Applications of Simulation

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Section 1
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Objectives
This course builds on the coverage of simulation in the core Decision Science course and deepens the student’s knowledge and abilities in performing simulation studies in a variety of application areas. It also introduces the student to discrete-event simulation for modeling systems with queuing behavior, and dynamic system simulation for modeling systems with feedback. The course will emphasize model building using Crystal Ball, a Monte Carlo simulation add-in for Excel, and Extend+, a visual-interactive programming tool for discrete-event and dynamic system simulation.

The course begins with a review of the basics of Monte Carlo simulation modeling using spreadsheets: deterministic modeling and sensitivity analysis, identifying random variables, selecting probability distributions, structuring simulations, and analyzing outputs. We will cover a range of applications from finance (e.g., valuation, cash management, real options), marketing (e.g., market share with advertising and promotions), operations (e.g., capacity planning, inventory management), and economics (e.g., competitive bidding). These applications allow us to introduce advanced simulation topics such as optimization of simulation models, as well as to provide the student with a broad range of simulation modeling experience and skills.

The middle portion of the course focuses on dynamic system simulation, which involves modeling systems that evolve over time and are subject to feedback. This is a powerful approach for modeling long-term, strategic business problems that are typically thought to be too complex and too qualitative to benefit from modeling. It also provides an introduction to the software Extend+. The final portion of the course is devoted to discrete-event simulation, which is used to model queuing behavior in systems such as manufacturing processes, service sector business processes, call center operations, and hospital emergency rooms. While simple models of these systems can be built in a spreadsheet, Extend+ provides a flexible and powerful environment for modeling in this domain.

Requirements

Homework
There will be homework for every class. A typical homework assignment will consist of one or more business situations requiring simulation modeling and analysis. Students will be expected to present their models and the conclusions they have drawn from those models in class. Students are encouraged to work individually on
all assignments, and are also encouraged to discuss their results (models and conclusions) with each other.

**Project**
Students will carry out a self-selected project related to simulation. Projects will normally be done individually. However, projects teams are possible with my permission, if justified by the scale and challenge of the project. The results of these projects will be presented during the final week of class. More information on the projects will be provided separately.

**Project Schedule**
April 3: initial project proposal (one-half page description)
May 1: interim report
May 22: draft final report
May 23-30: final project presentations

**Office hours**
I will hold open office hours on Tuesdays from 2-4:00 in Tuck 210. I will be available at other times by appointment.

**Attendance**
All policies of the Tuck School apply.

**Materials**

**Text**
There is no text for this course. Readings will be supplied where necessary. The following texts may be useful for reference.

*Introduction to Simulation and Risk Analysis*, James Evans and David Olson, Prentice Hall, 2002.
This is an MBA-level text that covers Monte Carlo and discrete-event simulation. The software used for Monte Carlo simulation is Crystal Ball. For discrete-event simulation this text uses ProcessModel, which is similar to Extend+.

Another MBA-level text, but with an engineering flavor. It uses @Risk (instead of Crystal Ball) and Arena (instead of Extend).

This is one of the standard graduate-level references on simulation methods. It emphasizes discrete-event simulation and provides more of the theory behind simulation than the other books listed here.

The definitive text on dynamic system simulation. The software used is ITThink, but equivalent models can be built in Extend+.
This book contains a number of interesting examples worked out in detail. @Risk is
the major competing product to Crystal Ball. @Risk models can be converted to
Crystal Ball fairly easily.

Would-be Worlds: How Simulation is Changing the Frontiers of Science, John Casti,
This is a fascinating and accessible book on the frontiers of computer modeling and
simulation. The focus is primarily on science, but a number of applications in
economics and business are included.

Financial Models using Simulation and Optimization, Wayne Winston, Palisade,
1999.
Another book of examples, this time from finance. Also uses @Risk.

Decision Making under Uncertainty with RiskOptimizer, Wayne Winston, Palisade,
1999.
RiskOptimizer does for @Risk what OptQuest does for Crystal Ball: optimize
simulation models. This book contains many interesting examples, most of which
can be solved using Crystal Ball and Optquest.

Software
The students will use Crystal Ball 2000 V5.2 and Extend+ V6 with Manufacturing
and BPR throughout the course. The Sensitivity Toolkit, an add-in to Excel, will also
be used.

Grading
Grades will be based on homework assignments, class participation, three quizzes,
and the project. Extraordinary contributions to the intellectual process of the course
will also be recognized in the final grade. The following weights will be used in
grading:

Homework 20%
Quiz on Monte Carlo simulation 10%
Quiz on Dynamic System simulation 10%

Quiz on Discrete-event simulation 10%
Project 40%
Participation 10%

Schedule
March 27
Introduction to Simulation
Preparation: Read The Art of Modeling with Spreadsheets, Chapter 9, pages 1-8

Topics:
Course objectives
Logistics
Expectations
Overview of simulation
Benefits and limitations of simulation
Review of homework

March 28
Monte Carlo Simulation
Monte Carlo Simulation: Overview
Preparation: Read The Art of Modeling with Spreadsheets, Chapter 9, pages 9-21.
Topics:
Deterministic modeling
Sensitivity analysis
Data Sensitivity
Tornado chart
Linearity: when not to simulate
Simulation process
Review of homework.

April 2
Monte Carlo Simulation: Process Details
Preparation: Read The Art of Modeling with Spreadsheets, Chapter 9, pages 21-38.
Prepare: Office Building
Topics:
Selecting uncertain parameters
Selecting distributions
Run length and precision
Crystal Ball settings
Interpreting outputs
Review of homework

April 3
Optimization in Simulation
Preparation: Read The Art of Modeling with Spreadsheets, Chapter 9, pages 38-60.
Prepare: Cash Management Topics:
Grid Search
Model replication
CB Sensitivity
OptQuest
Embedded Solver
Review of homework

Assignments
Initial Project Proposal
Prepare a short summary of your proposed project. Describe the problem area and the sources of information you will use. Outline any specific problems you anticipate encountering.

April 9
Application: Inventory planning
Preparation: *Inventory Planning at Rowers North, Inc.*

**April 10**
Application: Real options and the value of flexibility
Preparation: *Capacity Planning at Drugco*

**April 11-15**
Take Home quiz on Monte Carlo simulation
Quiz

**April 16**

**DYNAMIC SYSTEM SIMULATION**
Introduction to Dynamic System Simulation
Preparation: Read *Business Dynamics*, Chapter 1, pp. 3-39. Study the Extend model Stocks and Flows.mox
Topics:
What is DSS?
How does it differ from other simulation approaches?
Typical problems
Strengths and weaknesses
Barriers to learning
Examples: inventory model
market share

**April 17**
Structure and Behavior of Dynamic Systems
Preparation: Read *Business Dynamics*, Chapter 4, pp. 108-133. Build Extend models to represent the generic structures shown in Figures 4.2, 4.4, 4.6, 4.8, 4.10, and 4.12.
Topics:
Fundamental modes of behavior
Interactions of modes
Growth, decay, and equilibrium
Example: carrying capacity

**April 23**
Mapping and Modeling Dynamic Systems
Topics:
Causal loops
Balancing loops
Reinforcing loops
Delays
Goals
Example: managing workload

**April 24**
Modeling Stocks and Flows
Topics:
- Stocks, flows, accumulation
- Identifying stocks and flows
- Mapping stocks and flows
- Feedback
- Aggregation
- Example: automobile recycling

**April 30**
Application: Dynamic Strategy
Preparation: *Auto Leasing*

**May 1**
Application: The Evolution of Standards
Preparation: *VHS versus Betamax*

**Interim Project Proposal**
Prepare an interim report on your project. Describe the current problem statement. Outline any specific problems you anticipate encountering.

**May 2-6**
Take-home quiz on dynamic system simulation
Quiz

**May 7**
**Discrete Event Simulation**
Introduction to Discrete-Even Simulation
Preparation:
Topics:
- Applications of discrete-event simulation
- Common features
- Sources of queues
- Queueing models in Excel
- *Extend+ versus Excel*
Lab: simple waiting line

**May 8**
Building Modeling Skills
Preparation: Car Wash case
Topics:
- Extend concepts
- Discrete event library
- Modeling by Elaboration
Lab: Car Wash model
May 14
Application: Consultants, Inc.
Preparation: Consultants, Inc.

May 15
Application: Circuit board manufacturing
Preparation: Circuit Board Manufacturing

May 21
Application: Staffing a Honda sales room
Preparation: Staffing a Honda Sales Room

May 22
Application: Emergency room planning
Preparation: Emergency room planning

Final Project Report
Submit the final report on your project. This should include a description of the problem and the model(s) you have built, along with your final recommendations and conclusions.

May 23-27
Take-home quiz on discrete event simulation
Quiz

May 23-29
Project Presentations