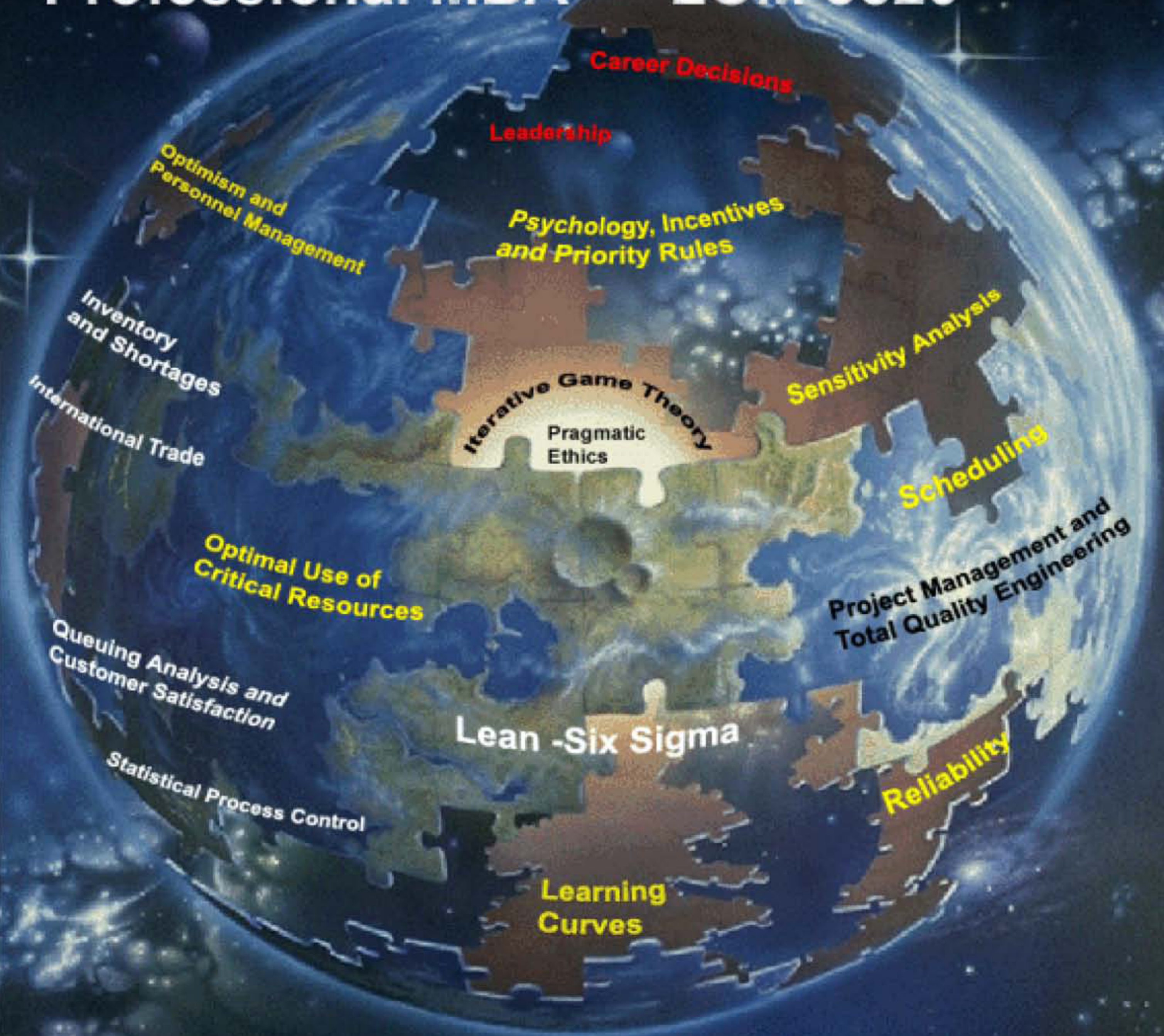
Production & Operations Management
Professional MBA LOM 5320



....It's a way of living life

Dr. Bud Banis Book I

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UM-St.Louis LOM5320

LOM 5320- Introduction to Operations Management

Professional MBA,Fall 2011. Prerequisites: IS6800, LOM5300

Text: Operations Management by Heizer/Render, 9E with POM CD, Course resource CD

Tentative grading:

- 80% Five or six Case study/problem sets/quizzes
- 20% Application Research Report presented on last day of class

"When you try to pull just one thing out of the Universe, you find it attached to everything else."
--John Muir

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Onsite #1 -Saturday,September 10

Introduction & Overview of tools

Making Quality Decisions

Decision models: risk avoidance vs. risk management	module A
Decision trees and value of information	

Onsite #2 -Friday,September 30

Joint events-reliability and redundancy	Chapter 17
Game theory, the cooperation dilemma	The Evolution of Cooperation
TQM-Statistical Process Control, Control Charts in EXCEL	Chapter 6, Chapter 6S
6-Sigma and Lean Operations	The Machine that Changed the World

Facilities /Capacity and Location Planning:

Capacity & Cost Structures	Chapter 7S
"Location" Break even Analysis	Chapter 8
Spreadsheet Budgeting	(NIB)

Onsite #3 -Saturday,October 1

Optimization models

Linear Optimization Models Geometric with POM-Win	Module B
Computer Solutions using Excel Solver	Packet+ Videotutorials
Transportation Model--Greedy solutions and opportunity cost	
EXCEL Solver solution of the Transportation Model	
Job Matching -Assignment Method-Excel Solver	Chapter 15

Onsite #4 -Friday,October 28

Microscheduling/ job sequencing:

Queuing: Infinite Source (POM-Win)	Module D
Simulation modeling	Module F, Extend software
Process Priority Rules-Excel	Chapter 15

Scheduling & Inventory Management

Aggregate Planning - scheduling	Chapter 13
EOQ Model & --Economic Run Size (ERS)	Chapter 12
Quantity discountsService Level, Safety Stock, Reorder Point.	self study
Make vs. Buy & Just in Time Philosophy (Lean Operations)	Chapter 16

Onsite #5 -Saturday,October 29

Project management, CPM & PERT	Chapter 3 -Videos
Learning Curves	Module E-videos

Onsite #6, Friday,November 18, Application Project reports, Presentations

Project reports and presentations-Application Project

Projects may be either team or individual. If a Team project, responsibility for separate sections or aspects of the project should be identified clearly. A project should consist of application of tools studied in this course to some real-life case related to work, volunteer activity, or selected observed situation in everyday life.

A project should involve quantitative analysis and work proportional to the number of participants. The presentation should be concise with 30 minutes or less per aspect/individual. Written reports are due by the last class session. Written reports should be broken into sections with identified authors for each part, as the same grade may not be assigned to all participants of a given project.

Suggested information for Application Report:

Introduction:

Name of organization , contact information if applicable
Background on the organization and nature of the problem
Brief Abstract on the Results

Body

Areas Addressed in This Project
Purpose, Brief Description of Activities
Observations (Data)
Application of the model /Analysis

Conclusions

Progress/Recommendations / Recommendations for Future Work

Keep it simple. Reports should be on the order of several pages (including data and analyses) per aspect/participant. They must be neat and legible, though graphics need not be elaborate. Reports may consist of, *e.g.,* powerpoint printouts if there is enough added description to make it understandable on its own. Participants' sections of each report will receive grades based on criteria such as novelty, clarity, correct application, significance/utility of the result. Reports will not be returned, so please keep a copy for yourself, and specify if any of the information is to be treated as confidential.

The Free Rider Problem on Team Projects--A Prisoner's Dilemma Model

A relevant example from the Course, related to team project reports:
Joe and Sally are working together on a team project for a management course. If either one works hard on the project, they will both get an A in the course. If neither does any work, they will both fail this course, but they could do better in other courses by spending less time on this one. There is a temptation to let the other person do all the work on the project and spend more time getting better grades in the other courses. If one person does all the work, then the effort required would put that person behind in other courses. Taking all this into account, here is a table showing probable semester grade point averages for different combinations of strategies. Joe's are in the upper right and he controls rows. Sally's are in the lower left, and she controls columns. What is most likely to happen? What would be better, and how can you get it? Would you rather have an A or a C+? Understanding this phenomenon is the key to achieving cooperation that is the central requirement for Total Quality Management, Just-in-Time inventory and Lean Production strategies..

Semester average for Joe and Sally depending on effort distribution

Joe / / Sally	Let Joe do it	moderate effort	work hard on project	Sally's best average
let Sally do it	2.47 / / 2.47	3.33 / / 2.33	3.67 / / 2.33	
moderate effort	2.33 / / 3.33	3.0 / / 3.0	3.33 / / 2.67	
work hard on project	2.33 / / 3.67	2.67 / / 3.33	3.55 / / 3.55	
Joe's best				

Planning Horizons

&

Hierarchy of Management Decisions

Broad Scope

- What is the business?
- locations
- choice of technology

Moderate Scope

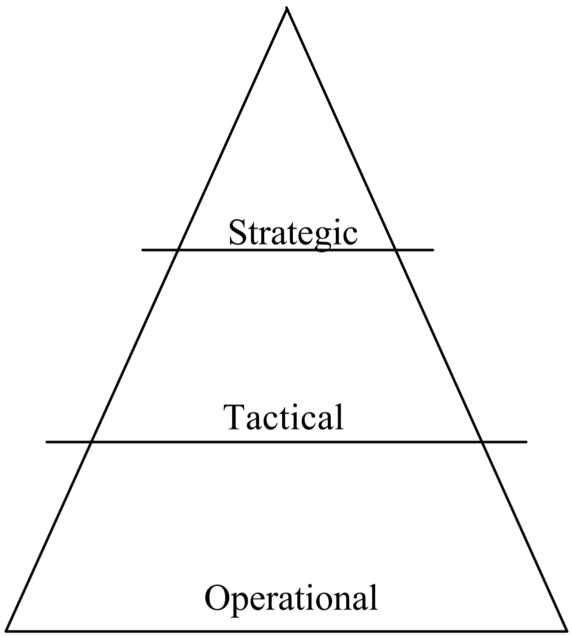
- Equipment selection
- Employment levels
- project selection
- Annual Budgets

Narrow scope

- Monthly scheduling
- Adjusting outputs
- Controlling quality
- moving inventory

Immediate

- Happy hour time & location



CEO (one in ten million)

10 - 20 Years   Industry

VP

5 Years   Corporation

Manager/Director

3 - 5 Years   Division

Supervisors

1 year   Department

Hourly workers

Days -weeks   Group

Elliot Jacques --at the Institute of Organizational & Social Studies
Brunel University, England

optimists, pessimists and statisticians views on decisions in the dark
Three States of Nature

Payoff Table ($M, NPV)

	Demand-->	Low	Moderate	High	Optimist	Pessimist	statistician
	Probability						
Alternatives: plant size							
	small	10	10	10			
	medium	7	12	12			
	large	-4	2	16			
	if certain:						

Optimistic and pessimistic views on hiring smokers:

Total fringe benefit costs for smokers <u>vs</u>. non-smokers

Many companies are adopting restrictive policies about smoking in the workplace. This direction is usually related to the rights of non-smokers and the established ill effects of "second hand smoke". There are other good economic reasons for discouraging employees from smoking. Smoking in the workplace results in higher facilities costs: more frequent repainting, airhandler maintenance, effects on furnishings; lost time is higher for smokers due to more frequent breaks and sick time, and smokers have higher health care costs. However, it's been suggested that total fringe benefits for heavy smokers hired late in their careers may actually be lower than for non-smokers as life expectancy is less and so there may be substantial savings on pensions for smokers.

Suppose you are the benefits director of a large company, and you want to develop a policy of hiring only non-smokers, moderate discrimination, or no discrimination against the large number of smokers that have trouble getting jobs at other companies. One of the uncertainties is the possibility that advances in medical science might give effective, albeit costly, treatments for the health effects of smoking, that would prolong the lives of smokers, or else that someone might discover breakthrough cures - either for the ills or for curing smoking itself.

The following table gives costs that might reflect this situation:

<u>Total benefits cost as a function of policies on hiring smokers</u> ($M)

	medical progress			optimist	pessimist
	none	treatments	cures	<u>(Maximax)</u>	<u>(Maximin)</u>
only non-smokers	200	200	200		
some discrimination	360	280	210		
no discrimination	150	300	220		

<u>Potential Regrets about policies on hiring smokers</u>

	medical progress			Minimax
	none	treatments	cures	<u>regret</u>
only non-smokers				
some discrimination				
no discrimination				

Optimism and Three Dimensions of Explanatory Style:

Dimension	Bad Events	Good Events
Permanence:	Optimist: temporary Pessimist: Permanent	Optimist: Permanent Pessimist: Temporary
Pervasiveness	Optimist: Specific Pessimist: Global	Optimist: Global Pessimist: Specific
Personalization:	Optimist: External Pessimist: Internal	Optimist: Internal Pessimist: External

Martin E.P. Seligman, Ph.D.,1991, Learned Optimism, A.A. Knopf, New York

optimists, pessimists and statisticians views on decisions in the dark
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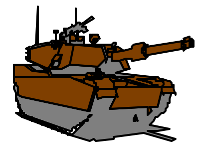
	Demand-->	Low	Moderate	High	Optimist	Pessimist	statistician
	Probability						
Alternatives: plant size							
	small	10	10	10			
	medium	7	12	12			
	large	-4	2	16			
	if certain:						

regrets

	Demand-->	Low	Moderate	High
	Probability			
Alternatives: plant size				
	small			
	medium			
	large			
	if certain:			

The Safe Driver Training Program for Humongo Corp.

An example of best average result approach vs. Fear of criticism and punishment.



A government agency has delivered an administrative ruling that companies must have documented training for their drivers or they may get fined. The Consulting Yahoo Agency (CYA) would do training. Bob Koehler, as Safety Coordinator at Humongo Corp., is being paid big bucks to help the Safety and Operations Council (SOC) make an informed decision to do one of three things:

1. Ignore the issue and hope the courts overturn it-- training cost, $0.
2. Train just those employees who drive company vehicles--training cost, $100K.
3. Train everybody---Training cost, $4 M.

The probability of a stringent interpretation is low (1%), but would result in a $20M fine if everyone isn't trained. A moderate ruling would give a fine of $3M only if the company drivers aren't trained. This gives the costs shown in the table. Calculate expected monetary loss for each approach.

Total cost of as a function of policies on driver safety training ($K)

	combined cost of training and fines ($K)			
Court attitude	loose	moderate	stringent	EMLoss
Probability	0.75	0.24	0.01	
Nobody	0	3,000	20,000	
Company car drivers	100	100	20,100	
Everybody	4,000	4,000	4,000	

If Bob were trying for the best average result, which approach would he recommend?

	Potential regrets		
Court attitude	loose	moderate	stringent
Nobody			
Company car drivers			
Everybody			

If costs are "too high", Bob would never get promoted. He could even get fired for giving bad advice (sacked by SOC). Show what he would recommend if he were taking a minimax regret strategy.

On average, how much more would it cost the company to have minimax regret strategies used in cases like these instead of expected monetary value?

What could SOC do to promote decisions based on best average result?

Expected Monetary Value
Three States of Nature

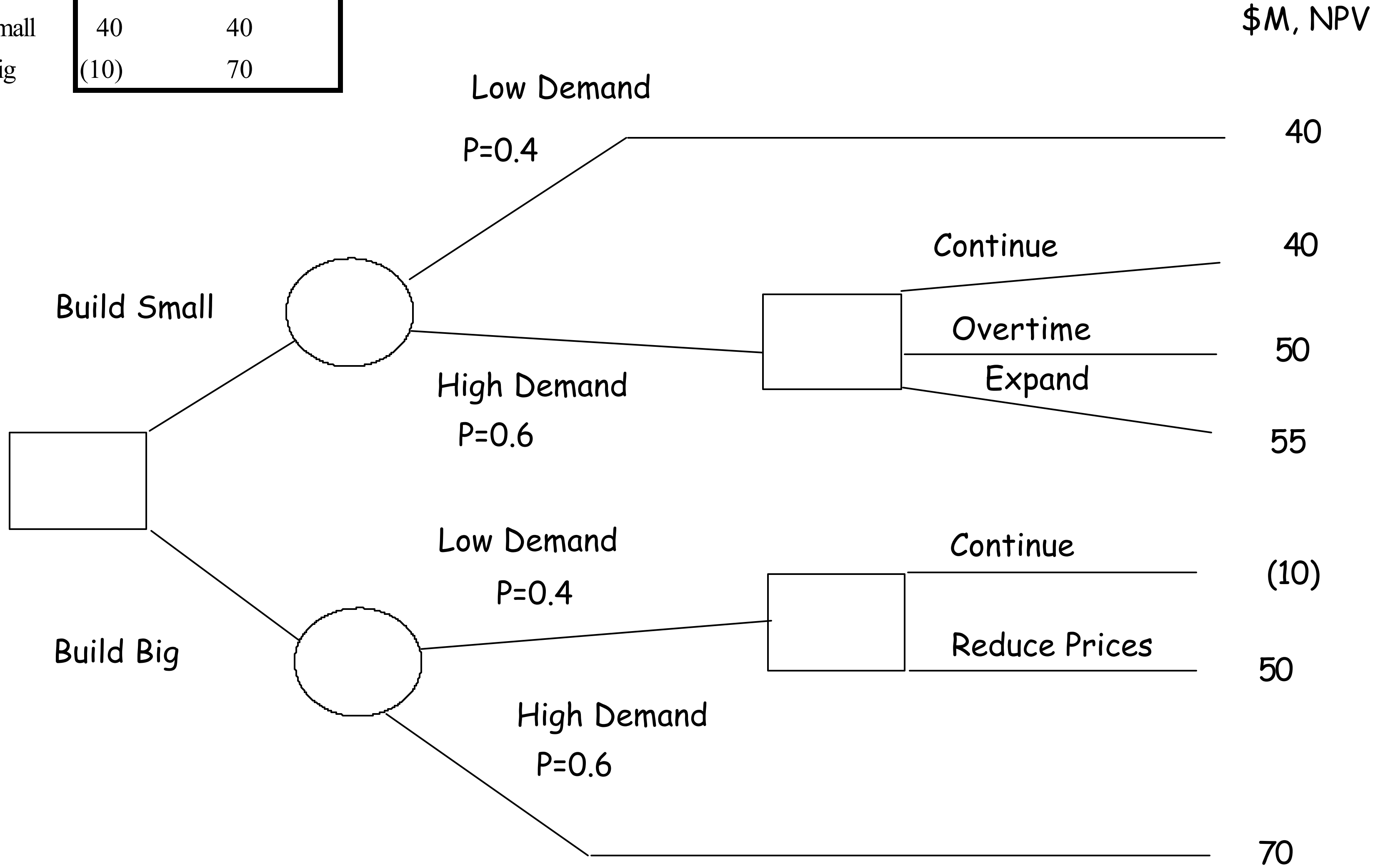
Payoff Table ($M, NPV)

	Demand-->	Low	Moderate	High	total
	Probability	0.3	0.5	0.2	1
Alternatives: plant size					
	small	10	10	10	
	medium	7	12	12	
	large	-4	2	16	
	if certain:				

expected Value of Perfect information=
(EVPI)

Future Options may change the decision

Demand	low	high
Probability	0.4	0.6
	$M,NPV	
build small	40	40
build big	(10)	70



EVPI=

Expected Value of sample (imperfect) information

Market test for National introduction of a new perfume

	$M, NPV
do nothing	0M.
National success	30M.
National failure	(10M.)

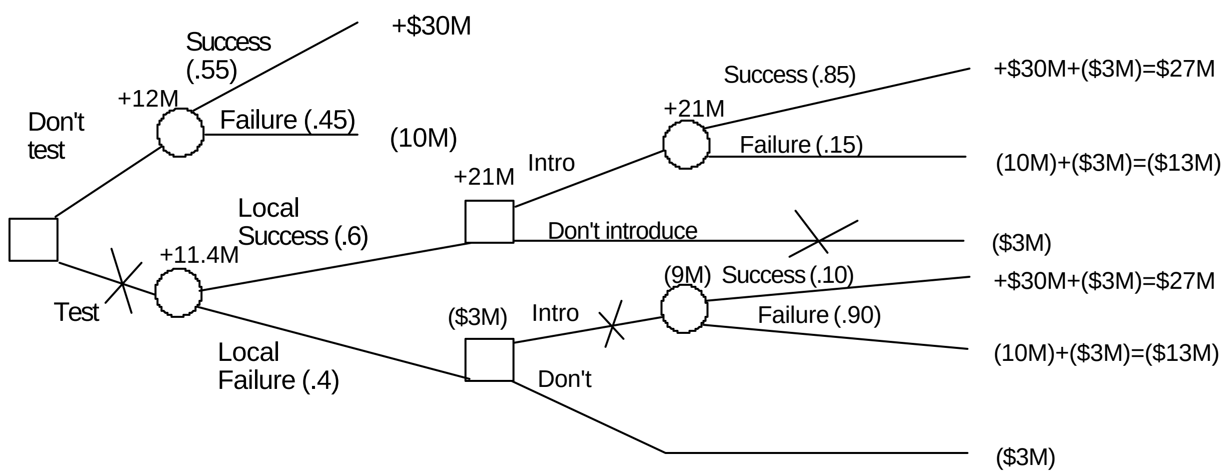
Estimate of national success Without Prior Knowledge:

Psuccess = 0.55
Pfailure = 0.45
Cost of market test = $3M

Test outcome gives revised estimates of national rollout success:

Good test Result (P=0.6) ==> Psuccess =.85
Pfailure =.15
Bad test Result (P=0.4) ==> Psuccess =.10

Note (Thomas Bayes):
Overall $P_{success}$ = 0.6*0.85 + 0.4*0.10 =0.55
Overall $P_{failure}$ = 0.6*0.15 + 0.4*0.90 = 0.45
"Sums of the posterior probabilities must = the prior probabilities."



Pfailure =.90
With Cost of the Test = $ 3 M

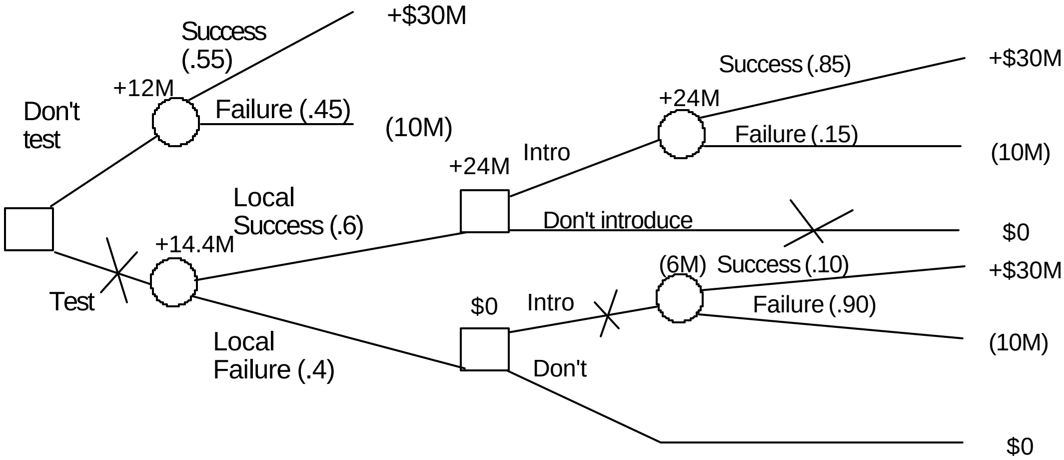
	EMV do Test =	+ 11.4 M	
less	EMV don't test =	+ 12 M	
	Difference =	- 0.6 M	(a loss!)

If we had to pay $3.0M for the test, the value of testing vs. not testing is - $0.6M. What is the value of the information from the test?

The test cost us $3M and resulted in a loss (reduction of EMV) of $0.6M. This doesn't mean the information has a negative value, it just means that we paid more for it than it was worth. Specifically, we paid $0.6M more for the information than the breakeven cost. Therefore, the breakeven cost, or value of the information is $3.0 - 0.6 = $2.4M.

Another way to look at this would be to consider how much the information would increase our EMV if it had no cost.

Change in EMV if the cost of the test were $0



With Cost of the Test = $ 0

	EMV do Test =	+ 14.4 M
less	EMV don't test =	<u>+ 12 M</u>
	Difference =	+ 2.4 M

The Value of the information from the test is $2.4M (Q.E.D.)

Other costs:

As an aside, other than direct costs, market testing has other costs to consider:

1. Delay- Loss of time value of money
2. Delay - missing a transient opportunity (fad or patent life)
3. Loss of surprise market advantage - Information to competitors.

A billion $/yr. product with a 36% contribution margin costs one million dollars in lost profit for every day of delay. What would it cost to get the resources to avoid that delay?

Decision Trees - Procedure:

1. Start with primary decision
2. Draw all branches (states of nature), with probabilities
3. Show secondary decisions
4. ...repeat 2 & 3 as needed ...
5. Assign values to the terminal nodes
6. Work back from the future
7. Trim branches, evaluate nodes
8. Calculate EMV's
9. Make decisions
10. Calculate EMV's for primary decision
11. Pick the biggest number (accounting)

Good Decisions aren't made.
They follow from the data.

Decision Tree Applications

Fix the Car or Junk It?

The oil pump failed on your car. There's a 60% chance the engine is ruined as well but you can't tell whether it is until after the oil pump is repaired. Fixing the oil pump would cost $700. If the engine is ruined, repairing it would cost an additional $1200. Alternatively, you could junk the car and replace it with an equivalent car for $1400.
If your objective is to minimize expected cost, should you fix the oil pump or not? If you decided to fix the oil pump and then found the engine was ruined, should you junk the car or do the additional repairs? Why or why not?

Which job? Value of Future Growth Potential

A) Only the immediate:

You have two job offers. One is for a plant superintendent in Iowa, which has a present value of income streams of $1M. The other is a job in the General Offices (G/O), with a present value of $1.1M. Draw a tree diagram for this immediate decision, ignoring all future events. If your only interest is to maximize present value, which would you take?

B) What Happens Next? 5 Years out.

Neither position is necessarily a dead-end job. In Iowa there is a 70% probability of being promoted to plant manager in a few years, which would have an NPV of $1.5M. The probability of promotion at the G/O is only 20%, but the NPV would be $1.6M. Draw another tree showing these future events and calculate EMV's for the alternatives. Given these additional future possibilities, which job would you pick to maximize EMV?

C) The Value of Future Options -- 10 Years out.

At the G/O, if you're not promoted, you may still choose to quit your job and find a better one outside the company, raising NPV to $1.4M. The plant is in such a desolate location, and you would have become so specialized that there are no outside opportunities in Iowa. You can't move. Draw a new tree showing your future option to stay or find a new job if you're at the G/O and haven't been promoted.

D) Value of advance information.

How much would it be worth to you (EVPI) to have prior knowledge of whether or not the G/O job will grow? Consider future options and assume no new information about promotion at the plant.

Income Tax Deductions and Audit Risk

You have a one time opportunity this year to make some substantial deductions on your income tax that would reduce your taxes by $10,000. Although these are completely legitimate, the amounts are unusual enough that you would increase the probability of being audited from 10% to 60%. In the event you're audited, a number of other previous deductions will be disallowed resulting in charges of $40,000. However, You can appeal the audit ruling with a 70% chance of winning. Your court costs for the appeal would be $10,000 whether you win or lose. Should you claim the deductions?

High option vs. Low Option Health Insurance Plans

You're trying to decide whether to buy the High option health insurance plan for $700 or the low option plan for $500. The difference between the two plans is that the high option plan has major dental coverage with a $50 deductible (amount not covered, that you have to pay). there is a 60% chance that you're going to need major dental work in the next year, which would cost $500 if you don't have dental coverage.

You can upgrade from the low option to high option plan later (after you know whether the dental work is necessary) for an additional $400.

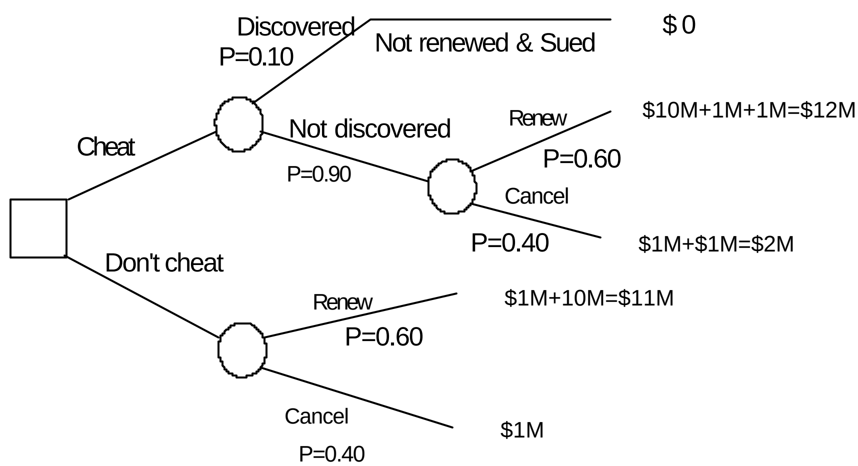
Should you make an insurance claim even though it may raise your rates?

You've just had a minor automobile accident in your driveway. There is no legal requirement to report the accident, but you're wondering whether you should put in an insurance claim for the $300 in damage. Your "accident free" rate on your insurance policy would be unaffected by this one claim, but if you had another claim in the next 3 years, your rates would go up enough to cost you an extra $1000 (present value). Of course, you could always claim this accident and choose not to claim a future accident if it happens. There are three possible future states (adjusted to present values): no accident (P=.5), a $300 accident (P=.2), or a $1200 accident (P=.3). For simplicity, assume that the accident free rate will be eliminated after three years due to changes in the insurance laws, so any accidents beyond this planning horizon would be irrelevant.

Should you report the first accident and claim compensation ?

Is 100% Audit of Invoices really necessary?

In the spirit of Just-in-Time inventory management, ABC Co. has a partnership arrangement with one of its vendors and has decided to eliminate 100% audit of invoices. As a result, the vendor could overcharge on the invoices and there would only be a 10% chance that ABC would discover it. Suppose the two plan to do enough business this year that the vendor would net \$1M. If the vendor cheats without getting caught, he could make an additional \$1M. If ABC discovered the cheating, the vendor would be sued and would lose the \$1M gained through cheating, the normal \$1M profit, and would be eliminated from future business with ABC. The present value of future business is \$10M. If ABC is unaware of any overcharges, the probability of a contract renewal is 60%.



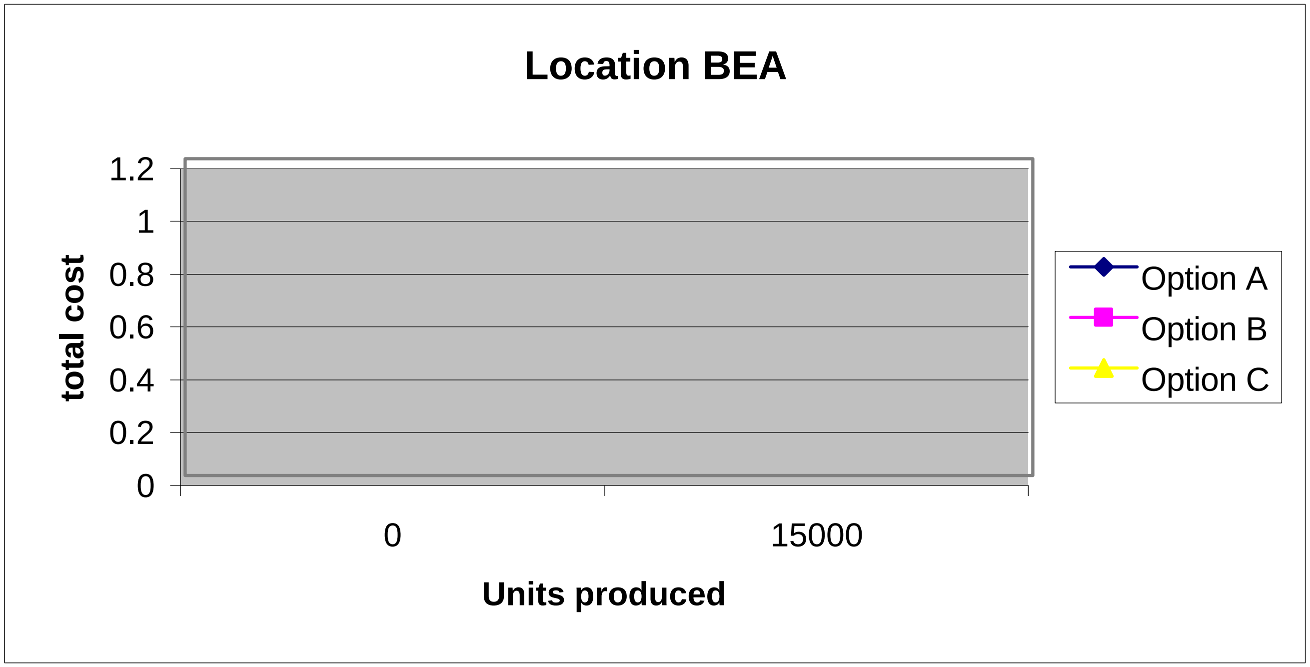
A) Under these conditions, would the vendor have incentive to cheat or be honest?

B) How high would the probability of discovery have to be to eliminate the incentive to cheat (indifferent between cheating or not)?

C) What are three other things that could be changed to reduce the incentive to cheat?

"Location" Break Even Analysis

Option	Cost ($) FC ($K)	UVC	TC@0 U 0	TC@15,000 U 15000
A	250000	10		
B	150000	20		
C	100000	30		



Spreadsheet Budgeting

You can use a spreadsheet to compute detailed budgets for your Department using fixed and variable costs.

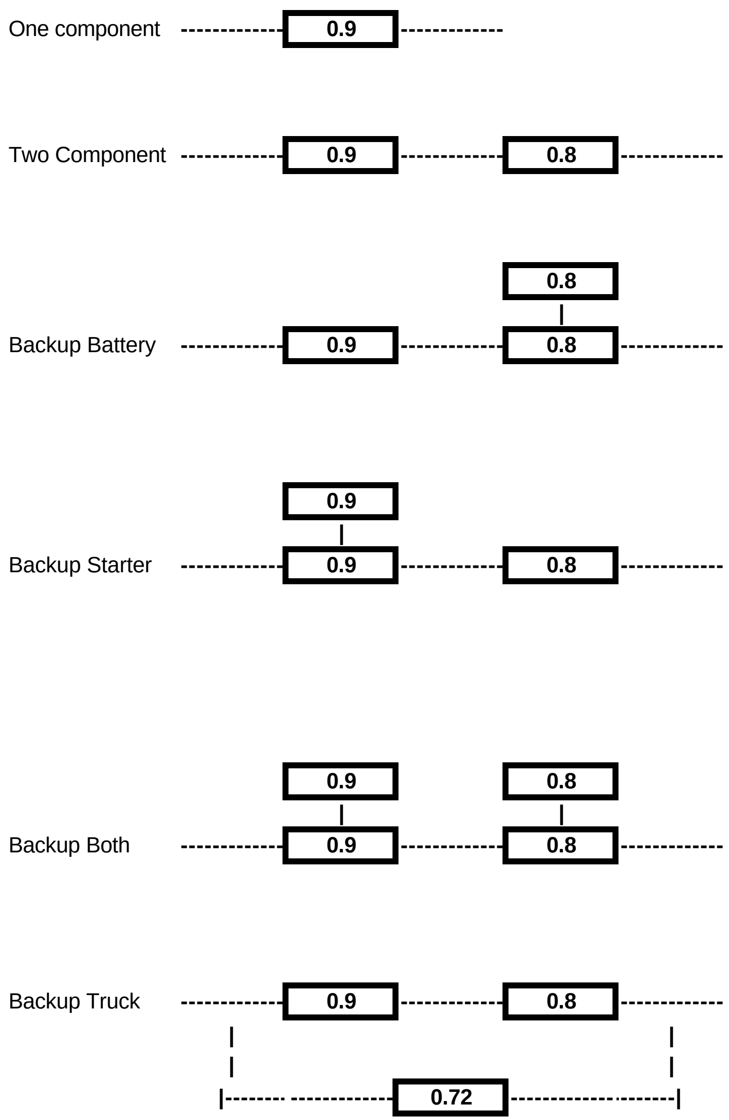
Last year's actual expenses are shown in column B. Amounts are in thousands, rounded to hundreds. 472 Units were produced last year. Expenses are categorized as either fixed or variable with a factor of 1.0 in column D if a cost is completely independent of production rate.

1. Forecast expenses for 700 units production by rolling over fixed costs and adjusting variable cost for costs per unit
2. Suppose revenues of $30 per unit were left to cover your budgeted costs after deducting selling costs, etc.. You can manipulate volume in cell G5 (circled) to find the break-even point. At what volume is unit cost $30 ?
3. Suppose 20% of your operators were needed just to maintain the buildings, so that 20% of operator's salaries should be considered as fixed cost. Change the fixed factor for Operator's salaries to 0.2 and get a new projected budget for 700 units.

	A	B	C	D	E	F	G	H	I	J
1	=NOW()	This Year	-			Next Year	-	-	-	
2	Expense	Annual'd	Fixed		Unit	Fixed	Variable	Total	Unit	
3	Class	Actuals		or	Cost	Cost	Cost	Budget	Cost	
4	-	-		Var.	-	-	-	-	-	
5	Volume	472	Factor		=B5		700		=G5	%
6	-	-			-	-	-	-	-	
7	Spvsr Pay	=30.2*15	F	1	=B7/$E$5	=B7*D7	=E7*$G$5*(1-D7)	=G7+F7	=H7/$I$5	=H7/$H$19
8	Operat.Pay	=22.1*80	V		=B8/$E$5	=B8*D8	=E8*$G$5*(1-D8)	=G8+F8	=H8/$I$5	=H8/$H$19
9	Materials	1347.2	V		=B9/$E$5	=B9*D9	=E9*$G$5*(1-D9)	=G9+F9	=H9/$I$5	=H9/$H$19
10	Ofc.Supplies	3.7	F	1	=B10/$E$5	=B10*D10	=E10*$G$5*(1-D10)	=G10+F10	=H10/$I$5	=H10/$H$19
11	Supplies	1923.5	V		=B11/$E$5	=B11*D11	=E11*$G$5*(1-D11)	=G11+F11	=H11/$I$5	=H11/$H$19
12	Heat	451.4	F	1	=B12/$E$5	=B12*D12	=E12*$G$5*(1-D12)	=G12+F12	=H12/$I$5	=H12/$H$19
13	Telephone	=1.6*9	F	1	=B13/$E$5	=B13*D13	=E13*$G$5*(1-D13)	=G13+F13	=H13/$I$5	=H13/$H$19
14	Electric	257.6	V		=B14/$E$5	=B14*D14	=E14*$G$5*(1-D14)	=G14+F14	=H14/$I$5	=H14/$H$19
15	Rep.&Maint.	113.6	V		=B15/$E$5	=B15*D15	=E15*$G$5*(1-D15)	=G15+F15	=H15/$I$5	=H15/$H$19
16	Reworks	567.2	V		=B16/$E$5	=B16*D16	=E16*$G$5*(1-D16)	=G16+F16	=H16/$I$5	=H16/$H$19
17	Adm.Alloc'n	5000	F	1	=B17/$E$5	=B17*D17	=E17*$G$5*(1-D17)	=G17+F17	=H17/$I$5	=H17/$H$19
18		-			-	-	-	-	-	-
19	TOTALS	=SUM(B6:B18)			=SUM(E6:E18)	=SUM(F6:F18)	=SUM(G6:G18)	=SUM(H6:H18)	=SUM(I6:I18)	=SUM(J6:J18)
20	Bud Banis									
21						Category		Budget		
22						-		-		
23						Payroll		=H7+H8		
24						Mat. & Supplies		=H9+H11		
25						Reworks		=H16		
26						Other Op. Cost		=H29-H23-H24-H25-H27		
27						Allocations		=H17		
28								-		
29						TOTAL		=H19		
30								=SUM(H22:H28)		

Compound Events & Reliability Models

System P(work)

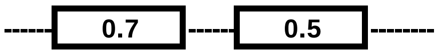


Cost Tradeoffs - Failure vs. backup Costs

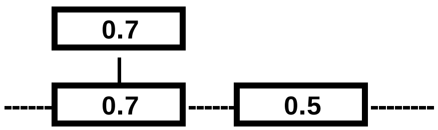
Backup Cost	$2000 per
$300/cycle	Failure

Reliability	Pfail	Expected Fail cost	Backup Cost	Total Cost

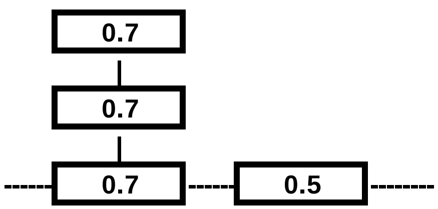
No Backups



one backup



two backups



Cost Tradeoffs - Failure vs. backup Costs

Backup Cost	$2000 per
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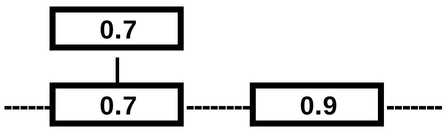
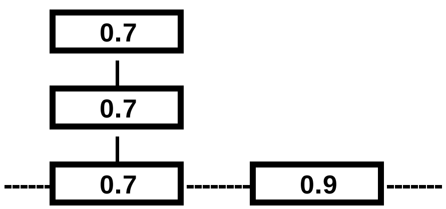
	Reliability	Pfail	Expected Fail cost	Backup Cost	Total Cost

No Backups

one backup



two backups



Spreadsheet Factor Rating

Here is a factor rating spreadsheet to help you decide among job offers.

A) Enter your weights in column C for each factor and the rating you would give each job on each factor in columns D, E, and F, respectively. The job that ends up with the highest weighted mean score is the one you would take. But there's more to the story!

B) For each of the two rejected jobs: use the sheet to explore what changes you would have to get to make each of these your preferred option. For example, would higher pay or a contract (security) sway your decision? Do not change your weights. They represent what YOU think is important. Consider what you would ask to have changed about the offers to make them conform to what YOU want. provide printouts for each of these scenarios.

C) Consider the changes required to get you to change your mind in each case. Don't accept less. The first step in successful negotiation is knowing what **you** want!

For example, suppose you have three job offers:

Job#1: Humongous Chemical Co., St. Louis. Jr. Assistant to the Vice Gopher. Community conscious. People-oriented. Abundant computers and self- improvement programs. Nobody leaves. Comfortable salary, annual raises. Weekends with the family.

Job#2: Cutthroat Sales Ltd., San Francisco. Vice President Consumer Electronics. Privately owned by a tyrranical street fighter who will give you equity if he likes you. Lotsa bucks but high rent. Forget weekends.

Job#3: Cosmofad Advertising, TBA (The Big Apple). Account Exec. for cosmetics and teen jeans. Need a good liver & comfort with the Concorde. Opportunity to advance rapidly on the merits of your work, but lots of politics with the customers -sometimes on weekends, but your spouse is expected to participate.

A B C D E F G H I J

File: JOBRATE
Similar to
Prob.5.9, P.246-247

Factor	(0-100) Weight	Scale 0-100 Rating Job#1	Job#2	Job#3	Normal Weight	Wtd.Rating Job#1	Job#2	Job#3
Pay	23	70	90	35	+B7/$B$18	+C7*$G7	+D7*$G7	+E7*$G7
Status/Title	34	56	90	75	+B8/$B$18	+C8*$G8	+D8*$G8	+E8*$G8
Location	56	78	90	85	+B9/$B$18	+C9*$G9	+D9*$G9	+E9*$G9
Security	75	34	56	90	+B10/$B$18	+C10*$G10	+D10*$G10	+E10*$G10
humane culture	80	90	50	35	+B11/$B$18	+C11*$G11	+D11*$G11	+E11*$G11
stability	50	65	30	20	+B12/$B$18	+C12*$G12	+D12*$G12	+E12*$G12
resources/tools	35	50	20	25	+B13/$B$18	+C13*$G13	+D13*$G13	+E13*$G13
learning	25	40	10	60	+B14/$B$18	+C14*$G14	+D14*$G14	+E14*$G14
Advancement	90	34	45	90	+B15/$B$18	+C15*$G15	+D15*$G15	+E15*$G15
Spouse' opinion	10	25	80	5	+B16/$B$18	+C16*$G16	+D16*$G16	+E16*$G16
TOTAL	@SUM(B16..B7)				@SUM(G16..G7)	@SUM(H16..H7)	@SUM(I16..I7)	@SUM(J16..J7)

Bud Banis
09-Nov-94

Game Theory

Assumptions:

- opponents are rational, intelligent, and act in their own self interest.
- Rules and outcomes are known. Each player decides on his own strategy with regard to the opponents' projected response and the resulting expected outcomes.

Definitions:

- ***Games*** -differ from other decision theory in that the events which are not under our control are under the control of a sensate opponent who is assumed to be rational - acting in his own self-interest. This contrasts with "nature" which was assumed to act with some definable probabilities but without prejudice.
- ***Zero Sum game*** -game in which the sum of all players' gains and losses is zero. That is, any player's gain must be balanced by some other player's loss. The size of the pie to be divided doesn't change.
- ***Nonzero sum game*** -the wealth to be divided among the players changes in response to the strategies of the players. In a two player game, both players can be winners, or both players can be losers. The essence of the prisoner's dilemma is that the stable strategy is one in which both players are losers.
- ***Cooperative model*** -Players agree to split the winnings at the end of the game, so they act in agreement to achieve the outcome that maximizes total wealth. (max profit, min loss).
- ***Win-win negotiation*** -outcome in which the settlement results in an increase in the total wealth, with each party improving his condition through the exchange.
- ***Free trade*** **-**Exchange in which both parties gain (increase wealth). Since players have the option of not playing, or playing another game, the exchange won't take place unless both players win.
- ***Competitive model*** -Each player independently acts to maximize his own winnings without regard to the total wealth at the end.
- ***Compromise*** -process by which someone who isn't going to get his way makes sure no one else does either.

A Zero Sum Game with a stable "saddle point" solution:

by convention, the table shows payoffs for player A, whose alternative strategies are listed down the left hand side. Alternative strategies for player B are listed across the top of the table. Gains for A are losses for B.

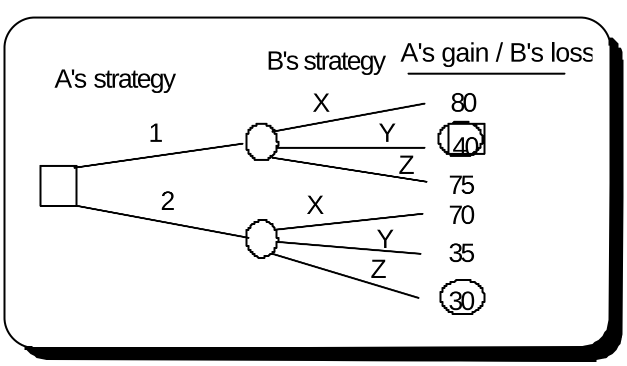
Values in the final row are the highest gains A could choose if B pursued each of the strategies, X, Y, or Z. Thus, if B elected strategy X, A would choose strategy 1. If B pursued Y, A would choose 1, and if B chose Z, A would still choose 1. Each choice of A is enclosed in a square.

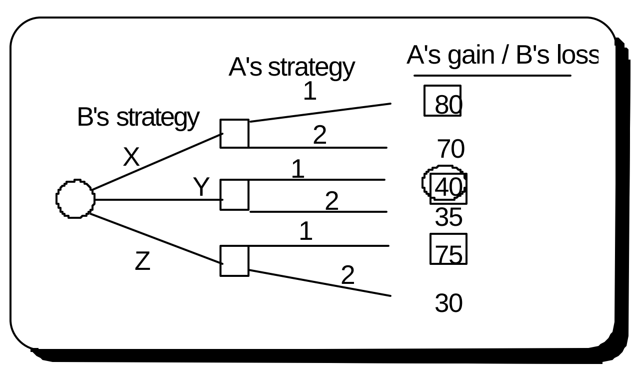
A \ B	Strategy	Strategy Y	Strategy	Min
strategy 1	80	40	75	40 B's best
Strategy 2	70	35	30	30
Max Gain	80	40	75	

A's best

Values in the final column are the minimum losses B could choose for each strategy of A (each is circled). If A pursued 2, then B would choose the lowest loss strategy, Z. If A chooses 1, B would choose Y.
The stable solution is for A to choose 1, and B to choose Y. This is the minimum of A's maximum gains for each of B's strategies(Maximin for A), and the Maximum of B's minimum losses for each of A's strategies (Minimax for B). This is called a "saddle point solution" because -viewed as profits -- it's on minimum point for both the A and B Axes -like a saddle.

Another way to look at this is as a tree diagram:
A, in planning his strategy, would consider what B would do in response and what the resulting payoff would be. A then chooses the strategy that would result in the best final outcome. B does the same thing. Thus, in this case, A would pick the strategy that results in the maximum of the minimum gains. The solution is stable because, with these particular numbers, neither A nor B has incentives to switch to another strategy. This is a *Nash Equilibrium.*





A's market share as a function of advertising strategy				
A / B	None	Medium	Large	B's min loss
none	60	50	40	40
medium	70	70	50	50
large	80	60	75	60

Zero sum games requiring mixed strategies:

Not all games have equilibrium points with simple strategies. In the following example, if B knew that A was going to choose no advertising, then B would max it's market share by pursuing large advertising. However, if A could predict that B would do large advertising, Then A would also do large advertising. But, if B could predict that A would do large advertising, then B would choose to do medium advertising, and so forth. Since there isn't any combination of strategies that both would pursue simultaneously, there isn't any stable simple strategy. For any strategy A would pursue, B would prefer a strategy that would cause A to prefer a different strategy. One solution is for players to pursue random strategies to keep opponents from reacting effectively. (Assume opponents have to choose strategies ahead of time) . However, even in random mixed strategies, if the probabilities are known, the competitor can still gain an advantage by treating it as a max EMV decision problem. To avoid this, Each opponent should choose mixed strategies with probabilities that would make the opponent indifferent - no advantage can be gained by pursuing one strategy versus another. Predictable pure strategies would result in lower gains than using mixed strategies with probabilities chosen to make the opponent indifferent. First, to simplify the matrix, let's eliminate strategies that A & B wouldn't pursue in any case. No matter what B would do, A wouldn't pursue the strategy of no advertising. Likewise, for all strategies of A, B would do some advertising. Eliminating the strategies of no advertising on the parts of both A and B reduces the problem to the 2 by 2 matrix shown. Now, suppose A chose to do medium advertising. B, knowing this, would choose to do a large amount of advertising to minimize A's market share. A's payoff would be 50% market share. Likewise, if B knew that A was going to pursue a strategy of large advertising, B would follow the strategy of medium advertising, and A's share would be 60%. From the other side, suppose B were to pursue a pure strategy of medium advertising. A, knowing this, would choose a strategy of medium advertising as well, giving B a market share of only 30% (100%-70%). If B consistently did large advertising, A would also do large advertising, and B's market share would be only 25%. The only way to get equilibrium is for each to pursue strategies in unpredictable patterns with probabilities such that the other guy is indifferent between his alternatives (expected values are the same for each alternative).

Solving for the probabilities required:

<u>A's EMV's:</u>

EMV medium for A = EMV large for A

$70q + 50 (1-q) = 60q + 75(1-q)$

Solving for q gives $q = 5/7$;

so $(1-q) = 2/7$.

Therefore: if B pursues medium 5/7 of the time and large 2/7 of the time, A will be indifferent between his own strategies of medium or large advertising and will have an expected return of 64 and 2/7% market share. This is better than the 60% obtainable from a pure strategy of large advertising.

Matrix Reduced by eliminating dominated strategies

A / B	medium	large	proportion
medium	70	50	p
large	60	75	1 - p
proportio	q	1- q	

<u>B's EMV's:</u>

EMV medium for B = EMV large

$70p + 60 (1-p) = 50p + 75 (1-p)$

Solving for p gives $p= 3/7$, so $(1-p) = 4/7$

therefore, if A pursues the medium strategy 3/7 of the time, B will have the same expected payoff (B's market share = 100% - 64 and 2/7% = 35 and 5/7%) for both strategies and will be indifferent between them. This payoff is better than the best pure strategy result of 30%. The combined result is stable. Neither party has incentive to change.

A Nonzero-Sum Game and The Prisoner's Dilemma: Now, picture two partners in crime who have been picked up by the police. The penalty for robbery is 10 years in jail. If neither confesses, then the worst they can be convicted of is stealing the car they used for the getaway, which has a penalty of one year in prison. If, on the other hand, they both confess, they will be convicted of the robbery as well, and will get 5 years in prison as a reduced penalty for being cooperative with the police. The District attorney, in order to split the team and provide incentive for confession, has offered each separately to let him off with a suspended sentence if he confesses and his partner doesn't. In the event one of the partners is convicted without being cooperative (confessing) he will get the full penalty of 10 years in prison. The matrix shows the different payoffs in this game in which the total penalties change depending on the combination of strategies. A's outcome is in the upper left corner of each split cell, and B's outcome is shown in the lower right corners. To minimize the total penalty, both should agree to stay quiet and not confess. In this case, the total penalty would be 2 years in prison, one for each. However, if each considers his best strategy in case of each strategy that might be pursued by his opponent (former partner), it's apparent that he would achieve the best result in each case by confessing. A's best strategy if B is quiet is to confess and get off. A's best strategy if B confesses is to confess as well so that his sentence will be reduced. Thus, regardless of B's strategy, A's best strategy is to confess. The same holds true for B's options. The strategy of staying quiet is dominated by the strategy of confessing - which leads to the inevitable result that both will be convicted and sent up the river for 5 years each. The prisoner's dilemma is whether or not to trust his colleague with the hope of a 1 year penalty or to pursue his dominant strategy of confessing --betraying his partner -- in the hopes that his colleague trusted him not to do so. Research on simulated conditions of this sort has shown that game players who take a chance on the good faith of their fellows and follow the no-confession strategy are consistently exploited by their less-trusting partners. Consider how this process applies to everyday games such as nuclear armaments, advertising costs, cartels and price fixing arrangements.

It's a tough life. Never trust anybody.

A / B	hold quiet	Confess	B's Min penalty
Hold Quiet	-1 / / -1	-10 / / 0	0
Confess	0 / / -10	-5 / / -5	-5
A's Min	0	-5	

References:
Bierman, jr., H.,Bonini, C.P. &Hausman, W.H., 1969, Quantitative Analysis for Business Decisions, Irwin, Homewood, IL
Falletta, N., 1990, The Paradoxicon, John Wiley & sons,Inc, NY
Lee, S.M.,& Moore, L.J., 1975, Introduction to Decision Science Petrocelli/Charter, NY.
Levin,R.I., & Kirkpatrick, C.A., 1971,Quantitative Approaches to Management,2nd Edition, McGraw Hill,NY.
Maki, D.P., & Thompson, M.,1983,Finite Mathematics,2nd Edition,McGraw-Hill, NY.

Game Theory--The Prisoner's dilemma

A / B	hold quiet	Confess	B's Minimum penalty
Hold Quiet	-1 / / -1	-10 / / 0	
Confess	0 / / -10	-5 / / -5	
A's Minimum penalty			

Picture two partners in crime who have been picked up by the police. The penalty for robbery is 10 years in jail. If neither confesses, then the worst they can be convicted of is stealing the car they used for the getaway, which has a penalty of one year in prison. If, on the other hand, they both confess, they will be convicted of the robbery as well, and will get 5 years in prison as a reduced penalty for being cooperative with the police. The District attorney, in order to split the team and provide incentive for confession, has offered each separately to let him off with a suspended sentence if he confesses and his partner doesn't. In the event one of the partners is convicted without being cooperative (confessing) he will get the full penalty of 10 years in prison.

The matrix shows the different payoffs in this game in which the total penalties change depending on the combination of strategies. A's outcome is in the upper left corner of each split cell, and B's outcome is shown in the lower right corners.

North & South Highschools' wrestling training programs--a Zero-sum game:

North & South Highschools' wrestling coaches are both eager to win as many matches as they can. There are three different training/preparation strategies they can employ. The first is to do healthful training. The second is to have wrestlers fast and purge themselves before weigh-in to shift some larger wrestlers into lower weight classes where they would have an advantage over smaller wrestlers. The third strategy is to not only purge, but to use steroids in training to increase strength. Assuming that the steroid and purging strategies work, the expected results of a ten match series might be represented by the following outcome table:

North's wins

North\ South \	Healthful	Purge	Purge & Dope	South's best - Fewest losses
Healthful	6	5	4	
Purge	7	6	5	
Purge & Dope	8	7	6	
North's best - most wins				

A) North would like the most wins possible. For each strategy of South, show which strategy North would prefer, and vice versa. Use squares for North's choices and Circles for South's strategies. Write the results in the last row and last column.

B) What strategies wouldn't be pursued in any case? Which combination of strategies would result in a stable outcome? Why would this outcome be stable?

C) Is this really a zero sum game, or does the total wealth include more than just the wins and losses?

R.J.Banis

Highway Merge Lanes During Rush Hour--A Prisoner's Dilemma Model

This is a drastic oversimplification, but let us pretend we can project the results of interacting strategies by representing populations on the highway as two people in a prisoner's dilemma game. There is a merge lane at the junction of highways 40 and 270 where people can either take turns and merge smoothly, or else pass everyone in the right hand lane (which ends) and cut into the front at the last minute. Of course, if people pursue this "me first" approach, all the cars approaching the forced merge have to slam on their brakes, and as a result, the highway is jammed up with stop-and-go traffic for miles. Once someone starts the aggressive game, anyone who is courteous ends up being constantly cut off and pushed back. The paradox is that if traffic merged smoothly, this part of the highway could be traversed at a steady speed of about 40 mph by everyone. In the discourteous mode, everyone suffers. Here is a table that might represent speeds achieved by each type of player for different combinations of strategies.
Joe controls rows. His speeds are the upper left.Sally controls columns. Her speeds are in the lower right
If you are the only one being overly aggressive, you may get arrested, which will slow you down a little.
Joe is also a little more proficient in the aggressive-aggressive game than Sally is.
Please note that each party wants to MAXIMIZE the speed of getting through this section of highway.

Joe's and Sally's speed at the merge of highways 40 and 270

Joe / / Sally	courteous	aggressive weaving	duels and cutting off	Sally's best speed
courteous	40 / / 40	20 / / 50	2 / / 45	
aggressive weaving	50 / / 20	30 / / 30	5 / / 25	
duels and cutting off	45 / / 2	25 / / 5	10 / / 3	
Joe's best speed				

Use squares for Joe and circles for Sally to show which strategies would prevail if each party only chose to maximize their speeds in each situation. What is the **stable solution from this inconsiderate behavior?** (Big hint: if you get the result that both would be courteous, you are doing it wrong!)
circle one for each: Answers must be consistent to get credit.

Joe would: be courteous aggressively weave duel and cut off other people

Sally would: be courteous aggressively weave duel and cut off other people

Show, by drawing lines through those rows and columns, which strategies are dominated and wouldn't be pursued by each player in any case in this application of the prisoner's dilemma model.

What would be a better solution for them both? What are three things that could be done to enforce a stable agreement on that better solution?

1.

2.

3.

Team Games From Core Workshop in Conflict Resolution

--Miranda Duncan, January 28, 1995

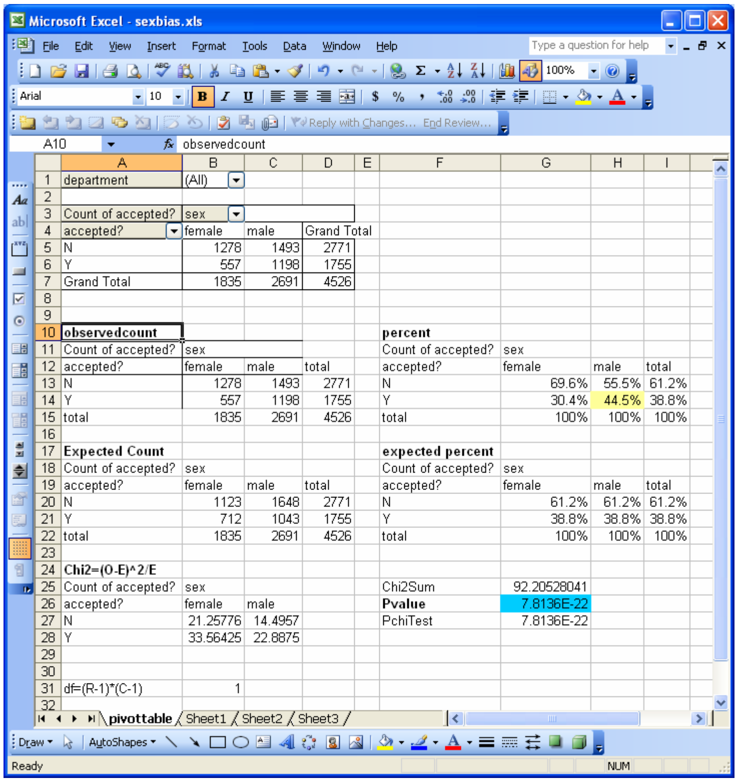
Rules

- Five Rounds.
- Each group chooses to take "X" or "Y" on each round.
- If both groups choose "Y", then each gets 3 points.
- If both groups choose "X", then each gets 1 point.
- If groups choose differently, the group choosing "X"gets 5 Points, The group choosing "Y"gets 0 points.

A / B	Y	X	B's Best
Y	3 / / 3	0 / / 5	
X	5 / / 0	1 / / 1	
A's Best			

Round	Team 1A	Team 1B	Team 2A	Team 2B
	Total	Total	Total	Total
1				
2				
3				
4				
5				
5				

Exposition of Simpson's Paradox Using PivotTables in Microsoft EXCEL



Microsoft Excel - sexbias.xls

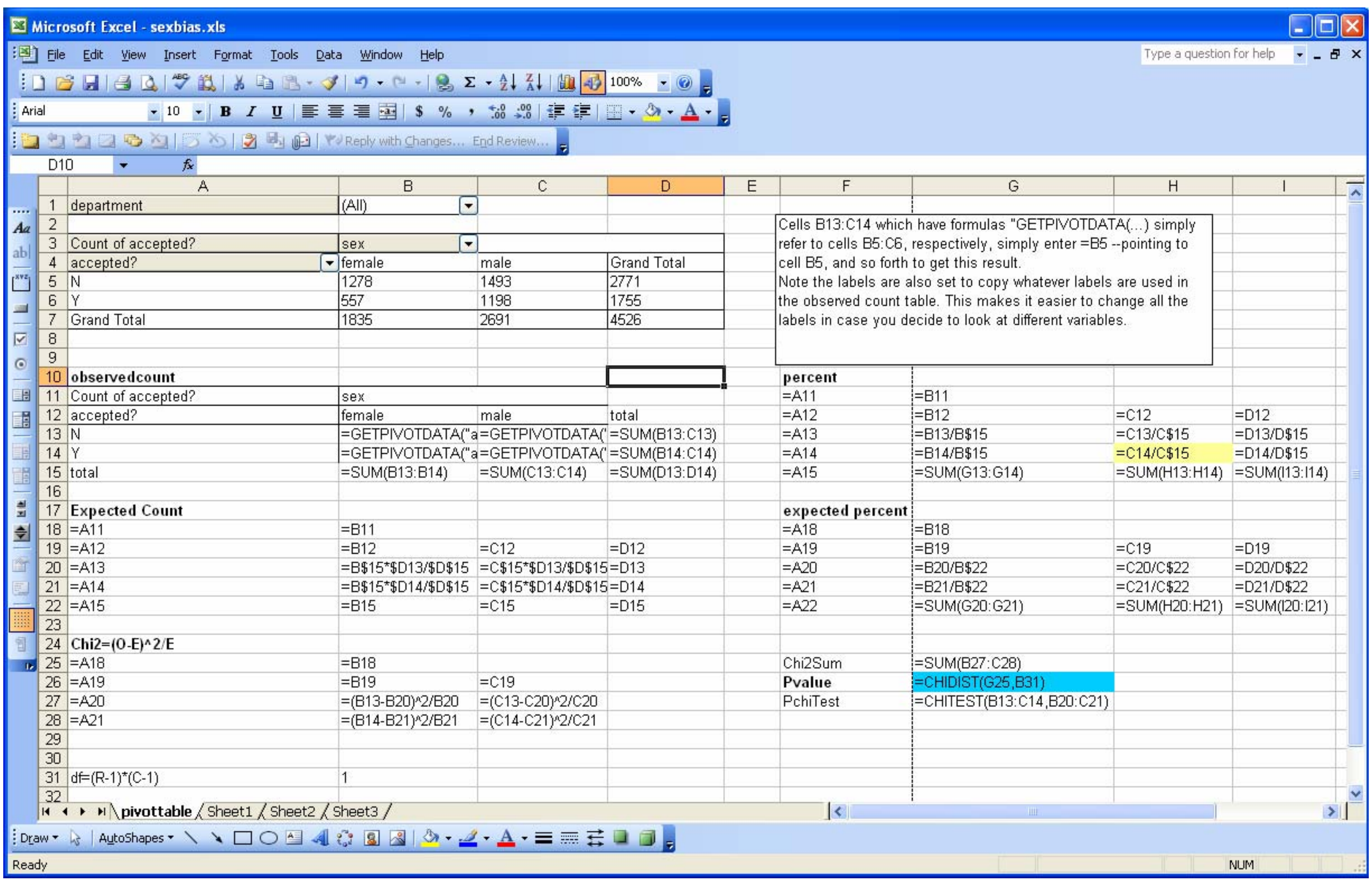
A10 — observedcount

	A	B	C	D	E	F	G	H	I
1	department	(All)							
2									
3	Count of accepted?	sex							
4	accepted?	female	male	Grand Total					
5	N	1278	1493	2771					
6	Y	557	1198	1755					
7	Grand Total	1835	2691	4526					
8									
9									
10	**observedcount**					**percent**			
11	Count of accepted?	sex				Count of accepted?	sex		
12	accepted?	female	male	total		accepted?	female	male	total
13	N	1278	1493	2771		N	69.6%	55.5%	61.2%
14	Y	557	1198	1755		Y	30.4%	44.5%	38.8%
15	total	1835	2691	4526		total	100%	100%	100%
16									
17	**Expected Count**					**expected percent**			
18	Count of accepted?	sex				Count of accepted?	sex		
19	accepted?	female	male	total		accepted?	female	male	total
20	N	1123	1648	2771		N	61.2%	61.2%	61.2%
21	Y	712	1043	1755		Y	38.8%	38.8%	38.8%
22	total	1835	2691	4526		total	100%	100%	100%
23									
24	**Chi2=(O-E)^2/E**								
25	Count of accepted?	sex				Chi2Sum	92.20528041		
26	accepted?	female	male			**Pvalue**	7.8136E-22		
27	N	21.25776	14.4957			PchiTest	7.8136E-22		
28	Y	33.56425	22.8875						
29									
30									
31	df=(R-1)*(C-1)	1							
32									

pivottable / Sheet1 / Sheet2 / Sheet3

Here are screen captures showing layout and formulas for use in a four-cell crosstabulation in EXCEL.
The data is a partial from the classical Berkeley Graduate School Admissions sex-bias case in which proportions for admissions data aggregated over departments gave a clear indication of bias toward males in graduate school admissions. Inclusion of a Department variable as a page variable in cell B1 allows filtering to give subgroup results. What we learn from this is that even very high confidence in a conclusion is not "proof." Our understandings of situations may change as a result of digging further into the data. Sometimes, aggregations of data may be inappropriate because there are other variables lurking in the subsets that could change the interpretation substantially.

The partial dataset was obtained from Gerstman B.B. (2000) Data Analysis with Epi Info, Binary Outcome, Stratified Analysis on the web at http://www.sjsu.edu/faculty/gerstman/EpiInfo/stratified.htm
Some other useful links on this topic:
http://plato.stanford.edu/entries/paradox-simpson/
http://www.google.com/search?hl=en&q=simpson%27s+paradox
http://core.ecu.edu/psyc/wuenschk/StatHelp/Reversal-Paradox.txt
http://repository.upenn.edu/cgi/viewcontent.cgi?article=1014&context=wharton_research_scholars
http://wolfweb.unr.edu/homepage/jerryj/NNN/Aggregates.pdf



Microsoft Excel - sexbias.xls

D10

	A	B	C	D	E	F	G	H	I
1	department	(All)							
2									
3	Count of accepted?	sex							
4	accepted?	female	male	Grand Total					
5	N	1278	1493	2771					
6	Y	557	1198	1755					
7	Grand Total	1835	2691	4526					
8									
9									
10	**observedcount**					**percent**			
11	Count of accepted?	sex				=A11	=B11		
12	accepted?	female	male	total		=A12	=B12	=C12	=D12
13	N	=GETPIVOTDATA("a	=GETPIVOTDATA("	=SUM(B13:C13)		=A13	=B13/B$15	=C13/C$15	=D13/D$15
14	Y	=GETPIVOTDATA("a	=GETPIVOTDATA("	=SUM(B14:C14)		=A14	=B14/B$15	=C14/C$15	=D14/D$15
15	total	=SUM(B13:B14)	=SUM(C13:C14)	=SUM(D13:D14)		=A15	=SUM(G13:G14)	=SUM(H13:H14)	=SUM(I13:I14)
16									
17	**Expected Count**					**expected percent**			
18	=A11	=B11				=A18	=B18		
19	=A12	=B12	=C12	=D12		=A19	=B19	=C19	=D19
20	=A13	=B$15*$D13/$D$15	=C$15*$D13/$D$15	=D13		=A20	=B20/B$22	=C20/C$22	=D20/D$22
21	=A14	=B$15*$D14/$D$15	=C$15*$D14/$D$15	=D14		=A21	=B21/B$22	=C21/C$22	=D21/D$22
22	=A15	=B15	=C15	=D15		=A22	=SUM(G20:G21)	=SUM(H20:H21)	=SUM(I20:I21)
23									
24	**Chi2=(O-E)^2/E**								
25	=A18	=B18				Chi2Sum	=SUM(B27:C28)		
26	=A19	=B19	=C19			**Pvalue**	=CHIDIST(G25,B31)		
27	=A20	=(B13-B20)^2/B20	=(C13-C20)^2/C20			PchiTest	=CHITEST(B13:C14,B20:C21)		
28	=A21	=(B14-B21)^2/B21	=(C14-C21)^2/C21						
29									
30									
31	df=(R-1)*(C-1)	1							
32									

Cells B13:C14 which have formulas "GETPIVOTDATA(...) simply refer to cells B5:C6, respectively, simply enter =B5 --pointing to cell B5, and so forth to get this result.
Note the labels are also set to copy whatever labels are used in the observed count table. This makes it easier to change all the labels in case you decide to look at different variables.

pivottable / Sheet1 / Sheet2 / Sheet3

Total Quality Management---

Total Quality Management, from Cooperative Decision-Making

- **Focus on the Long Term best average result rather than immediate short-term outcome.**
- **Emphasize process rather than single result.**
- **Design quality into the process rather than testing defects out of the product.**
- **Aim for zero defects through continuous improvement.**
- **Base vendor decisions on relationship and statistical evidence of quality rather than price.**
- **Buy value rather than price.**
- **Reduce perception of personal risk in decision making.**
- **Drive out fear.**
- **Foster rational laziness.**
- **Let People do the things that are important and they will seek out the important things to do.**

back to BA103 home page

Back to BA252 Homepage

UMSL Courses
Student Projects
Exam Tips

Transportation model -Service representative travel.

The Wacko Equipment Company (WEC) does business in three cities. WEC maintains technicians in each city to service machines in the field. Travel costs and needs for service gives the following transportation matrix: Traditionally, the company has filled needs for each city's technical support with the technician friom that city, resulting in the intuitive solution shown below:

Transportation costs ($/trip) & number of service trips required

Demander	New York	St. Louis	Houston	Supplied
New York	0	350	800	200
St. Louis	300	0	250	50
Houston	900	200	0	125
Demanded	100	75	200	

Transportation costs ($/trip) & number of service trips required

Demander	New York	St. Louis	Houston	Supplied
New York	0 100	350 25	800 75	200
St. Louis	300	0 50	250	50
Houston	900	200	0 125	125
Demanded	100	75	200	

Transportation costs ($/trip) & number of service trips required

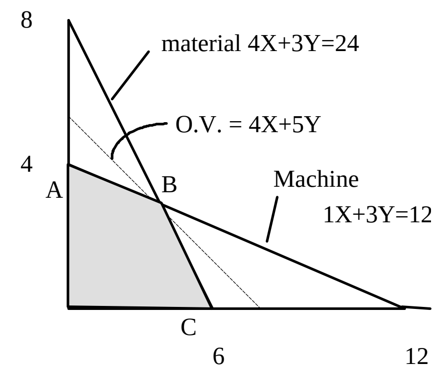
Demander	New York	St. Louis	Houston	Supplied
New York	0 100	350 25	800 75	200
St. Louis	300	0 50	250	50
Houston	900	200	0 125	125
Demanded	100	75	200	

Transportation costs ($/trip) & number of service trips required

Demander	New York	St. Louis	Houston	Supplied
New York	0	350	800	200
St. Louis	300	0	250	50
Houston	900	200	0	125
Demanded	100	75	200	

Production & Operations Management

Graphical Linear Programming Lecture Example Dr. Banis



Objective Function: MAX 4X + 5Y

Subject to:

Constraints: Machine time: 1X + 3Y <= 12

Material: 4X + 3Y <= 24

increase the objective value by moving the objective function line out from the origin. The farthest it can go while still having a point in the feasible solution space is the intersection of the constraints, Point B. If the slope were different, the last point of intersection could be A or C instead of B. The boundaries between the solutions are the conditions where the Objective Function is parallel to (has the same slope as) each of the constraints.

Algebraic Solution: *Three corners to consider:*

Point A: X=0; Y=4; OV = 4(0) + 5(4) = $20

Point C: X=6; Y=0; OV = 4(6) + 5(0) = $24

Point B (Intersection of the constraints):

1X+3Y=12	Substituting:	
-1 * (4X+3Y=24)	1X + 3Y = 12	O.V. = 4X + 5Y
-3X = -12	1(4)+ 3Y = 12	= 4(4) +5(8/3)
X = 4	Y = 8/3	O.V. = $29.33 ***

MAX profit:
B is the Optimal solution:
X =4; Y= 8/3
O.V. = $29.33

Slacks:

Machine: 1X + 3Y <= 12
1(4)+3(8/3)=12
No slack, all used

Material: 4X + 3Y <= 24
4(4)+3(8/3)=24
No slack, all used

Ranges of Optimality on Objective Function (cost/profit) Coefficients, 4X + 5Y:

If profitability of one of the products changes enough, the solution shifts to another corner. The changeover is when the Objective Function line is parallel to a limiting constraint. When the ratio of coefficients is the same in the O.F. as it is in the constraint, the optimal O.F. is a line that lies right on the constraint line, and there are an infinite number of equally good point solutions on this line, including the two corners that are bounded by this constraint. Because there isn't one unique solution, this solution is called *degenerate.*

Effect of changing the Coefficient of Y on the Objective (Profit) function Value

Corner	Product mix	4X + 2Y	4X + 3Y	**4X + 5Y**	4X + 12Y	4X + 13Y
A	Y = 4 ; X = 0	8	12	20	48	52
B	Y=8/3; X = 4	21.33	24	29.33	48	50.67
C	Y= 0; X= 6	24	24	24	24	24

Limits of Optimality for Coefficient X (Keeping coefficient of Y constant at 5):

Parallel to Material Constraint when:

$$\frac{CoeffX,O.F}{Coeff.Y,O.F.} = \frac{CoeffX,mat}{CoeffY,mat}$$

$$Coeff.X,O.F = \frac{CoeffX,mat}{CoeffY,mat} * Coeff.Y,O.F$$

$$Coeff.X,O.F = \frac{4}{3} * 5 = 6.67$$

Parallel to Machine Constraint when:

$$\frac{CoeffX,O.F}{Coeff.Y,O.F.} = \frac{CoeffX,mach}{CoeffY,mach}$$

$$Coeff.X,O.F = \frac{CoeffX,mach}{CoeffY,mach} * Coeff.Y,O.F$$

$$Coeff.X,O.F = \frac{1}{3} * 5 = 1.67$$

Range of Optimality for corner B, coefficient of X:
Upper Limit = $6.67
Lower limit = $1.67

Limits of Optimality for Coefficient Y (Keeping coefficient of X constant at 4):

Parallel to Material Constraint when:

$$\frac{CoeffY,O.F}{Coeff.X,O.F.} = \frac{CoeffY,mat}{CoeffX,mat}$$

$$Coeff.Y,O.F = \frac{CoeffY,mat}{CoeffX,mat} * Coeff.X,O.F$$

$$Coeff.Y,O.F = \frac{3}{4} * 4 = 3$$

Parallel to Machine Constraint when:

$$\frac{CoeffY,O.F}{Coeff.X,O.F.} = \frac{CoeffY,mach}{CoeffX,mach}$$

$$Coeff.Y,O.F = \frac{CoeffY,mach}{CoeffX,mach} * Coeff.X,O.F$$

$$Coeff.Y,O.F = \frac{3}{1} * 4 = 12$$

Range of Optimality for corner B, coefficient of Y:
Upper Limit = $12
Lower limit = $3

Outside these limits of profit per unit, the optimal production plan changes to another corner. Within these ranges of optimality, the total profit may change, but the optimal production plan stays the same, as the corner B solution.

Shadow price: Value of making one more unit of a constraining element available. Effect on profit or reduced cost caused by relaxing a constraint.

<u>New intersection corner B with one more unit of material:</u>

1X+3Y=12	<u>Substituting:</u>	
<u>-1 * (4X+3Y=25)</u>	1X + 3Y = 12	O.V. = 4X + 5Y
-3X = -13	1(4.33)+ 3Y = 12	= 4(4.33) +5(2.56)
X = 4.33	Y = 2.56	O.V. = $30.11

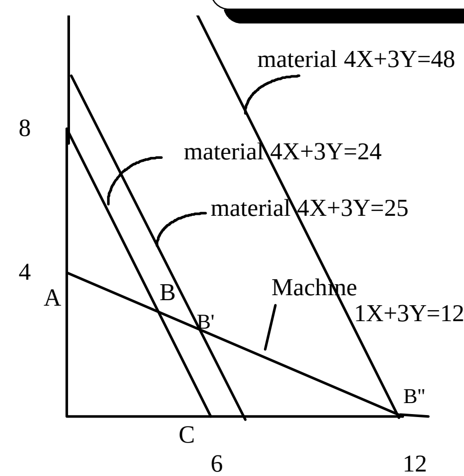
Shadow price for material:
new O.V.=$30.11
old O.V.=$29.33
increase = $0.78

<u>New intersection corner B with one more unit of Machine time:</u>

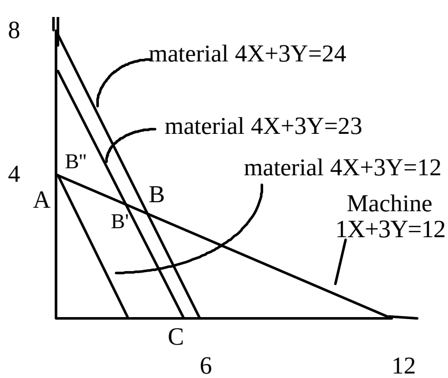
1X+3Y=13	<u>Substituting:</u>	
<u>-1 * (4X+3Y=24)</u>	1X + 3Y = 13	New O.V. = 4X + 5Y
-3X = -11	1(3.67)+ 3Y = 13	= 4(3.67) +5(3.11)
X = 3.67	Y = 3.11	New O.V. = $30..22

Shadow price for machine time:
new O.V.=$30.22
old O.V.=$29.33
increase = $0.89

Ranges of Validity:



Shadow prices are valid "until something changes." such as the end of an intersecting constraint. In the diagram, **increasing the amount of material** available from 24 to 25 units shifts the solution at the intersection from corner B to corner B'. the increase in value for this new solution is the shadow price. This shadow price is valid as long as the profit is changing at the same rate for every new unit of material, that is, as long as the same two constraint lines intersect. when the intersecting machine constraint line runs out at B", the next increment of material will have a different effect. At this point, X=12, Y=0, and material use is 4X +3Y =4(12) +3(0) = 48 units. having more material than 48 units would do us no good, as there wouldn't be enough machine time to let us use more than 48 units of material. Although each unit of material up to that point increases our profit by $0.78, The 49th unit has a value of $0, because we can't do anything with it. Thus, the shadow price of $0.78 is only valid up to 48 units (24 units more than we started with).



Reducing the amount of material available from 24 units to 23 units would reduce our profit by $0.78. this reduction per unit given up would continue until the the material constraint intersects corner A. At point A, we'd be making 4 units of Y, using 3units of material for each one for a total of 3*4=12 units of material. At that point, machine time is no longer constraining, and so each unit change in material will have a larger effect. Since we'd be making all Y, and each unit of material is enough to make 1/3 unit of Y, the reduction in profit would be 1/3 of the profit on a unit of Y, or $5*(1/3)= $1.67 per unit of material. Within the range where shadow price is $$0.78, we would be willing to sell some of our material as long as we were paid as at least as much as the profit we would lose by not having it available. We would sell material for any price greater than or equal to the shadow price of $0.78 per unit. **Thus, the shadow price on material of $0.78 is valid to an upper limit of 48 and to a lower limit of 12.**

Similarly, for the shadow price on machine time:

The ends of the material constraint define the limits on the the range of validity.
Upper limit: Y=8, X=0; material = 1X+3Y=1(0) + 3(8) = 24
Lower Limit: Y=0, X=6; material = 1X + 3Y = 1(6) + 3(0) = 6
Therefore, the range of validity on the $0.89 shadow price on machine time is 6 units to 24 units.
If the optimal solution were at corner A rather than corner B, then the shadow price would be determined simply by the amount of Y that could be made by having the additional time (Note, material wouldn't be limiting at corner A unless we only had 12 units). No X would be made at corner A . The upper limits on the ranges of validity would be defined by the points at which the other resource runs out. The lower limits would be zero (where there is no more to sell).

Linear Programming, Computer solution - Product mix and sensitivity analysis

A garden store prepares three grades of pine bark for mulch: Nuggets, mininuggets, and chips. The process requires pine bark, machine time , labor time, and storage space. Profits are $9 per bag of nuggets, $9 per bag of mininuggets, and $6 per bag of chips.
there are 600 pounds of bark available, 480 hours of labor, 660 minutes of machine time and enough storage space for 150 bags. Each bag of nuggets takes 5 pounds of bark, 2 minutes of machine time, and 2 hours of labor. A bag of mininuggets takes 6 pounds of bark, 4 minutes on the machine, and 4 hours of labor. A bag of chips takes 3 pounds of bark, 5 minutes on the machine, and 3 hours of labor. All this leads to the following printout for a linear programming optimization:

A) What is the optimum solution?

B) How low could the profit on mininuggets go before a different solution would be better?

C) If you could buy more bark for $2.10/ lb., how much would you buy?

D) If you could sell some of your labor for $5 per hour, how much are you sure you would sell?

E) If you could sell some of your storage space for $3 per bag-space, how much are you sure it would be worthwhile to sell?

F) How high would the profit on chips have to go before you would change the production mix to make more chips?

Computer Printout

	Nuggets	Mininuggets	Chips		RHS= Available
Unit Profit-->	9	9	6		
constraint					
Bark	5	6	3	<=	600
Machine	2	4	5	<=	660
Labor	2	4	3	<=	480
Storage	1	1	1	<=	150

Range of Optimality for Objective Function Coefficients

Variable	Value	Current Coefficient	Lower Limit	Upper Limit
Nuggets	75	9	8	10
Mininuggets	0	9	-infinity	11
Chips	75	6	5	9

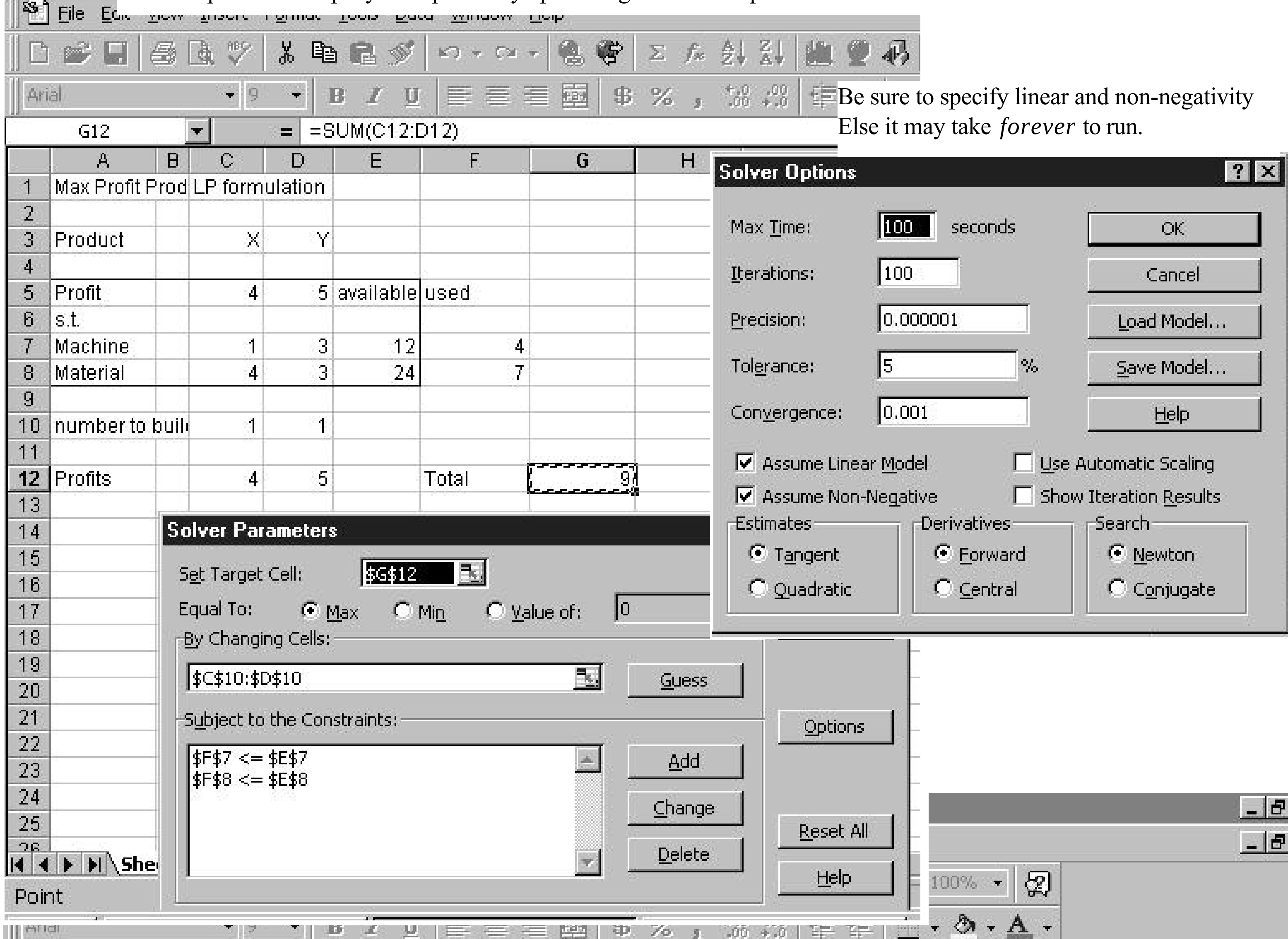
Objective Function Value = 1125.0000

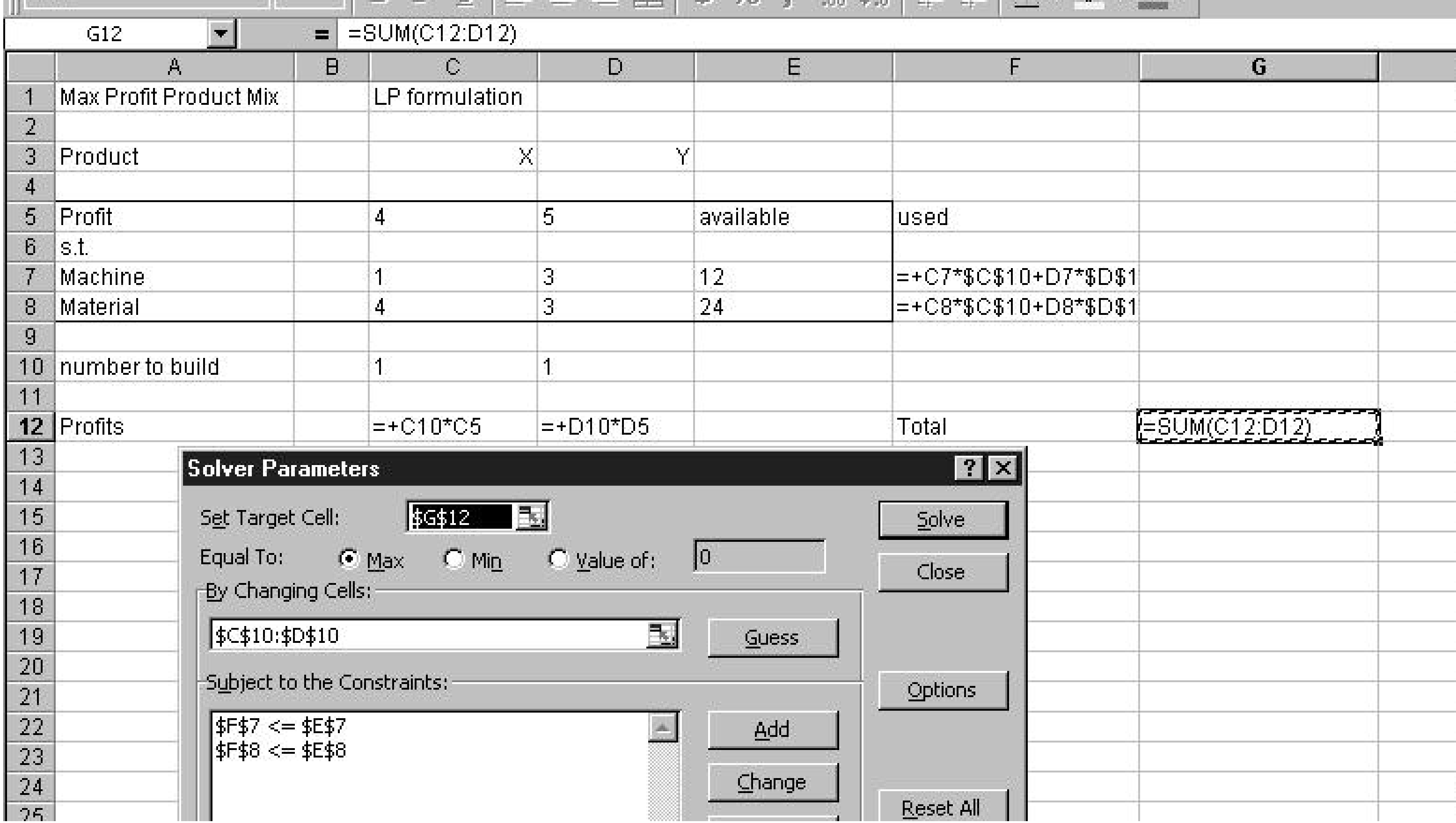
Range of Validity for Shadow Prices

Constraint	RHS	Slack	Shadow Price	Lower Limit	Upper Limit
Bark	600	0	2	510	750
Machine	660	135	0	525	infinity
Labor	480	105	0	375	infinity
Storage	150	0	2	120	164

The X-Y product Company Max profits by optimizing constrained product mix in Excel Solver

Be sure to specify linear and non-negativity
Else it may take *forever* to run.





Linear Programming with EXCEL Solver gives the same as the geometric solution.
See Videos on the X-Y Company Problem
Dr. Bud Banis

Microsoft Excel - xylp.xls

File Edit View Insert Format Tools Data Window Help

G12 = =SUM(C12:D12)

	A	B	C	D	E	F	G	H
1	Max Profit Prod		LP formulation					
2								
3	Product		X	Y				
4								
5	Profit		4	5	available	used		
6	s.t.							
7	Machine		1	3	12	12		
8	Material		4	3	24	24		
9								
10	number to buil		4	2.667				
11								
12	Profits		16	13.33		Total	29.33333	

Solver Results

Solver found a solution. All constraints and optimality conditions are satisfied.

Reports: Answer, Sensitivity, Limits

(•) Keep Solver Solution
( ) Restore Original Values

OK | Cancel | Save Scenario... | Help

Answer Report

Target Cell (Max)

Cell	Name	Original Value	Final Value
$G$12	Total	9	29.33333333

Adjustable Cells

Cell	Name	Original Value	Final Value
$C$10	number to build X	1	4
$D$10	number to build Y	1	2.666666667

Sensitivity Report

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$F$7	Machine used	12	$F$7<=$E$7	Binding	0
$F$8	Material used	24	$F$8<=$E$8	Binding	0

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$C$10	number to build X	4	0	4	2.666667	2.333333
$D$10	number to build Y	2.666666667	0	5	7	2

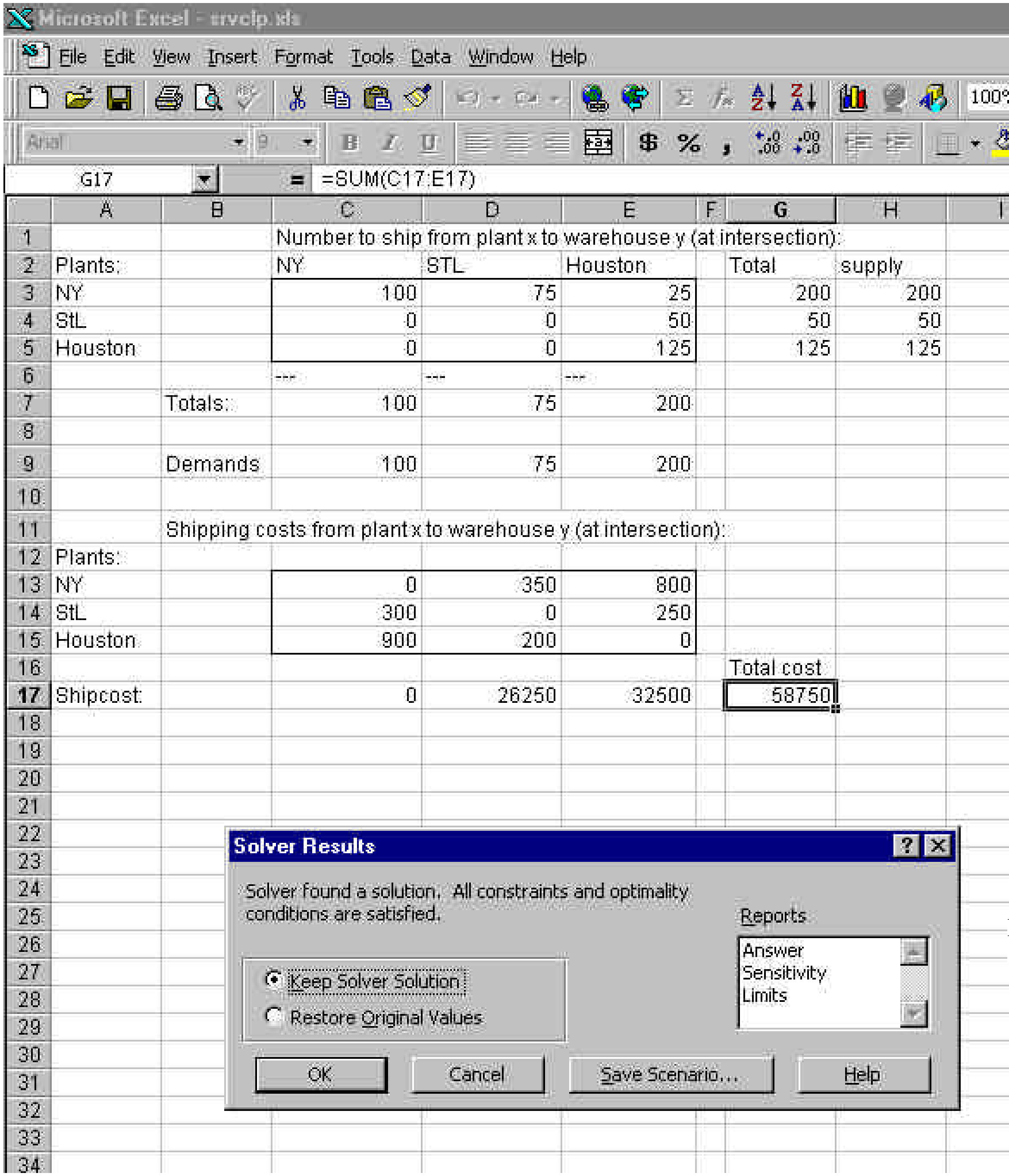
Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$F$7	Machine used	12	0.888888889	12	12	6
$F$8	Material used	24	0.777777778	24	24	12

Dr. Bud Banis

This is the solution to the three-city service engineer problem. "Plant" in this case is the source of engineers, "warehouse" is the site serviced.

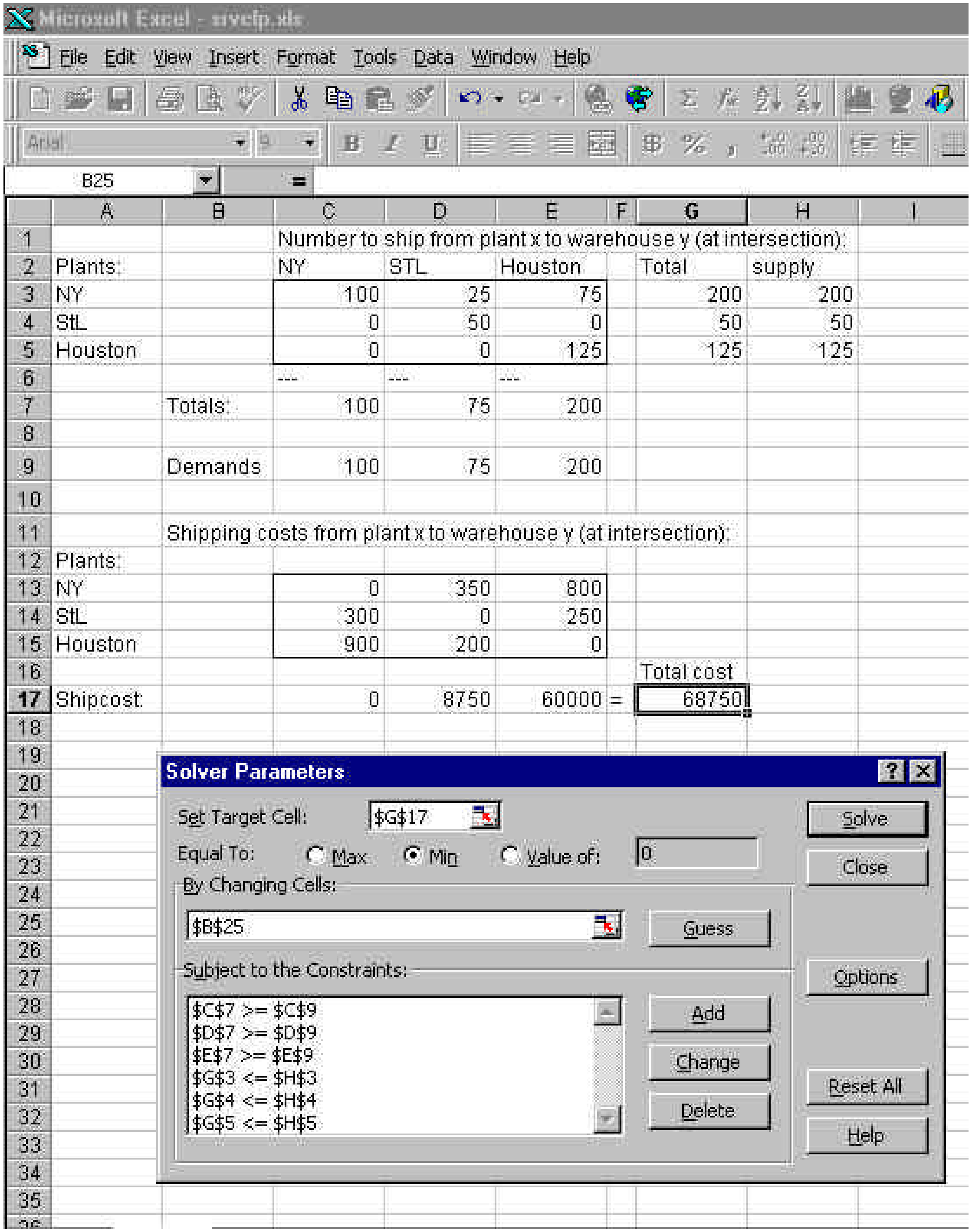
The result shows it's better to ship all the St Louisans to Houston and bring in New yorkers to service the St. Louis sites. Failing to use the zero cost option of keeping St. Louisans in their home city is counterintuitive, but it has to do with opportunity costs and the high cost of sending New York engineers to Houston.



	A	B	C	D	E	F	G	H
1			Number to ship from plant x to warehouse y (at intersection):					
2	Plants:		NY	STL	Houston		Total	supply
3	NY		100	75	25		200	200
4	StL		0	0	50		50	50
5	Houston		0	0	125		125	125
6			---	---	---			
7		Totals:	100	75	200			
8								
9		Demands	100	75	200			
10								
11		Shipping costs from plant x to warehouse y (at intersection):						
12	Plants:							
13	NY		0	350	800			
14	StL		300	0	250			
15	Houston		900	200	0			
16							Total cost	
17	Shipcost:		0	26250	32500		58750	

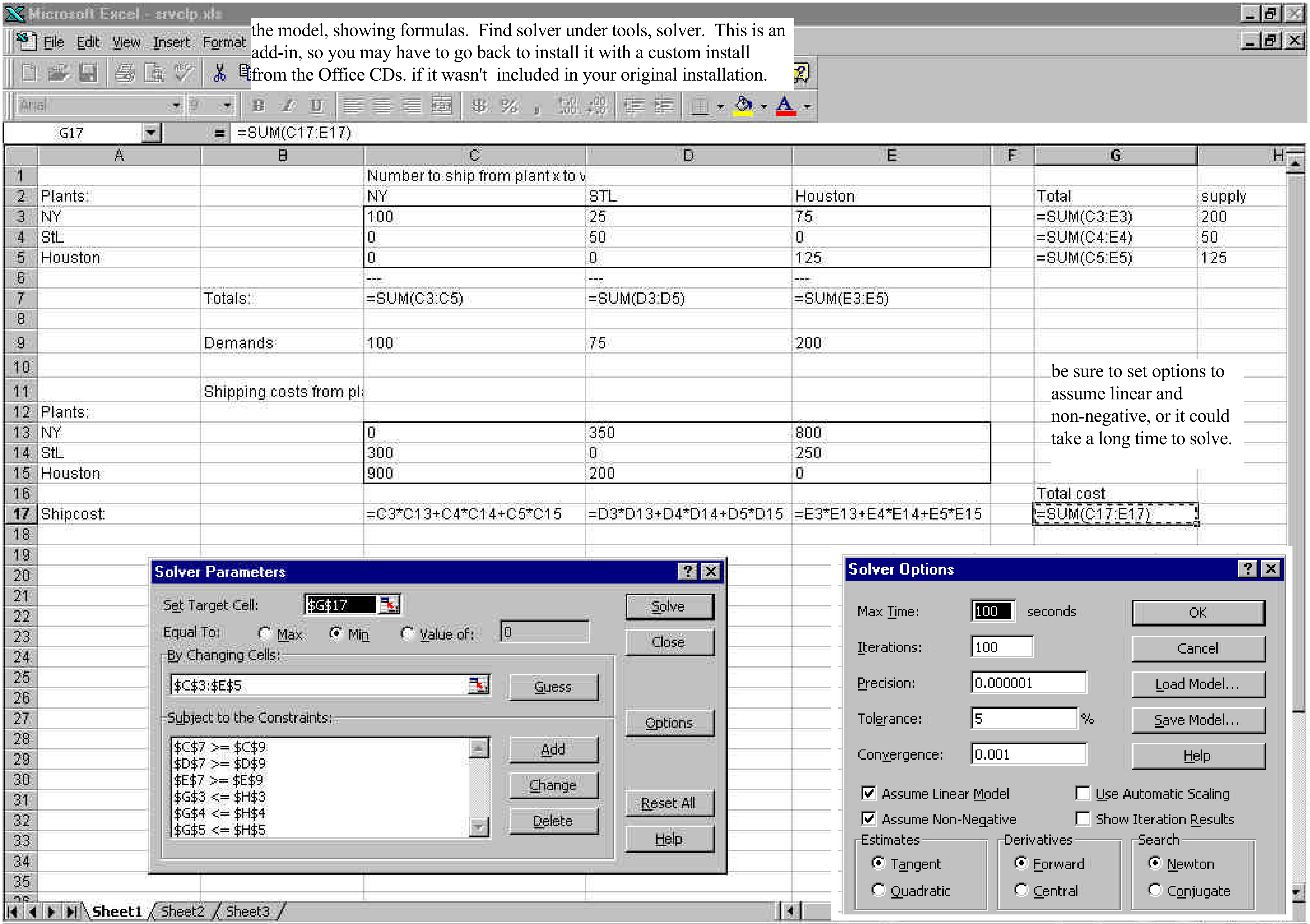
solver gives the new optimal solution

Reports will give you sensitivity analysis



With the original myopic solution. Using zero-cost cells sounds good, but has opportunity costs.

the model, showing formulas. Find solver under tools, solver. This is an add-in, so you may have to go back to install it with a custom install from the Office CDs. if it wasn't included in your original installation.



be sure to set options to assume linear and non-negative, or it could take a long time to solve.

Linear Programming problem Diet Mix: Computer Exercise 3

(problem B-42 from the heizer Render web site)
http://cwx.prenhall.com/bookbind/pubbooks/heizer2/chapter24/deluxe.html
goto additional problems, Module B, B.42

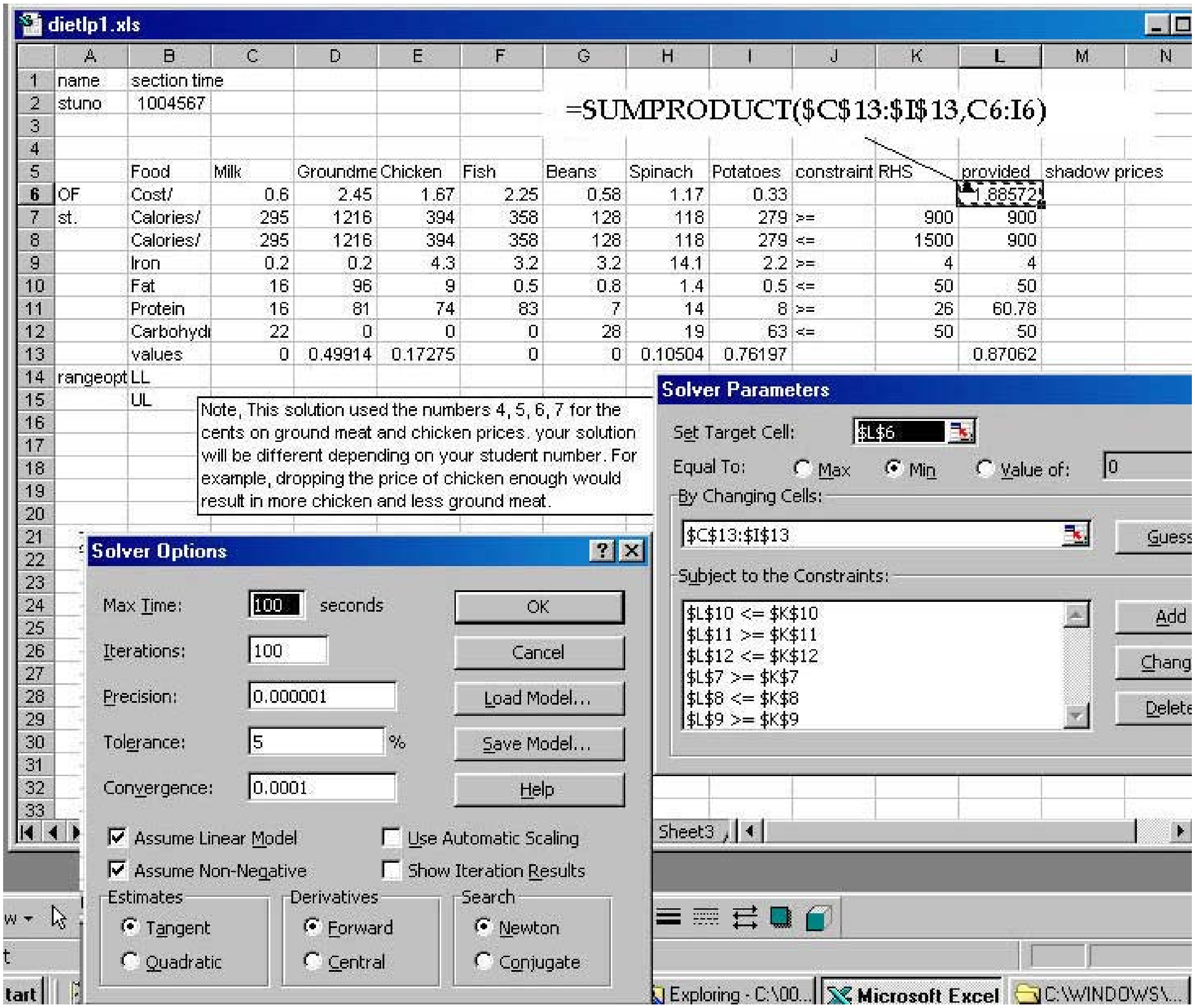
Set this up in EXCEL and solve using Solver
set up the same problem in POM-Win and compare the results. This comparison should help you interpret the sensitivity and range analyses from the solver output. Everyone will have slightly different numbers as you will use the last 4 digits of your student number to replace the cents in the prices for ground meat and chicken.

Rachel Yang, campus dietitian for a small Illinois college, is responsible for formulating a nutritious meal plan for students. For an evening meal, she feels that the following five meal-content requirements should be met: (1) between 900 and 1,500 calories (you will need two rows for calories, one to set the upper limit, one to set the lower limit); (2) at least 4 milligrams of iron; (3) no more than 50 grams of fat; (4) at least 26 grams of protein; and (5) no more than 50 grams of carbohydrates.
On a particular day, Rachel's food stock includes seven items that can be prepared and served for supper to meet these requirements. The cost per pound for each food item and its contribution to each of the five nutritional requirements are given in the accompanying table:
What combination and amounts of food items will provide the nutrition Rachel requires at the least total food cost?
(a) Formulate as an LP problem.
(b) What is the cost per meal?
(c) What would the value be of relaxing each of the constraints (changing the RHS) by one unit? These are the shadow prices.
(d) How sensitive is the solution to price changes in milk, ground meat, fish, and chicken? Report, in each case, upper and lower limits on the ranges of optimality

Procedure: Data can be put into EXCEL in one of three ways:

1. Use the text tool in Acrobat to copy it from the Heizer-Render website. Paste into EXCEL. use data/text-to columns (space delimiter) to parse it, make necessary adjustments. See the Video
2. Copy the data from the bottom of this page and paste into EXCEL. use data/text-to-columns (space delimiter) to parse it, make necessary adjustments.
3. Type the data in, being careful to avoid transcription errors.

Use copy, paste special /transpose (video on paste special transpose) to put the data in a more familiar configuration (columns for decision variables, rows for objective function and constraints). Duplicate the calories row to allow two (upper and lower) constraints on calories. Move the cost coefficients row (objective function) to the top data row. Add a row for Values (which Solver will manipulate), and rows for Upper and Lower Limits on the ranges of optimality. Add columns for direction of constraint, RHS, amount provided, and Shadow Price for each ingredient.



The formula for each 'amount provided' will consist of the sum of each of the (variable values * amount provided per pound) The easiest way to do this is through the Sumproduct Function. In cell L6, enter =sumproduct($C13:$I13,C6:I6) you can do this by enetering "=sumproduct(" then select the ranges, use F4 to absolute references to the value row and put in the close parenthesis before pushing enter. You will only have to enter the calculation once, then you can just copy it down to subsequent rows.

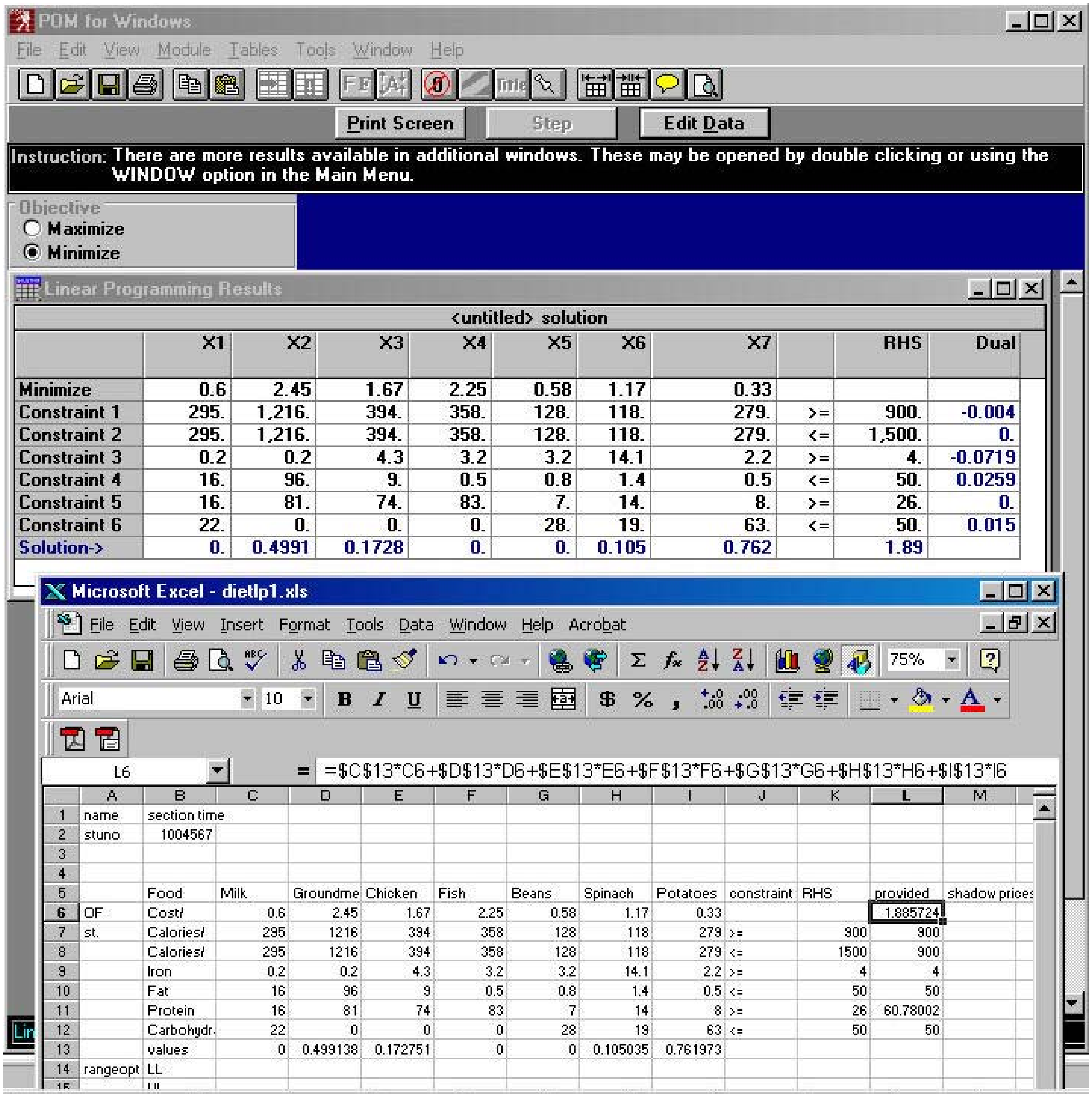
In the event solver tells you there is "no feasible solution found" check your formulas and make sure you have the right directionality on the constraints. (The selections for sensitivity reports will be greyed out if there is no feasible solution.) Note that the amount provided column for the cost row will give the cost.

Use Solver to solve this problem and give sensitivity analysis. See the videos on the X-Y problem to see how to add in and use Solver and how to interpret the sensitivity analysis.

Tips for using POM-WIN

Use POM-Win's LP module to solve this same problem and print out the results to help you interpret the EXCEL output.

It is possible to copy and paste data one part at a time using the POM-WIN menu item, edit/paste-from-clipboard (doesn't work for the constraint directions from EXCEL to POM-WIN), but it's a little tricky and probably just as easy to simply type in the data using your EXCEL sheet layout as a guide. POM-WIN should give the same solutions as SOLVER. Be aware the sensitivity numbers are expressed differently, but the solutions (values and objective value) should be the same.
If EXCEL and POM-WIN don't agree on the basic values, see the list of things that can go wrong, below.



Enter values for the Upper and Lower Limits on the Range of Optimality and the Shadow Prices. It's easiest to understand these on the POM-QM sensitivity analysis (Ranging) but you should compare these to the SOLVER sensitivity analysis just to understand how they are expressed differently.

Printouts due:

1) the EXCEL problem formulation sheet, Adding in results to summarize shadow prices and ranges of optimality. Printouts of the range and sensitivity analyses as needed to support the summary numbers put in the initial sheet.
2) the same for the POM-win solution. No need to add summaries as you will show these on the EXCEL sheet. The results should be the same as the EXCEL Solver solution.

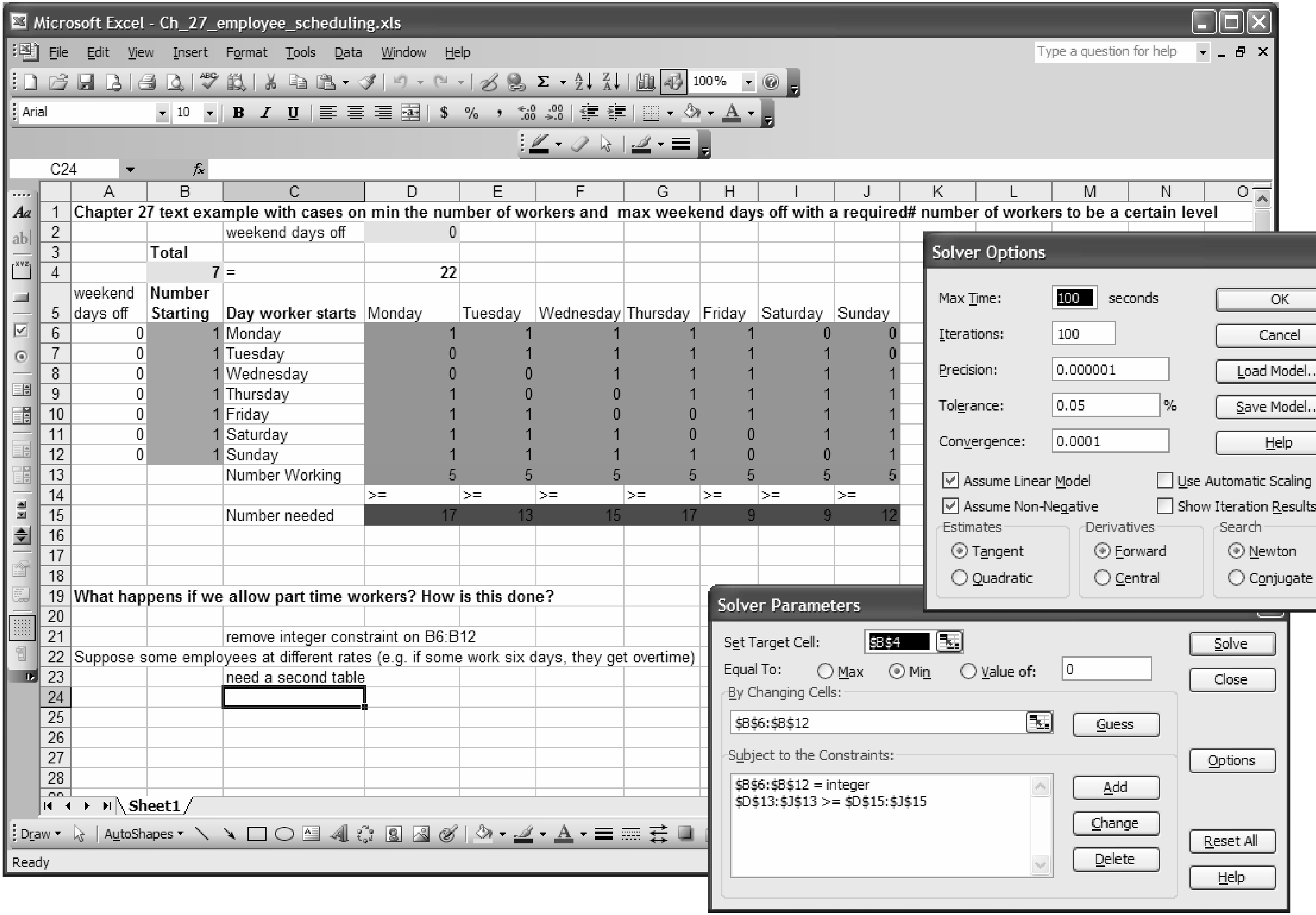
Write brief commentaries on the summary excel sheet about the prasctical meaning of the shadow prices and ranges of optimality. What do these values mean? Discuss the UL and LL for the cost of one of the ingredients as an example as an example.

Table of Food Values* and Costs
Food Calories/ Iron Fat Protein Carbohydrates Cost/
Item Pound (Mg/Lb) (Gm/Lb) (Gm/Lb) (Gm/Lb) Pound ($)
Milk 295 0.2 16 16 22 0.60
Ground meat 1216 0.2 96 81 0 2.AB
Chicken 394 4.3 9 74 0 1.CD
Fish 358 3.2 0.5 83 0 2.25
Beans 128 3.2 0.8 7 28 0.58
Spinach 118 14.1 1.4 14 19 1.17
Potatoes 279 2.2 0.5 8 63 0.33
Source: C. F. Church and H. N. Church, Bowes and Church's, Food Values of Portions Commonly Used, 12th ed. Philadelphia, J. B.
Lippincott, 1975.

Things that can go wrong:

If POM-Win and EXCEL solutions are different:
try putting in the $2.45 for ground meat and $1.67 for chicken and compare to the screen captures above, this will tell you whether things are set up right and will identify which one is off.

Proofread the directionalities of the constraints.


Microsoft Excel - Ch_27_employee_scheduling.xls
File Edit View Insert Format Tools Data Window Help
Type a question for help
Arial 10 100%
C24
Chapter 27 text example with cases on min the number of workers and max weekend days off with a required# number of workers to be a certain level
weekend days off 0
Total
7 = 22
weekend days off
Number Starting
Day worker starts
Monday Tuesday Wednesday Thursday Friday Saturday Sunday
0 1 Monday 1 1 1 1 1 0 0
0 1 Tuesday 0 1 1 1 1 1 0
0 1 Wednesday 0 0 1 1 1 1 1
0 1 Thursday 1 0 0 1 1 1 1
0 1 Friday 1 1 0 0 1 1 1
0 1 Saturday 1 1 1 0 0 1 1
0 1 Sunday 1 1 1 1 0 0 1
Number Working 5 5 5 5 5 5 5
>= >= >= >= >= >= >=
Number needed 17 13 15 17 9 9 12
What happens if we allow part time workers? How is this done?
remove integer constraint on B6:B12
Suppose some employees at different rates (e.g. if some work six days, they get overtime)
need a second table
Sheet1
Draw AutoShapes
Ready
Solver Options
Max Time: 100 seconds
Iterations: 100
Precision: 0.000001
Tolerance: 0.05 %
Convergence: 0.0001
OK
Cancel
Load Model...
Save Model...
Help
Assume Linear Model
Use Automatic Scaling
Assume Non-Negative
Show Iteration Results
Estimates: Tangent, Quadratic
Derivatives: Forward, Central
Search: Newton, Conjugate
Solver Parameters
Set Target Cell: $B$4
Equal To: Max Min Value of: 0
By Changing Cells:
$B$6:$B$12
Guess
Subject to the Constraints:
$B$6:$B$12 = integer
$D$13:$J$13 >= $D$15:$J$15
Add
Change
Delete
Solve
Close
Options
Reset All
Help

Microsoft Excel - cH27__2_COSTS_AND_OT.xls

Suppose bank employees are paid $150 per day for the first 5 days and can work a day of overtime at $350 per day.
Thus, we may assign some employees for 5 days only at a cost of 5*150=$750 per week and some employees for
6 days at a cost of 750+350=$1100.

	A	B	C	D	E	F	G	H	I	J
2	Suppose bank employees are paid $150 per day for the first 5 days and can work a day of overtime at $350 per day.									
3	Thus, we may assign some employees for 5 days only at a cost of 5*150=$750 per week and some employees for									
4	6 days at a cost of 750+350=$1100.									
5										
6	**OT cost**	1100								
7	**RT cost**	750								
8										
9		**Total cost**								
10		**$ 14,600.00**								
11	**OT workers**	**Number working**	**Day worker off OT**	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
12		0	**Sunday**	1	1	1	1	1	1	0
13		0	**Monday**	0	1	1	1	1	1	1
14		0	**Tuesday**	1	0	1	1	1	1	1
15		0	**Wednesday**	1	1	0	1	1	1	1
16		0	**Thursday**	1	1	1	0	1	1	1
17		0	**Friday**	1	1	1	1	0	1	1
18		1	**Saturday**	1	1	1	1	1	0	1
19	**RT workers**									
20		7	Monday	1	1	1	1	1	0	0
21		0	Tuesday	0	1	1	1	1	1	0
22		2	Wednesday	0	0	1	1	1	1	1
23		4	Thursday	1	0	0	1	1	1	1
24		0	Friday	1	1	0	0	1	1	1
25		2	Saturday	1	1	1	0	0	1	1
26		3	Sunday	1	1	1	1	0	0	1
27			Number Working	17	13	15	17	14	8	12
28				>=	>=	>=	>=	>=	>=	>=
29	**total employees**	19	Number needed	17	13	15	17	9	9	12

Sheet1

Solver Parameters

Set Target Cell: $B$10

Equal To: ○ Max ◉ Min ○ Value of: 0

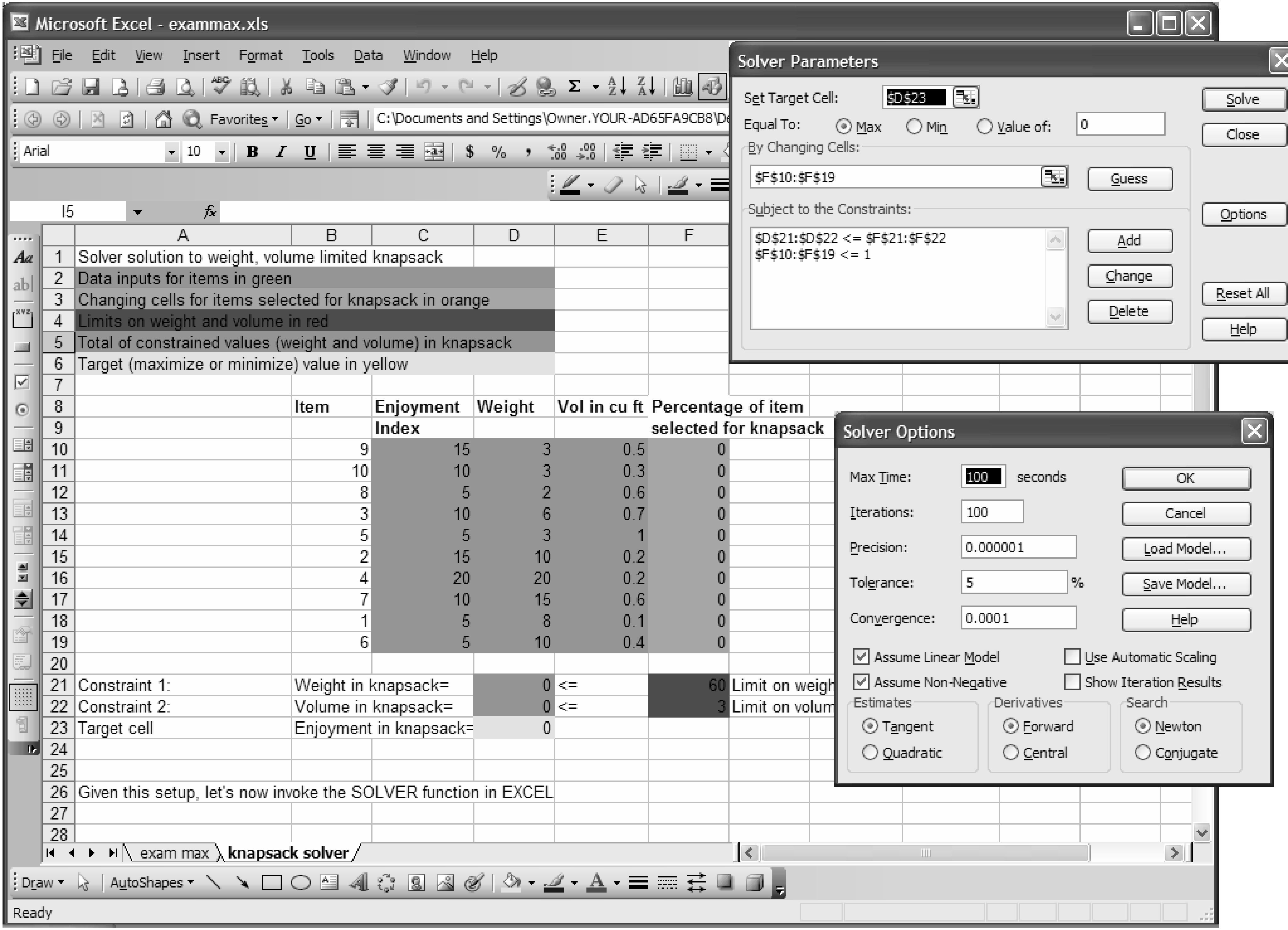
By Changing Cells:

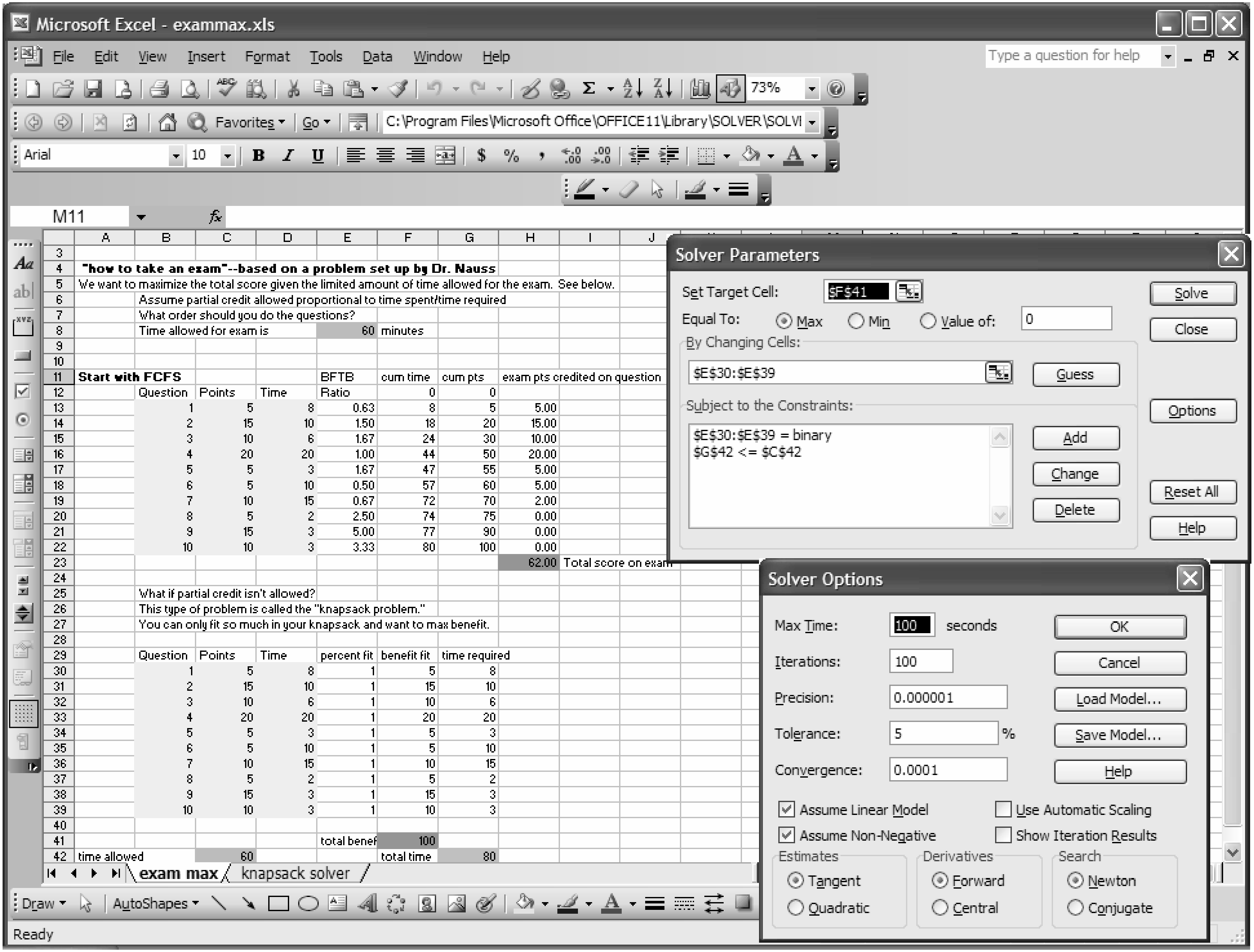
$B$20:$B$26,$B$12:$B$18

Subject to the Constraints:

$B$12:$B$18 = integer
$B$20:$B$26 = integer
$D$27:$J$27 >= $D$29:$J$29

Guess | Add | Change | Delete


Microsoft Excel - exammax.xls
File Edit View Insert Format Tools Data Window Help
Solver solution to weight, volume limited knapsack
Data inputs for items in green
Changing cells for items selected for knapsack in orange
Limits on weight and volume in red
Total of constrained values (weight and volume) in knapsack
Target (maximize or minimize) value in yellow
Item | Enjoyment Index | Weight | Vol in cu ft | Percentage of item selected for knapsack
9 | 15 | 3 | 0.5 | 0
10 | 10 | 3 | 0.3 | 0
8 | 5 | 2 | 0.6 | 0
3 | 10 | 6 | 0.7 | 0
5 | 5 | 3 | 1 | 0
2 | 15 | 10 | 0.2 | 0
4 | 20 | 20 | 0.2 | 0
7 | 10 | 15 | 0.6 | 0
1 | 5 | 8 | 0.1 | 0
6 | 5 | 10 | 0.4 | 0
Constraint 1: Weight in knapsack= 0 <= 60 Limit on weigh
Constraint 2: Volume in knapsack= 0 <= 3 Limit on volum
Target cell Enjoyment in knapsack= 0
Given this setup, let's now invoke the SOLVER function in EXCEL
exam max
knapsack solver
Ready
Solver Parameters
Set Target Cell: $D$23
Equal To: Max Min Value of: 0
By Changing Cells:
$F$10:$F$19
Subject to the Constraints:
$D$21:$D$22 <= $F$21:$F$22
$F$10:$F$19 <= 1
Solve Close Guess Options Add Change Delete Reset All Help
Solver Options
Max Time: 100 seconds
Iterations: 100
Precision: 0.000001
Tolerance: 5 %
Convergence: 0.0001
OK Cancel Load Model... Save Model... Help
Assume Linear Model
Assume Non-Negative
Use Automatic Scaling
Show Iteration Results
Estimates: Tangent, Quadratic
Derivatives: Forward, Central
Search: Newton, Conjugate



Microsoft Excel - exammax.xls
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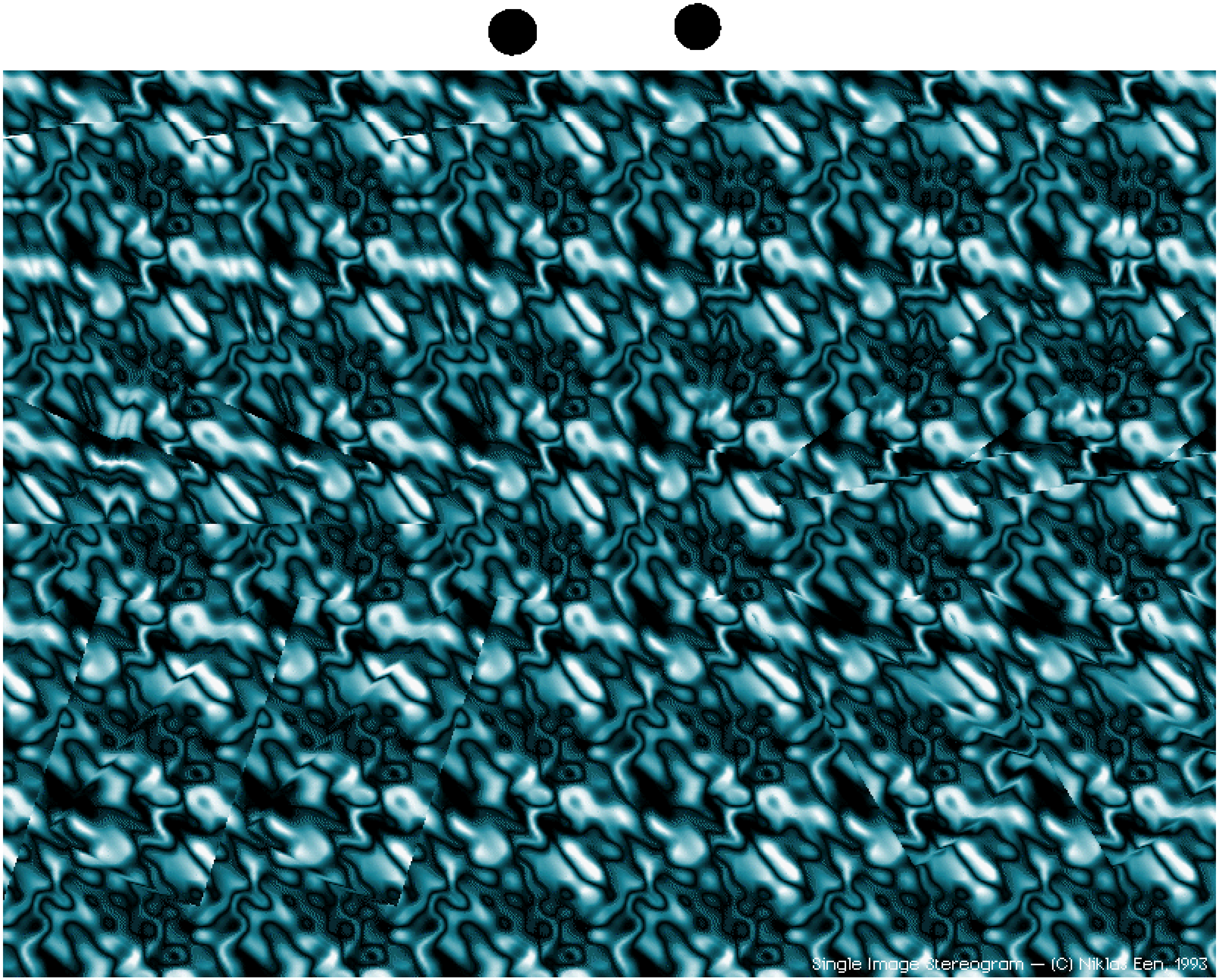
M11
"how to take an exam"--based on a problem set up by Dr. Nauss
We want to maximize the total score given the limited amount of time allowed for the exam. See below.
Assume partial credit allowed proportional to time spent/time required
What order should you do the questions?
Time allowed for exam is 60 minutes
Start with FCFS
Question Points Time BFTB Ratio cum time cum pts exam pts credited on question
1 5 8 0.63 8 5 5.00
2 15 10 1.50 18 20 15.00
3 10 6 1.67 24 30 10.00
4 20 20 1.00 44 50 20.00
5 5 3 1.67 47 55 5.00
6 5 10 0.50 57 60 5.00
7 10 15 0.67 72 70 2.00
8 5 2 2.50 74 75 0.00
9 15 3 5.00 77 90 0.00
10 10 3 3.33 80 100 0.00
62.00 Total score on exam
What if partial credit isn't allowed?
This type of problem is called the "knapsack problem."
You can only fit so much in your knapsack and want to max benefit.
Question Points Time percent fit benefit fit time required
1 5 8 1 5 8
2 15 10 1 15 10
3 10 6 1 10 6
4 20 20 1 20 20
5 5 3 1 5 3
6 5 10 1 5 10
7 10 15 1 10 15
8 5 2 1 5 2
9 15 3 1 15 3
10 10 3 1 10 3
total benef 100
time allowed 60 total time 80
exam max knapsack solver
Ready
Solver Parameters
Set Target Cell: $F$41
Equal To: Max Min Value of: 0
By Changing Cells:
$E$30:$E$39
Subject to the Constraints:
$E$30:$E$39 = binary
$G$42 <= $C$42
Solve Close Guess Options Add Change Delete Reset All Help
Solver Options
Max Time: 100 seconds
Iterations: 100
Precision: 0.000001
Tolerance: 5 %
Convergence: 0.0001
OK Cancel Load Model... Save Model... Help
Assume Linear Model
Use Automatic Scaling
Assume Non-Negative
Show Iteration Results
Estimates Tangent Quadratic
Derivatives Forward Central
Search Newton Conjugate



Gaze beyond the immediate detail to be propelled by the vision