Games Against Nature: Decision Making Under Uncertainty — Evaluation

Today's topics:

1. Why Use an Influence Diagram?
2. Influence Diagram Exercises
3. Case 1a: Decision Trees
4. Probability
5. Case 2: Laura's Decision
6. The Certain Equivalent
7. Gaining Insight — next lecture
   - Deterministic evaluation — the Tornado Diagram
   - Probabilistic evaluation.
   - The value of information.

1. Why Use An Influence Diagram?

IDs provide the ability to:

- **capture and**
- **communicate (delegate) —**

the essence of an uncertainty problem in an easy-to-understand manner.

Influence diagrams:

➢ **Help to structure the uncertainty problem discussion,**

➢ **Identify influences and dependencies between decisions and uncertainties, (that's influences of uncertainties resolved after the first decision).**

➢ **Show how the value is created,**

➢ **Provide a means to identify information sources and to assign tasks,**

➢ **Develop the logic and structure for the computer decision model.**

Step-By-Step Procedure of Plotting an I.D.

IDs as much an art as a science. IDs focus on developing a clear and meaningful diagram. IDs ask probing questions. IDs make sure *not* to develop a flow diagram. IDs do not have feedback loops.

Step 1: **Explain to the team why this is important and how it will be used.**

Step 2: **Consider the essence of the problem:**

— is it business, marketing, R&D, exploration etc?

Helps to guide the development of the diagram.

Step 3: **Put a value node labelled with the decision criterion at the middle of the RHS of the page.**

Most diagrams use NPV as the value node, influenced by Revenue and Costs.

Step 4: **What piece(s) of information would most help in resolving the uncertainty or determining the value?**

Procedure (cont.)

Step 5: Choose one uncertainty influencing the final value node, and develop it completely before tackling the other nodes.

Make sure the nodes are clearly defined and specific.

Step 6: Review the uncertainties on the previous issue-raising list: should those missing from the diagram be included?

If not, why not?

Step 7: Eliminate any irrelevant, preexisting influences, such as those "influencing" the very first decision.

Step 8: Identify deterministic uncertainty nodes, designated by double ovals. Can you write the formulas for the value in these nodes?

If not, list the missing information.

Step 9: Identify information sources and write each source's name by the node it can resolve.

Step 10: Is the diagram complete and has the problem been described accurately?

Step 11: Write an information-gathering task list.

2. Influence Diagram Exercises

1. Nuptials

a. Who is the decision maker?

b. What are the values?

c. What are the uncertainties that influence events/values/decisions after the first decision?

2. Texaco versus Pennzoil

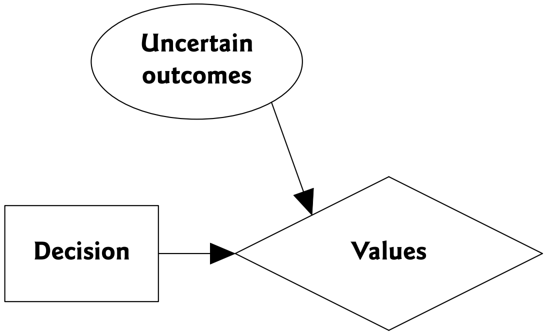
a. **Who is the decision maker?**

b. **What are the values?**

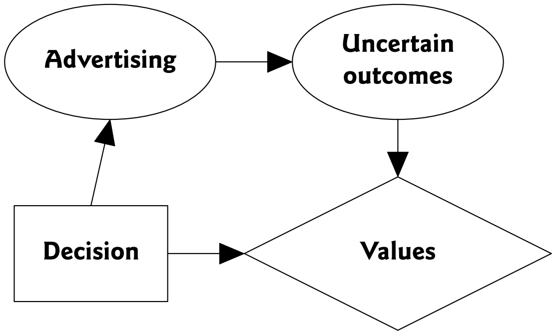
c. **What are the uncertainties that influence events/values/decisions after the first decision?**

Types of Influence Diagrams

1. **Simple, 1-stage, non-strategic decision, then resolution of uncertainty, then payoffs. (Laura's marketing decision)**

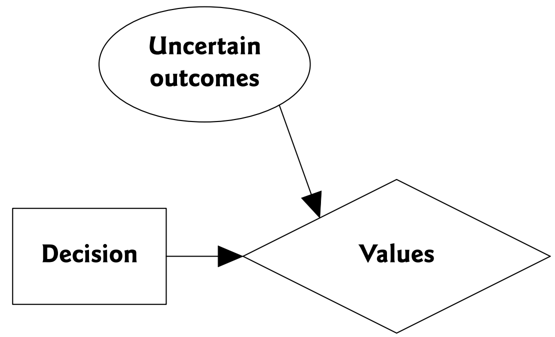


2. **Decision influences the probabilities. (e.g. advertising)**

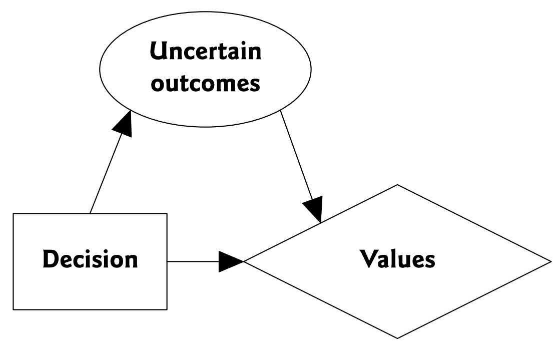


Types of Influence Diagrams (cont.)

3. **Insurance (such as an umbrella)**

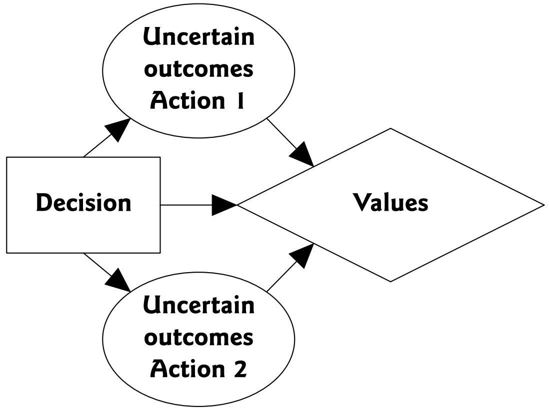


4. **Incentives: moral hazard with insurance (i.e. less care about locking up the house if 100% insured against theft.)**

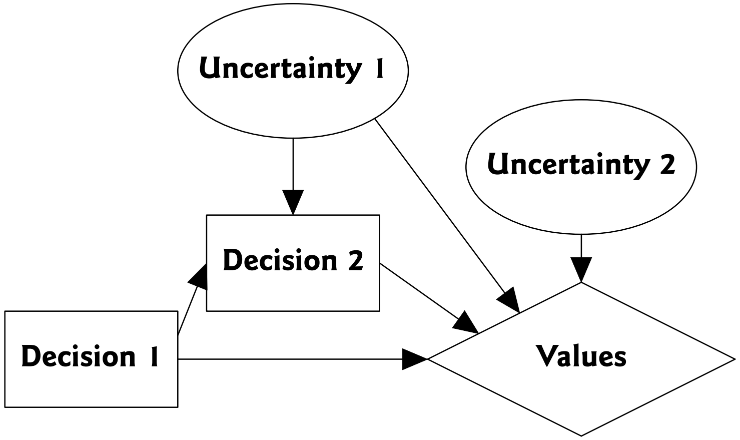


Types of Influence Diagrams (cont.)

5. Probabilities are a function of the alternative chosen. (e.g. nuptial vows)

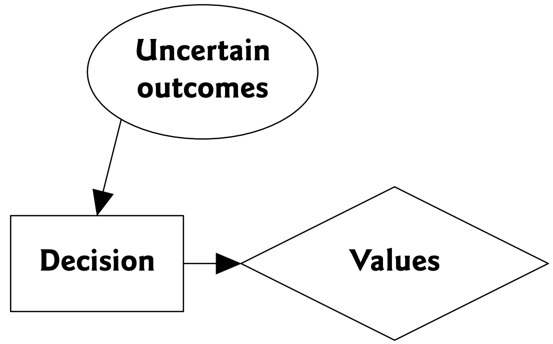


6. Two-stage decision (e.g. Pennzoil)



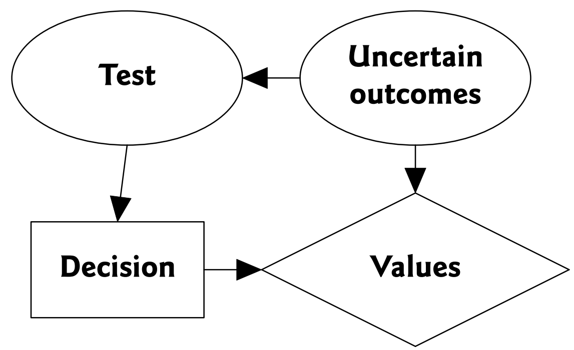
Types of Influence Diagrams (cont.)

7. **As no. 1, plus Value of Perfect Information. (Compare EV of 7. with the EV of 1.) (e.g. the clairyoyant)**



Note: all uncertainty has been resolved *before* the decision is made here. (There must have been an earlier decision to obtain the clairvoyant's information.)

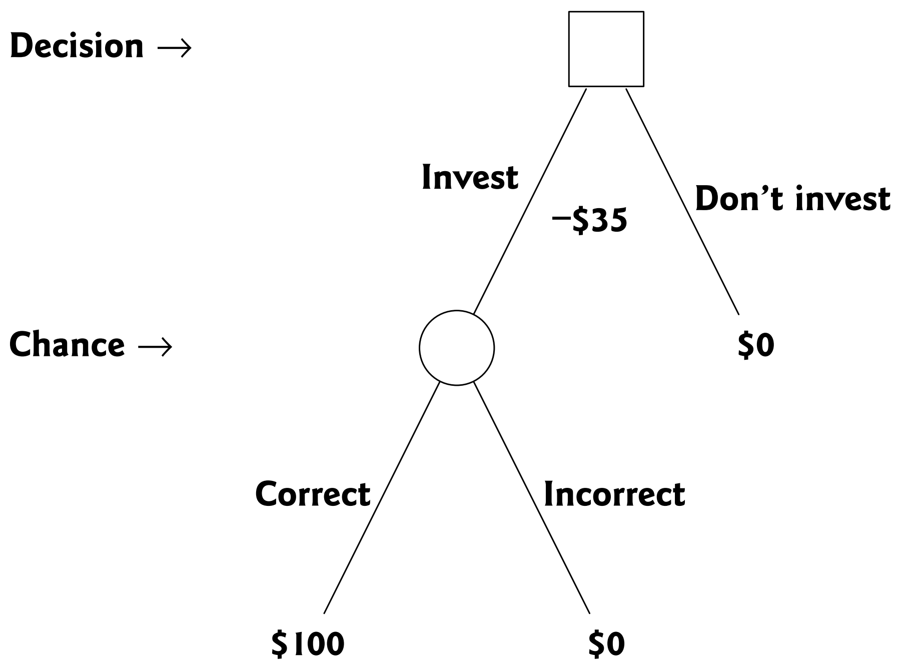
8. **Value of Imperfect Information (Compare the EV of 8. — less than the EV of 7. — with the EV of 1. (e.g. test marketing, forecasting)**



(There must have been an earlier decision to obtain information from the test.)

3. Case 1a. The Decision Tree for a Simple Opportunity:

Whether or not to invest $35 for the opportunity to receive $100 or $0 as the outcome on the call of a die roll as odd or even.



What else is needed to evaluate this opportunity?

Decision Trees

Flow diagrams showing the logical structure of a decision problem.

Visual aids to lay out all the elements of a decision.

Contain four elements:

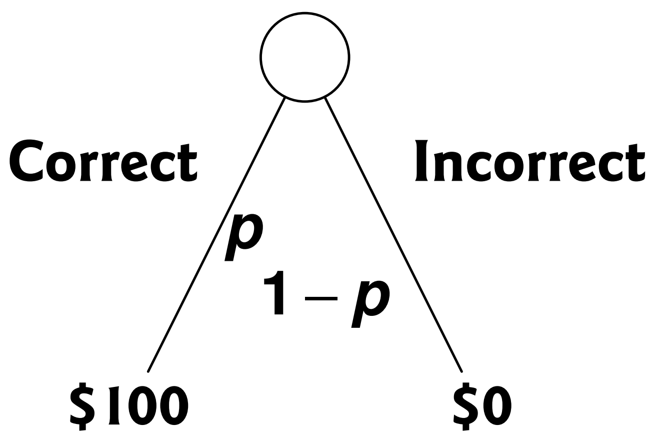
- ***Decision nodes,*** **□, indicating all possible courses of action open to the decision maker, as before in game trees;**
- ***Chance nodes,*** **○, showing the intervening uncertain events and all their possible outcomes;**
  i.e., Nature plays — new
- ***Payoffs,*** **summarizing the consequences of each possible combination of choice and chance; and**
- ***Probabilities*** **for each possible outcome of a chance event.**

The tree is missing the probability assessments for a good and a bad outcome.

The tree does not yet incorporate the investor's judgement of the *probabilities* of success and failure.

What information would help with this assessment?

- **The number of sides on the die**
- **Any known bias the die might have**
- **Who gets to roll the die**



p: the probability of being correct

4. What is Probability?

Two distinct views of probability — *frequentist* and *Bayesian* (or subjective).

The frequentist view:

an empirical set of historical data defined by the number of times (the frequency) that something has happened. Need a sufficient amount of historical data.

The Bayesian (or subjective) view:

a state of knowledge based upon one's experience, beliefs, knowledge and historical data and research.

Provides a means of assessing situations where something has either never occurred or is a rare event, or you have no information on past occurrences.

Subjective Probabilities

Statements of: *how likely you believe an event will occur*.

What is your probability that:

1. **The BHP Billiton share price will be AU $45.00 or more at the end of the year?**
2. **You will die in a car accident before you turn 65?**
3. **You can name 30 or more of the 50 state capitals of the USA, or the English monarchs since 1066 in order, without aid?**

Subjective probability: an expression of your state of knowledge, based on your beliefs, knowledge, data, and experience.

We all form subjective probabilities of events all the time (driving, playing, working, at home).

The distinction between objective and subjective probability:

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

- **Cancer risk factors**
- **Lightening strikes**
- **Tossing a coin**

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

- **Market acceptance of a new product.**
- **Probability of the Swans reaching next season's Grand Final.**
- **Probability of Latvia's bankruptcy?**

Why are probabilistic statements so important?

Everyday language is imprecise and often ambiguous.

- **We *might* win next season**
- **It *could* rain tonight**

Probability is the only way to state our degree of certainty about future events correctly.

- **There is an 80% chance of rain tonight [Canberra]**

Example: Weather forecasts

- **The *value of weather forecasts* varies from company to company and from person to person.**
- **depends upon the company's or person's *abilities to take actions* in response to forecasts to reduce losses or to increase profits.**
- **e.g., a local department store will have to decide when to phase out their summer fashion range and highlight the winter range.**
- **Sometimes choosing when to act is done by custom or convention, sometimes by watching rival stores.**
- **But it can also be decided using decision analysis.**

Q: If accurate weather forecasts were available for a price, *what should the store pay for these forecasts*?

A: No more than the higher profits it could earn by taking advantage of the information.

Other Uncertainties Facing Managers:

Apart from the weather, in their "games against Nature" managers are concerned about such uncertainties as:

- the future demand for a particular product
- the cost and reliability of untried technology
- the levels of future interest rates
- the levels of future exchange rates
- employees' reactions to change
- the value of Amazon.com shares at the open of trading next year.

None of these is a simple: you can't simply say that the future demand for a product, say, will be High or Low.

Rather than trying to identify all possible levels, you can determine thresholds, or points at which the prudent decision changes from one action to another, using *sensitivity analysis*.

Moral: There are no payoffs for spending more time and money to obtain more information than you really need.

Using probabilistic statements of uncertainty

Consider the following four sentences:

It could happen	______________
It might happen	______________
I think it will happen	______________
I'm sure it will happen	______________

On each line to the right of the sentence, write down your assessment of the likelihood of happening. Write down a *single number*, the midpoint of your range.

Take-away?

An Example of Subjective Probability.

You are shown a dictionary containing over 1,400 pages of information.

What is the probability that the first new word on page 1025 begins with the letter Q?
(This experiment can be run only once.)

Write your probability here __________.

States of knowledge

Subjective (Bayesian) probabilities rely upon expert knowledge which is always changing as new information becomes available. So probabilities should also change as new information becomes available.

Helpful hints (i.e. new information):

- Q is the seventeenth letter of the English alphabet
- Page 1025 is in the last third of the dictionary
- You have knowledge that some letters — such as the letters Z, X, and Y — begin fewer words than do others.

Does this information change your probability?

If so, what is it now __________?

Is your probability assessment correct?

Assessing Uncertainty

Finding the Right Experts:

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 event.

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

Assessing Uncertainty:

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

We need the ability to elicit subjective assessments from experts.

One device for doing so is the Probability Wheel.

The Subjective Probability Wheel

Encode your subjective probability of a specific event: e.g. of sales volume exceeding $\$xxx$ this year.

1. **Imagine the colour wheel spinning so fast that the colours seem to blend completely.**
2. **Now ask which you would rather bet on: that the event occurs (sales exceed $\$xxx$), or that the throw of a dart hits yellow rather than blue.**
3. **If you prefer to bet on the event's occurring, increase the yellow area. If you prefer to take your chances on the dart's hitting yellow, reduce the yellow area.**
4. **Continue adjusting the areas until you are *indifferent* between the two bets.**
5. **Read your subjective probability of the event from the back of the Wheel.**

The “10–50–90” distribution:

When we assess an expert, we want to obtain at least three points in order to adequately describe the curve or distribution.

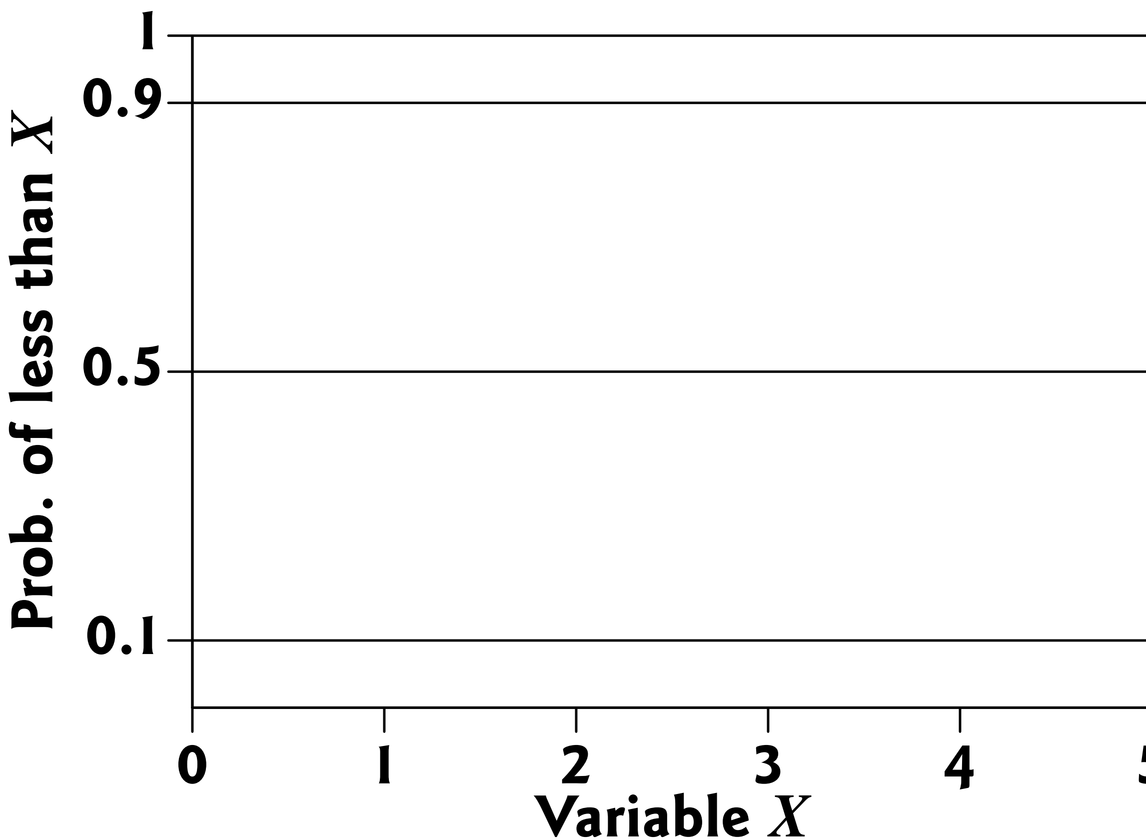
We do this by gathering a “10–50–90”.

The 10 point is a 1-in-10 chance that the assessed value could be that low or lower.

The 50 point is where the expert is indifferent: the event could equally be above or below the 50 point.

The 90 point is a 1-in-10 chance that the assessed value could be that high or higher.

Plotting the distribution.



Getting a “10–50–90” distribution:

One can assess the “10–50–90” distributions either directly or indirectly.

A direct method would be simply to ask the expert for the three values.

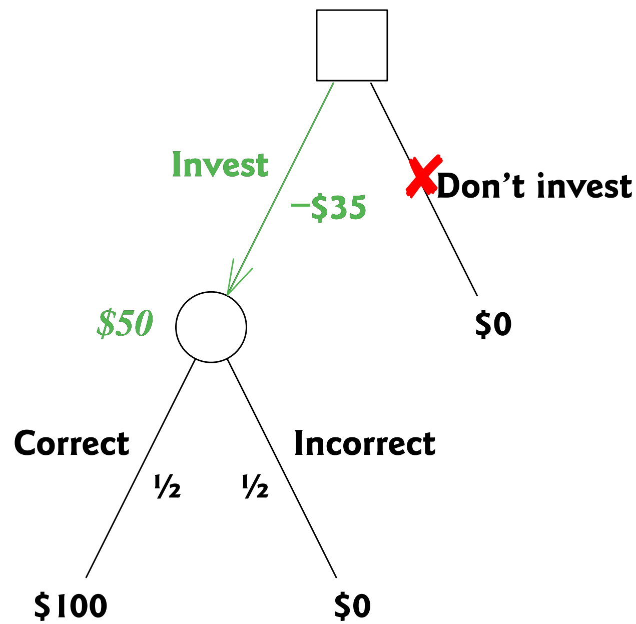
An indirect method is to use the probability wheel or some other method (such as coloured balls in the box).

Either way, there is a six-step process:

A Six-Step Process of Eliciting Probabilities

1. **Motivate the expert**
2. **Structure (definition, measure) the questions**
3. **Condition against framing (counter cognitive biases)**
4. **Encode the probability (use Probability Wheel, plot, review discrepancies)**
5. **Verify the answers (does the expert believe the assessment?)**
6. **Make discrete rather than continuous (for a small number of alternatives)**

EMV (Expected Monetary Value) is the probability-weighted average:



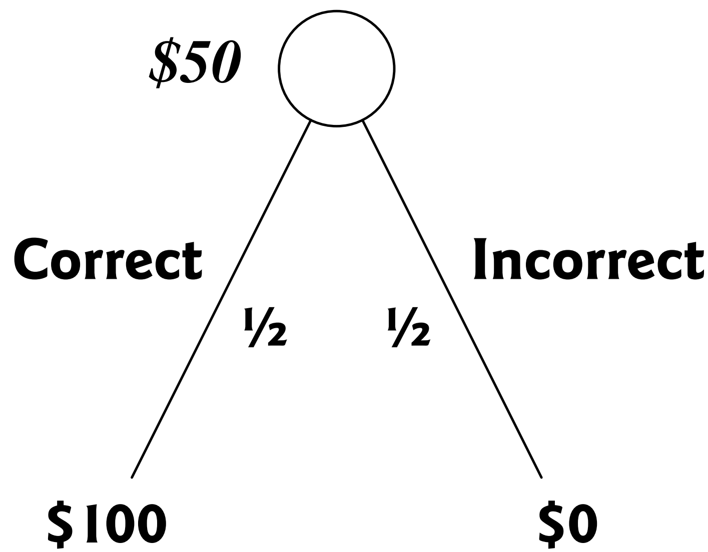
Probability		Outcome		EMV
0.50	×	$100	=	$50
0.50	×	$0	=	$0
		EMV	=	$50
		Investment	=	−$35
		Expected Net Profit	=	$15

You have decided to take the opportunity.

You believe the probabilities of success or failure are equal, or 50:50.

You have paid the $35 investment.

Now what does the decision tree look like?



How has the opportunity changed?

Beware the sunk-cost fallacy.

Before deciding to pursue the investment, it is appropriate and important to include the costs to enter the deal.

But don't include what you've already paid to get into an investment: that decision has already been made and the resources allocated, usually irreversibly.

"Let bygones be bygones."
"Don't throw good money after bad."
"Don't cry over spilt milk."

Evaluate future decisions for what they are worth.

The value you place on the future investment opportunity should not depend on costs already sunk.

5. Case 2. Laura's Shoe Decision

The Decision Maker:
Laura, a divisional manager of a large department store.

Her decision:
must decide on the new season's range of styles of footwear:

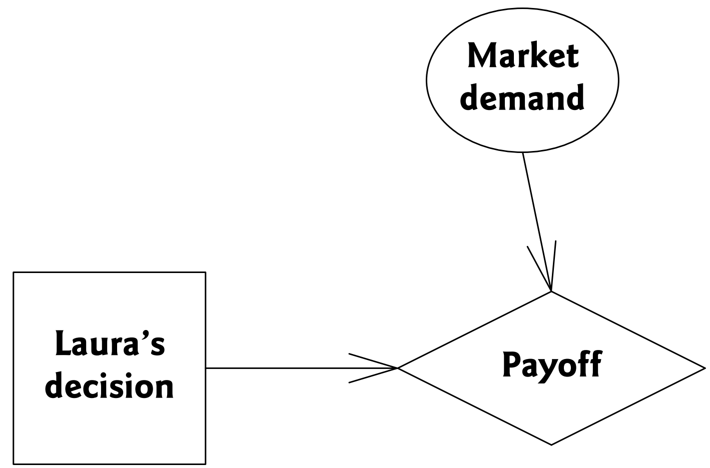
- **the sure-thing "Trad" range, or**
- **the risky "Retro" range.**

She has a choice of *actions:*

- **the "Trad" range, not risky, could cater to a traditional segment of the market**
  For the budgeted investment in this range, a net return of \$200k.
- **the "Retro" range, risky, a new range of 1940s retro shoes.**
  - **if it's a Goer (success), the net return will be \$240k, but**
  - **if it's a Fizzer (failure), she'll net only \$150k.**
  - **Laura believes that the *probability* of success of Retro is only 0.4,**

  ∴ **with a probability of 0.6 it'll fizzle.**

The *influence diagram* for Laura's decision:



Very similar to the influence diagram of the die-rolling decision.

Since Laura's decision of which fashion line to go with does not influence the market outcome (whether or not Retro will be a success), there is no arrow from the decision node to the chance node.

And since Laura will choose the line before she knows how the market will respond to it, the arrow from the chance node goes to the payoff node.

Advertising? Pricing? Promotion?

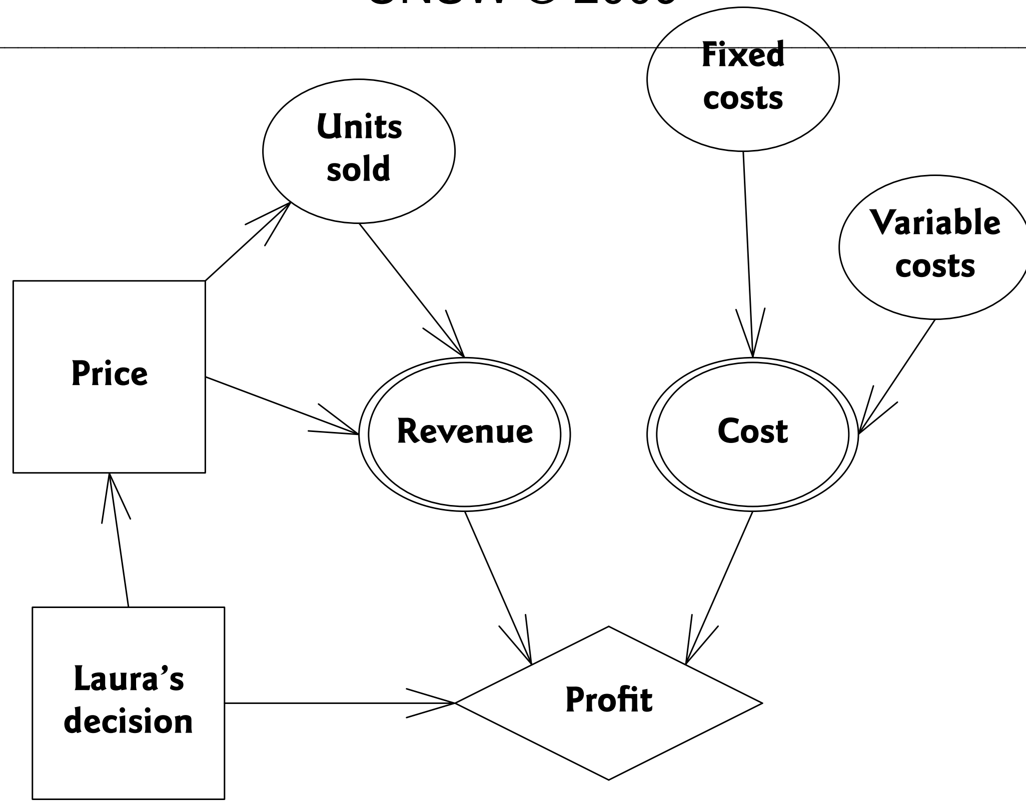
Embellishments.

Possible to consider the decision in more detail:

- **what prices to charge for the new line;**
- **how this affects the numbers sold and so the revenues;**
- **how the uncertainty over the fixed costs of setting up the new range and the uncertainty of the costs of production and promotion will impact on the profit.**

- **Other lines, with different expected costs, revenues, and $\therefore$ different net returns.**

Laura's ID

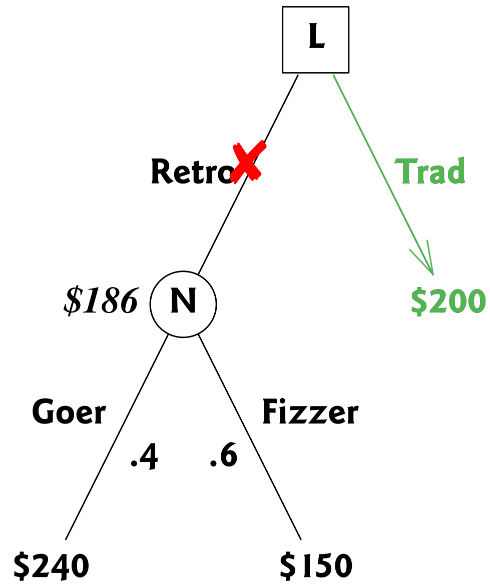


The double circles/ellipses are *deterministic nodes*: given the inputs from the predecessor (upstream) nodes, the outcome of the deterministic node can be found immediately.

After the conditioning variables of the decisions and the chance events are known, there is no uncertainty.

Deterministic nodes are useful in simplifying an influence diagram. Why no arrow from Decision to Costs?

Laura's Decision Tree



With the payoffs and probabilities, Laura can calculate:

- **the long-run, expected return of Retro, the payoffs weighted by the probabilities:**

$$\$240k \times 0.4 + \$150k \times 0.6 = \$186k.$$

- **which is less than the certain return of $200k for Trad.**

Laura's decision?

A risk-neutral or risk-averse decision maker (see later) would opt for Trad.

With a complex decision, a risk-neutral decision maker will choose:

- **the action associated with *the maximum expected return* at every stage of a complex decision,**
- **allows us to "prune" branches on the decision tree associated with sub-maximal expected returns.**

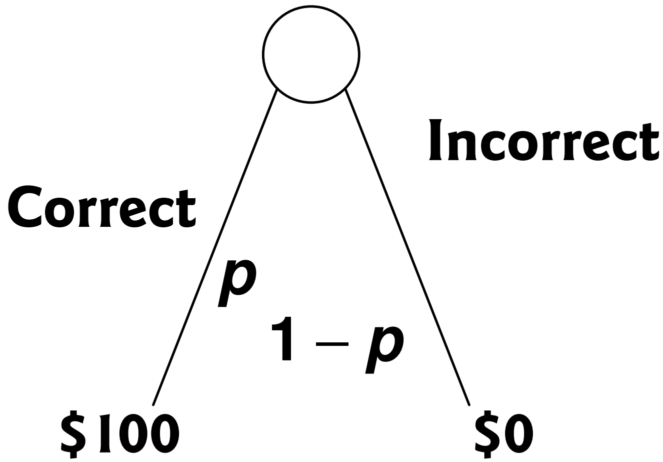
6. The Certain Equivalent

A better evaluation technique is the *Certain Equivalent*

The Certain Equivalent allows for inclusion of both *risk* and *time value* of money separately.

The Certain Equivalent of a deal is when the investor is indifferent between a deal with at least two opportunities and a guaranteed sum of money — also know as the investor's minimum selling price.

The Certain Equivalent of a lottery.



= $_____

a deal or opportunity = **its Certain Equivalent**