SOLUTION

Engineering Systems Analysis for Design

Mid-Semester Quiz **October 28, 2008**

This is a closed book exercise. Computers and other wireless enabled devices for communication with web and outside are not allowed.

You may use old-fashioned, non-communicating calculators that are not miniature computers with extensive memory (if you have them! And if so, show me first…)

Grade Table

There are 90 points possible for the regular test. Points associated with each question correspond to the estimated time it might take to answer them. .

Item	**Score**	
	Max	**Yours**
Your Name (provided we can read it)	1	
Concepts	18	
Static valuation of projects	11	
Decision Analysis	60	
Total	90	

I have completed this test fairly, without copying from others, a book, or the web.

Please sign your name legibly JOHN Q. SOLUTION **(1 point)**

SOLUTION

Concepts (18 points)

Note: Full marks only for conceptually precise responses

Write a short definition or description explaining the following:

Technical Efficiency **(2 points)**

The maximum production level or amount of output **(1 pt.)** that can be achieved for a given **(1 pt.)** set of inputs.

Production Function **(2 points)**

…is the functional relationship between a set of inputs **(1 pt.)** and the maximum or technically efficient **(1 pt.)** output. Commonly modeled for the one-output form via the Cobb-Douglas function **(0 pts.)**.

Economic Efficiency – define and contrast with Technical Efficiency **(2 points)**

Economic efficiency is defined by combination of technical efficiency (production function) **(1 pt.)** and economic (in general, value) **(1 pt.)** relationships. Defining economic efficiency as the most economic output was not acceptable; you need to define economic! The difference between economic and technical efficiency is that the former maximizes value **(1 pt)**. Two points max.

Criterion for Attaining Technical Efficiency **(2 points)**

Combination of inputs **(1 pt.)** such that the highest level of output is reached **(1 pts.)** produces a technically efficient design.

Isoquant **(2 points)**

The set of all input combinations that yield the same output **(1 pt.)** in a technically efficient **(1 pt.)** process.

Expansion Path **(2 points)**

The set of inputs that minimize cost **(1 pt.)** for all levels of production **(1 pt.)** or the locus of input combinations that define economically efficient design

Output Cost Function -- define and compare with input cost function **(2 points)**

Total cost as a function of the output **(1 pt.)**, assuming technical and economic efficiency **(1 pt.).**
The input cost is the relationship between the inputs that create the budget cost available **(1 pt)**.

Discount Rate -- define and compare with interest rate **(2 points)**

Rate used to evaluate the cash flows of a project over time **(1 pt.).**
The discount rate represents the opportunity cost of the resources used for the project **(1 pt.)**
It differs from the interest rate in that it adds a return premium representing the risk of the project **(1 pt.)**

WACC – define concept and discuss advantages and disadvantages for use as discount rate **(2 points)**

Weighted Average Cost of Capital **(1 pt.)**

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… the rate of return achieved by an organization on previous projects having similar risk **(1 pt.)**
… or as average rate required by lenders and investors external to the project. **(1 pt.)**
… often used as a measure of the discount rate that should be used for an average project **(1 pt.)**
… In financial terms, this is $R = Re \times E/(E+D) + Rd \times D/(E+D) \times (1-t)$ **(1 pt.)**
Two points max.

Static Valuation of Projects (11 points)

Consider the project with the following revenues and costs:

	Year				
	0	1	2	3	4
Revenues		300	400	600	340
Costs	1200	25	37	41	48
Net Cash Flow	**-1200**	**275**	**363**	**559**	**292**
$(1+r)^N$	**1.00**	**1.10**	**1.21**	**1.33**	**1.46**
Present value	**-1200**	**250**	**300**	**420**	**200**

Assume a discount rate of r = 10%. Use no more than 3 significant figures

a) Define Net Present Value and calculate it for this case **(5 Points)**

Net present value is the sum total of net cash flows **(1 pt.)** appropriately discounted to the present time **(1pt.)** using appropriate discount factor.

Here, NPV = -30. **(3 pts.)**

b) How would you calculate the benefit-cost ratio? What are the major advantages and disadvantages of the Benefit/Cost ratio as a criterion of evaluation? **(3 points)**

NOTE: THIS PROBLEM DOES NOT ASK TO CALCULATE THE B-C RATIO

The benefit-cost ratio is the ratio of the present values of all benefits to all costs. **(1 pt.)** That is, while the NPV can simply discount the net cash flow for each year, the B-C ratio discounts each separately.

Formula for benefit-cost ratios:

$$\frac{Benefit}{Cost} = \frac{PV all\ benefits}{PV all\ costs} = \frac{PV\ B}{PV\ C_k + C_r}$$

$$\frac{Net\ Benefit}{Cost} = \frac{PV net\ benefits}{PV\ investments} = \frac{PV\ B - C_r}{PV\ C_k}$$

B is the benefit (revenue), Ck is capital investment, and Cr is recurring cost.

Advantages: simple to calculate; allows a rating of the alternatives; unit-less **(1 pt.)**

Disadvantages: biased against recurring cost projects **(1 pt.)**; does not give a definitive ranking; may disagree with NPV

In high recurring costs projects, Cr is relatively high compared to Ck. Given two projects, one with a high-recurring cost and one with low-recurring cost, both with same Ck, the B-C ratio will be higher for a low-recurring cost project because Cr is smaller (thus the denominator is lower), even though the NPV of the high-recurring cost project might be higher. This causes the bias against high-recurring projects with benefit-cost ratio approach.

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c) Define and Calculate the Pay Back Period. What are the major advantages and disadvantages of this criterion of evaluation? **(3 points)**

Pay Back Period is the time period that will be required to recuperate the initial investment as based upon undiscounted **(1 pt.)** future cash flows

Formula for payback period:

$$Payback\ \ Period = \frac{Initial\ \ Investment}{Annual\ \ Net\ \ Undiscounted\ \ Benefits}$$

But this formula assumes the same annual net undiscounted benefits every year!

Here, we have different undiscounted net benefits every year. So we need to add up the benefits every year until they get to 1200, which is the initial investment. The first three years contribute 275 + 363 + 559 = 1197 towards this. So we already have 3 years counted. The third year, we only need 1200 – 1197 = 3 out of the 292 available, which represents 3/292 = 1% of the year. So we count 3 years + 0.01 year ≈ 3 years total.

$$PBP = 3years + \frac{1200 - (275 + 363 + 559)}{292} \approx 3\ \ years$$ **(1 pt.)**

Advantages: useful when short turn-around is a priority; really simple; avoids the difficulty of picking the proper discount rate; avoids speculative long-term forecasts **(1 pt)**

Disadvantages: ignores cash flows after the initial pay-back period (that could turn negative), projects could become very profitable later on!; useless for ranking projects with lives beyond the shortest pay-back period; does not account for the time value of money **(1 pt.)**

Three points max, but must calculate the PBP correctly and have partial answers for each part in order to receive full credit.

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SOLUTION

Decision Analysis (60 points)
Congratulations! You're the consultant to the UN agency about to launch satellites to provide educational resources over central Africa. Your job is to help choose the system architecture.

They face 2 choices. Either they launch 2 satellites right away, or they launch 1 with the possibility of launching a second one 5 years later. If they launch only one, they are committed to launch the second if growth in educational resources demanded in the first period is "high". Conversely, if the growth in the first period is "low", they are required to stay with only 1 satellite.

The UN education advisors estimated the possible results from the project, in terms of the number of students served in each period. They believe that:

- the first period "high" and "low" outcomes are equally likely, and
- the following second period possible outcomes are also equally likely.

Note that the actual number of students served depends on the availability of sufficient capacity in the satellite fleet.

Students Served, millions		Students Served, if no constraints			
First Period	Second Period	first	second	total	Probability
High = 120	180	120	180	300	1/4
	140	120	140	260	1/4
Low = 80	140	80	140	220	1/4
	100	80	100	180	1/4

The best estimates of cost and performance are given below. Costs are all in present values.

	2 Satellites at t = 0	1 Satellite at t = 0	2nd Satellite at t = 5
Ground Stations	30	20	10
Launches	10	10	10
Satellite	80	40	30
Total Present Costs	120	70	50
Capacity (in terms of Maximum students served)	180	100	70

Let's first examine the technology.
a) Define the concept of the returns to scale. What are they for the production of educational capacity? Show how you determined this conclusion. **(5 points)**

Returns to scale occurs when a certain change in scale of all inputs creates a change in the output (1 pt). Increasing returns to scale (IRS) occurs when for instance a doubling of all inputs more than doubles the output, while decreasing returns to scale (DRS) would less than double the output (1 pt).

Here the input is the number of satellites while the output is the number of students served (1 pt). Looking at the second table, for 1 satellite 100 students are served, while for 2 satellites 180 students are served (1 pt). Therefore, as the input is doubled, the output is less than doubled, so we have decreasing returns to scale (1 pt).

b) What about economies of scale? Show how you came to that conclusion **(4 points)**

Economies of scale (EoS) occur when the cost increases slower than the output (1 pt). In other words, this occurs when the average cost per unit decreases as output increases (1 pt). Here the output is the number of students served while the cost is associated to the satellites. For 1 satellite, the cost is $70 and 100 students are served for a unit cost of $0.70/student. For 2 satellites, the cost is $120 and 180 students are served for a unit cost of $0.67 (1 pt). As the output increases from 100 to 180 students, the unit cost decreases from $0.70/student to $0.67/student, so we have EoS (1 pt).

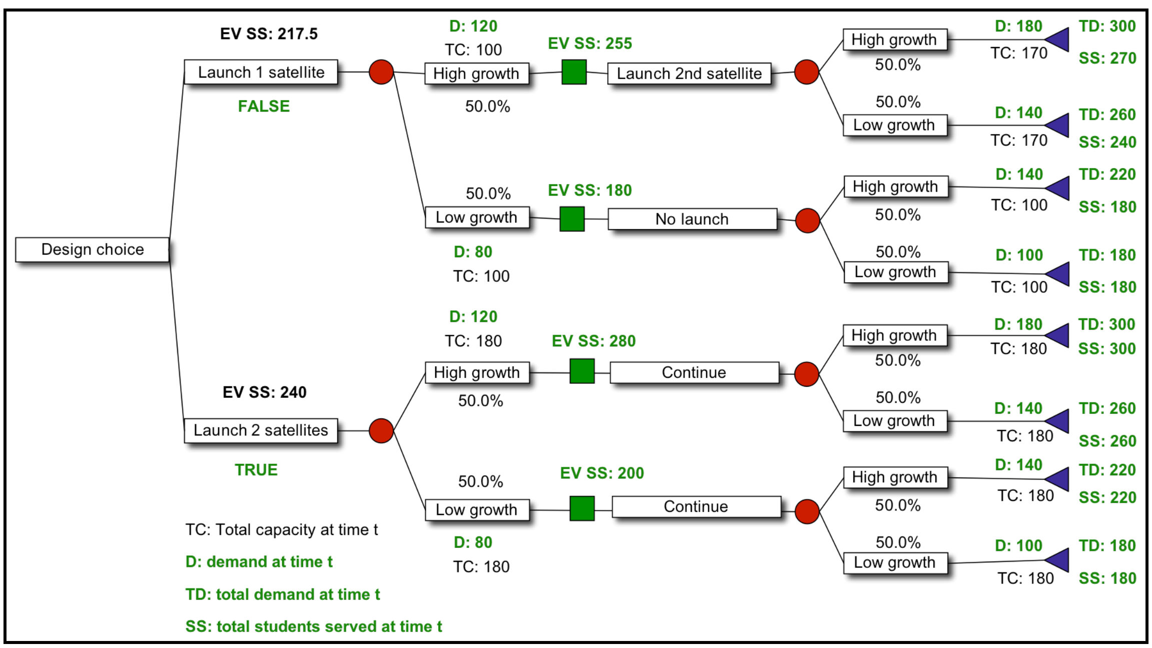
c) Why is it possible to get different results for returns and economies of scale? **(3 points)**

The economic results result from a combination of the technical and the value system (1 pt). Whether there are economies of scale or not depends on whether the value system (of costs in particular) outweigh the effect of increasing (or decreasing) returns to scale (1 pt). Only in the case of linear values do increasing (or decreasing) returns to scale imply economies (or diseconomies) of scale (1 pt). It is important to appreciate that non-linear value systems are pervasive in real life (1 pt).

Now proceed to the decision analysis of the situation

d) Draw the decision tree for this choice, giving all information provided. **(6 points)**
Remember, the performance of the system (in terms of number of students served) can be constrained by the satellite capacity available)

For full credit in this section, the two main branches of the decision tree **(3 pts. each)** need to be shown, including the value of each outcome and probabilities for the chance branch. For each branch, **1 pt** for existence of branch, **1 pt** for correct values, **1 pt** for correct probabilities.



SOLUTION

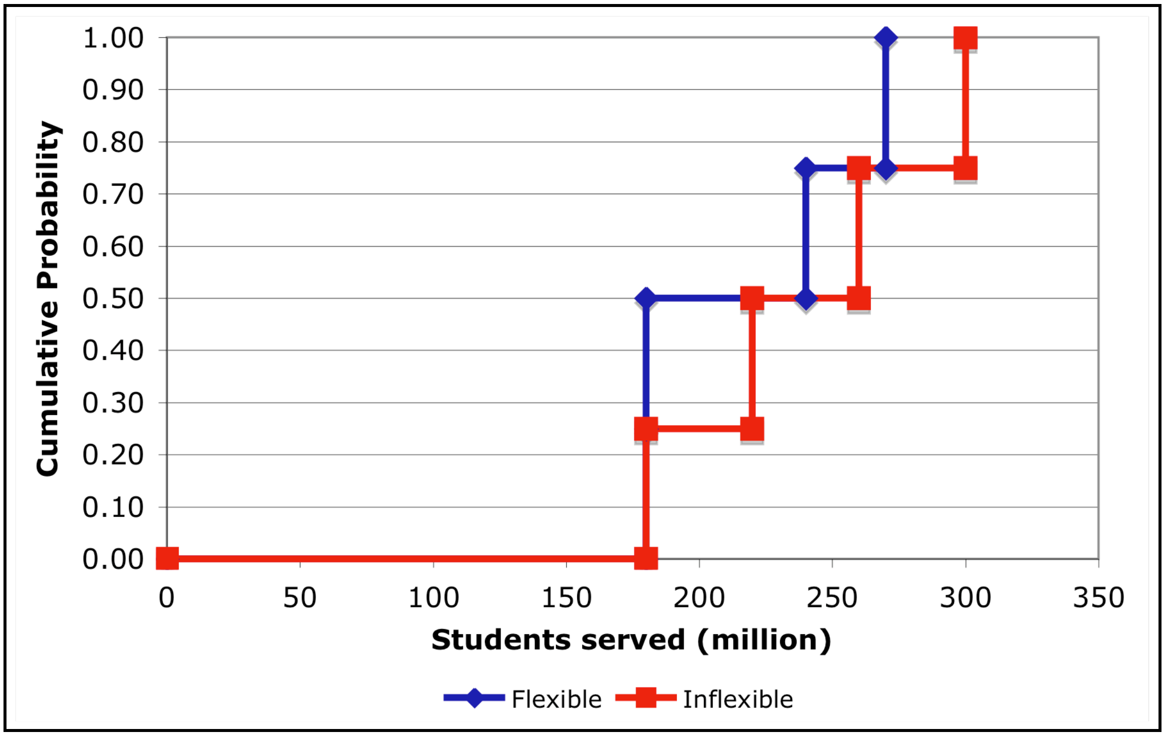
e) Define and calculate the value of the strategy that maximizes the expected number of students served over the 2 periods **(6 points**)

The strategy that maximizes the expected number of students served is to launch 2 satellites right away (3 pts). An expected total of 240 students will be served through this strategy (3 pts).

One metric is not enough

f) Graph the Value at Risk and Gain (VARG) for the two system architectures **(8 points**)

3 pts each curve for correct shape and values. 1 pt each if either shape or values is incorrect. 2 pts for correctly labeling the horizontal (1 pt) and vertical axes (1 pt).



g) Fill in the table of possible measures of performance of the system **(10 points)**

Metric	2 Satellites now	1 Satellite now	Which Preferable?
E(Students Served)	240	217.5	2 satellites
Max Students Served	300	270	2 satellites
Min Students Served	180	180	Same
Initial Investment	120	70	1 satellite now
Cost-Effectiveness = Students/investment $	2.0	3.1 (for initial) 2.6 (if no 2nd) 1.8 (with 2nd)	1 satellite now

2 pts per row for correct values.

h) Now that you have the information from the VARG and the table, discuss the relative merits of the choices. Which would you recommend? Why? **(6 points)**

The recommendation depends on the set of metrics chosen for valuation, and their relative importance in the mind of the decision-makers (2 pts). If one wants to maximize E(students served) or the maximum students served, deploying 2 satellites makes sense (2 pts). On the other hand, if the goal is minimize the initial investment or maximize the cost-effectiveness, it makes sense to deploy1 satellite now with the possibility to deploy another one in 5 years (2 pts). 2 pts overall for quality of recommendation, max 6 pts total.

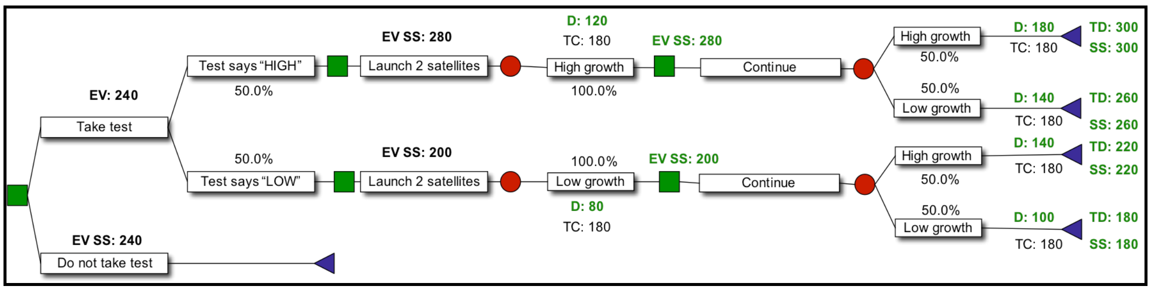
Value of Information

You realize that it would be nice to resolve the uncertainty about whether the demand for satellite education would be "high" or "low" in the first period.

i) Define the concept of perfect information? **(3 points)**

Perfect information assumes that the "machine" or "device" providing additional information is 100% reliable (1 pt). When it predicts a specific outcome, this outcome will occur with 100% probability (1 pt). Perfect information is a theoretical construct helpful to quickly calculate the upper bound on the expected value of perfect information (EVPI) (1 pt), or how much at the maximum we would be willing to pay to get that information.

j) Set up the appropriate decision tree for defining the EVPI, based on the assumption that you should focus on maximizing the expected number of students served **(6 points)**



2 pts if there are two branches. 4 pts for "test" branch, 2 pts for correct tree and 2 pts for correct values.

k) Based on the above, what is the EVPI **(3 points)**

EVPI = EV(with test) – EV(without test) = 240 – 240 = 0

2 pts for formula, 1 pt for correct value

Note in this case, better information would not change the decision and outcome, and so is worth nothing. However, if the decision-makers were not choosing based upon expected number of students (for example, if they focus on cost-effectiveness and were choosing the 1 satellite architecture) the "perfect information" could change their decision and have value.