ESD.70J Engineering Economy

Fall 2006
Session One

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Link for this PPT:

Today’s class outline

1. Introduction
2. Course Outline and Philosophy
3. About Excel
4. Session 1 – base case construction and sensitivity analysis
About this class

• ESD.70 – Excel modeling
• Learn enough Excel to:
  – Become dangerous
  – Appreciate the power of Excel
  – Gain confidence in own Excel modeling prowess
  – Prepare for ESD.71

This class is:

• Informal:
  – Please ask questions at any time - A question not asked is a waste of your tuition money!
  – Compare notes/help each other
• Theoretically easy going:
  – I’ll cover a few relevant theories – you do NOT have to learn theory to benefit from this class
  – Just learn how to use them in Excel
• Take it for credit, or attend to learn/have fun
• No tests/exams!
Course Outline

Four (4) recitation-style sessions:
1. NPV and Sensitivity Analysis – today
2. Monte Carlo Simulation
3. Modeling Uncertainty with common stochastic models
4. Analyzing and Valuing the Flexibility and other advanced topics

Course Materials

• Excel spreadsheets on the web:
  – Session# – 1.xls : setup before the class
  – Session# – 2.xls : reflects all the work done in class
  – Do the exercises with me → the only way to learn
  – Refer to the Session# – 2.xls to validate your work

• Lecture PDFs – this is the first one...
• Files posted on the Web (ask for a CD if you can not connect)
Good Habits

• Help each other:
  – Introduce yourself to your neighbors … now!
  – It’s late in the day and everyone is liable to tune-out intermittently. When you do:
    • Check with your neighbor to catch-up
    • Ask me – please do!
    • Look-up solutions in Session# –2.xls file
  – Help your neighbor and he/she will help you (and you might make new friends)!
Course Philosophy

- Decision-making with an eye towards the future can be approached from two strategic directions:
  - **Deterministic** – improving forecast (and making the best decision based on the probabilities of the expected outcomes)
  - **Dynamic** – admitting that the forecast is likely to be wrong (trading-off suboptimal near-term decisions for the flexibility to delay longer-term commitment until the uncertainties resolve or the forecasts improve)
- Exercises built around analyzing the case of “Big vs. Small”

Human (in-)ability to forecast

*Heavier-than-air flying machine are impossible.*
Lord Kelvin – British Mathematician, Physicist, and President of the British Royal Society, c. 1895

*They couldn’t hit an elephant at this dis___*
General John Sedgwick – Union Army Civil War officer’s last words, uttered during the Battle of Spotsylvania, 1864

*Reagan doesn’t have the presidential look.*
United Artists Executive – dismissing Ronald Reagan for the starring role in the movie of THE BEST MAN, 1964

… weather … oil supply … stock market …
Modeling with dynamic mentality

- We cannot ignore the intrinsic uncertainty of the future \(\rightarrow\) Dynamic mentality in decision-making to the rescue
- Excel is a decent tool for decision analysis.
- Excel is far more powerful than you may think! It is the focus of this class.
- We teach how to unleash the power of Excel to model in a dynamic setting

Other courses

  - ESD.70 provides necessary knowledge of Excel for ESD.71
  - Introduction of advanced Excel techniques
- Want more \(\rightarrow\) consider ESD.76/.762 and others
Why Excel?

• Seems too simple …
• Why not something more exotic, like MatLab, SAS, C++, etc?

• Excel is a LOT more POWERFUL than you think
• Excel is ubiquitous
• Excel forces you to build your models at a granular level – great for learning the nuts and bolts
• Knowledge of Excel is assumed in ESD.71 and in many real-world modeling situations
• Excel models are relatively easy to explain, understand and debug

Why not Excel

• Quirky
• It will crash on you, not if but when…
• Performance limitations
• Data<->Model coupling  
  – Does not scale as data size grows
• Certain Functionality constraints  
  – it will take you VERY far, but at some point you may need to get really serious
Session one – Big vs. Small

- Objective:
  - Good spreadsheet setup habits to facilitate sensitivity analysis
  - Charts
  - One-way/two-way Data Tables
  - Goal Seek

Proper spreadsheet setup

- Programming/modeling → debugging
- Sensitivity analysis requires input changes

Good habits that will make your life easier:
- Enter inputs in a separate area or a sheet
- Set up the calculations by formulas linked to entries => NEVER HARD CODE INPUTS
NPV primer (Net Present Value)

- NPV = Net Cash Flows for all time periods
  \[ NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t} \]
  - where \( r \) reflects the riskiness of the cash flows

- \( NPV > 0 \) => profitable project

What Discount Rate ‘\( r \)’?

- ‘\( r \)’ reflects the riskiness of the cash flows
- Conversion rate across time
- Different ways to refer to \( r \)
  - Opportunity cost of capital
  - Required rate of return
  - Appropriate discount rate
  - Hurdle rate
  - Etc.
Set up NPV base case

Open session1-1.xls

*(we have saved you the joy of manually entering the data)*

Link for Excel: http://ardent.mit.edu/real_options/ROcse_Excel_latest/Session1-1.xls

Big vs. Small setup

- Building a computer plant
- Demand projections for years 1, 2 and 3 are 300,000, 600,000, and 900,000 respectively
- No sales in year 4 or thereafter
- Plan A – a big plant; Plan B – one small plant each year;
- Plants take 1 year to construct
- Big plant capacity of 900,000 with capital cost of $900 million
- Each small plant capacity of 300,000 with capital cost of $300 million
- No salvage value for Plan A; $300 million salvage value for Plan B
- Discount rate for plan A is 9%, Plan B 8%
- The company will sell each computer for $2,000
- Variable cost for Plan A is $1,280; Variable cost for Plan B is $1,500
### Worksheet for Plan A

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of plants</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Capacity (Thousand dollar)</td>
<td>900</td>
<td>900</td>
<td>900</td>
<td></td>
</tr>
<tr>
<td>Demand</td>
<td>300</td>
<td>600</td>
<td>900</td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>300</td>
<td>600</td>
<td>900</td>
<td></td>
</tr>
<tr>
<td>Unit Price (Thousand dollar)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Revenue (Million dollar)</td>
<td>600</td>
<td>1200</td>
<td>1800</td>
<td></td>
</tr>
<tr>
<td>Unit Variable Cost (Thousand dollar)</td>
<td>1.28</td>
<td>1.28</td>
<td>1.28</td>
<td></td>
</tr>
<tr>
<td>Variable Cost (Million dollar)</td>
<td>384</td>
<td>768</td>
<td>1152</td>
<td></td>
</tr>
<tr>
<td>Investment (Million dollar)</td>
<td>900</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Salvage (Million dollar)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Net value (Million dollar)</td>
<td>-900</td>
<td>216</td>
<td>432</td>
<td>648</td>
</tr>
<tr>
<td>Discount Factor @ 9.0%</td>
<td>1</td>
<td>0.917431</td>
<td>0.84168</td>
<td>0.772183</td>
</tr>
<tr>
<td>Present Value (Million dollar)</td>
<td>-900.0</td>
<td>198.2</td>
<td>363.6</td>
<td>500.4</td>
</tr>
<tr>
<td>NPV (Million dollar)</td>
<td>162.1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NPV (Million dollar) = \frac{1}{(1+9.0\%)^{3}}

### Worksheet for Plan B

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of plants</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Capacity (Thousand dollar)</td>
<td>300</td>
<td>600</td>
<td>900</td>
<td></td>
</tr>
<tr>
<td>Demand</td>
<td>300</td>
<td>600</td>
<td>900</td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>300</td>
<td>600</td>
<td>900</td>
<td></td>
</tr>
<tr>
<td>Unit Price (Thousand dollar)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Revenue (Million dollar)</td>
<td>600</td>
<td>1200</td>
<td>1800</td>
<td></td>
</tr>
<tr>
<td>Unit Variable Cost (Thousand dollar)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Variable Cost (Million dollar)</td>
<td>450</td>
<td>900</td>
<td>1350</td>
<td></td>
</tr>
<tr>
<td>Investment (Million dollar)</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Salvage (Million dollar)</td>
<td>300</td>
<td>750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net value (Million dollar)</td>
<td>-300</td>
<td>-150</td>
<td>0</td>
<td>300</td>
</tr>
<tr>
<td>Discount Factor @ 8.0%</td>
<td>1</td>
<td>0.925926</td>
<td>0.857339</td>
<td>0.793832</td>
</tr>
<tr>
<td>Present Value (Million dollar)</td>
<td>-300.0</td>
<td>-138.9</td>
<td>0.0</td>
<td>595.4</td>
</tr>
<tr>
<td>NPV (Million dollar)</td>
<td>156.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Few Excel Tricks

- Working with multiple sheets – referencing fields across sheets and files: “=Entries!C9”
- ‘$’ fixed cell references
- Entering series
- Conditional & permanent cell formatting

Check the solution sheet.

Please ask questions now…
Sensitivity Analysis

• With the “Big vs. Small” analysis, a manager may want to know:
  – What is the impact of changes in discount rate for Plan B while keeping the discount rate for Plan A constant?
  – What is the impact of simultaneous changes of two variable costs?

Tools for Sensitivity Analysis

• Data Tables (1- and 2-way)

• Charts

• Goal seek
Data Tables

• Use data tables to see how different input values affect the output.
• Data tables provide a shortcut for calculating, viewing and comparing multiple versions in one calculation (what-if scenarios)

• Two types of Data Tables:
  – one-way data tables: evaluate how changes in one input variable effect the output
  – two-way data tables (a matrix): evaluate how changes in two input variables effect the output

One-way Data Tables

• Step 1: Create a list of relevant input variable values either down a column (column-oriented) or across a row (row-oriented).
• Step 2: Enter the output formula:
  – If the data table is column-oriented, type the output formula in the row above the first value and one cell to the right of the column of values.
  – If the data table is row-oriented, type the formula in the column to the left of the first value and one cell below the row of values.
• Cells that hold output formulas in Data Table contain references to cells in the model.
One-way Data Table (Cont)

- Step 3: Select the range of cells that contains the formulas and values (no labels!), select “Table” under “Data” menu:
  - If the data table is column-oriented, type the cell reference for the input cell in the “Column input cell” box.
- The “input cell” is cell reference to the input variable in your model whose value Excel will vary as it iterates through the Data Table.
- Finally, click “OK”.

More Excel tricks

- Reference “input cell” MUST BE on the same sheet as the data table
  - Solution: establish a reference cell on the Data Table sheet referencing the input variable (worked for older Excel versions)
  - Insert Data Table on the Entries sheet
- Once you create a Data Table, you can then copy/paste it onto another sheet
One-way Data Table Example

- Varying discount rate for Plan B from 7.5% to 9.5%
- Incremental step 0.1%
- Keep discount rate for Plan A constant at 9%
- Calculate the delta of $\Delta (\text{NPV}_A - \text{NPV}_B)$ for each discount rate for Plan B
Give it a try…

Check with your neighbors…
Check the solution sheet…
Ask me questions …

Modifying Data Tables

- You can change the input values down the left-hand column of the Data Table. The Data Table recalculates automatically.
- You can NOT change the matrix size. If you want to extend the range of input values or change the number of output variable columns, you’ll need to erase and rebuild the Data Table.
- You can explore Data Table with output calculation beyond those in your model.
Two-way Data Tables

- Same idea as one-way, only now we explore output dependency on 2 inputs
- Expect a 2-D matrix

Step 1: Create one column and one row varying input values for each of the inputs
Step 2: Enter the output formula in the upper-left corner of the data table matrix.
Step 3: Select the range of cells that contains the formula and input values
Step 4: <Data>→<Table>. In the Row input cell and Column input cell boxes, enter corresponding output formula input references.
# Two-way Data Table Example

- Varying variable cost for Plan A from $1200 to $1450
- Varying variable cost for Plan B from $1400 to $1600
- Incremental step $100
- Find out the corresponding delta of \((\text{NPV}_A - \text{NPV}_B)\) for each pair of variable costs for Plan A and B

## Step 1

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1200</td>
<td>$1400</td>
</tr>
<tr>
<td>$1300</td>
<td>$1500</td>
</tr>
<tr>
<td>$1400</td>
<td>$1600</td>
</tr>
</tbody>
</table>

## Step 2

<table>
<thead>
<tr>
<th>Row 1</th>
<th>Row 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1200</td>
<td>$1400</td>
</tr>
<tr>
<td>$1300</td>
<td>$1500</td>
</tr>
<tr>
<td>$1400</td>
<td>$1600</td>
</tr>
</tbody>
</table>

## Step 3

![Excel Data Table Screenshot](image-url)
Conditional formatting

• You can vary text appearance with values
• Step 1: Enter value range for varying number appearance (i.e.: min/max)
• Step 2: Select the target formatting range
• Step 3: Define formatting rules: `<Format> → Conditional Formatting`

Give it a try….

Check with your neighbors…
Check the solution sheet…
Ask me questions …
• With the sensitivity analysis, we’ve generated a lot data for ‘what-if’ scenarios.

• Would it be great to generate a visual aid to summarize all the sensitivity analysis?

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Excel Charts

• Charts are used to take data from a table and transform it into a graphical illustration

• They are useful for displaying data patterns or results

• To create a chart, we will use the Chart Wizard
  – Click “Chart” under “Insert” menu
  – icon from standard toolbar
The Chart Wizard

- There are 4 main steps in using the Chart Wizard:
  - Step 1: Chart Type
  - Step 2: Source Data
  - Step 3: Chart Options
  - Step 4: Chart Location
- Chart Type = bar graph, scattered graph, pie chart...
- Source Data = data range or various series
- Chart Options = title, axes, legend, gridlines, etc
- Chart Location = object or chart sheet

Chart example

Plot the curve of $\text{NPV}_A - \text{NPV}_B$ as a function of discount rate for Plan B...
Chart example (Cont)

- Step 1: Chart Type – XY(Scatter)
- Step 2: Source Data
- Step 3: Chart Options
- Step 4: Chart Location

Give it a try….
Check with your neighbors…
Check the solution sheet…
Ask me questions …

Link for solution:
http://ardent.mit.edu/real_options/ROcse_Excel_latest/Session1-2.xls
Goal Seek

• Vary (find) input value until the output equals a desired target value
• Click “Goal Seek” under “Tools” menu
  – Set Cell
  – To Value
  – By Changing Cell

Goal Seek Example

• Determine the maximum variable cost of Plan A such that Plan A is favored, given the variable cost of small plants is $1,500.
  – Set Cell: NPV_A - NPV_B
  – To Value: 0
  – By Changing Value: where the variable cost for Plan A is

• Result?
Additional note: NPV function

- You may use NPV(rate,value1,value2, ...)
  - “rate” is the discount rate for one time period.
  - “value1”, “value2”, ... are the value you wish to discount
  - Excel’s NPV function assumes that all cash flows occur at the END of their time period. In other words, “value1” will be discounted at the rate of 1/(1+r)

- See sheet...

Additional Note: Text function

- When you change an input variable, you may wish that fact to be propagated through a text label:

  ![Discount Factor @ 9.0%](image)
Text Functions used:
"Discount Factor @ "&TEXT(Entries!C3,"##.0%")

- "&": Connects, or concatenates, two values to produce one continuous text value
- "text" function: Converts a value to text in a specific number in a specific format
  - #: format code for displaying only significant digits and does not display insignificant zeros
  - 0: format code for displaying insignificant zeros if a number has fewer digits than there are zeros in the format

Questions?
Comments?
Suggestions?
Summary

- Excel is a powerful DA modeling tool
- We’ve just scratched the surface
- Good habits will make your life easier *(separate input variables, no hard coding)*
- Data tables allow sensitivity analysis
- One picture is worth a thousand words *(Excel charts)*

Want to learn more Excel?

- MS Excel training:
Next class…

With the deterministic base case NPV sheet finished, we proceed onto the Monte Carlo simulation.

Critical class in the course!