ENGINEERING SYSTEMS ANALYSIS FOR DESIGN

Final Examination, 2002

Item	Points				
	Possible	Actual	Extra Credit	Achieved	
Your Name	2				
1 Supply Chain Management	28				
2 Optimizing Delivery	18		5		
3 System Design Change	20				
4 PDA Process Prototype	22		10		
5 Back my company	17		10		
6 What does the boss want?	23				
7 Use of Real Options	20				
SUBTOTALS	150		25		
TOTAL (Actual + Achieved)					
GRADE ON 100 (TOTAL/1.5)					

Your Name: _____ (2)

Note: The points for each problem and sub-problem are marked in parentheses. They correspond to the amount of time you might spend on them.

You might want to use these as a guide for how you should spend your time. Don't spend 10 minutes on a 3-point problem, for example.

You may find it worthwhile to turn to the section that is easiest for you, and to do that section first. No need to respond to questions in the order presented.

1 SUPPLY CHAIN MANAGEMENT (28)

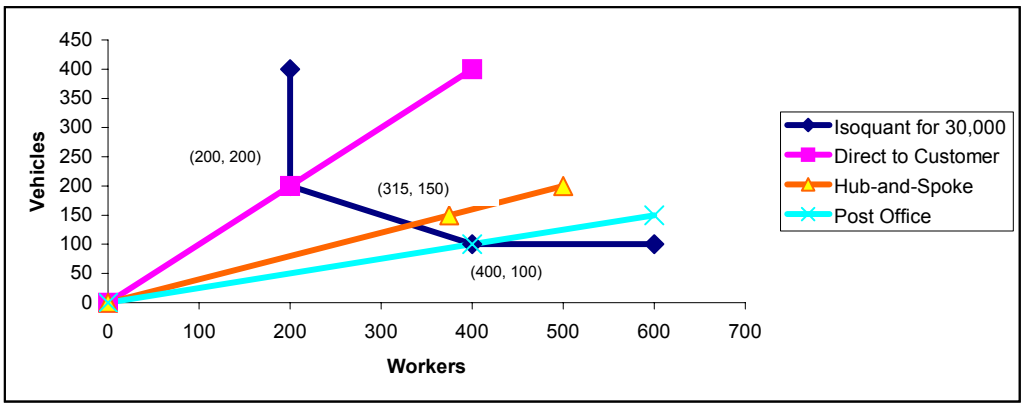
Assume that there are 3 ways to distribute Holiday packages. Each uses vehicles and workers in different combinations. Each has its own cost and productivity. See Table below.

Supply Chain Concept	**Vehicles**	**Workers**	**Output (parcels/day)**
"Post Office"	100	400	30,000
"Direct to Customer"	100	100	15,000
"Hub-and-Spoke"	200	500	40,000
	$ 500/day each	$200/day each	

a) Define an isoquant (3)

An isoquant is a locus on the production function of all equal levels of product.

b) Plot isoquant for 30,000 parcels/day (6)



c) Define "marginal rate of substitution" (MRS) (3)

Marginal rate of substitution is the rate at which marginal increases in one output must substitute for marginal decreases in another input so that the total product remains constant.

d) Determine MRS as completely as feasible from above data (6)

$$0 < wor\ker s < 200, MRS = -\infty;$$

$$200 < wor\ker s < 400, MRS = -\frac{200-100}{400-200} = -\frac{1}{2};$$

$$400 < wor\ker s, MRS = 0.$$

e) Define and Contrast Economic and Technical Efficiency . (5)

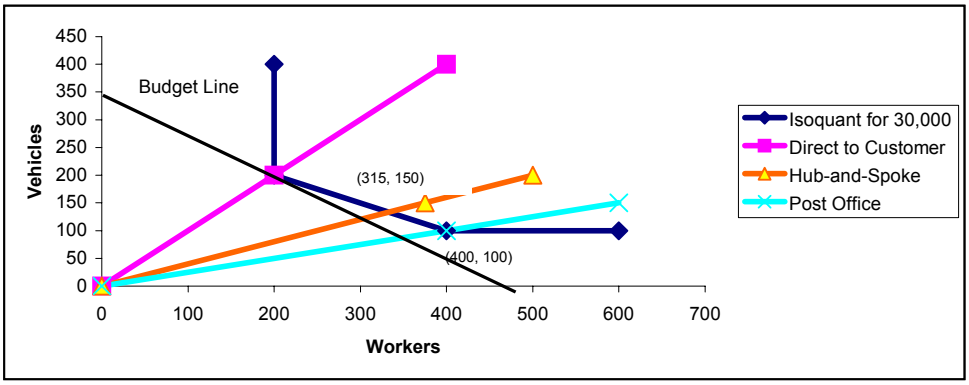
Technical efficiency represents the maximum product that can be obtained from any given set of resources. Economic efficiency is whether a design is best economically.

Technical efficiency is a necessary but not a sufficient condition for economic efficiency.

f) What wage rates justify the use of the "Direct to Customer" concept? Assume cost of delivery vehicles is fixed. (5)

The slope of the budget line = $-\frac{\text{vehicle cost}}{\text{wage rate}}$

To justify the use of the "Direct to Customer" concept, the slope of the budget needs to be greater than or equal to –1/2, or wage rate ≥ $250/day each



2. OPTIMIZING DELIVERY

Assume that there are 3 ways to distribute Holiday packages. Each uses vehicles and workers in different combinations. Each has its own cost and productivity. See Table below.

Supply Chain Concept	**Vehicles**	**Workers**	**Output (parcels/day)**
"Post Office"	100	400	30,000
"Direct to Customer"	100	100	15,000
"Hub-and-Spoke"	200	500	40,000
	$ 500/day each	$200/day each	

Your company needs to distribute 40,000 parcels/day over the holidays.
They have on hand 100 vehicles and a work force of 200 people, and must pay them in any case.
The company could (if it wanted to) hire in this crucial week up to 700 vehicles and 1000 temporary workers. They wish to minimize their costs.

a) What are the decision variables? (5)
Xpo: units of "Post Office" concept used
Xdc: units of "Direct to Customer" concept used
Xhs: units of "Hub-and-Spoke" concept used

b) Formulate as a linear programming problem. (8)

$$\text{Min } (100Xpo + 100Xdc + 200Xhs)\cdot 500 + (400Xpo + 100Xdc + 500Xhs)\cdot 200$$

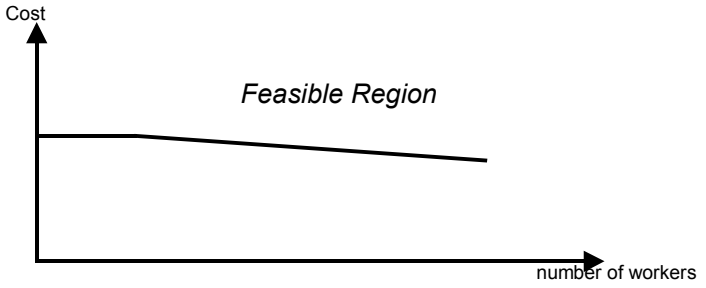
$$\text{s.t. } 30000Xpo + 15000Xdc + 40000Xhs = 40000$$

$$100 \le 100Xpo + 100Xdc + 200Xhs \le 800$$

$$200 \le 400Xpo + 100Xdc + 500Xhs \le 1200$$

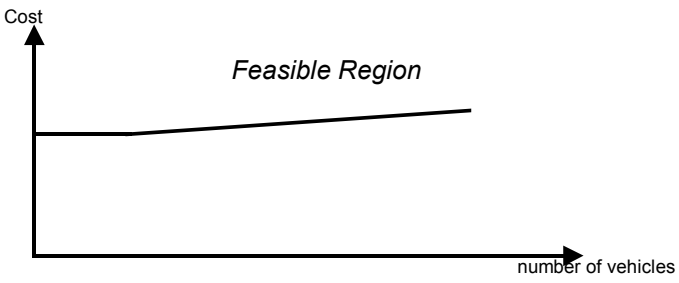
$$Xpo, Xdc, Xhs \ge 0$$

c) Explain why this problem could (or could not) be formulated as a linear program if the cost of temporary workers were less than the normal rate of $200 per day. (3)



The feasible region is non-convex, so the problem could not be formulated as a LP problem.

d) Explain why this problem could (or could not) be formulated as a linear program if the cost of rented vehicles were more than the $500 per day for owned vehicles. (3)



The feasible region is convex, so the problem could be formulated as a LP problem

EXTRA CREDIT Suppose the company now recognizes that, to implement the "hub and spoke" concept, they have to open a warehouse that would cost $10,000 plus $100 per 1000 packages. Could a linear program handle this possibility? Explain reasoning. **(5)**

This is a fixed charge problem.

LP could not solve it generally.

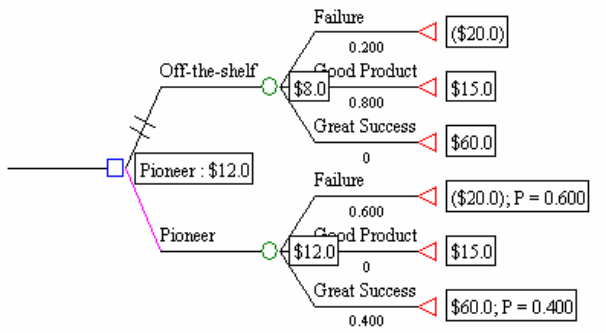
3. SYSTEM DESIGN CHANGE (20)

Your find that your customers require a new feature in PDA you produce. Your problem is how to modify this device to maintain your market position.

Your engineers tell you that you have 2 choices. One uses off-the-shelf technology and should meet the market requirements. The other pioneers new technology that might fail to meet requirements but could, if successful, position you to jump ahead of your competition significantly. See Table below.

Approach to System Design	**Possible Results of Design Approach -- probability and financial return**		
	Failure	**Good Product**	**Great Success**
"Off-the-shelf"	0.2	0.8	0
"Pioneer"	0.6	0	0.4
	Loss of $20 million	$15 million profit	$60 million profit

a) Draw decision tree for company's choice, showing all outcomes and probabilities. (6)



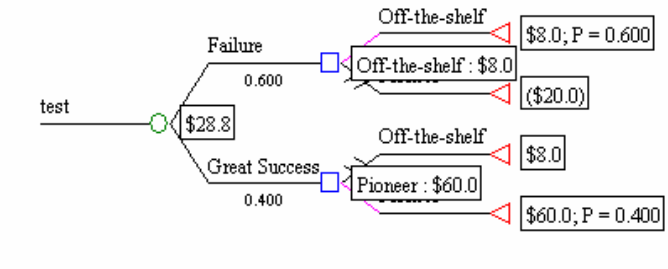
b) Which approach is the better? Assume company will base decision on expected profit. (4)

Pioneer with an expected profit of 12M

c) Define the concept of "expected value of perfect information" (EVPI) (4)

The increase in expected value to be obtained from a situation due to the perfect information, without regard for the cost of obtaining it (or if it is realistic to obtain the perfect information).

d) Calculate the EVPI for perfect information on the outcomes of the "Pioneer" approach (6)



EVPI = 28.8-12 = 16.8 M

4. PDA PROCESS PROTOTYPE (22)

Your could pay $1 million to a lab research that would run tests on the "Pioneer" technology. You believe, based on your experience with this lab, that the lab anticipates future outcomes correctly 75% of the time (that is, for example, the lab will report "failure" 3/4 of the times when failure occurs). With their information, you would revise your prior estimate of the probability of success for the "Pioneer" technology, displayed in the Table from Problem 3:

Approach to System Design	**Possible Results of Product Launch -- probability and financial return**		
	Failure	**Good Product**	**Great Success**
"Off-the-shelf"	0.2	0.8	0
"Pioneer"	0.6	0	0.4
	Loss of $20 million	$15 million profit	$60 million profit

a) Explain what Bayes' formula does. (3)

Bayes' Theorem is a simple process for revising estimates of probabilities. Prior probability is revised to obtain the posterior probability when new information is acquired.

b) Write Bayes' formula (4)

$$P(E/O) = P(E)[\frac{P(O/E)}{P(O)}]$$

c) What is the estimated probability of failure for the "Pioneer" approach, if the lab predicts failure? Show calculations that justify this conclusion (8)

$$P(E/O) = P(E)[\frac{P(O/E)}{P(O)}] = 0.6 \cdot \frac{0.75}{0.6 \cdot 0.75 + 0.4 \cdot 0.25} = \frac{9}{11}$$

d) What is the estimated probability of "great success" for the "Pioneer" approach, if the lab predicts great success? Show calculations that justify this conclusion (4)

$$P(E/O) = P(E)[\frac{P(O/E)}{P(O)}] = 0.4 \cdot \frac{0.75}{0.4 \cdot 0.75 + 0.6 \cdot 0.25} = \frac{2}{3}$$

e) Define "expected value of sample information" (EVSI) (3)

The increase in expected value to be obtained from a situation due to the sample information, without regard for the cost of obtaining it.

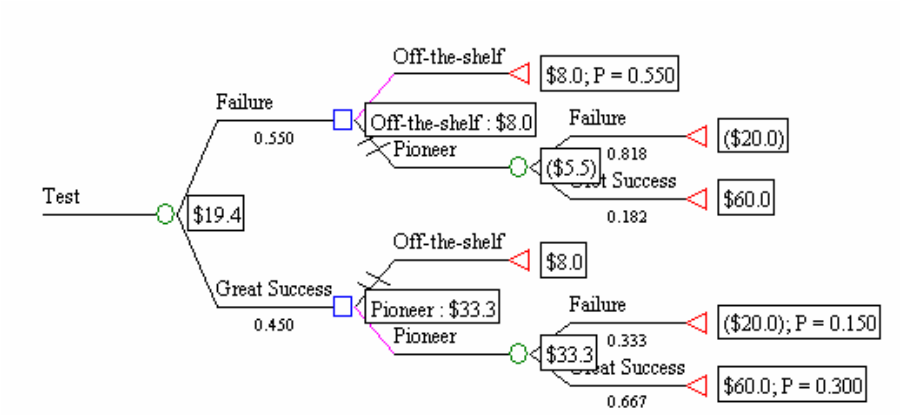
EXTRA CREDIT Calculate the EVSI for the process prototype activity. **(10)**

The probability that the test predicts failure:

$$P(F) = 0.6 \cdot 0.75 + 0.4 \cdot 0.25 = 0.55$$

The probability that the test predicts success:

$$P(S) = 0.4 \cdot 0.25 + 0.6 \cdot 0.75 = 0.45$$



EVSI = 19.4 –12 = 7.4M

5. BACK MY COMPANY (17)

Your company develops, makes and distributes medical instruments and devices. It is always on the look-out for new products that it either develops in-house or acquires.

Researchers from a highly reputable technical university are developing a concept for a cheaper, more efficient stent (a device for protecting arteries). Their company (Stentor) now has a market value of $5 million.

Stentor approaches your company with the following proposition:
- you invest X million in Stentor to develop this product
- you get the right to buy this company for 10 million
- This right can be exercised 2 years from now

From knowledge of the worldwide market for stents, experts estimate that
- If the new product is a success, the value of the Stentor will be at least $50 million
- If the new product is a failure, the value of Stentor would drop to $2 million. However, if your company accepted Stentor's proposal, it would avoid any losses beyond the X million investment.

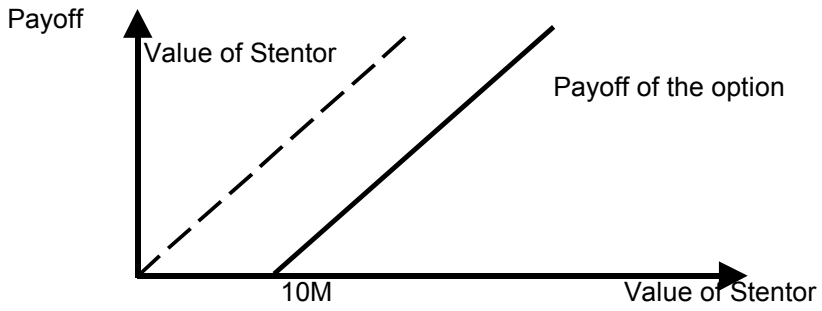
a) Define an option (4)

An option is a right, but not an obligation to take some action now or in the future for a pre-determined price.

a) What kind of option is Stentor offering your company? Explain your answer. (4)

A European Call option.

c) Draw a diagram showing the payoffs from the option on this R&D venture. (4)



d) Define the concept of arbitrage enforced pricing of options. (5)

A risk-free portfolio with the same outcomes as the option can be constructed to balance an option absolutely. This defines the prices of the option.

EXTRA CREDIT Calculate the arbitrage enforced price for the option on this R&D development project. **(10)**

You can assume that:

- You could actually buy the company for $5 million immediately
- The risk-free discount rate over the next two years is 5%/year.

	Start	End	End
Value of Stentor	5M	2M	50M
Payoff	-C	0	50 – 10 = 40M

	Start	End	End
Assets	-5M	2M	50M
Loan	$\frac{2}{(1+r)^2}$	-2M	-2M
	$-5+\frac{2}{(1+r)^2}$	0	48M

$$-\frac{6}{5}C = -5 + \frac{2}{(1+r)^2}$$

r = 5%, and C = 2.67 M

6. WHAT DOES THE BOSS WANT? (23)

You review two design decisions your boss made last year to change the reliability of the product you are working on. You find that the boss was prepared to
Case 1: add new features that would reduce MTBF (mean time between failure) by 500 hours, so that you could have a 60% chance of increasing MTBF by 1200 hours (and a 40% chance of no effect at all); and
Case 2: get rid of a process that has a 25% chance of decreasing MTBF by 500 hours (and a 75% chance of no effect on MTBF). This action would decrease MTBF by 400 hours.

a) What is the lottery defined by Case 1? (5)

A buying lottery: 0 ~ (700, 0.6; -500)

b) What is the lottery defined by Case 2? (5)

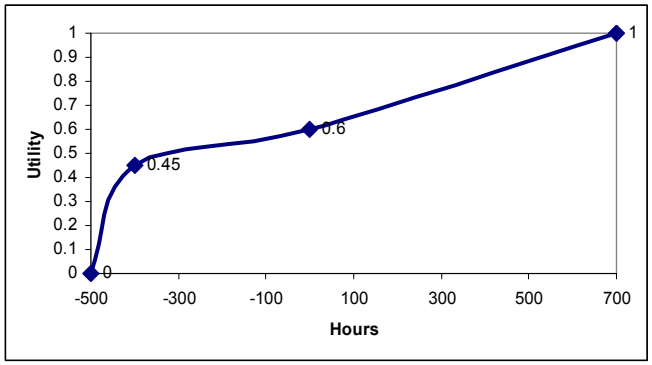
A selling lottery: -400 ~ (-500, 0.25; 0)

c) Determine and sketch the boss' utility function from this information. (6)

Define *U(700)* = 1 and *U(-500)* = 0.

$$U(0) = 0.6 \times U(700) + 0.4 \times 0.6U(-500) = 0.6$$

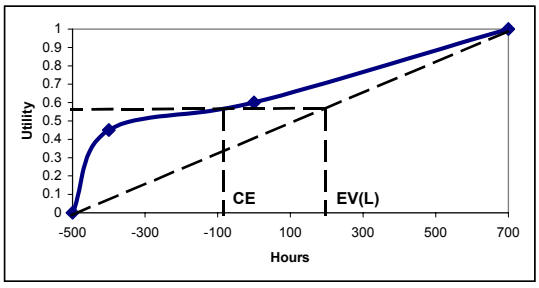
$$U(-400) = 0.25 \times U(-500) + 0.75 \times U(0) = 0.45$$



d) Define risk aversion (3)

When people are risk averse, their certainty equivalence to a lottery will be less beneficial than the certain amount equal to the expected value of the lottery.

e) Is the boss risk averse in these kinds of design decisions? Justify your answer. (4)



The boss is risk averse.

The longer the MTBF is, the more beneficial it is. And as the figure shows, CE < EV(L). Therefore, the utility function of the boss is risk avesrse.

7. USE OF REAL OPTIONS (20)

In your field of professional interest, define a significant "real option" that might be worth incorporating "IN" the design of the systems you might be concerned with.

a) Describe this example (4)

b) Indicate what kind of option it is (4)

c) Identify the cost of acquiring the option (4)

e) Define the cost of exercising the option (4)

d) Define the conditions that would make it worthwhile to exercise (4)