Applied Advanced Analytics

Professor: Chaithanya Bandi
Office: KGH 4169
E-mail: c-bandi@kellogg.northwestern.edu

Course Overview

In this course, we will learn how to model, analyze, solve and interpret solutions to business decision problems. We will use a combination of Excel (with associated addins), Python (IPython notebook), and R notebooks.

We will address problems involving optimal resource allocation (how to best utilize the available resources), risk analysis (how to incorporate uncertainty in problem parameters), decision analysis (how to make sequential decisions under uncertainty with information), data analysis (how to synthesize the available data into useful information) and forecasting (how to extrapolate the past data into the future).

The focus of the course will be on modeling, analysis and interpretation, rather than the underlying mathematical theory or computational algorithms.

Class Setup

The course involves hands-on, in-class learning, so attending each class, on time, bringing a laptop, and actively participating in problem solving in class are essential. Groups of 3 will be randomly assigned.

Recommended Text:

Data, Models, and Decisions: The Fundamentals of Management Science
(Dimitris Bertsimas and Robert Freund, any edition)

Analytics Edge by Dimitris Bertsimas

Course Packet: Classroom cases, examples, homework assignments and supplementary readings
Course Outline

I. Introduction to Excel, Python and R Modeling: Structuring, analyzing and solving business decision problems in Excel and Python. Review of basic Excel, including Goal Seek, Data Tables and Solver. Applications to new product development, buy vs. lease decision, and monopoly pricing. (1 week)

II. Optimal Resource Allocation: Constrained optimization models of problems involving allocation of limited resources – equipment, personnel, materials, time, space, capital – to optimize some measure of performance such as profit, cost, sales, return on investment. Model formulation, solution by Solver, sensitivity analysis, and economic interpretation. Applications to product mix, portfolio planning, blending, transportation, project selection, work assignment, budget allocation, asset-liability matching, workforce planning, production planning, and portfolio optimization. (3 weeks)

III. Risk Analysis by Simulation: Monte Carlo simulation of uncertain parameters using the Rand() function, data tables, and @Risk. Applications to performance evaluation, inventory planning, yield management, optimal bidding, project valuation, cash flow analysis, income statement, stock and option pricing, and optimal stopping. (2 weeks)

IV. Sequential Decision Analysis: Modeling and analysis of sequential decision problems involving uncertainty. Constructing and analyzing decision trees with Precision Tree. Bayesian decision analysis and value of information. (1 week)

V. Data Analysis and Machine Learning in Industry: We will introduce latest tools and techniques used in Industry such as Deep Learning, Topological learning with examples from Industry. We will have industry speakers for certain sessions. (2 weeks)

Course Requirements and Guidelines

♦ Class Work: Preparation for each class involves reading and thinking about the cases to be analyzed in that class. Excel files of the case data should be downloaded from the Blackboard before (not during) the class. The problem solving process involves modeling, analyzing, solving and interpreting the solution. It seems deceptively simple to watch someone else perform it or simply read their solution, but the only way to learn this important and difficult skill is by practicing it yourself.

♦ Grading: The course grade will be based on the homework assignments (40%), a midterm (40%), and a term project (20%), adjusted in light of peer evaluations and class participation, which includes class attendance as an essential component. Each group member must fill out the peer evaluation form that reflects individual members’ contribution to the group output.

♦ Assignments: The homework cases and problems are designed to enhance your understanding of the process of modeling and analysis learned in class. Sufficient guidelines and numerical answers are provided for each assignment, so grading will not be based on correctness of the answers per se, but on demonstrated comprehension of the problem, logic of the analytical model, and application of concepts, methods and tools learned in class. The credit will be distributed approximately as follows:
  ♦ 25% for a short write-up summarizing the problem, model, analysis and results
25% for organization of the spreadsheet, its clarity, explanation, and documentation, showing formulas, gridlines, row-column headings, color coding/shading,...for readability

The remainder will be equally distributed among the specific questions asked in the case

Although many homework assignments are to be submitted in groups, everyone is expected to work on each assignment individually first, and then discuss and combine the individual efforts to produce the best group output. Each group should submit one report per assignment, and it should be a hard (not electronic) copy of their model, analysis and solution. There will be some individual assignments as well. All assignment solutions will be discussed in class when they are due, so late submissions will not be accepted or graded.

Guidelines: Each submission should include (a) a short write-up explaining your model, analysis and conclusions, and (b) supporting exhibits such as spreadsheets, charts, formulas, figures, etc. Think of your submission as a business report that you will present to your client or superior, who does not have time or patience to try to understand your work. So it is in your best interest to explain your work – the thought process in structuring the problem, step by step development of the spreadsheet model, its analysis, and final results – as clearly as possible. It is very critical that you communicate your work as clearly and effectively as possible so the reader can follow it instantly and effortlessly. A concise, logically organized, well documented and aesthetically pleasing report will improve your chances of getting the client’s business, your next promotion, or a high course grade! Here are some guidelines:

Format: Each submission should be a typewritten and stapled hard-copy with

- The assignment title, your group’s number and names of the participating members
- Font size of at least 10 points, and page margins of at least 1/4” for readability

Write-up: This should be a clear and concise explanation of your approach to the problem, model, analysis, and conclusions. Use a presentation format with outlines, bullets and tables, rather than long verbose essays. The write-up should include:

- Executive Summary: Overview of the problem addressed, key issues involved, and your solution, clearly demonstrating your understanding of the problem and results
- Model: Explanation of the logical structure of your model, outlining its step-by-step development, which summarizes your thought process in approaching the problem. State the objective, decisions and tradeoffs involved, as well as the key assumptions you made to simplify the analysis. (Do not simply restate the problem data as assumptions). Explain key formulas in words, such as: Cash Receipts this month = 0.2*Sales 2 months ago + 0.8*Last Month’s Sales + 0.2*This month’s sales
- Analysis: Summarize which and how the key spreadsheet functions, commands and tools were used to analyze your model. (Do not simply list them.)
- Conclusions: Provide concrete answers to the specific questions asked. Highlight the key results, and provide an intuitive interpretation. Make references to the exhibits attached, but do not simply state “See Exhibit 1 for answer to part (a)”.
♦ **Spreadsheets:** Spreadsheets are notoriously difficult to understand, trace the logic of, and debug, even for the person who creates them, let alone for an unfamiliar reader. It is *your* responsibility to make your spreadsheets absolutely clear and easy to follow. For tractability, try to organize your model and results on one page. If it cannot fit on one page, determine logical break point(s) and provide sufficient documentation to guide the reader from one page to the next. The goal is to help the reader follow your work effortlessly. Each spreadsheet should be self-contained and well documented to show

- The title of the exhibit that is descriptive of its content
- Careful, logical layout, separating data from the model and its analysis
- Key cell formulas displayed using the Formula List add-in. Try to place the text close to the cells containing the formulas. For conciseness, do not repeat similar formulas, manually typing instead “copied to..”. Make sure to print the gridlines, and row and column headings, without which formula lists are useless. Add explanations, comments and text boxes to help the reader understand your spreadsheet model
- Color coding and shading to highlight key cells and results, along with a legend

♦ **Project:** This involves creating, modeling, and analyzing a business case of your choice. It may be based on your own work experience, a case from another course, a magazine article, or even your imagination! You should then develop and analyze a spreadsheet model for this problem to illustrate a *new* application of the modeling concepts and analytical methods learned in this course. The case should be an internally consistent business story, and the model its stylized representation that captures its essence. The case need not have real data, and the model need not address all aspects of the problem or employ all of the tools learned in this course. The key is to identify and focus on a central nugget of an interesting problem and write a convincing business case around it. Keep the model manageable by suppressing inessential details and by making simplifying assumptions about the rest. The project should involve an equivalent of about two weeks’ (two assignments’) worth of work. At the end of the term, you will make a fifteen-minute presentation of your project to the class. At that time, you will also submit a typewritten report, clearly explaining your problem, model, and solution, just as in case of the weekly assignments.

♦ **Mid-Term:** This will be based on the all the material covered in the first seven weeks and will test conceptual taught through these weeks. Sample exams will be provided.

♦ **Honor Code:** We will strictly follow the Kellogg honor code as described at [http://www.kellogg.northwestern.edu/stu_aff/policies/honorcode.htm](http://www.kellogg.northwestern.edu/stu_aff/policies/honorcode.htm). In particular, you must *not* obtain solutions to the cases, assignments or projects from other students in the past or present classes. Also, you must *not* include your name on a group report if you have not contributed substantially to the group work. You must also fill out peer evaluations that accurately reflect all group members’ contribution to the group submissions.

♦ **Class Room:** We will adhere to the Kellogg classroom etiquette as described at [http://www.kellogg.northwestern.edu/stu_aff/policies/etiquette.htm](http://www.kellogg.northwestern.edu/stu_aff/policies/etiquette.htm). In particular, everyone is expected to attend all classes on time. To minimize delays and disruptions, please come to the class early and set up your laptop, so that the class can start on time, and then stay in your seats until the end of the class. In the interest of minimizing distraction to your fellow students, you must not browse the internet or use e-mail during class.
Peer Evaluation

Please evaluate all members of your group in terms of their contribution to the group assignments and the final project, and record the scores on the spreadsheet on the back page. Highlight your own name and grade each member of your group on each assignment. Distribute a total of 10 points among all group members (including yourself) to reflect their relative contributions to the group effort on each assignment as well as the term project. At the end of the quarter, compute the average scores for all of your group members in the last column and return this evaluation form with your final project report, folded and stapled for confidentiality. Please fill out this form carefully, as it will be an important input used in determining individual course grades. Submission of the peer evaluation forms is mandatory; your grade may be withheld for failure to submit it. These peer evaluations will be guarded with utmost confidentiality, and will be used only by me, and only for grading purposes.

During this peer evaluation process, please keep in mind the following criteria in terms of each individual group member’s contribution.

- **Communication**: Does the group member listen to and consider others’ points of view? Communicate ideas well? Adhere to the group meeting schedule? Is open to feedback?

- **Innovation**: Does he/she generate ideas on how to achieve group goals? Apply past knowledge and experience to the current project? Offer alternative approaches to current ways of thinking? Challenge the status quo when necessary? Encourage innovative thinking among the group members?

- **Initiative**: Does the member help move ahead efficiently? Go beyond the requirements of the task? Look for opportunities to improve? Help others in the group’s understand the background material?

- **Team Orientation**: Does the member work well with the group? Acknowledge and pay attention to the group and individual activities? Treat all members as colleagues? Complete individual task requirements to achieve group goals? Give other members credit for their ideas? Consider the group goals as the top priority? Attend all group meetings or provide advance notice when absent? Inform the group of his/her task so that it can be completed when absent?
## Peer Evaluation Form

### Your Name

### Group No.

<table>
<thead>
<tr>
<th>Assignment Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Project</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Score</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

### Group Member / Score

1.

2.

3.

4.

### Comments:
## I. Introduction to Excel, Python and R Modeling

### Week 1
- Introduction to Decision Modeling
- Review of Excel: *Goal Seek* and *Data Tables*
- Case: New Product Development
- Case: Buy Now, Pay Later
- Case: The Price Is Right: *Solver*
- Case: Saving For the Future*
- Case: Mastering the Mortgage*

### II. Optimal Resource Allocation

### Week 2
- Introduction to Resource Allocation
- Linear Optimization: Product Mix Problems
- Case: Producing PDAs for Profit
- Sensitivity Analysis: *Shadow Prices*
- Case: Portfolio Planning
- Case: Shelby Shelving
- Will be announced

### Week 3
- Blending Problems
- Case: Make Me Wine (and Wealthy too!)
- Binary Optimization: Selection Problems
- Case: Picking Projects
- Case: Product Promotion
- Integer Optimization
- Case: Cashflow Matching at a Pension Fund
- Case: Red Brand Canners
- Will be announced

### Week 4
- Multi-period Planning Problems
- Case: Workforce Planning at Gulf Coast Airlines
- Case: Production Planning at Drinking Duck
- Parametric Optimization: *Solver Table*
- Case: McPherson Refrigeration
- Case: Portfolio Optimization: Part A
- Case: Portfolio Optimization: Part B
- Will be announced
<table>
<thead>
<tr>
<th>Day</th>
<th>Classwork</th>
<th>Homework</th>
<th>Readings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>III. Risk Analysis by Simulation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Week 5 | Introducing Uncertainty: The `Rand()` function  
Case: Performance Evaluation  
Discrete Probability Models  
Case: Inventory Planning in Retailing  
How to Excel in Probability Models  
Binomial and Poisson Models  
Case: Revenue Management at AN Airlines | Case: Let’s Make a Deal | Will be announced |
| Week 6 | Continuous Models: Normal and Triangular  
Case: The Best Bid  
Case: New Product Development (B)  
Simulation Add-ins: Simtable, @Risk  
Case: Cash Flow Analysis of a Project  
Case: Income Statement of ABC Company | Case: Marsh and McLennan | Will be announced |
| | | Project Proposals | Will be announced |
| Week 7 | Role of Time and Uncertainty  
Case: Pricing Bonds, Stocks and Options  
Case: Waiting for the Right Offer  
Analysis of multiple stage decisions involving uncertainty: Precision Tree | Case: Mergers and Acquisitions | Will be announced |
| | | | |
| **V. Data Analysis and Forecasting** | | | |
| Weeks 8 and 9 | *Clustering, Regression, Time series analysis, Network Analysis in R* | Internet Users | |
| **VI. Term Project Presentations** | | | |
| Week 10 | Group presentations of new applications and cases | Project Reports and Peer Evaluations | |