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ENGINEERING SYSTEMS ANALYSIS FOR DESIGN Final Examination, 2006

I will complete this test fairly, without copying from others, a book, or the web.

Please sign your name legibly ____ (1 point)

Item	Points	
	Possible	Achieved
Your Name	1	
1 Cost of Plant	18	
2 Engrg Economy Valuation	21	
3 Decision Analysis	19	
4 Value of Information	16	
5 Lattice Development	27	
6 Value at Risk and Gain	18	
7 Option Evaluation	60	
TOTAL POSSIBLE	180	
TOTAL ACHIEVED		
GRADE ON 100% (TOTAL/1.80)		

Structure of the Exam
The questions all tie to the design and justification of a proposed project. They take you through the material of the course from the beginning to the end.

The technological part is deliberately simple, to reduce the complexity of the calculations and focus on the concepts of the course.

Project
You are the chief engineer responsible for the design of an automobile assembly plant. As such, you need to justify the design to the decision-making board that can authorize the project.

GIVE RESULTS USING TWO-DECIMAL PLACE ACCURACY

Grading
The concepts are the focus of the exam. You will earn most of your points by demonstrating that you know what the correct procedures are, and how to use them. You will do this by "running the numbers'. However, in this exam the numbers themselves are not too important – points will be deducted for mistakes, but neither the course nor the exam is focused on arithmetic.

Because the focus is on the concepts, you should clearly indicate how you going about each part of the exam so that we can give you the credit you deserve.

If the numbers are wrong and you have not explained your analysis, we will not be able to give you credit.

BEST WISHES!

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1. Cost of Plant (18 points)

Your engineers have come up with a design for the plant. Their design capacity is 160,000 cars/year, based on an estimated initial production of 80,000 cars/year, that would double every 10 years (that is, would grow at about 7% /year compounded).

As you wonder whether if it might be better to roll out the capacity in a couple stages, your staff gives you their formula for estimating the cost of building assembly plants:

Cost of building and equipping plant = $16 + 0.01\,(\text{Capacity})^{3/4}$ **[Eqn 1]**

The cost is expressed in terms of millions of dollars; the capacity in terms of cars/per year.

a) Define "economies of scale". How do these differ from "increasing returns to scale" ? **(4 pts)**

b) Does **[Eqn 1]** exhibit economies of scale? Increasing returns to scale? Explain each answer **(4 pts)**

c) In general, if a cost function does NOT exhibit economies of scale, how would this fact affect your thoughts about developing a project in stages? **(4 pts)**

d) Define the concept of the "cost function" and its connection to the production function. **(4 pts)**

e) What would you call **[Eqn 1]**? **(2 pts)**

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2 Engineering Economy Valuation (21 pts)

Being pressed for time, you decide to see if you can justify the "base case" project proposed by your design staff. Therefore you do some traditional calculations.

As previously, you assume that the

- design is for Capacity = 160,000 cars/year
- cost formula is: Cost = 16 + 0.01 (Capacity) $^{3/4}$ -- in millions of dollars
- initial production = 80,000 cars/year
- growth rate ~ 7 % /year (which means that it doubles every 10 years, which is the equivalent of increasing by √2 every 5 years)

You further assume that

- life of plant is 15 years
- net revenues (in millions) in any 5-year period
  = 5 x (production at end of the period in thousands) x ($0.2 per 1000 cars) **[Eqn 2]**
- revenues are paid in at the end of each period
- the company normally uses a discount rate ~ 15%, which is its estimated WACC

In keeping with 2 decimal point accuracy, use: (1 +0.15) exp(5) = 2

Not having a spreadsheet available, you will do your analysis by filling in the table below.

Base Case Project

Years	Units	0	1- 5	6 -10	10 -15
Production at period end	thousands	0	113	160	160
Net Revenue for 5 years	millions	----			
Cost	millions		-----	-----	-----
Net Cash Flow	millions				
Discounting Factor at 15%					
Discounted Cash Flow	millions				
Net Present Value	millions				

a) What is your estimate of the project NPV? **(10 pts)**

b) Define pay-back period. Estimate it for the project. **(4 pts)**

c) Define internal rate of return. Guess at it for the project and give reasoning. **(3 pts)**

d) One of your engineers asks you to justify the discount rate, "…which is a lot more than the bank interest rate!" You therefore explain that the WACC is….. **(4 pts)**

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3 Decision Analysis (19 pts)

Wondering about the desirability of an alternate design that would develop the project in 2 phases, both to defer construction costs and provide for future production, you decide to do a simple decision analysis to test the following alternatives:

- Base Case: build 160,000 capacity now
- Phased Case: build for 80,000 at start, add 80,000 capacity at end of 5 years
- The cost of construction is as before: 16 + 0.01 $(\text{Capacity})^{3/4}$
  (Calculation help: (1/8)^(1/4) = 0.5946)
- When you expand in year 5, you immediately pay the construction costs and obtain the expanded project (so that the revenues for the expanded project are applied to the following 5-year period).

However, your tax consultants advise that there is a 1/3 chance that local authorities will give your company tax benefits if you expand (as opposed to no tax benefits if you choose to build the "base case"). The tax benefits would be realized as a doubling of net revenues per car **after** year 5.

Phased Project (with no tax benefit)

Years	Units	0	1-5	6-10	10-15
Production at period end	thousands	0	80	160	160
Net Revenue for 5 years	millions	----			
Cost	millions			----	-----
Net Cash Flow	millions				
Discounting Factor at 15%					
Discounted Cash Flow	millions				
Net Present Value	millions				

Phased Project (with tax benefit that double net revenues after year 5)

Years	Units	0	1-5	6-10	10-15
Production at period end	thousands	0	80	160	160
Net Revenue for 5 years	millions	----			
Cost	millions			----	----
Net Cash Flow	millions				
Discounting Factor at 15%					
Discounted Cash Flow	millions				
Net Present Value	millions				

a) Draw the decision tree. Fill in all relevant data. (**15 pts)**

b) Which is the better choice? The base case or the phased project? **(4 pts)**

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4 Value of Information (16 pts)

Thinking about the possibility that the phased alternative is attractive, you decide to estimate whether if would be worthwhile to gather better information on the possibility that the local authorities might give you the tax benefit. You plan to do this using EVPI.

a) "What's this 'perfect information' stuff?" asks a fellow project manager. "Nobody's perfect!"
You then explain the concept of EVPI using the following words: **(5 pts)**

b) To reinforce the above, you draw the diagram showing the decision tree associated with EVPI about the tax benefit **(5 pts)**

c) What is your estimate of EVPI in this case? **(4 pts)**

d) What is the most money you might justify spending to improve your information? **(2 pts)**

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5 Lattice of Probabilities (27 pts)

After using decision analysis to reach some conclusions regarding the phasing of the plant in view of the possibility of tax benefits, you start looking into production uncertainty.

You model the evolution of production with a binomial lattice, based on these parameters:

- Initial production = 80,000 cars/year
- Annual Growth, v = 7%
- Std Deviation of change in demand over 1 year, σ = 35%

As previously, you are looking at 3 blocks of 5 year periods

Useful formulas:

$p = 0.5 + 0.5\,(v/\sigma)\,\sqrt{\Delta T}$ $u = e$ power$[\sigma \sqrt{\Delta T}]$ $d = 1/u$

a) Using the data table on next page, what are the values for p, u, d ? **(5 pts)**

b) Fill in the Tables **(14 pts)**

Table of Probabilities at nodes

Year 0	Year 5	Year 10	Year 15
1			

Table of Production at end of each 5-year period (in thousands)

80			

c) Draw the distribution of production in year 15. Label axes and use grid to scale accurately **(8 pts)**

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Image of Data Table defining formula

sigma, σ	0.1									
Δ T	0.5									
					Sigma, σ					
e power[σ vΔT]	1.073271	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5
	0.5	1.07	1.11	1.15	1.19	1.24	1.28	1.33	1.37	1.42
The “v” is a square root symbol	1	1.11	1.16	1.22	1.28	1.35	1.42	1.49	1.57	1.65
	1.5	1.13	1.20	1.28	1.36	1.44	1.54	1.63	1.74	1.84
	2	1.15	1.24	1.33	1.42	1.53	1.64	1.76	1.89	2.03
	2.5	1.17	1.27	1.37	1.48	1.61	1.74	1.88	2.04	2.20
	3	1.19	1.30	1.41	1.54	1.68	1.83	2.00	2.18	2.38
	3.5	1.21	1.32	1.45	1.60	1.75	1.92	2.11	2.32	2.55
	4	1.22	1.35	1.49	1.65	1.82	2.01	2.23	2.46	2.72
	4.5	1.24	1.37	1.53	1.70	1.89	2.10	2.34	2.60	2.89
	5	1.25	1.40	1.56	1.75	1.96	2.19	2.45	2.74	3.06
	5.5	1.26	1.42	1.60	1.80	2.02	2.27	2.56	2.87	3.23
	6	1.28	1.44	1.63	1.84	2.09	2.36	2.66	3.01	3.40
	6.5	1.29	1.47	1.67	1.89	2.15	2.44	2.77	3.15	3.58
	7	1.30	1.49	1.70	1.94	2.21	2.52	2.88	3.29	3.75
	7.5	1.32	1.51	1.73	1.98	2.27	2.61	2.99	3.43	3.93
	8	1.33	1.53	1.76	2.03	2.34	2.69	3.10	3.57	4.11
	8.5	1.34	1.55	1.79	2.07	2.40	2.77	3.21	3.71	4.30
	9	1.35	1.57	1.82	2.12	2.46	2.86	3.32	3.86	4.48
	9.5	1.36	1.59	1.85	2.16	2.52	2.94	3.43	4.00	4.67
	10	1.37	1.61	1.88	2.20	2.58	3.02	3.54	4.15	4.86

Note: Rows correspond to values of T, expressed in years.

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6. Value at Risk and Gain (VARG) (18 pts)

The distribution you have calculated sets off alarm bells in your head. Although the project could be a big winner, the data also indicate that there is a possibility that the production would not justify the capacity planned for the base case (160,000 cars/year).

To illustrate this possibility, you decide to draw up a Value at Risk and Gain Diagram for the revenues in the **third period (year 15)**, for these **two situations** that contrast the unrealistic assumption and the recognition of uncertainty:

- Production is as projected for the base case (Exercise 2)
- Production has the distribution you have just calculated

Note that the plant capacity is limited to 160,000 in both situations

For your convenience, the assumptions used to calculate revenue in a period are repeated here:

- revenues in any period = 5 x (production at end of the period in thousands) x ($0.2 per 1000 cars)
- revenues are paid at the end of each period

a) Enter the revenues in the following table (the 2 left hand columns come from Exercise 5) **(8 pts)**

Probability	Production	Revenue
Sum =	------	-----
Expected Value	------	

b) Sketch the VARG diagram. Label axes and grid and draw accurately. **(6 pts)**

c) In telling your boss what you've been doing, you explain the VARG diagram as follows: **(4 pts)**

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7 Option Evaluation (60 points)

Using the VARG diagram, you have persuaded your boss that something ought to be done to protect the organization from the possibility of spending money on a lot of capacity that might not be used. You thus need to investigate the possibility of deferring investments in capacity.

So you revert to the possibility of building the assembly plant in two phases of 80,000 units of capacity, one at beginning and the other at the end of the 5th year, as in Exercise 3.

Assume as before that if you expand in year 5, you immediately:

- incur the construction costs
- obtain the expanded project (so that the revenues for the expanded project are applied to the following 5-year period).

Do not consider any possible tax incentives in this analysis. The net revenues are as originally given:

- net revenues (in millions) in any 5-year period
  = 5 x (production at end of the period in thousands) x ($0.2 per 1000 cars) **[Eqn 2]**

Being pressed for time, you use the probability distribution you generated in Exercise 5

a) On your way to calculate the option value for the phased project, the Vice-President (Finance) challenges you: "how can you be doing options analysis? I bet you don't even know what 'arbitrage-enforced pricing' is!" But you show that you do understand this concept, explaining it as follows **(6 pts)**

b) You reinforce your argument by showing him a version of the Black-Scholes formula:

$$\text{Option Price} = P * N(q_1) - A * e^{-rY} * N(q_2)$$

Where A = strike price; P = price of the Stock. You then explain the intuition behind its two terms. **(5 pts)**

c) You also tell the VP (Finance) why you **do not** plan to base your analysis on "arbitrage-enforced pricing", citing the following reasons why using an analysis based on arbitrage enforced pricing would be inappropriate in this case **(5 pts)**

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d) Use the table to calculate the Expected NPV of the base case (capacity 160,000). **(15 pts)**

Years	0	1-5	6-10	11 -15
Demand at period end (Exercise 5 b)	80,000			
Actual Production to meet demand at period end	0			
Remember! plant size limits production				
Net Revenue at each node (millions)	0			
Probability of each node (Exercise 5b)	1			
Cost of 160,000 capacity plant (Exercise 2)				
Expected Value in each period (millions)				
Discount factor at 15% (Exercise 2)				
Discounted Value in each period (millions)				
Net Present Value				

e) Similarly you calculate the Expected NPV of having a capacity = 80,000 cars/year **(10 pts)**

Actual Production at period end	0			
Remember! plant size limits production				
Net Revenue at each node (millions)	0			
Probability of each node (Exercise 5b)	1			
Cost of 80,000 Capacity plant (Exercise 3)				
Expected Value in each period (millions)				
Discount factor at 15% (Exercise 2)				
Discounted Value in each period (millions)				
Net Present Value				

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f) Now calculate the value of starting with the smaller capacity and expanding it optimally – **which you assume can only be done in year 5. (15 pts)**

You need to choose which plant size you will select for end of year 5. To do this, you need to calculate the value of being in the 2 possible nodes at year 5, for each of two capacities.
Reminder: The value of being in a node at period N = Expected value of following 2 nodes, properly discounted over period.

As a reminder in your calculations, from Exercise 5, p =________ (1-p) = ________

Expected Value of being in node (millions)	----			
160,000 cars/year case				
Cost of Expansion	----		----	----
Expected Value of being in node (millions)	----			
80,000 cars/year case				
Expected Value of being in node (millions)	----			
Based on optimal choice, remember to Deduct cost of expansion if used				
Probability of each node (Exercise 5b)	1			
Cost of 80,000 Capacity plant (Exercise 3)				
Expected Value in each period (millions)				
Discount factor at 15% (Exercise 2)				
Discounted Value in each period (millions)				
Net Present Value				

g) Under what circumstances, if ever, do you expand capacity in year 5? **(4 pts)**

THANK YOU FOR YOUR PARTICIPATION IN THE CLASS. ALL BEST WISHES!!!!

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BLANK PAGES PROVIDED AS EXTRA SPACE

FOLLOWED BY EXTRA COPY OF PAGES 10 AND 11, IN CASE YOU NEED THEM

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d) Use the table to calculate the Expected NPV of the base case (capacity 160,000). **(15 pts)**

Years	0	1-5	6-10	11 -15
Demand at period end (Exercise 5 b)	80,000			
Actual Production to meet demand at period end	0			
Remember! plant size limits production				
Net Revenue at each node (millions)	0			
Probability of each node (Exercise 5b)	1			
Cost of 160,000 capacity plant (Exercise 2)				
Expected Value in each period (millions)				
Discount factor at 15% (Exercise 2)				
Discounted Value in each period (millions)				
Net Present Value				

e) Similarly you calculate the Expected NPV of having a capacity = 80,000 cars/year **(10 pts)**

Actual Production at period end	0			
Remember! plant size limits production				
Net Revenue at each node (millions)	0			
Probability of each node (Exercise 5b)	1			
Cost of 80,000 Capacity plant (Exercise 3)				
Expected Value in each period (millions)				
Discount factor at 15% (Exercise 2)				
Discounted Value in each period (millions)				
Net Present Value				

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f) Now calculate the value of starting with the smaller capacity and expanding it optimally – **which you assume can only be done in year 5. (15 pts)**

You need to choose which plant size you will select for end of year 5. To do this, you need to calculate the value of being in the 2 possible nodes at year 5, for each of two capacities. **Reminder: The value of being in a node at period N = Expected value of following 2 nodes, properly discounted over period.**

As a reminder in your calculations, from Exercise 5, p =________ (1-p) = ________

Expected Value of being in node (millions)	----			
160,000 cars/year case				
Cost of Expansion	----		----	----
Expected Value of being in node (millions)	----			
80,000 cars/year case				
Expected Value of being in node (millions)	----			
Based on optimal choice, remember to Deduct cost of expansion if used				
Probability of each node (Exercise 5b)	1			
Cost of 80,000 Capacity plant (Exercise 3)				
Expected Value in each period (millions)				
Discount factor at 15% (Exercise 2)				
Discounted Value in each period (millions)				
Net Present Value				

g) Under what circumstances, if ever, do you expand capacity in year 5? (**4 pts**)

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