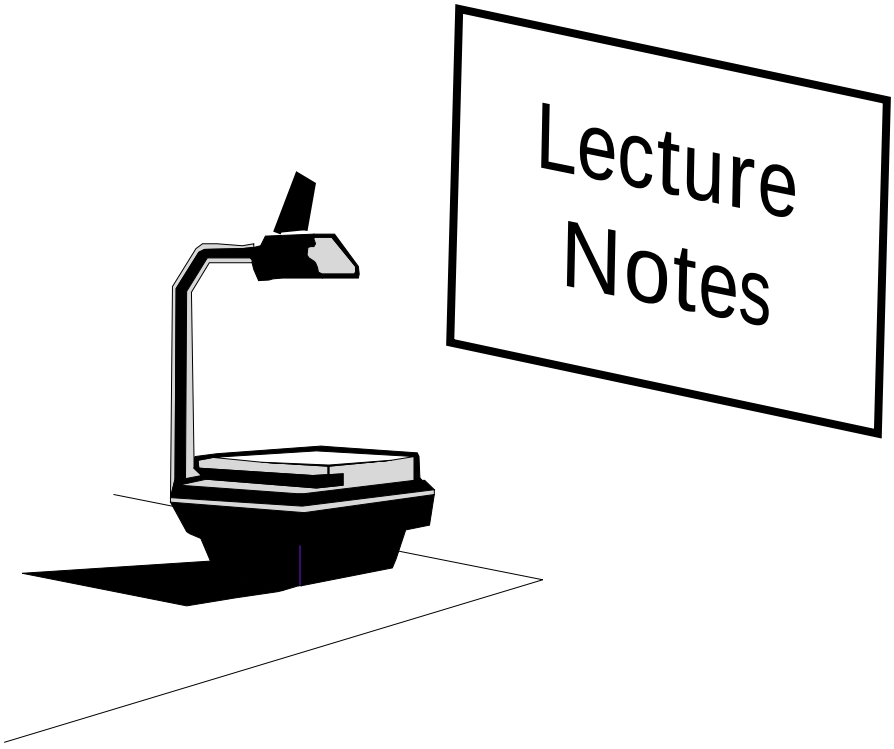
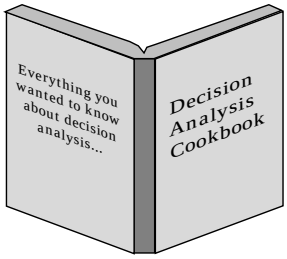

Lecture
Notes

What is decision analysis?

Decision analysis **IS**:
A methodology based on a set of probabilistic frameworks which facilitates high-quality, logical discussions, leading to clear and compelling action by the decision maker.

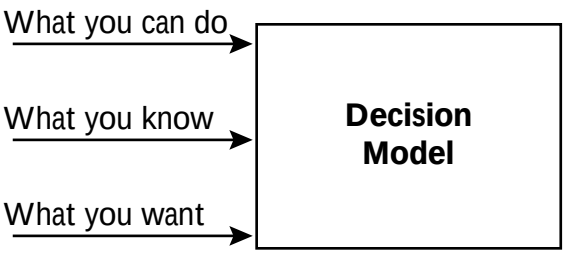
Decision analysis is **NOT**:
A method for justifying decisions already made.
Cost-benefit analysis.
A cookbook.



Beginning principles.

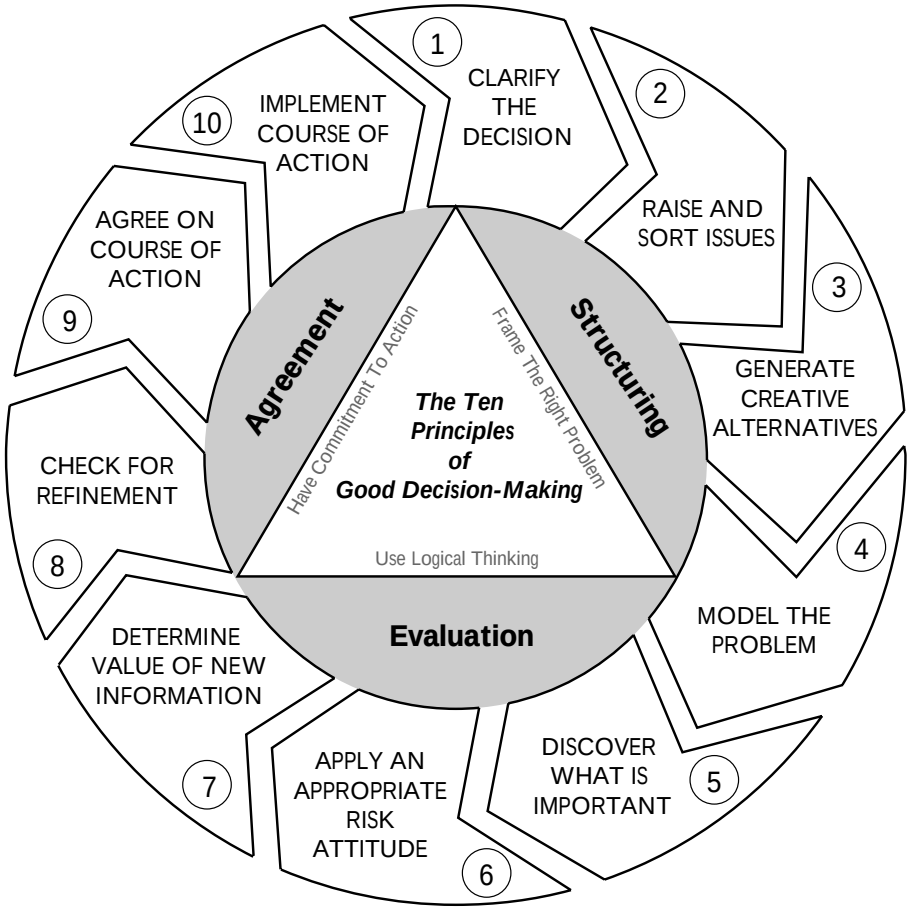
The best you can do is integrate in a logical manner:

- What you can do
- What you know
- What you want or value



The decision analysis process.

Decision analysis is a ten-step, quality process. ***However***, if at any step in the process the decision becomes obvious, you should stop and make the decision.



Decision analysis is a *normative* process.

The term ***decision analysis*** is becoming a broadly used term in many industries. While it can be used *descriptively*, in this course we will use the *normative* meaning.

Descriptive decision analysis is a present-state approach, describing how things **are**.

Normative decision analysis is a future-state approach, describing how things **should be**.

Describe a normative situation which applies to you?

_____

Creating distinctions:

Distinctions are a break in the world: **If something is this, it is not that.**

Example: A person is either *male* or *female*.

Distinctions are used to define the problem to be solved.

Distinctions about *distinctions*

- Must be **clear**
- Must be **observable**
- Must be **useful**

There are **kinds** and **degrees** of distinctions.

What is probability?

There are two distinct views of probability—***frequentist*** and ***Bayesian***.

Frequentists view probability as an empirical set of data defined by the total number of times something has happened. This viewpoint works as long as you have a sufficient data set.

The Bayesian view of probability is a state of knowledge based upon your experience, beliefs, knowledge, and data. This provides a means to assess situations where something has either never occurred or is a rare event.

The difference between objective and subjective probability:

Probabilities obtained from a large data set are usually considered to be objective.

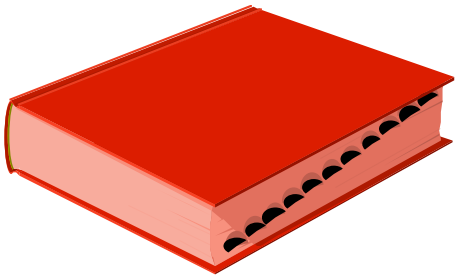
- Cancer risk factors
- Lightning strikes
- Tossing a coin

Probabilities obtained from experts, based on their knowledge, experience, beliefs, and data, are considered subjective. Most decisions require subjective probabilities.

- Probability of market acceptance of a new product
- Probability of the Yankees making it to the World Series

An example of subjective probability.

You are shown a dictionary containing 1,400+ pages of information. What is the probability the first word listed on page 1025 begins with the letter Q. (This experiment can only be run once.)



Write your probability here_____

States of knowledge:

Subjective probabilities rely upon expert knowledge which is always changing as new information becomes available. Therefore probabilities should also change as new information becomes available.

We use a simple nomenclature for describing the state of information for a given probability.

$$p(\mathbf{D} \mid \&)$$

This states the probability we assign to event **D** *given* our present state of information **&**.

Helpful hints:

- Q is the 17th letter of the alphabet
- Page 1025 is in the last third of the dictionary
- You have knowledge that some letters have less words than others, such as the letters Z, X, and Y

Does this change your probability?

If so, what is it now_____

Is your probability assessment correct?

Understanding states of knowledge:

Your state of knowledge prior to the helpful hints page was:

$$p(D_1 | \&)$$

Your new state of information may be the same if you incorporated all the helpful hints previously. But what if you learned the last word that started with the letter P was on page 1010. How would you incorporate this new information?

$$p(D_1 | \&')$$

&' indicates a new state of knowledge. If the knowledge was conditioned upon several pieces of information you can write them with the "," to denote "and".

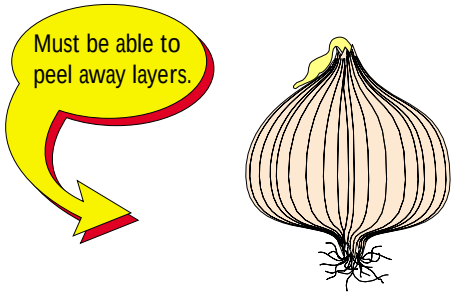
$$p(D_1 | X,\&)$$

Finding the right expert:

An expert is like an onion.

You can peel away layers of information, with each new layer revealing more depth and breadth of information about the subject.

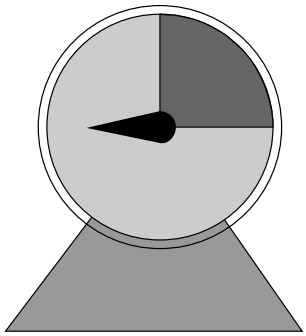
When there is no more information, a *true* expert tells you and does not continue commenting.



Assessing uncertainty:

Probability provides a language to communicate in an unambiguous manner, your beliefs about future events.

We need the ability to elicit subjective assessments from experts.



Probability Wheel

To begin structuring we must first define the problem and the decision criteria.

What is the decision?

Who is the decision maker?

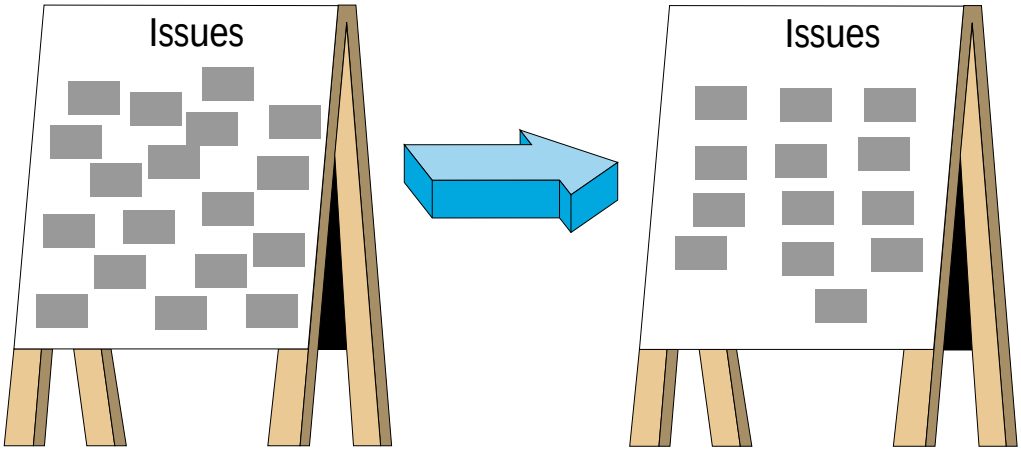
What is the decision criteria?

The decision criteria can be anything that allows the decision maker to quantitatively differentiate one alternative from another:

- Net present value (NPV)
- Internal rate of return (IRR)
- Cash flow

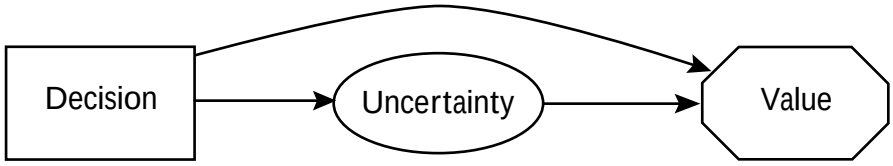
Once the problem has been defined we need to brainstorm and sort issues.

Raise issues by writing each one on a sticky note and then placing them on a wall or flip chart for easy sorting.

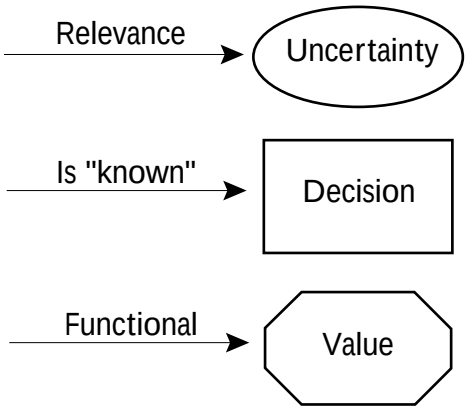


Influence diagrams typically flow from decisions to uncertainties to value.

Arrows indicate relevance and show relationship.

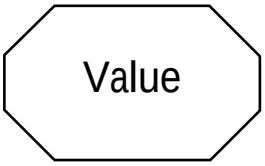


Be careful when adding arrows. **Influence diagrams are not flow charts.** The lack of an arrow says more than having an arrow.

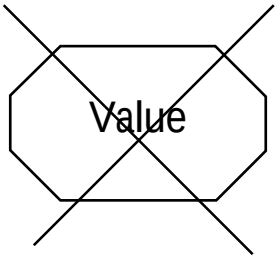


Influence diagrams are constructed from right to left beginning with what you value.

How will you judge the success of the decision–what is the decision criteria?



Nodes should be well defined.
The diagram should be at the right level for the problem.



Consider the following problem:

The Swanson Company has developed a new product—S234. While you think this product has great potential, you are unsure whether S234 will be profitable if brought to market.

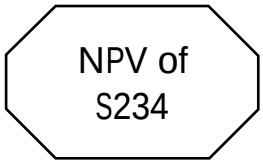
Issues about S234 include:

- Whether to:
  - launch S234
  - sell S234 to another company
  - license S234
- Market size
- Revenue
- Marketing costs
- Profit
- Stock price
- Manufacturing costs

Begin by clarifying the decision and the decision criteria and work from right to left.

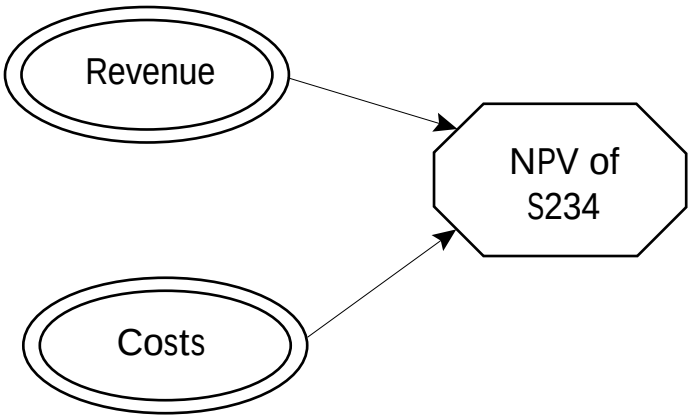
The decision is whether to launch, sell, or license the S234 product.

Management has determined net present value (NPV) is the correct decision criteria.



What are the determinants of net present value?

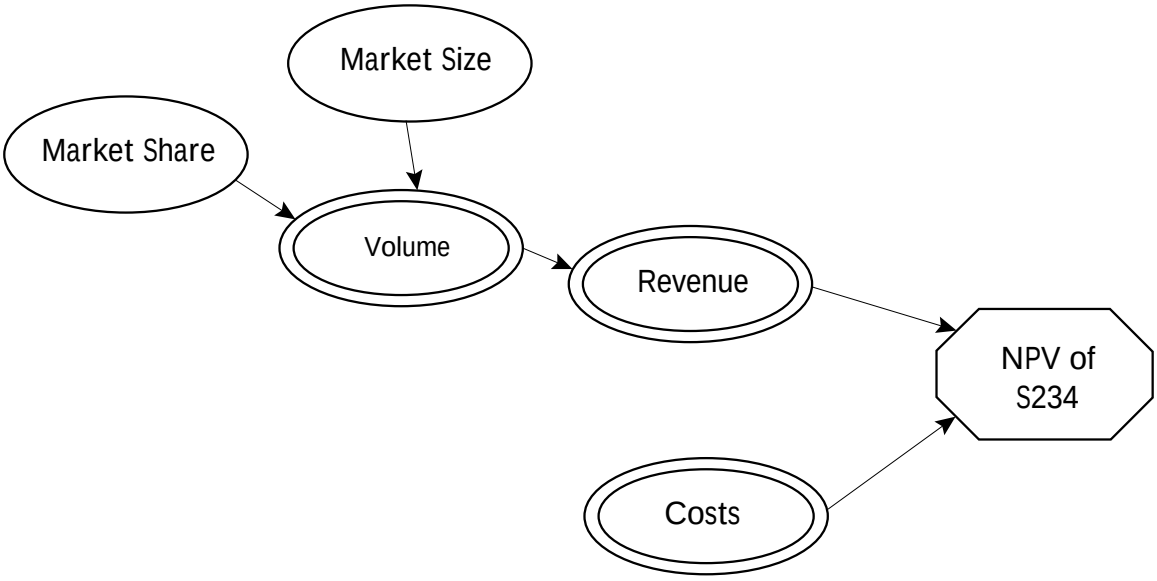
- Revenue
- Cost



What are the determinants of revenue?

What do you need to know to calculate revenue?

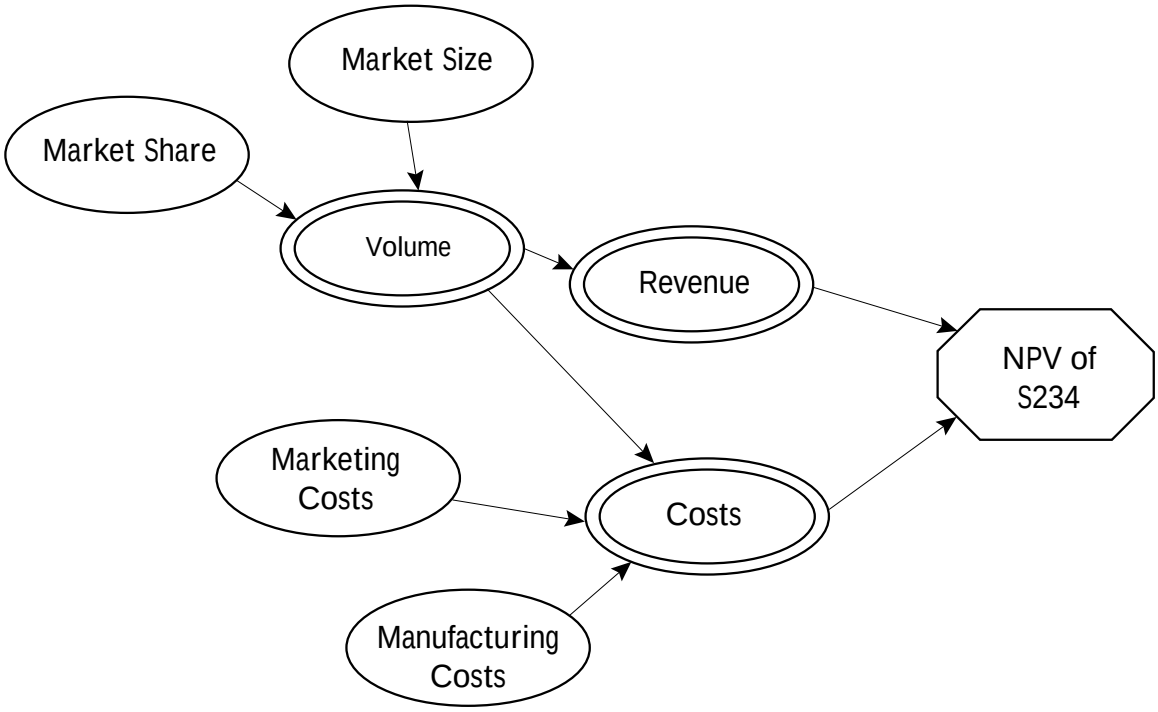
Consider the price of S234 to be set at $5.00 per pound.



Next, consider the determinants of cost.

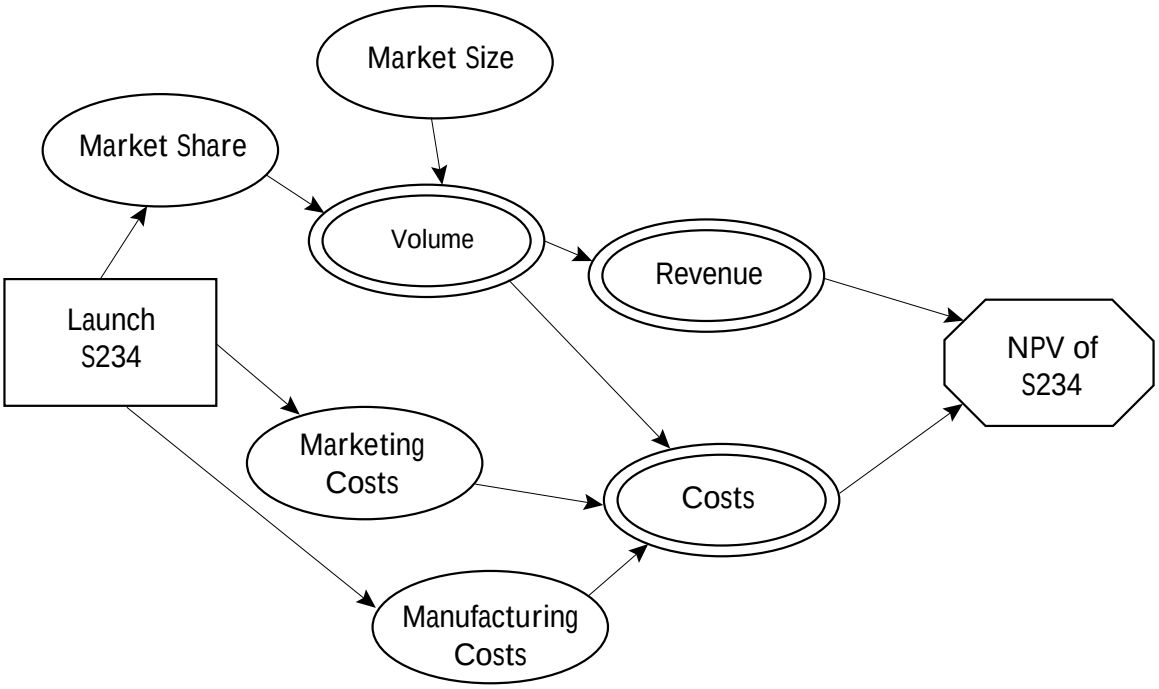
What do you need to know to estimate the costs associated with S234?

There is a manufacturing facility in place, and will only need minor modifications at a cost of $1,500,000.



Lastly, we need to add the decision.

What key uncertainties does the decision influence?



Checklist for structuring:

√ Have the objectives for this project been defined and agreed to?

√ Has the scope of this project been defined appropriately?

√ Who is the sponsor of the project?

√ What is the decision criteria?

√ Have appropriate resources been committed?

√ Are the right people on the project team?

Summary

Influence diagrams provide a graphical description of the problem.

Influence diagrams are a good communication tool.

The focus of a decision analysis should be at the strategic level.

Brainstorming issues and then separating the issues into decisions, uncertainties, objectives, and facts helps to frame the problem.

The product of any analysis should be new insights which clarify a course of action.

There are several tools which we will use to generate these new insights into the problem.

The process of evaluation has three parts:

Deterministic evaluation
- Sensitivity analysis
- Tornado diagrams

Probabilistic evaluation
- Cumulative distribution
- Sensitivity to probability

Value of information
- Value of perfect information
- Value of imperfect information

Deterministic evaluation:

Deterministic evaluation is probably most consistent with the way you currently perform analyses.

$$A \times B = C$$

Sensitivity analysis provides the ability to determine the most important factors which affect either the decision or the bottom line. We can then use the tornado diagram to graphically illustrate the sensitivity of each variable.

Variable ranges for S234.

	10	50	90
Market size (Mlbs.)	.2	1	2
Market share (%)	15	20	25
Mfg. Costs ($/lb.)	1	1.5	2
Mkt. Costs ($/lb.)	.5	.75	1

Building the value model:

The value model for S234—

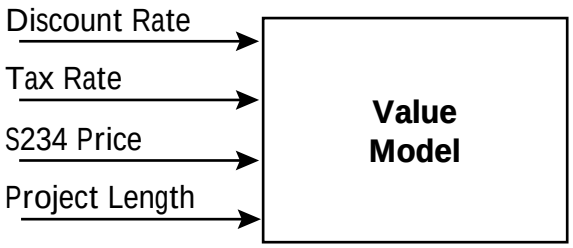
Fixed inputs:

Discount rate = 10%
Tax rate = 40%
S234 price/lb. = $5.00
Project length = 10 years

NPV of S234 = (Revenue – Cost) x Discount Factor for each year
(See discount factor table in Appendix)

Revenue = Price x Volume
Volume = Mkt. Size x Mkt. Share
Cost = (Mfg. Cost + Mkt. Cost) x Volume

Base case value =
Revenue = $5.00 x 1,000,000 lbs. x 20%
Costs = ($1.50 + $0.75) x 1,000,000
= $1,000,000 – $450,000
= $550,000 /yr x (1– .40) Tax rate
= $330,000 x 10 years x 10% discount rate
= $1,209,525

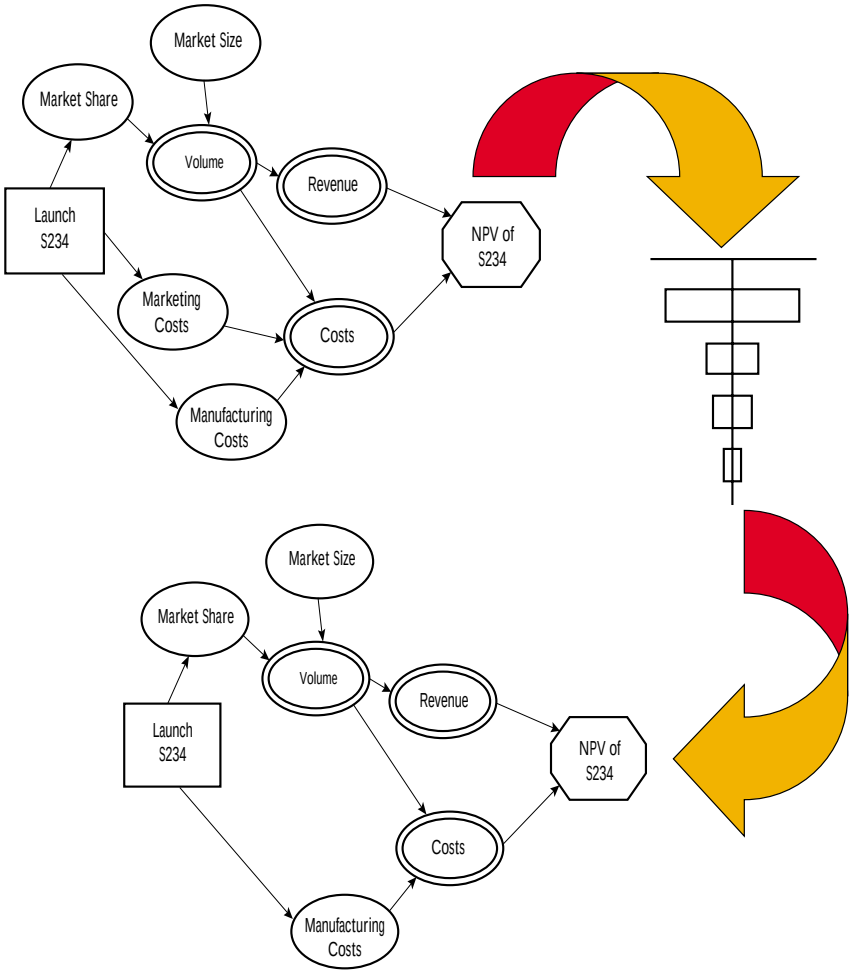


Simplifying the model:

Tornado diagrams provide insight into the key uncertainties affecting the decision.

The decision model can then be simplified using the insights gained from the sensitivity analysis. **This is very important for large models with many uncertainties.**

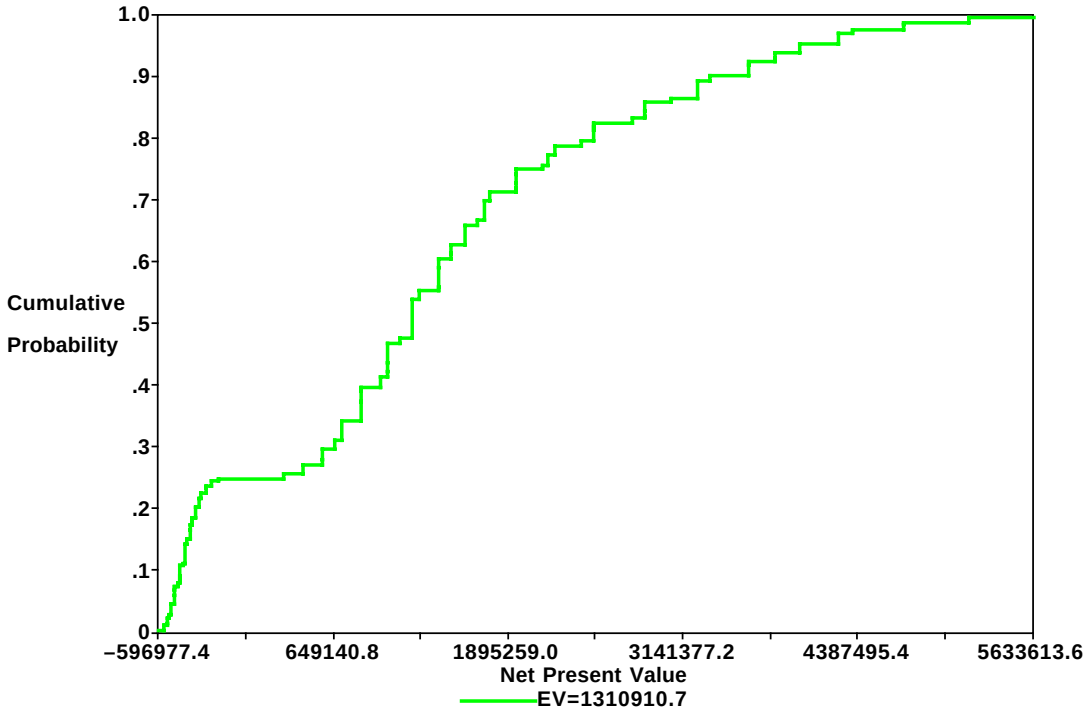
With project S234 the most important uncertainty is market size, and the least important is marketing costs.



Incorporating probability:

Deterministic sensitivity is important for identifying key variables but does not provide insight into the likelihood of any scenario.

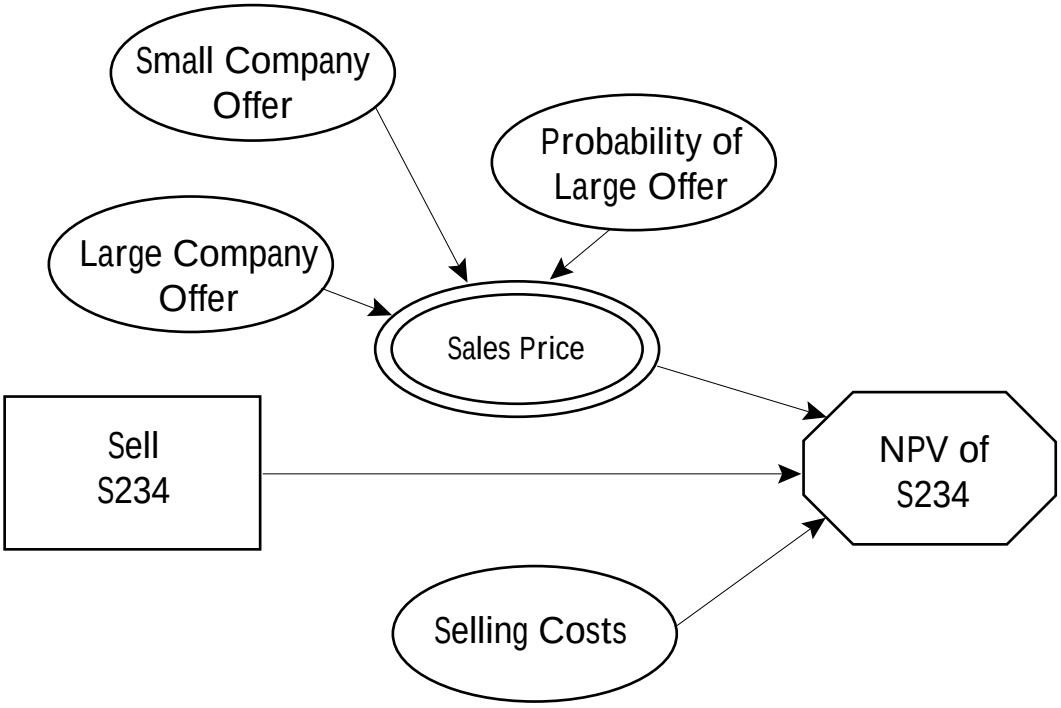
The cumulative distribution provides a graphical risk profile for the project or each alternative.



Another alternative? Selling S234:

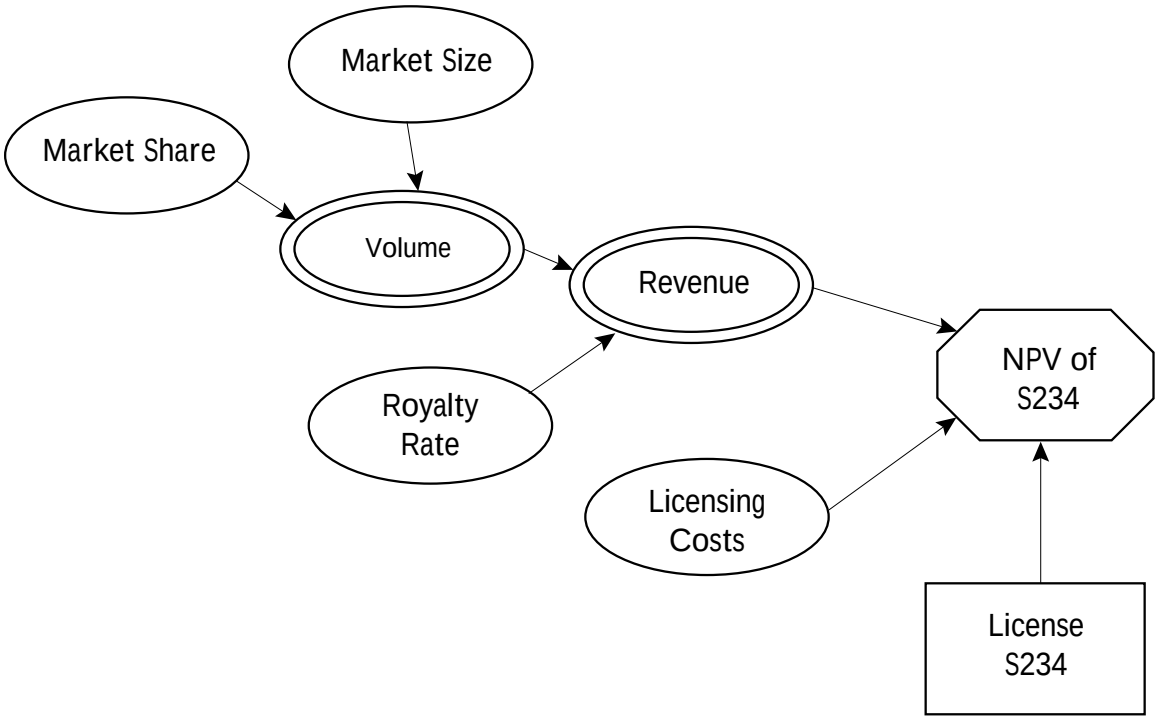
In addition to launching S234 the company also wanted to evaluate the alternatives of selling and/or licensing the product.

The influence diagram for selling S234 to another company:



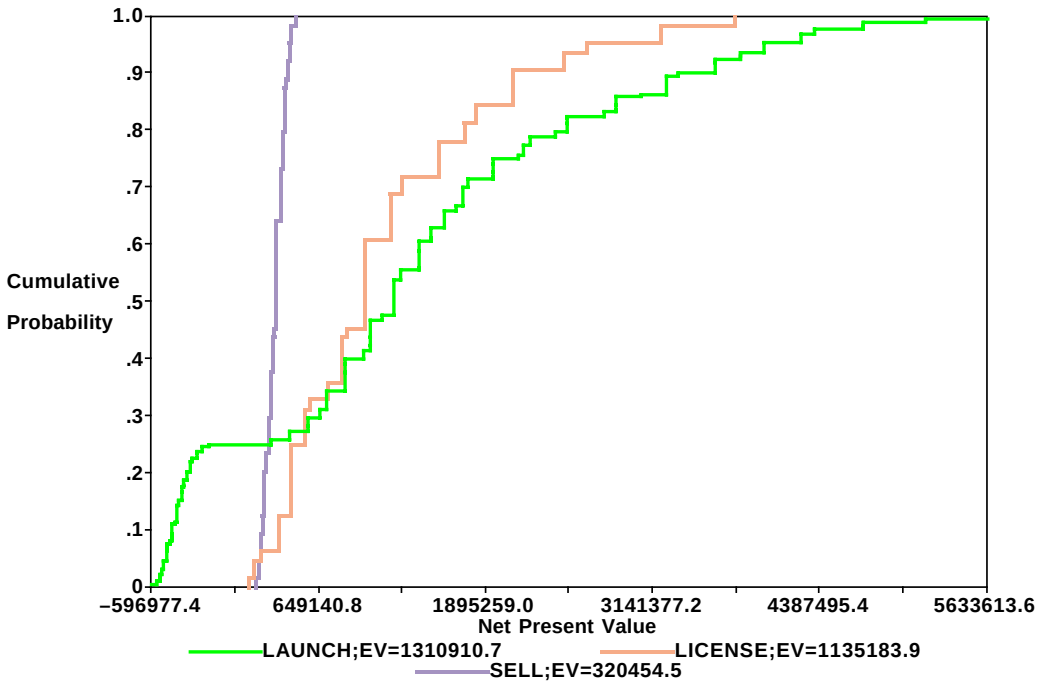
Licensing S234:

The company could license S234 and receive royalties from the sales.



Comparing alternatives:

We can compare each alternative on a consistent basis, thereby fully examining the risk and opportunity of each alternative.



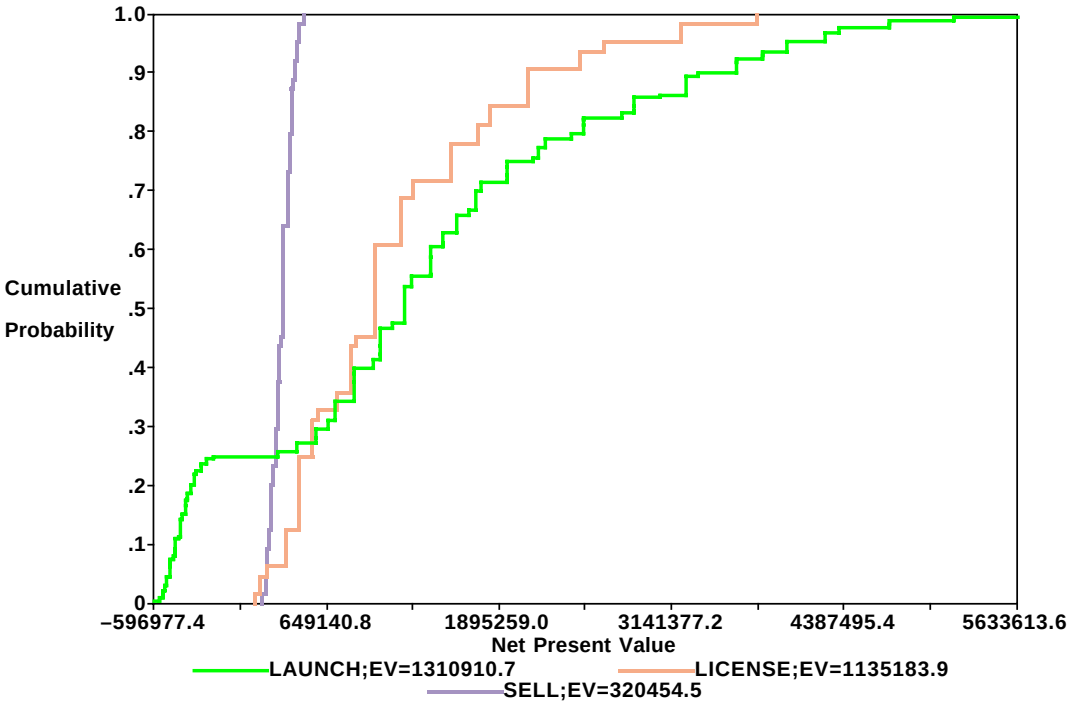
Which alternative would you choose?

Choosing wisely:

Dominance—

- Dominance can be *deterministic* or *stochastic*
- Allows inferior alternatives to be eliminated
- Is always better than the other alternatives

None of the three alternatives show complete dominance over the other two. The sell option, however, is less attractive based on an EMV of $320,455.

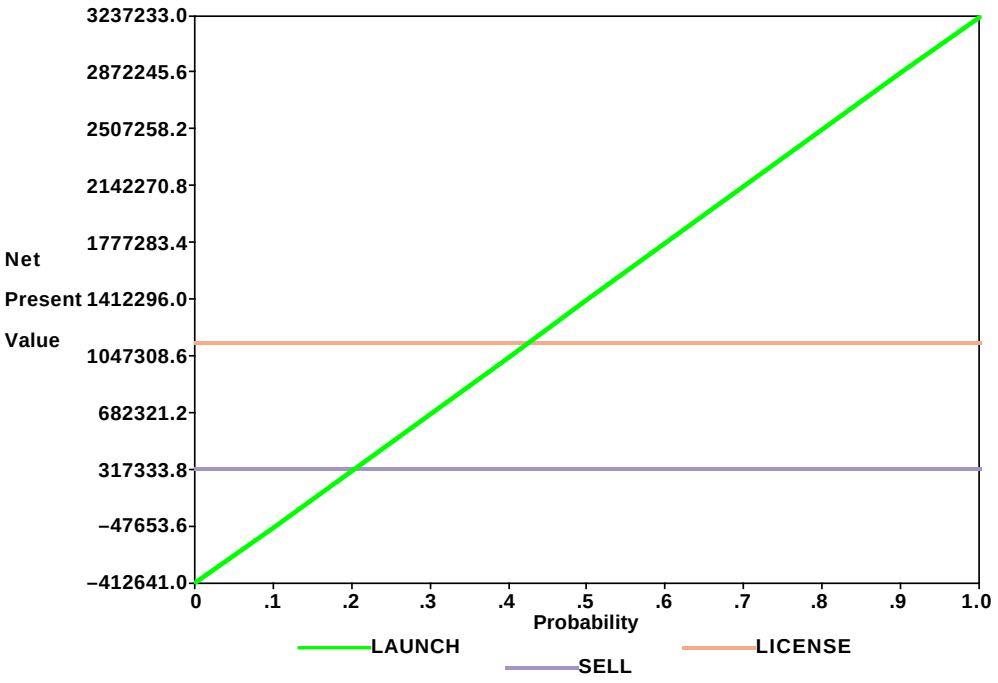


Sensitivity to probability:

Sensitivity to probability is similar to deterministic sensitivity analysis in that the object is to identify variables which would change the decision.

Having said that any subjective probability incorporating the expert's available knowledge, beliefs, experiences and data is correct, we need to know how sensitive the decision is to any particular probability. This will help us choose between launching or licensing S234.

We should launch if we are confident that *launching* has a greater than 40% chance of success.



Value of information

We can determine the value of gathering additional information before spending time or money to gather it.

The value of perfect information is the easiest to calculate and provides an upper boundary as to the most we ***should*** ever spend on new information. This is also know as ***the value of clairvoyance***.

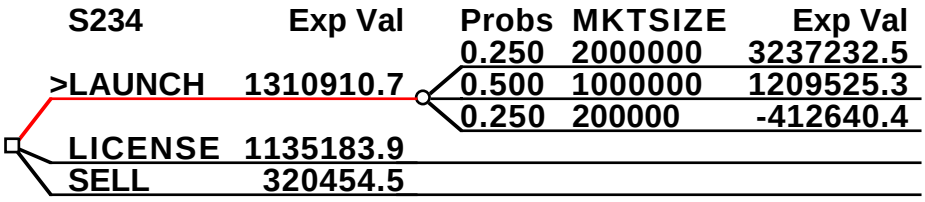
Most companies spend more on information than it is worth.

The value of imperfect information is the most that we should spend for new information which is not perfect.

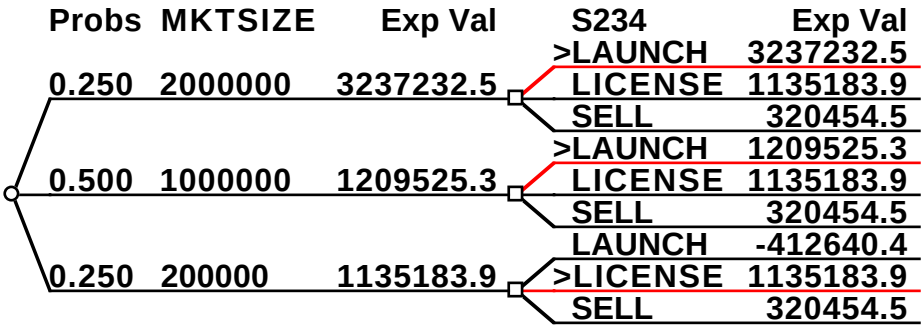
Calculating value of *perfect* information:

The value of perfect information is calculated by placing the uncertainty you want to evaluate, before the decision. Then, recalculate the expected value.

Original tree: EMV $1,310,910



VOPI tree: EMV $1,697,866

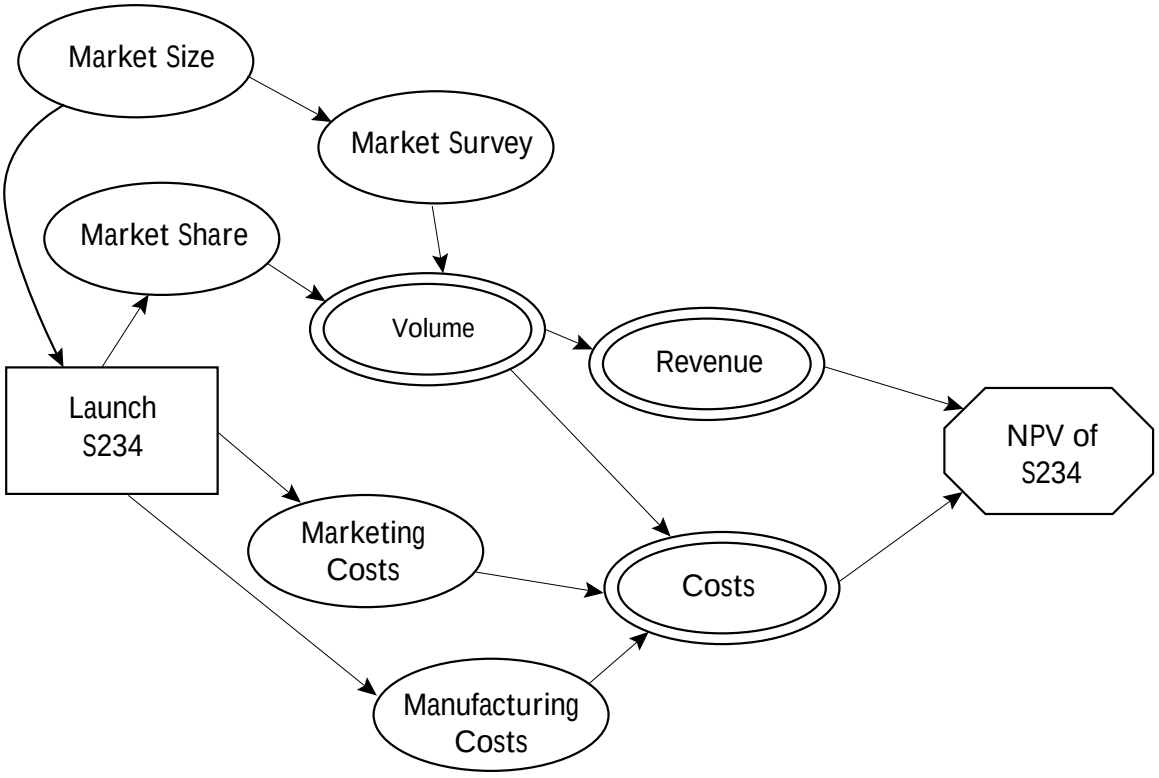


= Value with perfect information
– Value without perfect information
= $1,697,866 – $1,310,910
= $386,956 = Value of perfect information

Value of *imperfect* information:

We know the value of perfect information is $386,956. What if we could conduct a market survey for $300,000? Would it be worth the investment?

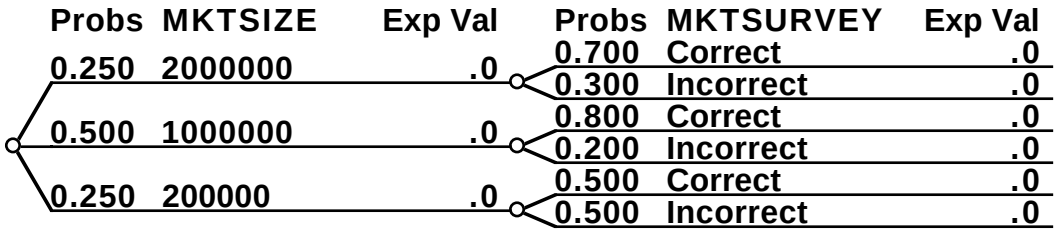
First, we must create a new influence diagram. Notice the Survey is influenced by Market Size rather than vice versa. This is to preserve the state of nature.



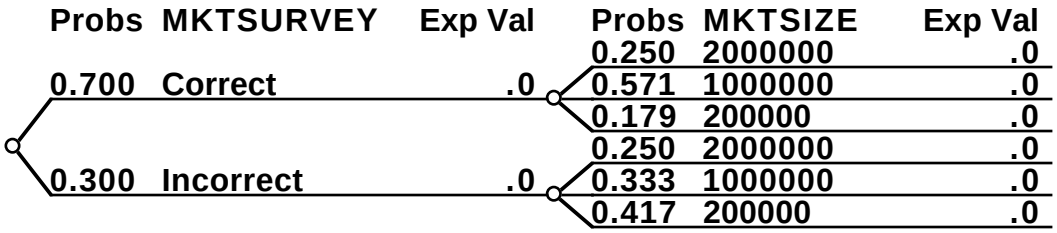
Reversing the tree:

In order to calculate the value of imperfect information we must reverse the tree.

Prior tree



Posterior tree

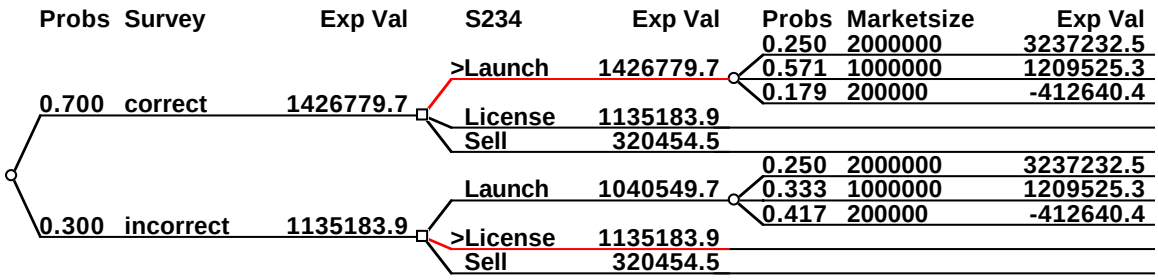


The posterior tree indicates that the MKTSIZE assessment is correct 70% of the time.

The new tree reveals:

= Value ***with imperfect*** information
– Value ***without***
= $1,426,779 – $1,310,910
= $115,869 = Value of imperfect information

We would not pay more than $115,869 for the market survey.



Summary

Decision analysis provides tremendous insight into the value of all the different alternatives and can help to create new alternatives.

Sensitivity analysis is important in identifying the factors which affect the decision.

Sensitivity to probability can help identify the variance that would cause you to change your decision.

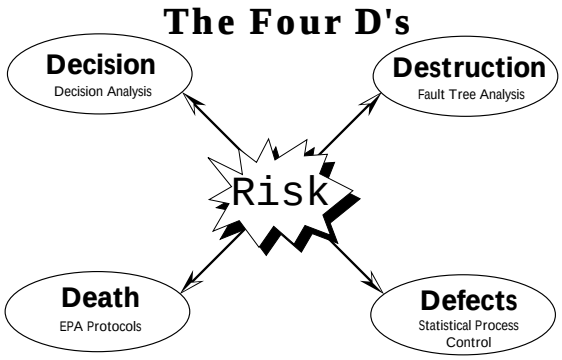
The value of gathering new information can be calculated ***before*** gathering the information.

Remember to consider the feasibility and reliability of gathering new information. Just because you can calculate the value ***does not mean*** you can either find the information or obtain it.

What is risk?

Risk means different things to different people.

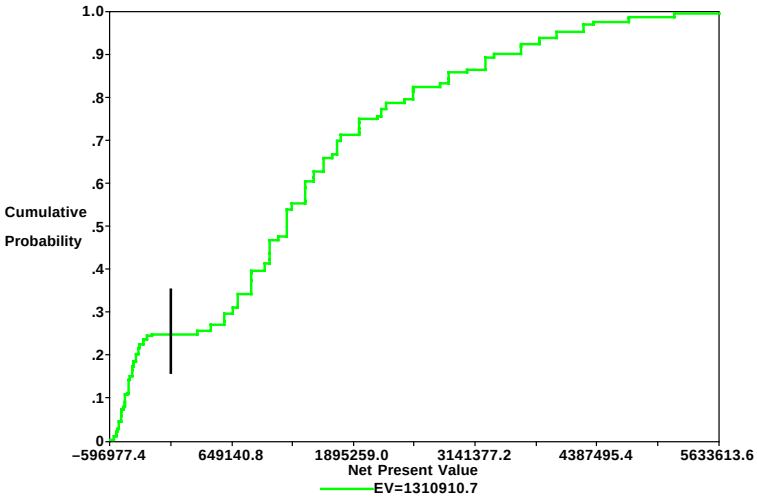
We will use the word risk to mean ***uncertainty in future financial outcomes***.



Risk is typically measured by a probability distribution:

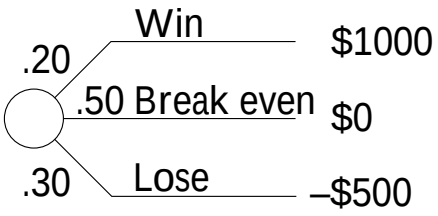
Risk = Probability X Outcome

This graph shows a 25% probability of losing money.



Risk attitude is how individuals or organizations view decisions involving risk.

What is this deal worth to you?
How much would you pay for the opportunity?

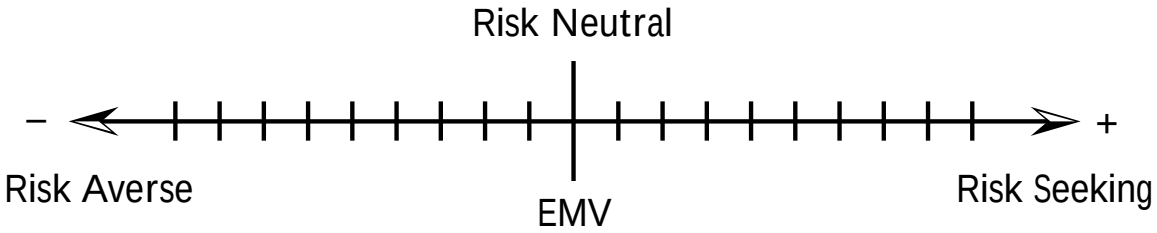


The Risk-Taking Scale:

An individual's willingness to take risk is often based on a personal risk attitude rather than on the corporate risk attitude.

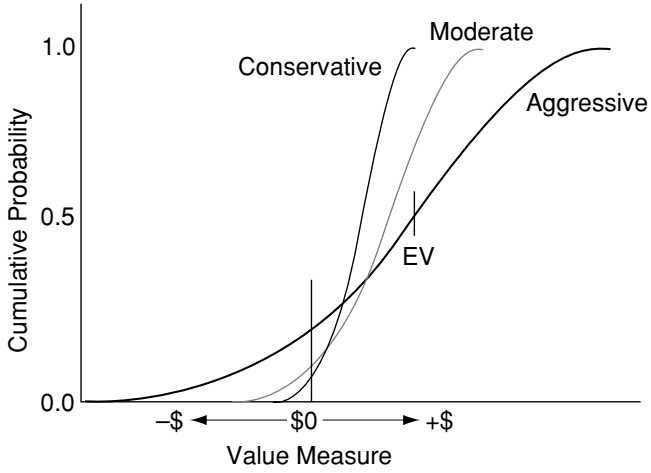
Where do you fall on this scale for most decisions? (Look at your response to the DRIVE exercise)

What should your risk attitude be for corporate decisions?



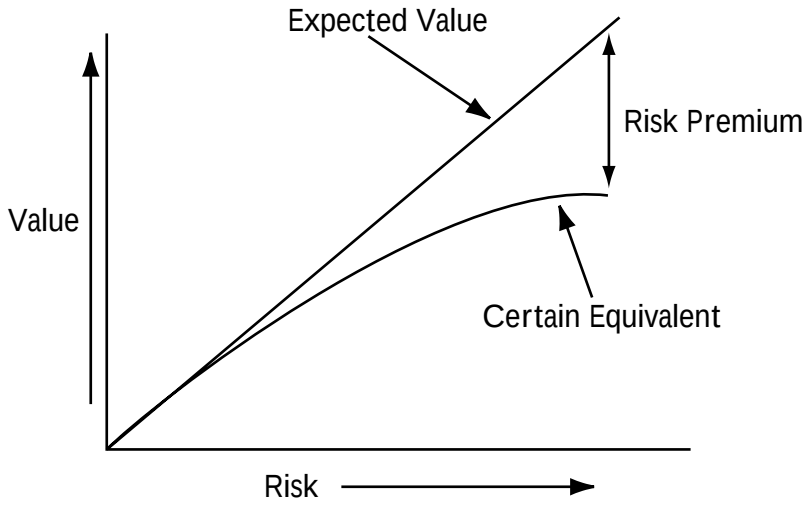
Risk and return trade-offs:

Usually higher return means higher risk.



Risk premium and the certain equivalent:

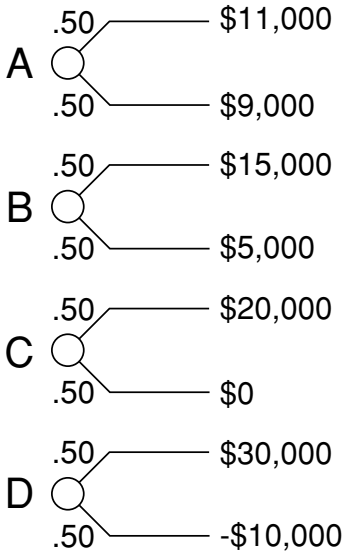
The risk premium is the difference between the certain equivalent the expected monetary value.



Linear approximation of the certain equivalent:

You have the opportunity to invest $5,000 in one of four deals.
Each deal has an expected value of $15,000.
Your total net worth or risk tolerance is $20,000.
Which deal should you choose?

CE = EMV – (R.P. x EMV)
R.P. = Risk Premium = Risk/Risk Tolerance



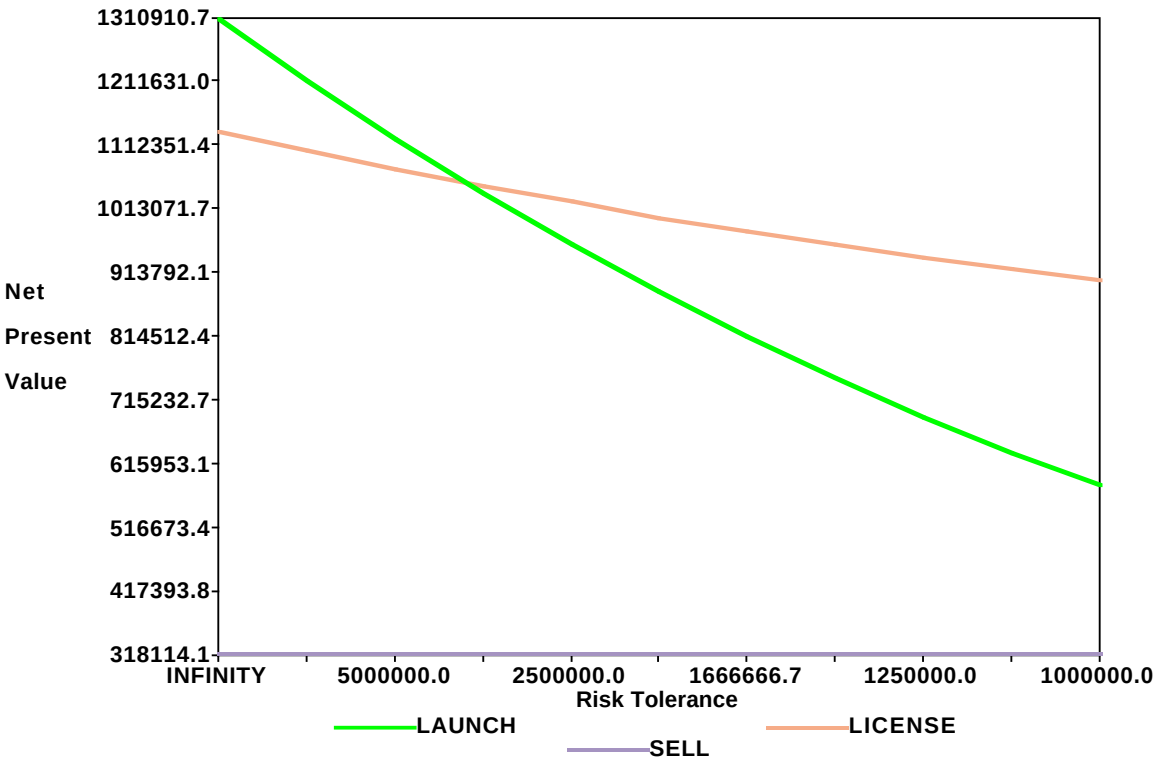
	A	B	C	D
Expected Value	5,000	5,000	5,000	5,000
Risk	0	0	5,000	
Risk Tolerance	20,000	20,000	20,000	
Risk Premium R.P.	0	0		
Certain Equivalent	5,000	5,000		

Utility method of calculating the certain equivalent for S234:

Using utility allows for curvature and scaling of risk.

U(X) = 1– exp(–X/R)
where R = Risk Tolerance

R is assessed by:
Maximum you would pay for a 50/50 chance at Winning R or Losing 1/2 x R



Summary

We should account for risk separate from the time value of money.

Using the certain equivalent we can account for both the risk associated with the potential for loss and the time value of money.

Risk means different things to different people, make sure you understand how the word ***risk*** is being used.

The value of any deal depends on the decision maker's risk attitude.

Most people are risk averse, but we should in most cases be risk neutral when making corporate decisions.

What is agreement?

Agreement is the last framework in the decision analysis process.

Check for refinement

Is the proposed alternative complete and doable, or is additional refinement needed?

Agree on course of action

Does management and the project team agree on the same alternative? Is there commitment to a course of action?

Implement the course of action

Have the right people for implementation been identified and involved in the process?

Preparing the organization:

Effectively applying decision analysis means changing the organizational culture.

- Good decisions ≠ good outcomes
- Uncertainty should be expressed using probability
- Expertise is knowing what you don't know
- Information has a price, and that price can be determined before gathering the information
- Good strategic decisions require the expertise and collaboration of the right people at the right time

Checklist for agreement:

√ Does management understand and accept the analysis findings?

√ Has the decision changed?

√ Has the right level of analysis been performed?

√ Have all the decision maker's uncertainties and preferences been identified and incorporated?

√ Are there any issues unresolved or unaccounted for that affect the decision?

√ Is the recommendation appropriate and doable?

Summary

The decision analysis process is a quality process for making decisions.

Always look for refinement that would change the decision.

Management must be committed to the process and the results.

Include the implementation personnel in the process.

Don't try to solve your ***hardest*** problem first. Begin with a simple problem and gain an understanding of the process through experience.