36106 Managerial Decision Modeling
Decision Analysis in Excel

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Reading and Excel Files

Reading:

- Powell and Baker: Sections 13.1, 13.2, and 13.3
- Course Pack: “Decision Analysis”’ by George Wu

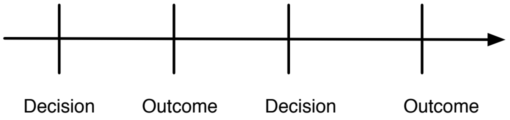
Files used in this lecture:

- `wertzTree.xlsx`
- `wertzTree_key.xlsx`
- `wertzUtility.xlsx`
- `sarahChangData.xlsx`
- `sarahChangKey.xlsx`
- `sarahChangOptimal.xlsx`
- `sarahChangSensitivity.xlsx`

Lecture Outline

Learning Objectives

1. Begin to incorporate uncertainty into an Excel model
2. Learn to model sequential decision problems
3. Learn how to use Precision Tree in Excel



Software Install – DecisionTools Suite

CRITICAL AND IMPORTANT:

1. Close all programs except Excel.
2. Minimize number of open files in Excel.

Remember my Corollary to Murphy's law – *When it comes to computers, Murphy was an optimist.*

Another Corollary: Excel Add-ins increase the probability that problems arise.

Software Install – DecisionTools Suite

Software – see link at Canvas

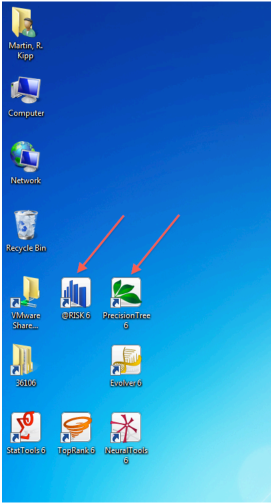
Please do the default install.

We will use:

- Precision Tree
- @Risk
- Risk Optimizer

Software Install – DecisionTools Suite

If you do the default install, you should see desktop icons like:



Software Install – DecisionTools Suite

Make sure Excel is closed.

Open Excel by “clicking” on the PrecisionTree 6 desk icon.

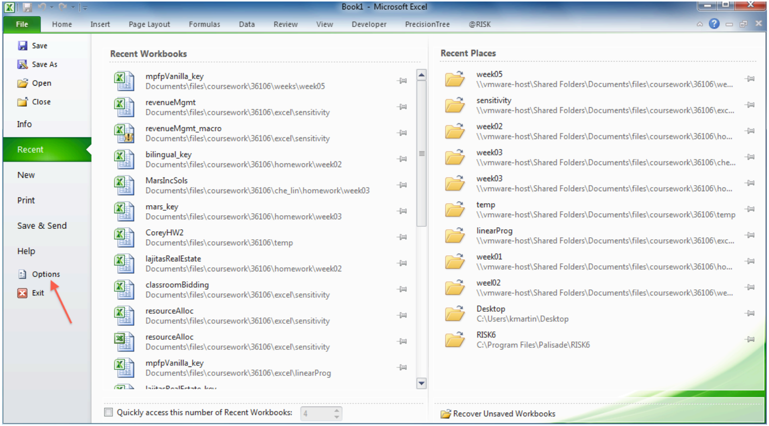
This should open Excel for you.

Now click on the @Risk icon.

Now add these to your Ribbon.

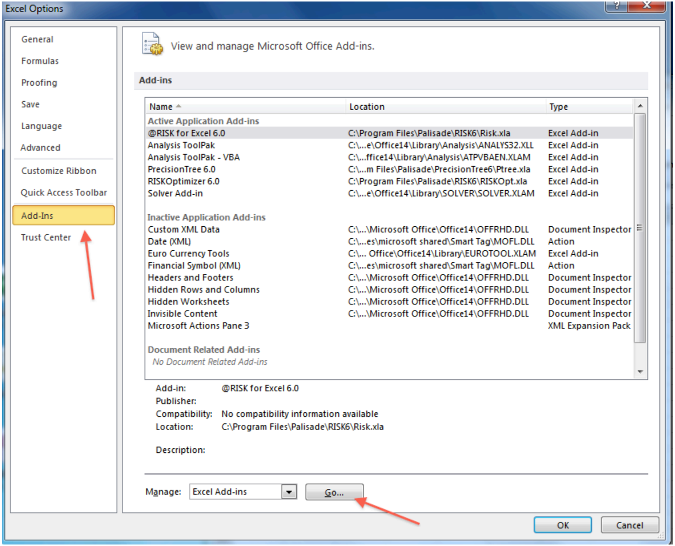
Software Install – DecisionTools Suite

Under **File** select **Options**



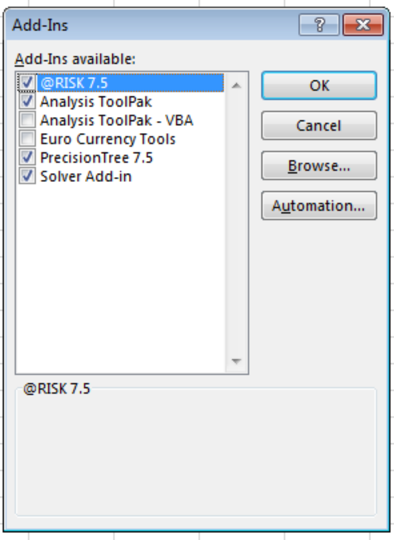
Software Install – DecisionTools Suite

Select **Add-Ins** and then under **Manage: Excel Add-ins**, select **Go..**



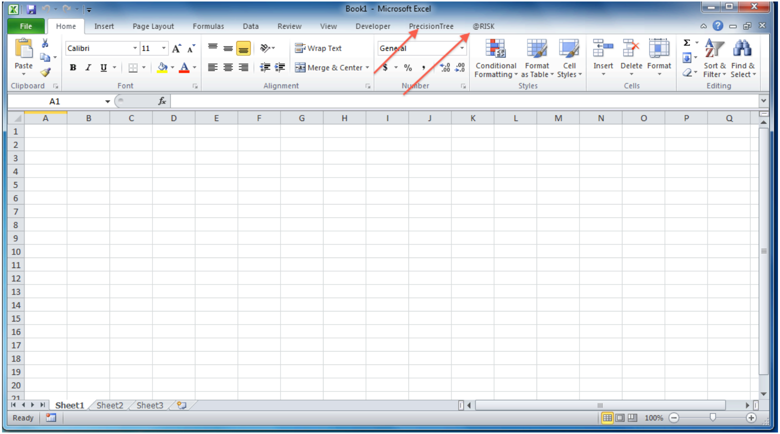
Software Install – DecisionTools Suite

If you have opened Excel by clicking on both @Risk 7.5 and PrecisionTree 7.5 you should see



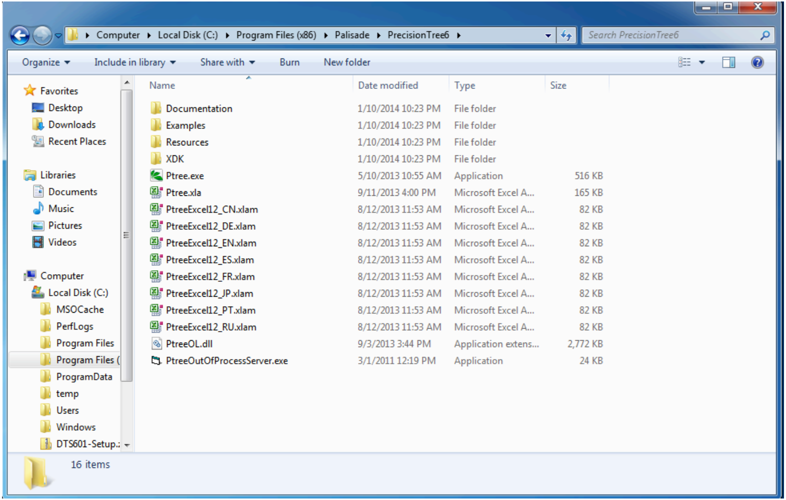
Software Install – DecisionTools Suite

From now on, you can open Excel and do not need to use the desktop icons. You should see Tab items for both PrecisionTree and @Risk.



Software Install – DecisionTools Suite

Your software download comes with lots of documentation and examples.



Motivation

See `http://www.palisade.com/cases/bucknell.asp?caseNav=byProduct`

- Disaster Planning
- Geothermal Power Plant Equipment Procurement
- Portfolio Management
- Exchange Rate Analysis
- Endangered Species Protection
- Pollution Cleanup

Motivation

Key Concept: most people do not understand

- the concept of an optimal solution
- variables
- parameters
- constraints
- an objective function

Thinking about your problem in the context of these ideas may be very beneficial.

Motivation

Key Concept: the biggest the benefit of an Excel model is that it forces a user to:

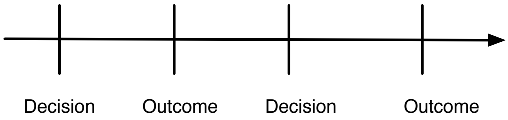
- think about decision alternatives
- think about potential outcomes that result from making a decision
- quantify an outcome (you need numbers and formulas in Excel)
- quantify uncertainty (you need numbers and formulas in Excel)

Motivation

We are going to study **Decision Analysis**.

Differences from Solver models:

- There are a limited number of possible decisions to make (as opposed to potentially infinite)
- The outcomes of a decision are uncertain
- Decisions are made sequentially over time



Motivation

We are going to use PrecisionTree to model these kinds of problems.

- We are going to look at the **expected value** of our decisions
- This requires a structured approach to modeling which has great benefits
- **Warning:** no guarantee that this approach does not lead to a bad outcome

Motivation

It is critical to realize that *when making decision under uncertainty:*

- a **good** decision may lead to a bad result
- a **poor** decision may lead to a good result

See the discussion by former Booth student Zeger Degraeve at

`http://www.youtube.com/watch?v=1qor-igeE0k`

Example 1: Wertz Game and Toy

Wertz Game and Toy Data (Section 13.2 of Powell and Baker)

	A	B	C	D	E	F
1	**Wertz Game and Toy**					
2				Market Response		
3				Good	Fair	Poor
4			Single Version	100	60	-10
5		Decision	Two Versions	200	50	-40
6			Full Line	300	40	-100
7						
8						
9				Market Response		
10				Good	Fair	Poor
11			Probability	0.2	0.5	0.3
12						

Example 1: Wertz Game and Toy

We look at four criteria:

- maximax payoff
- maximin payoff
- minimax regret
- maximize expected payoff

Example 1: Wertz Game and Toy

17	**Maximax payoff criterion**					
18						
19			Market Response			**Max**
20			Good	Fair	Poor	**Payoff**
21		Single Version	100	60	-10	**100**
22	Decision	Two Versions	200	50	-40	**200**
23		Full Line	300	40	-100	**300**
24						

Decision: full line

Example 1: Wertz Game and Toy

Maximin payoff criterion

		Market Response			Min
		Good	Fair	Poor	Payoff
	Single Version	100	60	-10	**-10**
Decision	Two Versions	200	50	-40	**-40**
	Full Line	300	40	-100	**-100**

Decision: single line

Example 1: Wertz Game and Toy

37	**Minimax regret criterion**					
38						
39						
40			Market Response			**Max**
41			Good	Fair	Poor	**Regret**
42		Single Version	200	0	0	**200**
43	Decision	Two Versions	100	10	30	**100**
44		Full Line	0	20	90	**90**
45						

Decision: full line

Example 1: Wertz Game and Toy

Maximize expected payoff:

Calculate the expected payoff of decision d_i :

P_j = probability of state of nature j

V_{ij} = value of outcome given decision i and state of nature j

$$EV(d_i) = \sum_{j=1}^{N} P_j V_{ij}$$

Make the decision with the maximum expected payoff.

Assumption: $\sum_{j=1}^{N} P_j = 1.0$

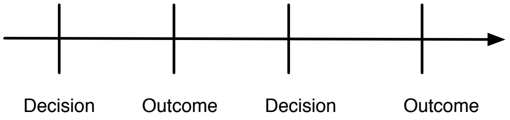
Example 1: Wertz Game and Toy

48	**Expected payoff criterion**						
49							
50							
51				Market Response			**Expected**
52				Good	Fair	Poor	**Payoff**
53			Single Version	100	60	-10	**47**
54		Decision	Two Versions	200	50	-40	**53**
55			Full Line	300	40	-100	**50**
56							

Decision: Two Versions

The Cost of Uncertainty

The basic problem:



Must make a decision **before** the outcome is known.

It would be nice to know the outcome before making the decision.

For example, if Wertz managers knew the market response would be good, they would bring out the full line.

How much should Wertz be willing to pay to know the outcome first?

The Cost of Uncertainty

Expected Value of Perfect Information (EVPI) – the increase in the expected payoff if one knew with certainty which state of nature would occur.

The expected payoff with perfect information must be at least as great as the expected payoff of the optimal solution.

For example, for Wertz the EVPI must be at least 53 which is the optimal expected payoff.

The Cost of Uncertainty

Expected Value of Perfect Information – make the calculation as follows:

Step 1: For each possible state of nature, determine the optimal decision and corresponding outcome

Step 2: Weight each outcome by the probability of the state of nature associated with that outcome and calculate the expected value

Step 3: Subtract the EV of the optimal decision from the number calculated in Step 2.

The Cost of Uncertainty

Expected Value of Perfect Information – Wertz:

Step 1: For each state of nature determine the outcome for the optimal decision.

- **Good:** best outcome is 300 (full line is the optimal decision)
- **Fair:** best outcome is 60 (single version is the optimal decision)
- **Poor:** best outcome is -10 (single version is the optimal decision)

Step 2: Weight each optimal outcome by the probability assigned to that state of nature

$$.2 * 300 + .5 * 60 + .3(-10) = 60 + 30 - 3 = 87$$

Step 3: Subtract the EV of the optimal decision from the number calculated in Step 2.

$$EVPI = 87 - 53 = 34$$

Example 1 (Follow UP): Wertz Game and Toy

Expected value of perfect information (EVPI)

Profit	300	60	-10	
Probability	0.2	0.5	0.3	87
Expected Value	87			
EVPI	34			

Example : Wertz Game and Toy

Wertz is a very simple model.

There is only one decision made at time 0

It is trivial to find the optimal decision in an Excel table. Just calculate the expected payoff for each decision.

However, real life is more complicated, and often involves a *sequence* of decisions.

More sophisticated tools are required.

Decision Theory

See *Decision Analysis* by George Wu.

Four Steps in Decision Making Process

Step 1: Structuring a Decision Problem (alternatives, uncertainties, and objectives)

Step 2: Assessment and Information Gathering

Step 3: Evaluation of Decision Problem (PrecisionTree used in this step)

Step 4: Sensitivity Analysis (PrecisionTree used in this step)

Decision Theory

Step 1: Structuring a Decision Problem Instead of the Solver (A (adjustable cells), B (best cell), and C (constraint cells)) we have:

- What are the alternatives?
- What are the critical uncertainties?
- What are the objectives?

Decision Theory

Step 2: Assessment and Information Gathering: Collect the relevant information,

- assess the values of the outcomes given decisions that were made (e.g. in Wertz the outcome of a good market response, given the decision to produce the full line is 300)
- determine the likelihood of uncertain events (e.g. in Wertz the probability of a fair market response is 0.5)

Discussion Point: What is meant by the probability of an event?

Decision Theory

What do we mean by probability? See pages 8 and 9 of the *Decision Analysis* case.

Probabilities measure the likelihood of uncertain events.
In most cases a probability is a judgement. This does not imply it is arbitrary.

Sarah Chang says the probability of successfully developing the microprocessor in six months is .40.

Sarah Chang is saying that she believes this event is just as likely as drawing a red ball from an urn where 40% of the balls in the urn are red.

Decision Theory

Step 4: Sensitivity Analysis:

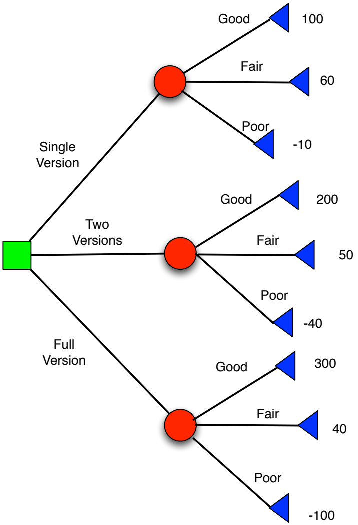
Determine how sensitive the optimal solution is to the probabilities and the outcome values.

We use the sensitivity analysis features of Precision Tree.

For example, how much can probability estimates change before we change our decisions?

Example 1: Wertz Game and Toy

We are going to build in Excel something that looks like this:



Example 1: Wertz Game and Toy

Icon coding scheme:

- a green square – a point in time where we make a decision
- a red circle – a chance node, an uncertain outcome occurs
- a blue triangle – indicates the end of branch

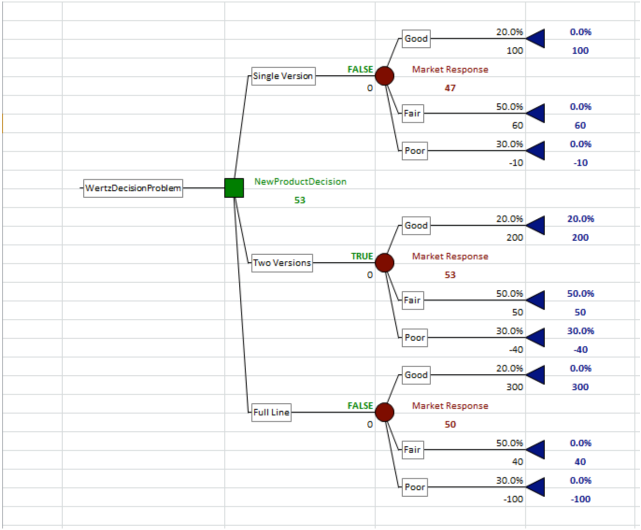
Time proceeds left to right.

Probabilities and monetary values are placed next to nodes

Expected values are computed by the **folding-back process**

The optimal path is indicated by **TRUE** nodes.

Example 1: Wertz Game and Toy



Example 2: Sarah Chang

Step 1: Structuring a Decision Problem

Step 2: Assessment and Information Gathering

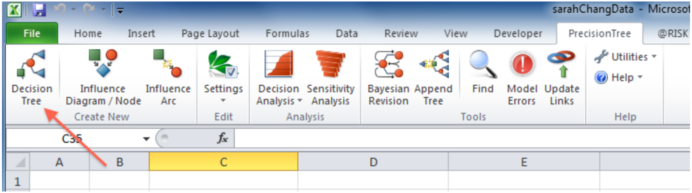
Sarah Chang Data

Stage	Event	Alternatives/Possibilities	Return ($)	Probability	
Stage 1	Decision	Continue the project	-200000	-	
		Abandon the project	0	-	
Stage 2	Outcome	Project Succeeds	0	0.4	
		Project Fails	0	0.6	
Stage 3	Decision	Make the Proposal	-50000	-	
		Don't make the proposal	0	-	
Stage 4	Outcome	Win Contract	850000	0.9	(If project succeeds in Stage 2)
			850000	0.05	(If project fails in Stage 2)
		Do not Win Contract	0	0.1	(If project succeeds in Stage 2)
			0	0.95	(If project fails in Stage 2)

Note the breakdown between Decisions and Outcomes.

Example 2: Sarah Chang

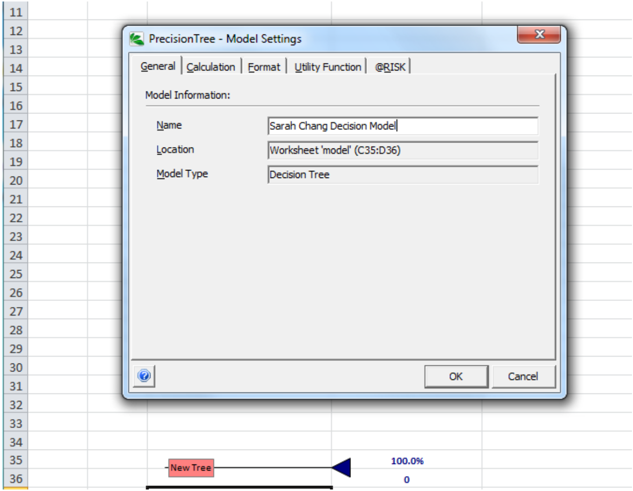
- Open the file `sarahChangData.xlsx` Workbook.
- see the spreadsheet **data** for the result of the *addressing and information gathering* step.
- open the spreadsheet **model** – it is currently empty.
- select an arbitrary cell, say C35
- Go to the **PrecisionTree** tab and select **Decision Tree**



Example 2: Sarah Chang

Click OK

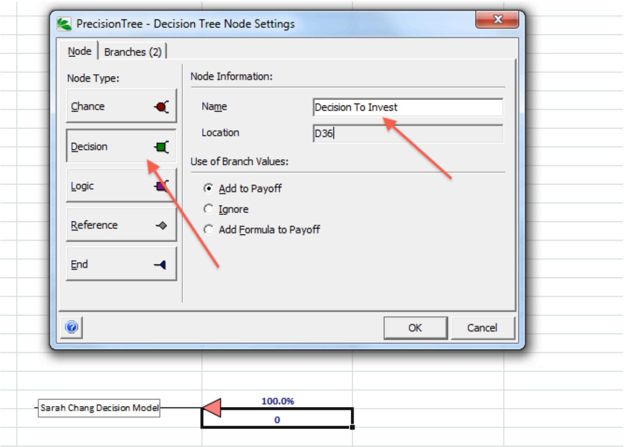
Name the model *Sarah Chang Decision Model*



Example 2: Sarah Chang

Click on the end blue triangle node.

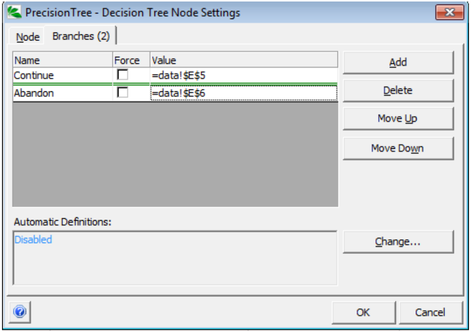
Select a Decision node and name it *Decision to Invest*.



Example 2: Sarah Chang

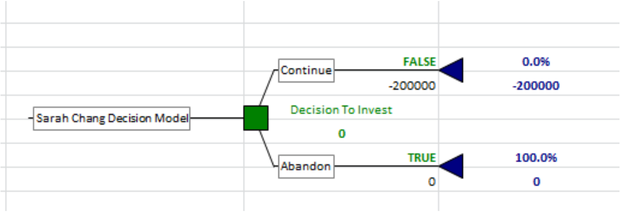
Next click on the **Branches** tab and do the following:

- Name the branches *Continue* and *Abandon*
- Give the *Continue* branch a value of **=data!E5**
- Give the *Abandon* branch a value of **=data!E6**



Example 2: Sarah Chang

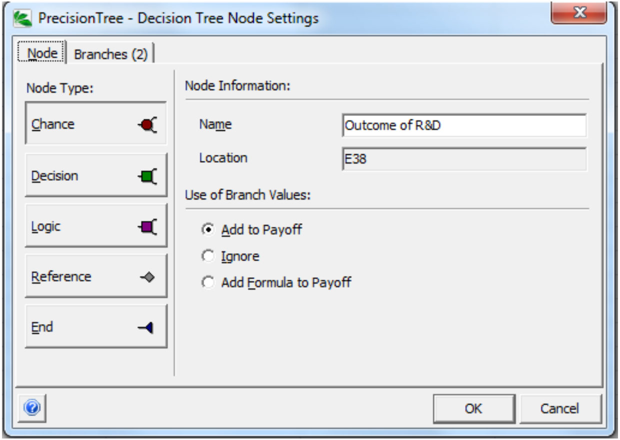
At this point, your decision tree should look like:



Example 2: Sarah Chang

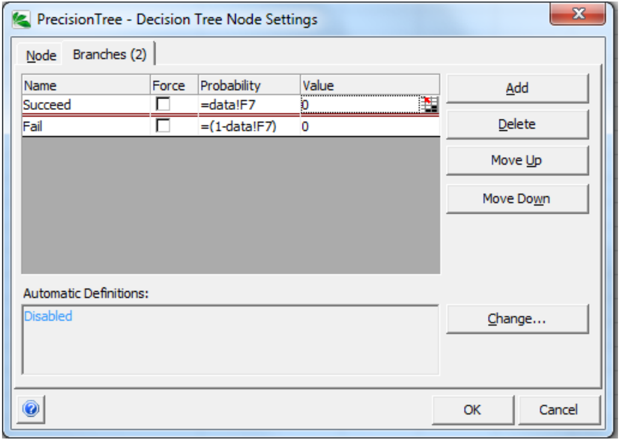
Click on the end blue triangle node for the *Continue* branch.

Click on **Chance** button and give the node the name *Outcome of R & D*.



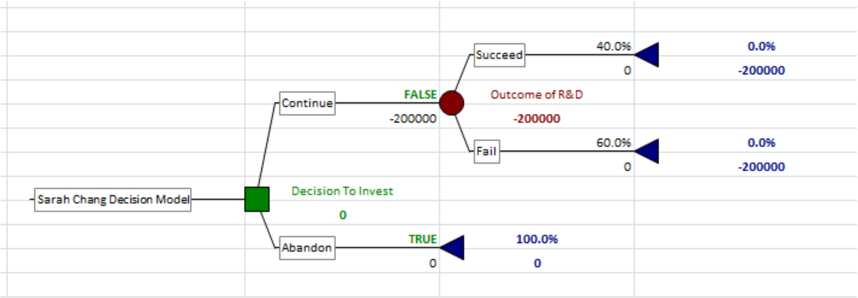
Example 2: Sarah Chang

- Name the branches *Succeed* and *Fail*
- Give the *Succeed* branch a probability of **=data!F7**
- Give the *Fail* branch a probability of **=(1-data!F7)**



Example 2: Sarah Chang

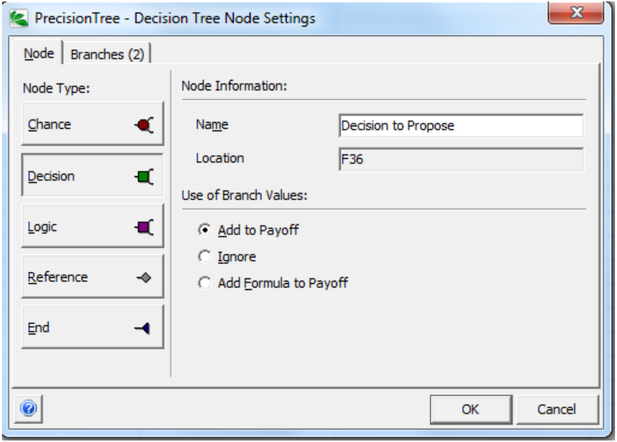
Your tree should now look like this:



Example 2: Sarah Chang

Now click on the blue triangle at the end of the *Succeed* outcome.

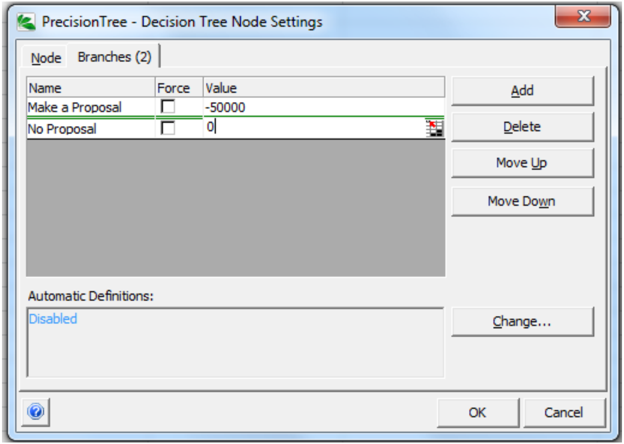
Create a **Decision** node named *Decision To Propose*



Example 2: Sarah Chang

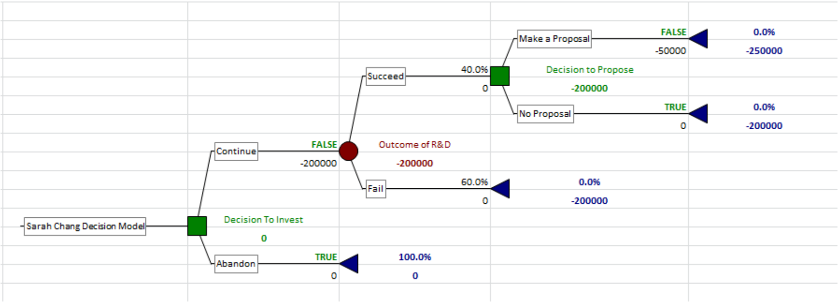
Click on the **Branches** tab:

- Name the branches *Make a Proposal* and *No Proposal*
- Give the *Make a Proposal* branch a value of **-50000** or **data!E9**
- Give the *No Proposal* branch a value of **0** or **data!E10**



Example 2: Sarah Chang

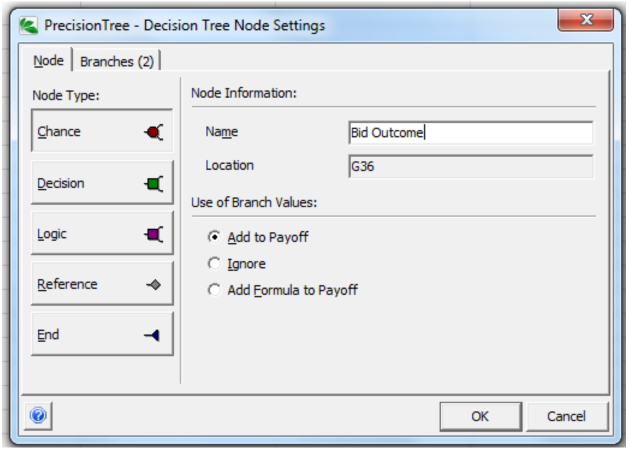
Your tree should look like this



Example 2: Sarah Chang

Now click on the blue triangle at the end of the *Make a Proposal* outcome.

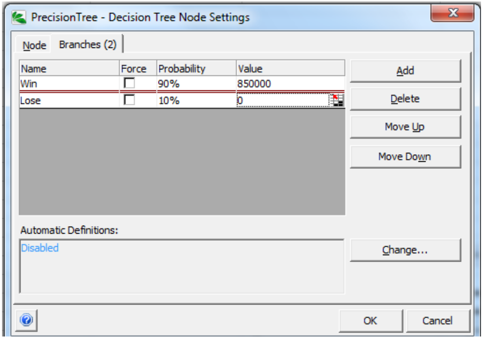
Create a **Chance** node named *Bid Outcome*



Example 2: Sarah Chang

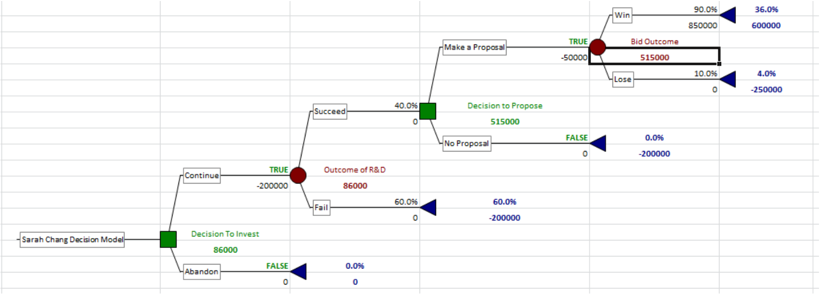
Click on **Branches** tab:

- Name the branches *Win* and *Lose*
- Give the *Win* branch probability of **90%** or **data!F11**
- Give the *Lose* branch a probability of **10%** or **(1 - data!F11)**
- Give the *Win* branch a value of **850000** or **data!E11**
- Give the *Lose* branch a value of **0** or **data!E13**



Example 2: Sarah Chang

Your Decision Tree should look like this:



Example 2: Sarah Chang

Wow that was a lot of work!

Sarah may wish to submit a Proposal even if the R&D failed.

Consider the blue triangle termination node at the end of the *fail* branch of the *Outcome of R&D* **chance** node.

The **structure** of the decision and outcome nodes at the end of the *fail* branch are identical to those at the end of the *succeed* node.

However, the probabilities and values differ.

Do a copy and paste!

Example 2: Sarah Chang

Right click on the *Decision to Propose* node and select **Copy Subtree**.

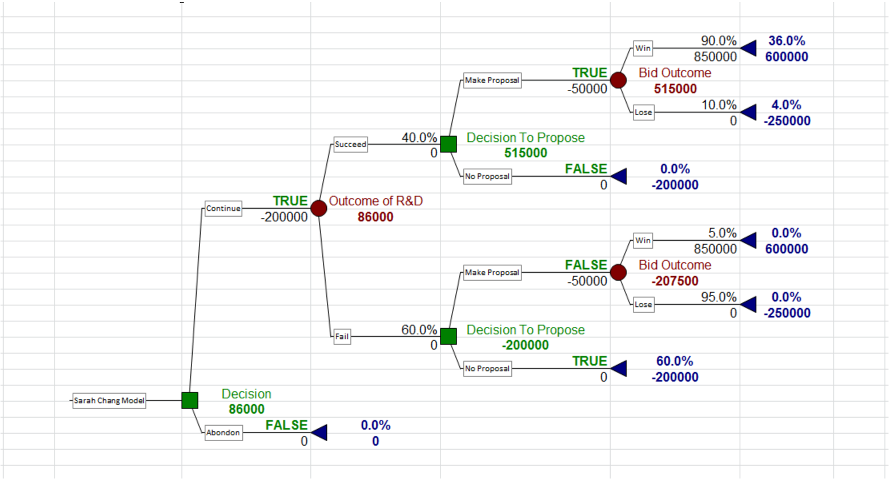
Right click on the blue triangle termination node at the end of the *fail* branch of the *Outcome of R&D* **chance** node.

Select **Paste Subtree**

Adjust values accordingly: the *Win* probability is changed from 90% to 5% and the *Lose* probability is changed from 10% to 95%.

Example 2: Sarah Chang

Your Decision Tree should look like this. See `sarahChangKey.xlsx`.



Example 2: Sarah Chang

The optimal solution: Trace the green **TRUE** values through the tree. The optimal strategy for Sarah is to

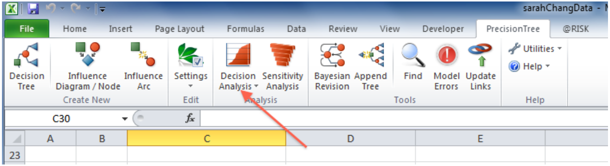
- First, proceed with the project and continue R&D on the microprocessor
- If the outcome of R&D is success then make the proposal to the Olympic committee
- If the outcome of R&D is failure then do not make the proposal to the Olympic committee

PrecisionTree will generate the above information for you.

PrecisionTree will fold-back the tree for you.

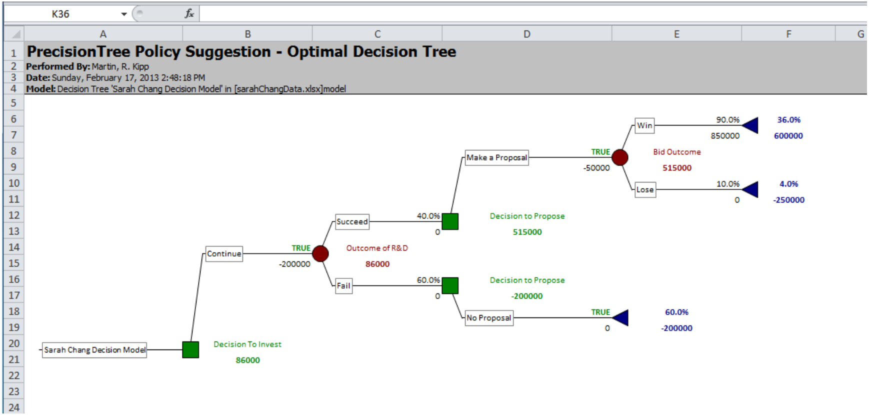
Example 2: Sarah Chang

Click on **Decision Analyis** button to generate a `Policy Suggestion`.



Example 2: Sarah Chang

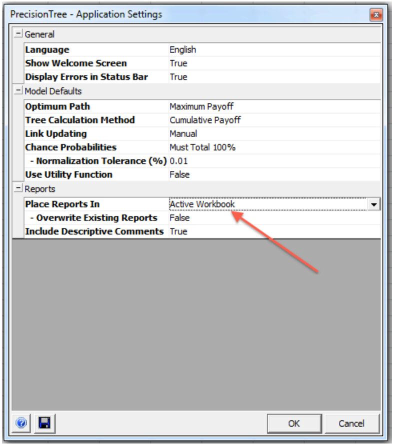
The optimal policy for Sarah Chang. Notice the coloring scheme. We return to this picture shortly.



Example 2: Sarah Chang

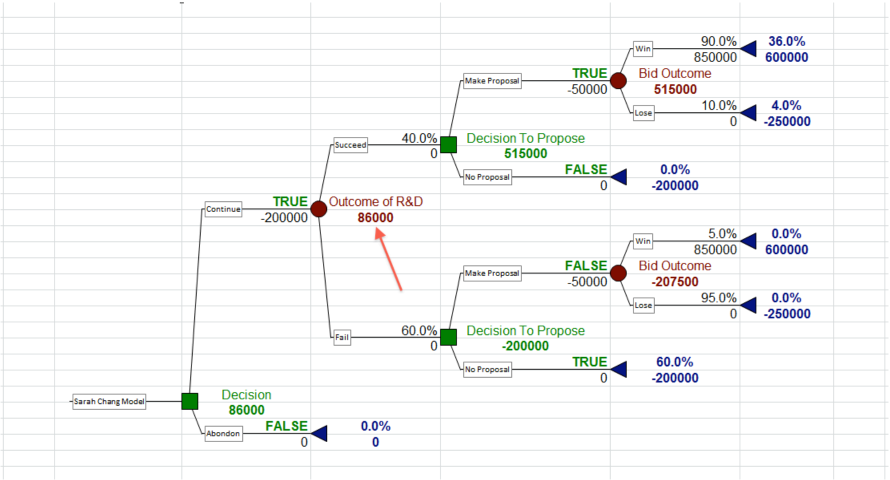
You may wish to place reports in the open workbook instead of creating a new workbook.

Under **Utilities** select **Application Settings ...**



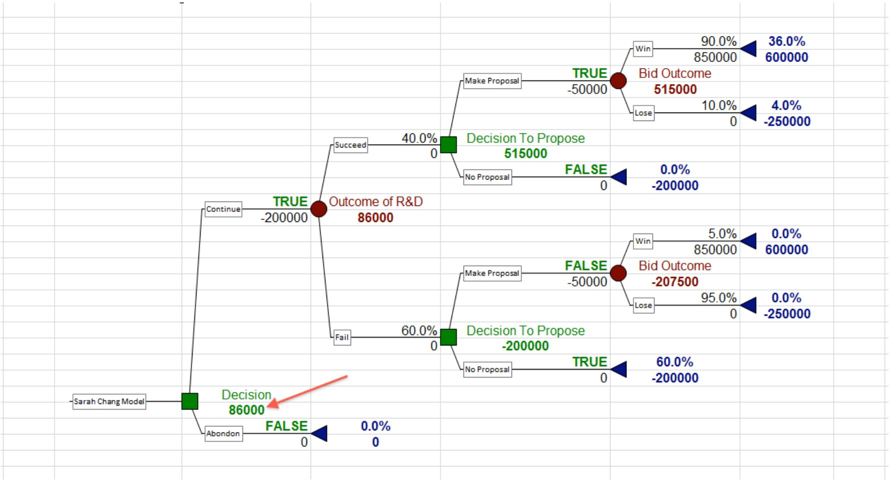
Optimal Value

How is the 86000 calculated at the outcome node?



Optimal Value

What is the meaning of the 86000 in the decision tree?



Optimal Value

You should understand:

- How the numbers at each decision node are calculated (and what they mean)
- How the numbers at the outcome nodes are calculated
- How the numbers at the terminal nodes are calculated

Optimal Value

Example Calculations:

The Outcome of R&D node has a value of \$86,000. This comes from:

$$86000 = .4 * 515000 + .6 * -200000$$

The terminal node at the top of the tree has a probability value of 36.0%. We reach this point in the tree given successful R&D and winning the bid. These are independent events so the probability is

$$.36 = .4 * .9$$

Optimal Value

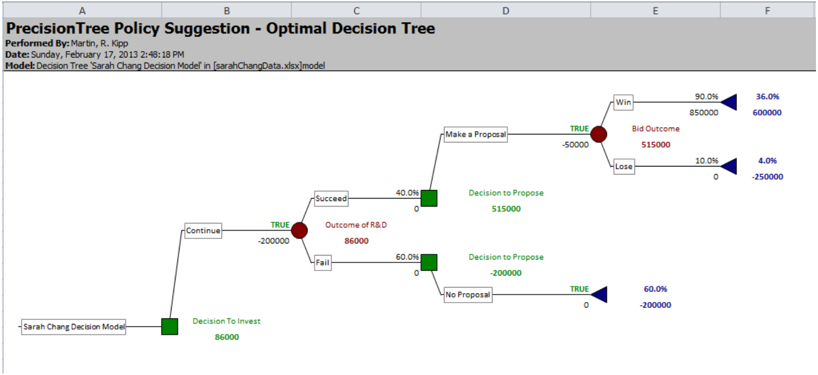
Example Calculations:

This terminal node also has a value of \$600,000. At this terminal node, we won the bid with a return of \$850,000 but paid \$50,000 to prepare the bid and \$200,000 to continue the R&D. This gives

$$\$600,000 = \$850,000 - \$50,000 - \$200,000.$$

Now, how do you interpret the \$86,000 at the root decision node?

Optimal Value



See next slide.

Optimal Value

Important: Observe that there are only **three** outcomes for Sarah if she pursues the optimal strategy. They are

1. \$600,000 with probability .36
2. -\$250,000 with probability .04
3. -\$200,000 with probability .6

Her expected value is

$$86000 = .36 * 600000 - .04 * 250000 - .6 * 200000$$

Expected Monetary Value

We maximize expected monetary value. What if we have a one-time decision?

Che-Lin example of drug company where they are repeating the process many times.

Expected value does have meaning here.

Some Tips

- Separate the model from the data
- Separate the model from the data – you get the idea
- Make use of copy and paste – but be careful of cell references
- Make sure probabilities sum to 1.0
- **Do not** play with the formulas generated by PrecsionTree (blue, red, green)
- You should only edit through the user interface

Some Tips

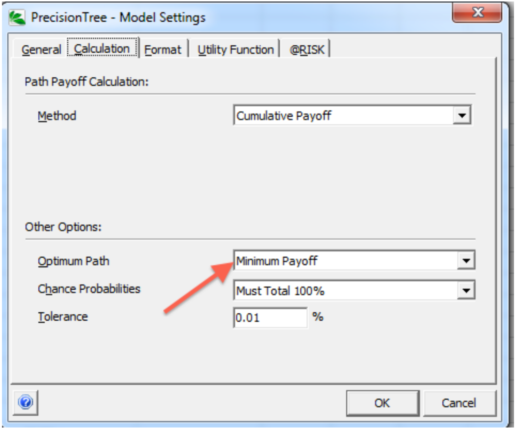
If you get a **Value** error at nodes instead of **True** or **False** make sure:

- The probabilities sum to one at each chance node. This is the **number one** cause of getting a **Value** error. You should see an error message about probabilities not summing to 1.0 in small print at the bottom of the Excel spreadsheet.
- Do a File save. The **Value** error may go away.
- Recalculate the spreadsheet – hit key **F9.** Even better, make sure under Workbook Calculations, that Automatic is checked.
- Always enter probabilities and values through Precision Tree. **Do not** enter them directly into the cells.

Have these tips at your side for the exam.

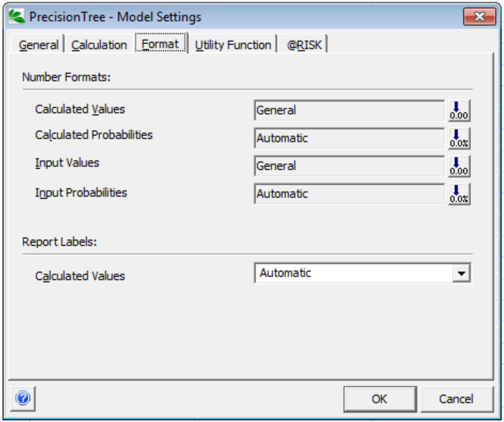
Some Tips

You can have PrecisionTree minimize expected cost instead of maximize profit/revenue.



Some Tips

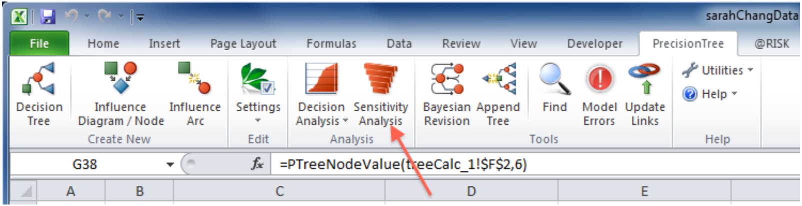
You can set up PrecisionTree to format the various cells – see the Format tab under Model Settings.



Sensitivity Analysis

Sensitivity Analysis: See pages 12-13 of the *Decision Analysis* case. How *sensitive is the model to the probability estimate of winning the bid?*

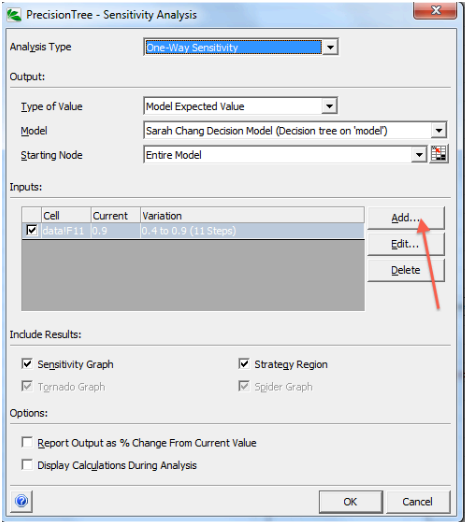
Select the **Sensitivity Analysis** menu item from the **Analysis** group.



We are going to do sensitivity analysis on cell `data!F11`

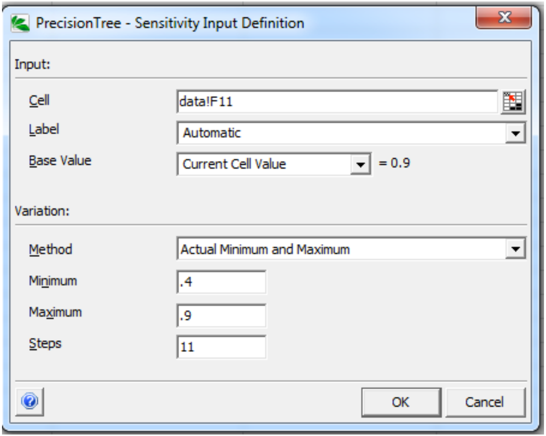
Sensitivity Analysis

Add the cell `data!F11` we use for sensitivity analysis.



Sensitivity Analysis

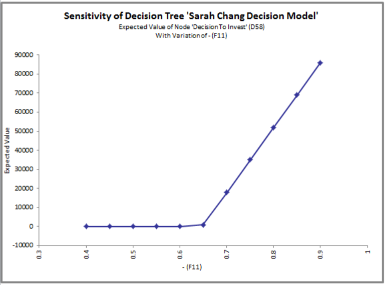
Vary the probability of win the bid (assuming successful R&D) from .4 to .9 in increments of .05 (11 steps).



Sensitivity Analysis

At approximately what probability should we make the Continue decision?

Performed By: Martin, R. Kipp
Date: Sunday, February 17, 2013 6:57:53 PM
Output: Decision Tree 'Sarah Chang Decision Model' (Expected Value of Entire Model)
Input: - (F11)



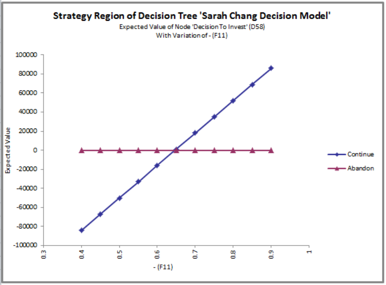
Sensitivity Data

	Input		Output	
	Value	Change (%)	Value	Change (%)
#1	0.4	-55.56%	0	-100.00%
#2	0.45	-50.00%	0	-100.00%
#3	0.5	-44.44%	0	-100.00%
#4	0.55	-38.89%	0	-100.00%
#5	0.6	-33.33%	0	-100.00%
#6	0.65	-27.78%	1000	-98.84%
#7	0.7	-22.22%	18000	-79.07%
#8	0.75	-16.67%	35000	-59.30%
#9	0.8	-11.11%	52000	-39.53%
#10	0.85	-5.56%	69000	-19.77%
#11	0.9	0.00%	86000	0.00%

Sensitivity Analysis

PrecisionTree Sensitivity Analysis - Strategy Region

Performed By: Martin, R. Kipp
Date: Sunday, February 17, 2013 6:57:53 PM
Output: Decision Tree 'Sarah Chang Decision Model' (Expected Value of Entire Model)
Input: - (F11)

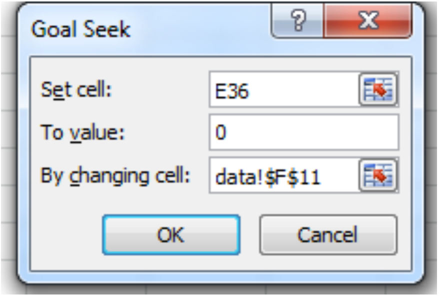


Strategy Region Data

	Input		Continue		Abandon	
	Value	Change (%)	Value	Change (%)	Value	Change (%)
#1	0.4	-55.56%	-84000	-197.67%	0	-100.00%
#2	0.45	-50.00%	-67000	-177.91%	0	-100.00%
#3	0.5	-44.44%	-50000	-158.14%	0	-100.00%
#4	0.55	-38.89%	-33000	-138.37%	0	-100.00%
#5	0.6	-33.33%	-16000	-118.60%	0	-100.00%
#6	0.65	-27.78%	1000	-98.84%	0	-100.00%
#7	0.7	-22.22%	18000	-79.07%	0	-100.00%
#8	0.75	-16.67%	35000	-59.30%	0	-100.00%
#9	0.8	-11.11%	52000	-39.53%	0	-100.00%
#10	0.85	-5.56%	69000	-19.77%	0	-100.00%
#11	0.9	0.00%	86000	0.00%	0	-100.00%

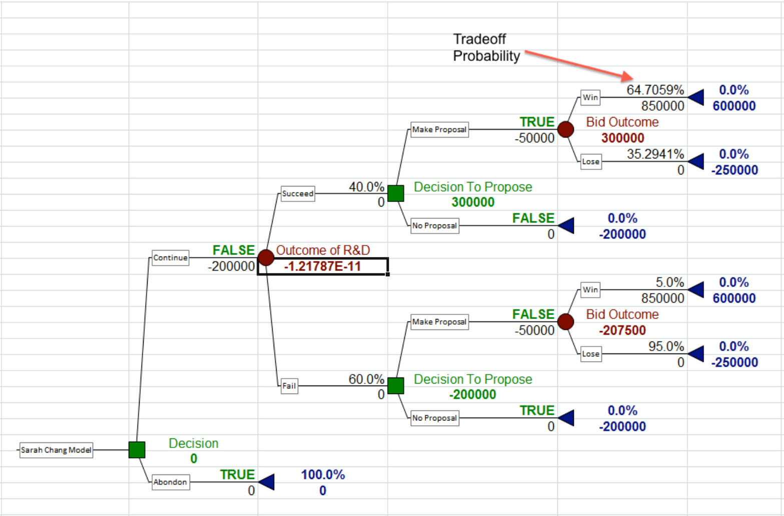
Goal Seek

Using Excel **GoalSeek** we can calculate exactly the probability of the bid being accepted at which we are indifferent to the decision to abandon the R&D of the chip.



Goal Seek

The tradeoff probability is approximately 64.71%



Goal Seek

What is the expected value of the continue decision?

What is the expected value of the abandon decision?

Which do you prefer?

Goal Seek

Oil Drilling Example (practice midterm) – the optimal decision is to not hire the geologist. How much would the report have to cost in order to be indifferent between a hire and no hire decision?

Perhaps the kind of question that would appear on the final.

Utility

Motivation: Assume the probability of making one million dollars is 10% and the probability of losing one million dollars is 10%.

The contribution to the expected value of winning one million is

$$100,000 = .1 * 1,000,000$$

The contribution to the expected value of losing one million is

$$-100,000 = .1 * (-1,000,000)$$

These two events are of *equal magnitude* in the expected value calculation.

Problem: in real life *people care about their tail!*

Clarification: By tail, I mean tail of their expected payoff distribution.

Utility

Key Concept: *If you maximize expected value (payoff) there may be a nontrivial probability of losing money.*

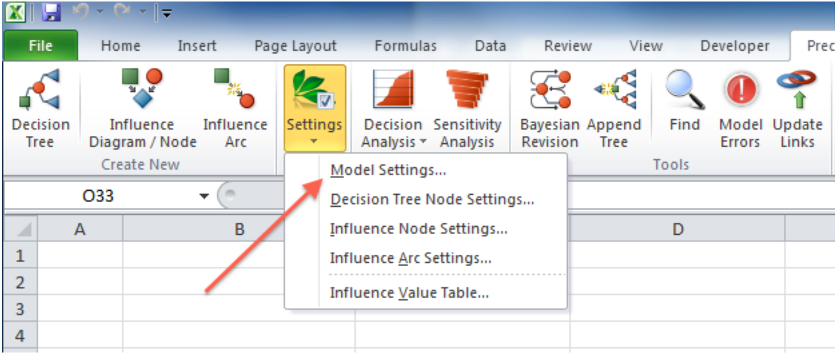
Key Concept: *If you maximize expected value (payoff) bad things may happen.*

- In Wertz, if you make the decision to produce two versions, there is a 30 percent chance you will lose 40 thousand dollars
- If Sarah Chang follows the optimal policy recommended by Precision Tree there is a 60 percent chance she will lose 200,000 dollars.

If you are risk averse you may wish to use a **utility function.**

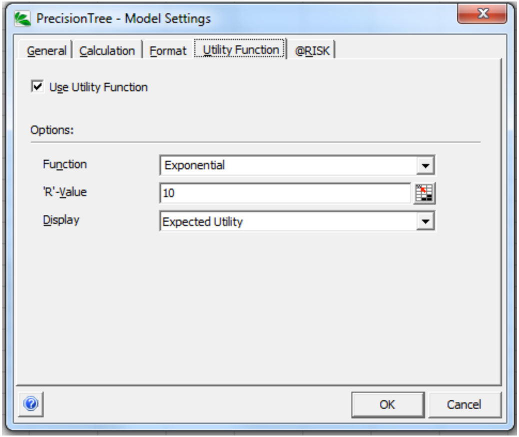
Utility

In PrecisionTree the default behavior is to use expected value or payoff. You can change that by going to **Settings** and then **Model Settings.**



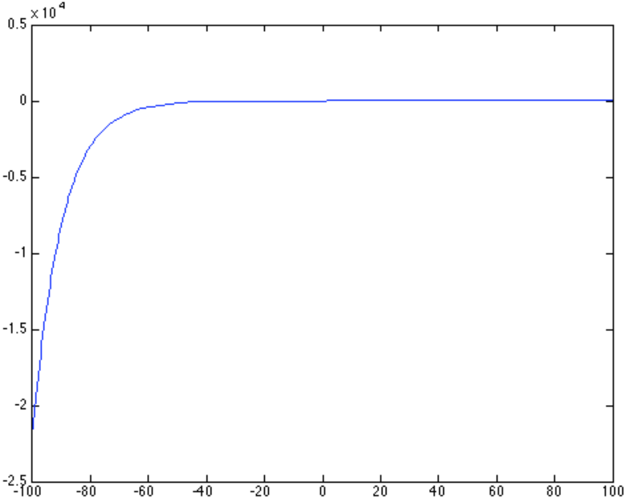
Utility

If you are risk averse (concave function), select an exponential utility function. In this case we have the utility function $f(x) = 1 - exp(-x/10)$.



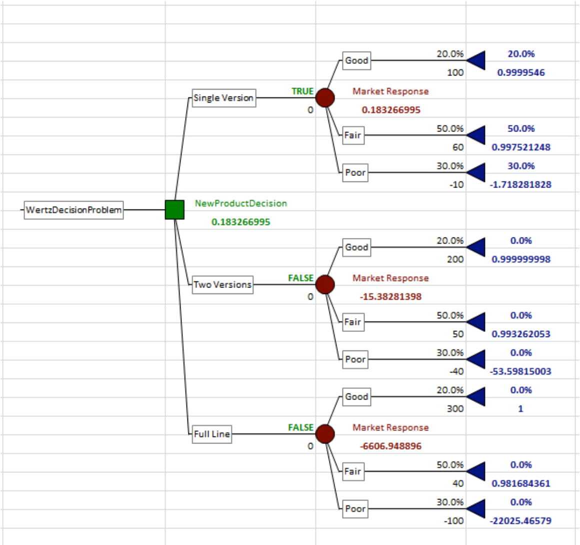
Utility

The utility function $U(x) = 1 - e(-x/10)$.



Utility

Wertz (**wertzUtility.xlsx**) with maximizing expected utility.



Utility

Now the optimal decision is to go with the single version.

This is a safer strategy. We lose at most 10,000 dollars.

The expected utility of this decision is:

$$.2*(1-e(-100/10))+.5*(1-e(-60/10))+.3*(1-e(10/10)) = 0.183266995$$

See next slide for a more detailed calculation.

Utility

In terms of **expected monetary value** the single decision value is

$$.2 * 100 + .5 * 60 + .3 * (-10) = \$47$$

$$20 + 30 - 3 = 47$$

Now replace the dollar values of \$100, \$60, and -\$10 with the **utility of those dollar amounts.**

$$.2*(1-e(-100/10))+.5*(1-e(-60/10))+.3*(1-e(10/10)) = 0.183266995$$

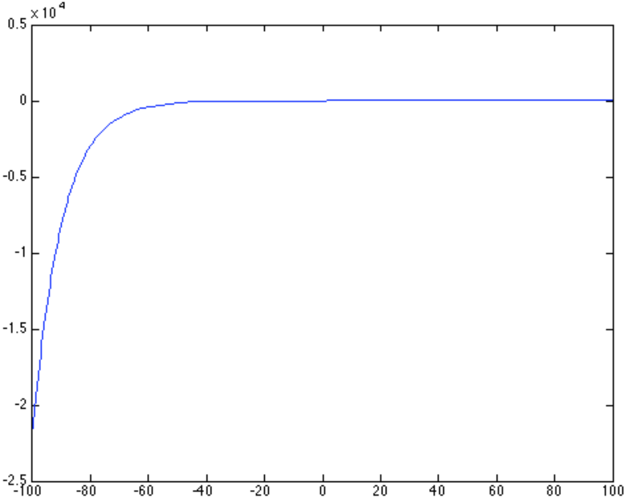
$$.2 * (.999) + .5 * (.998) + .3 * (-1.72) = 0.183266995$$

$$.2 + .498 - .515 = 0.183266995$$

We change the slope of the curve by altering the 10 in the denominator.

Utility

Bottom Line: You can pick a utility function that puts more weight on a loss than a gain.



Utility

When applying this material in the public sector it may be difficult to measure the value of outcomes even when probabilities are reasonably estimated.

Consider “black swan” events.

Blizzards are good examples.