How to Excel in Analytical Decision Modeling

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This paper outlines a course in business analytics that provides a rigorous, logical, analytical, yet intuitive and practical approach to business problem solving using Microsoft Excel. The course concept, methodology and pedagogy are illustrated through a variety of business applications. The course primarily addresses problems involving optimal resource allocation (how to best utilize given resources) and risk analysis (how to analyze decisions involving uncertainty), although some Excel tools for data analysis (how to estimate model parameters) and forecasting (how to extrapolate past observations into the future) are also covered. In each area, we consider specific problems in operations, finance and marketing, build models to set them up on Excel spreadsheets, analyze and solve them using the available Excel commands, tools and add-ins, and study their economic interpretations. In this sense, the course also integrates various functional areas of business management on a common Excel platform. This practical approach to problem solving in Excel has proved to be readily accessible to managers, who usually find spreadsheets natural, intuitive, and user friendly medium for organizing information and performing "what if' analyses, which has made them indispensable tools of modern business analysis.

1. Introduction

Business decisions are challenging because (a) the decision maker has only limited amount of resources (materials, equipment, personnel, time, space, capital), which have to be allocated among several competing activities, (b) outcomes of decisions depend upon uncertain economic environment (raw material costs, product prices, customer demand, competition) that is beyond decision maker's control, (c) decisions are often made sequentially over time, so current decisions should take into account their impact on future decisions and their outcomes, and (d) decisions often have to be based on imperfect information about the environment. The Analytical Decision Modeling (ADM) course, developed over the past 15 years, addresses each of these four areas, illustrated by applications primarily in operations and finance, but also some in marketing.

In general, the problem solving process involves (a) collecting relevant data, (b) building a model to capture the essence of the situation at hand, (c) analyzing the model to yield a solution, and (d) performing sensitivity analysis of the solution. Data collection and data analysis are of course essential to all business activity that emphasizes "management by fact", which the central theme of the business analytics approach to problem is solving. A model is a simplified view of the real world that abstracts away inessential details, identifies patterns and makes simplifying assumptions in order to facilitate its analysis bytoolsand methods of economics, mathematics, statistics, and spreadsheet analysis. The process of modeling involves tradeoffs: if we simplify too much, the model and its conclusions will not be relevant to reality, but if we do not simplify the enough, the model its analysis will become intractable. As statistician George Box famously said "All models are wrong, but some are useful… ... the practical question is how wrong do they have to be to not be useful. "Finally, given that a model is only an imperfect representation of the real world, it is important that we verify its robustness through sensitivity analysis of model parameters.

The objectives of this course are to learn how to model, analyze, and solve business decision problems involving (a) allocation and valuation of the available resources using mathematical optimization methods, (b) uncertainty in model parameters using probabilistic and simulation methods, (c) sequential decision analysis by decision trees and Bayesian methods, and (d) data analysis and forecasting through time series analysis. We do all this in Excel, with its powerful, yet intuitive, graphic interface.

However, the main emphasis of this course is not on *learning* Excel, but on systematic, logical, analytical thinking and problem solving *using* Excel. Working knowledge of basic Excel is assumed so that we can focus on analytical modeling and problem solving aspects of the course. However, a typical Excel user may not be familiar with more advanced tools, techniques and add-ins that have significantly increased the power of spreadsheet analysis. In this course we introduce and apply these advanced Excel skills, thereby furthering the spreadsheet knowledge base of even an expert Excel user. In particular, we employ Excel's **Solver** tool for decision optimization, **Simtools**and **@Risk** add-ins for Monte Carlo simulation, and **Precision Tree** software for analyzing sequential decisions over time. We also learn Excel's simple, yet powerful tools for data analysis, including **Pivot tables** and **Filters** that synthesize and summarize the available data, and **time series analysis** for forecasting. Thus the experience in spreadsheet modeling and analysis gained in this course help enhance students 'problem solving capabilities as well as Excel skills. And, hopefully, we all have fun doing so!

This course involves hands-on, in-class learning, so attending each class with a laptop, and coming to class well-prepared for active participation in problem solving are essential. Course requirements consist of building, analyzing, and solving models of assigned cases, creating a term project that illustrates a new application of the course material to a business problem of students' choice, and taking a final examination. Homework assignments and the term project may be completed in groups of three members.

The rest of this paper briefly outlines the main topics, along with business applications covered in the course.

2. Excel in Modeling

In this introductory module of three hours, we briefly review basic (and not so basic) Excel. Starting with the basics of developing formulas with relative and absolute cell referencing, and drawing and editing charts, we learn Excel tools such as *Goal seek* and *Solver*, as well as Excel's powerful *Data Tables* for sensitivity analysis. We do this through three applications: break even analysis, monopoly pricing, and buy versus lease decisions, learning along the way few financial functions such as NPV and PMT. Homework consists of two financial applications.

3. Optimal Resource Allocation

In this major course module of nine hours, we cover optimal allocation and valuation of limited resources as *the* fundamental problem of economics and management. Although the underlying methods of optimization are mathematical in nature, we do everything in Excel, which consultant Sam Savage calls as "tearing down the algebraic curtain". We start with linear optimization for a product mix problem set up in Excel, and use Solver to get the optimal solutions well as the sensitivity report. We learn the important concept of a shadow price and study its economic interpretation. We illustrate these concepts further with a blending problem. Binary optimization is illustrated by a project selection and product promotion problems, while bond portfolio selection and workforce planning problems illustrate integer optimization, and production planning involves mixed integer optimization. The module concludes with nonlinear optimization to construct risk-reward tradeoffs in portfolio selection. We also cover more advanced "array functions" in Excel including matrix multiplication. Homework consists of three cases involving product mix, blending, and production-inventory planning.

4. Risk Analysis

In this major module of 12 hours, we introduce uncertainty into decision models. After briefly reviewing basic probability and Bayes rule through a performance evaluation example, we introduce Monte Carlo simulation as a natural method of analysis through sampling from a given distribution. We then introduce single period inventory problem, and solve it three different ways, based on economic, probabilistic and simulation methods. We then develop binomial, Poisson, and normal distributions as models of uncertainty, and illustrate their applications to problems of revenue management, cash flow analysis, and competitive bidding. We also develop and analyze some advanced models of pricing stocks and options, and optimal stopping. The goal is to illustrate how such mathematically advanced models can be analyzed much more easily and intuitively through simulation in Excel. Finally, we consider sequential Bayesian decision analysis with information, with application to real options.

5. Data Analysis and Forecasting

In this short module of three hours, we illustrate Excel's simple but useful *Pivot tables* and (*Auto and* Advanced) *filters* for data analysis and develop forecasts by *Exponential smoothing* with trend and seasonality. This illustrates again the power of Excel in performing these computations with ease and intuition.

6. Course Materials

Although we do not follow any book closely, the recommended text for the course is *Practical Management Science*, by Wayne Winston and Chris Albright, which is in its 5th edition, published by Cengage Learning, 2016. The main required course packet consists of cases for classroom discussion, homework assignments, and supplementary readings. Although we use few Harvard Business School cases, most of the material is developed by myself and my co-authors.