4. Gaining Insight

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

There are several tools to generate these new insights into the problem. The process of evaluation has three parts: (See Clement, Package.)

1. *Deterministic evaluation*
   - ➢ Sensitivity analysis
   - ➢ Tornado diagrams

2. *Probabilistic evaluation*
   - ➢ Cumulative probability distribution
   - ➢ Sensitivity to probability

3. *Value of Information*
   - ➢ Value of Perfect Information (VPI)
   - ➢ Value of imperfect information

4.1 Deterministic Evaluation

Deterministic evaluation may be closest to the way most analyses are performed outside decision analysis.

Sensitivity analysis provides the ability to determine the most important factors which affect either the decision or the value ("the bottom line"). We can then use the *Tornado diagram* to illustrate the relative sensitivities of each variable.

Variables for Glix:

	Probabilities		
	10	50	90
Market size (Gigagrams)	0.2	1	2
Market share (%)	15	20	25
Mfg. Costs ($/kg)	1	1.5	2
Mktg. Costs ($/kg)	0.5	0.75	1

↑

baseline

4.1.1 Conducting sensitivity analysis on uncertainties:

Step 1: Build a deterministic value model which uses the uncertainties identified in the frame and calculates according to the decision criterion.

Step 2: Choose a low (10th percentile), base (50), and high (90) value for each uncertain event.

Step 3: Run the model with all uncertainties set at their base values, and record the calculated value.

Step 4: Run the model swinging each variable from its 10th percentile to its 90th, while holding all other variables at their base values. Record the calculated value at each setting.

Step 5: Plot a Tornado diagram using the data.

Building the value model

The value model for Glix:

Fixed inputs:

Discount rate = 10%
Tax rate = 40%
Glix price/kg = \$5.00
Project length = 10 years

NPV of Glix = (Revenue − Cost) × Discount Factor for each year

Revenue = Price × Volume

Volume = Market Size × Market Share

Cost = (Manufacturing Cost + Market Cost) × Volume

Base case value for Glix:

Revenue = $\$5.00 \times 1{,}000{,}000$ kg $\times$ 20%

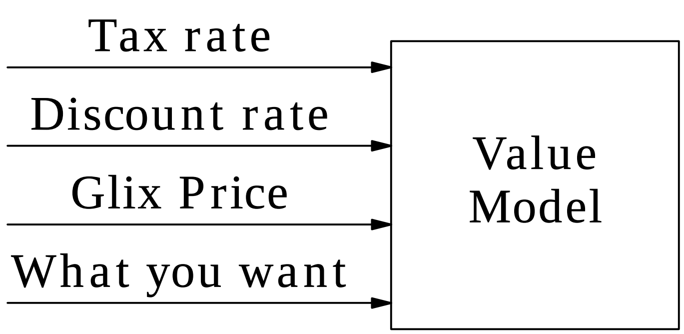
Costs $\rightarrow$ $(\$1.50 + \$0.75) \times 1{,}000{,}000$

$\rightarrow$ $\$1{,}000{,}000 - \$450{,}000$

$\rightarrow$ \$550,000/year $\times$ $(1-0.40)$ after tax

$\rightarrow$ $\$330{,}000 \times 10$ years $\times$ 10%

$\therefore$ Profit = \$1,209,525



4.1.2 Plot the Tornado using graph paper or software.

Step 1: Calculate the swing of each variable.

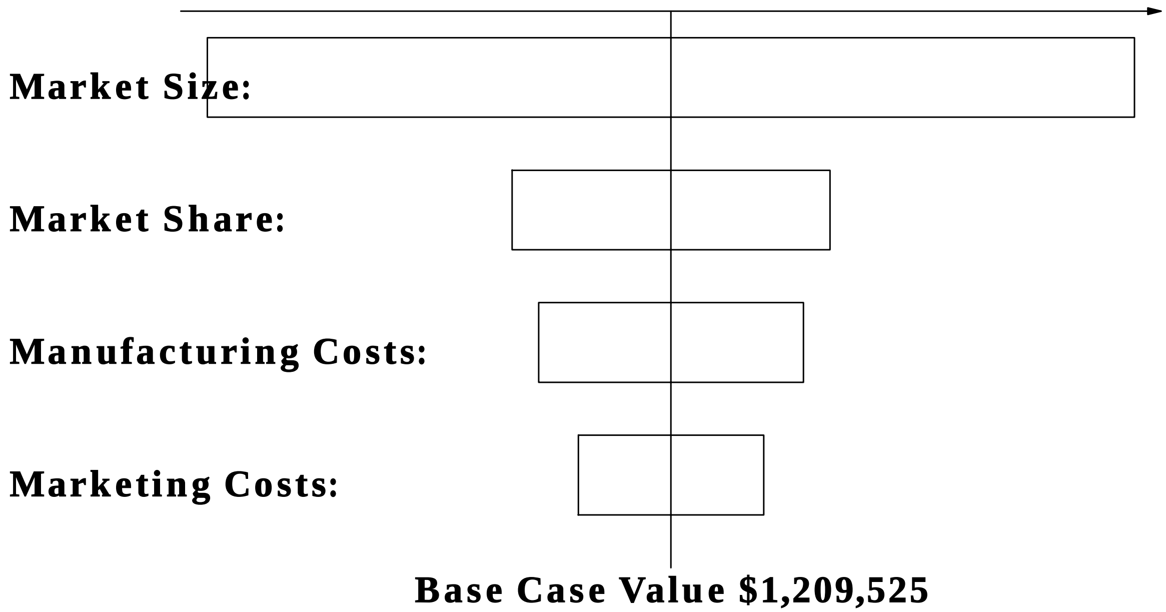
Step 2: Rank in order the swings in value from largest to smallest.

Step 3: Draw a horizontal line and determine an appropriate value scale.

Step 4: Draw a vertical line which cuts the horizontal line at the base case value.

Step 5: Draw horizontal bars for each uncertainty relative to their swings in value.

The Tornado Diagram.



Simplifying the model:

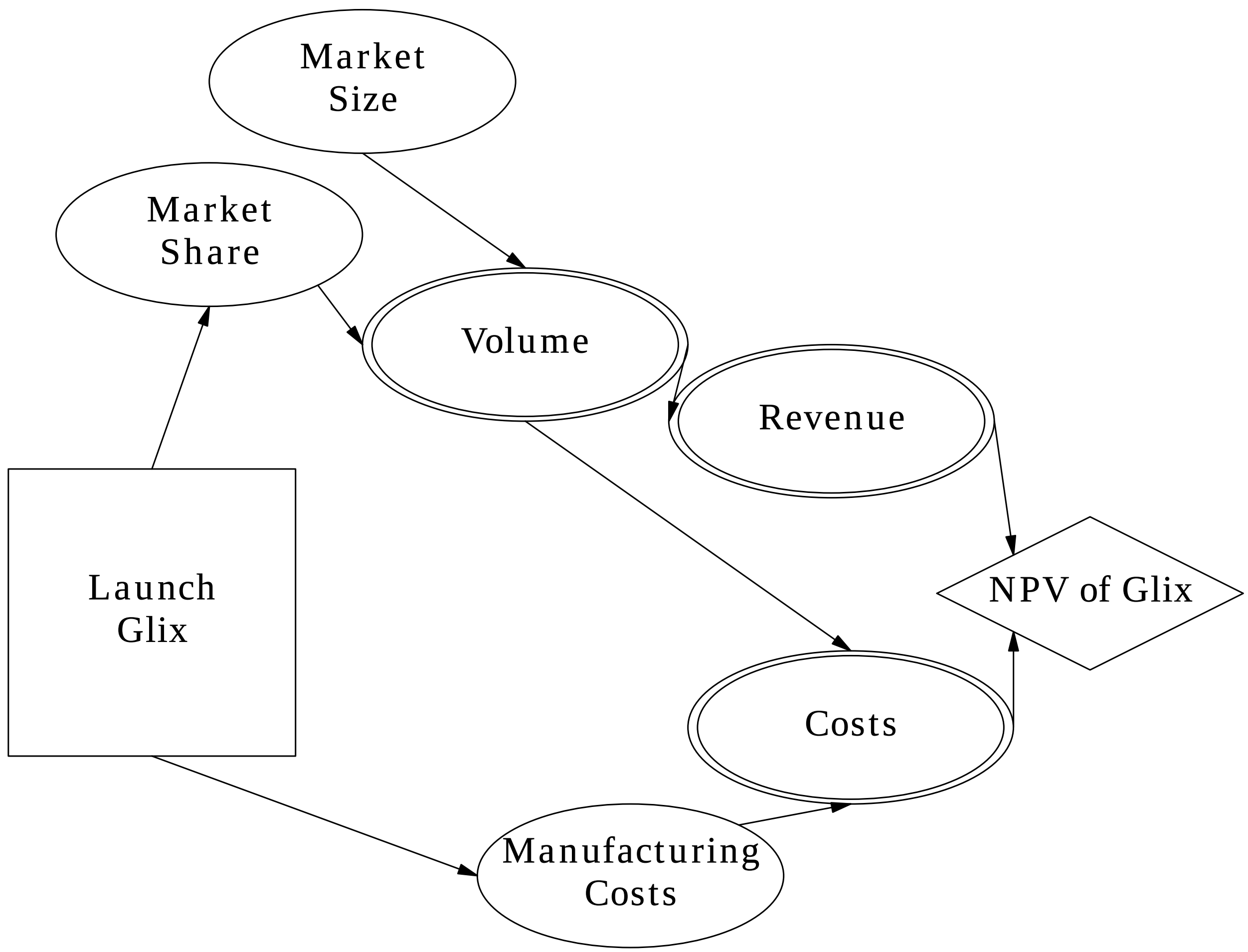
Tornado diagrams provide insight into the key uncertainties affecting the decision.

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 Glix, the most important uncertainty is Market Size, and the least important is Marketing Costs, from above.

Important: always strive to simplify your Influence Diagrams: use Tornado diagrams and your intuition to reduce the degree of complexity of the ID — they are much more useful when simple!

Influence Diagram



4.2 Probabilistic Evaluation

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

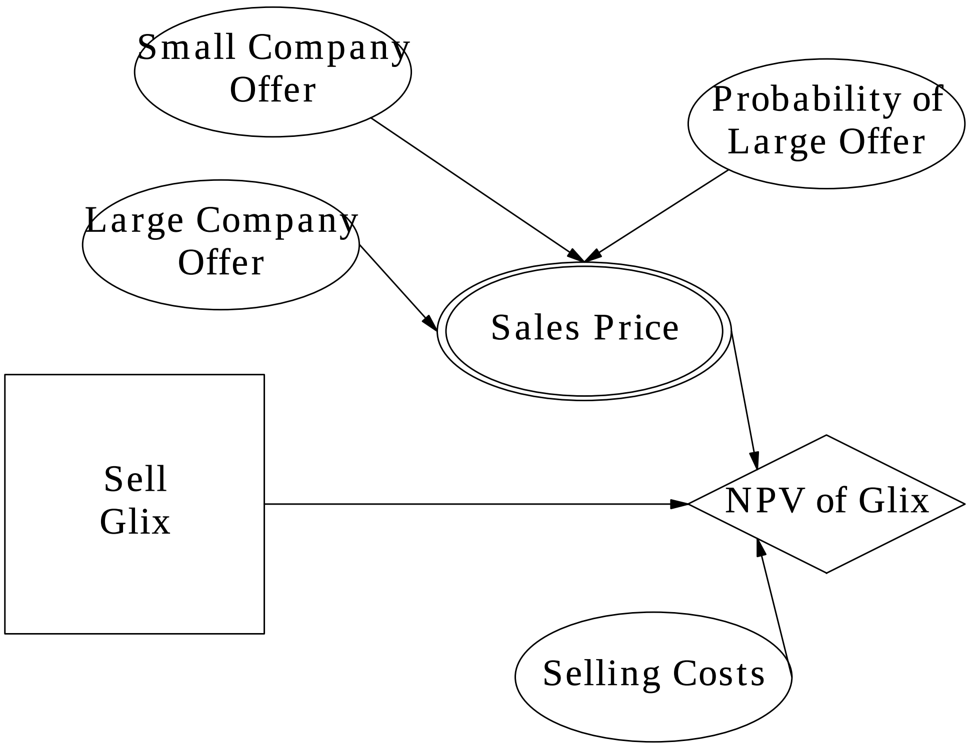
The cumulative probability distribution provides a graphical risk profile for the project or each alternative.

(This is more technical: see David C. Skinner, *Introduction to Decision Analysis* (Gainesville, Fl., 2nd. ed., 1999), pp. 112−113, 218−220.)

Another alternative? Selling the Glix project.

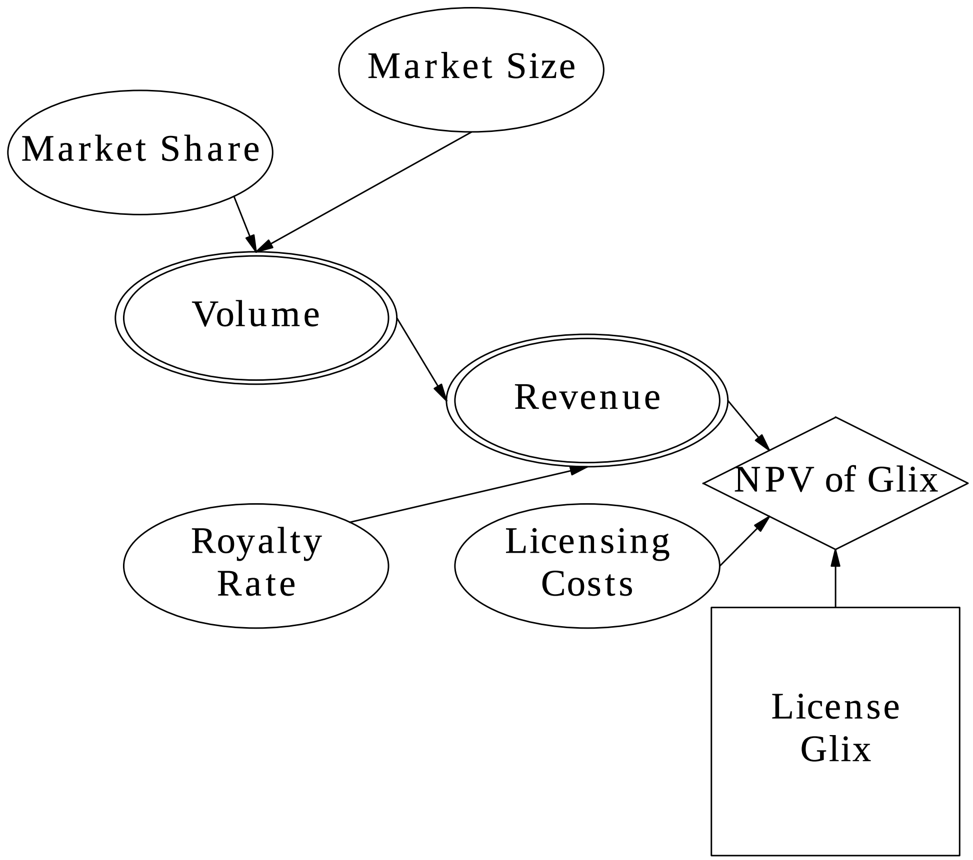
In addition to launching Glix, the company also wanted to evaluate the alternatives of selling and/or licensing the product.

The influence diagram for selling Glix to another company:



Or Licensing Glix:

The company could license Glix 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.

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 shows complete dominance over the other two.

The “sell” alternative, however, is less attractive, based on an EMV of $320,455.

4.2.1 Sensitivity to probability:

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

Having said that any subjective probability which incorporates 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 Glix.

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

4.3 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.

Most companies over-invest in information, spending more than it is worth to them.

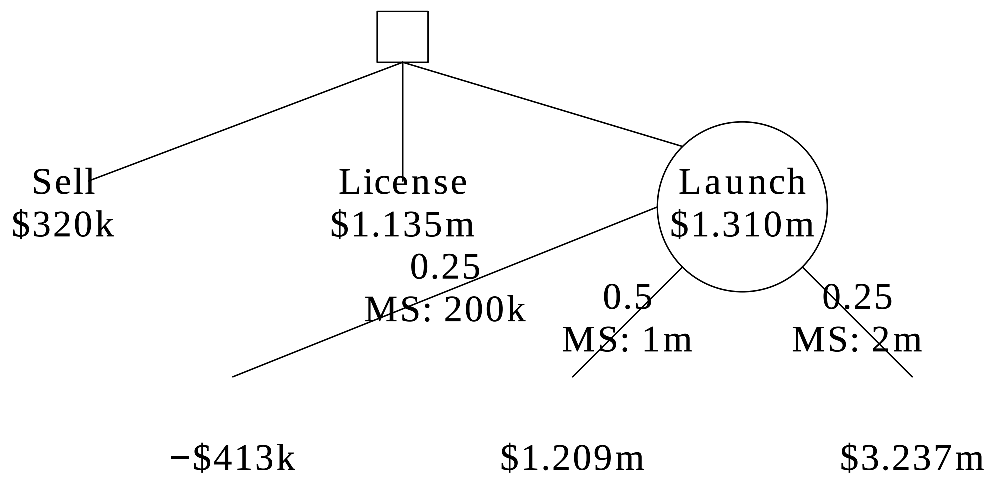
The Value of Perfect Information (VPI) is the most that we should spend for new information which is not 100% reliable.

We would only value Perfect Information if it changed our decisions, otherwise not.

4.3.1 Calculating the VPI of the Glix case

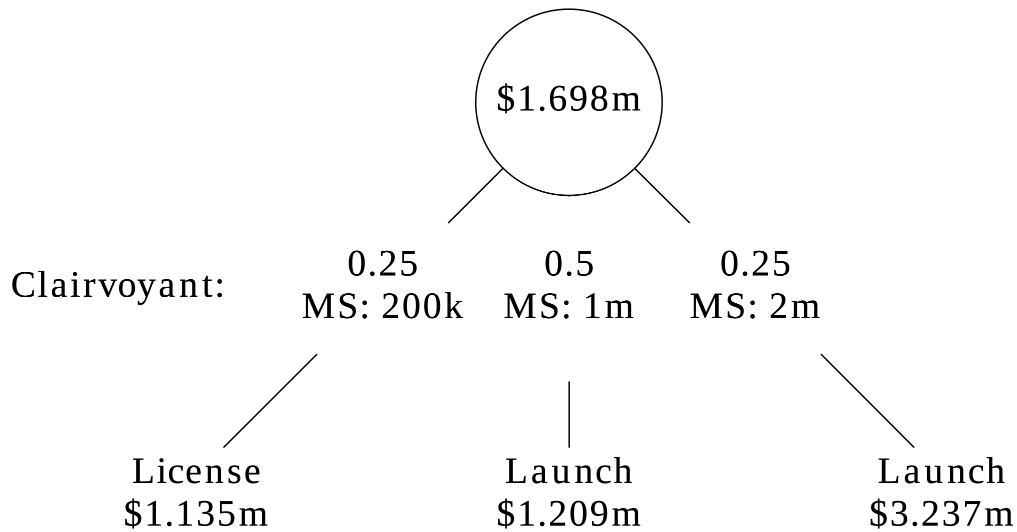
VPI is calculated by placing the uncertainty you want to evaluate before the decision. Then, recalculate the expected value.
Focus on Market Size (MS) uncertainty.

Original tree: EMV = $1,310,910



Plot the Tree with Perfect Information

Tree with perfect information: EMV = \$1,697,866



∴ VPI = \$1,697,866 − \$1,310,910 = \$386,956

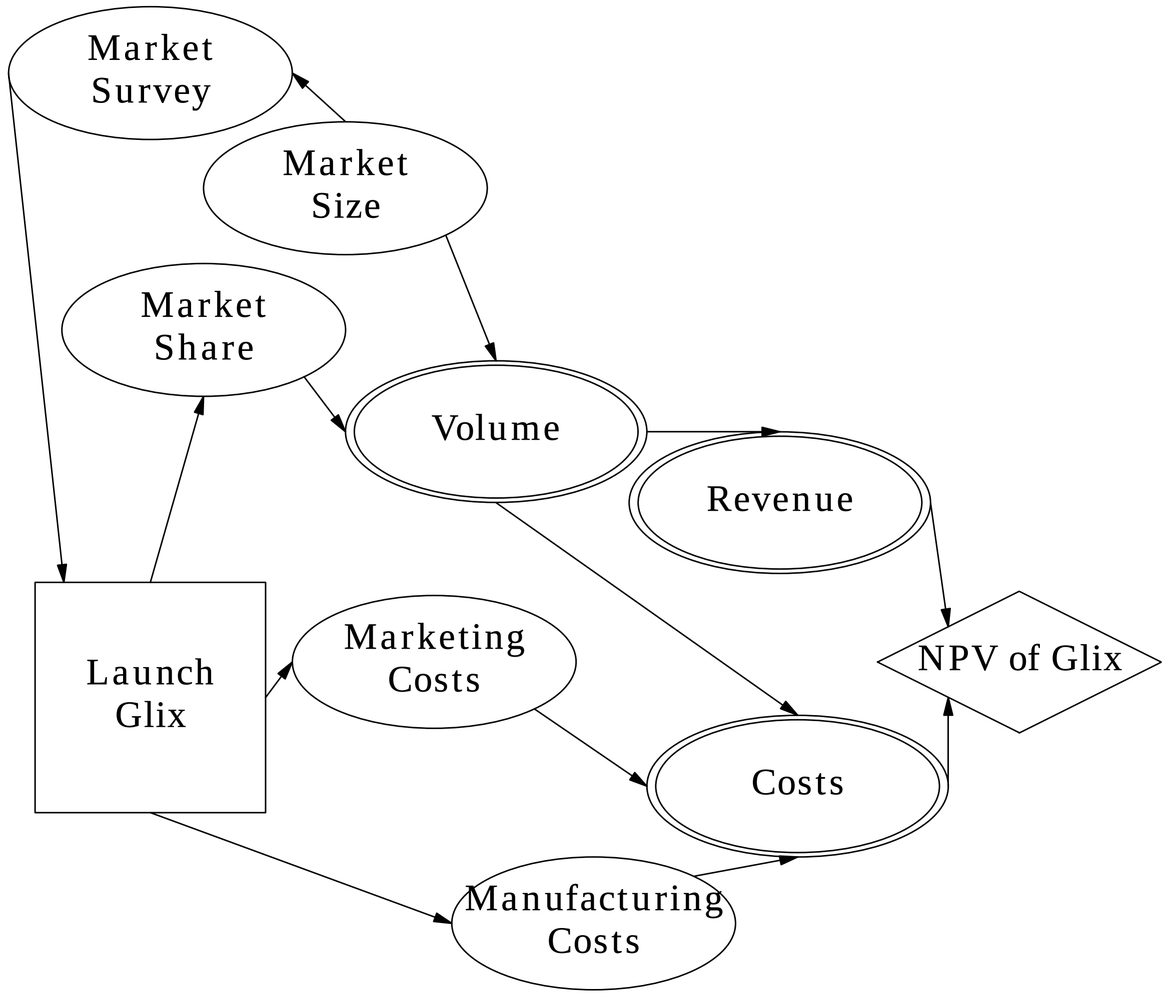
4.3.2 Value of Imperfect Information of Glix:

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 that the Survey is influenced by Market Size rather than vice versa. This is to preserve the state of nature.

Survey Influence Diagram.



4.4 Laura’s Case — The VPI

Laura could reduce uncertainty through *information gathering*:

- Laura could employ a market-research firm to test for the acceptance and demand for Retro.
- If totally reliable (no errors), then
  - — if “Retro is definitely a goer”, then a return of $240,000, less costs
  - — if the Trial indicates Retro is a fizzer, then choose a net return of $200,000 with Trad, less costs

Laura has two decisions to make:

1. Whether or not to Trial, which is related to the cost of the Trial.

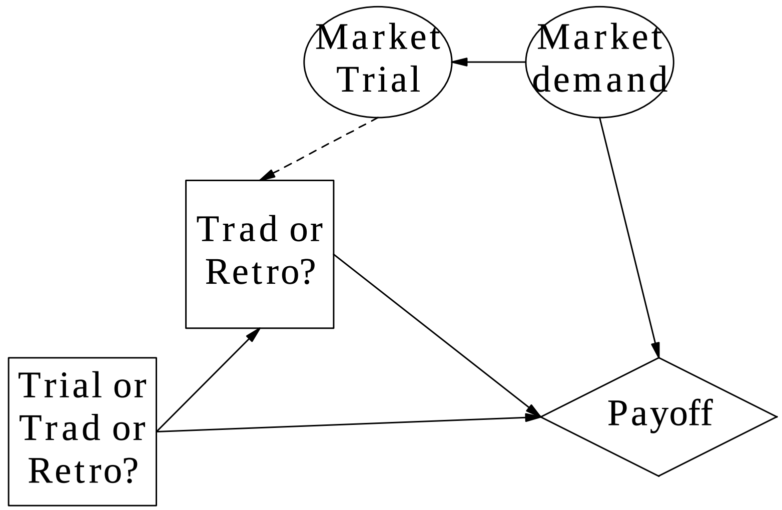
   For a given cost, should she Trial?

   If not, then the decision is as before: Trad or Retro?
2. If she buys the Trial, what's the most she should pay for it?

   To answer this, we need to examine her best choice with the Trial: Trad or Retro?

The *value of information* is the difference between Laura's expected returns with the Trial and without the Trial.

If the Trial is 100% reliable, then this is the *Value of Perfect Information* (VPI):



The dotted arrow from the Market Trial chance node to Laura's second decision represents the information (perfect or not) that she receives from the Trial.

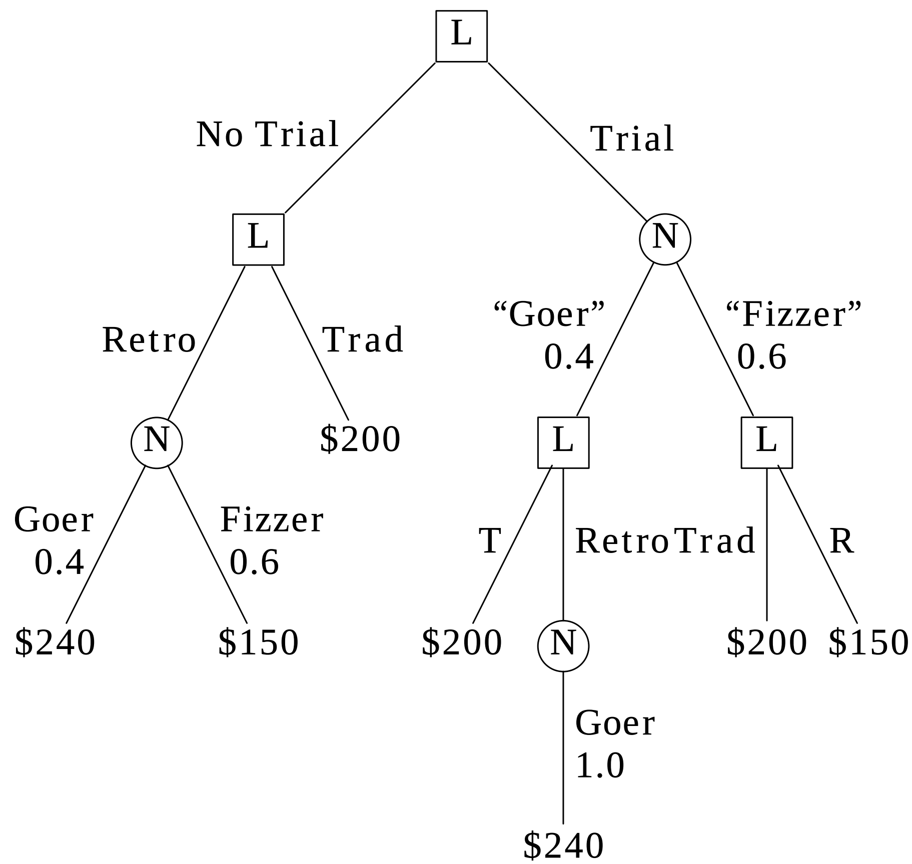
That information in turn is influenced (perfectly or not) by the actual Market Demand.

What Laura would like to know is what a specific piece of information implies for the eventual market demand for Retro, that is,

Probability (Retro is a Goer, given that Trial says so)

With perfect information, this probability is 1.

The new decision tree, including the test marketing decision:



The Shoe Decision with Perfect Information

(Remember: the Trial is 100% accurate.)

The new decision tree has four decision nodes:

1. whether or not to test,
2. which range to choose if the test shows that Retro is a goer,
3. which range to choose if the test says Retro is a fizzer, and
4. which range to choose without testing.

How many chance nodes?

➣ Possibly three: the outcome of the test, and the outcomes if she chooses Retro.

➣ But if the test is 100% reliable, it would rule out any uncertainty about Retro, one way or the other, and so the third chance node disappears.

The second, third, and fourth decision nodes are trivial:

2. choose Retro if the test says it's a goer,
3. otherwise choose Trad,
4. or choose Trad if Laura chooses not to test. (Without testing, Trad pays $200,000, which is better than the $186,000 expected from Retro.)

Question: What is Laura's estimate of the probability of the test coming up with Retro as a goer?

Well, her "prior" that Retro will be a goer is probability 0.4.
And *consistency* dictates that this is also her belief that testing will give the result that Retro is a goer.

➢ Laura's expected return from the Trial:

$240,000 × 0.4
(the Trial indicated that Retro is a goer and Laura chooses Retro)
+ $200,000 × 0.6
(the Trial indicated that Retro will fizz and Laura chooses Trad)
= $216,000

➢ Her expected return of No Trial = $200,000 from choosing Trad
(which is higher than the expected return of $186,000 of choosing Retro),

∴ The maximum Laura would be prepared to pay for the Trial is:

$216,000 − $200,000 = $16,000.

This is the *Value of Perfect Information* in this decision;

The value of imperfect information would be less than $16,000.

4.4.1 Probabilistic Sensitivity Analysis — Laura

Have taken as 0.4 Laura’s belief in the probability p of Retro’s being a goer,

At what probability p would Laura choose Retro with No Trial,

What would the value of a completely accurate Trial be then?

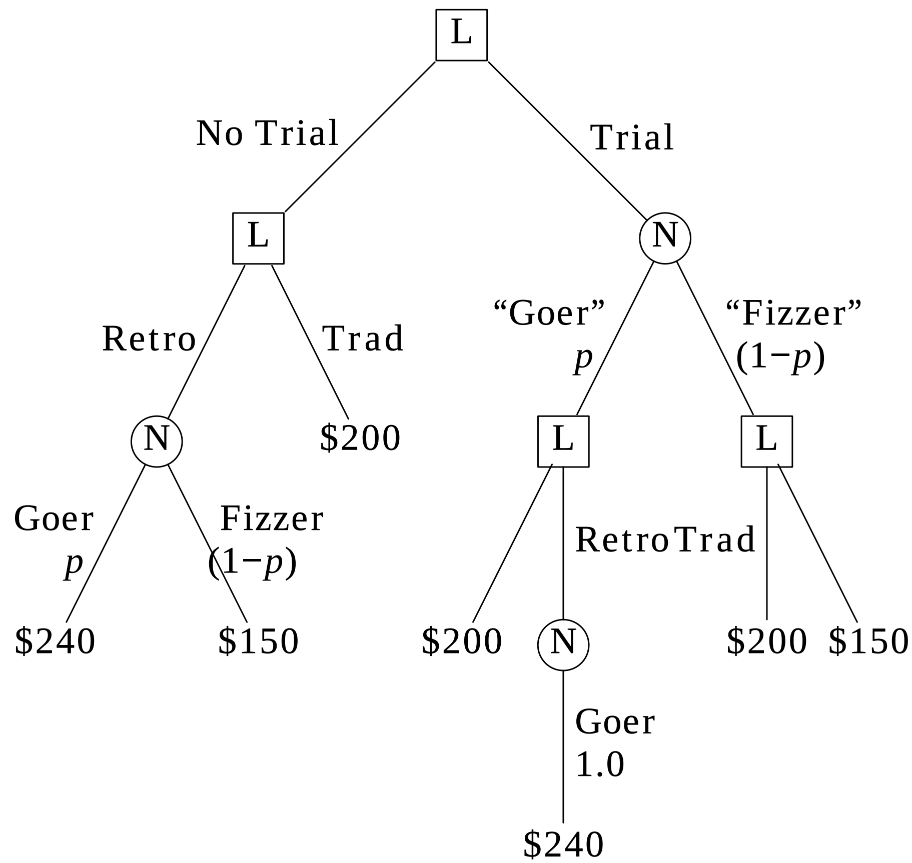
Parameterise the probability of Goer as p,
so the probability of Fizzer is $1 - p$.

If Laura’s probability that Retro is a goer is p, then that must be her best guess as to the probability of the event that the Trial says Retro is a goer.

To be consistent, what else could she believe?

If she’s uncertain about Retro’s success, then she cannot be certain that a 100%-reliable Trial would say that Retro would, or would not, be a success

Laura’s Decision Tree



The Shoe Decision with Perfect Information

(i.e. a 100%-reliable test)

The expected value of choosing Retro in the absence of a Trial:

$$\$150 + 90\,p,$$

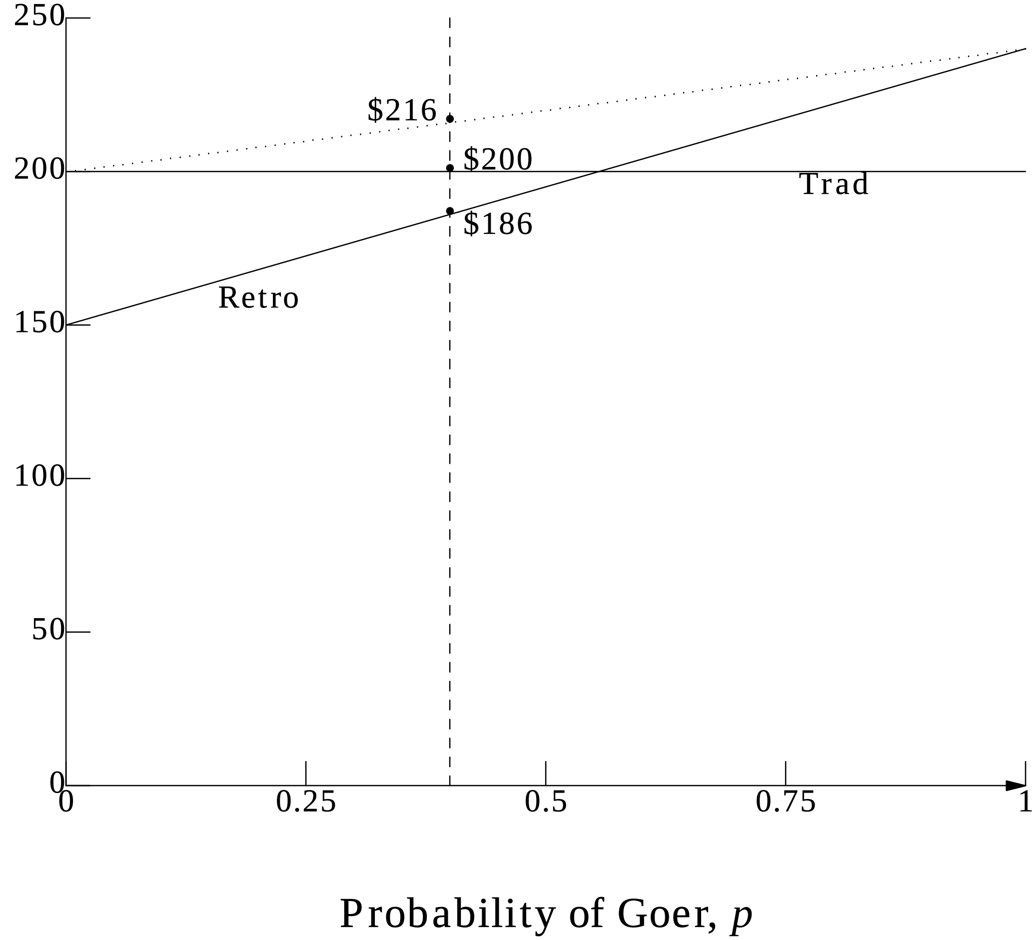
compared with the unchanged value of \$200 of choosing Trad.

On the Trial side of the tree, to be consistent the probability of the test indicating that Retro will be a “Goer” must be p, and a “Fizzer” $1 - p$.

The expected value of choosing Trial =

$$200 + 40\,p.$$

Plotting these expected values as a function of the probability of Goer:



Sensitivity Diagram: Expected Value against Probability of Goer

4.4.2 The Value of Perfect Information (VPI) — Laura

The dotted line: the expected value with the Trial.

At p = 0.4,
- ➢ the expected value of Retro is \$186,
- ➢ the value of Trad is \$200,
- ➢ and the value with Trial is \$216,

The VPI = the improvement in expected value with the Trial,

= the difference between the dotted line and the next highest value, whether Trad or Retro.

When Laura is certain about the outcome with Retro, the value of reducing uncertainty is zero.

She is certain twice: when she

- ➢ knows that Retro is a Goer (p = 1.0), or
- ➢ is certain that Retro is a Fizzer (p = 0.0).

The cross-over probability $\hat{p}$ at which choosing Retro has a higher expected value than choosing Trad is 0.556.

Probability $\hat{p}$ corresponds to the highest VPI, and occurs when her decision is most sensitive to the probability p of Goer.

4.4.3 Which variables are most crucial? — Laura

Have considered the decision's sensitivity to a *single variable*, the probability that Retro is a Goer.

But some uncertainty about the payoffs of Trad and Retro under the two possibilities.

Which is the most critical variable on which to perform a sensitivity analysis?

Ronald Howard (1988, in Package) has suggested that, holding all other variables at their most likely values, one by one each variable be taken from its lowest likely value to its highest, and the effect of this on the optimand (the variable being maximised or minimised) be plotted.

He suggests a *Tornado plot*, with the variable with the greatest effect on top and that with the least on the bottom.

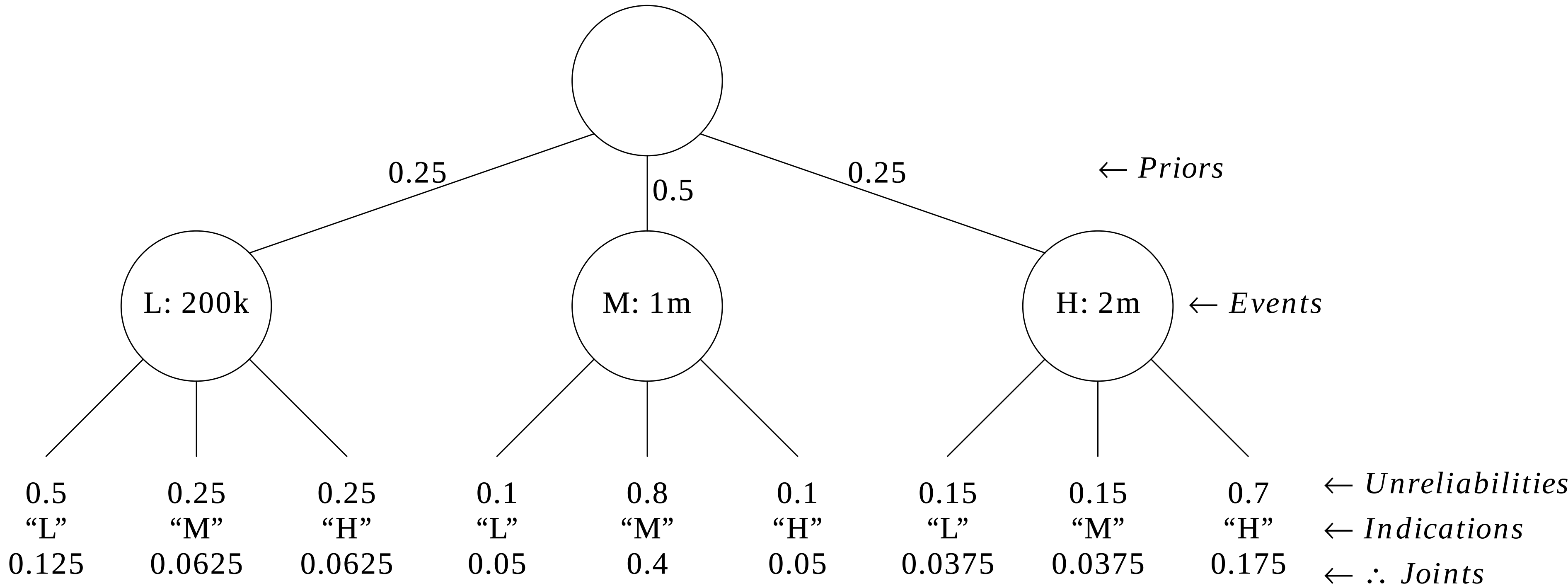
Those variables which can push the maximand lowest are the ones that should be subject to a sensitivity analysis.

See Clemen (1996) for further discussion of this topic, and Howard in the Package.

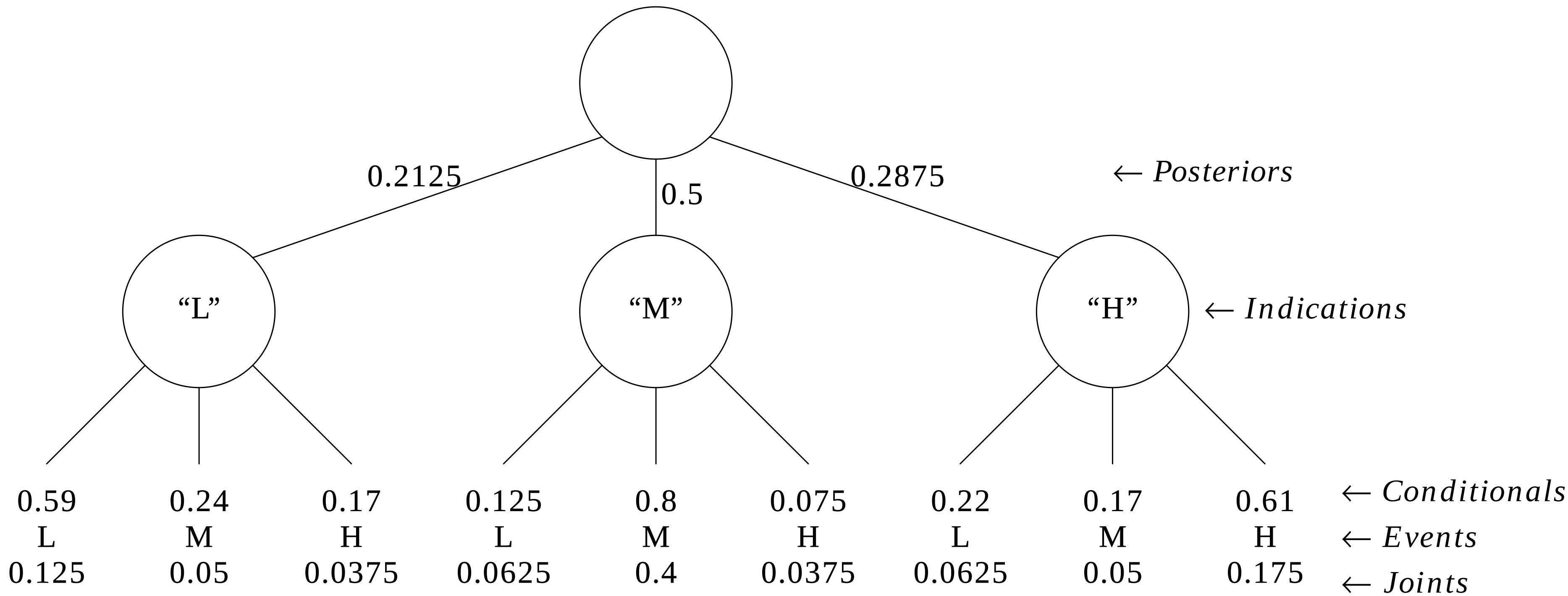
4.5 The Value of Imperfect Information — Reversing or Flipping the Tree

In order to calculate the value of imperfect information, we must flip the tree, to obtain the *conditional probabilities*,
such as Prob (MS = 200k | the survey indicates “L”).
Assume: if the survey is incorrect, then the two wrong indications equally likely.

Prior tree: Glix



The Posterior tree (flipped)



The posterior tree indicates that the Survey assessment is correct 70%

We seek the Conditional Probabilities: given an Indication, how likely is the Event?

The new (posterior) tree also reveals:

The flipped (posterior) tree indicates that if the Survey indicates “L”, then
$p_L = 0.59$, $p_M = 0.24$, $p_H = 0.17$,
which means (from p. 7-16) the EMV(Launch | “L”) = \$596.8k $\rightarrow$ Licence = \$1,135k

If the Survey indicates “M”, then
$p_L = 0.125$, $p_M = 0.8$, $p_H = 0.075$,
which means the EMV(Launch | “M”) = \$1,158.4k, so Launch > Licence

If the Survey indicates “H”, then
$p_L = 0.22$, $p_M = 0.17$, $p_H = 0.61$,
which means the EMV(Launch | “H”) = \$2,089k, so Launch > Licence

The unconditional EMV with the Survey

$$= 0.2125 \times \$1.135\text{m} + 0.5 \times \$1.1584\text{m} + 0.2875 \times \$2.089\text{m} = \$1.420\text{m}$$

$\therefore$ The value of the Survey = \$1.420m − \$1.310m = \$110k,
which is the maximum that should be paid for the Survey.

4.5.1 Laura's Case: The Value of Imperfect Information

But what if the Trial is *not* 100%-reliable?

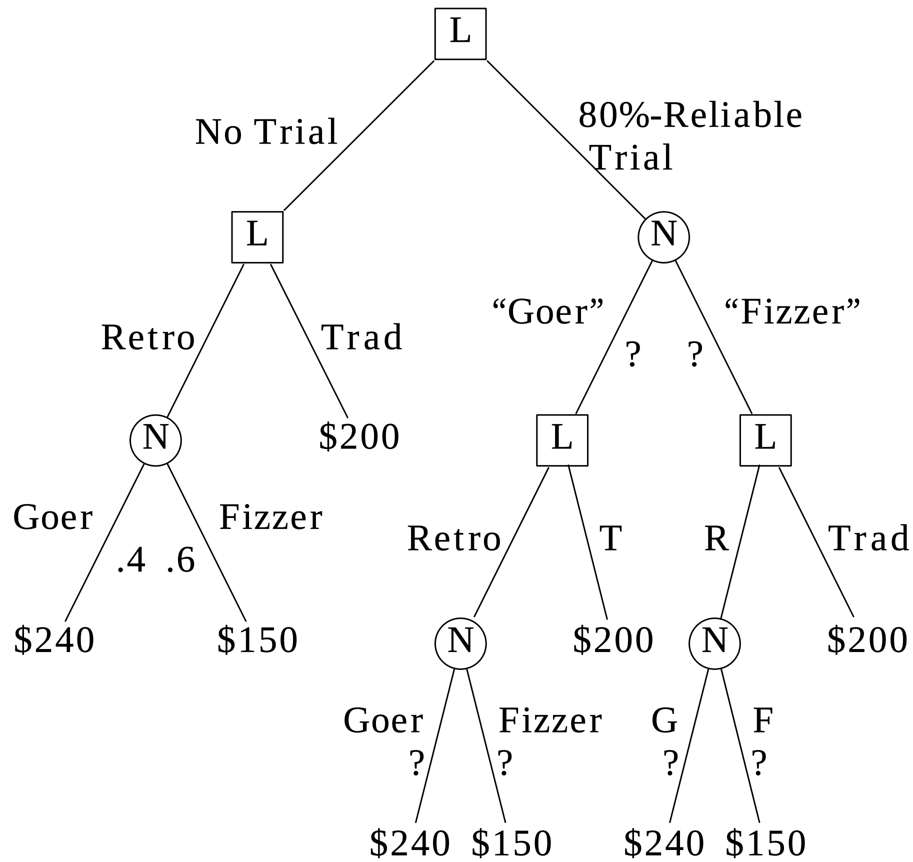
We'd like to know the maximum that risk-neutral Laura should pay for the test.

To answer this, we need to calculate two things:

- ➢ Laura's probability that the unreliable test will indicate "Goer",
- ➢ and the *conditional probability* of Retro being a goer if that's what the test indicates.

(With a 100%-reliable test, the former probability is 0.4 and the latter is 1.0.)

The following tree models
Laura's decision:



What probabilities do the question marks represent?

To answer this question we need to flip the tree to calculate the *conditional probabilities.*

4.5.2 Conditional Probability

Before we continue with Laura’s decision, we shall examine a diagnostic problem that, unfortunately, is all too common these days.

If a diagnostic test is not 100% reliable, then what does a positive test (or a negative test) mean in terms of being ill?

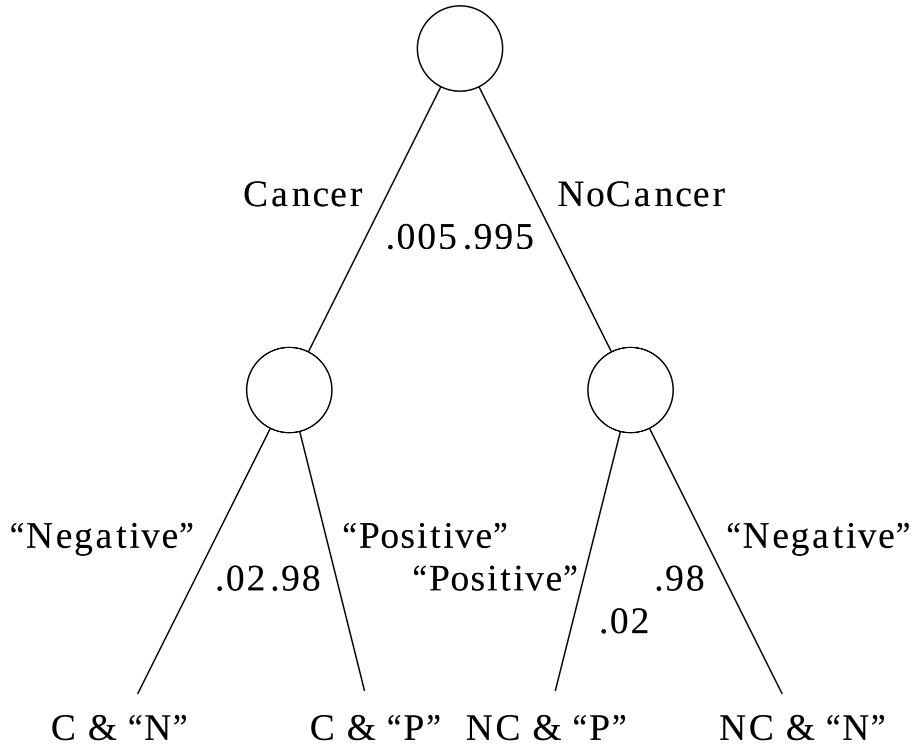
Example: Assume that cancer testing is 98% accurate:

- ➢ If you have cancer, then the test will show “Positive” 98% of the time, and
- ➢ if you do not have cancer, then the test will show “Negative” 98% of the time.
- ➢ You have read that 0.5%, or 1 in 200, of the population actually have cancer.

Note: the probability of a false Positive is know as Note: the probability of a false Negative is know as

Now you test positive. What is the probability that you have cancer?

Cancer Testing



C & "N": false negative

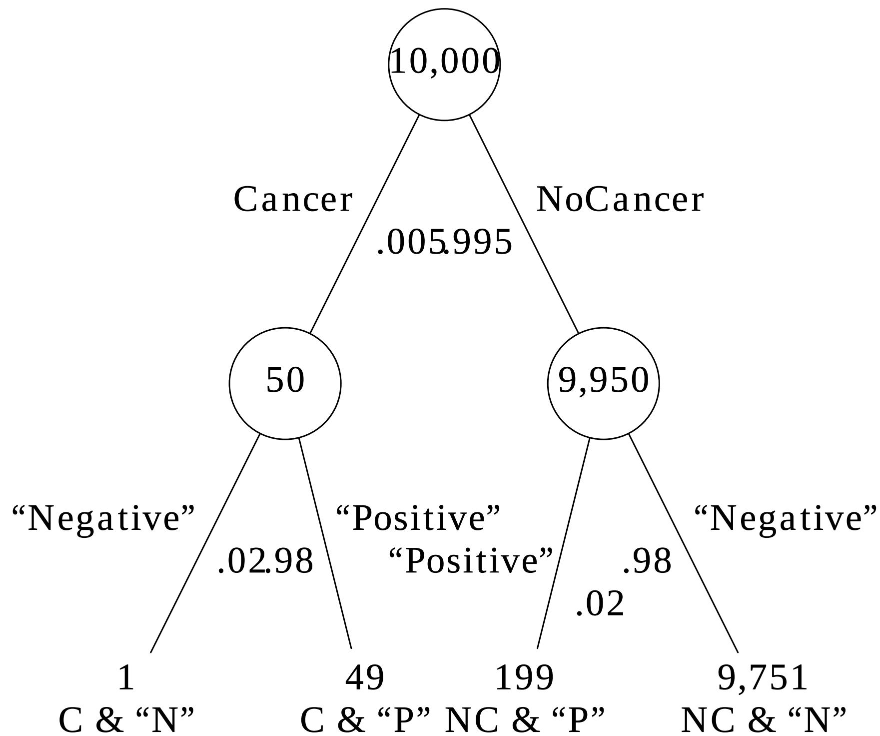
NC & "P": false positive

Conditional Probability

We want the *conditional probability* of Cancer, given that the test says “Positive”:

probability (Cancer | “Positive”)

Assume that 10,000 tests performed. Using the probabilities in the tree, can calculate the expected numbers at the ends of the tree:



$$\therefore \text{ Probability of C \& “P”} = \frac{49}{49 + 199} = 19.8\%$$

Do you really have cancer?

- Of the 10,000 tests, on average 50 people will have cancer.
- Of these, 98% will test positive and so, on average,
- there will be 49 positive tests.
- Of the (on average) 9,950 cancer-free people, 2%, or 199, test positive.
- Thus there are a total of 248 positive tests, of which 199 are false positives.
- So the probability of a positive test indicating cancer is only 49/248, or only 19.8%.

  or probability (Cancer | “Positive”) = $\dfrac{49}{49 + 199}$ = 19.8%
- Surprisingly, only 20% of those testing positive will actually have cancer.

Flipping the Tree

But trees like the one above are not very useful:

➢ Useless to screen *after* we know that someone has cancer.

➢ Need to know what the likelihood is

— that a positive test means that the person has cancer, or

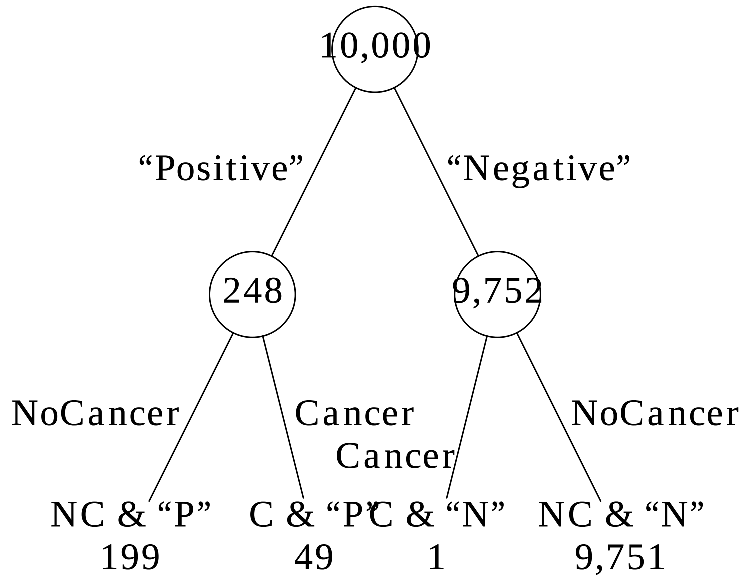
— that a negative test means that the person does not.

➢ That is, we want to know what the probability is that the patient has cancer, given that the test is positive (or negative).

➢ Or, in Laura's case, we want to know what the probability of Retro being successful is, given that the (imperfect) market trial suggests that it will be successful.

➢ In the jargon, we want to "flip" the tree.

The flipped (posterior) tree:



Joint probabilities:

$$\text{Prob ("P" \& NC)} = \frac{199}{10000} = 0.0199$$

$$\text{Prob ("P" \& C)} = \frac{49}{10000} = 0.0049$$

$$\text{Prob ("N" \& C)} = \frac{1}{10000} = 0.0001$$

$$\text{Prob ("N" \& NC)} = \frac{9751}{10000} = \underline{0.9751}$$

$$1.0000$$

Conditional probabilities:

$$\text{Prob (NC | "P")} = \frac{199}{248} = 0.8024$$

$$\text{Prob (C | "P")} = \frac{49}{248} = \underline{0.1976}$$

$$1.0000$$

$$\text{Prob (NC | "N")} = \frac{9751}{9752} = 0.9999$$

$$\text{Prob (C | "N")} = \frac{1}{9752} = \underline{0.0001}$$

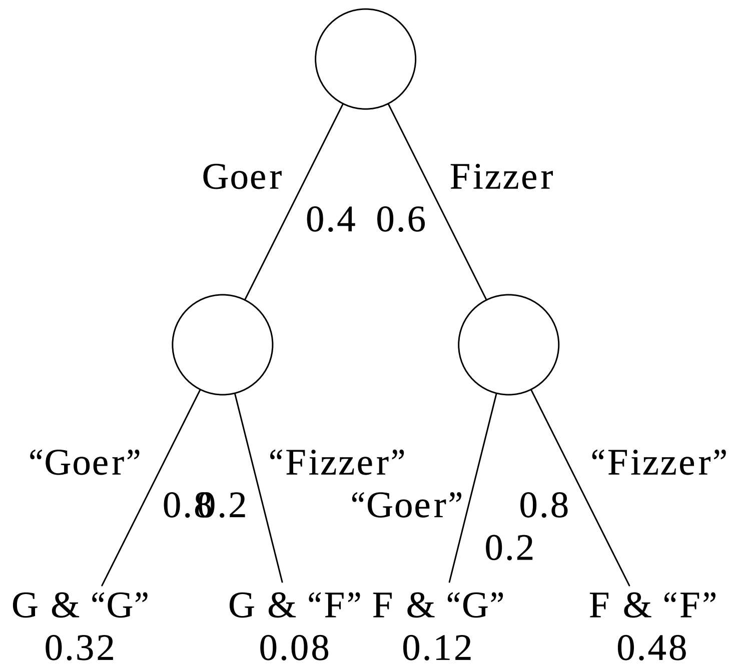
$$1.0000$$

4.5.3 Laura and the Shoe Decision (continued)

Laura decides to employ the Acme Marketing Company. Unfortunately, they are only 80% reliable:

➢ given that Retro is a Fizzer, Acme will say otherwise 20% of the time, and

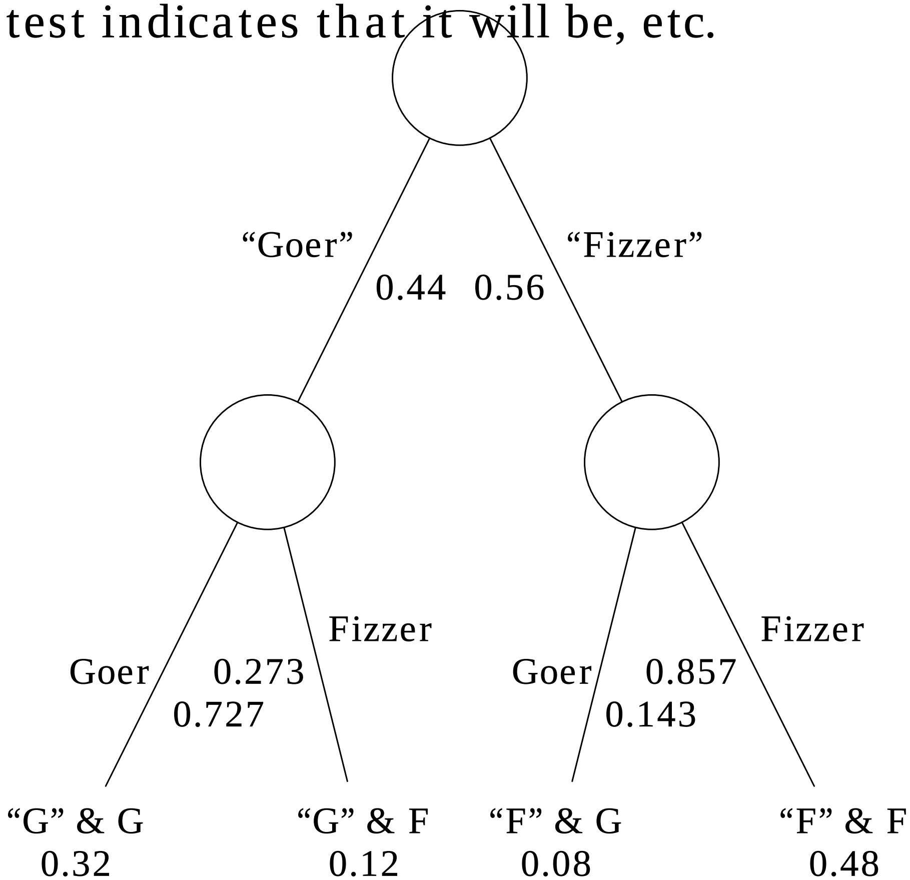
➢ given that Retro is a Goer, Acme will say otherwise 20% of the time.



Market Testing

The flipped tree.

“Flip” the above tree, to determine the chance of Retro being a Fizzer, given that the unreliable test indicates that it will be, etc.



Market Testing

From the flipped decision tree:

- ➢ the conditional probability of Retro being a Goer given that Acme says it's a "Fizzer" is 0.08/(0.08+0.48) or 1/7 or 0.143;
- ➢ the conditional probability of Retro being a Goer given that Acme says it's a "Goer" is 0.32/(0.32+0.12) or 8/11 or 0.727.
- ➢ based upon Laura's prior belief that Retro is a Goer with a probability of 40%, she expects that with probability 0.32 + 0.12 = 0.44 Acme will say "Goer".

We can now replace the question marks in the decision tree above, which allows us to solve the decision problem, with expected values.

Value of Imperfect Information — Laura

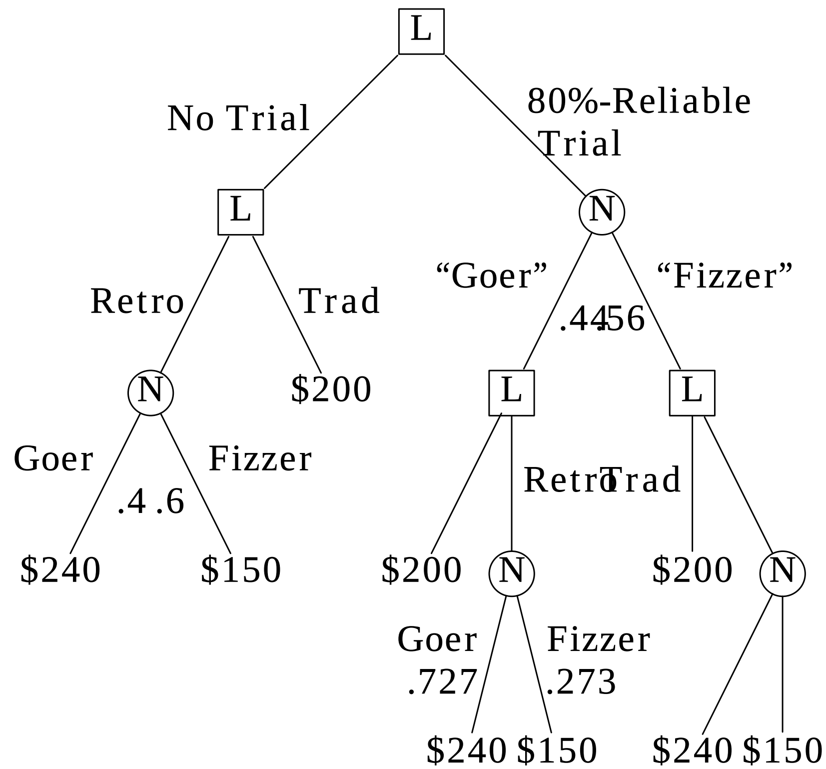
From the sensitivity graph above, the crossover probability is greater than 0.44:

- if Acme says “Goer”, which Laura expects will happen with probability of 0.44, then she will choose Retro.
- Her expected payoff is $(150 + 90\,p) \times 1000$ = \$215,430, with p = the conditional probability that Retro is a Goer, given that Acme said “Goer” = 8/11 or 0.727.
- If Acme says “Fizzer”, which Laura expects will happen with probability of 0.56, then she will choose Trad, with a payoff of \$200,000.
- Her expected payoff with Acme’s imperfect information is thus $0.56 \times$ \$200,000 + $0.44 \times$ \$215,430 = \$206,789.
- Her expected payoff without this information is \$200,000, since she chooses Trad.
- Thus the expected value to Laura of 80%-reliable information is \$6,789.

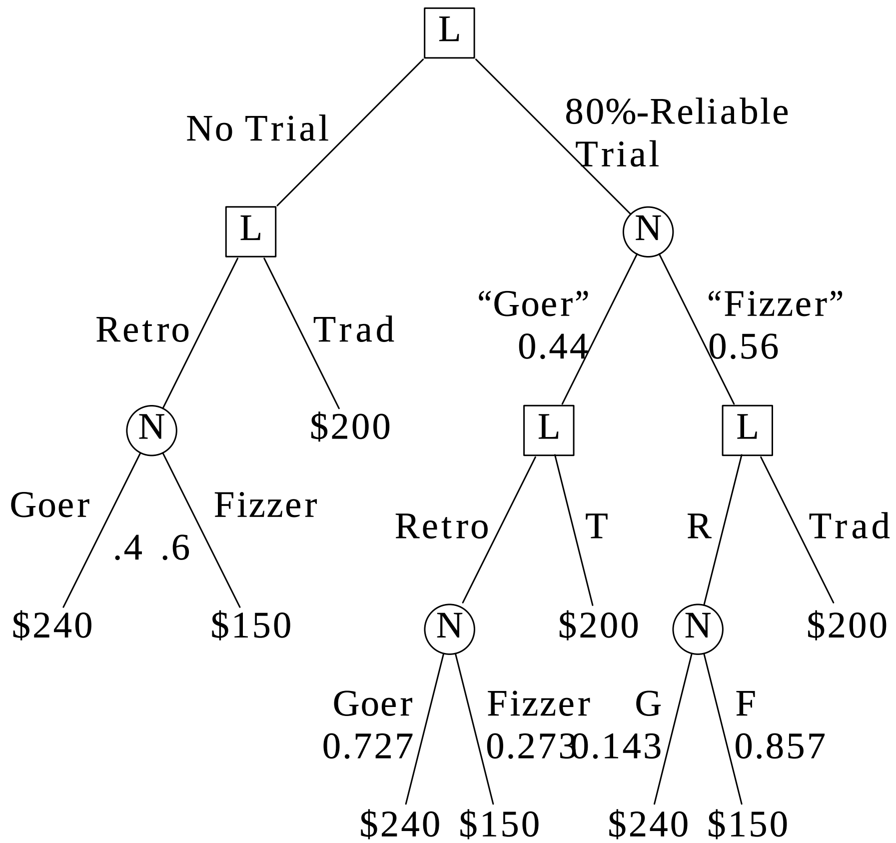
After tree-flipping:

- ➢ Laura's *conditional probability* that Retro is a Goer, given that Acme has states that it will be a Goer, is 8/11, or 0.727.
- ➢ Laura's probability that Acme will state that Retro is a Goer is 0.44.

Laura's full decision tree:



So the following tree models Laura's decision:



EV with the 80%-test = $206,790
EV without the test = $200,000

∴ EV of the 80%-reliable information = $6,790

4.6 Summary of Sensitivity Analysis and Value of Information

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: Tornado diagram.

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

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

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

(Reading: Clemen)

5. *Risk*

5.1 What is Risk?

Risk mean different things to different people.

- ➢ Risk of death (EPA)
- ➢ Risk of defects (TQI)
- ➢ Risk of destruction (fault trees)
- ➢ Risk of decision (Decision Analysis)

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

Risk is typically measured by a probability distribution.

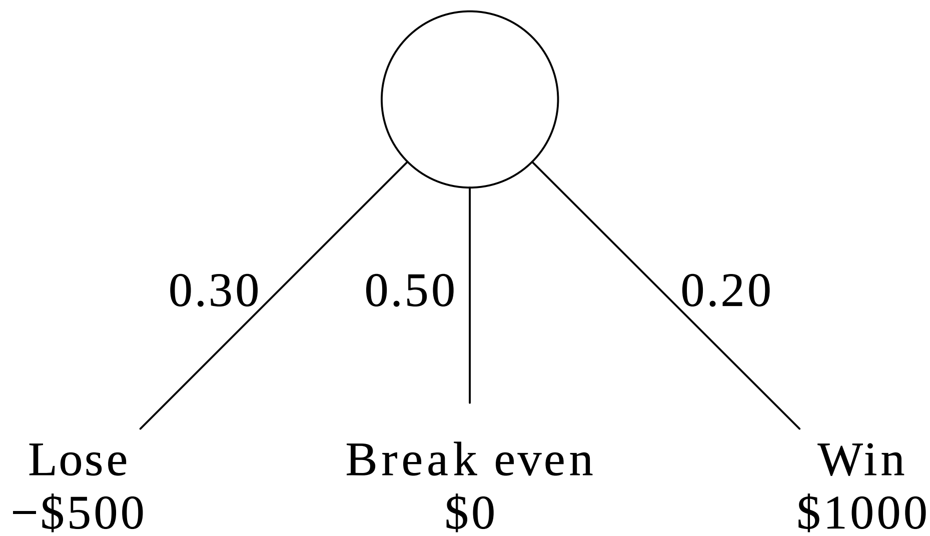
Risk = Probability × Outcome

5.2 Risk Attitude

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

Consider the follow decision tree.

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



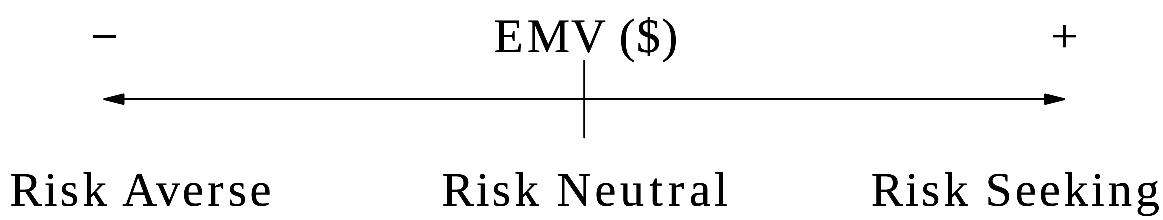
Good decisions don’t necessarily lead to good outcomes.

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 questionnaire.)

What should your risk attitude be for corporate ($) decisions?



Personal risk attitude may depend on:

- ➢ Age
- ➢ Wealth
- ➢ Culture
- ➢ Personal needs
- ➢ Decision setting

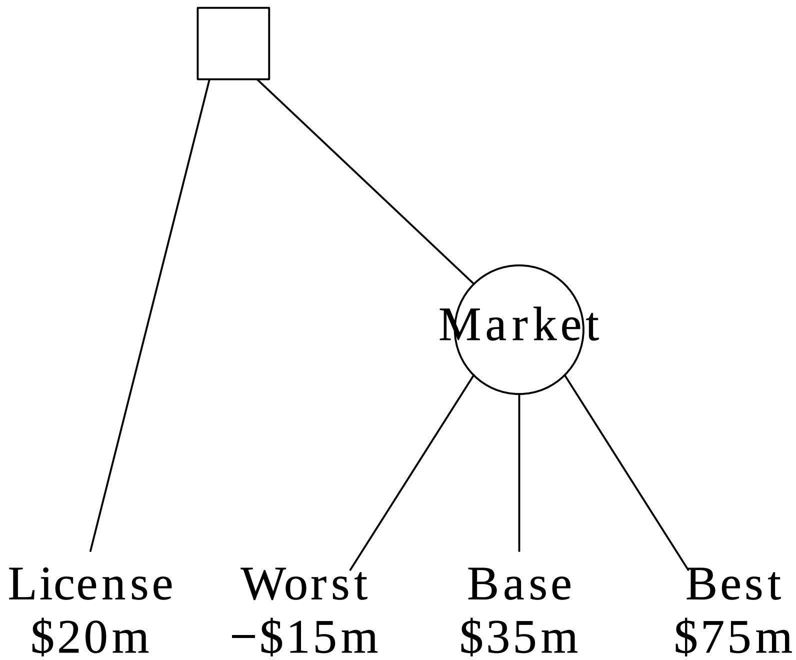
There is not a single, correct risk attitude that should apply to all people: *It is a matter of personal choice.*

Most people tend to be risk averse.

Often an individual's personal risk attitude is placed on corporate decision:

Which decision is best for the organisation?

Which decision is the least risky for the individual?

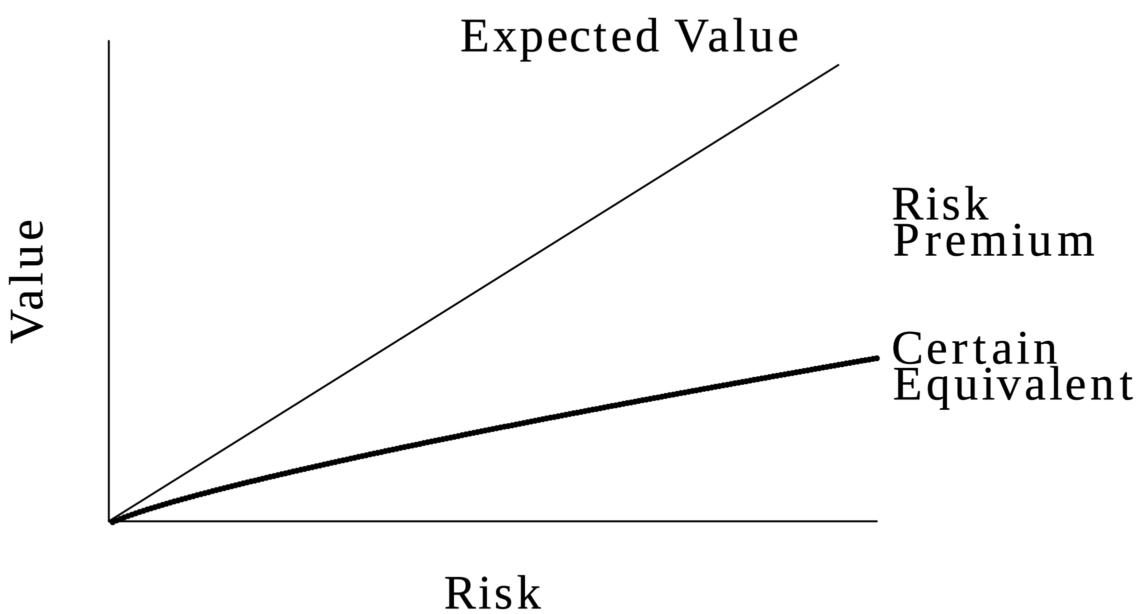


Nearly all corporate decisions should be risk neutral.

(When over one sixth of the corporation's net assets are at risk, the corporation should adjust for risk.)

Risk premium and the certain equivalent:

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



For a risk-averse person, the C.E. is less than the Expected Value.

5.3 Summary of Risk

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

Using the certain equivalent, we can account both for the risk associated with the potential for loss and for 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.

6. Agreement

6.1 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 a course of action

Do 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 Organisation:

Effectively applying decision analysis means changing the organisational culture:

- ➢ Good decisions ≠ good outcomes, necessarily
- ➢ Uncertainty should be expressed using probability
- ➢ Expertise is knowing what you don’t know
- ➢ Information has a value, and an upper limit to that value 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:

➢ Do 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?

An Action Statement

Problem: Should Gaggle comercialise or dispose of product Glix?

Alternatives for Glix:

- Launch
- License
- Sell

Chosen alternative: License.

Rationale: Provides the ability to generate needed revenue with minimum up-front costs and is consistent with the company's attitude to risk.

Objective: Maximise the value of product Glix without creating a financial strain on the company's finances.

Expected Value: $1.13 million

6.2 Summary of Agreement

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* problems first. Begin with a simple problem and gain an understanding of the process through experience.

Multi-attribute Decision Analysis

It is possible to trade off attributes in several dimensions explicitly:

➢ The bottom line ($)

➢ staff morale

➢ ownership

➢ pollution

➢ safety

➢ reliability

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