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**Applications of Simulation**

**Spring term**

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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, *Extend*+, a visual-interactive programming tool for discrete-event simulation, and *IThink*, a tool for 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 *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.

The final portion of the course is devoted to *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. *IThink* will be used to model these systems.

**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. Homework will be collected and graded. Solutions to homework problems will be posted after class.

**Optional Project**

Students who wish to compete for an H grade will carry out a self-selected project related to simulation. (Students who choose not to carry out a project will receive a maximum grade of S+). Projects are normally done individually. However, projects teams are possible with my permission, if justified by the scale and level of challenge of the project. The results of these projects will be presented during the exam week. More information on the projects will be provided separately.

**Project Schedule**

April 6: initial project proposal

April 27: interim report

May 18: draft final report

May 26-31: final project presentations

**Office hours**

During five weeks of the term the assignment will consist of a modeling project to be performed in teams of two. The Wednesday class will be cancelled during these weeks, and students will be required to use office hours on Monday or Tuesday in preparation for class on Thursday.

I will hold open office hours every week on Tuesdays from 2-4:00. I will be available at other times by appointment.

**Attendance**

All policies of the Tuck School apply. In addition, *unexcused* absences will lead to reduced grades as follows:
2 unexcused absences: LP
3 unexcused absences: F

**Materials**

**Text**

There is no text for this course. Several chapters from the second edition of the Decision Science text (*The Art of Modeling with Spreadsheets*) will be used as readings. Other readings will be supplied where necessary.

The following texts may be used 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).

*Business Process Modeling, Simulation, and Design,* Manuel Laguna and Johan Marklund, Pearson Prentice Hall, 2005.
This book focuses on business process design from a simulation point of view and uses Extend+ throughout.

*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 7.2*, *Extend+ V6, and IThink Version 9*. The *Sensitivity Toolkit*, a publicly available add-in to Excel, will also be used. (The Toolkit can be downloaded from <http://mba.tuck.dartmouth.edu/toolkit/>.)

All students should check the version of *Crystal Ball* they have installed and upgrade to version 7.2 if necessary with the help of Tuck Computing. A disk for *Extend+* will be included in the course packet. *Ithink* will be downloaded from the web (instructions will be given out in class).

**Grading**

Grades will be based on homework assignments, class participation, three quizzes, and the optional project. (Students who choose not to carry out a project will receive a maximum grade of S+.) 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 10%*
*Quiz on Monte Carlo simulation 25%*
*Quiz on discrete-event simulation 25%*
*Quiz on dynamic system simulation 25%*
*Class participation 15%*
*Optional project (only for students seeking an H)*

**Schedule**

 **03/30**
Introduction to Simulation

Preparation: Review *The Art of Modeling with Spreadsheets*, Chapters 5 and 6. Check that Crystal Ball 2000 V5.2.2 is running on your computer, along with the Sensitivity Tookit. Install Extend+ from the CD supplied in your registration packet.

Topics: Course objectives

Logistics

Expectations

Overview of simulation

Monte Carlo

discrete-event

dynamic system

Benefits and limitations of simulation

**03/31**
Monte Carlo Simulation: Overview

Preparation: Review *The Art of Modeling with Spreadsheets,* Chapter 9, pages 265-285.

Submit one spreadsheet simulation model from a prior course at Tuck (not including Decision Science). Add a worksheet named Context that explains in short paragraphs what the problem was that motivated the spreadsheet and what the results were (that is, what did you learn?). Save to the course folder using the following naming convention for your file: powells331.xls.

Topics:

Deterministic modeling

Sensitivity analysis

Data Sensitivity

Tornado chart

Linearity: when not to simulate

Simulation process

Review of homework

**04/06**
Monte Carlo Simulation: The Simulation Process

Preparation: Read *The Art of Modeling with Spreadsheets,* Chapter 9, pages 285-308.

Prepare: *Office Building*

Topics:

Selecting uncertain parameters

Selecting distributions

Run length and precision

Crystal Ball settings

Interpreting outputs

Review of homework

**04/07**
Optimization in Simulation

Preparation: Read *The Art of Modeling with Spreadsheets,* Chapter 9, pages 309-336.

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.

**04/13**
Application: Tax loss harvesting
Preparation: *Optimal Tax Loss Harvesting - A Simulation Analysis*

**04/14**
Application: Real options and the value of flexibility
Preparation: *Bidding for Antamina*

**04/14**
Take-home quiz on Monte Carlo simulation

**04/20**
Introduction to Discrete-Event Simulation

Preparation: Read *Business Process Modeling, Simulation, and Design*, Chapter 5, pp. 139-158 and Chapter 7, pp. 240-263.

Topics: Applications of discrete-event simulation

Common features

Sources of queues

Queuing models in Excel

Extend+ versus Excel

Lab: simple waiting line

**04/21**
Building Discrete-event Modeling Skills

Preparation: Read *Business Process Modeling, Simulation, and Design*, Chapter 8, pp. 267-312 and prepare the Car Wash case.

Topics:

Extend concepts

Discrete event library

Modeling by Elaboration

Lab: Car Wash model

**04/27**
Discrete-event Systems Principles
Preparation: *Consultants, Inc.*

**04/28**
Application: Circuit board manufacturing
Preparation: *Circuit Board Manufacturing*

**05/04**
Application: Staffing a Honda sales room
Preparation: *Staffing a Honda Sales Room*

**05/05**
Application: Emergency room planning
Preparation: *Emergency room planning*

**05/05**
Take-home quiz on discrete-event simulation

**05/11**
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; market share

**05/12**
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

***Interim Project Proposal***

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

**05/18**
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

**05/19**
Modeling Stocks and Flows
Preparation: Read *Business Dynamics*, Chapter 6, pp. 191-230, and prepare *Consultants, Inc.*

Topics:

Stocks, flows, accumulation

Identifying stocks and flows

Mapping stocks and flows

Feedback

Aggregation

Example: automobile recycling

**05/25**
Strategic Innovation and the Science of Learning
Visitor: Chris Trimble

Preparation: *TBD*

**05/26**
Application: The Evolution of Standards
Preparation: *VHS versus Betamax*

***Final Project Report***

Submit a draft of 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.

**05/26**
Take-home quiz on dynamic system simulation

**05/30 -06/02**
**Project Presentations**