

## ESD.70J Engineering Economy Module

4 Sessions: (Monday – Wednesday) 5h30pm to about 7h30pm  
[Additional 1 hour session for absolute beginners, 4.30 of first Monday]

Room 32-115 (Stata Center)

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### **BRING LAPTOPS TO CLASS, PREFERABLY WIRELESS NETWORK READY**

This intensive micro-subject provides the necessary skills in Excel spreadsheet modeling for ESD.71 – Engineering Systems Analysis for Design. It is also useful for a variety of other subjects. Its crux is the dynamic rather than the general deterministic modeling.

Its purpose is to bring entering students up to speed on some of the advanced techniques that we routinely use in analysis. It is motivated by our experience that many students only have an introductory knowledge of Excel, and thus waste a lot of time thrashing about unproductively. Many people think they know Excel, but overlook many efficient tools – such as Data Table and Goal Seek.

We assume students know Excel basics such as referencing, names, functions, and formulas. If you do not know these basics, please get yourself an introductory manual and learn them.

Three units of credit are offered to those who care to complete the assignment. However, we expect most students will simply learn from doing the worked out examples in class, and will not require credit.

### **Day One – NPV and Sensitivity Analysis**

Objective: set up spreadsheet properly for efficiency, set up charts, and understand sensitivity analysis by Data Table

#### Issues:

1. proper set-up of spreadsheets: entire entries of input in separate area; set up by formulas (the question is generated from the self-assessment problem)
2. one-way/two-way Data Table (one-way Data Table: for sensitivity on the discount rate for Plan B while the discount rate for Plan A is fixed ; two-way Data Table: for sensitivity on variable costs of Plan A and B; using Goal Seek functionality to find the maximum of variable cost for Plan A so that Plan A is still favored)
3. drawings (Plot the difference of NPVs for the two plans)
4. reference point for the function of “NPV” (also, students need to know how to set up the NPVs using formulas) examples of the use of “Text” function.

Steps:

1. opening introduction of the course (objective, schedule, teaching methods, and requirements)
2. objective of the class on Day One
3. question (for set-up of the base case), students try 5 minutes
4. lecturing on proper set-up of the spreadsheet and charts
5. students setup the spreadsheet for the base case, 15 minutes
6. posting solution
7. Q&A
8. question (for sensitivity analysis), students try 5 minutes
9. lecturing on Data Table/Goal Seek/Drawings
10. students set up spreadsheet for sensitivity analysis, 15 minutes
11. posting solution sheets
12. lecturing on "NPV" and "Text" function
13. Q&A

**Day Two - Simulation**

Objective: random number generator (using simple even distribution), how to count, and simulate

Issues:

1. random number generator function such as "Rand()"
2. function such as "Countif"
3. generating Histogram, Cumulative Distribution Function
4. establish a complete simulation sheet (simulate 2000 times for NPV of Plan A)

Steps:

1. Objective for the class
2. question (generate a random realization of demand over years), students try 5 minutes
3. lecture on random number generation function
4. students set up spreadsheet for generating realization of demand, 15 minutes
5. posting solution
6. Q&A
7. question (how to simulate thousands of times and draw histogram and CDF), students try 5 minutes
8. Lecturing
9. students set up spreadsheet for simulation, 15 minutes
10. posting solution sheets
11. Q&A

**Day Three – Modeling Uncertainties**

Objective: generation of advanced distribution of random variables and the statistical package to analyze available data

Issues:

1. Triangular, normal, lognormal distribution
2. exponential growth of demand
3. trend plus uncertainty (generating a stock price realization path)
4. try call option
5. statistical analysis tools to find out important parameters from data set (find out average return and standard deviation for return)

Steps:

1. objective of the class
2. lecture on triangular, normal, and lognormal distribution, exponential growth
3. question (simulate stock price), tell them basics for stock price movement
4. students setup the spreadsheet for stock price movement
5. posting solution sheet
6. ask how to simulate a call option and give answer
7. Q&A
8. lecture on statistical analysis tool
9. question (find out average return and standard deviation for return)
10. students work on a data set of stock price
11. posting results
12. Q&A

**Day Four – Analyzing Flexibility and other**

Objective: What-if analysis and building contingency rules (flexibility) into the spreadsheet, and further

Issues:

1. logical functions (“if”, “and”, “or”, etc.)
2. Value at Risk and Gain (VARG) Chart
3. using spinner to facilitate sensitivity analysis for simulation spreadsheet where Goal Seek does not work
4. introduction to using Solver
5. future self-learning: overview of Excel, how to use Excel Help

Steps:

1. objective of the class
2. question (adding flexibility and simulating to see what happens), students try 5 minutes
3. introducing logical functions
4. students set up spreadsheet for studying flexibility
5. posting solution sheets
6. Q&A
7. Questions on VARG, students try 10 minutes
8. posting solution sheets
9. Q&A
10. question (find out the maximum of variable cost for Plan A so that Plan A is still favored under uncertain demand), students try 10 minutes
11. posting solution sheets
12. Q&A
13. lecturing on self-learning Excel and overview of Excel for future guidance

## Appendix

### Big or small?

A manufacturer is considering two investment programs to supply a new PC. Market research anticipates rapid market growth: sales are expected to be 300,000 the first year, 600,000 the second, and 900,000 the third. However, the company recognizes that actual sales may differ by plus or minus 50%.

The company has two plans to produce 900,000 units:

- **Plan A.** Build a single plant that could produce 900,000 units. Construction would cost \$900 million and be finished in a year. The company would get \$2,000 per computer sold, and the incremental manufacturing costs beyond the capital cost of the plant is expected to be \$1,280 per computer.
- **Plan B.** Build three 300,000 unit plants, one each year, in an effort to match expected annual demand. The capital expenditure for each small plant is \$300 million. The smaller plant has a unit manufacturing cost of \$1,500. This plan gives the company the flexibility not to build successive plants if the demand falls short in the first or second year.

Note that both plans have drawbacks:

- Plan A involves a large amount of excess capacity in the first two years until market demand grows; and there is always a chance that demand falls short of expectations. Thus the demand in year 3 might be as high as 1.35 million or as low as 450 thousand units.
- Plan B is less efficient. Also, if the demand grows faster than expected, it cannot take advantage of it.

The CFO asks you to prepare spreadsheets to analyze this decision. As the company will want to carry out extensive sensitivity analyses on the spreadsheet, all the input variables must be set in an input sheet, so that the rest of the spreadsheet will be an automated black-box that generates the required results. :

**Step 1:** Based on the forecast demand expectation without variability, set up a spreadsheet to calculate the net present values (NPVs) for Plan A, and Plan B with an inflexible expansion plan (build one plant each year regardless of market demand). Based on this first analysis, which plan is better? See end of exercise for assumptions you should use for the NPV analysis.

**Step 2:** Now consider the effect of uncertain market demand. Assuming that the market forecast is evenly distributed over the range, simulate the performance of Plan A, and Plan B without the flexibility.

- Generate random demand scenarios and use “Data Table” function to simulate 2000 scenarios for both plans;
- Get the maximum, minimum, and expected NPVs for both plans;
- Draw the histogram for the distribution of NPVs and the cumulative probability function (i.e, the Value at Risk and Gain (VARG) curve) and
- Determine the probability that the company loses money (NPV is less than 0) for each plan.

**Step 3:** Embed flexibility into Plan B, that is, give the company the opportunity to decide not to construct one or two smaller plants, into the sheet for Plan B. Use the decision rule that the next small plant is not built if the demand is less than capacity.

- Simulate the performance of Plan B with this flexibility;

- Get the maximum, minimum, and expected NPVs ;
- Draw histogram for the expected NPVs and the VAR<sub>G</sub> curve;
- Determine the probability that the company loses money;
- Comparing the results for Plans A, B with and B without flexibility, what are your observations and recommendation?

**Step 4:** Now, suppose the Chief Engineer reports that the manufacturing cost per computer for the big plant can be reduced. Determine the maximum of this cost such that Plan A is still favored.

**Assumptions for NPV analysis:**

- Use a discount rate of 9% for Plan A, and 8% for Plan B.
- No salvage value for Plan A at year 3. Salvage value for Plan B is \$300 million at year 3.
- No corporate overhead or selling costs allocated to the projects.
- For simplicity, assume that a new PC will replace the product in the 4th year so that there will be no sales in year 4 and beyond.

(This problem is inspired by Copeland, T. (2002) "The Growth Ladder," Harvard Business School Case N9-202-098, Rev: March 8.)