Simulation Modeling

Quiz Study Guide — Chapter 1

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How to Use This Deck

This deck is a **checklist**, not a summary. Every slide is phrased as something you should be able to *state* or *recognize* without looking it up.

- **Question formats:** multiple choice, true/false, matching, fill-in-the-blank, and **multiple answer** ("select all that apply").
- The **Common Traps** slides are built from the actual wrong answers — read them last.

Watch for the select-all questions

Chapter 1 is the one chapter whose bank uses **multiple-answer** items. Partial knowledge is not enough there: you must be able to rule options **out** as well as in, so pay attention to the "not a good use" and "not part of this phase" framings.

What This Chapter Covers

What simulation is

- The textbook's definition
- Classifying systems
- Discrete-event versus continuous
- Descriptive and prescriptive use

How a study is run

- The simulation methodology, phase by phase
- Verification versus validation
- The DEGREE problem-solving process
- Professional rules of practice

Objectives

You should be able to:

- Give the textbook's definition of computer simulation
- Classify a system as static/dynamic, deterministic/stochastic, and discrete/continuous/combined — and say which class this book focuses on
- Order the phases of the simulation methodology and place an activity in the right one
- Distinguish **verification** from **validation**, and name techniques supporting each
- Expand **DEGREE** and describe each step
- Recognize good uses of simulation, and the cases where it is the wrong tool
- Name the conceptual modeling diagrams and the goals of a simulation study
- List the professional rules of practice and the `KSLCore` sub-packages

What Simulation Is

Computer simulation is a **numerical technique for conducting experiments on a digital computer** involving logical and mathematical relationships that describe the behavior of a system over time.

Three things that definition is *not*:

- A **physical replica** used for hands-on training
- An **analytical closed-form solution** to a system of differential equations
- A **statistical regression model** fitted to historical data for forecasting

Trap

A simulation is **not** the real system, and even a well-built one is **not** equivalent to direct experimentation on the real system.

Classifying Systems

Type	Description
Static	Time is not a significant factor; the state does not evolve over time
Dynamic	The system state changes with respect to time
Deterministic	Variables are **not** governed by underlying random processes
Stochastic	Some variables **are** governed by underlying random processes
Combined continuous-discrete	The state vector holds **both** continuous and discrete variables — e.g. velocity together with number of wheels deployed

This textbook focuses primarily on **stochastic, dynamic, discrete** systems.

The **state** of a system is the set of properties or variables that describe it at any time t.

Discrete-Event Simulation

In a discrete-event simulation, observations of the system state are collected **only at selected points in time when certain changes take place**. Those selected points are called **events**.

- **Not** continuously at every point in simulated time.
- **Not** at fixed, equally spaced intervals set by an integration step size.
- Well suited to systems such as a fast-food service counter, where the state changes at arrivals and service completions.
- **Not** the method for the continuous flow of liquids — oil into a tanker — nor does it integrate differential equations over small equal intervals.

Descriptive and Prescriptive

Simulation is a **predictive modeling methodology** that is both **descriptive** and — when coupled with optimization or rigorous design evaluation — **prescriptive**. It is neither purely descriptive nor a pure optimization technique.

In the prescriptive picture, the **alternative generator** produces **different scenarios (inputs) to be fed into the simulation model** for evaluation. It does *not* generate random variates, estimate input distributions, or perform the output analysis.

Goals of a Simulation Study

Goal	Meaning
Comparison	Compare system alternatives and their performance measures across factors, with respect to objectives
Optimization	Find the configuration that optimizes performance subject to constraints
Prediction	Predict the behavior of the system at some future point in time
Investigation	Learn about and gain insight into the behavior of the system given various inputs

When Simulation Is the Right Tool

Good uses — the select-all answers:

- Understanding how **complex interactions** in the system affect performance
- Understanding how **randomness** affects performance
- **Training** people for events that would be disruptive in the real system
- Evaluating a **proposed system that does not yet exist**, to ensure the design will meet specifications
- **Comparing a fixed set of design alternatives** against performance goals

Not a good use: a problem that can be solved more directly by a simpler analytical technique or an exact closed-form formula. Re-driving a simulation from **one day's** recorded observations is likewise **not** an appropriate way to simulate a month of operation.

The Simulation Methodology

Phase	Representative activities
Problem Formulation	Define the system, establish performance metrics, build the conceptual model
Simulation Model Building	Model translation, input data modeling, **verification**, **validation**
Experimental Design and Analysis	Conduct preliminary and final experiments; analyze the results
Evaluate and Iterate	Produce model and user documentation; iterate as needed
Implementation	Execute the recommended solution and follow up on projected benefits

Verification is not part of problem formulation — it belongs to model building. That distinction is asked directly.

Verification versus Validation

Verification

Determining whether the **computer program performs as intended** — that the implementation is correct. Debugging the code. Supported by, among other things, **stressing the model via sensitivity analysis**.

Validation

Determining whether the **model adequately represents the real system**. Supported by **comparing simulation output to real-system output**.

They are **not** the same activity and are **not** interchangeable.

DEGREE

The problem-solving methodology, step by step:

Letter	Step
D	**D**efine the problem
E	**E**stablish measures of performance
G	**G**enerate alternatives
R	**R**ank alternatives
E	**E**valuate and iterate
E	**E**xecute and evaluate the solution

Conceptual Modeling Diagrams

Table 1: The temporary/permanent entity distinction separates the two activity diagrams

Diagram	Purpose
Context diagram	A pictorial general system description, often with typical flow patterns
Activity flow diagram	The process for a **temporary** entity flowing through the system, and its use of resources
Activity cycle diagram	The activities of a **permanent** entity that remains in the system throughout its life
State chart	A software-engineering style diagram of states and transitions

Model conceptualization does **not** start by writing code — diagrams and narrative descriptions come first.

Professional Rules of Practice

- Only perform simulation studies that have **clearly defined objectives and performance metrics**.
- **Never accept results or decisions based on a sample size of one.**
- Use **statistically valid methods** to determine the sample size for experiments.
- Take steps to **mitigate initialization bias** in steady-state simulations.
- Report results with the **sample size, the sample average, and a measure of sample variation**.

> **Trap**
>
> "Always assume independence and normality without checking, to simplify the analysis" is the planted wrong answer in the select-all version of this question.

Queueing Models and the KSL

Queueing models are *not* generally adequate for a total analysis of complex, dynamic systems — a hospital emergency department with non-stationary arrivals and complex resource allocation policies is the textbook's counterexample.

The **KSL supports both the event-view and the process-view** of simulation.

`KSLCore` **sub-packages** — another select-all item:

- `calendar`
- `simulation`
- `modeling`
- `observers`
- `utilities`

Terms to Have on the Tip of Your Tongue

Term	Definition
Model translation	Implementing the model in computer code — timing, general procedures, and the representation of the conceptual model as a program
State	The set of properties or variables describing a system at any time t
Events	The selected points in time at which the system state changes
System definition statement	A narrative accurately and concisely defining the system, particularly its **boundaries**

More Terms

Term	Definition
Validation	Determining whether the model adequately represents the real system
Input data modeling	Analyzing and characterizing data to develop probability models for model inputs
Documentation	Producing technical and user manuals to support ongoing use of the model

Common Traps

- A simulation is **not** the real system and is **not** equivalent to experimenting on it.
- **Verification** = the program works as intended. **Validation** = the model represents the real system. Never interchange them.
- **Verification is not** a problem-formulation activity.
- Sensitivity analysis supports **verification**; comparing to real output supports **validation**.
- Discrete-event simulation observes at **events**, not continuously and not at fixed intervals.
- Re-driving from **one day** of historical data is not a valid way to simulate a month.
- Simulation is the **wrong** tool when a simpler analytical technique will do.
- Conceptualization starts with **diagrams and narrative**, not code.
- Queueing models alone are **not** adequate for a complex dynamic system.
- On select-all items, the distractor is usually the one absolute claim — “always assume independence and normality”, “verification and validation are the same”.

Quick Self-Test

Without looking back, answer these:

1. Give the textbook's definition of computer simulation in one sentence.
2. Which three-way classification does this book focus on, and what does each word rule out?
3. Name the five phases of the simulation methodology, in order.
4. State the difference between verification and validation, and give one supporting technique for each.
5. Expand DEGREE.
6. Name the four conceptual modeling diagrams and say which two are distinguished by temporary versus permanent entities.
7. List the five professional rules of practice.
8. Name the five `KSLCore` sub-packages.