onsider the example of a banking system, in this system:

The **system entities** are **CUSTOMER** and **TELLERS**.
The **attribute** of customer is **BALANCE** (may be more attributes: customer_id, name, mobile_number, address etc.)
The **activity** is **WITHDRAW_CASH or DEPOSIT_CASH**.
The **system events** are **CUSTOMER_ARRIVAL** and **CUSTOMER_DEPARTURE**.
The **system states**, which are changed by these events, are **NUMBER_OF_CUSTOMERS_IN_THE_QUEUE** (an integer from 0 to n) and **STATUS_OF_TELLER** (busy or idle).

The progress of the system is studied by changing in the states of the system.

Example 2: If one wants to make a study on a bank to determine the number of tellers needed to provide adequate service for customers who want just to cash a cheque or make a savings deposit, the system can be defined to be that portion of the bank consisting of the tellers and the customers waiting in line or being served.

System Environment: The external components which interact with the system and produce necessary changes are said to constitute the system environment. In modeling systems, it is necessary to decide on the boundary between the system and its environment. This decision may depend on the purpose of the study.
Example: Customers are the external component which interact with the bank system and produce changes.
Endogenous System: The term endogenous is used to describe activities and events occurring within a system. **Example: Drawing cash in a bank.**

Exogenous System: The term exogenous is used to describe activities and events in the environment that affect the system. **Example: Arrival of customers.**

Closed System: A system for which there is no exogenous activity and event is said to be a closed system. **Example: Water in an insulated flask.**

Open system: A system for which there is exogenous activity and event is said to be an open system. **Example: Banking System**

Modeling & Simulation

Modeling	Simulation
Obtain a set of equations (mathematical model) that describes the behavior of the system.	**Use the mathematical model to determine the response of the system in different situations.**
	"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." Simulation uses a computer to evaluate a model numerically, and data are gathered in order to estimate the desired true characteristics of the model.

Model: "A set of assumptions about how the system works, which usually take the form of mathematical or logical relationships, constitute a model. It is used to try to gain more understanding of how the corresponding system behaves". **It means a model describes the mathematical relationship between inputs and outputs**.
or
A model is like (similar) to the original in shape or in working or both.

Reasons for making Models: or why we make Models?
1. To study the behavior of the system when the original is not available.
2. Study of a model is much easier, faster, cheaper, and safer in comparison to the real system.
3. To help us visualize and organize our own design thoughts.

4. To help us communicate our design thoughts to others.
5. We can try wide-ranging ideas with the model.
6. To give the training to the trainees (space travel).

Example1: Suppose a builder wants to make a colony, then he will not directly make colony. First he makes a model such that people may visualize and see the design layout before purchasing flats in that particular colony.

Figure 1.3: Model of a colony

Example2: Model of earth

Figure 1.4: Model of Earth

Example3: Model of solar system

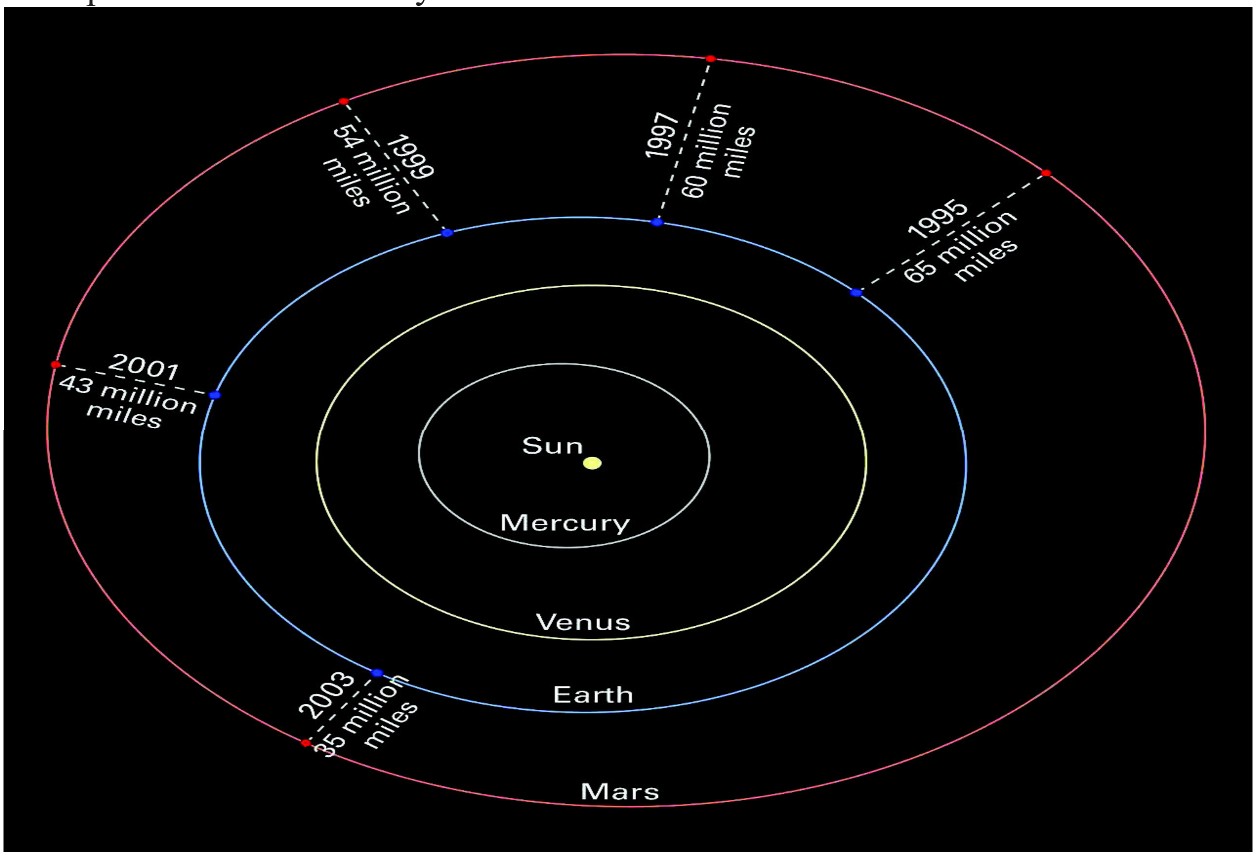

Figure 1.5: Model of Solar system

Ways to Study a system:

At some point in the lives of most systems, there is a need to study them to try to gain some insights into the relationship among various components or to predict performance under some new conditions being considered. The figure below maps different ways in which a system might be studied.

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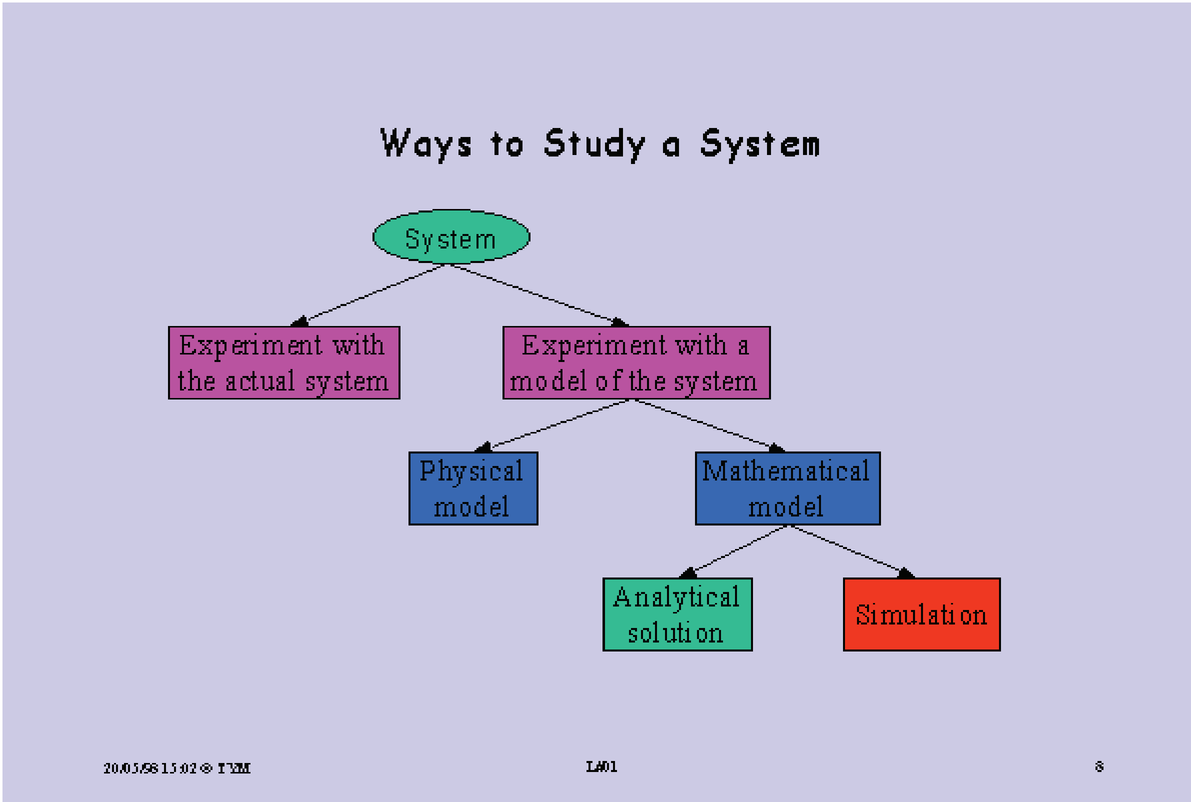

Figure1.6: Ways to Study a system

Why Simulation is necessary:

1. It enables us to test hypotheses without having to carry them out, saving both life and money.
2. It provides cost effective means of exploring new processes, understanding of the world around us.
3. It can be used 24/7. Not restricted by weather, time of day, etc.
4. Description of system behavior by experiment might not be feasible due to:
(i) inaccessible input and outputs.
(ii) experiment may be too dangerous.

When Simulation is an appropriate tool:

1. Simulation enable the study of internal interaction of a subsystem with complex system.
2. A simulation model helps us to gain knowledge about improvement of system.
3. Finding important input parameters with changing simulation inputs.
4. Simulation can be used with new design and policies before implementation.
5. Simulating different capabilities for a machine can help determine the requirement.

6. Simulation models designed for training make learning possible without the cost disruption.
7. A plan can be visualized with animated simulation.
8. The modern system (factory, wafer fabrication plant, service organization) is too complex that its internal interaction can be treated only by simulation.

When simulation is not appropriate:
1. When the problem can be solved by common sense.
2. When the problem can be solved analytically.
3. If it is easier to perform direct experiments.
4. If cost exceed savings.
5. If resource or time are not available.
6. If system behavior is too complex. (Like human behavior)

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Classification of Simulation models

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(1) Static vs. Dynamic : A static simulation model is a representation of a system at a particular time.(e.g: Monte Carlo Models).
Dynamic simulation model represents a system as it evolves over time (e.g: Conveyor system in factory)

(2) **Deterministic vs. stochastic :** If a model does not contain any probabilistic (i.e: Random) components, it is called deterministic (e.g: A complicated system of differential equation describing a chemical reaction).
Stochastic simulation models have some random input components and produce output that is random and is treated as only an estimate of the true characteristics of a model.

(3) Continuous vs. discrete :
Continuous Simulation is used to model systems which vary continually with time; the systems modeled are dynamic but may be either deterministic or stochastic.
Discrete Simulation is used to model systems which are assumed to change only at discrete set of points in time (correspond to state changes). The systems modeled are dynamic and almost invariably, stochastic.
Most operational models are dynamic, stochastic, and discrete – will be called discrete-event simulation models.

Application areas of Simulation:
● Designing and analyzing manufacturing systems.
● Evaluating military weapons systems or their logistics requirements.

● Determining hardware requirements or protocols for communication networks.
● Designing and operating transportation systems such as airports, freeways, ports and subways. ● Evaluating designs for service organizations such as call centers, fast-food restaurants, hospitals, and post offices.
● Reengineering of business processes.
● Determining ordering polices for an inventory system.
● Analyzing financial or economic systems.

ADVANTAGES OF SIMULATION

● Simulation allows one to estimate the performance of an existing system under some projected set of operating conditions.
● Alternative proposed system designs (or alternative operating policies for a single system) can be compared via simulation to see which best meets a specified requirement.
● In a simulation we can maintain much better control over experimental conditions than would generally be possible when experimenting with the system itself.
● Simulation allows us to study a system with a long time frame---e.g., an economic system---in compressed time, or alternatively to study the detailed workings of a system in expanded time.

DISADVANTAGES OF SIMULATION

● Each run of a *stochastic* simulation model produces only *estimates* of a model's true characteristics for a particular set of input parameters. If a "valid" analytic model is available or can be easily de developed, it will generally be preferable to a simulation model.
● Simulation models are often expensive and time-consuming to develop.
● If a model is not a "valid" representation of a system under study, the simulation results will provide little useful information about the actual system.

PITFALLS TO THE SUCCESSFUL COMPLETION OF A SIMULATION STUDY

● Failure to have a well-defined set of objectives at the beginning of the simulation study
● Inappropriate level of model detail
● Failure to have people with a knowledge of simulation methodology and statistics on the modeling team
● Failure to collect good system data
● Inappropriate simulation software
● Using the wrong performance measures.

<u>Parallel (distributed) simulation</u>

Parallel (distributed) simulation refers to the technology concerned with executing computer simulations over computing systems containing multiple processors.

- ➢ Tightly coupled multiprocessor systems
- ➢ Workstations interconnected via a network (e.g., the Internet)
- ➢ Handheld computers with wireless links
    - Parallel computers (tightly coupled processors)
    - Shared memory multiprocessors – Distributed memory multicomputers
- ➢ Distributed computers (loosely coupled processors)
    - Networked workstations

جدول

	Parallel Computers	Distributed Computers
Physical extent	Machine room	Building, city, global
Processors	Homogeneous	Often heterogeneous
Comm. Network	Custom switch	Commercial LAN / WAN
Comm. Latency (small messages)	A few to tens of microseconds	hundreds of microseconds to seconds

In recent years computer technology has enabled individual computers or processors to be linked together into *parallel* or *distributed* computing environments. For example, several relatively inexpensive minicomputers (or even microcomputers) can be networked together, or a larger computer can house a number of individual processors that can work on their own as well as communicate with each other. In such an environment, it may be possible to "distribute" different parts of a computing task across individual processors operating at the same time, or in "parallel," and thus reduce the overall time to complete the task. The ability to accomplish this naturally depends on the nature of the computing task, as well as on the hardware and software available.

Why Execute Over Multiple CPUs?

• Reduced model execution time.. (Up to N-fold reduction using N CPUs)

• May not have enough memory on a single machine

• Scalable performance

– Maintaining the same execution speed for bigger models/virtual environments by using more CPUs

– Particularly important in virtual environments

• Geographically distributed users and/or resources (e.g., databases, specialized equipment)

– Co-location is expensive! May be impractical

• Integrate simulations running on different platforms (Network rather than port)

• Fault tolerance (Not as easy as it might)

Steps in Simulation Study

readcarfull!!.

1. Formulate problem and plan the study.

Every study must begin with a clear statement of the study'S overall Objectives and specific issues to be addressed; without such a statement there is little hope for. success. The alternative system designs to be studied should be delineated (if possible), and criteria for evaluating the .efficacy of these alternatives should be given. The overall study should be planned in terms of the number of people, the cost, and the time required for each aspect of the study.

- Clearly state the problem.
- How we should approach the problem.

2. Collect data and define a model.

Information and data should be collected on the system of interest (if it exists) and used to specify operating procedures and probability distributions for the random variables used in the model.

- Establish a reasonable model.
- Collect the data necessary to run the simulation (such as arrival rate, arrival process, service discipline, service rate etc.).

3. Valid?

In building the model, it is imperative for the modelers to involve people in the study who are intimately familiar with the operations of the actual system. It is also advisable for the modelers to interact with the decision maker (or the model's intended user) on a regular basis. This will increase the actual validity of the model, and the credibility (or perceived validity) of the model to the decision maker will also be increased.

- involve people familiar with the system
- involve the user
- check adequacy of the probability distributions

4. Construct a computer program and verify.

The simulation modeler must decide whether to program the model in a general-purpose language or in a specially designed simulation language. A general-purpose language will probably already be known and available on the modeler'S computer. It may also lead to shorter execution times. On the other hand, by providing many of the features needed in programming a model, a simulation language may reduce the required programming time significantly.

- general purpose language versus a simulation language
- verify codes

5. Make pilot runs.

Pilot runs of the verified model are made for validation Purposes in step 6. Pilot runs can be used to test the sensitivity of the model's output to small changes in an input parameter.

6. Valid?

Verification is the process of ensuring that the model behaves as intended, usually by debugging or through animation. Verification is necessary but not sufficient for validation, that is a model may be verified but not valid. Validation ensures that no significant difference exists between the model and the real system and that the model reflects reality. Validation can be achieved through statistical analysis. Additionally, face validity may be obtained by having the model reviewed and supported by an expert.

- Test sensitivity of output to changes in input parameters.
- Compare output with a current system.

7. Design experiments.

It must be decided what system designs to simulate if, as is sometimes the case in practice, there~ are more alternatives than one can reasonably simulate.
Often the complete decision cannot be made at this time. Instead, using output data from the production runs (from step 8) of certain selected system designs, the analyst can decide which additional systems to simulate. For each system design to be simulated, decisions have to be made on such issues as initial conditions for the simulation run(s) , the length of the warmup period (if any), the length of the simulation run(s) , and the number of independent simulation runs (replications) to make for each alternative.
When designing and ~ making the production runs, it is sometimes possible to use certain *variance-reduction techniques* to give results with greater statistical precision.

- initial conditions
- warm up periods
- length of run
- Number of replications.

8. Make production runs.

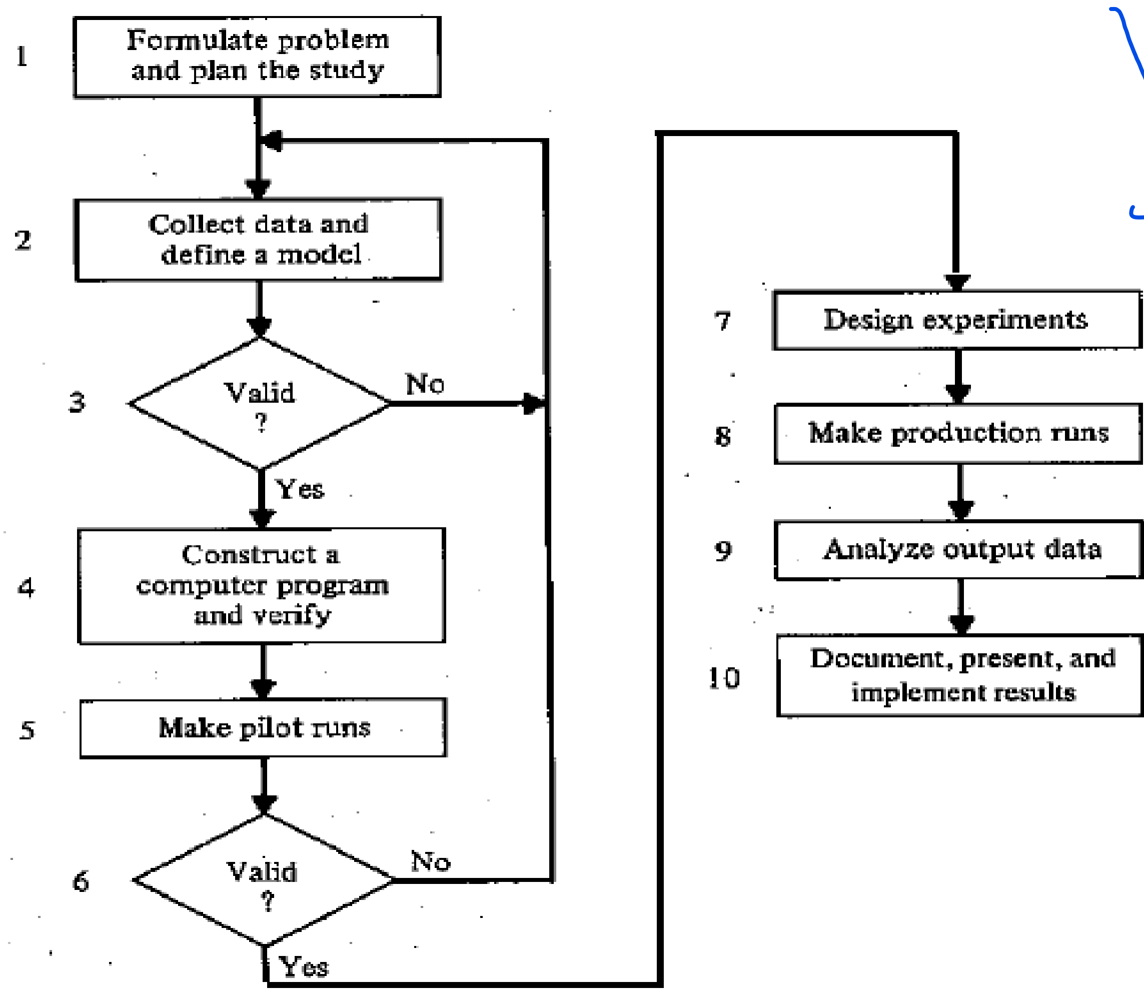
Production runs are made to provide performance data on the system designs of interest. Production runs, and their subsequent analysis, are used to estimate measures of performance for the system designs that are being simulated the analysis of simulation experiments.

9. Analyze output data.

Experimentation involves developing the alternative model(s), executing the simulation runs, and statistically comparing the alternative(s) system performance with that of the real system.

- Confidence intervals
- Compare alternatives

10.Document present, and implement results.



Flowchart of Steps in Simulation Study

Questions

Question 1: Name entities, attributes, activities, events, and state variables for the following systems:

(a) University library
(b) Bank
(c) Call center
(d) Hospital blood bank
(e) Departmental store
(f) Fire service station
(g) Airport
(h) Software organization

Question 2: A simulation is to be conducted of cooking a spaghetti dinner to discover at what time a person should start in order to have the meal on the table by 7:00 P.M. Read a recipe for preparing a spaghetti dinner or ask a friend or relative for the recipe). As best you can, trace what you understand to be needed in the data-collection phase of the simulation process of Figure 1.3, in order to perform a simulation which the model includes each step in the recipe. What are the events, activities, and state variables in this system?

Question 3: List down the events and activities applying for master's program in a university.

Question 4: Search the web for "Applications of discrete simulation" and prepare a report based on the findings.

Question 5: Search the web for "Manufacturing Simulation and prepare a report based on the findings.

Question 6: Search the web for "Call Center Simulation" and prepare a report based on the findings.

Question 7: Describe what you think would be the most effective way to study each of the following systems, in terms of the possibilities in Fig. 1.1, and discuss why:

(a) A small section of an existing factory
(b) An emergency room in an existing hospital
(c) A pizza-delivery operation
(d) The shuttle-bus operation for a rental-car agency at an airport

Question 8: For each of the systems in Prob. 1.1, suppose that it has been decided to make a study via a simulation model. Discuss whether the simulation should be static or dynamic, deterministic or stochastic, and continuous or discrete.

Question 9: Go to the winter simulation conference and get the "Approaches and Benefits for Modeling & Simulation".

Question 10: Go to the winter simulation conference 2016,17, and get the list of tutorials.

Question 11: Go to the winter simulation conference and write a report on "Experiments: Better Data, Not Just Big Data (Tutorial)"