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Module 1

CHAPTER 1 Introduction to Simulation

1.1 Introduction to Simulation

Q.	Define simulation.
Q.	Explain different types of simulation. **MU - Dec. 04, May 07**

- A simulation is the act of imitating (representing) the behaviour of some situation or some real world process or system over period of time.
- Simulation is technique for studying real-world systems by representing their behaviour using a model of the system. Generally model of system is implemented on a computer.
- In simulation we generally generate an artificial history of a system and observe the artificial history to study characteristics/behaviour of the real system.
- A simulation may be performed through solving a set of equations (a mathematical model), constructing a physical model or a computer graphics model (such as an animated flowchart).
- Computer simulation can refer to a computer program that simulates an abstract model so that it can be studied and analyzed. In computer simulation we first design model of actual or theoretical physical system, then execute the designed model on computer to analyze the output.
- Computer simulations are used to study the dynamic behaviour of systems in response to conditions that cannot be easily or safely applied in real life.
- Simulation is used to describe and analyze the behavior of a system. For many real world problems simulation is an almost necessary step in driving their solution.
- Simulation modelling can be used as an analysis tool (modelling existing system) or design tool (modelling new system) i.e. existing system and conceptual system can be modeled with simulation.

- Example : Simulation of Aircraft, Simulation of Inventory System, Simulation of Bank, etc.
- Consider operation of a bank as an example :
  - Counting how many people come to the bank; how many tellers, how long each customer is in service; etc.
  - Establishing a model and its corresponding computer program.
  - Executing the program, varying parameters (number of tellers, service time, arrival intervals) and observing the behavior of the system.
  - Drawing conclusions : increasing number of tellers; reducing service time; changing queuing strategies; etc.
- By developing a simulation model we can study the behavior of a system over time
- A model is a set of entities and the relationship among them.
- For the bank example : entities would include customers, tellers, and queues. Relations would include customers entering a queue; tellers serving the customer; customers leaving the bank.

1.1.1 Types of Simulation

There are two types of simulation :

1. Continuous Simulation
2. Discrete Event Simulation

1.1.1.1 Continuous Simulation

- **Continuous Simulation** refers to a computer model of a physical system that continuously tracks system response over time according to a set of equations typically involving differential equations.
- Continuous simulation is found inside, commercial flight simulators, jet plane auto pilots and advanced engineering design tools.
- A system in which state variable changes continuously is called continuous system. E.g. the amount of water flows over a dam.
- Continuous simulations are based on a set of differential equations. For continuous simulation models, numerical analysis techniques are used to solve differential equations.

1.1.1.2 Discrete Event Simulation

- A discrete system is one in which the state variable(s) change only at a discrete set of points in time. e.g. customers arrive at 3:15, 3:23, 4:01, etc.
- This is useful when our problem is like a queue of events, sorted by the simulation time at which they should occur.
- It means that the system can change only at a countable number of points in time. These points in time are the ones at which an event occurs.
- Event is defined as an instantaneous occurrence that may change the state of the system.
- There is huge amount of data that must be stored and manipulated for most real applications, hence discrete event simulation are done on a digital computer.
- Common applications of DES include stress testing, evaluating potential financial investments, and modeling procedures and processes in various industries, such as manufacturing and healthcare.
- Discrete-event simulations can help determine rules for building and maintaining many different types of systems. They help determine the best way to set up a system, such as the number of people required to adequately staff a tech support center, or the number of incoming lines required, or even the optimal ratio of agents to phone lines.
- Discrete-event simulations can optimize situations such as the following:
- Number of customer service representatives, bank tellers, or store clerks required to provide good service to customers, given a variable rate of arrival and type of service required as well as a certain minimal acceptable level of service
- Number of gates and equipment required at an airport to service a certain number of flights
- Best defense weapons or strategies to use in certain circumstances
- Increased punctual delivery of products
- Economic and financial forecasting
- Reduced operating expenses and equipment requirements
- Table 1.1.1 is a classification of various stochastic processes. The man made systems have mostly discrete state. Monte Carlo simulation deals with discrete time while in discrete even system simulation the time dimension is continuous.

Table 1.1.1 : A classification of stochastic processes

		Change in the States of the System	
		Continuous	Discrete
Time	Continuous	Level of water behind a dam	Number of customers in a bank
	Discrete	Weekdays' range of temperature	Sales at the end of the day

1.1.2 Appropriateness and Inappropriateness of Simulation

Q. When can you simulate? When simulation is not appropriate ? **MU - Dec. 04, May 06, May 08, May 09**

Q. State when simulation is appropriate. **MU - Dec. 10, May 12**

Q. Mention some of the area when simulation can be applied. Also explain when a system cannot be simulated. **MU - May 13**

1.1.2.1 When Simulation is Appropriated Tool

Simulation can be used for the following purpose :

- Simulation enables the study of, and experiment with, the internal interactions of a complex, dynamic system, or a subsystem.

  E.g. when setting up a telephone sales department (such as the 2011 Cricket World Cup), how many operators are enough to handle the calls? Many factors can play a role here: the number of tickets left, estimated number of people who want the ticket, capacity of the phone lines, how long would it take to service one call, etc.

- Informational, organizational, and environmental changes can be simulated and the effect of these alterations on the model's behavior can be observed.

  E.g. to study the behavior of a web server, we can simulate the client traffic and see how it responds.

- The knowledge gained in designing a simulation model may be of great value toward suggesting improvement in the system under the investigation.

  E.g. before actually building a cache system, one can simulation the various configuration of the cache, study its behavior and find out the optimum solution.

- By changing simulation inputs and observing the resulting outputs, valuable insight may be obtained into which variables are most important and how variables interact.

- E.g. in studying the performance of a computer network, a number of parameters affect the outcome, cable length, transmission speed, packet size, arrival rate, number of stations, etc. which one is the most important on the delay? It's the ratio of arrival rate and service rate.
- Simulation can be used as pedagogical device to reinforce analytic solution methodologies.
- Simulating different capabilities for machine can help determine the requirement on it. i.e. simulation can be used to determine capabilities and requirements of the system.
- Simulation can be used to experiment with new designs or policies prior to implementation, so as to prepare for what may happen.
- Simulation can be used to verify analytic solutions.
- Simulation models designed for training make learning possible without the cost and disruption of on job instruction.
- The modern systems (factory, chemical plants etc.) are so complex that its internal interaction can be represented only through simulation.
- With the help of simulation system parameters can be adjusted.
- Simulation can be to provide better understanding of system operation.
- Simulation can be to perform bottleneck analysis.
- Simulation can be to visualize the plan through animation.

1.1.2.2 When Simulation is not Appropriated

Simulation should be avoided under the following circumstances :

- When the problem can be solved by common sense.
- When the problem can be solved analytically.
- If it easier to perform direct experiments.

  Example : A hotel needs to decide whether putting up an order counter or sending the waiters to take up the orders manually will reduce the service time for the customers. This can be solved without actually doing simulation.

- If cost exceeds the savings.

  Example : If the simulation study costs is Rs.15,000 and the savings is Rs.12,000, then simulation is not appropriate.

- If the resources or time are unavailable.

  Example : If decision needs to be taken in a week and simulation will take a month, simulation is not advisable.

- If no data or even estimates of data are available.
- If power of simulation is overestimated.

  Example : In cases where top management put up unrealistic expectations.
- If the system is too complex or cannot be determined.

1.1.3 Advantages

Q. Write a short note on Advantages of Simulation. MU - May 10, May 11

- Explore new design options without disrupting existing systems.
- Test new hardware, transportation systems, etc., without investing resources for their acquisition.
- Time scale can be compressed (for slow moving systems) or expanded (for fast moving systems).
- Internal variables can be made observable.
- Sensitivity and interaction of variables can be studied to understand their impact on the system behaviour.
- Bottleneck analysis can be performed.
- Deployment options can be studied : what-if questions may be answered.

1.1.4 Disadvantages

Q. Write a short note on Disadvantages of Simulation. MU - May 10, May 11

- Building a simulation model is art and it requires special skill/training and experience to build model. If model for same problem is constructed by two different people, they may not be same but they might have similarities.
- Results of simulation are random variables, so even for experts it is difficult to interpret the simulation results.
- Simulation modelling and analysis is time consuming and expensive methodology as compared with other methods
- Sometime when analytical solution is possible then also simulation is used.

1.1.5 Areas of Applications

Q. Give the application of simulation. MU - May 05, Dec. 05, Dec. 06

Simulation is used for modelling of natural systems or human systems, performance optimization, testing, training and education and engineering field.

Some application areas

- Designing and analyzing manufacturing systems.
- Evaluating military weapons systems or their logistics requirements.
- Determining hardware requirements or protocols for communications networks.
- Determining hardware and software requirements for a computer system.
- 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 policies for an inventory system.
- Analyzing financial or economic systems.

I. Manufacturing Applications

- Simulation is used in manufacturing system to enhance performance. Commonly system performance is measured in terms of throughput, peak load, utilization of resource, labor, and machines etc.
- For example in steel manufacture modelling is done for quality and productivity of rods.

II. Military Applications

Military simulations are useful to develop tactical, strategical and doctrinal solution

Simulators are being used to teach :

- Air Force pilots to fly advanced fighters-such as the stealthy F-117.
- Navy submarine officers to navigate in harbors and ship channels.
- Army howitzer crews to execute indirect fire mission operations.
- Marine infantry squads to clear a house during combat condition

III. Logistics, Supply Chain, and Distribution Applications

- Simulation modelling of logistics, supply chain can help you manage complexity, increase profitability, and improve customer service to enhance competitiveness.
- Examples are inventory simulation, supply network simulation, analysis of departure passenger flows in airport.

iv. Transportation Modes and Traffic

- Transportation simulation is simulation of freeway junctions, arterial routes, roundabouts, downtown grid systems, aircraft delay absorption , ship arrivals in ports, ambulance service , traffic performance etc.
- Simulation of transportation systems can produce attractive visual demonstrations of present and future scenarios.
- Ground Transportation/roadway simulation is done to analyze planning, design and operations such as delay, pollution, and congestion.
- Air transportation simulation primarily involves modeling of the airport terminal operations (baggage handling, security checkpoint), and runway operations.

v. Business Process Simulation

- Business process simulation is analysis of business processes. It assess the dynamic behaviour of processes over time.
- It can be used for simulation and optimization of telephone call centre, a telecommunications billing system, segmentation of customer base to get maximum revenue.

vi. Health Care

- Medical simulators are increasingly being developed and deployed to teach therapeutic and diagnostic procedures as well as medical concepts and decision making to personnel in the health professions.
- Simulators have been developed for training procedures ranging from the basics such as blood draw, to laparoscopic surgery and trauma care. They are also important to help on prototyping new devices for biomedical engineering problems. Currently, simulators are applied to research and development of tools for new therapies, treatments and early diagnosis in medicine.
- Simulation can be used for estimating max capacity of emergency department and modelling front office etc.

vii. Simulation in education and in training

- Simulation is often used in the training of civilian and military personnel. This usually occurs when it is prohibitively expensive or simply too dangerous to allow trainees to use the real equipment in the real world. In such situations they will spend time learning valuable lessons in a "safe" virtual environment.

- Often the convenience is to permit mistakes during training for a safety-critical system. For example, in some School teachers practice classroom management and teaching techniques on simulated students, which avoids "learning on the job" that can damage real students. There is a distinction, though, between simulations used for training and Instructional simulation.
- Training simulations typically come as "live" simulation, "virtual" simulation or "constructive" simulation.

viii. Diagnosing process issues

- Simulation approaches are particularly well equipped to help users diagnose issues in complex environments. The Goal (Theory of Constraints) illustrates the importance of understanding bottlenecks in a system.
- Only process 'improvements' at the bottlenecks will actually improve the overall system. In many organizations bottlenecks become hidden by excess inventory, overproduction, variability in processes and variability in routing or sequencing. By accurately documenting the system inside a simulation model it is possible to gain a bird's eye view of the entire system.
- A working model of a system allows management to understand performance drivers. A simulation can be built to include any number of performance KPIs such as : worker utilization, on-time delivery rate, scrap rate, cash cycles, and so on.

ix. Hospital applications

- An operating theatre is generally shared between several surgical disciplines. Through better understanding the nature of these procedures it may be possible to increase the patient throughput.
- **Example :** If a heart surgery takes on average four hours, changing an operating room schedule from eight available hours to nine will not increase patient throughput. On the other hand, if a hernia procedure takes on average twenty minutes providing an extra hour may also not yield any increased throughput if the capacity and average time spent in the recovery room is not considered.

x. Custom order environments

- Many systems show very different characteristics from day to day depending on the order mix. Many small orders may cause bottle-necks due to excess changeovers. Large custom orders may require extra processing at a point where the system has particularly low capacity.

- Simulation modeling allows management to understand what changes 'on average' would have the largest impact and greatest return-on-investment.

xi. Lab test performance improvement ideas

- Many systems improvement ideas are build on sound principles, proven methodologies (Lean, Six Sigma, TQM, etc.) yet fail to improve the overall system.
- A simulation model allows the user to understand and test a performance improvement idea in the context of the overall system.

xii. Evaluating capital investment decisions

- Simulation modeling is commonly used to model potential investments. Through modeling investments decision-makers can make informed decisions and evaluate potential alternatives.
- Often these decisions look at altering existing operations. Typically, a model of the current state is constructed. This 'current state' model is tested and validated against historical data. Once the model is operating correctly, the simulation is altered to reflect the proposed capital investments. This 'future state' model is then stress-tested to ensure the alterations perform as desired.
- Occasionally, organizations take on entirely new operations processes. These could be new Lean facilities, designed around new products or using new technology. In these cases only a 'future state' model is constructed. The testing and validation may require more analysis. There are companies and experts that specialize in simulation building who may be brought in to help.

xiii. Stress test a system :

- Models can be used to understand how a system will be able to weather extraordinary conditions.
- A simulation can help management understand: large increases in orders, significant swings in product mix, new client delivery demands (i.e. 1 week lead times), and economic events (i.e. a multinational with operations in South America and Asia sees significant swings in currencies).

1.2 System and System Environment

- System is defined as an aggregation of objects that are joined together in some regular fashion for the accomplishment of some purpose.

- *According to* Taylor *System* is a collection of entities (people, parts, messages, machines, servers,) that act and interact together toward some end.
- In practice, system depends on objectives of study.
- **Example :** Production system manufacturing computers. An example is a production system manufacturing automobiles. The machines, component parts, and workers operate jointly along an assembly line to produce a high-quality vehicle.
- ***State* of a system :** Collection of variables and their values necessary to describe the system at that time.
- State of system depend on desired objectives, output performance measures.
- **Example**: In Bank number of busy tellers, time of arrival of each customer, represent state of system etc.
- **System environment** is a region which is outside to the system but still affect the behavior of the system. Changes occurred outside the system may affects the system, such changes are said to occur in the *system environment*. When modeling a system, we generally decides boundary between the system and its environment.
- E.g. When studying cache memory using simulation, one has to decide where is the boundary of the system. It can be simply the CPU and cache, or it can include main memory, disk, O.S., compiler, or even user programs.
- Another Example : Production system manufacturing computers. The factors controlling the demand can be considered to be outside the control of the company but still affect the company and hence are part of the system environment.
- Fig. 1.2.1 shows system and its environment :

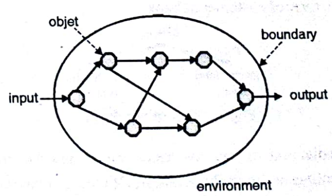

Fig. 1.2.1 : System and its environment

1.2.1 Components of a System

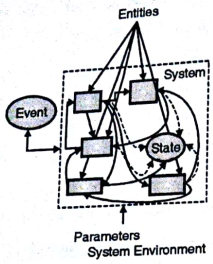

Fig. 1.2.2

- **Entity :** An object of an interest in a system is called an entity.

  Example : Customer, Student, etc.
- **Attribute :** An attribute is a property that describes an entity.

  Example : Customer name, Student roll number, etc.
- **Activity :** It is a process that causes changes in the system. It represents a time period of specific length. Example: Debit and Credit, Issue and Return, etc.
- Activities are of two types :
  - **Deterministic :** Here for fix number of input will get fix output.

    Example : Arrival of patient at dentist clinic depending upon appointment.
  - **Stochastic :** Here for fix number of input, output will vary.

    Example : Arrival of customer at bank.

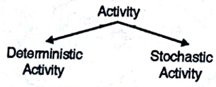

Fig. 1.2.3 : Activity types

- **State :** It is the collection of variable necessary to describe the system at any time, relative to the objectives of the study. Example: Running state of process P1.
- **Delay :** a delay is an indefinite duration that is caused by some combination of system conditions.

- **Resources :** a resource is an entity that provides services to dynamics entities. A resource can serve one or more than one dynamic entity at the same time thus operating as parallel server.
- **Event :** Instantaneous occurrence that may change the state of the system. Example: Click event on keyboard.
- Events are of two types :
  - **Endogenous :** Event occurring inside to the system.

    Example : Completion of service of worker in company.
  - **Exogenous :** Event occurring outside to the system.

    Example : Arrival of customer.

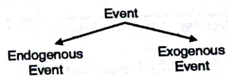

Fig. 1.2.4 : Event types

1.2.2 Types of System

A. Open System

The system which have exogenous event is called as open system.

Input is external and independent → *open*

Example : Arrival of customer.

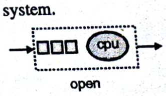

Fig. 1.2.5 : Open system

B. Closed System

The system which have endogenous event is called as closed system.

Example : Completion of service of worker in company.

Closed model has no external input.

Ex. : If same jobs leave and re-enter queue then closed system.

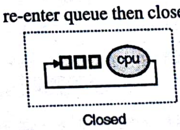

Fig. 1.2.6 : Closed system

C. Continuous System

In this type of system, the state variable changes continuously over time.

Example : Temperature of the day.

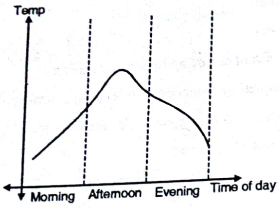

Fig. 1.2.7 : Temperature of day

D. Discrete System

In this type of system, the state variable changes only at discrete set of point in a time.

Example : Student in library.

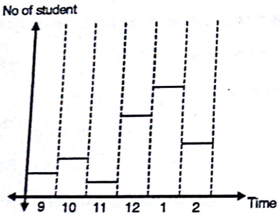

Fig. 1.2.8 : Students in library

1.3 Model of a System

> **Q.** Define model. What are the different types of models ? Give example of each.
> MU - Dec. 04, May 05, Dec. 05, Dec. 06, May 07
>
> **Q.** Give an example for each type of model and state the one that leads to simulation.
> MU - Dec. 12

- The behaviour of a system as it evolves over time is studied by developing a simulation model.
- A model is a representation of a real system. It is used to gain an understanding of how the system behaves.
- A model contains only those components that are relevant to the study of the system.
- The model of a system should be complex enough to answer the questions raised, but not too complex as to make understanding difficult.
- Care as to be taken about the limits or boundaries of the model that represents the system.
- A simulation model will consider a system model and an environment model instead of the actual physical system
- The purpose of any model is to enable us to draw conclusions about the real system by studying and analyzing the model.
- The major reasons for developing a model are : economics, unavailability of "real" system, deeper understanding
- Model should only include relevant features (variables) of the systems under study.

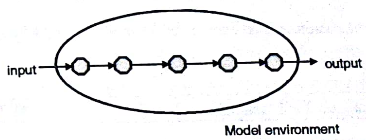

Fig. 1.3.1 : Model and its environment

System Modeling

- A model is defined as the body of information about a system gathered for the purpose of studying the system.
- The purpose of studying will determine the nature of the information that is gathered, there is no unique model of the system.
- Different analysts, who are interested in different aspects of the system, will produce different model of the same system.
- The task of deriving a model of a system can be divided as :
  a. Establishing model structure and supplying the data.

b. Establishing the structure determines the system boundary and identifies entities, attributes, and activities of the system.

- The data provides the value of the attributes and define the relationship between various activities.
- Assumptions about the system direct the gathering of data, and analysis of the data confirms or refutes the assumption.
- Often, the data collected will disclose an unsuspected relationship that changes the model structure.
- Example : Elements of a supermarket model.

Entity	Attribute	Activity
Shopper	Number of items	Arrive, Get
Basket	Availability	Shop, Queue, Check-out
Counter	Number, Occupancy	Return, Leave

- In the example of supermarket, the concept of supermarket does not appear as a whole. It defines the system boundary and hence distinguishes between the system and its boundary.
- The arrival of the customer is an exogenous event affecting the system.

1.3.1 Types of Models

Q. Explain types of model with examples. **MU - May 13, Dec. 13**

1. **Mathematical model**
   - A model that uses symbolic notations and mathematical equations to represent a system.
   - It represents system in terms of logical and quantitative relationships.
   - System attributes are represented by variables and activities are represented by mathematical functions.
   - It is used to solve mathematical formula and prove mathematical theorem.
   - Example : Volume of a sphere = $(4/3)\pi r^3$
2. **Physical model**
   - This model is based on some analogy between systems such as mechanical and electrical, electrical and hydraulic.

- System attributes are represented by measurements such as voltage or position of shaft.
- It is also called look a like model.

  Example : Scale model, prototype plant.

3. **Static model**
   - It is also called as *Monte Carlo* simulation model.
   - This model represents a system at a particular point of time. i.e. Snapshot of system at a single point in time.

     Example : Model of the building.
4. **Dynamic model**
   - A model that represents a given system as it changes over time.

     Example : Simulation of a restaurant from 8 A.M to 9 P.M.
5. **Deterministic model**
   - Deterministic model is one whose behavior is entire predictable. The system is perfectly understood, then it is possible to predict precisely what will happen.
   - This model does not contain random variables.
   - It has known set of inputs that produce a unique set of outputs.

     Example : Arrival of patient at doctor's clinic as per their appointment.
6. **Stochastic model**
   - Behaviour of Stochastic model can't be entirely predicted. This model has random inputs, so it produces random output.
   - Due to random output produced by stochastic model, it is used only for estimating true characteristics of the system.

     Example : Simulation of Library, Cafeteria, etc.
   - The simulation of a library would usually involve random interarrival times and random service times.
7. **Discrete model**
   - In this model, the state variables change only at a discrete set of points in time.
   - These points in time are the ones at which the event occurs/change in state.

     Example : Arrival of customer in bank.

8. Continuous model

- A model in which state variable changes continuously over time is called continuous model.
- Here variables change in a continuous way, and not abruptly from one state to another (there are infinite number of states).

  Example : Level of water in dam.
- Airplane flight : State variables like position, velocity change continuously.

Some examples

- Banking system : waiting time performance for customers.

  State variables : number of busy tellers, number of waiting customers (in the line).

  Model is discrete, stochastic and dynamic.
- Production : factory performance.

  State variables : status of machines : busy, idle, down.

  Model is discrete, stochastic and dynamic.
- Memory-less coin flipping experiment.

  State variable : head or tail.

  Model is discrete, stochastic and static.
- Noise in an electronic circuit.

  State variable : current noise level.

  Model is continuous, stochastic and static.
- Steam engine simulation :

  State variable : pressure

  Model is continuous, deterministic and dynamic.

1.4 Steps in Simulation Study

MU - May 16

Q. Explain the steps involved in simulation study. Why is it necessary to have program and process documentation?

MU - May 05, May 06, Dec. 06, Dec. 07, Dec. 08, Dec. 09

Q. Explain steps in simulation study along with the flow chart.

MU - Dec. 11, May 12, Dec. 12, May 13, Dec. 13, May 14, Dec. 14, May 15

In simulation of any system various steps have to be followed. They are explained with help of flowchart as shown in Fig. 1.4.1.

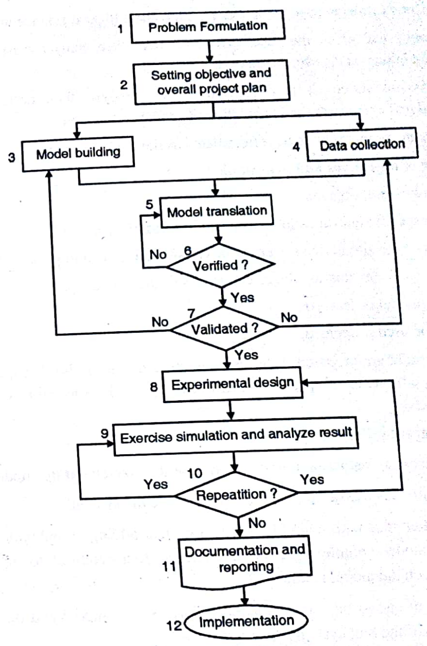

Fig. 1.4.1 : Steps in Simulation Study

Step 1: Problem formulation

- In this step, problem statement of simulation model is prepared.
- Define clear problem statements, scopes.
- Here are some examples of good and bad problem statement.

- o **Bad :** To study the performance of system X.
- o **Better :** To study the performance metric M of system X under factors A, B, C, D.
- o **Bad :** To study if systems X is better than system Y.
- o **Better :** Compare systems X and Y with respect to performance metric M1, M2.

- When policy had given the statement of problem then analyst must ensure that the described problem is clearly understood.
- When problem statement is developed by the analyst, then policy makers must understand and agree with the formulation of problem statement.
- Sometimes the problem must be reformulated as the study progress.

Step 2: Setting of objectives and overall plan

- The study of overall objectives.
- List out the specific questions to be answered by simulation.
- A statement of the alternative system to be considered in overall project plan.
- A method is set for evaluating the effectiveness of these systems.
- Scope of the model is decided.
- Software to be used is decided.
- Plan for the study are prepared in terms of number of people involved, the cost of the study, and time frame to complete work of each stage with expected result at the end of each stage.

Step 3: Model conceptualization

- Abstract the essential feature of a problem and use it to sketch out the model.
- Select and modify basic assumptions that characterize the system.
- It is always better start with a simple model and then adding complexity step by step. However, the model complexity need not exceed that required to accomplish the purposes for which the model is intended.
- It does not require one to one correspondence between the model and the real system. Only the essence of the real system is needed.
- Always involve the model user in model conceptualization phase to raise the quality of resulting system.

Step 4: Data collection

- Data requirement changes as the complexity of the model changes.
- There is a constant interplay between the construction of the model and the collection of the needed input data.

- Data collection always takes large amount of time of the simulation process hence it is necessary to begin it as early as possible, usually together with early stages of the model building. The objective of the study indicates the kind of data to be collected.
- Collect data on the system layout and operating procedure.
- Specify level of details :
  - o Too much detail more development time, more bugs, more execution time.
  - o Too simplified less accurate.

  Hence you must capture only essential features.

Step 5 : Model translation

- Program the model constructed in model conceptualization phase using programming language like C or GPSS.
- Model can also be used to create simulation using simulation software like Arena, Extend, etc.
- The modeller must decide whether to program the model in a simulation language such as Arena, GPSS/H, SUMUL8, ProModel, AutoModel, CISM, and etc, or to use special-purpose simulation software.

Step 6 : Verification

- Verification is refers to the process of ensuring that the model is free from logical errors; that it does what it is intended to do.
- Verification concerns with determining whether the conceptual simulation model has been translated into computer program or not.
- It is highly advisable that verification takes place as a continuous process.
- Also, use of an interactive run controller, or debugger, is highly encouraged as an aid to the verification process.
- Besides this, General techniques for simulation verification are used.

1.4.1 General Techniques for Simulation Verification are used

- Use of software engineering principles :
  - o Structured programming in modules.
  - o Independent testing of modules.
  - o Testing interface between modules.
  - o Structured code walks through.

- Examine a trace listing :
  - o To examine variable values and the event list at various points in the program. (simulation languages support this)
- Use animation to debug :
  - o Visualization of simulation model behavior and apply knowledge/intuition of how system should work.(many simulation languages support this)
- Testing logic :
  - o Run special cases that can be checked by hand.
  - o Run extreme or boundary cases.
- Use a simulation language or a simulator instead of a general purpose language.
  - o Greatly reduces lines of code in program and possibility of error.

Step 7 : Validation

- Validation is the process of determining whether the simulation model is a meaningful and accurate representation of the real system under study.
- Validation is basically defined as the comparing model and its behavior with real system.
- Validation is usually achieved through the calibration of the model, an iterative process of comparing the model to actual system behaviour are using the discrepancies between the two, and the insights gained, to improve the model. This process is repeated until model accuracy is jugged acceptable.

1.4.2 General Techniques for Simulation Validation

- Run a special case of the simulation for which known results exists.
  - o Compared either with analytical or measurement results.
  - o This usually involves simplifying assumptions in the simulation model.
  - o If simulation is compared with analytical model, the confidence intervals obtained from simulation results should contain the analytical results.
  - o If simulation is compared with measurement, the confidence intervals of results from both should overlap.
  - o If simulation model is not valid, model refinement may be needed (adding more detail to the model).

- Run a trace driven simulation :
  - o Use the actual captured input data from a real system and compared with the corresponding output from the real system.
  - o This approach is very popular in industry and is often called ***"calibration"*** of simulation model.
  - o Iterative process must be done to improve a simulation model until its output data closely match a corresponding set of system output data.
- Introduce special case or study trends :
  - o Boundary conditions (i.e. errors) – look for surprises in the output data.
  - o Extreme behavior conditions.
  - o Use system domain knowledge for trend behavior (e.g., increase load – delay increases).
- Delphi method :
  - o Ask other researchers their subjective opinion.
  - o Refer to other models.

Step 8 : Experimental design :

- The alternative designs that are to be simulated must be determined in this step.
- The decision about which alternatives to simulates may be a function of runs that have been completed and analyzed.
- Also, decision need to be made about the length of the initialization period, the length of simulation runs, and the number of replication are required for each run.

Step 9 : Exercise simulation and analyze result :

- Production runs and analysis of output data are used to estimate measures of performance for the system design that are being simulated and comparing alternative system configuration.

Step 10 : Repeation ?

- On the basis of runs completed in previous step, the analyst determines if additional runs are required (or not) and what design those additional experiments should follow.

Step 11: Documentation and reporting :

- Two types of documentation are prepared : program and progress.
- Program documentation is necessary :
  i. To understand how program operate.

ii. The program modification is much easier.

iii. Model user can change parameter if required to determine the relationship between input parameter and output measures of performance.

- Sequential order in which work done and decision made are documented in progress document.(written history of project)
- In reports, all the final analysis and results are given in clear and concise manner. This enables the client to review the final formulation, the alternatives system design that were discussed, result of experiment and final recommended solution to problem.

Step 12: Implementation :

- Implementation of project/ simulation project is depend on how well above 1-11 steps are performed and how the analyst involved in entire simulation model building process.
- If model user is involved in model building process and model user understand the model and its output , then model implementation will succeed. Implementation of model will be attracted, if the model and its underlying assumptions have not been properly communicated.

Review Questions

Q. 1 Define simulation Or what is meant by simulation ?

Q. 2 Explain different types of simulation.

Q. 3 When is simulation appropriate and when it is not ?

Q. 4 When can you simulate ? When simulation is not appropriate?

Q. 5 Mention some of the areas where simulation can be applied.

Q. 6 Give the application of simulation.

Q. 7 What is system modeling ? Give example and explain different types of model.

Q. 8 Define model. What are the different types of models ? Give example of each.

Q. 9 What are the various steps in simulation study ?

Q. 10 Explain the steps involved in simulation study ? Why is it necessary to have program and process documentation ?

Q. 11 Elaborate the steps in simulation study. Why is it necessary to have program and process documentation ?

1.5 University Questions and Answers

May 2010

Q. 1 Write a short note on Advantages and Disadvantages of Simulation. **(Sections 1.1.3 and 1.1.4)** **(10 Marks)**

Dec. 2010

Q. 2 State when simulation is appropriate. **(Section 1.1.2)** **(5 Marks)**

May 2011

Q. 3 Explain steps in simulation study along with the flowchart. **(Section 1.4)** **(10 Marks)**

Q. 4 Write a short note on Advantages and Disadvantages of Simulation. **(Sections 1.1.3 and 1.1.4)** **(10 Marks)**

May 2012

Q. 5 State when simulation is appropriate. **(Section 1.1.2)** **(5 Marks)**

Q. 6 Explain steps in simulation study along with the flow chart. **(Section 1.4)** **(10 Marks)**

Dec. 2012

Q. 7 Briefly explain the steps in simulation study. **(Section 1.4)** **(10 Marks)**

Q. 8 Give an example for each type of model and state the one that leads to simulation.**(Section 1.3)** **(10 Marks)**

May 2013

Q. 9 Explain steps involved in simulation study. **(Section 1.4)** **(10 Marks)**

Q. 10 Explain types of model with examples. **(Section 1.3.1)** **(10 Marks)**

Q. 11 Mention some of the area when simulation can be applied. Also explain when a system cannot be simulated. **(Section 1.1.2)** **(10 Marks)**

Dec. 2013

Q. 12 Discuss types of simulation models. **(Section 1.3)** **(5 Marks)**

Q. 13 Explain the steps in simulation study in detail. **(Section 1.4)** **(10 Marks)**

May 2014

Q. 14 Explain the steps in simulation study. **(Section 1.4)** **(10 Marks)**