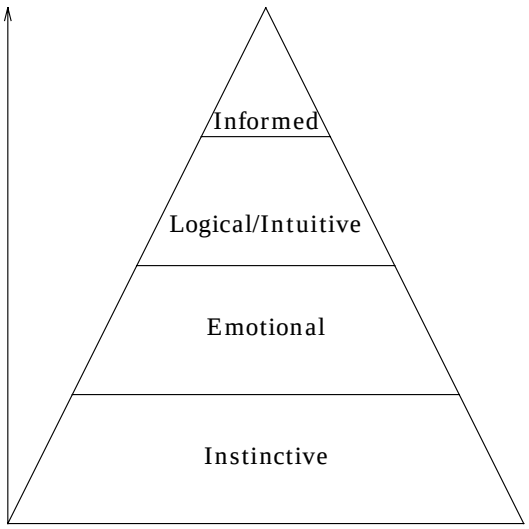
2. Decision Analysis: Games Against Nature

2.1 The Decision Response Hierarchy



The Decision Response Hierarchy

Moving up the hierarchy corresponds to increasing consciousness, clarity, and power.

Which response do you use most often in making decisions?

- ☐ Informed
- ☐ Logical or Intuitive
- ☐ Emotional
- ☐ Instinctive

2.2 Basic Concepts

A technique for helping make decisions, and avoiding pitfalls.

We discuss:

- ➢ Formulating the issue.
- ➢ Identifying the alternative actions.
- ➢ Valuing the possible outcomes.
  (Not merely in monetary terms.)
- ➢ Encoding uncertainty.
  → probabilities
- ➢ Certain Equivalent (C.E.).
- ➢ The Value of Perfect Information.
- ➢ The value of imperfect information.
- ➢ Utility and risk aversion.
  The utility of a lottery is its expected utility

2.3 Why Is Decision-Making Difficult?

- ➢ Uncertain consequences or outcomes.
- ➢ Conflicting objectives
- ➢ Competing projects or alternatives
- ➢ Being held accountable for outcomes
- ➢ Multiple decision makers
- ➢ Risk attitude

Decision Analysis Addresses These Issues By:

- ➢ Focussing on what *don't know* rather than refining what you already knew.
- ➢ Applying a logically correct methodology to consistently evaluate alternatives
- ➢ Gaining insight into the decision problem

  — the numbers should always be subservient to the insights gained.

2.4 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 actions by the decision maker.

— insights, not just numbers.

Decision analysis is **not**:

— A method for justifying decisions already made.

— Cost-benefit analysis

— A cookbook

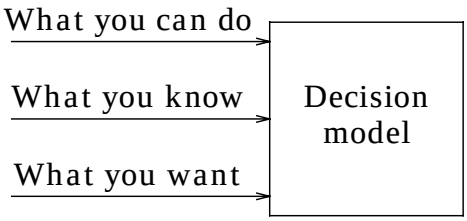
Decision analysis provides answers to questions such as:

- How risky is this project?
- Which plan do we follow?
- Which assumptions are most important?
- What is the project's potential?
- Should we gather more data?

Beginning Principles:

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

- What you *can* do.
- What you *know*. (Such as likelihoods and values)
- What you *want* or *value*. (Such as your risk attitude)



2.5 The Decision Analysis Process.

Decision analysis is a three-stage, quality process. But if at any step in the process the decision becomes obvious, you should stop and make the decision.

1. *Structuring:* Frame the Right Problem
   - ➢ Clarify the decision.
   - ➢ Raise and sort issues.
   - ➢ Generate creative alternatives.
   - ➢ Model the problem.

The Decision Analysis Process — Stage 2

2. *Evaluation:* Use Logical Thinking
   - ➢ Discover what is important.
   - ➢ Apply an appropriate risk attitude.
   - ➢ Determine the value of new information.

3. *Agreement:* Have Commitment to Action
   - ➢ Check for refinement.
   - ➢ Agree on course of action.
   - ➢ Implement course of action.

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*, here we 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*.

Why Decision Analysis?

- *Decision making* is at the heart of most technical, business and governmental problems, not to mention one's private life.
- Decision making requires the study of *uncertainty*. There are no sure things;
  risk-taking is inescapable.
  - How does uncertainty affect decision-making?
  - How can one make a rational decision (a "good" decision) without knowing exactly what consequences will follow?
- Think of risk-taking in terms of gambles or lotteries. Uncertainty can only be studied formally through *probability* theory, the only theory of uncertainty which has *this important property:*

  > the likelihood of any event following the presentation of a sequence of points of data does not depend upon the order in which those data are presented.

Probability is a state of mind, not things.

- The Bayesian approach allows us to assign probabilities in once-off situations.

  What is the value to you of a single toss of a coin: \$100 if heads, nothing if tails?

  Define the *expected return* from the single toss to be the average return of a hypothetical series of many tosses: $\$100 \times ½ + \$0 \times ½ = \$50$. Treat unique events as if they were played over many times.

- All *prior experience* must be used in assessing probabilities. (Coins are almost always fair; it's warm enough to go to the beach most weekends in March in Sydney.)

Values plus probabilities.

- Decision making requires the assessment of *values* as well as probabilities.

  Would you pay as much as \$50 to play in the once-off coin toss? Few people would; most people would pay a premium to reduce their risk: they are *risk averse*, and would sell their lottery ticket at something less than \$50; the lowest selling price is their *Certain Equivalent* (C.E.).

  The *risk premium* equals the expected return less the certain equivalent, when selling.

  Risk aversion can be defined and measured using *utility theory*.

The utility of a lottery ...

- Decisions can only be made when a criterion is established for choosing among alternatives.

  The utility of a lottery is its expected utility.

  (by the definition of utility)

- The implications of the present for the future must be considered. What *discount rate* to use.

- Must distinguish between a *good decision* and a *good outcome*.

  Prudent decision-making doesn't guarantee the desired outcome invariably, but should improve the odds.

The Value of Perfect Information?

- Often we can, at a cost, reduce our uncertainty about Nature's future events (using market research, forecasting, statistical analysis). There must be a limit to what we should spend in these endeavours—how much is it?

  The Value of Perfect Information. (VPI)

- The value of *im*perfect information is less.

  Often we can, at a cost, buy more certainty about the future (pay an insurance premium, buy a hedge against future outcomes).

  What is a fair price to pay?

2.6 Summary of Introduction

We need a methodology to help us make difficult decisions. Decision analysis provides that methodology.

Decision analysis focuses on what we don't know, rather than on refining what we do know.

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

- What you can do.
- What you know.
- What you value.

Decision analysis has three distinct stages — *Structuring, Evaluation,* and *Agreement.*

The Simplest Decision — Case 1

The simplest decision under uncertainty —
calling a coin toss: you win $5 or nothing.

Highlights some concepts which are useful in more complex decisions.

Let's start with a volunteer ( ) and ask some questions.

1. Would you pay $1 for a ticket to play the game?
2. What's the minimum you'd sell the ticket for?
3. What's the maximum you'd pay for perfect information about the toss (from a clairvoyant)?
4. And for imperfect information?

Everyone write down your answers to Questions 2 and 3.

Coin toss

_____ values this game at ___¢.

_____ values *perfect information* at $_____

_____ values *imperfect information* at < $_____

Consistency Check

Minimum selling price
(The Certain Equivalent)
+
Value of Perfect Information
=
Maximum Payoff

But why?

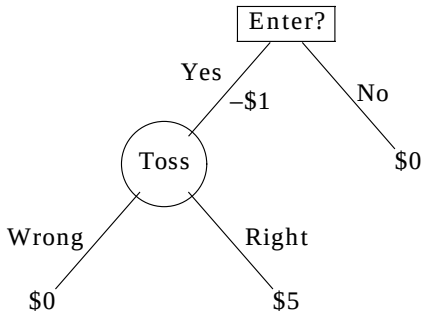
So the Value of Imperfect Information
must be less than
the Maximum Payoff
minus
Minimum selling price
(The Certain Equivalent)

Calling the Toss

Concepts:

- ➢ Uncertainty and probability
- ➢ Profit lotteries
- ➢ Decisions as allocations of resources
- ➢ Sunk cost — irretrievable allocations of resources
- ➢ Certain Equivalent — value of the lottery
- ➢ Information and probability

- ➢ Value of information
- ➢ Consistency in decision making
- ➢ Decisions versus outcomes
- ➢ What is meant by a *good decision*?
- ➢ Individual decisions, corporate decisions
- ➢ Decision trees:



2.6.1 Points to Ponder:

1. Probability is a state of mind (information)
2. Limit to the Value of Perfect Information
3. Limit to the value of imperfect information
   < the Value of Perfect Information (VPI)
4. Consistency check:

   Certain Equivalent + VPI = maximum payoff.

5. ∴ Value of imperfect information
   < maximum payoff – Certain Equivalent

6. Risk averse or risk preferring or risk neutral?

Insights?

1. The three elements of a decision:
   - *actions*: here call "Heads" or "Tails".
   - *events* are Nature's possible moves: here Heads or Tails.
   - *outcomes*: here either $5 for a correct call or nothing.

2. Her *attitude to risk*: the minimum she was prepared to sell the ticket for.

3. Her *value of information*: limited by the Value of Perfect Information, a function of the probabilities and payoffs.

3. Decision Quality

3.1 Without Decision Quality ...

- ➢ Garbage in — garbage out: GIGO
- ➢ Cannot maintain objectivity
- ➢ No better than intuition
- ➢ No commitment without quality
- ➢ No means to measure success

(See Matheson in the Readings.)

Strategic and operational decision making require different perspectives.

Operational Decision Making —

- ➢ Attends to details and follow through
- ➢ Concentrates on near-term performance
- ➢ Ignores uncertainty
- ➢ Is action based
- ➢ Is generally routine.

Strategic decision making.

Strategic Decision Making —

- ➢ Focusses on important issues
- ➢ Considers long-term horizon
- ➢ Accounts for uncertainty
- ➢ Chooses among significantly different alternatives
- ➢ Generally once-off.

Organisations have difficulty achieving high-quality decisions routinely because of:

- ➢ Lack of creative and significantly different alternatives
- ➢ Too much time spent on unimportant details
- ➢ Competing values which are difficult to trade off
- ➢ Inappropriate scope of analysis
- ➢ Scope changes at each step in the approval process

Low-quality analyses often have these oversights:

- ➢ Implementation personnel are not included in the process
- ➢ The real decision maker is not involved
- ➢ Information is obviously biassed
- ➢ Analysis is a justification of a decision already made
- ➢ New issues are raised *after* recommendation

3.2 Six Dimensions of Good Decision Making.

① *The appropriate frame:*
the correct background, setting, and context

② *Creative, doable alternatives:*
no alternatives, no decision.

③ *Meaningful, reliable information*

④ *Clear values and trade-offs:*
criteria for measuring the value of and trading off alternatives

⑤ *Logically correct reasoning:*
which alternatives maximise value?

⑥ *Commitment to action:*
implementation.

3.2.1 Frame

① *The appropriate frame:*

the correct background, setting, and context

"Have we asked the right questions?"

"Are the assumptions clearly identified?"

"Have different areas of the organisation been heard from on this issue?"

"Does this course of action fit with the organisation's strengths and larger objectives?"

3.2.2 Alternatives

② *Creative, doable alternatives:*

no alternatives, no decision.

"Have alternatives been identified and evaluated?"

"Is there a recovery plan in case of failure?"

"Is there a feasible plan for implementing the decision?"

3.2.3 Information

③ *Meaningful, reliable information*

"Have we asked the right questions and got valid answers?"

"What are the probabilities of technical and market success?"

"Have we obtained a cross-section of good information?"

"Have different areas of the organisation been heard from on this issue?"

3.2.4 Values

④ *Clear values and trade-offs:*
criteria for measuring the value of and trading off alternatives

"What is the risk/return relationship?"

"What is the expected value of the decision we're about to make?"

"What is the cost of failure?"

3.2.5 Reasoning

⑤ *Logically correct reasoning:*
which alternatives maximise value?

"Is there a clear logic to our approach to the decision?"

"What does our financial model tell us?"

"What does our marketing model tell us?"

"What does our technical model tell us?"

3.2.6 Commitment

⑥ *Commitment to action:*
implementation.

"Have different areas of the organisation been heard from on this issue?"

"Can the organisation get behind this decision?"

"Is there a feasible plan for implementing the decision?"

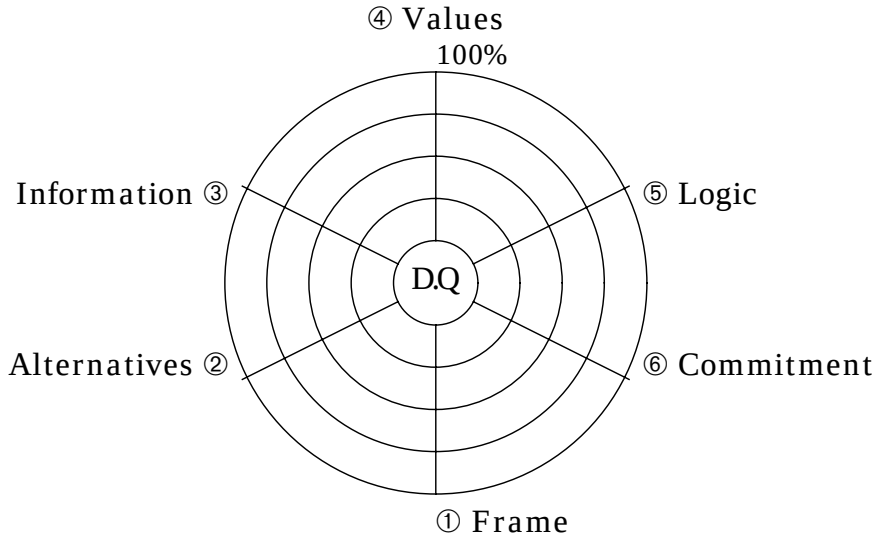
3.3 Measuring decision quality

Decision quality can be measured using a “spider” diagram.

Simple to use, and quickly points out which dimensions need attention.

Constructed by placing a dot on the axis of each dimension and then connecting the dots. The centre is zero percent quality, and the circumference is 100 percent, where additional effort to improve this dimension would not be worth the cost.

A Spider Diagram for Decision Quality.



Decision Quality Checklist.

- Management commitment to:
  - the process and
  - the recommendations
- Correctly framed problem
- Reliable, honest information
- Adequate time and resources
- Trained facilitators and analysts
- Thorough communication of the process and its results to the organisation.

3.4 Summary of Decision Quality

Without decision quality the analysis is no better than an intuitive process.

The Six Dimensions of Good Decision Making provide the foundation for ensuring decision quality.

A quality process must be in place so that the decision process is not coopted or perverted to provide predetermined answers.

The value of any analysis is the insight it provides, not the output.

e.g. golf: luck or technique?

4. Structuring the Decision

4.1 Define the Problem and the Decision Criterion

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

- What is the decision?
- Who is the decision maker?
- What is the decision criterion?

  the decision criterion can be anything that allows the decisionmaker to quantitatively distinguish one alternative from another:

  — Net present value (NPV)

  — Internal rate of return (IRR)

  — Cash flow

  — Goodwill/reputation

  — Others

Brainstorming

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

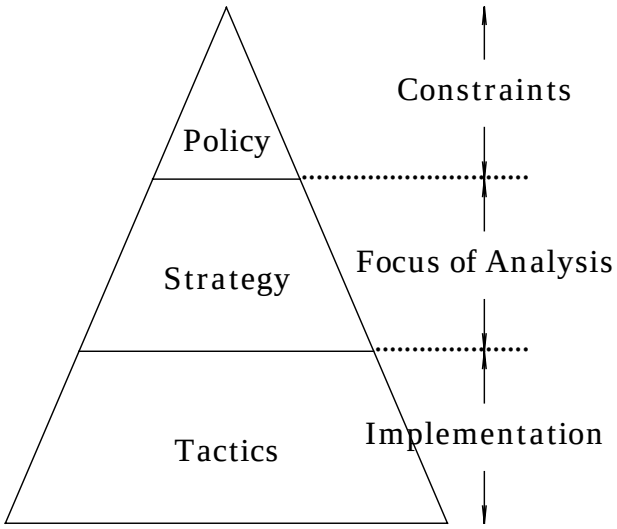
Raise issues.

Separate issues in order to begin problem framing.

Categorise the decisions using the decision hierarchy, to help identify the scope of the problem and to separate constraints and implementation from the focus of the analysis.

4.1.1 The Decision Hierarchy

The focus of decision analysis is at the strategic level.



Decision levels.

Policy decisions are constraints.

Strategy decisions are the focus of the analysis.

Tactical decisions are follow-on implementation decisions.

4.2 Influence Diagrams

The next step is to model the decision making using influence diagrams.

Influence diagrams:

- ➢ Provide a clear, graphical picture of a problem
- ➢ Show relationships and relevance
- ➢ Facilitate dialogue among team members with different backgrounds and interests
- ➢ Provide a means to compare alternatives
- ➢ Cannot have circular references or feedback loops
- ➢ Are not flow diagrams

Plotting an Influence Diagram:

Uncertainties are chance events, ◯

Decisions are controllable, □

Values are what you prefer, ◇

Arrows indicate relevance, →

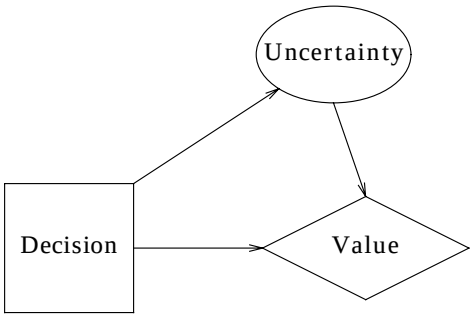
An arrow into an uncertain node ◯ means relevance.

An arrow into a decision node □ means is “known”.

An arrow into a value node ◊ means “functional”.

Influence diagrams typically flow from decisions to uncertainties to value.

Arrows indicate relevance and show relationships.

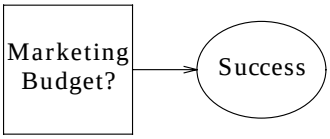


Be careful when adding an arrow: *influence diagrams are not flow charts.* The lack of an arrow says more than having an arrow.

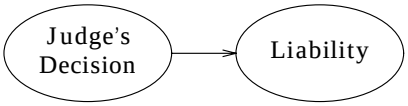
Three Types of Influence — Probabilistic:

(See DATA 3.5 Manual.)

1. *Probabilistic Influence*



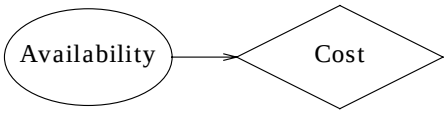
Decision about the Marketing Budget influences the probability of success.



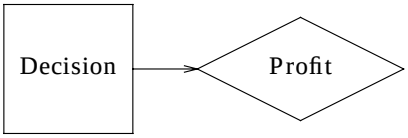
The probability of the defendent's liability depends on whether the judge will admit particular evidence.

Three Types of Influence — Value:

2. *Value Influence*



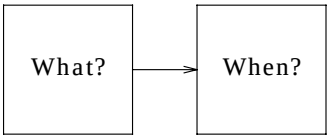
The manufacturing cost depends on the (unknown) local availability of an input.



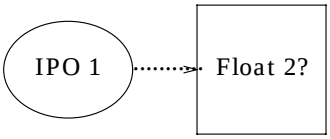
The manager's decisions influence the profit of a plant.

Three Types of Influence — Structural:

3. *Structural Influence*

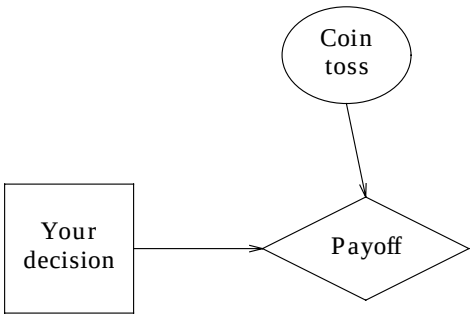


What to make is decided before When to make it.



The outcome of floating firm 1 will be known before the decision of floating firm 2 is made.

The influence diagram for the coin-tossing decision:



Since your decision (of whether to invest, and, if so, whether to call “heads” or “tails”) does not influence the outcome of the coin toss, there is no arrow from the decision node to the chance node.

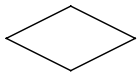
And since you will call the toss before you know the outcome, the arrow from the chance node goes to the payoff node.

This is a very common Influence Diagram. Other examples?

4.2.1 Influence Diagrams — Summary

An influence diagram provides a simple graphical representation of a decision problem. It contains at least three elements, linked with arrows to show the specific relationships among them:

- *Decisions* are represented by squares □ or rectangles.
- *Chance events* (the uncertainty of which will be resolved before the payoff) are represented by circles ◯ or ellipses.
- *Values* or payoffs are represented by diamonds:



- *Deterministic nodes* are represented by double ellipses::

Influence diagrams.

Influence diagrams provide a snapshot of the decision environment at one point in time.

They are not flow charts or diagrams.

They cannot contain cycles.

The arrows must indicate how uncertainty is revealed (all will be revealed before the final payoff, but decisions are made with some uncertainty remaining).

4.3 The Glix Case:

The Gaggle Company has developed a new product — Glix.

While you think that Glix has great potential, you are unsure whether Glix will be profitable if brought to market.

Your decision: There are three alternatives facing you:

1. launch Glix yourself
2. sell Glix to another company, or
3. licence Glix to all comers

Issues about Glix.

Issues about Glix include:

- Market size
- Revenue
- Marketing costs
- Profit
- Share price
- Manufacturing costs
- Regulations

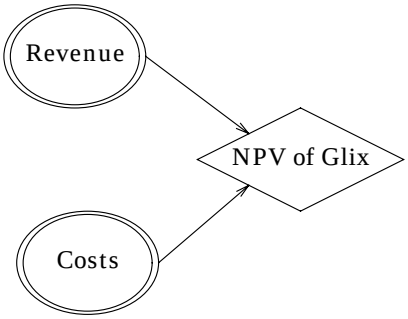
Begin by clarifying the decision and the decision criterion, and work from right to left.

The *decision* is whether: to launch; to sell; or to license the Glix product.

Management have determined that net present value (NPV) is the correct decision *criterion*.

Launching Glix: What are the determinants of net present value?

- Revenue
- Cost

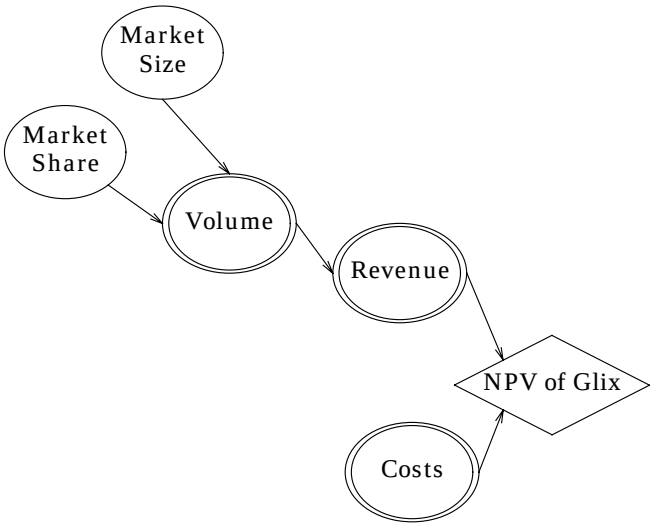


The double circles/ellipses are *deterministic nodes*: given the inputs from the predecessor (upstream) nodes, the outcome of the deterministic node can be found immediately.

What are the determinants of revenue?

What do you need to know the calculate revenue?

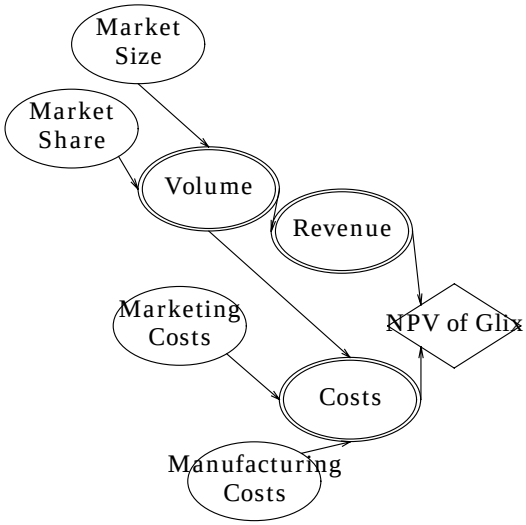
Consider the price of Glix to be $5.00 per kilo.



Next consider the determinants of cost.

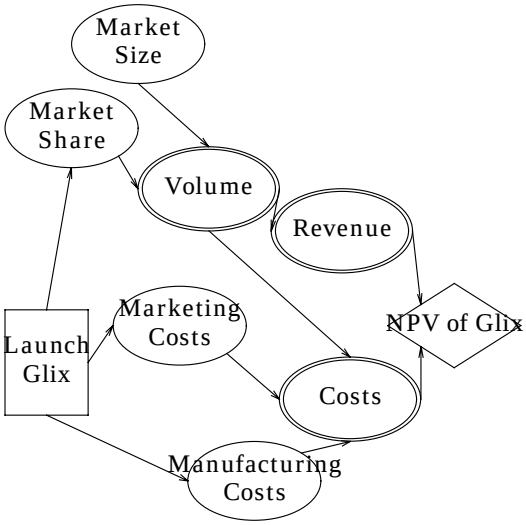
What do you need to know to estimate the costs associated with Glix?

There is a factory in place that will only need minor modifications at a cost of $1,500,000.



Lastly, we need to add the decision.

Which key uncertainties does the decision influence?



4.4 Case 2: Laura's Shoe Decision

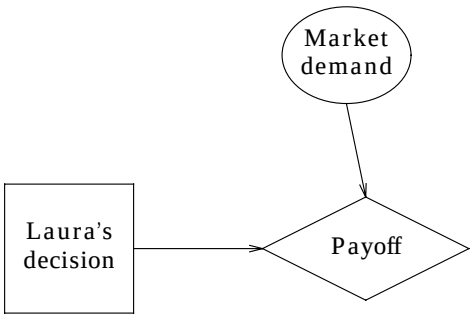
The Decision Maker: Laura, a divisional manager of a large department store,

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

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 $200,000.
- the "Retro" range, risky, a new range of 1940s retro shoes.
  - if it's a goer (successful), the net return will be $240,000, but
  - if it's a fizzer (failure), she'll net only $150,000.
  - 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?

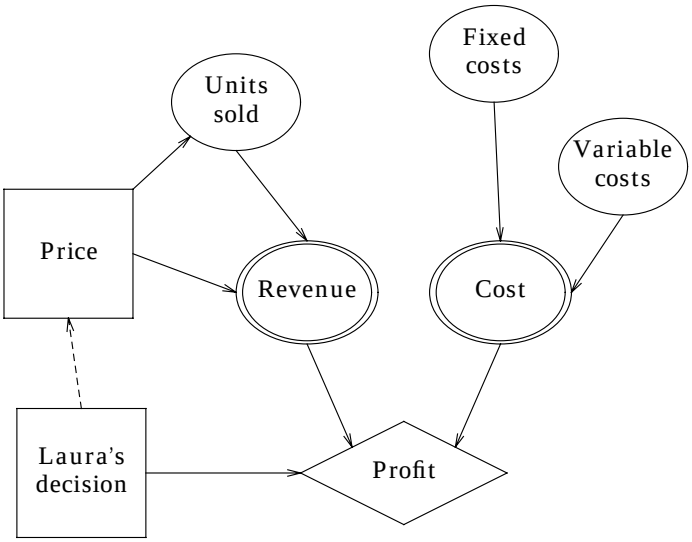
Embellishments.

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.

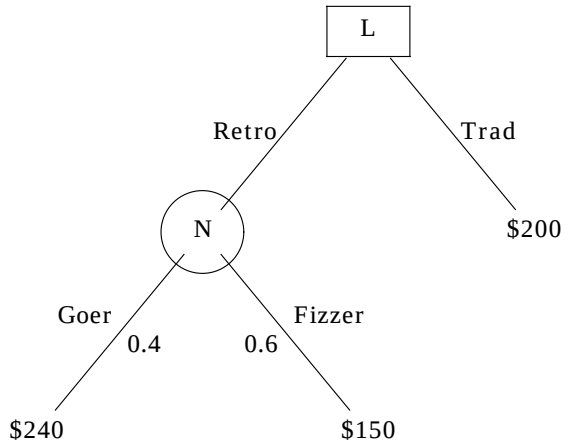


The double circles/ellipses are *deterministic nodes*: given the inputs from the predecessor (upstream) nodes, the outcome of the deterministic node can be found immediately.

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.

Laura's Decision Tree (which are introduced below)



With the payoffs and probabilities, Laura can calculate:

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

$$\$240{,}000 \times 0.4 + \$150{,}000 \times 0.6 = \$186{,}000.$$

- which is less than the certain return of $200,000 for Trad.

Laura's decison?

A risk-neutral or risk-averse decision maker 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.

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 criterion?
- Have appropriate resources been committed?

4.5 Summary of Structuring

Influence diagrams provide a graphical description of the essence of the problem.

Software (such as Treeage's DATA) allows us to model the entire decision as an influence diagram, which can be transformed into a decision tree and solved.

Influence diagrams are also a good communication tool.

The focus of 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.

4.6 Why Use An Influence Diagram?

IDs provide the ability to:

— capture and

— communicate

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

Influence diagrams:

- ➢ Help to structure the problem discussion,
- ➢ Identify influences and dependencies between decisions and uncertainties,
- ➢ 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.

4.7 Step-By-Step Procedure

IDs as much an art as a science. Focus on developing a clear and meaningful diagram. Ask probing questions. 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 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: 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.

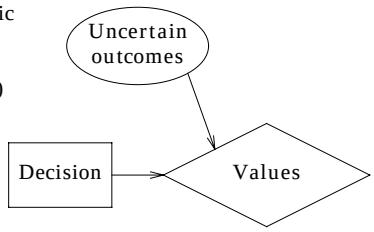
Step 8: Identify information sources and write each source's name by the node it can resolve.

Step 9: Is the diagram complete and has the problem been described accurately?

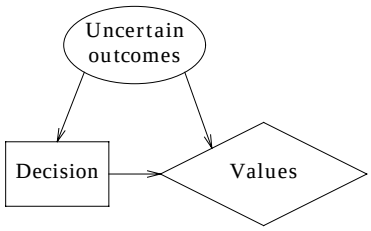
Step 10: Write an information-gathering task list.

4.8 Types of Influence Diagrams

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

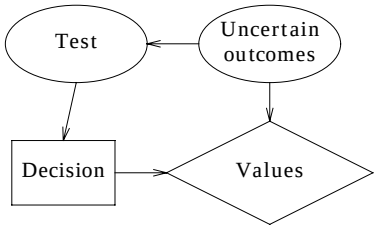


2. As no. 1, plus Value of Perfect Information. (Compare EV of 2. with the EV of 1.) (e.g. the clairyoyant)

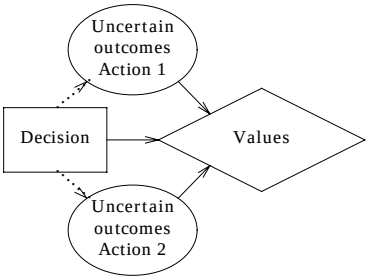


Types of Influence Diagrams

3. Value of Imperfect Information
(Compare the EV of 3. — less than the EV of 2. — with the EV of 1.
(e.g. test marketing, forecasting)

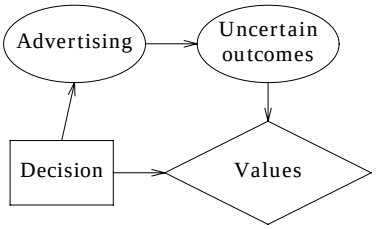


4. Probabilities are a function of the alternative chosen.
(e.g. nuptial vows)

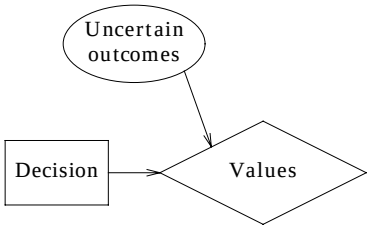


Types of Influence Diagrams (cont.)

5. Decision influences the probabilities.
(e.g. advertising)

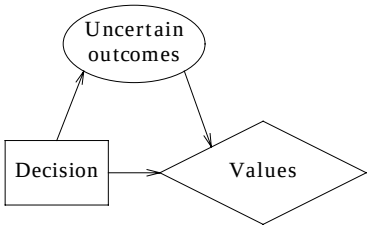


6. Insurance
(such as an umbrella)

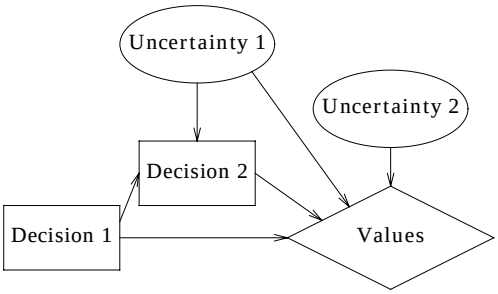


Types of Influence Diagrams (cont.)

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



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



4.9 Hidden Traps in Decision Making

(See Hammond, Keeney, and Raiffa)

1. The Anchoring Trap
2. The Status-Quo Trap
3. The Sunk-Cost Trap
4. The Confirming-Evidence Trap
5. The Framing Trap
6. Estimating and Forecasting Traps
   - Overconfidence
   - Prudence
   - Recallability

4.9.1 The Anchoring Trap

Is the population of Argentina greater than 35 million?

What's your best estimate of Argentina's population?

The first question "anchors" your answer to the second, given that you don't know the answer.

Examples: a comment, a past trend, old numbers, history, an opening offer in negotations

What to do?

— different perspectives

— think and write by yourself first

— be open-minded

— don't anchor your advisors

— beware in negotiations

4.9.2 The Status-Quo Trap

Example: "horseless carriages", inherited shares.

What to do?

— remember your objectives

— identify other alternatives

— would you have chosen the s.q. if it weren't?

— avoid exaggerating the cost of switching

— look ahead — will the s.q. always be attractive?

— choose the best of the superior alternatives

4.9.3 The Sunk-Cost Trap

Warren Buffet: When I find myself in a hole, I stop digging.

"Throwing good money after bad."

What to do?

— get uninvolved views

— why does admitting an earlier mistake distress you?

— look for s.c. biases in subordinates

— don't allow perpetuation of mistakes via corporate culture

4.9.4 The Confirming-Evidence Trap

Seeking information that supports our instinct or point of view, while avoiding information that challenges it.

What to do?

— look at all evidence equally: question confirmation

— a Devil's Advocate

— what are your motives?

— don't ask leading questions of advisors

4.9.5 The Framing Trap

You are the marine property adjuster charged with minimizing the loss of cargo on three insured barges that sank yesterday off the coast of Alaska. Each barge holds $200,000 worth of cargo, which will be lost if not salvaged within 72 hours. The owner of a local marine-salvage company gives you two options, both of which will cost the same:
Plan A: *This plan will save the cargo of one of the three barges, worth $200,000.*
Plan B: *This plan has a one-third probability of saving the cargo on all three barges, worth $600,000 but has a two-thirds chance of saving nothing.*

Which plan would you choose?

Plan C: *This plan will result in the loss of two of the three cargoes, worth $400,000.*
Plan D: *This plan has a two-thirds probability of resulting in the loss of all three cargoes and the entire $600,000, but has a one-third probability of losing no cargo.*

Examples: gains versus losses, different reference points

A 50:50 chance of either losing $300 or winning $500 versus *keeping your $2000 account or accepting a 50:50 chance of $1,700 ot $2,500 in your account.*

What to do?

— don't automatically accept the first frame: "think different"

— try posing problems in a neutral way that combines gains and losses

— keep thinking about your framing

— how have others framed the problem? challenge them

4.9.6 Estimating and Forecasting Traps

Examples: overconfidence in your forecasting abilities, over-cautiousness, remembering the outliers.

What to do?

— discipline yourself: forecasts, values, probabilities

— consider extremes first, then challenge yourself to extend them

— state your estimates honestly

— use data, not impressionable memories

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