**Modeling and Simulation**

**System**

 The term system is derived from the Greek word systema, which means an organized relationship among functioning units or components.

 The system exists because it is designed to achieve one or more objectives.

* A system is an orderly grouping of interdependent components linked together according to a plan to achieve a specific objective.

The study of the systems concepts, then, has three basic implications:

1. A system must be designed to achieve a predetermined objective

2. Interrelationships and interdependence must exist among the components

3. The objectives of the organization as a whole have a higher priority than the objectives of its subsystems.

**System**

A system exists and operates in time and space.

**Model**

A model is a simplified representation of a system at some particular point in time or space intended to promote understanding of the real system.

**Modelling**

A model is a simplified representation or abstraction of reality. It is usually simplified because reality is too complex to describe exactly and because much of the complexity is irrelevant to solving the specific problem. Models can represent systems or problems with various degrees of abstraction. They are classified, based on their degree of abstraction, as either iconic, analog, or mathematical.

**ICONIC (SCALE) MODEL S** An iconic model the least abstract type of model is a physical replica of a system, usually on a different scale from the original. An iconic model may be three-dimensional, such as that of an airplane, car, bridge, or production line. Photographs are two-dimensional iconic-scale models.

**ANALOG MODELS,** An analog model behaves like the real system but does not look like it. It is more abstract than an iconic model and is a symbolic representation of reality. Models of this type are usually two-dimensional charts or diagrams. They can be physical models, but the shape of the model differs from that of the actual system. Some examples include: -

* Organization charts that depict structure, authority, and responsibility relationships
  + Maps on which different colors represent objects, such as bodies of water or mountains
  + Stock market charts that represent the price movements of stocks
  + Blueprints of a machine or a house
  + Animations, videos, and movies

**MATHEMATICAL (QUANTITATIVE) MODEL**S

The complexity of relationships in many organizational systems cannot be represented by icons or analogically because such representations would soon become cumbersome, and using them would be time-consuming. Therefore, more abstract models are described **mathematically.** Examples of mathematical models: -

Optimization. Analytical, linear, nonlinear, simulation etc,

1. **Simulation Models:**
   * Mathematical Basis: Simulation models use mathematical equations and algorithms to replicate the behavior of real-world systems. These models can incorporate a variety of mathematical techniques, including differential equations, stochastic processes, and numerical methods.
   * Purpose: They are often used for complex systems where analytical solutions are impractical or impossible. Simulations allow for the exploration of how systems evolve over time and under different conditions.
   * Approach: Simulation involves computational methods, and it typically requires running numerous iterations to study the dynamic behavior of systems.

This is the first step in M & S, creating a model approximating an event or a system. In turn, the model can then be modified in which simulation allows for the repeated observation of the model. After one or many simulations of the model, analysis takes place to draw conclusions, verify and validate the research, and make recommendations based on various simulations of the model.

In M & S, the term system refers to the subject of model development; that is, it is the subject or thing that will be investigated or studied using M & S. When investigating a system, a quantitative assessment is of interest to the modeler — observing how the system performs with various inputs and in different environments. Of importance is a quantitative evaluation of the performance of the system concerning some specific criteria or performance measures.

**THE BENEFITS OF MODELS**

A management-support system uses models for the following reasons:

* + Model manipulation (changing decision variables or the environment) is much easier than manipulating the real system. Experimentation is easier and does not interfere with the daily operation of the organization.
  + Models enable the compression of time. Years of operations can be simulated in minutes or seconds of computer time.
  + The cost of modeling analysis is much less than the cost of a similar experiment conducted on a real system.
  + High cost of making mistakes during a trial-and-error experiment is much less when models are used rather than real systems.
  + The business environment involves considerable uncertainty. With modeling. a manager can estimate the risks resulting from specific actions.
  + Mathematical models enable the analysis of a very large, sometimes infinite, number of possible solutions. 1"ven in simple problems, managers often have a large number of alternatives from which to choose.
  + Models enhance and reinforce learning and training.
  + Models and solution methods are readily available over the Web.
  + There are many java applets (and other Web programs) that readily solve models.

**Simulation**

* the imitation of the operation of a real-world process or system over time to estimate the measures of performance of the system with the simulation-generated data

A simulation is the manipulation of a model in such a way that it operates on time or space to compress it, thus enabling one to perceive the interactions that would not otherwise be apparent

because of their separation in time or space.

Simulation is the representation of a real-life system by another system, which depicts the important characteristics of the real system and allows experimentation on it.

 In other words, simulation is an imitation of the reality.

 Simulation has long been used by researchers, analysts, designers and other professionals in physical and non-physical experiments and investigations.

**Simulation modeling can be used**

* as an analysis tool for predicting the effect of changes to existing systems
* as a design tool to predict the performance of new systems

**Why Simulate?**

 It may be too difficult, hazardous, or expensive to observe a real, operational system

 Parts of the system may not be observable (e.g., the internals of a silicon chip or biological

system)

* Advantages
  + New polices, operating procedures, decision rules, information flows, organizational procedures, and so on can be explored without disrupting ongoing operations of the real system.
  + New hardware designs, physical layouts, transportation systems, and so on, can be tested without committing resources for their acquisition.
  + Hypotheses about how or why certain phenomena occur can be tested for feasibility.
  + Insight can be obtained about the interaction of variables.
  + Insight can be obtained about the importance of variables to the performance of the system.
  + Bottleneck analysis can be performed indicating where work-in-process, information, materials, and so on are being excessively delayed.
  + A simulation study can help in understanding how the system operates rather than how individuals think the system operates.
  + “What-if” questions can be answered. This is particularly useful in the design of new system.

**Advantages of Simulation**

 Simulation helps to learn about real system, without having the system at all. For example, the wind tunnel testing of the model of an aeroplane does not require a full-sized plane.

 Many managerial decision-making problems are too complex to be solved by mathematical programming.

 In many situations experimenting with actual system may not be possible at all. For example, it is not possible to conduct experiment, to study the behavior of a man on the surface of moon. In some other situations, even if experimentation is possible, it may be too costly and risky,

 In the real system, the changes we want to study may take place too slowly or too fast to be observed conveniently.Computer simulation can compress the performance of a system over years into a few minutes of computer running time.

 Conversely, in systems like nuclear reactors where millions of events take place per second, simulation can expand the time to required level.

 Through simulation, management can foresee the difficulties and bottlenecks, which may come up due to the introduction of new machines, equipments and processes. It thus eliminates the need of costly trial and error method of trying out the new concepts.

 Simulation being relatively free from mathematics can easily be understood by the operating personnel and non-technical managers. This helps in getting the proposed plans accepted and implemented.

 Simulation Models are comparatively flexible and can be modified to accommodate the changing environment to the real situation.

 Simulation technique is easier to use than the mathematical models, and can be used for wide range of situations.

 Extensive computer software packages are available, making it very convenient to use fairly sophisticated simulation models.

 Simulation is a very good tool of training and has advantageously been used for training the operating and managerial staff in the operation of complex system. Space engineers simulate space flights in laboratories to train the future astronauts for working in weightless environment.

 Airline pilots are given extensive training on flight simulators, before they are allowed to handle real planes.

* Disadvantages
  + Model building requires special training. It is an art that is learned over time and through experience. Furthermore, if two models are constructed by two competent individuals, they may have similarities, but it is highly unlikely that they will be the same.
  + 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.
  + Simulation modeling and analysis can be time consuming and expensive. Skimping on resources for modeling and analysis may result in a simulation model or analysis that is not sufficient for the task.
  + Simulation is used in some cases when an analytical solution is possible, or even preferable, as discussed in Section 1.2. This might be particularly true in the simulation of some waiting lines where closed-form queueing models are available.

**Areas of Applications**

 **Manufacturing**: Design analysis and optimization of production system, materials management, capacity planning, layout planning, and performance evaluation, evaluation of process quality.

 **Business:** Market analysis, prediction of consumer behavior, and optimization of marketing strategy and logistics, comparative evaluation of marketing campaigns.

 **Military:**Testing of alternative combat strategies, air operations, sea operations, simulated war exercises, practicing ordinance effectiveness, inventory management.

 **Healthcare applications;** such as planning of health services, expected patient density, facilities requirement, hospital staffing , estimating the effectiveness of a health care program.

 **Communication Applications**: Such as network design, and optimization, evaluating network reliability, manpower planning, sizing of message buffers.

 **Computer Applications:** Such as designing hardware configurations and operating system protocols, sharing networking.

 **Economic applications**: such as portfolio management, forecasting impact of Govt. Policies and international market fluctuations on the economy. Budgeting and forecasting market fluctuations.

 **Transportation applications**: Design and testing of alternative transportation policies, transportation networks, railways, airways, etc. Evaluation of timetables, and traffic planning.

 **Environment application:** Solid waste management, performance evaluation of environmental programs, evaluation of pollution control systems.

 **Biological applications;** Such as population genetics and the spread of epidemics.

When Simulation is the Appropriate Tool (1)

* Simulation enables the 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 effect of these alterations on the model’s behavior can be observed.
* The knowledge gained in designing a simulation model may 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 device to reinforce analytic solution methodologies.
* 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.
* By simulating different capabilities for a machine, requirements can be determined.
* Simulation models designed for training allow learning without the cost and disruption of on-the-job learning.
* Animation shows a system in simulated operation so that the plan can be visualized.
* The modern system (factory, wafer fabrication plant, service organization, etc.) is so complex that the interactions can be treated only through simulation.

When Simulation is not Appropriate

* When the problem can be solved using common sense.
* When the problem can be solved analytically.
* When it is easier to perform direct experiments.
* When the simulation costs exceed the savings.
* When the resources or time are not available.
* When system behavior is too complex or can’t be defined.
* When there isn’t the ability to verify and validate the model.

**Uses of simulations**

 Analyze systems before they are built

 Reduce the number of design mistakes

 Optimize design

 Analyze operational systems

 Create virtual environments for training, entertainment

**When to use Simulation**

 Over the years tremendous developments have taken place in computing capabilities and special-purpose simulation languages, and in simulation methodologies.

 The use of simulation techniques has also become widespread.

**Following are some of the purposes for which simulation may be used.**

1. Simulation is very useful for experiments with the internal interactions of a complex

system, or of a subsystem within a complex system.

2. Simulation can be employed to experiment with new designs and policies, before

implementing

3. Simulation can be used to verify the results obtained by analytical methods and

reinforce the analytical techniques.

4. Simulation is very useful in determining the influence of changes in input variables on

the output of the system.

5. Simulation helps in suggesting modifications in the system under investigation for its

optimal performance.

**Types of Simulation Models**

 Simulation models can be classified as being **static or dynamic, deterministic or**

**stochastic and discrete or continuous.**

 A **static simulation** model represents a system, which does not change with time or

represents the system at a particular point in time. (linear programming models)

 **Dynamic simulation** models represent systems as they change over time.

 **Deterministic models** have a known set of inputs, which result in a unique set of

outputs.

 In a **stochastic model**, there are one or more random input variables, which lead to

random outputs.

 Systems in which the state of the system changes continuously with time are called

**continuous systems(stock pricing model)** while the systems in which the state changes abruptly at discrete points in time are called **discrete systems(queing model).**

The second concept, model , is a physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process. Simply, models serve as representations of events and/or things that are real (such as a historic case study) or contrived (a use case). They can be representations of actual systems. This is because systems can be difficult or impossible to investigate. As introduced above, a system might be large and complex, or it might be dangerous to impose conditions for which to study the system. Systems that are expensive or essential cannot be taken out of service; systems that are notional do not have the physical components to conduct experiments. Thus, models are developed to serve as a stand - in for systems. As a substitute, the model is what will be investigated with the goal of learning more about the system. To produce a model, one abstracts from reality a description of the system. However, it is important to note that a model is not meant to represent all aspects of the system being studied. That would be too timely, expensive, and complex — perhaps impossible. Instead, the model should be developed as simply as possible, representing only the system aspects that affect system performance being investigated in the model. Thus, the model can depict the system at some point of abstraction or at multiple levels of the abstraction with the goal of representing the system in a reliable fashion. Often, it is challenging for the modeler to decide which aspects of a system need to be included in the model. A model can be physical , such as a scale model of an airplane to study aerodynamic behavior. A physical model, such as the scale model of an airplane, can be used to study the aerodynamic behavior of the airplane through wind - tunnel tests. At times, a model consists of a set of mathematical equations or logic statements that describes the behavior of the system. These are notional models. Simple equations often result in analytic solutions or an analytic representation of the desired system performance characteristic under study. Conversely, in many cases, the mathematical model is sufficiently complex that the only way to solve the equations is numerically. This process is referred to as computer simulation. Essentially, a system is modeled using mathematical equations; then, these equations are solved numerically using a digital computer to indicate likely system behavior. There are distinct differences between the numerical and the analytic way of solving a problem: Analytic solutions are precise mathematical proofs, and as such, they cannot be conducted for all classes of models. The alternative is to solve numerically with the understanding that an amount of error may be present in the numerical solution.

**Steps in a simulation study**

 Problem formation

 Model construction

 Data Collection

 Model programming

 Validation

 Design of experiment

 Simulation run and analysis

 Documentation

 Implementation

**Phases In Simulation Study**

This process is divided into four phases

**Phase 1: Problem Formulation:** This includes the problem formulation step.

**Phase2: Model Building:** This includes model construction, data collection, programming, and

validation of model.

**Phase3: Running the Model:** This includes experimental design, simulation runs and analysis

of results.

**Phase4: Implementation:** This includes documentation and implementation.



