

**What is
Simulation?**

Chapter 1

Last revision June 7, 2003

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 1 of 23

Simulation Is ...

- **Simulation** – very broad term – methods and applications to imitate or mimic real systems, usually via computer
- Applies in many fields and industries
- Very popular and powerful method
- Book covers simulation in general and the *Arena* simulation software in particular
- This chapter – general ideas, terminology, examples of applications, good/bad things, kinds of simulation, software options, how/when simulation is used

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 2 of 23

Systems

- **System** – facility or process, actual or planned
 - Examples abound ...
 - Manufacturing facility
 - Bank operation
 - Airport operations (passengers, security, planes, crews, baggage)
 - Transportation/logistics/distribution operation
 - Hospital facilities (emergency room, operating room, admissions)
 - Computer network
 - Freeway system
 - Business process (insurance office)
 - Criminal justice system
 - Chemical plant
 - Fast-food restaurant
 - Supermarket
 - Theme park
 - Emergency-response system

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 3 of 23

Work With the System?

- **Study the system – measure, improve, design, control**
 - Maybe just play with the actual system
 - Advantage — unquestionably looking at the right thing
 - But it's often impossible to do so in reality with the actual system
 - System doesn't exist
 - Would be disruptive, expensive, or dangerous

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 4 of 23

Models

- **Model – set of assumptions/approximations about how the system works**
 - Study the model instead of the real system ... usually much easier, faster, cheaper, safer
 - Can try wide-ranging ideas with the model
 - Make your mistakes on the computer where they *don't* count, rather than for real where they *do* count
 - Often, just *building* the model is instructive – regardless of results
 - Model *validity* (any kind of model ... not just simulation)
 - Care in building to mimic reality faithfully
 - Level of detail
 - Get same conclusions from the model as you would from system
 - More in Chapter 13

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 5 of 23

Types of Models

- **Physical (*iconic*) models**
 - Tabletop material-handling models
 - Mock-ups of fast-food restaurants
 - Flight simulators
- **Logical (*mathematical*) models**
 - Approximations and assumptions about a system's operation
 - Often represented via computer program in appropriate software
 - Exercise the program to try things, get results, learn about model behavior

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 6 of 23

Studying Logical Models

- **If model is simple enough, use traditional mathematical analysis ... get exact results, lots of insight into model**
 - Queueing theory
 - Differential equations
 - Linear programming
- **But complex systems can seldom be *validly* represented by a simple analytic model**
 - Danger of over-simplifying assumptions ... model validity?
 - Type III error – working on the wrong problem
- **Often, a complex system requires a complex model, and analytical methods don't apply ... what to do?**

Simulation with Arena, 3rd ed.

Chapter 1 – What Is Simulation?

Slide 7 of 23

Computer Simulation

- **Broadly interpreted, *computer simulation* refers to methods for studying a wide variety of models of systems**
 - Numerically evaluate on a computer
 - Use software to imitate the system's operations and characteristics, often over time
- **Can be used to study simple models but should not use it if an analytical solution is available**
- **Real power of simulation is in studying complex models**
- **Simulation can tolerate complex models since we don't even aspire to an analytical solution**

Simulation with Arena, 3rd ed.

Chapter 1 – What Is Simulation?

Slide 8 of 23

Popularity of Simulation

- **Consistently ranked as the most useful, popular tool in the broader area of operations research / management science**
 - 1978: M.S. graduates of CWRU O.R. Department ... after graduation
 1. Statistical analysis
 2. Forecasting
 3. Systems Analysis
 4. Information systems
 5. Simulation
 - 1979: Survey 137 large firms, which methods used?
 1. Statistical analysis (93% used it)
 2. Simulation (84%)
 3. Followed by LP, PERT/CPM, inventory theory, NLP, ...

Simulation with Arena, 3rd ed.

Chapter 1 – What Is Simulation?

Slide 9 of 23

Popularity of Simulation (cont'd.)

- 1980: (A)IIE O.R. division members
 - First in utility and interest — simulation
 - First in familiarity — LP (simulation was second)
- 1983, 1989, 1993: Longitudinal study of corporate practice
 1. Statistical analysis
 2. Simulation
- 1989: Survey of surveys
 - Heavy use of simulation consistently reported

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 10 of 23

Advantages of Simulation

- **Flexibility to model things as they are (even if messy and complicated)**
 - Avoid *looking where the light is* (a morality play):
 You're walking along in the dark and see someone on hands and knees searching the ground under a street light.
 You: "What's wrong? Can I help you?"
 Other person: "I dropped my car keys and can't find them."
 You: "Oh, so you dropped them around here, huh?"
 Other person: "No, I dropped them over there." (Points into the darkness.)
 You: "Then why are you looking here?"
 Other person: "Because this is where the light is."
- **Allows uncertainty, nonstationarity in modeling**
 - The only thing that's for sure: nothing is for sure
 - Danger of ignoring system variability
 - Model validity

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 11 of 23

Advantages of Simulation (cont'd.)

- **Advances in computing/cost ratios**
 - Estimated that 75% of computing power is used for various kinds of simulations
 - Dedicated machines (e.g., real-time shop-floor control)
- **Advances in simulation software**
 - Far easier to use (GUIs)
 - No longer as restrictive in modeling constructs (hierarchical, down to C)
 - Statistical design & analysis capabilities

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 12 of 23

The Bad News

- **Don't get exact answers, only approximations, estimates**
 - Also true of many other modern methods
 - Can bound errors by machine roundoff
- **Get random output (*RIRO*) from stochastic simulations**
 - Statistical design, analysis of simulation experiments
 - Exploit: noise control, replicability, sequential sampling, variance-reduction techniques
 - Catch: "standard" statistical methods seldom work

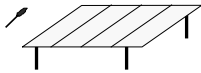
Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 13 of 23

Different Kinds of Simulation

- **Static vs. *Dynamic***
 - Does time have a role in the model?
- **Continuous-change vs. *Discrete-change***
 - Can the "state" change continuously or only at discrete points in time?
- **Deterministic vs. *Stochastic***
 - Is everything for sure or is there uncertainty?
- **Most operational models:**
 - *Dynamic, Discrete-change, Stochastic*
 - Though Chapter 11 discusses continuous and combined discrete-continuous models

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 14 of 23

Simulation by Hand: The Buffon Needle Problem



- Estimate π (George Louis Leclerc, c. 1733)
- Toss needle of length l onto table with stripes d ($>l$) apart
- P (needle crosses a line) = $\frac{2l}{\pi d}$
- Repeat; tally \hat{p} = proportion of times a line is crossed
- Estimate π by $\frac{2l}{\hat{p}d}$

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 15 of 23

Why Toss Needles?

- **Buffon needle problem seems silly now, but it has important simulation features:**
 - Experiment to *estimate* something hard to compute exactly (in 1733)
 - *Randomness*, so estimate will not be exact; estimate the error in the estimate
 - *Replication* (the more the better) to reduce error
 - *Sequential sampling* to control error — keep tossing until probable error in estimate is “small enough”
 - *Variance reduction* (*Buffon Cross*)

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 16 of 23

Using Computers to Simulate

- **General-purpose languages (FORTRAN)**
 - Tedious, low-level, error-prone
 - But, almost complete flexibility
- **Support packages**
 - Subroutines for list processing, bookkeeping, time advance
 - Widely distributed, widely modified
- **Spreadsheets**
 - Usually static models
 - Financial scenarios, distribution sampling, SQC

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 17 of 23

Using Computers to Simulate (cont'd.)

- **Simulation languages**
 - GPSS, SIMSCRIPT, SLAM, SIMAN (on which Arena is based, and is included in Arena)
 - Popular, still in use
 - Learning curve for features, effective use, syntax
- **High-level simulators**
 - Very easy, graphical interface
 - Domain-restricted (manufacturing, communications)
 - Limited flexibility — model validity?

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 18 of 23

Where Arena Fits In

- **Hierarchical structure**
 - Multiple levels of modeling
 - Can mix different modeling levels together in the same model
 - Often, start high then go lower as needed
- **Get ease-of-use advantage of simulators without sacrificing modeling flexibility**

Level of Modeling

Higher

- User-Created Templates**
Commonly used constructs
Company-specific processes
Company-specific templates
etc.
- Application Solution Templates**
Contact centers
Packaging lines
etc.
- Basic Process Panel**
Many common modeling constructs
Very accessible, easy to use
Reasonable flexibility
- Advanced Process, Advanced Transfer Panels**
Access to more detailed modeling for greater flexibility
- Blocks, Elements Panels**
All the flexibility of the SIMAN simulation language
- User-Written Visual Basic, C/C++ Code**
The ultimate in flexibility
VBA is built in
C/C++ requires compiler

Lower

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 19 of 23

When Simulations are Used

- **Uses of simulation have evolved with hardware, software**
- **The early years (1950s-1960s)**
 - Very expensive, specialized tool to use
 - Required big computers, special training
 - Mostly in FORTRAN (or even Assembler)
 - Processing cost as high as \$1000/hour for a sub-286 level machine

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 20 of 23

When Simulations are Used (cont'd.)

- **The formative years (1970s-early 1980s)**
 - Computers got faster, cheaper
 - Value of simulation more widely recognized
 - Simulation software improved, but they were still languages to be learned, typed, batch processed
 - Often used to clean up “disasters” in auto, aerospace industries
 - Car plant; heavy demand for certain model
 - Line underperforming
 - Simulated, problem identified
 - But demand had dried up — simulation was too late

Simulation with Arena, 3rd ed. Chapter 1 – What Is Simulation? Slide 21 of 23

When Simulations are Used (cont'd.)

- **The recent past (late 1980s-1990s)**
 - Microcomputer power
 - Software expanded into GUIs, animation
 - Wider acceptance across more areas
 - Traditional manufacturing applications
 - Services
 - Health care
 - "Business processes"
 - Still mostly in large firms
 - Often a simulation is part of the "specs"

When Simulations are Used (cont'd.)

- **The present**
 - Proliferating into smaller firms
 - Becoming a standard tool
 - Being used earlier in design phase
 - Real-time control
- **The future**
 - Exploiting interoperability of operating systems
 - Specialized "templates" for industries, firms
 - Automated statistical design, analysis
 - Networked sharing of data in real time
 - Integration with other applications
 - Distributed model building, execution
