Introduction to Simulation

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What is Simulation?

- A Simulation is the imitation of the operation of a real-world process or system over time.
- It can be done by hand or on a computer.
- The behaviour of a system as it evolves over time is studied by developing a simulation model.
- This model takes the form of a set of assumptions concerning the operation of the system.

The assumptions are expressed in

1. Mathematical relationships
2. Logical relationships
3. Symbolic relationships between the entities of the system.

Why Simulation?

- Accurate Depiction of Reality
- Insightful system evaluations

When Simulation is the Appropriate Tool

- Study of and experimentation with the internal interactions of a complex system, or of a subsystem within a complex system.
- Informational, organizational and environmental changes can be simulated and the model's behaviour can be observer.
- The knowledge gained in designing a simulation model can be of great value toward suggesting improvement in the system under investigation.
- By changing simulation inputs and observing the resulting outputs, valuable insight may be obtained into which variables are most important and how variables interact.
- Simulation can be used as a pedagogical (teaching) device to reinforce analytic solution methodologies.
- Can be used to experiment with new designs or policies prior to implementation, so as to prepare for what may happen.

- Can be used to verify analytic solutions.
- By simulating different capabilities for a machine, requirements can be determined. 10. Simulation models designed for training, allow learning without the cost and disruption of on-the-job instructions.
- Animation shows a system in simulated operation so that the plan can be visualized.
- The modern system (factory, water fabrication plant, service organization, etc) is so complex that the interactions can be treated only through simulation

When Simulation is Not Appropriate

1. Simulation should not be used when the problem can be solved using common sense.
2. Not, if the problem can be solved analytically.
3. Not, if it is easier to perform direct experiments.
4. Not, if the costs exceeds savings.
5. Not, if the resources or time are not available.
6. No data is available, not even estimate simulation is not advised.
7. If there is not enough time or the people are not available, simulation is not appropriate.
8. If managers have unreasonable expectation say, too much soon – or the power of simulation is over estimated, simulation may not be appropriate.
9. If system behaviour is too complex or cannot be defined, simulation is not appropriate

Advantages of Simulation

1. New policies, operating procedures, decision rules, information flow, etc can be explored without disrupting the ongoing operations of the real system.

2. New hardware designs, physical layouts, transportation systems can be tested without committing resources for their acquisition.

3. Hypotheses about how or why certain phenomena occur can be tested for feasibility

4. Time can be compressed or expanded allowing for a speedup or slowdown of the phenomena under investigation.

5. Insight can be obtained about the interaction of variables.

6. Insight can be obtained about the importance of variables to the performance of the system.

7. Bottleneck analysis can be performed indication where work-in process, information materials and so on are being excessively delayed.

8. A simulation study can help in understanding how the system operates rather than how individuals think the system operates.

9. “what-if” questions can be answered. Useful in the design of new systems

Disadvantages of simulation

1. Model building requires special training. It is an art that is learned over time and through experience.

2. If two models are constructed by two competent individuals, they may have similarities, but it is highly unlikely that they will be the same.

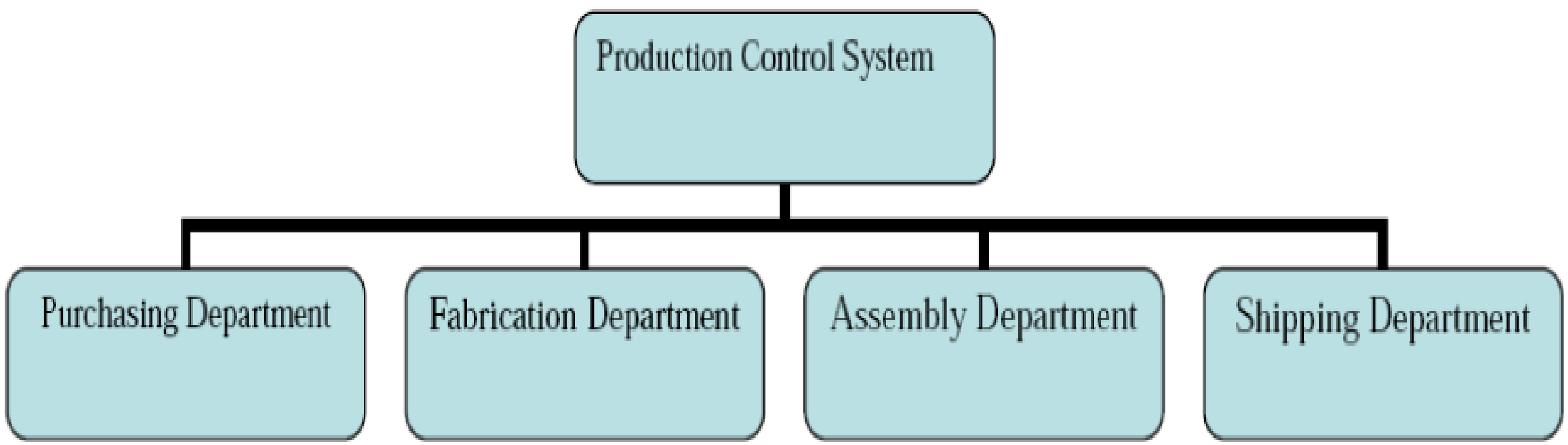
3. Simulation results may be difficult to interpret. Since most simulation outputs are essentially random variables (they are usually based on random inputs), it may be hard to determine whether an observation is a result of system interrelationships or randomness.

4. Simulation modelling and analysis can be time consuming and expensive. Skimping on resources for modelling and analysis may result in a simulation model or analysis that is not sufficient for the task.

5. Simulation is used in some cases when an analytical solution is possible, or even preferable. This might be particularly true in the simulation of some waiting lines where closed-form queueing models are available.

Systems

- A system is defined as an aggregation or assemblage of objects joined in some regular interaction or interdependence toward the accomplishment of some purpose.
- Example: Production System OR A system is assemblage of objects joined in regular fashion to accomplish a task.



System Environment

The external components which interact with the system and produce necessary changes are said to constitute the system environment.

Ex: In a factory system, the factors controlling arrival of orders may be considered to be outside the factory but yet a part of the system environment. When, we consider the demand and supply of goods, there is certainly a relationship between the factory output and arrival of orders.

Endogenous System: The term endogenous is used to describe activities and events occurring within a system.

Ex: Drawing cash in a bank.

- Exogenous The term exogenous is used to describe activities and events in the environment that affect the system.
- Ex: Arrival of customers.
- Closed System: A system for which there is no exogenous activity and event is said to be a closed.
- Ex: Water in an insulated flask.
- Open system: A system for which there is exogenous activity and event is said to be an open.
- Ex: Bank

Components of a System

1) Entity: An entity is an object of interest in a system. Ex: In the factory system, departments, orders, parts and products are the entities.

2) Attribute: An attribute denotes the property of an entity. Ex: Quantities for each order, type of part, or number of machines in a department are attributes of factory system.

3) Activity: Any process causing changes in a system is called as an activity. Ex: Manufacturing process of the department.

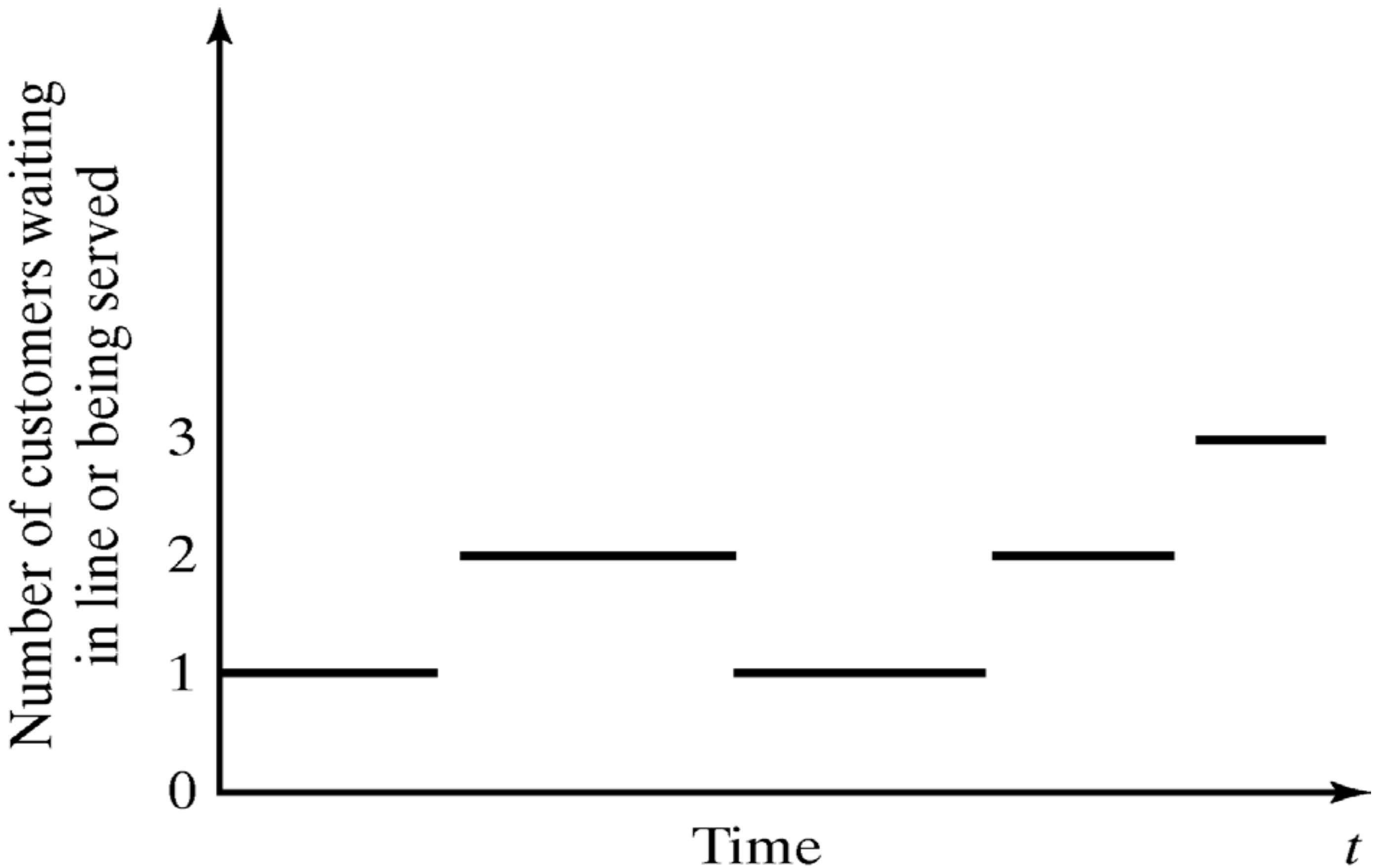
4) State of the System: The state of a system is defined as the collection of variables necessary to describe a system at any time, relative to the objective of study.

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

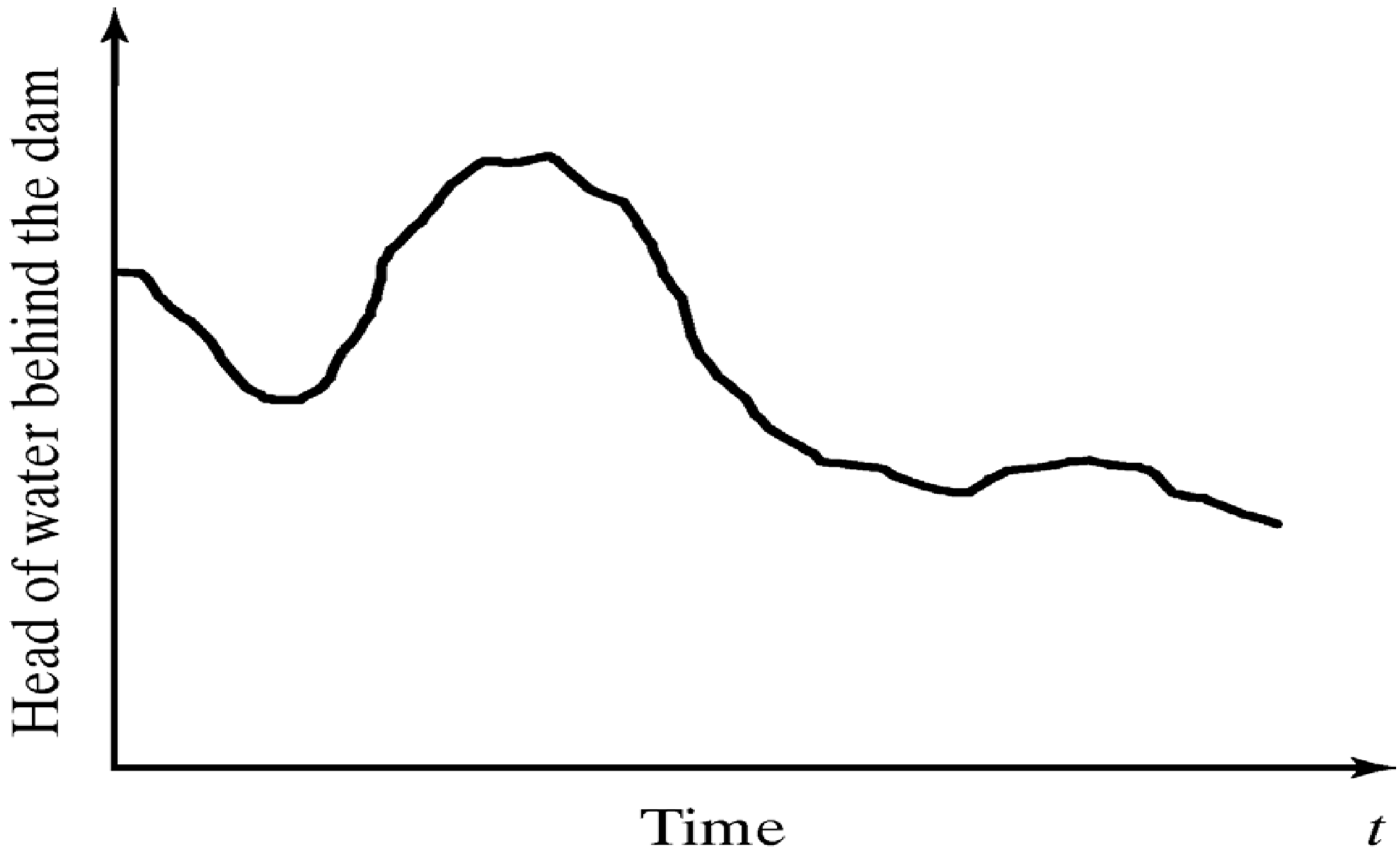
System	Entities	Attributes	Activities	Events	State variables
Banking	Customers	Checking-account balance	Making deposits	Arrival; departure	No. of busy tellers; no. of customers waiting.
Rapid rail	Riders	Origination; destination	Traveling	Arrival at station; arrival at destination	No. of riders waiting at each station; No. of riders in transit
Production	Machines	Speed; capacity; breakdown rate length	Welding; stamping	Breakdown	Status of machines (busy, idle or down)
Inventory	Warehouse	Capacity	Withdrawing	Demand	Levels of inventory; backlogged demands

Discrete and Continuous Systems

- A discrete system is one in which the state variables change only at a discrete set of points in time : Bank example



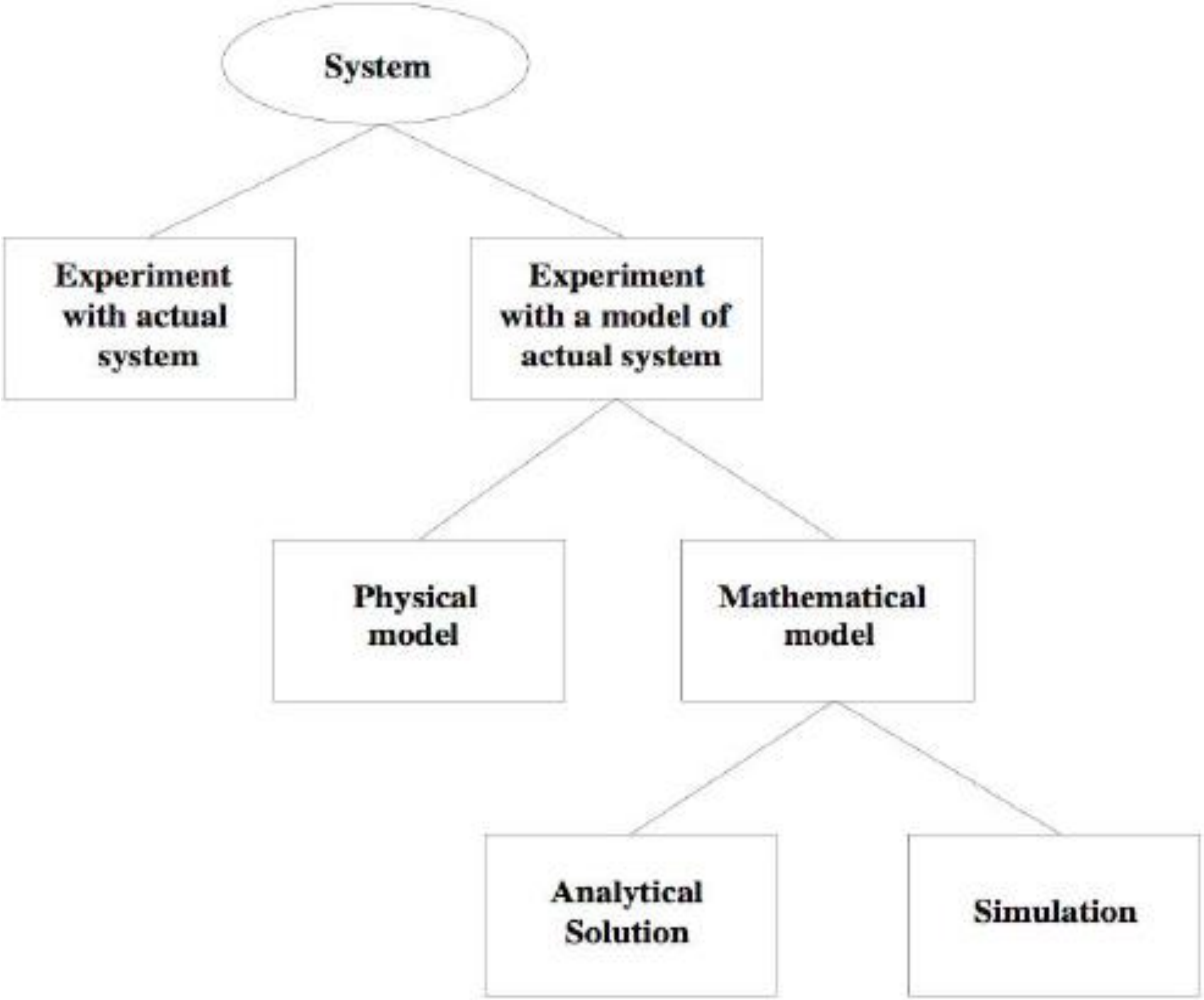
- A continues system is one in which the state variables change continuously over time: Head of water behind the dam.



Model of a system

- A **model** is defined as a representation of a system for the purpose of studying the system.
- It is necessary to consider only those aspects of the system that affect the problem under investigation.
- These aspects are represented in a model, and by definition it is a simplification of the system.

Types of Models



Types of Models

Sl. No	Model	Description
1	**Mathematical Model**	Uses symbolic notation and the mathematical equations to represent a system.
2	**Static Model**	Represents a system at a particular point of time and also known as Monte-Carlo simulation.
3	**Dynamic Model**	Represents systems as they change over time. Ex: Simulation of a bank
4	**Deterministic Model**	Contains no random variables. They have a known set of inputs which will result in a unique set of outputs. Ex: Arrival of patients to the Dentist at the scheduled appointment time.
5	**Stochastic Model**	Has one or more random variable as inputs. Random inputs leads to random outputs. Ex: Simulation of a bank involves random inter arrival and service times.
6	**Discrete and Continuous Model**	Used in an analogous manner. Simulation models may be mixed both with discrete and continuous. The choice is based on the characteristics of the system and the objective of the study.

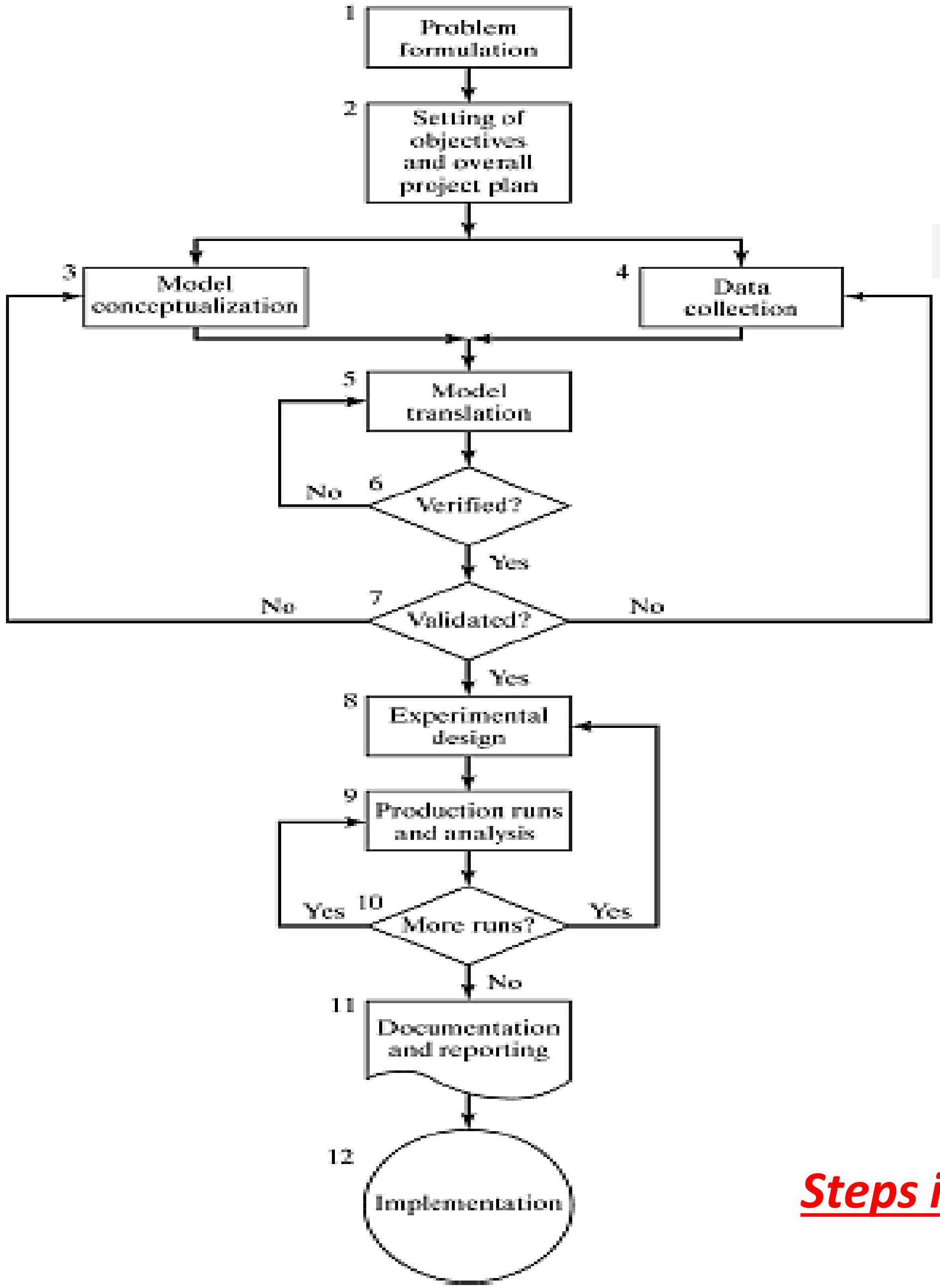
Discrete-Event System Simulation

- Modeling of systems in which the state variable changes only at a discrete set of points in time. **The simulation models are analyzed by numerical rather than by analytical methods.**

- **Analytical methods** employ the deductive reasoning of mathematics to solve the model. E.g.: Differential calculus can be used to determine the minimum cost policy for some inventory models.

- **Numerical methods** use computational procedures and are ‘runs’, which is generated based on the model assumptions and observations are collected to be analyzed and to estimate the true system performance measures.

- Real-world simulation is so vast, whose runs are conducted with the help of computer. Much insight can be obtained by simulation manually which is applicable for small systems.



Steps in Simulation study

1. **Problem formulation** Every study begins with a statement of the problem, provided by policy makers. Analyst ensures its clearly understood. If it is developed by analyst policy makers should understand and agree with it.

2. **Setting of objectives and overall project plan:** The objectives indicate the questions to be answered by simulation. At this point a determination should be made concerning whether simulation is the appropriate methodology. Assuming it is appropriate, the overall project plan should include

- A statement of the alternative systems
- A method for evaluating the effectiveness of these alternatives
- Plans for the study in terms of the number of people involved
- Cost of the study
- The number of days required to accomplish each phase of the work with the anticipated results.

3. Model conceptualization The construction of a model of a system is probably as much art as science. The art of modeling is enhanced by an ability

- To abstract the essential features of a problem
- To select and modify basic assumptions that characterize the system
- To enrich and elaborate the model until a useful approximation results

Thus, it is best to start with a simple model and build toward greater complexity. Model conceptualization enhance the quality of the resulting model and increase the confidence of the model user in the application of the model.

4. Data collection There is a constant interplay between the construction of model and the collection of needed input data. Done in the early stages. Objective kind of data are to be collected.

5. Model translation Real-world systems result in models that require a great deal of information storage and computation. It can be programmed by using simulation languages or special purpose simulation software.

Simulation languages are powerful and flexible. Simulation software models development time can be reduced.

6. Verified It pertains to he computer program and checking the performance. If the input parameters and logical structure and correctly represented, verification is completed.

7. Validated It is the determination that a model is an accurate representation of the real system. Achieved through calibration of the model, an iterative process of comparing the model to actual system behaviour and the discrepancies between the two.

8. Experimental Design The alternatives that are to be simulated must be determined. Which alternatives to simulate may be a function of runs. For each system design, decisions need to be made concerning

- Length of the initialization period
- Length of simulation runs
- Number of replication to be made of each run

9. Production runs and analysis They are used to estimate measures of performance for the system designs that are being simulated.

10. More runs Based on the analysis of runs that have been completed. The analyst determines if additional runs are needed and what design those additional experiments should follow.

11. Documentation and reporting Two types of documentation.

- Program documentation
- Process documentation

Program documentation Can be used again by the same or different analysts to understand how the program operates. Further modification will be easier. Model users can change the input parameters for better performance.

- **Process documentation** Gives the history of a simulation project. The result of all analysis should be reported clearly and concisely in a final report. This enables to review the final formulation and alternatives, results of the experiments and the recommended solution to the problem. The final report provides a vehicle of certification.

12. Implementation Success depends on the previous steps. If the model user has been thoroughly involved and understands the nature of the model and its outputs, likelihood of a vigorous implementation is enhanced.

The simulation model building can be broken into 4 phases.

I Phase

- Consists of steps 1 and 2
- It is period of discovery/orientation
- The analyst may have to restart the process if it is not fine-tuned
- Recalibrations and clarifications may occur in this phase or another phase.

II Phase

- Consists of steps 3,4,5,6 and 7
- A continuing interplay is required among the steps
- Exclusion of model user results in implications during implementation

III Phase

- Consists of steps 8,9 and 10
- Conceives a thorough plan for experimenting
- Discrete-event stochastic is a statistical experiment
- The output variables are estimates that contain random error and therefore proper statistical analysis is required.

IV Phase

- Consists of steps 11 and 12
- Successful implementation depends on the involvement of user and every steps successful completion.

Applications of Simulation

Manufacturing Applications

1. Analysis of electronics assembly operations
2. Design and evaluation of a selective assembly station for high precision scroll compressor shells.
3. Comparison of dispatching rules for semiconductor manufacturing using large facility models.
4. Evaluation of cluster tool throughput for thin-film head production.
5. Determining optimal lot size for a semiconductor backend factory.
6. Optimization of cycle time and utilization in semiconductor test manufacturing.
7. Analysis of storage and retrieval strategies in a warehouse.
8. Investigation of dynamics in a service oriented supply chain.
9. Model for an Army chemical munitions disposal facility.

Semiconductor Manufacturing

1. Comparison of dispatching rules using large-facility models.
2. The corrupting influence of variability.
3. A new lot-release rule for wafer fabs.
4. Assessment of potential gains in productivity due to proactive retied management.
5. Comparison of a 200 mm and 300 mm X-ray lithography cell.
6. Capacity planning with time constraints between operations.
7. 300 mm logistic system risk reduction.

<u>Construction Engineering</u>

1. Construction of a dam embankment.
2. Trench less renewal of underground urban infrastructures.
3. Activity scheduling in a dynamic, multi project setting.
4. Investigation of the structural steel erection process.
5. Special purpose template for utility tunnel construction.

<u>Military Applications</u>

1. Modeling leadership effects and recruit type in a Army recruiting station.
2. Design and test of an intelligent controller for autonomous underwater vehicles.
3. Modeling military requirements for non warfighting operations.
4. Multi trajectory performance for varying scenario sizes.
5. Using adaptive agents in U.S. Air Force retention.

Logistics, Transportation and Distribution Applications

1. Evaluating the potential benefits of a rail-traffic planning algorithm.
2. Evaluating strategies to improve railroad performance.
3. Parametric Modeling in rail-capacity planning.
4. Analysis of passenger flows in an airport terminal.
5. Proactive flight-schedule evaluation.
6. Logistic issues in autonomous food production systems for extended duration space exploration.
7. Sizing industrial rail-car fleets.
8. Production distribution in newspaper industry.
9. Design of a toll plaza
10. Choosing between rental-car locations.
11. Quick response replenishment.

Business Process Simulation

1. Impact of connection bank redesign on airport gate assignment.
2. Product development program planning.
3. Reconciliation of business and system modeling.
4. Personal forecasting and strategic workforce planning.

Human Systems

1. Modeling human performance in complex systems.
2. Studying the human element in out traffic control.