Chapter 1

Models and Modeling

The whole purpose of this course is to empower you as a manager or potential future manager in some special ways. Managers do many things, not all of which have to do with managing. But when a manager ***is*** managing, he or she must make many kinds of decisions that can be enhanced by analysis. We will consider some fairly technical topics this semester, but we will also do some things that are not all that technical at all. In many cases what is needed is essentially a rigorous application of common sense. One way of summarizing the basic steps is the following::

Diagnosis You have data, and maybe symptoms, but what *is* the problem? What are we trying to accomplish here?

Organize facts What do we already know? What pieces are missing? Can we "fill in the blanks"?

Select methodology Without bending, folding, stapling, spindling, and mutilating the problem situation, can we use some standard model framework? Or are we going to need to take an *ad hoc* approach, making it up as we go?

Formulate problem Organize the facts in the format that our methodology calls for. Make sure that we have stated those facts in ways that don't cause units of measure for related items to conflict with each other (this can lead us into mathematically plausible but factually nonsensical statements).

Solve problem In some problems, this calls for pencil and paper. To solve others, we may need a calculator. In many cases, a computer with appropriate software such as Lotus 123 or something more specialized like STAT+ makes sense. This course is not about mathematical algorithms, so some things we will do only on the computer. Other things I will want you to show me that you can handle in a variety of ways. And for some tasks, using a computer approximates killing a fly with a 12 guage shotgun.

Interpret results When the solution procedure is done, it's mostly just numbers. Find the meaning in those numbers, and discriminate between the numbers that are critical to the managerial problem and those that the procedure always generates because they are *sometimes* useful.

Validate Our methodologies can fool us sometimes. The results look so precise that they just have to be right. Sometimes validation involves checking *predictive validity*. The model always works with the data you started with. But how about with new data?

Face validity is another important issue. From time to time, some "expert" pops up trying to sell the notion that business problems can be solved with astrology. Or that sunspots can be used to predict economic activity. My favorite is the utility pole theory of crime. Data shows clearly that metropolitan areas with many utility poles tend to have more crimes against persons than do metro areas with few utility poles. Clearly, we must form a vigilante group with chain saws. If we can rid ourselves of those pernicious poles, we'll have no more crime problem!

Sensitivity analyze What is the solution sensitive to, and what makes little difference? Some methodologies call forth highly developed ways to test the sensitivity of their solutions to changes in our assumptions, some leave it up to us, and others are not really subject to sensitivity analysis. Sensitivity analysis helps us to focus on the things that can make an important difference and not waste time and attention on the "no-brainers".

Implement solution In reality, we haven't done the job until we have put it to work. We don't have an organization to run in the classroom environment, so we can't do this. That doesn't mean that we shouldn't consider how we would implement the solution. Arguably, if we can't see the path to implementation, then we have either found an impractical solution or we don't understand what we've done. Either is a recipe for disaster in the "real world".

Monitor results Seldom do we arrive at "set it and forget it" answers. Our model's description of reality may be incomplete, or reality itself may be subject to change. So we set in place a procedure to verify that our solution continues to be, in fact, a solution.

What is a Model?

A model is just a representation of an aspect of reality that has been reduced is scope or complexity relative to the reality itself. When you were a child, most of the toys with which you played were models in this sense. To be useful to a manager, a model must go beyond this sense of the term. The models we are concerned with are mathematical and/or logical abstractions. Some are wholly or partially graphical. Some models are built using elaborate systems of logic that we must learn, but many times a model is fundamentally *ad hoc* either because the problem is uncommon or because it is simple enough that it does not need an elaborate system.

A good model is economical; we also sometimes say that it is parsimonious. That is just a fancy way to say that it is no more complex than it needs to be to answer the question it is intended to answer. Consider a model intended to find the best price for a product that we already make and sell locally; no new investment is involved. We just think we might be able to make more profit from the product than we now make. Such a model need not incorporate a description of the manufacturing process. We have no need to know whether the product is green or purple. And we don't need any information about *sunk costs*. We try to limit the scope of the model to information that will help us to answer our question.

There are a number of categories of models. It may be helpful to look at some of them. We can classify models at least 2 ways.

Classify by what the model does:

Descriptive Models Some models only describe the behavior of the system. Waiting line models generally are descriptive in nature.

Prediction Models A prediction model predicts the behavior of some aspect of the system of interest. Forecasting models are prediction models. An accountant's *Pro Forma* is a prediction model. Breakeven models predict. Most models are prediction models, but the boundary between description and prediction is often gray, and usually not critical.

Optimization Models To optimize is to find a provably best solution. "Optimum" is a frequently misused term. Calculus optimization models obviously fit into the optimization category. So do Mathematical Programming models.

Classify by the type of problem the model solves, or by the methodology the model uses:

Forecasting Models These models forecast future values of things like demand, technology, interest rates, population, income, or whatever. There are many different methodologies that might be used.

Decision Analysis Models These models select from among a list of choices ("alternatives") by applying various criteria involving the possible outcomes ("states of nature").

Constrained Optimization The various branches of mathematical programming represent constrained optimization models. In particular, we will look at Linear Programming, which finds (if it exists) the best combination of activities that does not violate any limitations in the system, under the assumption that all relationships are linear.

Scheduling Models Scheduling models are useful for planning and control of large projects. Other scheduling models (beyond our scope) deal with scheduling and control of a variety of production operations.

Queueing Models A queue is a waiting line, and many systems can be described as waiting lines. Queueing models describe the behavior of those waiting lines.

Ad hoc Models Sometimes referred to as "deterministic simulation" models, this is a catchall category of (usually) Quick and Dirty models that managers and Management Scientists often build on a one-shot basis. A lot of real world modelling falls into this category.

Monte Carlo Simulation Add simulated random behavior of the random elements of a real system to the idea of ad hoc modelling and you have Monte Carlo Simulation. Monte Carlo simulation is exceptionally laborious to do by hand, so this almost invariably involves a computer. We use Monte Carlo simulation in situations where we would really like to perform an experiment, but can't.

Ad Hoc Models

To warm up for the more rigorous models to come, let's tackle a couple of *ad hoc* model situations. Hopefully, all we will need for them is the cumulative set of skills that you should have already acquired.

InstaFreezer

Liz Borden graduated 15 years ago from the North Avenue Trade School with an M.S. in Thermodynamics. Until recently, she was employed by NASA, and spent some of her spare time working in her home laboratory. She had a remarkable breakthrough at home, and resigned her job at NASA to focus on turning it into a commercial product. With the help of a venture capitalist, she has formed InstaFreez Corp., of which she is President and C.E.O., and has prepared to bring her first product to market. As an engineer, her biggest problem at the moment is pricing the product.

That product, the InstaFreezer, will be to refrigeration what the microwave oven was to cooking. It will cool a food item to any reasonable temperature in a very short time. It should be a dynamite product. The Market Research firm that she hired estimates that the weekly demand for the product will be approximately 2000 units less 5 times the wholesale price of the product. (The estimate is actually a little more complex than that. Over time they expect the 2000 unit base to grow. Similarly, inflation will cause the 5 unit per dollar price multiplier to need periodic adjustment. If we do our job properly, the adaptation to change will not be especially difficult.)

She has hired an accountant, Dewey Cheatham. Dewey, a recent GSU graduate, seems to Liz to be no help at all. According to Dewey, you could look at the InstaFreezer as costing either $67.50, $100.00, or $150.00 depending on how you look at it. Liz has asked him if he is maybe from the "2 + 2 = whatever you'ld like it to be" school of accounting thought. Dewey insisted not, and produced the following table..

Costs for InstaFreezer

Category	Item		Cost	Totals
Parts				
	Case		10	
	Door		5	
	Power Supply		10	
	Assorted Electronics		20	
	Motor		2.5	
	Pump		7.5	
Materials and consumable Supplies				
	Assorted		10	
Direct Utilities				
	Direct Power		2.5	
Subtotal			67.5	67.5
Labor				
	Direct Labor		32.5	
Subtotal			32.5	100
Overhead		Annual	Allocated	
	Factory Rent	50,000	1	
	Equipment Depreciation	500,000	10	
	Plant Supervision	500,000	10	
	Indirect Utilities	150,000	3	
	Security	350,000	7	
	Insurance	750,000	15	
	Taxes	200,000	4	
Subtotal		2,500,000	50	150

According to Dewey, the cost categories Parts, Materials and Supplies, and Direct Utilities represent costs that will occur every time the company makes another InstaFreezer. Labor is in that category only if the bosslady is willing to lay folks off whenever production slacks up. Liz says she'd lay off workers she doesn't need, in a heartbeat! Overhead represents estimated annual costs allocated on a per unit basis assuming an annual volume of 50,000 InstaFreezers. Dewey figures that 50,000 is a good initial guess, even though the plant capacity is 250,000 InstaFreezers per year, since the product is new and accountants are required to be conservative.

Liz has hired us to help her price the product. Let's see if we can build her a useful model. We'll start by laying out a few building blocks

P = **Price** The revenue that the company receives from selling an InstaFreezer, net of any incremental selling costs. These could include things like sales commission or freight out. We'll asssume she incurs no such costs. Note that if she did have such costs, we would need to exclude them from the price we use in estimating demand.

C = Unit Cost A cost represents money that goes out in order to produce (and sell) a product. Be cautious here. Much of your experience is as a consumer, and from a consumer viewpoint cost and price seem to be the same thing. From a producer viewpoint, they are entirely different!

Cost is one of the trickiest words in the English language; it is right up there with love. If someone tells you what it costs to make a product and you can see his lips move, you can be reasonably sure he is alive. Beyond that, be cautious about how much you believe of what you hear.

For decision making purposes, Unit Cost should represent the economic worth that the producer gives up in exchange for producing a unit. That is not the same thing as conventional accounting cost. In fact, an accountant who used economic worth for financial accounting purposes would risk jail. This cost, for decision making purposes, must be entirely incremental and future oriented.

D = **Unit Demand** The number of units that can be sold under given market conditions, including price.

DP = Demand Potential The number of units you could give away for free

PS = Prioce Sensitivity The decrease in demand per dollar increase in price

K = Capacity The rate at which a facility can produce goods or services. In many cases, costs rise in a striking manner as production gets very close to capacity. We will assume that this problem does not exist for Liz.

Q = Unit Sales The smaller of Demand or Capacity. Careers have been ruined due to ignoring the potential of capacity to limit unit sales.

TR = Total Revenue Price times Unit Sales. We may treat selling costs, if any, either as a reduction of Price (and therefore of Total Revenue) or as a separate cost category like Parts. Either way is OK if we are explicit about it. Ignoring selling costs if they are present is definitely not OK.

SC = Sunk Cost Irrelevant cost. Sunk Cost is a mix of period costs (e.g., rent) and fictional costs (e.g., depreciation) that have already been paid or promised and do not change as a function of the decision under consideration.. The only Fixed Costs that matter are those that are not yet fixed, and then only if the current decision determines whether they will be incurred.

FC = Fixed Cost Fixed Cost, just like sunk cost, is a mix of period costs (e.g., rent) and fictional costs (e.g., depreciation). The difference is that Fixed Costs depends on your decision, but no on the quantity produced or sold. The only fixed costs that matter are those that are not yet fixed, and then only if the current decision determines whether they will be incurred.

TVC = Total Variable Cost Unit Cost times Unit Sales. .

TC = Total Cost Total variable cost plus Total Fixed Cost. Do not take sunk cost into consideration for most decision making..

π = **Economic Profit** Total Revenue minus Total Cost. We try to avoid using this term. This is not because of the *rotten running dog capitalist exploiter of the innocent masses* implication. It is because Profit has a pretty explicit accounting definition that we have no interest in complying with. Often we will insist on using the term "Total contribution toward profit and overhead" instead. Here, we'll use the term profit but we'll cross our fingers behind our backs.

☠ **= Accounting Profit** Economic profit minus sunk cost. The symbol ☠ is chosen to emphasize that this quantity, as interesting as it is to accountants, is poison when used as a basis for operating decisions.

Let's assume that Liz wants to maximize profit. That makes this an optimization model that we are building. Profit is the Outcome Variable that Liz wants to optimize. Price is the Decision Variable she wants to manipulate. Everything else is just an intermediate variable. Technically, we could do without the intermediate variables, but that would be massively confusing and an invitation to error. Let's define some variables, remind ourselves of some basic relationships, and also put the results of the Marketing Research firm's work into equation form:

π = TR - TC
TR = P×D
TVC = C×D
D = DP - PS×P

In effect, what we must now do is work our way from the bottom of this set of relationships back up to the top. We'll do that now.

$$D = 2000 - 5P$$
$$TVC = 2000C - 5P \times C$$
$$TR = 2000P - 5P^2$$
$$\pi = (2000P - 5P^2) - (2000C - 5P \times C)$$
$$\pi = -5P^2 + (2000+5C)P - 2000C$$

We can find the Price that yields the best profit in 2 ways. The classic approach is through differential Calculus, and we'll do that first. You should recall the basic process:

- Find the first and second derivatives
- Set the first derivative to 0 and solve for P
- Plug P into the second derivative to verify that the result is a maximum, not a minimum.

$$\frac{d\pi}{dP} = -10P + 2000+5C \qquad \frac{d^2\pi}{dP^2} = -10$$

$$-10P + 2000+5C = 0$$
$$10P = 2000 + 5C$$
$$P = 200 + 0.5C$$

Since the second derivative is negative for all values of P, it is negative for this one. Thus profit is at its highest when we set the price equal to $200 plus half the Unit Cost. If Unit Cost is $150, that implies a price of $275. If Unit Cost is really $100, that implies a price of $250. If Unit Cost should be regarded as $67.50, then we should price the InstaFreezer at $233.75. I guess we had best settle the Unit Cost issue!

First off, since Liz is willing to lay off surplus labor, that implies that direct labor is at least very close to being a truly incremental cost. We aren't out to split hairs here ... for practical purposes, direct labor is variable <u>in this instance</u>. That means that Unit Cost is <u>not</u> $67.50.

For bookkeeping purposes, Overhead is a useful fiction. It is one mechanism for making the books balance at the end of each operating period and at the end of the fiscal year. For our purposes though, it has some real problems.

- Depreciation is merely an allocation of a past expenditure.
- It includes costs that are affected little, if at all, by the unit volume impact of the pricing decision.
- The accountant computes unit overhead by dividing his best guess at total overhead for the year by his best guess at total unit volume for the year. The total overhead guess is usually pretty good. Often, and in this instance, the guess at unit volume is horrible.

In short, our pricing decision doesn't affect what will actually be spent on overhead items. We should ignore overhead. The correct Unit Cost is $100.

Let's look at the result of our decision.

$P = 200 + 0.5 \times 100 = \$250$

$D = 2000 - 5 \times 250 = 750$ units

$\pi = -5 \times 250^2 + (2000 + 5 \times 100) \times 250 - 2000 \times 100$

$= -312{,}500 + (2{,}500) \times 250 - 200{,}000$

$= 625{,}000 - 512{,}500$

$\pi = \$112.500$

All in all, a weekly contribution of $112,500 toward profit and overhead is not a bad situation for a startup firm!

You may be thinking something like *"That's all fine, but the business about leaving overhead out of unit cost was picky, picky, picky. What harm could it do to leave it in?"* Let's look at that issue. Suppose we used the $150 unit cost in deciding on our price. That would have given us

$P = 200 + 0.5 \times 150 = \$275$

$D = 2000 - 5 \times 275 = 625$ units

Since the ***real*** incremental cost is $100 even if we fool ourselves into thinking it's $150, the profit equation gives us

$\pi = -5 \times 275^2 + (2000 + 5 \times 100) \times 275 - 2000 \times 100$

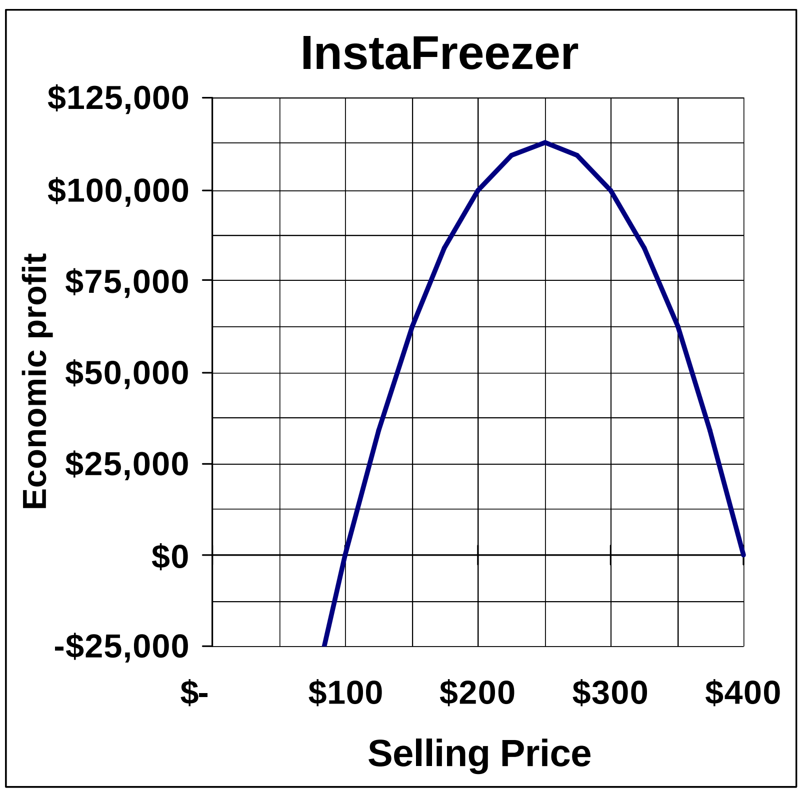
$= -378{,}125 + (2{,}500) \times 250 - 200{,}000$

$= 687{,}500 - 578{,}125$

$\pi = \$109{,}375$, a direct reduction of profit of $3,125 per week. It seems fair to say that most people would conside an avoidable error costing over $150,000 per year to be significant!

The correct way to view the fixed costs is to allocate them on a per-week basis (since we've done everything else on the basis of weekly demand and weekly profit). Based on 50 weeks per year, the weekly overhead allocation is $2,500,000/50 = $50,000 per week. Thus, the accounting profit becomes $62,500 per week.

Using a spreadsheet, it's not too hard to produce a graph like the following, which is generally more useful for management decision making than the calculus-based approach outlined above.



MoMo XQ-19

Now let's consider the case of Clovis del Novis and the marvelous MoMo QQ-19. Clovis, like Liz, is an inventor with a startup company, Unique/Oblique Ltd. The MoMo is a special cab for adding to most popular models of riding lawn mower. This cab adds many desirable features to a riding mower. To start with, it is heated and air conditioned. Beyond that, however, it gets better. If you place a special transmitter in your lawn, you need only mow the lawn once yourself. The MoMo will memorize your mowing pattern. From then on, you need only fire it up and go drink lemonade on your deck while MoMo does the work.-- and yes, MoMo can sense the presence of children and pets, and avoid them as you would. But there's more. MoMo also bags the clippings and deposits them where you want them.

Clovis and his backers are convinced that the world is ready for the MoMo XQ-19. Prototypes have performed flawlessly in tests. He has demonstrated that manufacture of the MoMo is practical. Market research has shown that there is a market, and that the wholesale price F.O.B. Unique/Oblique should be $491. The remaining question is *how* to manufacture the MoMo. Clovis investigation has revealed 3 alternatives.

1. Unique/Oblique could purchase the needed parts from outside sources and assemble the MoMo in its own plant.
2. Unique/Oblique could do essentially all manufacturing operations internally, producing all non-standard parts in its own plant and assembling the product.
3. Unique/Oblique could be essentially a marketing and distribution firm, subcontracting all manufacturing to another company.

While patents are pending on the critical MoMo technologies, Clovis knows that there are other ways to accomplish the same things, and other features (e.g., cab as tanning salon) that could be added by an aggressive competitor. He figures that the big bucks will be made in the first 3 years from the date of introduction. After 3 years, he expects to encounter serious competition. Needless to say, he intends to sell his share of the company while it is still riding high, and go on to other things. (This is not exactly the vaunted Japanese approach!) Thus he wants to base his choice of manufacturing method on the firm's potential profitability in the first 3 years from introduction of the MoMo.

Clovis' estimate of the manufacturing cost picture using these 3 alternatives looks like this:

Manufacturing Costs

Alternative	Unit Volume for 3 Years	Overhead & Administrative Costs for 3 Years	Incremental Cost Per Unit
Purchase Parts and Assemble	Any	549,000	142
Produce Parts and Assemble	First 2500	1,089,000	94
	Next 5000		54
	Above 7500		21
Subcontract Manufacture	Any	254,000	258

It seems clear that each alternative has advantages and disadvantages, depending on the 3 year unit sales volume. Clovis has a forecast of that volume under preparation, but once he has that forecast he must make a choice and live with it.

The classic approach to this problem is to treat it algebraically, as a breakeven problem. Let's start with that. We will let π stand for Unique/ Oblique's 3 year profit contribution and let D stand for units demanded. The equations look like this:

Alternative 1	$\pi = 491D - 549{,}000 - 142D \quad (D \geq 0)$
Alternative 2	$\pi = 491D - 1{,}080{,}000 - 94D \quad (0 \leq D \leq 2{,}500)$ $\pi = 491D - 549{,}000 - 94 \times 2{,}500 - 54(D - 2{,}500) \quad (2{,}500 \leq D \leq 7{,}500)$ $\pi = 491D - 549{,}000 - 94 \times 2{,}500 - 54 \times 5{,}000 - 21(D - 7{,}500) \quad (7{,}500 \leq D)$
Alternative 3	$\pi = 491D - 251{,}000 - 258D \quad (D \geq 0)$

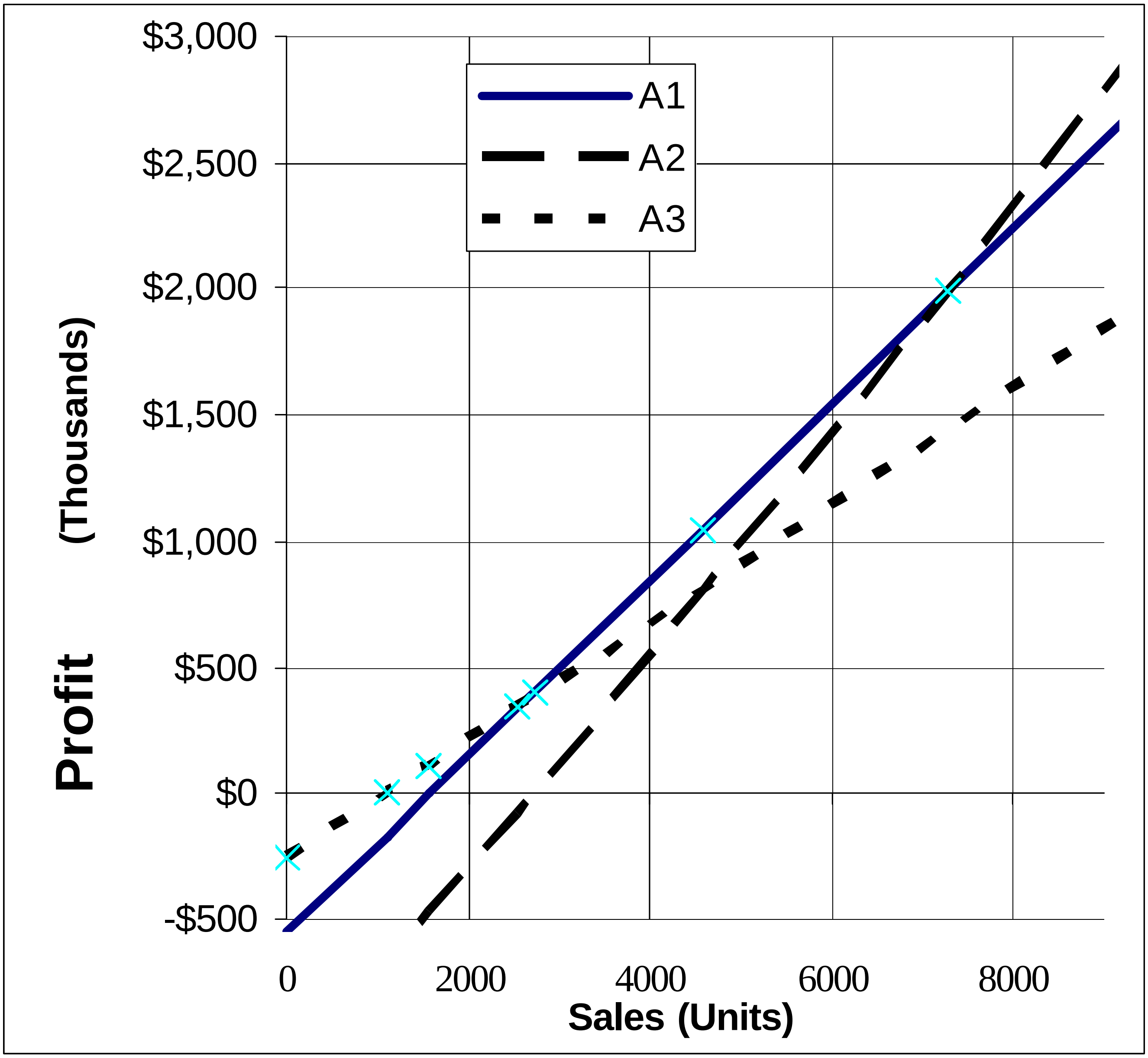
Setting π equal to zero would permit us to find the breakeven level of demand for each of these alternatives. But what Clovis wants to know is a little more sophisticated than that. Given any level of demand, which alternative is ***most*** profitable? We could handle that algebraically, but there's a better way.

This is a classic situation for using a spreadsheet program.

The first step is to set up an area for parameters. Parameters are the basic numeric information in the model. For this model, that part of my spreadsheet looked about like this:

	A1	A2	A3	
	Purchase parts & assemble	Produce parts & assemble	Subcontract Manufacture	
Fixed Admin. & Overhead costs for 3 years	$549,000	$1,089,000	$254,000	
- to 2,500 units	$142.00	$94.00	$258.00	
2,500 to 7,500 units	$142.00	$54.00	$258.00	
7,500 to 10,000 units	$142.00	$21.00	$258.00	
Selling Price per unit for MoMo XQ-19				$491.00
Quantity Sold during 3 years				8500
Revenue	$4,173,500	$4,173,500	$4,173,500	
Variable Cost				
- to 2,500 units	$355,000	$235,000	$645,000	
2,500 to 7,500 units	$710,000	$270,000	$1,290,000	
7,500 to 99,000 units	$142,000	$21,000	$258,000	
Total Variable Cost	$1,207,000	$526,000	$2,193,000	
Total cost	$1,756,000	$1,615,000	$2,447,000	
Profit	$2,417,500	$2,558,500	$1,726,500	Maximum
0	(549,000)	(1,089,000)	(254,000)	(254,000)
1090	(168,590)	(656,270)	(30)	(30)
1091	(168,241)	(655,873)	203	203
1573	(23)	(464,519)	112,509	112,509
1575	675	(463,725)	112,975	112,975
2543	338,507	(77,709)	338,519	338,519
2544	338,856	(77,272)	338,752	338,856
2720	400,280	(360)	379,760	400,280
2721	400,629	77	379,993	400,629
4583	1,050,467	813,771	813,839	1,050,467
4584	1,050,816	814,208	814,072	1,050,816
7272	1,988,928	1,988,864	1,440,376	1,988,928
7273	1,989,277	1,989,301	1,440,609	1,989,301
10000	2,941,000	3,263,500	2,076,000	3,263,500

The magic isn't in columns of numbers, though. The real gain here is that you can build a variety of graphs to show you what you need to see. I built several graphs, but the one shown is probably the most informative one:



I (and you, and Clovis) can get a pretty good idea of what the situation is from looking a the graph. Below a volume of about 1200 units, there's no money to be made. From 1200 or so units up to about 2700 units, alternative 3 (subcontract) is the most profitable. From there to about 7200 units, alternative 1 (purchase parts and assemble) makes the most money. Beyond 7200 units, alternative 2 (make it all at Unique/Oblique) is the way to go.

With some considerable effort, you could develop the same information manually. Using a spreadsheet program just makes it a lot easier.

Summary

The purpose underlying a model is to help the decision maker to structure the available information in a way that will make it easier to make a better decision. While there are many predefined model structures in existence, and we will study some of the more commonly useful ones, they don't cover every imaginable case. Sometimes you have to go out on a limb and invent your own model. Your background in economics, accounting, and spreadsheet use will serve you well in those cases. By the time you finish this course, your background in Decision Sciences will be at least as helpful.

If you assume that problem solving is difficult, it probably will be. Once you realize that ordinary people can solve a wide range of problems with a little practice, it can be fun. Fun is a lot better than difficult.

Problems

1) **Nichols Nickel Company** hired a consultant who has told them that their Total Revenue can be modeled as

$$TR = 2U + \frac{80{,}000}{U}$$

and that their Total Cost can be described with

$TC = U + 200 \quad (100 \le U \le 1500$

where U represents their total monthly Unit Sales. What monthly Unit Sales should they try for, assuming that their goal is profit? (Hint: If you're good at math, this is a pencil and paper problem. Good at math or not, it is easier with a spreadsheet program.) [*Max profit is 880]*

2) We got fancy and solved the **InstaFreeze Corp.** problem with differential calculus. That was not our only possibility. Try solving it using excel or the equivalent. You will probably want columns for Price, Demand, Total Revenue, Total Cost, and Total Contribution. The best graph is one that has price on the horizontal axis and profit on the vertical.

3) **Clemson University** has arranged for a train to Athens for the Clemson - Georgia game. The round trip fare will be $8.00 per student if 200 students go. Each additional student will reduce *everybody's* fare by 1¢ until the minimum fare of $3.00 each is reached. Thus, for example, if 250 students take the train to the game, each of them will ride for $7.50. The train won't run for fewer than 200 students. Since only 20 cattle cars will be available, they can't take more than 1000 students to the game. How many passengers would maximize the railroad's revenue? Read the hint for problem 1. [*Max Revenue is $1600}*

4) Alice Springs, an enterprising Australian exchange student who is a Senior at GSU, has assembled ***A Guide to all DSc 3120 Quiz Questions Used Since 1985***. She estimates that quarterly Demand for this jewel will be

$D = 180 - 20P \quad (4 \le P \le 8)$

where P is her selling price in dollars (American, not Australian). Her estimated Total Cost for producing and selling the booklet would be

$TC = 3U + 80 \qquad (40 \le U \le 150)$

per Quarter for *U* Units of her Guide. If she's smart enough to put all of this together, she's smart enough to pick a profit maximizing price. What will she charge? Apply the same 'ol hint. [*Max Profit/Quarter is $100]*

5) **E. Scrooge & Associates** owns an old Motel with 80 grubby rooms that they rent out to those who just can't pay for anything better. Their fixed cost amounts to $1200/month. After carefully studying his records, Ebeneezer (he doesn't really have any Associates) has determined that he can keep all rooms occupied at $120/month, but each $4 increase in the monthly rate reduces demand for these palatial cubicles by one. An occupied room costs him $12 more than if it were unoccupied (rent collection, utilities, etc.). At what rent does he come closest to breaking even? At what rent does he get the greatest profit? [*Max Profit/ month is $7264]*