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+.

Applied Simulation Modeling, Andrew Seila, Vlatko Ceric, and Pandu Tadikamalla, Duxbury, 2003.
Another MBA-level text, but with an engineering flavor. It uses @Risk (instead of Crystal Ball) and Arena (instead of Extend).

Simulation Modeling and Analysis, Averill Law and David Kelton, McGraw-Hill, 1999.
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.

Business Dynamics, John Sterman, McGraw-Hill, 2000.
The definitive text on dynamic system simulation. The software used is IThink, but equivalent models can be built in Extend+.

Simulation Modeling using @Risk, Wayne Winston, Duxbury, 2001.
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, Wiley, 1997.
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 sourceds of information you will usle. Outline any specific problems you anticipaste 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
Preparation: Read *Business Dynamics*, Chapter 5, pp. 137-157.
Topics:
Causal loops
Balancing loops
Reinforcing loops
Delays
Goals
Example: managing workload

April 24

Modeling Stocks and Flows
Preparation: Read *Business Dynamics*, Chapter 6, pp. 191-230.
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:
Read Extend+ Users Guide, pp. E30-E42 and work through the Bank Line tutorial.
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