36106 Managerial Decision Modeling
Introduction

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University of Chicago
Booth School of Business

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Reading and Excel Files

Reading (Powell and Baker):

- Chapter 1, Sections 1.1-1.3
- Chapter 2, Sections 2.1-2.2
- Chapter 4, Section 4.3.2, Sections 4.4-4.6

Files used in this lecture:

- hamilton.xlsx
- hamilton_key.xlsx
- HawaiiGetTax.xlsx

Lecture Outline

Syllabus and Course Policies

Prerequisities

Course Learning Objectives

Brief History of Excel and Why Excel

Spreadsheet Engineering

Managerial Decision Modeling

Equations and Circular Referencing

Syllabus and Course Policies

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Office Hours: Tuesday 2:30 PM - 3:30 PM, Wednesday 1:00 PM - 2:30 PM, or by appointment.

Canvas Website: `http://courses.uchicago.edu/`

Course Website: `http://faculty.chicagobooth.edu/kipp.martin/root/htmls/coursework/36106/36106.html`

TA: Kevin Chen (hongfan.chen@chicagobooth.edu)

Syllabus and Course Policies

Required Reading

1. *Management Science: The Art of Modeling with Spreadsheets,* Fourth Edition, by Baker and Powell (ISBN 978-1-118-58269-5) or *Business Analytics: The Art of Modeling with Spreadsheets,* Fifth Edition, by Baker and Powell (ISBN 978-1-119-29842-7). These two books are virtually identical except for the title change. I suggest you optimize on price.
2. Course Packet. See links at the Canvas Site.

Required Software

1. Microsoft Excel 2013 compatible for Windows.
2. The Palisade Corporation product DecisionTools Suite. This includes the Excel add-ins: Precision Tree, @RISK, and RiskOptimizer. This is available to students at the class Canvas site. This software may prove useful in other Booth courses.

Syllabus and Course Policies

Hardware and Software Issues

1. You must have a laptop for this course. It is essential to bring your laptop to class every week.

2. As a Mac lover and user, I find this bullet point painful. *You must be Windows compatible.* The Decision Tools Suite is *not* compatible with the Mac version of Microsoft Office. If you are a Mac user I recommend installing and using VMWare Fusion. I do not own a Windows machine and I use VMWare Fusion to develop the cases and examples for this class. Therefore Mac users should be safe with this option.

Syllabus and Course Policies

Midterm and Final Review Sessions

1. Tuesday, October 24: 5:00 PM - 7:00 PM, Gleacher Center

4. Tuesday, December 5: 5:00 PM - 7:00 PM, Gleacher Center

See the syllabus for the weekly topics and reading assignments.

Syllabus and Course Policies

Homework Assignments

1. A hard copy of the homework is **due at the start** of the class on the homework due date.
2. An electronic copy of the homework must be submitted to the Canvas site by 9 PM on the Friday it is due. **No late homework is accepted.**
3. Group work is encouraged. You may work in a group *up to size four*. You may form a group across sections. The group must submit the assignment for the earliest section that any of the group members attends.
4. You **may not** discuss the homework assignment with anyone not in your group. You may not transmit or receive any written or electronic information about the assignment to other students not in your group.

Syllabus and Course Policies

Grading:

Midterm	30%
Homework	30%
Final Exam	40%

- The **midterm** is Friday, October 27 from 1:30 PM - 4:30 PM Section 01 and 6:00 PM - 9:00 PM for Section 81.
- The **final exam** is Friday, December 8 from 1:30 PM - 4:30 PM Section 01 and 6:00 PM - 9:00 PM for Section 81.

Syllabus and Course Policies

Grading:

- If you miss the midterm the weight is added to the final (i.e. the final counts for 70% of your grade). I **strongly** suggest you do not miss the midterm. *This is a very dangerous option*.
- **Attendance:** Class attendance is extremely important. To master the material and apply these techniques in the real world requires full participation in class and goes beyond what is covered in homework and exams. You are permitted to miss two classes with no penalty. For each missed class thereafter you grade will be reduced by 3%.
- Your grade is determined using the percentages given above and is final.

Syllabus and Course Policies

Other Issues:

1. Students in this class are required to adhere to the standards of conduct in the Booth *Honor Code* and the Booth Standards of Scholarship. The Booth *Honor Code* also requires students to sign the following Booth Honor Code pledge, "I pledge my honor that I have not violated the *Honor Code* during this examination," on every examination and homework.

2. Booth has established that the upper bound for a class grade point average is 3.33. There are different grade combinations that result in a 3.33 and it is necessary to make tradeoffs. For example, an A and a B- average out to 3.33 and two B+ scores average out to 3.33. In the former case the B- student is unhappy. In the latter case the student who feels deserving of an A is unhappy.

Syllabus and Course Policies

Other Issues:

3. This course may not be taken pass/fail. Audits are not allowed.

4. I will address you by your first name, please feel free to address me by my first name. If you do not feel comfortable with that, Professor Martin also works.

5. Attending class is important. If you have to miss more than two classes you should consider taking this course when you have more time.

Syllabus and Course Policies

Other Issues:

6. Provisional Grades: if you are graduating this quarter and are making reasonable progress, I will assign a D for an early grade. You are **required** to take the final exam. After you take the final exam, I will adjust your grade. If you are graduating early **you must take the midterm.**

7. Please attend the section for which you are registered. If an important conflict arises such as job interview you may attend another section. However, because of how we use Canvas **you must take both the midterm and the final with the section for which you are registered.**

Syllabus and Course Policies

Other Issues:

8. Yes, I know you want to start Winter break early. However, you may not take an early final exam in order to get an early start on your Winter break. If you need to start your Winter break before the scheduled final exam, please do not take the course.

9. Material covered in Week 10 will be on the final exam. Week 10 is 10% of the quarter.

Syllabus and Course Policies

- **Please read the syllabus!**
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- **Please read the syllabus!**

Excel Prerequisities

Please see in the text:

- Chapter 3
- Appendix 1

Other great sources are Google and YouTube.

Other Booth Courses

The following courses are helpful but not required.

- Elementary knowledge of statistics at the level of 41000. Concepts such as a probability distribution, mean, and variance are used in this class.
- Elementary knowledge of financial accounting at the level of 30000. Net present value, discounting cash flows, etc.
- Elementary knowledge of microeconomics at the level of 33001. Profit maximization, demand and supply curves, price elasticity, etc.

Course Learning Objectives

1. Learn how to *structure* decision problems. In industry many extremely important decisions are made without clearly identifying the decision alternatives and relevant costs. In this class we will learn how to add structure to a problem by clearly identifying relevant variables, parameters, and sources of uncertainty.
2. Learn how to move from structuring a problem to actually building a mathematical model. Identifying the relevant variables, parameters, and sources of uncertainty is critical, but once this is done it is necessary to put this structure into an appropriate mathematical model. In this class we will learn about optimization models, decision tree models, and simulation models.
3. Learn how to incorporate uncertainty into the model. Virtually every decision problem involves uncertainty to some degree. It is important to understand which parameters can be treated as deterministic and which must be modeled using stochastic tools.

Course Learning Objectives

4. Learn how to analyze the model solution. Examine how robust the solution is, and how sensitive the results are to the model inputs.

5. Learn to use Microsoft Excel as the platform for model building, solution, and analysis. Microsoft Excel is one of the most widely used modeling and data analysis tools. In addition to standard Excel tools such as Goal Seek and Data Table, you will use learn to use important Excel add ons such as Solver, Precision Tree, @RISK, and RiskOptimizer. These tools can also be used in other Booth classes.

6. Learn how to apply spreadsheet modeling to important application areas such as finance, resource allocation, risk analysis, operations, marketing, and economics.

Course Learning Objectives

This course is about modeling in Excel.

Modeling Skill	Excel Implementation
Break-Even Analysis	Goal Seek
Sensitivity And What-If-Analysis	Data Tables/Scenario Manager
Optimization	Solver
Decision Trees	PrecisionTree
Risk and Uncertainty	@Risk
Optimization + Uncertainty	RiskOptimizer

We will also discuss good spreadsheet "engineering" throughout the quarter.

Brief History of Excel

The first spreadsheet program for the PC was **VisiCalc.**

Created by Dan Bricklin (Harvard MBA student) and his buddy Bob Frankston in 1978.

Product was sold and marketed by Dan Fylstra's (another Harvard MBA) company VisiCorp. Fylstra went on to develop **Solver**.

Lotus 1-2-3 was the first big commercial success.

- a spreadsheet
- a graphics package
- a database

Microsoft Excel is now the major player in this market.

Here is a link to the original Viscalc:

http://www.bricklin.com/history/vclicense.htm

An Aside

Here is a very interesting podcast from the NPR Planet Money on the history of spreadsheets.

`http://www.npr.org/blogs/money/2015/02/25/389027988/episode-606-spreadsheets`

Excel Features

- The key idea – have a formula associated with a cell, but the user sees the formula evaluation.
- Excel is excellent for creating graphs and histograms – this feature goes back to Lotus 1-2-3.
- Excel can serve as a database – this feature goes back to Lotus 1-2-3.
- Excel provides a huge library of functions – this library has grown immensely over time.
- You can add tremendous functionality to Excel by using VBA.

Excel Features

- You can use Excel for simulation. Excel is a great aid for decision making under uncertainty.
- You can use Excel for mathematical optimization.
- You can use Excel for modeling sequential decisions (decision trees).
- Excel can import and export data in various formats. It can even read and write XML.
- You can interface with other programs using Web services.

Why Excel?

There are a number of competing products.

- Similar comprehensive products include MATLAB, Mathematica and Maple
- Competitors in the area of statistics include SAS, R, S, and GAUSS.
- There are also programming and scripting languages such as Python, C++, Java, and Visual Basic (as opposed to VBA).

Why Excel?

So why are we using Excel instead of a competing product?

Willie Sutton has the answer. Who was Willie Sutton?

Spreadsheet Engineering

Spreadsheet engineering is extremely important.

Numerous studies show most spreadsheets have errors.

We will not have an explicit lecture on spreadsheet engineering. Rather, we will try to incorporate good design techniques throughout the quarter.

That said, **always separate data and model!**

Please read Chapter 3 of Powell and Baker.

Managerial Decision Modeling

In 2013 the Los Angeles Angels signed **Josh Hamilton** to a five year contract with the following payments.

Year	Salary (Millions)
2013	$25
2014	$15
2015	$23
2016	$30
2017	$30
Total	$123

The above payments do not reflect a $2 million contribution to the Josh Hamilton charitable foundation or other various perks and bonuses.

Was this a good decision by management?

Managerial Decision Modeling

This problem is not just for baseball fans!

Evaluating the decision by the Los Angeles Angels management to pay an employee $125 million is a generic problem.

- How much to pay to retain or obtain a *superstar* employee.
- How much to pay in wrongful death lawsuit.

Evaluating this decision illustrates much of what we will do this quarter.

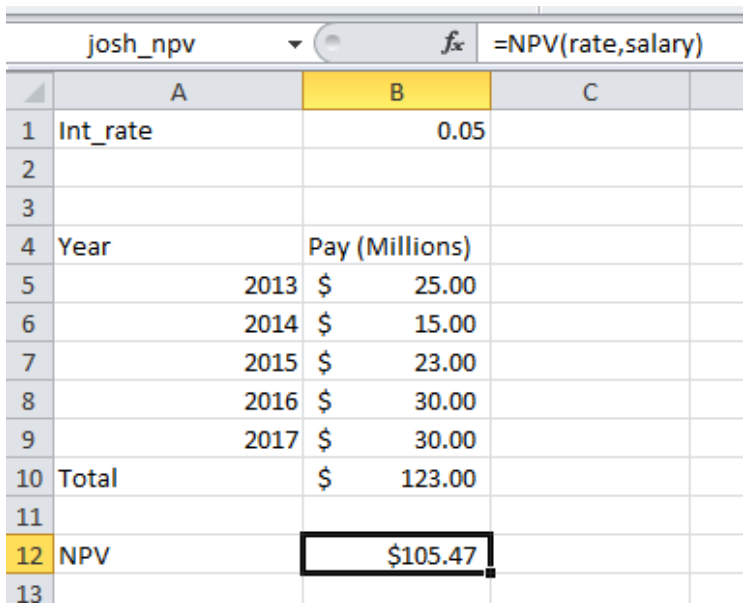
Managerial Decision Modeling

1. Learn to *structure a problem* in order to apply decision modeling – i.e. do the following:
2. Learn to identify objectives and constraints.
3. Learn to identify parameters that affect the model.
4. Learn to construct a simple model.
5. Learn to use the Excel NPV (Net Present Value) function.
6. Learn to use the Excel **Scenario Manager**, **Goal Seek**, and **Data Table** tools.
7. Learn to identify sources of uncertainty.

Managerial Decision Modeling

First Cut: At the minimum, let's at least make an NPV calculation of expenses (salary). Ignore the perks such as hotel suites.

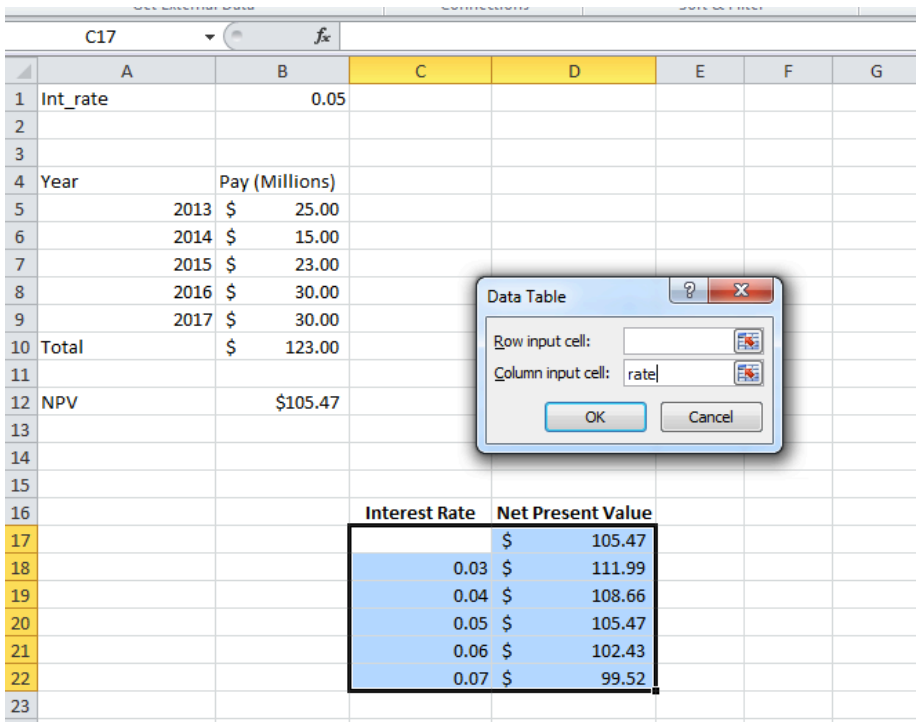
- Open the workbook **hamilton.xlsx**
- Calculate the NPV of salary payments for an interest rate of 5%.



Managerial Decision Modeling

Second Cut: Perform some trivial **Sensitivity or What-If Analysis.** Let's see how the NPV varies with the interest rate. Use Excel **Data Table**.

- Select the **Data** tab.
- Select the **What-If Analysis** Group
- Select the **Data Table** tool



Managerial Decision Modeling

Spreadsheet Engineering Tip 1: Use Range Names. Note the use of

- **rate**
- **salary**
- **josh_npv**

Spreadsheet Engineering Tip 2: Do not hard code parameters such as the interest rate. Define the interest rate in **only one** place.

See `http://www.youtube.com/watch?v=qWLHJ4dDUoo` for a nice video on constructing a Data Table.

Managerial Decision Modeling

Calculating the NPV of Josh Hamilton's salary and doing a What-If Analysis on the interest rate is a reasonable thing to do.

But so what?

Does knowing the discounted cash flow tell us if signing Josh Hamilton is a good thing to do?

Let's do some more sophisticated analysis.

- Identify **objectives** and **constraints**
- Identify **variables** and **parameters**

Managerial Decision Modeling

Learn to identify objectives and constraints.

What is the **objective function** of management?

- Win a World Series?
- Grow the fan base?
- Maximize profit for the next n years?
- Field a competitive team for the next n years?

What about **constraints**?

- Don't exceed a payroll limit?
- Avoid the luxury tax?

Managerial Decision Modeling

Learn to identify variables and parameters.

An example **variable** – ticket price, we can set that.

An example **parameter** – stadium capacity. We cannot change this, at least in the short run.

The stadium capacity is a **deterministic** parameter.

An example parameter – the number of games Josh Hamilton will play. *Nature* controls this.

The number of games Josh Hamilton plays is a **stochastic** parameter.

Managerial Decision Modeling

Second Cut Analysis: Consider potential *revenue increase from ticket sales alone*.

- The average attendance in 2012 was was 37,799 per game with a capacity of 83.3 percent.
  See `http://espn.go.com/mlb/attendance`.
- How much does attendance contribute to revenue?
  See `http://www.forbes.com/lists/2011/33/baseball-valuations-11_Los-Angeles-Angels-of-Anaheim_338666.html`.
- for 2013 ticket price (it was $22) information see
  `http://losangeles.angels.mlb.com/spring_training/tickets.jsp?c_id=ana`

Managerial Decision Modeling

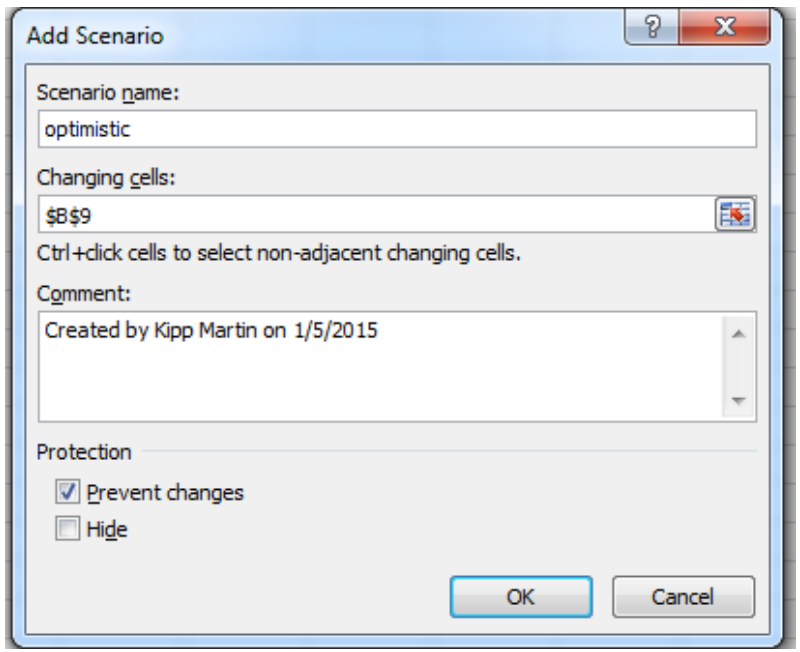
Second Cut Analysis: Consider potential *revenue increase from ticket sales alone*. See worksheet **revenues** in the workbook **hamilton.xlsx**.

- Calculate the NPV of additional ticket sales assuming a new capacity utilization number.
- Use **Scenario Manager** to create the following scenarios:
  1. Optimistic – assume a capacity utilization of .98
  2. Most Likely – assume a capacity utilization of .90
  3. Pessimistic – assume a capacity utilization of .85

Managerial Decision Modeling

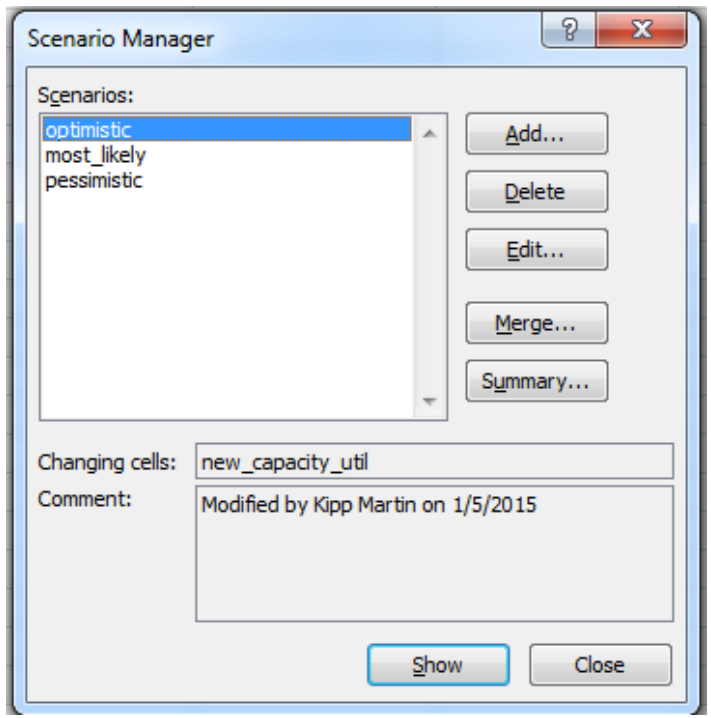
Using Scenario Manager: See the Tab **Data** and then the **What-If Analysis** Group. (See Section 4.3.2 of the text.)

In the What-If Analysis Group select **Scenario Manager** and add Optimistic, Most Likely, and Pessimistic scenarios.



Managerial Decision Modeling

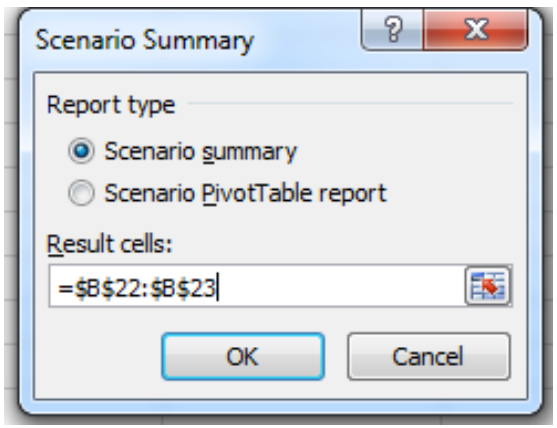
Using Scenario Manager: See the Tab **Data** and then the **What-If Analysis** Group.



Managerial Decision Modeling

Using Scenario Manager: Click on the **Summary** tab in Scenario Manager.

Pick the result cells you want in the summary. In this case we want revenue and salary npv.



Managerial Decision Modeling

Using Scenario Manager: Click on the **Summary** tab in Scenario Manager.

Scenario Summary				
	Current Values:	optimistic	most_likely	pessimistic
Changing Cells:				
new_capacity_util	0.98	0.98	0.9	0.85
Result Cells:				
revenue_npv	$52,703,150.89	$52,703,150.89	$24,594,803.75	$7,027,086.79
salary_npv	$ 105,470,089.99	$ 105,470,089.99	$ 105,470,089.99	$ 105,470,089.99

Notes: Current Values column represents values of changing cells at time Scenario Summary Report was created. Changing cells for each scenario are highlighted in gray.

Managerial Decision Modeling

Argh! Mr. Hamilton appears to be a fairly expensive acquisition!

In the optimistic scenario, the NPV of additional revenue is less than \$53 million yet the NPV of Hamilton's salary is *over* \$105 million.

Well, what would any good owner do? Let's increase ticket price!

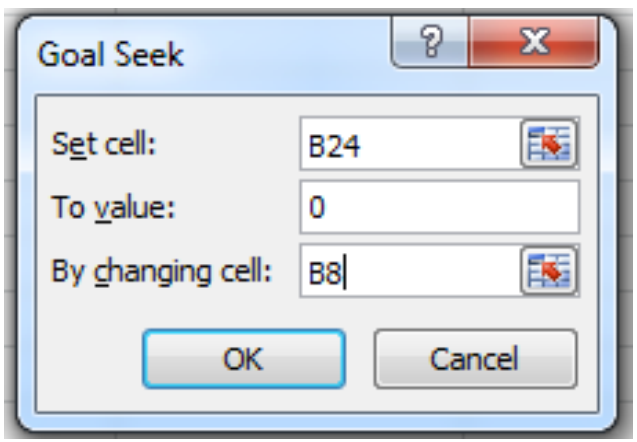
This is a good example of where **Breakeven Analysis** is useful.

Use **Goal Seek** to find the average ticket price so that the Angels break even. (See Section 4.4 of the text.)

Managerial Decision Modeling

Using Goal Seek: *Data* → What-If Analysis → *GoalSeek*. There are three things to pick:

- `Set Cell:` the cell you want to equal a certain value – in this case cell `breakeven`.
- `To Value:` The value that should be in the cell selected in `Set Cell` – this case $0 since we want a breakeven point.
- `By changing cell:` The cell that can change in order to give the value in the `Set Cell` – in this case cell `ticket_price`



Managerial Decision Modeling

The new average cost is approximately $25.37 per ticket to break even assuming a 98 percent capacity utilization.

Instead of raising ticket prices, what about other sources of revenue?

- Playoff revenues?
- Additional advertising dollars?
- Additional TV money?
- Parking and food (this is nontrivial – if you want to consume overpriced, bad food, eat at a ball park)?
- More merchandising (jerseys, etc.)?

How much additional revenue is necessary each year (going back to the $22 ticket price) in order to break even?

Use Goal Seek for this and assume the same amount of revenue each year.

Managerial Decision Modeling

Learn to identify sources of uncertainty.

Which of our parameters are deterministic?

Which of our parameters are stochastic?

What are other sources of uncertainty?

- an injury prone athlete
- an "old" athlete (games played versus chronological age)
- by his own admission, a person with a substance abuse problem

Our methods of dealing with uncertainty (Scenarios and Data Tables) are very primitive. Later we use @Risk and Monte Carlo simulation.

Hawaii GET Tax

Now we look at solving equations.

The state of Hawaii has a General Excise (Gross Income) Tax (GET) of 4% on retail sale of, goods, sale of services, contracting, commissions, rent, interest, and other activities. See `http://www.tfhawaii.org/taxes/get.html`.

The effect of this tax is quite predictable. Merchants markup their goods so that after paying the GET they get the revenue that they originally wanted.

The *Kalakaua Local Motion* surf shop would like to sell 72-inch surfboards for $450. What price should they ask for the surfboards so that they end up with $450 after paying the GET? What is the percentage markup?

Hawaii GET Tax

Solve the problem in a spreadsheet. See `HawaiiGetTax.xls`.

- in cell `B1` enter the GET which is 0.04
- in cell `B2` enter the desired price (revenue from sale of the surf board after paying the GET) which is $450
- in cell `B3` enter the amount of the markup which is

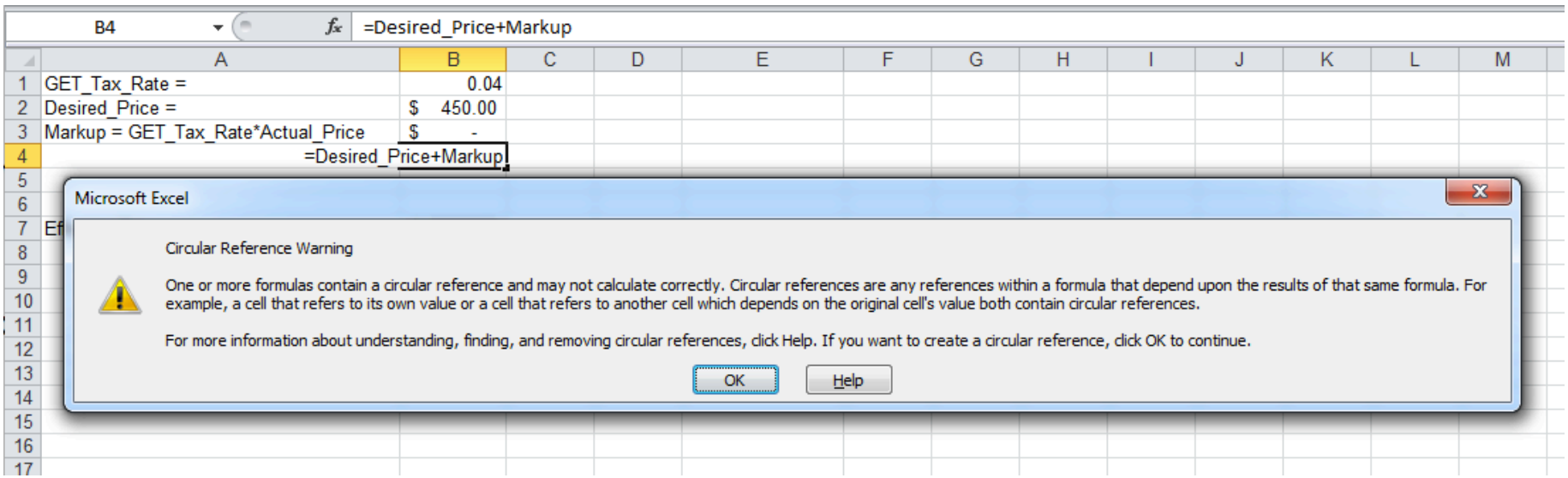
  `= GET_TAX_RATE*ACTUAL_PRICE=B1*B4`

- in cell `B4` enter the formula for the actual price the customer pays which is

  `=DESIRED_PRICE + MARKUP =B2+B3`

Hawaii GET Tax

Ugh! Here is what happens when I enter the formulas.



Hawaii GET Tax

Here is what is happening. The equations are:

```
GET_TAX_RATE = 0.04
DESIRED_PRICE = 450
MARKUP = GET_TAX_RATE*ACTUAL_PRICE
ACTUAL_PRICE = DESIRED_PRICE + MARKUP
```

Substitute out the constant terms

```
MARKUP = .04*ACTUAL_PRICE
ACTUAL_PRICE = 450 + MARKUP
```

Put constants on the right, variables on the left.

```
.04*ACTUAL_PRICE - MARKUP = 0
ACTUAL_PRICE - MARKUP = 450
```

I have two equations and two unknowns. **Why is this a problem?**

The Worksheet and Equations

Now let's really be mean to Excel. Consider the simple equations:

$$\begin{aligned} x + 3y &= 7 \\ 4x + y &= 6 \end{aligned}$$

The unique solution is $x = 1$ and $y = 2$.

In Excel name two cells `var_X` and `var_Y`.

In the cell named `var_X` put in the formula:

```
=7-3*var_Y
```

In the cell named `var_Y` put in the formula:

```
=6-4*var_X
```

The Worksheet and Equations

An Excel worksheet corresponds to system of equations. For every cell that is defined by an = (include all constant cells) define a variable and an equation. Let the variable be the cell label and the equation the cell formula.

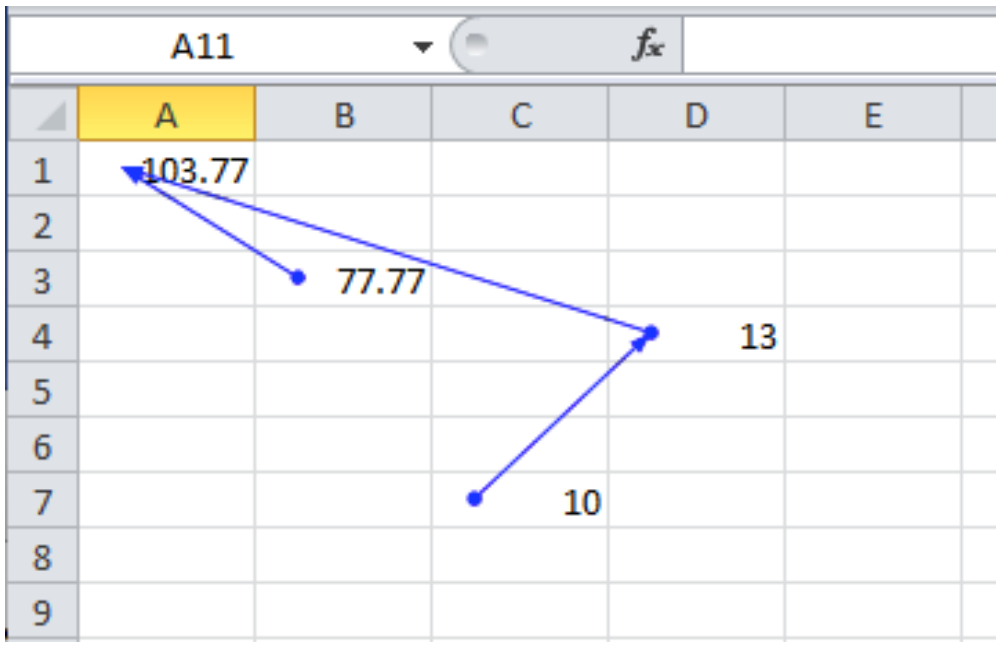
If cell `A1` contains `= B3 + 2*D4` then the corresponding equation is

$$A1 = B3 + 2*D4$$

A cell is a constant cell, if the variables in the cell formula become constants after recursive substitutions.

For example, if `A1` has the formula `=B3+2*D4`, cell `B3` has the formula `= 77.77`, cell `D4` has the formula `=C7+3`, and cell `C7` has the formula `=10` then `A1` is the constant cell `103.77`.

The Worksheet and Equations



Think of the cells as nodes of a graph with the **Trace Precedents** generating the arcs (arrows).

How would you characterize the graph?

The Worksheet and Equations

The system of equations generated from the Worksheet is a square system. Assume n variables and n equations.

$$\begin{aligned} f_1(x_1, x_2, \ldots, x_n) &= b_1 \\ f_2(x_1, x_2, \ldots, x_n) &= b_2 \\ &\vdots \\ f_n(x_1, x_2, \ldots, x_n) &= b_n \end{aligned}$$

The Worksheet and Equations

A triangular (in this case upper triangular) system can be written as

$$\begin{aligned} f_1(x_1, x_2, \ldots, x_n) &= b_1 \\ f_2(x_2, \ldots, x_n) &= b_2 \\ f_3(x_3, \ldots, x_n) &= b_3 \\ &\vdots \\ f_{n-1}(x_{n-1}, x_n) &= b_{n-1} \\ f_n(x_n) &= b_n \end{aligned}$$

The Worksheet and Equations

We had

$$\begin{aligned} x + 3y &= 7 \\ 4x + y &= 6 \end{aligned}$$

A triangular system would be

$$\begin{aligned} x &= 7 \\ 4x + y &= 6 \end{aligned}$$

or

$$\begin{aligned} x + 3y &= 7 \\ y &= 6 \end{aligned}$$

The Worksheet and Equations

If the system of equations corresponding to the worksheet is upper (lower) triangular no problem.

If it is **not** upper (lower) triangular you will get an error.

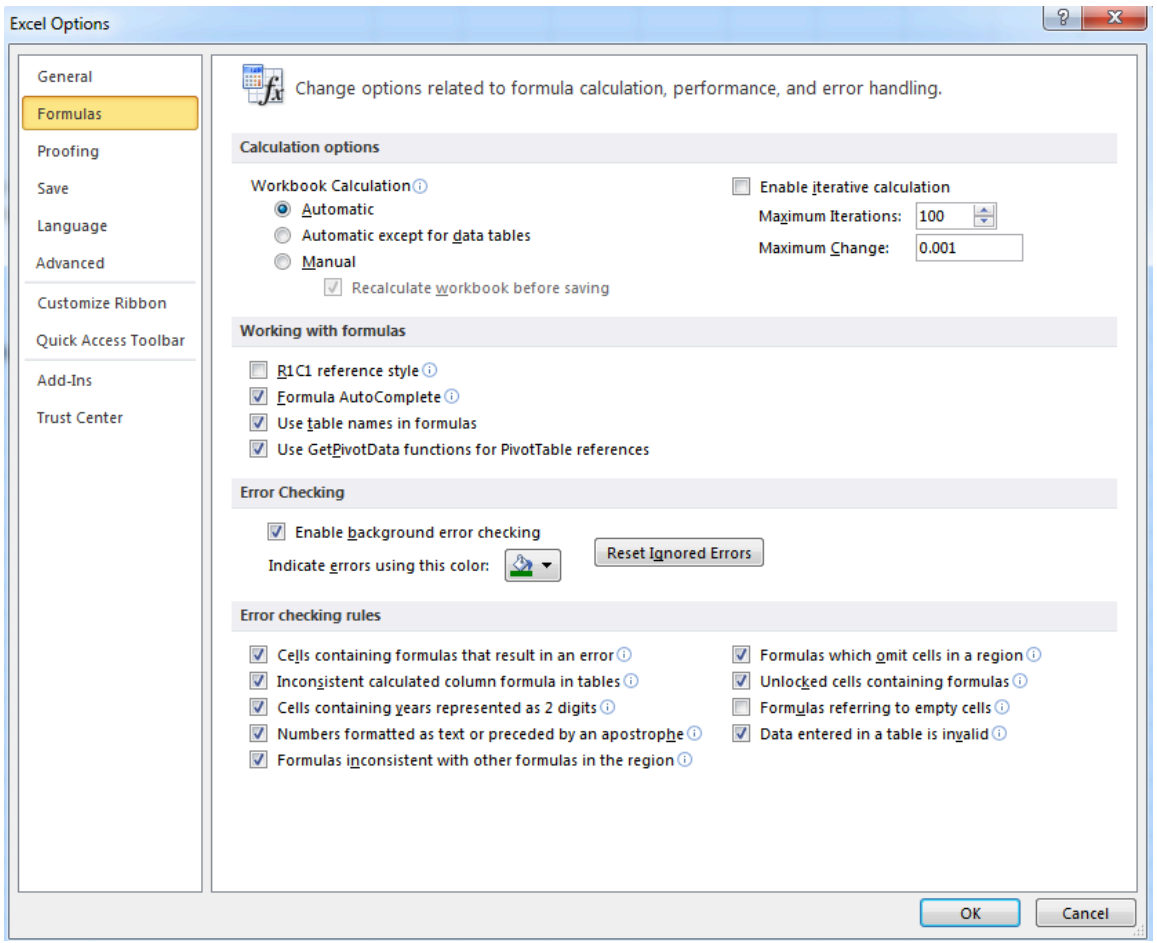
To avoid the error:

- Go to the `Tools menu` item
- Select `Options`
- Select the `Calculation` tab
- Check the `Iteration` box

This will *attempt* (perhaps without success) to find a solution to the system using Gauss-Seidel Iteration.

The Worksheet and Equations

Go to the `File` Tab and select `Options` and then `Formulas`. Click `Enable Iterative calculation`.



Where Are We Headed?

Excel is great! However, when it comes to sophisticated modeling, it is somewhat limited.

- Data Table and Scenario Manager *very limited* ways to handle uncertainty.
- Excel does not handle equation solving, or even worse optimization, very well.
- Excel is not good for sequential decision making (especially with uncertainty involved).

Solution: feed Excel performance-enhancing drugs (PEDS) in the form of Solver, PrecisionTree, @Risk, and RiskOptimizer.

References

Title: Competing on Analytics: The New Science of Winning
Author: Thomas H. Davenport , Jeanne G. Harris
Edition: First edition
Publisher: Harvard Business School Press
ISBN: 978-1-4221-0332-6

Title: Super Crunchers: Why Thinking-by-Numbers
is the New Way to be Smart
Author: Ian Ayres
Publisher: Bantam Books
ISBN: 978-0553384734

Title: The Flaw of Averages: Why we Underestimate Risk
in the Face of Uncertainty
Author: Sam Savage
Publisher: Wiley
ISBN: 978-0-471-38197-6

References

Title: The Numerati
Author: Stephen Baker
Publisher: Houghton Mifflin Company
ISBN: 978-0-618-78460-8

Title: Microsoft Office Excel 2010: Data Analysis and Business Modeling
Author: Wayne L. Winston
Edition: Third edition
Publisher: Microsoft Press
ISBN: 978-0-7356-4366-9