ESD.70J Engineering Economy
Fall 2010
Session One

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http://ardent.mit.edu/real_options/ROcse_Excel_latest/Excel_Class.html

Today's class outline

1. Introduction

2. Course outline and philosophy

3. Session 1 – base case construction and sensitivity analysis

About this class

- Informal:
  - Please ask questions at any time
  - Compare notes/help each other
- Theoretically easy going:
  - Covering a few relevant theories – you DON'T 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
- For credit – no exam – one final assignment!

Beyond this class

- More about uncertainty and flexibility in 1.146/3.56/16.861/ESD.71/ESD.710 – Risk and Decision Analysis / Engineering Systems Analysis for Design
  - ESD.70 provides necessary knowledge of Excel for ESD.710/ESD.71
  - Introduction of advanced Excel techniques

- Want more?
  - ESD.712: Tools for Analysis: Design for Real Estate and Infrastructure Development
  - ESD.344: Real Options for Product and Systems Design
  - ESD.77: Multi-Disciplinary Systems Design Optimization

Course Outline

Four (4) recitation-style sessions:

1. NPV, Data Tables, and Sensitivity Analysis

2. Monte Carlo simulations

3. Modeling uncertainty using different stochastic models and probability distributions

4. Analyzing the system in the context of flexibility

Course Materials

- Excel spreadsheets
  - ESD70session# –1.xls : setup before the class
  - ESD70session# –2.xls : reflects all the work done in class
  - Do the exercises with me → best way to learn
    - Cells marked as �as▬ are for you to fill
  - Refer to the ESD70session# –2.xls to validate your work

- Lectures in PDF on the web

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 (recognizing uncertainty explicitly and the capacity to makes decisions along the way)

- Exercises built around analyzing the case of "Big vs. Small"

Modeling with dynamic mentality

- Cannot ignore the intrinsic uncertainty of the future → DYNAMIC mentality in decision-making to the rescue

- Excel is a decent tool for decision analysis

- We teach you how to unleash the power of Excel to model in a dynamic setting

Session one – Big vs. Small

- Objectives:
  - Good spreadsheet setup habits to facilitate Sensitivity Analysis (examples anyone?)

  - 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 <u>linked</u> to entries => NEVER HARD CODE INPUTS

Net Present Value (NPV) primer

- NPV = PV (Revenues) - PV (Costs)

$$NPV = \sum_{t=0}^{T} \frac{R_t - C_t}{(1+r)^t}$$

NPV ≥ 0 $\Rightarrow$ valuable project

'r': *reflects risk of project, expressed as required rate of return. Also called discount rate or opportunity cost of capital. It is a "translation factor" between present and future money*

Set up NPV base case

Open ESD70session1-1.xls

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

Big vs. Small setup

- Building a computer plant
- Deterministic 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 a few months 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%, and 8% for Plan B
- The company will sell each computer for $2,000
- Variable cost for Plan A is $1,280 due to economies of scale; Variable cost for Plan B is $1,500
- See "Entries" Worksheet...

Worksheet for Plan A

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

Worksheet for Plan A

Inputs

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

Solution

Calculations

Let's now fill the yellow spaces together…

Give it a try!

Check with your neighbors…

Check the solution sheet…

Ask me questions…

Worksheet for Plan B

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

Conclusion?

- Which plan is better?
  - Plan A: $162.1M OR;
  - Plan B: $156.5M

- Express this finding as the difference between NPV_A and NPV_B
  - In cell D31, type "='Plan A'!C16-'Plan B'!C16"
  - If positive, Plan A is better; if negative, Plan B is better
  - We'll use this in a couple seconds...

Sensitivity Analysis

- With the "Big vs. Small" analysis, a manager may want to know about:
  - Impact of changing the discount rate for Plan B to find the "best plan" between A and B
  - Impact of simultaneous changes in both plans' variable costs on the "best plan"

Tools for Sensitivity Analysis

- Data Tables (1- and 2-way)
  - What Excel was presumably invented for...
- 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 or <u>simulations</u>)

- Two types of Data Tables:

    – One-way Data Tables: evaluate how changes in one input variable affect the output

    – Two-way Data Tables (a matrix): evaluate how changes in two input variables affect the output
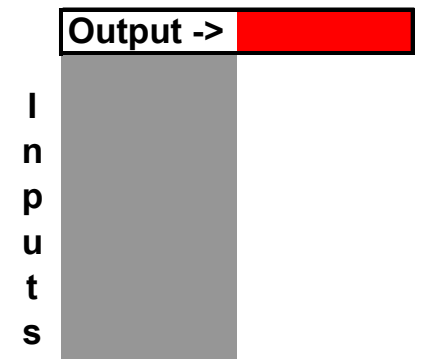
One-way Data Table

- Step 1: Create list of relevant input values (Plan B discount rates)
  - Either down a column (column-oriented) or across a row (row-oriented)
  - Varying discount rate for Plan B from 10.0% to 8.0%
  - Incremental step 0.1%

$NPV_A - NPV_B$

Plan B discount rate

10.0%	
9.9%	
9.8%	
9.7%	

One-way Data Table

- Step 2: Enter the output formula for NPV "='Plan A'!C16-'Plan B'!C16" in Cell D40:
  - If Data Table is **column-oriented**, output is in row above the first value and one cell to the right of the column of values

- Cells holding output values reference to cells in the model

Output ->

Inputs

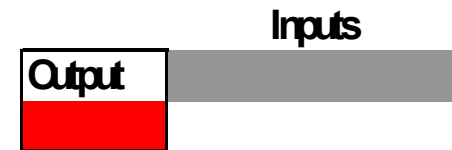NPV_A - NPV_B

Plan B discount rate   5.66

10.0%

9.9%

Output values

Output formula

One-way Data Table

- 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

Inputs

Output

One-way Data Table (Cont)

- **Step 3: create new output values**

  - Select the range of cells containing the formulas and values (no labels!)

  - Go to "Data" menu, select "Table"

    - Data menu $\Rightarrow$ 'What-If Analysis' in Excel 2007

  - Reference "**Column input cell**" to the input variable whose value Excel varies as it iterates through the Data Table (here Plan B discount rate)

    - If row-oriented, type the cell reference for the input cell in the "Row input cell" box

  - Finally, click "OK" (then press F9)

    - This calculates the delta of $NPV_A - NPV_B$ for each discount rate for Plan B

    - Keeps discount rate for Plan A constant at 9%

	$NPV_A - NPV_B$
Plan B discount rate	5.66
10.0%	
9.9%	
9.8%	
9.7%	
9.6%	
9.5%	
9.4%	
9.3%	

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

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More Excel tricks

- ISSUE: Reference *"input cell"* MUST BE on the same sheet as the data table

- SOLUTIONS:
    - Insert Data Table on the Entries sheet OR
    - Establish a reference cell on the Data Table sheet referencing the input variable (worked for older Excel versions)

- Once you create a Data Table, you can then copy/paste it onto another sheet, as done in sheets "One-way Data Table" and "Two-way Data Table"

Modifying Data Tables

- You can change the input values down the left-hand column of the Data Table. The Data Table recalculates automatically

- You CANNOT 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

Give it a try!

Check with your neighbors…

Check the solution sheet…

Ask me questions…

Two-way Data Tables

- Same idea as One-way, only now we explore output dependency on 2 inputs

- Expect a 2-D matrix

Two-way Data Tables

- Step 1: Create one column and one row varying input values for each of the inputs

  - Plan A variable cost varies from $1,200 to $1,450; for Plan B from $1,400 to $1,600

  - Incremental step $100

	1.40	1.41	1.42	1.43	1.44	1.45	1.46	1.47	1.48
1.20	-26.99	-11.92	3.15	18.21	33.28	48.35	63.41	78.48	93.54
1.21	-41.74	-26.67	-11.61	3.46	18.53	33.59	48.66	63.73	78.79
1.22	-56.49	-41.42	-26.36	-11.29	3.77	18.84	33.91	48.97	64.04
1.23	-71.24	-56.18	-41.11	-26.04	-10.98	4.09	19.16	34.22	49.29
1.24	-85.99	-70.93	-55.86	-40.80	-25.73	-10.66	4.40	19.47	34.54
1.25	-100.75	-85.68	-70.61	-55.55	-40.48	-25.41	-10.35	4.72	19.78
1.26	-115.50	-100.43	-85.37	-70.30	-55.23	-40.17	-25.10	-10.03	5.03
1.27	-130.25	-115.18	-100.12	-85.05	-69.99	-54.92	-39.85	-24.79	-9.72
1.28	-145.00	-129.94	-114.87	-99.80	-84.74	-69.67	-54.60	-39.54	-24.47
1.29	-159.75	-144.69	-129.62	-114.56	-99.49	-84.42	-69.36	-54.29	-39.22

Step 1

Two-way Data Tables

- 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 2

Step 3

	1.40	1.41	1.42	1.43	1.44	1.45	1.46	1.47	1.48
1.20	-26.99	-11.92	3.15	18.21	33.28	48.35	63.41	78.48	93.54
1.21	-41.74	-26.67	-11.61	3.46	18.53	33.59	48.66	63.73	78.79
1.22	-56.49	-41.42	-26.36	-11.29	3.77	18.84	33.91	48.97	64.04
1.23	-71.24	-56.18	-41.11	-26.04	-10.98	4.09	19.16	34.22	49.29
1.24	-85.99	-70.93	-55.86	-40.80	-25.73	-10.66	4.40	19.47	34.54
1.25	-100.75	-85.68	-70.61	-55.55	-40.48	-25.41	-10.35	4.72	19.78
1.26	-115.50	-100.43	-85.37	-70.30	-55.23	-40.17	-25.10	-10.03	5.03
1.27	-130.25	-115.18	-100.12	-85.05	-69.99	-54.92	-39.85	-24.79	-9.72
1.28	-145.00	-129.94	-114.87	-99.80	-84.74	-69.67	-54.60	-39.54	-24.47
1.29	-159.75	-144.69	-129.62	-114.56	-99.49	-84.42	-69.36	-54.29	-39.22

Two-way Data Tables

- Step 4: Menu "Data" → Table

  – In the **Row input cell** and **Column input cell** boxes, enter corresponding output formula input references

  – Find out the corresponding delta of $(NPV_A - NPV_B)$ for each pair of variable costs for Plan A and B

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

5.66		1.40	1.41	1.42
1.20		-26.98631191	-11.92001104	3.14629
1.21		-41.73833677	-26.6720359	-11.6057
1.22		-56.49036163	-41.42406076	-26.3578
1.23		-71.24238649	-56.17608562	-41.1098
1.24		-85.99441135	-70.92811048	-55.8618

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"

  – Home menu $\Rightarrow$ Conditional Formatting $\Rightarrow$ Highlight Cell Rules in Excel 2007

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Give it a try!

Check with your neighbors...

Check the solution sheet...

Ask me questions...

Excel charts

- 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 this information?

The Chart Wizard

- There are 4 main steps in using the Chart Wizard:

  - Step 1: Chart Type = Bar Graph, Scattered Graph, Pie Chart…

  - Step 2: Source Data = data range of various series

  - Step 3: Chart Options = Titles, Axes, Legend, Gridlines, etc

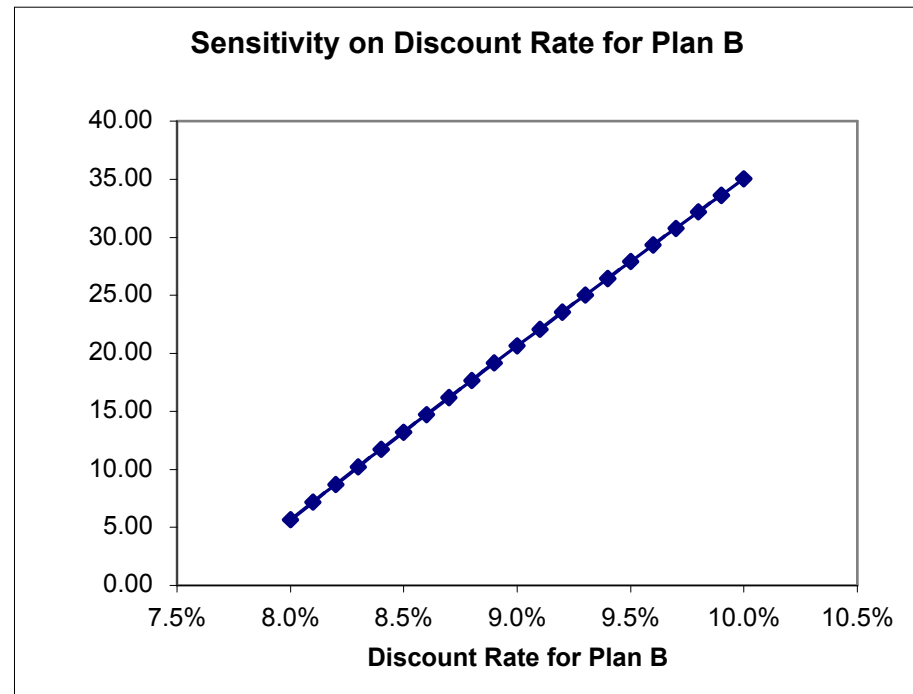 - Step 4: Chart Location = object or chart sheet
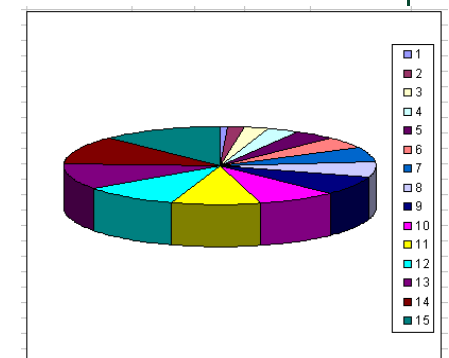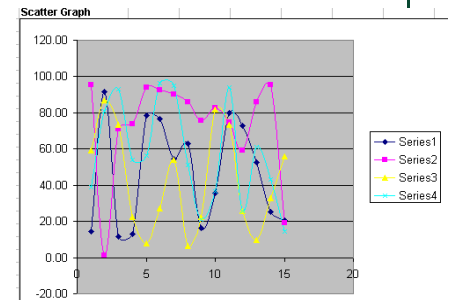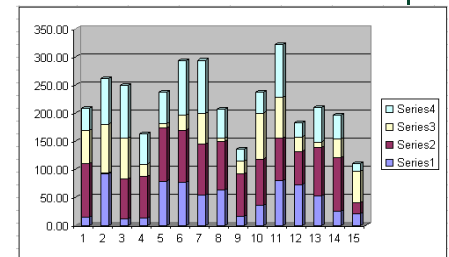
Excel charts

Plot the curve of $NPV_A - NPV_B$ as a function of discount rate for Plan B…

Chart example

- Step 1: Chart Type
  - XY(Scatter) with data points connected
- Step 2: Source Data
- Step 3: Chart Options
  - Titles, Legend, etc...
- Step 4: Chart Location
  - As object in "Entries"

Sensitivity on Discount Rate for Plan B

Give it a try!

Check with your neighbors…

Check the solution sheet…

Ask me questions…

Goal Seek

- Vary (find) input value until the output equals a desired target value

- Click "Goal Seek" under "Tools" menu on Mac, Data $\Rightarrow$ 'What-If Analysis' on PC
  - "Set Cell": cell whose value is changed to target value
  - "To Value": desired target value
  - "By Changing Cell": precedent cell value affecting desired output

Goal Seek Example

- Determine the maximum variable cost of Plan A such that Plan A is favored, given the variable cost of Plan B is $1,500

  - Set Cell: $NPV_A - NPV_B$ (or C3 in "Goal Seek" tab)

  - To Value: 0

  - By Changing Value: variable cost for Plan A (or D18 on "Entries" tab)

- Result?

  - $1,283.83/unit

Additional note: NPV function

- You may use NPV(rate,value1,value2, …)
  - "rate" is the discount rate for one time period
  - "value1", "value2", … are values 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 value to be propagated through a text label:

Discount Factor @ 9.0%

Additional note: Text function

- Text Functions used: ="Discount Factor @ "&TEXT(Entries!D3,"##.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 tool for decision-making

- We've just scratched the surface

- Good habits will make your life easier

  – Separate input variables, no hard coding

- Use Data Tables for Sensitivity Analysis

- One picture is worth a thousand words

  – Excel charts

- Reach a target value using Goal Seek

Next class…

With the deterministic base case NPV sheet finished, we proceed to Monte Carlo simulations

CRITICAL PART OF THE COURSE

See you tomorrow!