GEO530
Decision Analysis with Geostatistic
Lecture 15 - 030417

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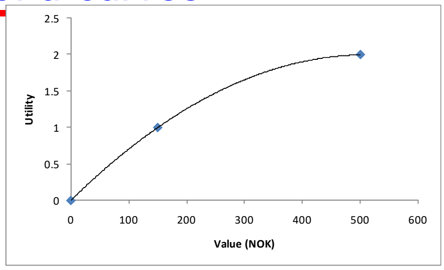
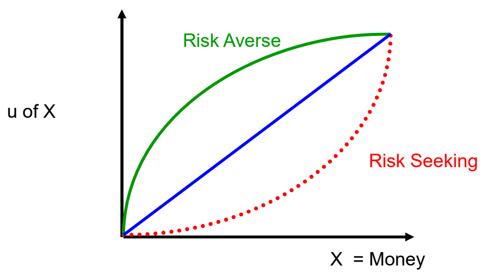
Some general properties of u-curves

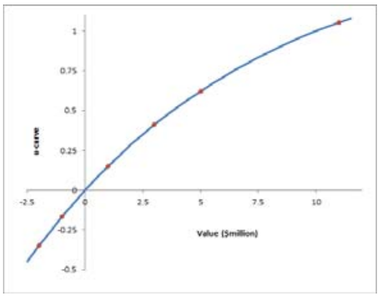
- Monotonically increasing
- It is the curvature of the function that is important
- Risk-neutral behavior (CE = EV) is described by a straight-line utility function
- Risk-seeking behavior is possible.





u-curves

- u-curves can be of any form or shape
  - Not limited to exponential
- Exponential and logarithmic most common functional forms



- u-curves can be elicited point-by-point
  - No functional form
  - Can curve fit point to generate an approximate function
  - A u-curve in functional form is not required but is easier to work with

When to Use the Exponential u-curve?

$$u(x) = a - be^{-x/RT}$$

- What is a reasonable range of values for which the exponential function is adequate?
- Normally, a reasonable range is one for which none of the values (positive or negative) are much larger than the risk tolerance
- There are a number of other functional forms that fit well to u-curves with a wider range of values but that are not as convenient to work with
- In general, probability distributions should be explicitly examined by the decision-maker when they involve a range of values so great that the exponential u-curve is inadequate
  - Decision makers will not rely solely on the decision implied by a u-curve when so much is at stake.

The Delta Property

- There are two families of u-curves for which the calculation of VOI is greatly simplified.
- If a decision maker has a u-curve that belongs to either one of these families, she satisfies the delta property and we can simply calculate the VOC as
  - *VOC = CE(free Clairvoyance) - CE(no Clairvoyance)*
- This simplification is of such great practical importance that it is wise in many cases to assume that the delta property holds exactly when it is close to being acceptable

Forms of u-curve Required by the Delta Property

- Straight line

$$u(y) = a + by$$

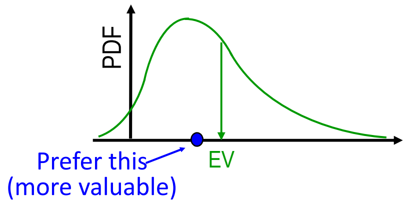
- Exponential

$$u(y) = a + be^{-\gamma y} = a + be^{-y/\rho}$$

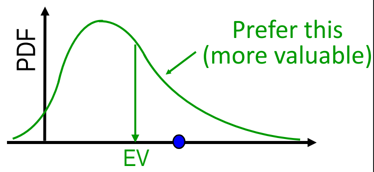
where: γ = Risk aversion coefficient
ρ = Risk tolerance

Risk Attitudes

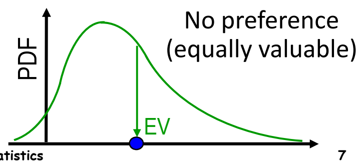
- Risk-Averse
  - Prefer (ascribe higher value to) a sure option (P=1) that is of less $ value than the Expected Value of the uncertain option
  - we put extra value on certainty



- Risk-Seeking
  - Prefer (ascribe higher value to) the uncertain option whose Expected Value in $ is less than a sure option
  - we put extra value on uncertainty



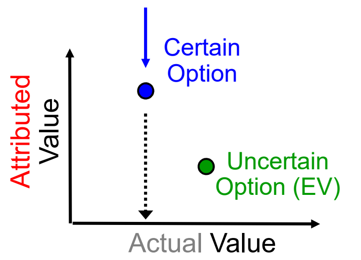
- Risk-Neutral
  - No preference (ascribe same value) between a sure option and an uncertain option with the same Expected Value



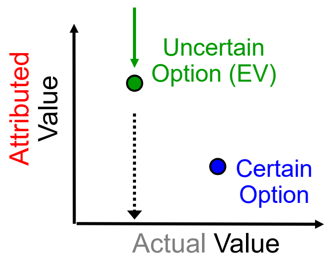
What is the Impact of Adopting a Risk Attitude?

- Choosing the certain option guarantees the actual value
- Choosing the uncertain option ensures that the actual value we will get in the long run (= over multiple decisions) is its EV, or close to it.

Risk-Avoiders Choice



Risk-Seekers Choice



In both cases (risk-seeking and risk-aversion) the lower actual value option is preferred!

Probability Calibration

Most decision situations involve events that that will occur once and once only

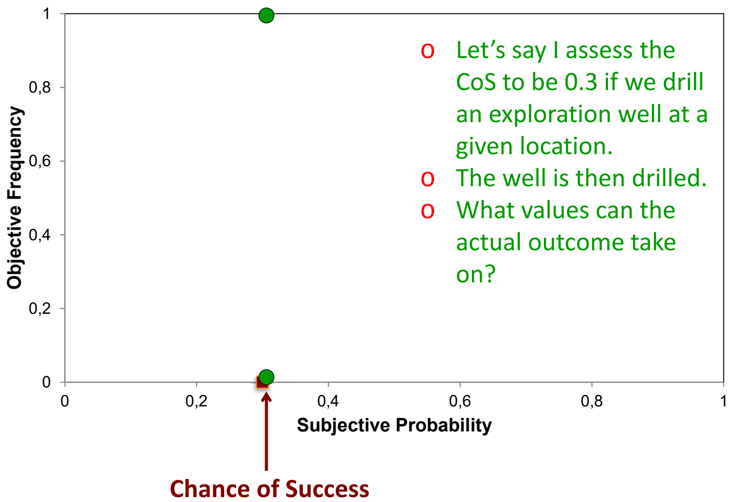
- There are many events that can be thought about in a probabilistic sense that do not fit with the frequency interpretation:
  - The next president of the US will probably be a woman
  - There's a greater chance of hitting a dry zone than commercial hydrocarbons if we drill at this location
  - Statoil will probably lose money on project XYZ
- These statements appear to be probabilistic statements and their meaning is clear to most listeners.
- Each of the four probability statements describes the speaker's *degree of belief* about a situation that will occur once and once only.
  - No repetitive trials of the uncertain situation

We use models that depend heavily on subjective estimates and yet ignore the research about how well experts estimate and how to adjust for their errors

- Probability judgments are not simply waiting in our heads to be pulled out when needed
- Discovering and developing these requires hard and systematic thinking about the important aspects of a decision
- Human beings are imperfect information processors
  - Personal insights about uncertainty and preference can be both limited and misleading
  - An awareness of human cognitive limitations is helpful in developing the necessary judgmental inputs

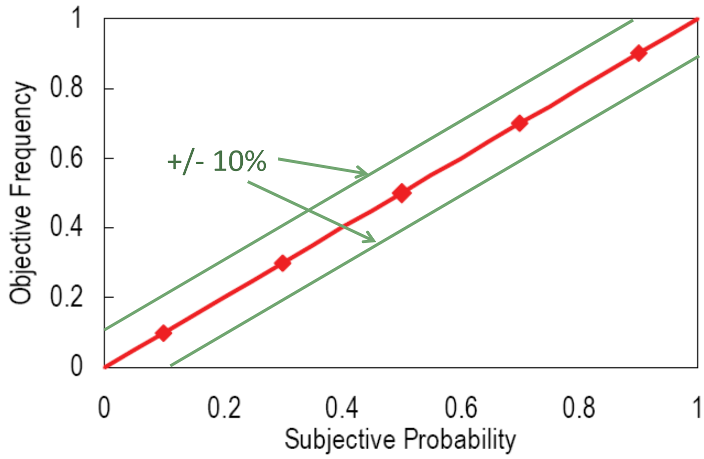
A disciplined elicitation and calibration process, not individual genius, is the key to improved assessments

What does it mean to be well calibrated?

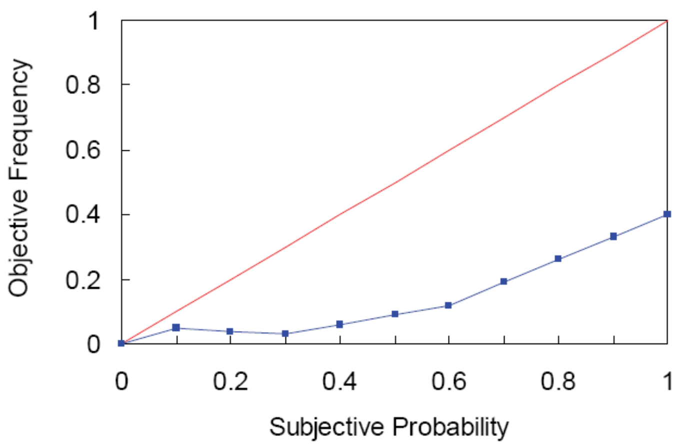


- Let's say I assess the CoS to be 0.3 if we drill an exploration well at a given location.
- The well is then drilled.
- What values can the actual outcome take on?

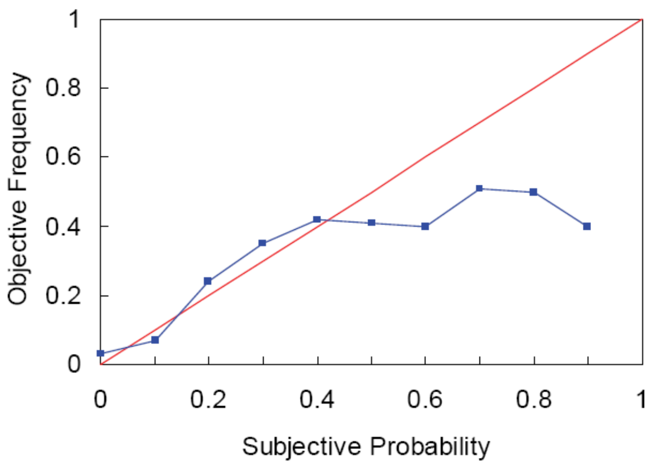
If a person is well calibrated, the Observed Frequencies (roughly) Match the Probabilities Assessed



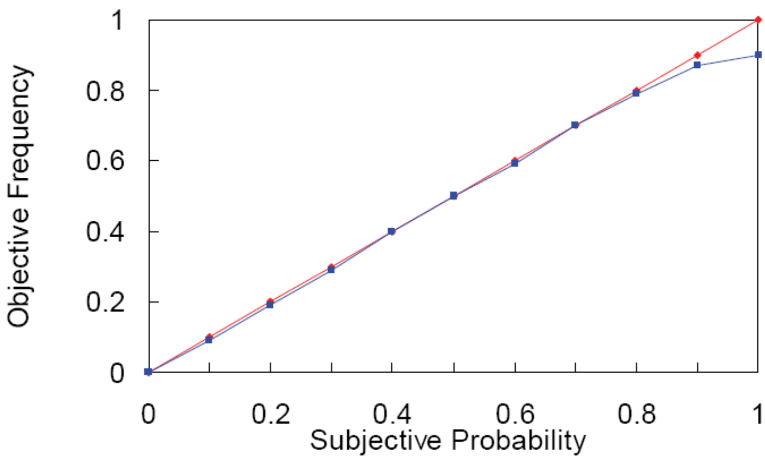
Example:Physicians diagnosis of pneumonia



Example: Economists’ predictions of recession in 3 – 6 months



Meteorologists’ prediction of precipitation (US)

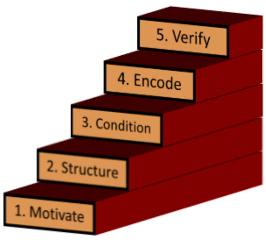


Champion Assessors

- The US Weather Service requires that forecasters give probabilistic forecasts for rain
- The forecasters are graded on their forecasts and promotions and pay raises are partially based on their performance
  - Motivation
  - Practice
  - Repetitive task

The quality of an assessment depends on recognizing biases and compensating for them

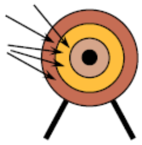
- Biases
  - Anchoring, overconfidence, group dynamics, recency, availability, illusion of control, over-optimism, motivational bias
  - Kahneman: *Thinking, Fast and Slow*
- Several methods exists for helping subject matter experts overcome these biases when assessing probabilities
- One of the most effective and commonly used was developed by Stanford Research Institute
  - 5 step procedure



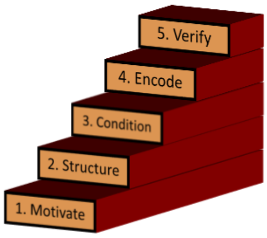
The goal is not to reduce uncertainty but to quantify the experts' degree of belief

We will discuss quantifying uncertainty with ranges and probability

- Avoiding biases



- Assessing ranges



The quality of an assessment depends on recognizing biases and compensating for them.

Expert Judgment Elicitation

Structured approach to capturing an expert's knowledge base and convert his/her knowledge base into quantitative assessments

Modelers skilled in decomposition and aggregation of assessments

NORMATIVE

EXPERTS

SUBSTANTIVE

Knowledge about the subject matter and extensive experience

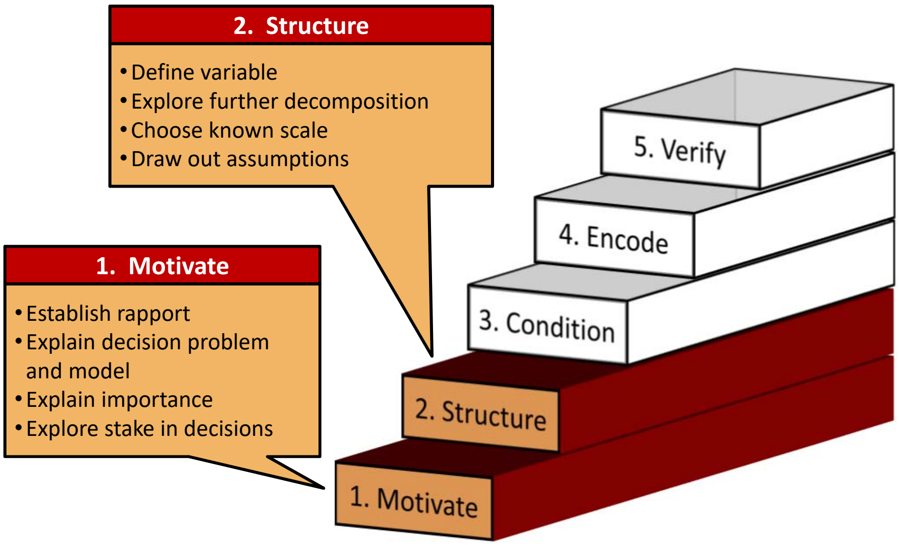
Elicitation process = Multiple cycles (at least 2)

1. Decomposition of event of interest to a meaningful level for substantive expert

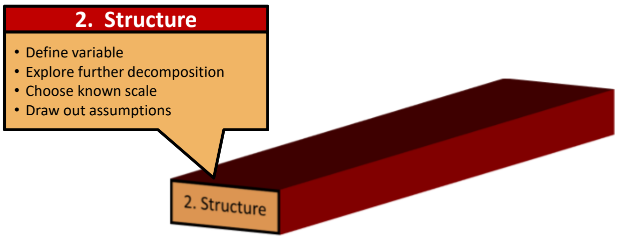
2. Elicitation of judgment of substantive expert facilitated by normative expert

3. Aggregation of judgment by normative expert

The first two steps motivate and structure the assessment

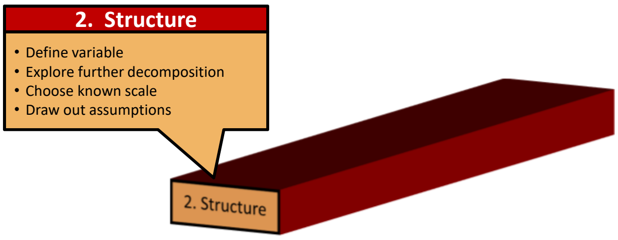


Define Variable – The Clarity Test



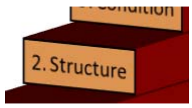
- Exploration Success
- Oil Price in Five Years
- Rain Tomorrow

Define Variable – The Clarity Test



- Exploration Success
  - Oil or gas show
  - Sufficient promise to justify completing and testing the well
  - The testwell produces commercial volumes of hydrocarbons
  - The field is developed and produced
  - The entire project produces profit

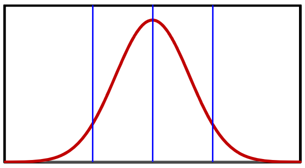
Document the definition and units



Oil price (Brent) on December 31, 2020	**Brief Description:** Spot price of Brent oil on Nymex
Units: US dollars per barrel	
Detailed Description: The average price of Brent oil as traded on the New York Stock Exchange on December 31, 2020	

Level of detail in probability distributions

- The most important uncertainties should be developed through a full encoding process
  - Many points assessed from some expert
- In practice, it is most important to obtain quality in the P10 - P50 - P90 values
  - Describes the uncertainty with three numbers
  - Give three point on the curve
  - Are used for sensitivity analysis in the early stages of the decision analysis

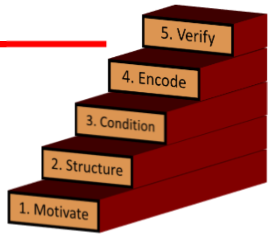


- Care should be taken in obtaining quality numbers
  - A second encoding session rarely occurs

One way to verify results is to ask "check" question

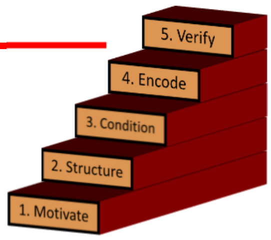
- Ask if the expert would rather bet on:
  - Whether the actual value will be below the 10^{th} percentile or above the 90^{th} percentile
  - Whether the actual value will be between the 10^{th} percentile and 50^{th} percentile or between the 50^{th} percentile and 90^{th} percentile
  - Whether the actual value will be above or below the 50^{th} percentile
- If the expert is not indifferent to each of these bets, revise the assessment

Elicitation Principles



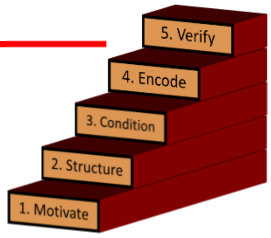
1. Reproducibility
   - It must be possible for peers to review and if necessary reproduce all calculations.
   - This means that the calculation model must be fully specified and the ingredient data made available
2. Accountability
   - The source of Expert Judgment must be identified (who do they work for and what is their level of expertise)
3. Empirical control
   - Expert probability assessment must in principle be susceptible to empirical control

Elicitation Principles



4. Neutrality
   - The method for combining/evaluating expert judgments should encourage experts to state true opinions
5. Fairness
   - The source of Expert Judgment must be identified (who do they work for and what is their level of expertise)

Practical Elicitation Guidelines



1. The questions must be clear
   - Prepare an attractive format for the questions and graphic format for the answers
2. Perform a dry run
   - Be prepared to change questionnaire format
3. An analyst must be present during the elicitation
4. Prepare a brief explanation of the elicitation format and of the model for processing the responses
5. Avoid coaching (you are not the expert)
6. The elicitation session should not exceed one hour

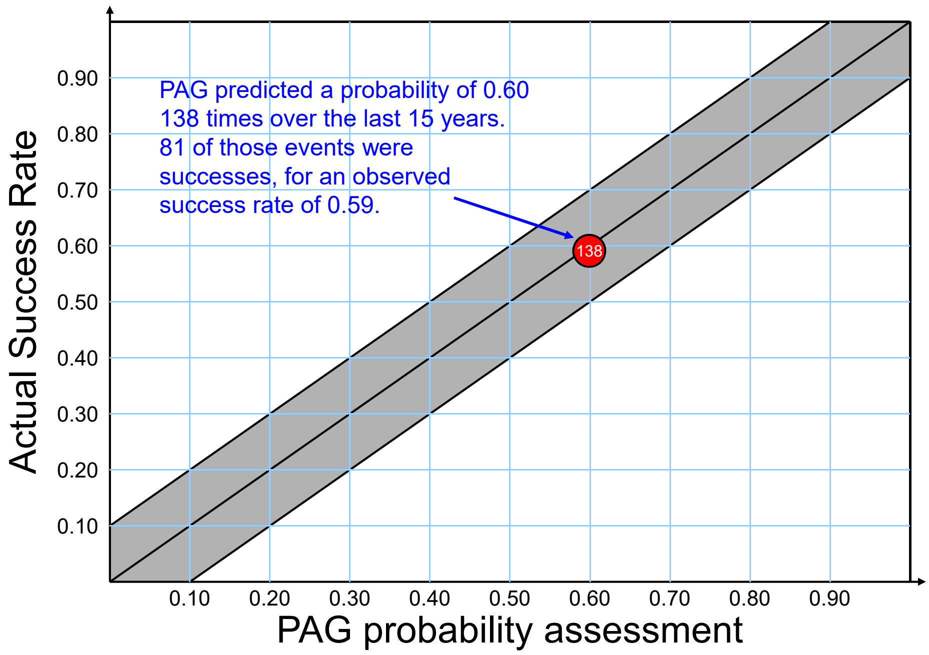
Probability Assessment in a Large Pharmaceutical Company

- In early 1997 an independent assessment group (PAG) was charged with the responsibility of objectively assessing the P(Technical Success) of projects.
- As of 2013, the company's database had over 940 probability estimates.
  - Estimates have been coupled with actual success and failures to determine the accuracy of probability assessments.

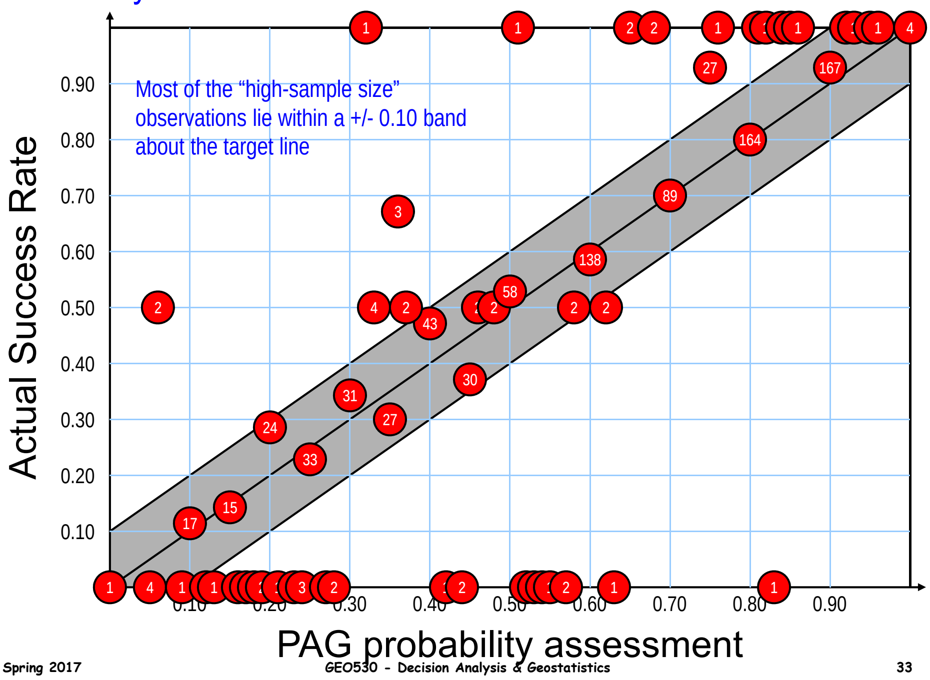
Assessment Group: Membership and High-Level Process

- Membership – some of the top scientists in the company
  - Breadth & depth of knowledge, objectivity, check ego at the door
  - Secretary – experienced probability facilitator
- Typical meeting – covers about 4-6 projects over one hour
- Pre-read contains the team development plans and perspectives, plus any previous assessments and rationale by the PAG itself
- Focus of the meeting is on the scientific discussion
  - Helps to have a secretary that can mange the flow of the discussion
  - Is the project new? How is it different from typical?
  - Has the project been assessed before? What has changed?
  - *Calibration!* How does this project compare to others?

Probability Assessment



Probability Assessment



Mean probability score

$$\overline{PS} = \frac{1}{n}\sum_{i=1}^{n}\left(f_i - x_i\right)^2$$

n = total no of forecasts (assessments)
f_i = ith probability forecast, $0 \le f_i \le 1$
x_i = outcome 1 or 0 for the ith forecast (1 = event occurred)

Interpretation

$$0 \le \overline{PS} \le 1$$

0 = perfect fit
1 = perfectly wrong

Example

- Two geologists provide very different assessments of the chance-of-success for three development or step-out wells

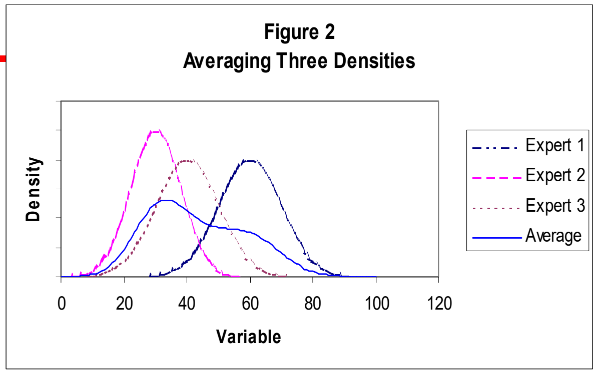
Well	Adams	Baker	Outcome	Adams	Baker
A-5	0.8	0.2	1	0.04	0.64
A-12	0.2	0.7	0	0.04	0.49
B-8	0.5	0.5	1	0.25	0.25
			Mean PS	0.11	0.46

- Based on this (very limited) evidence, Adams appears to be better (lower mean PS) than Baker at judging the Chance of Success

Probability Calibration
How Many Experts?

How Many Experts?

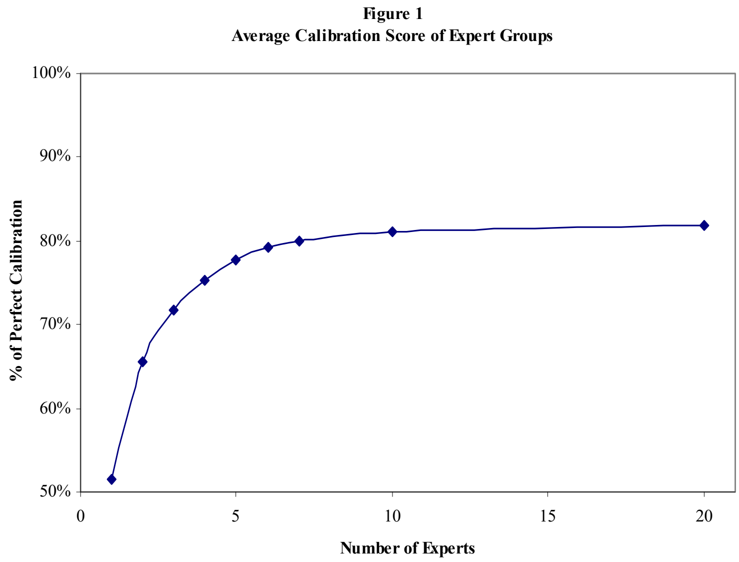
THE DIFFERENCES AMONG EXPERTS MAY OUTWEIGH THE UNCERTAINTY EXPRESSED BY INDIVIDUAL EXPERTS



How Many Experts?

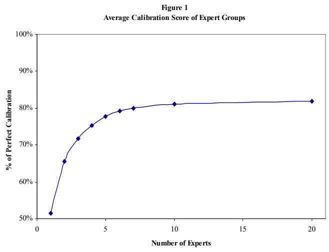
There is no single answer to this question

- Complex issues or issues spanning disciplines may require more experts
- Are experts likely to be dependent?
- How big is the budget like?
- How important is the issue?
- How many real experts are out there?
- Will experts act independently or as a team?



How many experts?

- One expert is not enough
- Three to six seem to be enough
- Calibration and information are both important
- Simple aggregation rules work well



Conclusions – Probability Assessments

- We are not very good at assessing probabilities
  - cognitive limitations, biases
- In order to become good at assessing probabilities, we should
  - adopt elicitation procedures that are designed to minimize the impact of cognitive limitations and biases
  - use calibration measure to investigate past probability assessments
  - use the learning based on past assessments to improve future assessments
- If possible, use more than one expert but no more than 6

Multi-Objective Decision-Making

MGD – Chapter 2

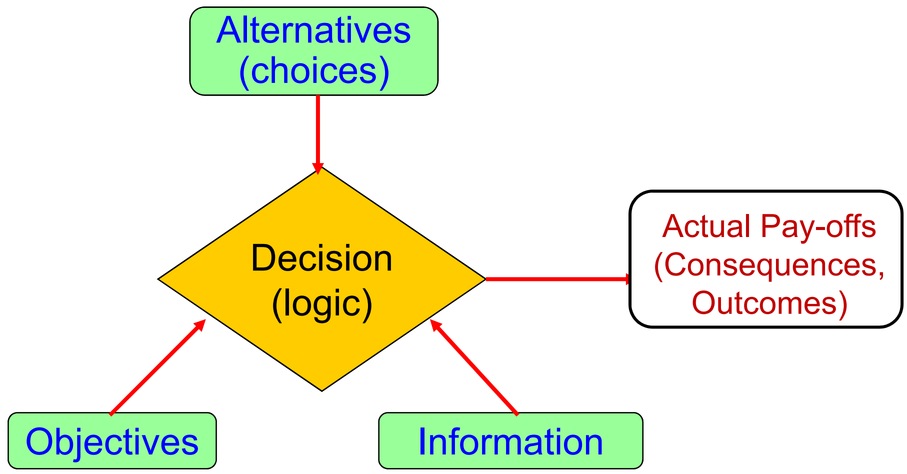
List what you think are the main elements of any decision problem

- Discuss in pairs for a couple of minutes, then list

*Elements of Decision Problems

- Values & Objectives
  - What you want
- Alternatives or Choices
  - What you can do
- Information
  - What you "know"
- Consequences or Pay-offs
  - What you will get
- Decision Criteria
  - How you will choose

*Elements of a Decision Problem



Elements: What is a decision?

- Chambers 20th Century Dictionary
  - "the act or product of deciding; settlement; judgment"
- Not very helpful !!

A <u>decision</u> is a conscious, irrevocable allocation of resources to achieve a desired objective

- Conscious: A deliberate act (not reflexive or involuntary)
- Irrevocable: Even if you change your mind later, you have lost resource (time, money, willpower)
- Must be two or more alternatives

Elements: Values and Objectives

- Values – general things that matter to you
  - Be rich, happy, profitable, successful
  - Learn a language
- Objectives – specific thing you want to achieve
  - Be top quartile performer
  - Maximize NPV
  - Minimize risk
- Objectives are often linked and hierarchical
  - Minimize costs => maximize profit
- An individual's objectives, taken together, make up his or her values
  - They define what is important in making a decision
  - Values are the reason for making decisions in the first place!

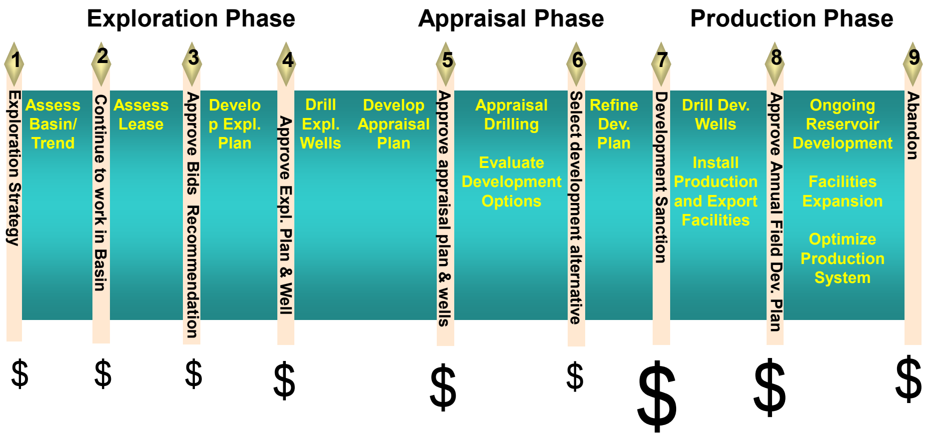
Elements: Alternatives (Choices)

- The list of things, options, strategies, courses-of-action to choose between
- For some decisions these will be specified by the decision context:
  - e.g. choose a new hire from the list of applicants
- For decisions with more of a problem-solving nature, the alternatives are open ended
  - coming up with new solutions is a major part of the process
  - a value creating activity
  - e.g. find the best well-site, develop and choose a field-development strategy

Elements: Information – Uncertain Events & their Outcomes

- Some future event or current state-of-nature whose outcome is unknown
  - Oil price next year
  - OOIP
- Outcomes are the possible things that can happen in the resolution of an uncertain event
- Multiple uncertain events might be considered but only some are relevant. Which?
  - those whose outcomes can impact at least one objective
- Beware of concentrating only on events you can model (or get information about) and ignoring those you cannot
- Events can be dependent
  - stock market goes up/down –> specific stock goes up/down
  - knowing something about one event tells you about another!

Major Oil-field Life-Cycle Decisions



Decisions versus Uncertainties

Decisions (controllable)

Uncertainties (not controllable)

- Specific things we can do
- Choices we can make
- Things we can influence
  - Investment
  - Partnering options
  - Gathering information
  - Running experiments

- Little to no influence
- Variance in input & output
  - Subsurface issues, Nature
  - Competitor actions
  - Market issues
  - Political issues
- Luck, chance

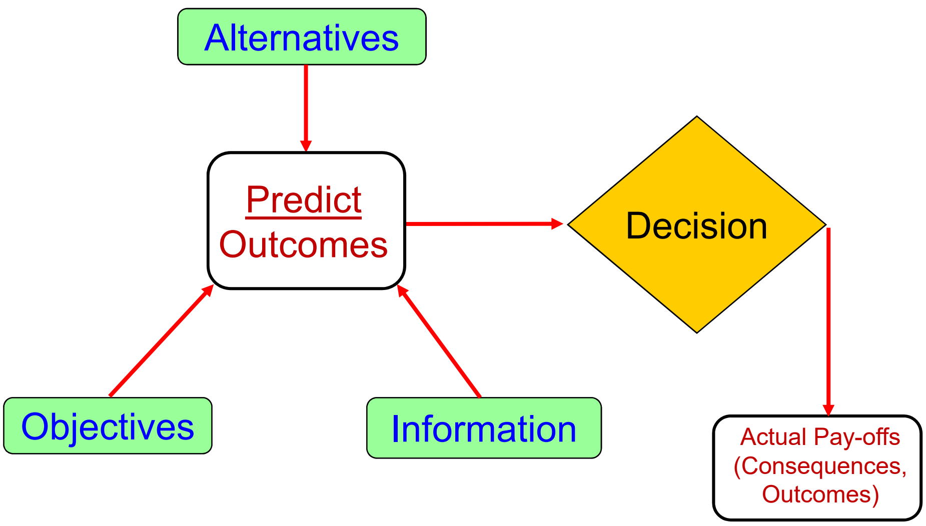
Luck

- By definition, luck (or unluck) is something over which you do not have control, therefore:
  - People are not inherently lucky or unlucky.
  - Lucky or unlucky things happen to people.
- People cannot “create their own luck”
  - but they can plan to exploit good luck when it happens, and minimize the impact of bad luck when that happens
  - “Plan”: by creating environment or opportunity, and preserving/creating good decision options when luck/unluck happens (rather than live with fate.)

Elements: Consequences or Pay-offs

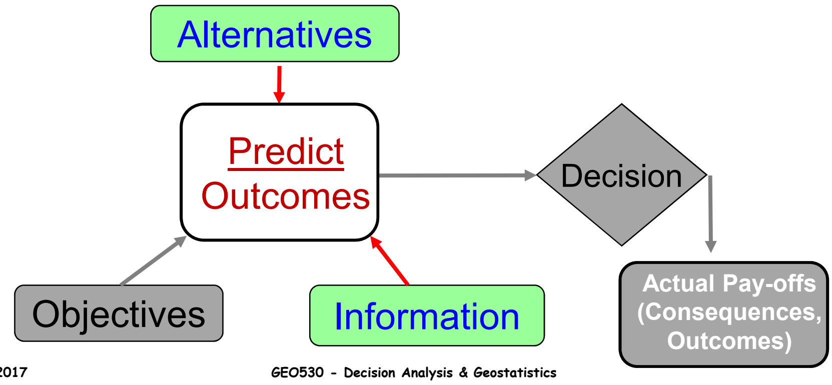
- Consequence or pay-off is what happens with respect to each objective after the decision(s) is made and the outcomes of uncertain events are resolved.
  - You made a profit of $10,000 or a loss of $2,000
  - You are happy at your new job
  - The actual outcome has no influence on the decision (unless known in advance)
- But how far into the future do you look for the consequences and their follow ons?
  - This is the "Planning Horizon"
  - Choose it such that events and decisions that follow are not part of the immediate decision
- The consequences, or pay-offs for each objective have to be valued, and if objectives conflict, trade-offs have to be made.
  - Next years oil rate v. ultimate recovery

Structure & Analysis (Model) of Decision-Making



Engineering & Geoscience Input to Major Decisons

- Engineering is largely
  - the design of the alternatives to be chosen between, and
  - of the “performance” of those alternatives



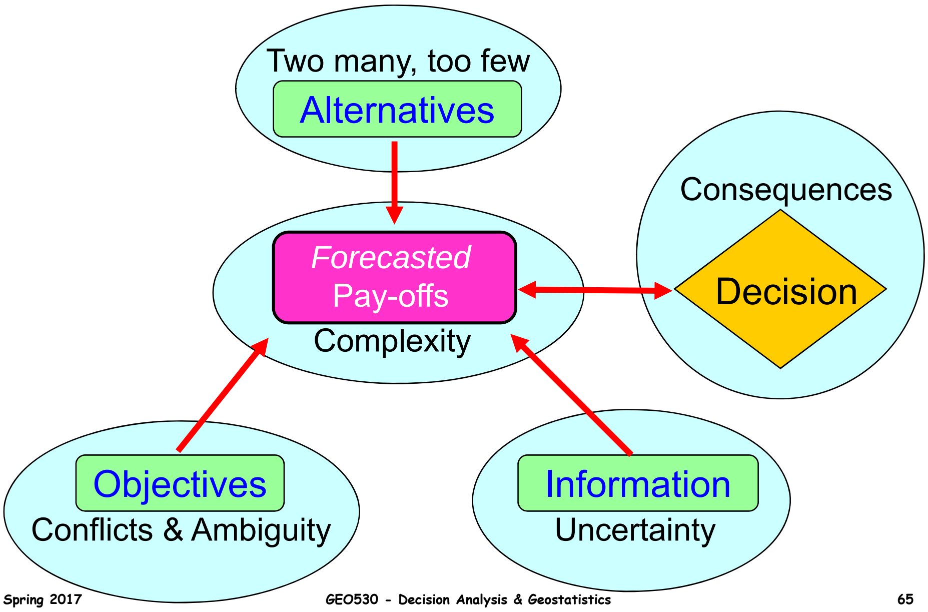
Decisions in minutes: Conversational approach to better decision making

- A good understanding of the elements is key to efficient decision-making.
  - Get into the habit of structuring decision-making conversations around the three main elements – in this order:
- Objectives:
  - “so what de want to get out of this decision?”
  - “is there anything else, anything we missed?”
  - “what is most important?”
- Alternatives:
  - “what are our options?”
  - “can’t we think of anything better?”
- Information:
  - “what do we know about how each option will satisfy our goals?”
  - “are we sure of these predictions?”, “what is the evidence?”

* Why are decisions hard?

- Multiple goals, objectives or criteria
  - Non-monetary values, (safety, environment, reputation)
  - Different measures for each criteria
  - Competing or conflicting criteria, or trade-offs
  - Ambiguous goals/objectives
  - Conflicting values when multiple decision-makers
- Complexity
  - Timing/sequencing, number of factors involved
  - Large number of alternatives are possible
    - Not all might be known or considered
- Uncertainty
  - Current states-of-nature or future events
- Too many, or too few, alternatives (no good ones)
- Anxiety about consequences
- Time pressure

Factors Surrounding High Level Decision Elements



What Makes a Good or Bad Decision?

- The weather report on the evening news predicts a warm, dry sunny day tomorrow
- When you get up and look out the window in the morning there's not a cloud in sight
- You decide to leave your umbrella at home and get soaked in an unexpected afternoon thundershower

Did you make a good or bad decision?

*Decisions vs. Outcomes

- One of the most important distinctions in DA.
- A good decision is one that is logically consistent with our objectives, alternatives, preferences and information
- You explicitly determine the quality of a decision *before* knowing the outcome.

When assessing how "good" a decisions was, an important question to ask is:

what other outcomes were possible and what were the chances of each?

A good outcome does not necessarily imply a good decision

Quality of Outcome

Quality of Decision		Good	Bad
	Good	Driving sober and arriving safely	Driving sober and getting into an accident
	Bad	Driving drunk and arriving safely	Driving drunk and getting into an accident

A good decision does not turn bad because the outcome is bad

A bad decision does not turn good because the outcome is good

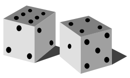
*Illusion of Control

- Illusion of control frequently causes people to repeat actions that in the past were followed by success.
- This is true even if there's no reason to believe the actions did anything to cause the success.
- Only by realistically assessing the role of chance in successes can you learn which of your actions you should repeat and which could be improved.

• uncontrollable factors, luck

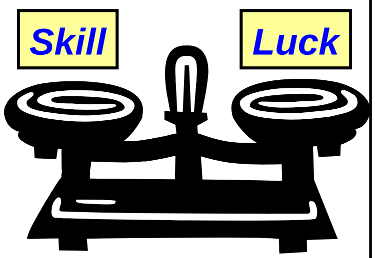
Are good results due to *skill* or *luck* ?

"The folklore of every company contains accounts of heroic decision makers, stalwarts who made crucial decisions under conditions of great uncertainty and were right. And they did this time and time again... Admiring such heroic decision makers makes about as much sense as admiring the heroic pennies that come up heads in each of the twenty tries of the usual introductory probability theory example."



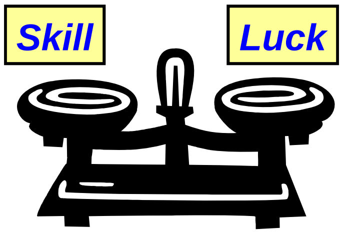
– Ritti, R. R. and S. Levy (2006). The Ropes to Skip and the Ropes to Know: Studies in Organizational Behavior, John Wiley & Sons.

Remarkably – very few, if any, oil companies make any serious attempt to answer the skill vs luck question



- They simply assume that a run of success is evidence of good decision making skills
  - Even when the success would require only moderate luck
- When the money involved is large enough, even one or two successes will do:
  - "Look, she has just made us $500 million. That can't be luck!"

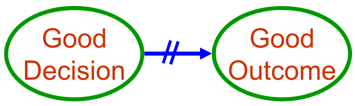
Answering the *skill* or *luck* question is not easy



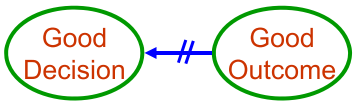
- Real world oil & gas decision making is often complex
- It is hard to tell whether or not a decision maker's performance can reasonably be attributed to luck
- This complexity and lack of repeated decisions makes it difficult to know whether or not a decision-maker's processes are good
- Yet, if you make decisions in oil company, or manage people who do, you should try to answer these difficult questions
  - Otherwise, for all you know, you could be paying people for just having been lucky (and penalizing them for being unlucky)

In an uncertain world, decision quality cannot be judged by a single outcome.

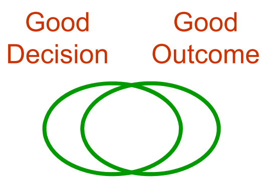
- When risk or uncertainty are present, making a good decision does not guarantee a good outcome.



- Conversely, a good outcome does not necessarily mean that a good decision was made!



But… when many, or a portfolio of decisions, are considered, there is a strong relationship between the number of good decisions and good outcomes.



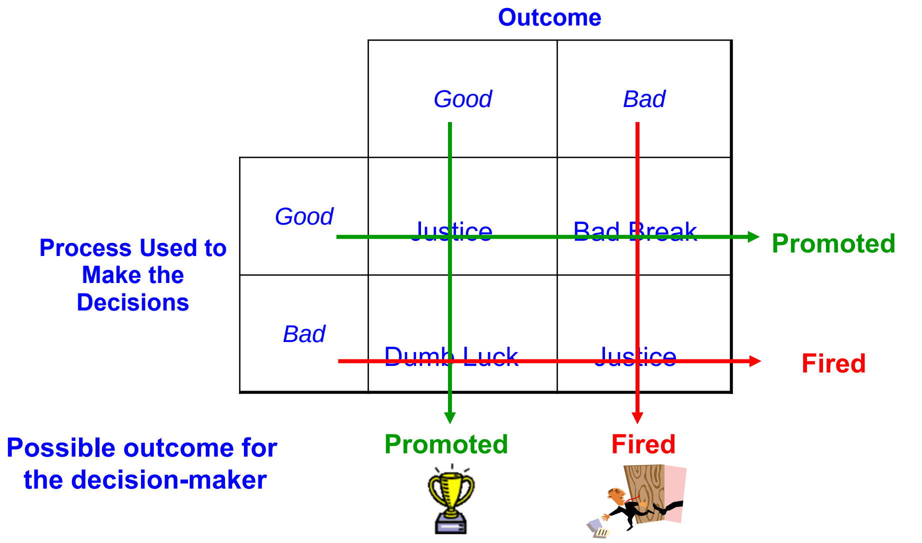
Questions: Discuss in pairs for a few minutes

- Do you currently face an important decision (work or personal)? If so, what uncertainties are you facing that make the decision difficult.
- Give an example of a recent decision you made involving uncertainty.
  - Was the outcome lucky or unlucky?
  - Was your process good or bad?

Too Much Focus on Outcome is Driving Poor Decision-Making

- The best hope for a good outcome is a good decision-process.
  - Decisions that are logically consistent with the alternatives we perceive, the information we have, our goals and objectives, and preferences between them.
- In an uncertain world a large number of decisions are required to expose the lucky-fool or to recognize the astute decision-maker
  - “in the long-run”

Decisions and incentives



Summary: Good Decisions vs Good Outcomes

- A *good outcome* is a future state of the world that we prize relative to other possibilities.
- A *good decision* is an action we take that is logically consistent with
  - the alternatives we perceive, the information we have, and the preferences we feel.
- The *quality* of a decision should be judged by the knowledge and information available at the time the decision was made, and by the logic used to arrive at the decision.
- In the presence of uncertainty, the best hope for a good outcome is a good decision-making methodology or process.
  - The focus on judging (and rewarding/penalizing) decision quality based on outcome drives poor decision-making!

Multi-Objective Decision-Making Prosess

Overview

Framing

Modeling

Analysis

Simplifications

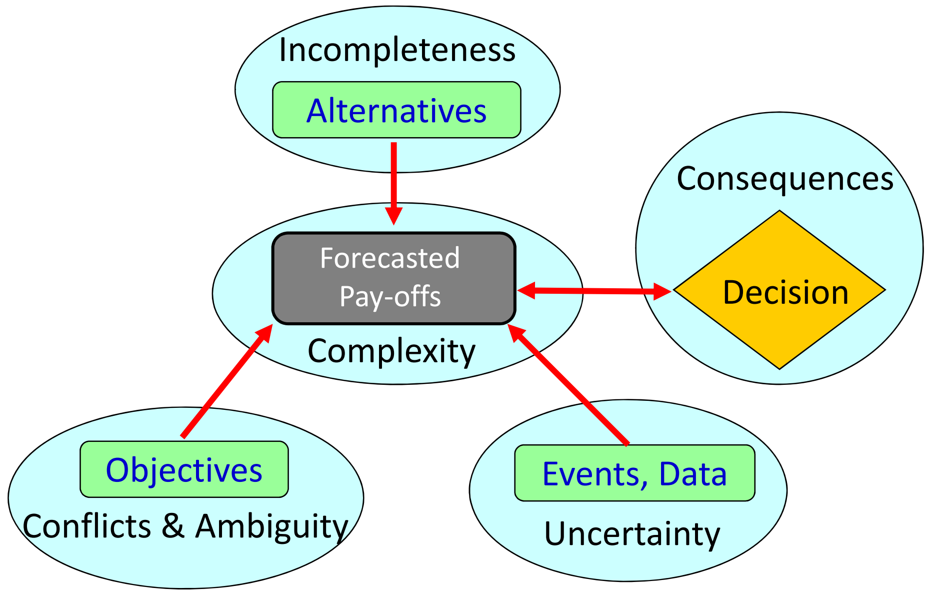
Relevant for all Decisions

- Decisions may have *qualitative* and *quantitative* objectives

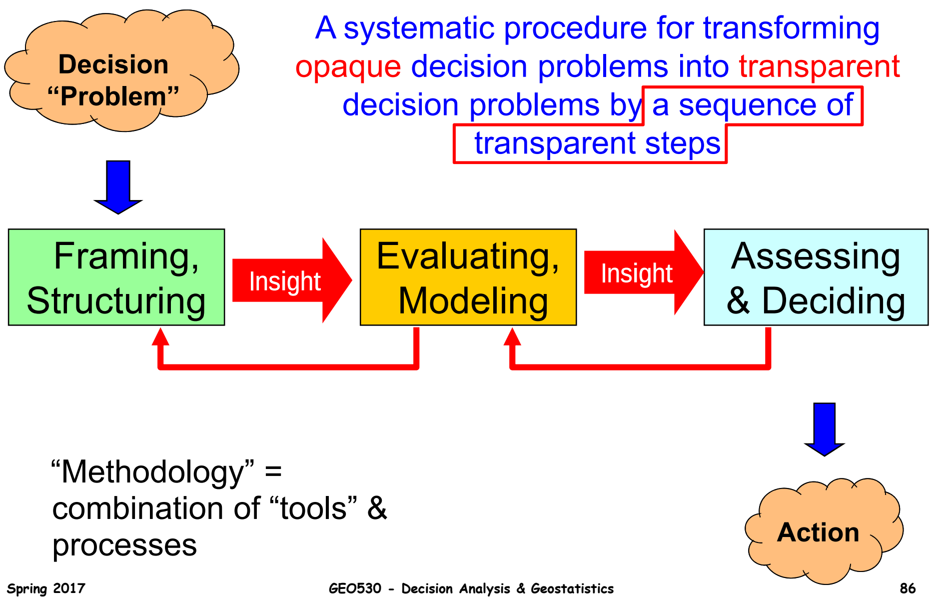
- Business Examples
  - Choose an exploration strategy
  - Select reservoir simulation software
  - Choose between potential well target locations
  - Choose a job applicant
  - Resource allocation amongst different programs

- Home/Personal Examples
  - Decide where to go on holiday
  - Choose a job/company
  - Select a flat/house-share

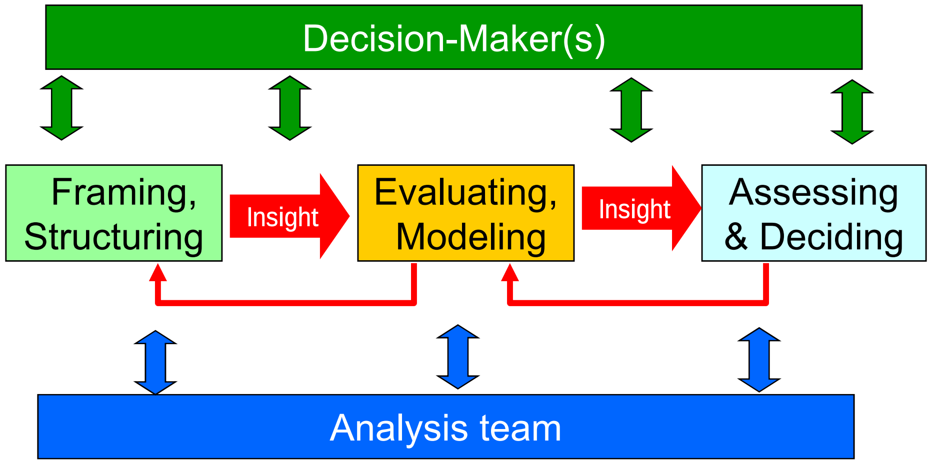
Methodology Designed to Deal with the Factors that make Decisions Hard



High-level view of methodology for making good decisions

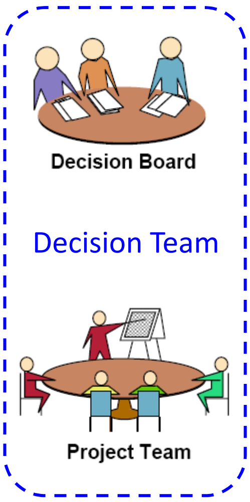


Implementation of Methodology (major decisions in oil company)



A dialogue based decision process requiring continuous communication between the decision-maker(s) and the analysis team.

The Dialogue Decision Process establishes clear roles for decision makers and project staff



Decision Board

Members:	Decision makers
Responsibilities:	”Declare” decisions, approve frame, provide values and trade-offs, and make decisions
Selection criterion:	A decision by this group will ”stick”

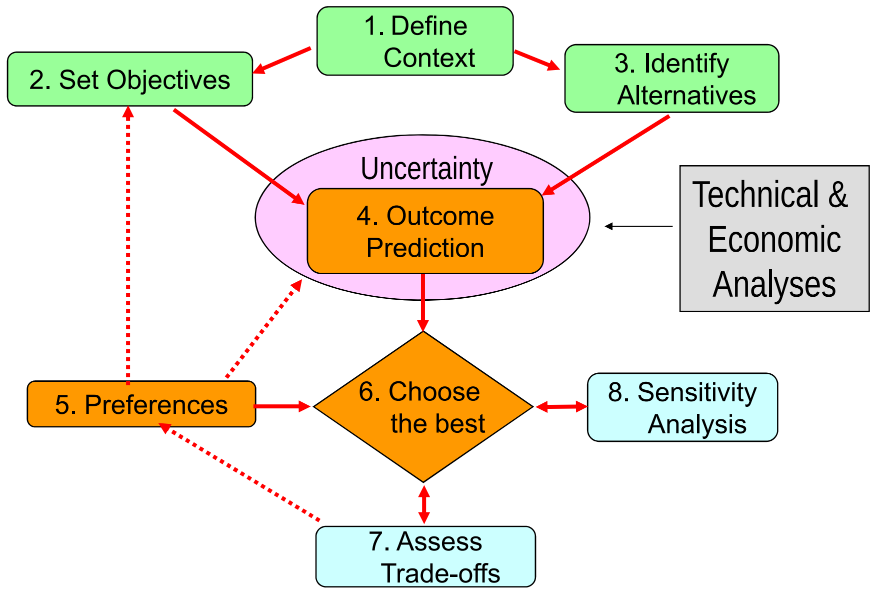
Project Team

Members:	Analysts and subject-matter experts
Responsibilities:	Develope frame and alternatives, assess information, evaluate alternatives, plan implementation
Selection criterion:	Recognized by decision board as credible experts and analysts

8-Step Multi-Objective Decision-Making Process

Framing	1) Define the decision context 2) Identify the criteria (objectives) by which each alternative will be evaluated 3) Enumerate/Generate the alternatives (choices)
Evaluating	4) Evaluate each alternative by how well it performs against the criteria (achieves the objectives) 5) Weight the criteria (objectives) according to their relative importance *for distinguishing between choices* 6) Calculate a overall weighted value for each alternative
Assessing	7) Make trade-offs between competing objectives 8) Perform a sensitivity analysis

Methodology for Making Good Decisions



Template for implementing & recording core of process

1. Define Context & Decision

Objectives			Alternatives
Name	Rank	Wt	3. List the choices
2. List your Objectives or Criteria.		5. Weight Your Obj.s	4. Score how each Alternative “performs” against each Objective
		Total Score	6. Calculate weighted score for each alternative

Example:

1. Context: Buy a car
Decision: Choose specific make & model.

Objectives			Alternatives				
Name	Wt	Norm Wt	Pajero	Jeep	Prado	Path-finder	Tribute
Min Purchase Cost	60	0.18	40	10	0	80	100
Max Build Quality	100	0.29	70	0	100	60	30
Max Size	40	0.12	100	40	90	30	0
Max Comfort/features	30	0.09	90	80	100	0	70
Max Safety	90	0.26	60	100	50	40	0
Min Operating Cost	20	0.06	40	80	0	90	100
Total Score			65.6	44.6	61.8	51.2	39.0

Multi-Objective Decision-Making Prosess

Overview

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Modeling

Analysis

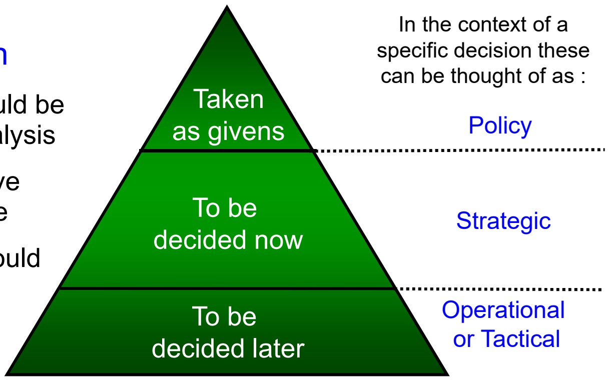
Simplifications

1) Define Decision Context

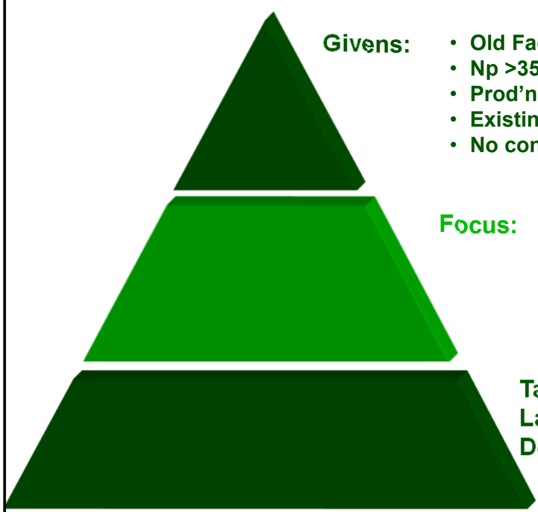
- Decision Context
  - Are you addressing the right problem / decision?
  - Clearly defining the context will help you to define appropriate objectives and solutions (choices, alternatives)
- Decision-Ownership
  - The person(s) who can assign resources! Who is it really? You, your boss? The broader the context the higher up the D-M
  - We need to know the D-M so that we can determine THEIR objectives and THEIR weighting for relative importance
- Feasibility
  - Do you have the necessary time and resources for analysis etc – especially if context is broad? If not: you and D-M are likely to be dissatisfied – better to narrow context

Decision Hierarchy Tool

- A tool for helping teams frame a problem
- Forces discussion on
  - what decision should be included in the analysis
  - what decisions have already been made
  - what decisions should be made after the analysis
- Identify critical assumptions



Example: Field management



Givens:
- Old Facilities, PSC ends 2020,
- Np >350MMbbl ~25% RF
- Prod'n below forecast and pressure declining,
- Existing manning philosophy defers oil
- No continuous flaring

Focus:
- Detailed Design
- Pump Sparing Philosophy
- WRM / SmartFields Initiatives
- Injector Completion Strategy

Tactics / Later Decisions:
- Detailed Surveillance Plan
- Viability of Chemical EOR
- 3D Appraisal / Crestal Dev't
- Minor Sands Water Injection

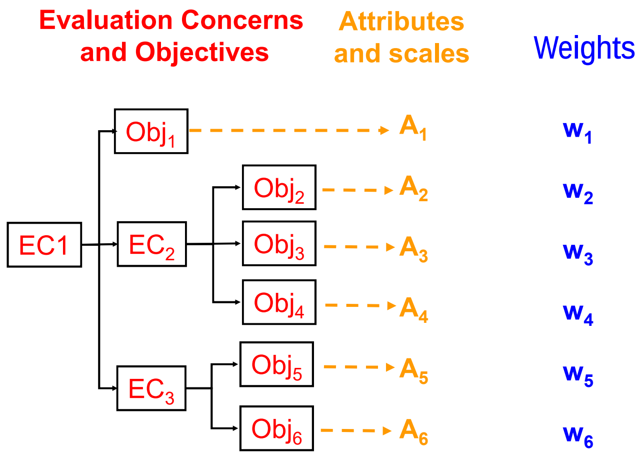
Example: 1. Context and Decision

1. Context: Need a car
Decision: Choose specific make & model.

Objectives			Alternatives				
Name	Wt	Norm Wt					
Total Score							

2) Develop Value Hierarchy

Value Hierarchy



Each attribute requires evaluation scale

Car Example: Specify Objectives (Criteria) and Scales: Components of a Value Hierarchy

- Evaluation Concerns (Values)
  - High level desires and issues that are important *in the context of the decision to be made*
  - E.g in choosing a car, its use for family camping is a "concern"
- Objectives (Criteria)
  - Specific goals to be achieved
  - E.g. Maximize cargo carrying size
- Objective Scales (Attributes)
  - How performance of each objective (criterion) is measured
  - E.g. Volume in litres (could be linear dimensions)
- Attribute Weights or Preferences (later)
  - Relative importance of each Objective
  - E.g. Safety is more important than cargo capacity

2) Attribute Scales for measuring Objectives

- Natural Scales
  - Objective measures are available

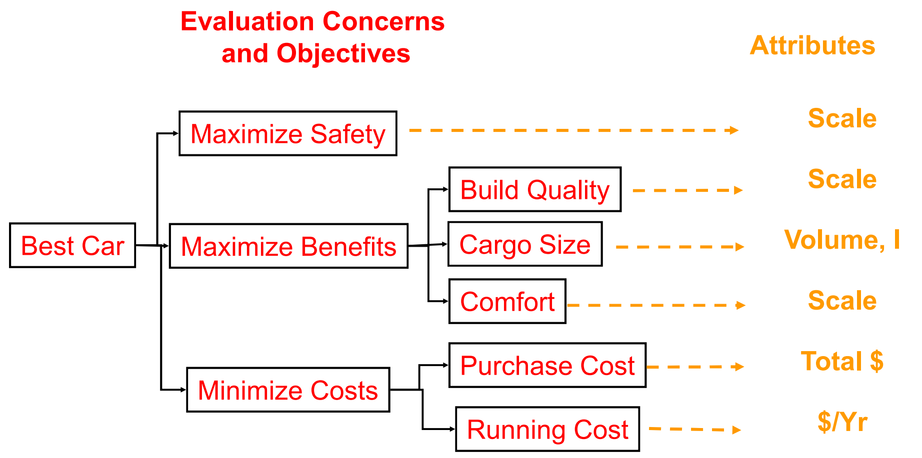
E.g.	Profit ($M):	$50 - $100
	OOIP (MMbbls):	200 – 400
	Drilling rate (m/hr):	2 - 5

  - Or a proxy measure that correlates with, or is representative of, the attribute is available
- Constructed Scales
  - There is no natural measure. Assign integer numbers that describe degrees of attainment
  - E.g. Skill level for hiring a new employee

No Skills	= 0
Rudimentary, still in learning phase	= 1
Competent, good experience in this job	= 2
Expert, wide experience on this & related jobs	= 3

Example: 2 - Value Hierarchy

Value Hierarchy



Example: 2. Objectives

1. Context: Buy a car
Decision: Choose specific make & model.

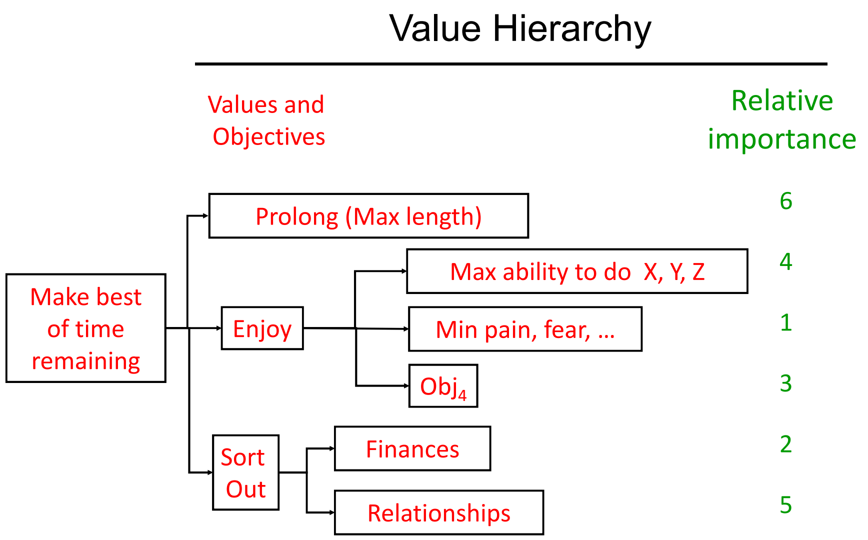
Objectives			Alternatives				
Name	Wt	Norm Wt					
Min Purchase Cost							
Max Build Quality							
Max Size							
Max Comfort/features							
Max Safety							
Min Operating Cost							
Total Score							

Weight the Attributes: Importance weights

- If all alternatives are not pre-specified, perform a direct, absolute, assessment of weights for the purposes of guiding the generation of alternatives & information collection
  - Weights denote relative preference between objectives
  - (Later, we will change the weights, and their values, for the purpose of choosing between the alternative)
- Rank order the objectives, assign relative weights from 0 to 100, normalize weights

Objective	Rank	Weight	Normalized
Safety	1.	100	40
Profit	2.	90	36
First Oil	3.	40	16
Reserves	4.	20	8
		sum = 250	100

Another Example: Barbara – brain cancer

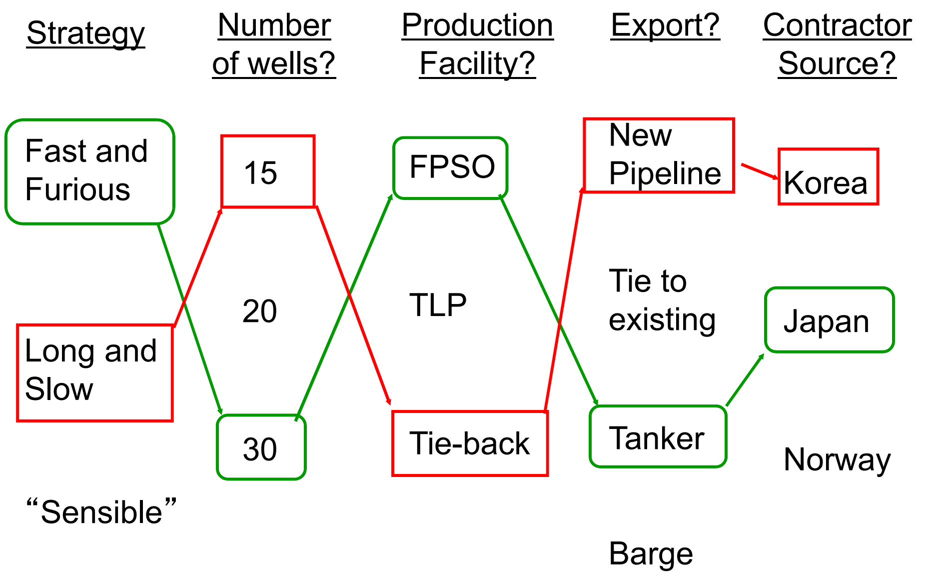


Where possible, make all end objectives of the form: minimize “this” or maximize “that”

3) Identify/Develop Alternatives (Choices) – key job of an engineer – design solutions

- Beware of unreasonably restricting your alternatives.
  - The decision can only be as good as the best alternative that has been identified
  - Examining "means objectives" and/or brainstorming may create more
- Rule out alternatives that do not meet "must have" criteria
  - E.g.   House must have 3 bedrooms. Profit > 0
  - Then REMOVE the "must have" criteria/objectives from list
- Use Strategy Tables to develop major decision alternatives
  - E.g between Tension-Leg Platform, FPSO, Sub-sea Dev. Each Strategy becomes a Decision Alternative
- List the alternatives if they are pre-specified
  - E.g. there are only 5 candidates for a job

Developing Alternatives -Strategy Tables



Example: 3. Identify Alternatives

1. Context: Buy a car
Decision: Choose specific make & model.

Objectives			Alternatives				
Name	Wt	Norm Wt	Pajero	Jeep	Prado	Path-finder	Tribute
Min Purchase Cost							
Max Build Quality							
Max Size							
Max Comfort/features							
Max Safety							
Min Operating Cost							
Total Score							

What might alternatives be if Context was "Need to get to work"?

Multi-Objective Decision-Making Prosess

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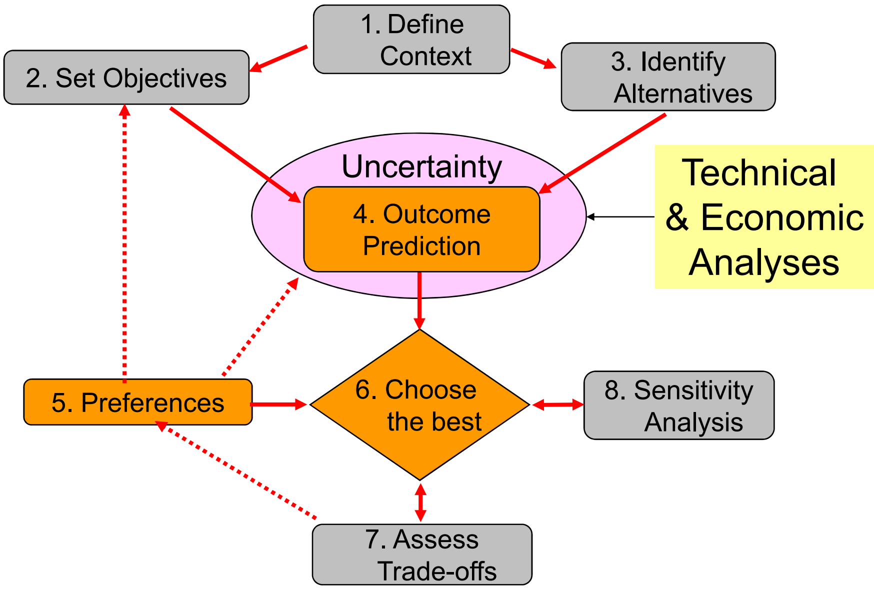
Simplifications

Stage 2): Analysis & Modelling



The main role of a Petroleum Geoscientist or Engineer is to support decision-making

- Whether you, your group or company explicitly recognize it or not – technical work is fundamentally about uncertainty assessment for the purpose of making decisions
- If you have a "make the best possible prediction" focus, there is no stopping rule
  - you can always reduce uncertainty a bit more (more data, more time, more analysis)
- A decision-driven focus gives a trivially simple stopping rule
  - Stop when further analysis doesn't change the decision!!
  - From a decision-making perspective we only need to find which option has the greatest value – we don't (usually) need a precise (= little uncertainty) estimate of that value

Decision Criterion under Uncertainty:
Choose the alternative with maximum Expected Value

- Mathematically
  - The probability weighted average of the possible values (discrete PDF)

$$\text{Expected Value} = \sum_{i=1}^{n} p_i x_1$$

- Expected Value Intuitively
  - Defines what would happen "on average" if we repeated the situation
- The Expected Value decision rule:
  - select the alternative with the highest expected value
  - no other metric (mode, P10/50/90, etc) will give a higher total value over multiple outcomes
  - multiple decisions not required - EV is optimal for a single decision
- BUT, don't "expect" the Expected Value!

4) Outcome Prediction: Assess Alternatives against Objectives: Pay-off matrix

Alternatives

Objective Attributes	A_1	A_2	A_3	A_4
O_1	p_1	p_2	p_3	p_4
O_2	p_1	p_2	p_3	p_4
O_3	p_1	p_2	p_3	p_4
O_4	p_1	p_2	p_3	p_4
O_5	p_1	p_2	p_3	p_4

p_j is the (predicted) pay-off of j^{th} alternative on the ,
as measured on the attribute scale for that objective

4) Assess Alternatives against Objectives

- For attributes with natural scales, this is where the results of modeling, analysis and evaluation get used

	A1	A2	A3	A4
....	.	.	.	.
NPV, $MM	$120	$150	$90	$130
Reserves, MMSTB	200	170	220	190
....	.	.	.	.

On Models

"All models are wrong, some models are useful"
Box

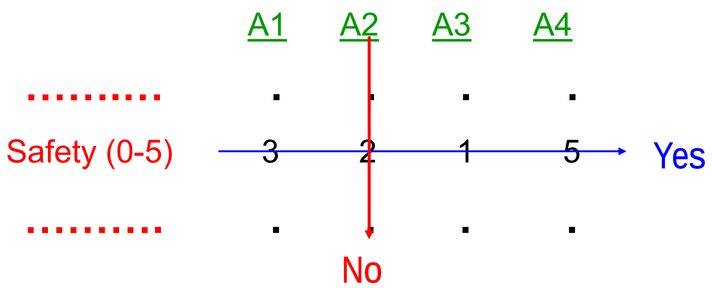
- Once you accept decisions really are made under uncertainty, and can be optimally so, it impacts the whole way you view "technical" work (geological, engineering, economic, commercial, legal)

"I would rather be vaguely right than precisely wrong"
Keynes

4) Assess Alternatives against Objectives

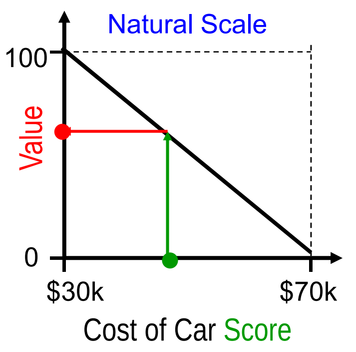
- Rate each alternative against each objective using the Attribute scales
- Take each Objective (Attribute) sequentially and rate each Alternative (Choice) against it, rather than vice versa, since the goal is comparison

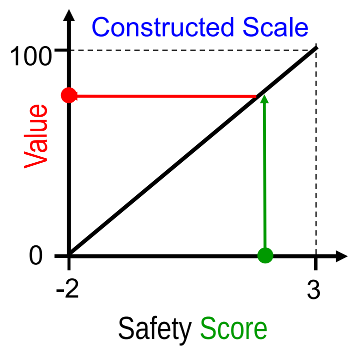
  E.g. Scoring the Alternatives (A1, A2, …) on the Safety Attribute



4) Assess Alternatives against Objectives: Convert SCORES to VALUES

- Each Objective (Attribute) is likely to have a different scale
  - E.g. Safety from –2 to + 3, Profit from $100m to $500m
- We need to convert to a common scale in order to combine Objective scores for each Alternative
- We convert the SCORES on the attribute scales to a common VALUE scale (say 0 to 1, or 0 to 100)





Example: 4. Score Alternatives against Objectives

1. Context: Buy a car
Decision: Choose specific make & model.

Objectives			Alternatives				
Name	Wt	Norm Wt	Pajero	Jeep	Prado	Path-finder	Tribute
Min Purchase Cost			40	10	0	80	100
Max Build Quality			70	0	100	60	30
Max Size			100	40	90	30	0
Max Comfort/features			90	80	100	0	70
Max Safety			60	100	50	40	0
Min Operating Cost			40	80	0	90	100
Total Score							

Value Functions: Variable Returns to Scale

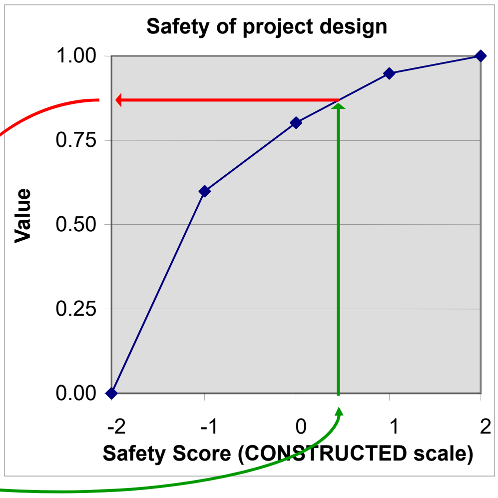
- Value Functions permit increasing or decreasing “returns to scale”
  - E.g. Safety on a scale of -2 to +3. Going from a safety score of -2 to -1 may be more valuable than going from +2 to +3
  - Your production target is 100 kbopd.
    - The incentives for exceeding it are relatively small compared to the penalties for missing it.
    - How do you feel about the relative value of increasing production from current 80 kbopd to your 100 kbopd target, versus from 100 kbopd to 120 kbopd?
  - You won $1 million in a lottery a week ago. Rich aunt Edna has just died and left you another million. How do you feel about the 2nd million v the first?
- The reason we have different values is that the consequences of identical outcomes are different depending on our current status

Piecewise Linear Value Function: Constructed Scale - increasing preference, decreasing returns

Defined by a set of (score, value) pairs

Input	
Risk score	Value
-2	0.00
-1	0.60
0	0.80
1	0.95
2	1.00

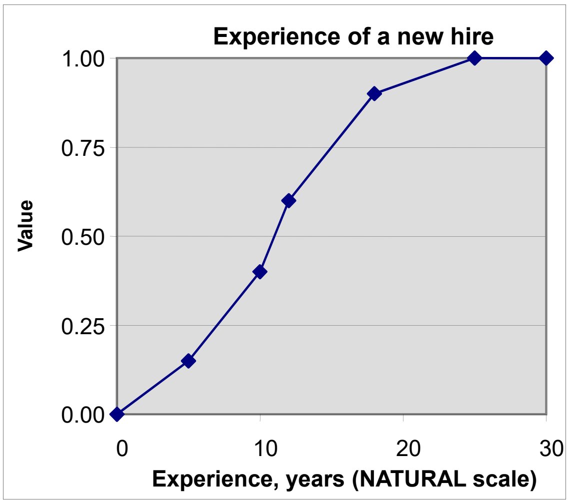
Calculated Values	
Risk score	Value
-1.5	0.30
0.5	0.88
1	0.95
1.5	0.98



Piecewise Linear Value Function: Natural Scale increasing preference - increasing -> decreasing returns

Input	
Years	Value
0	0.00
5	0.15
10	0.40
12	0.60
18	0.90
25	1.00
30	1.00

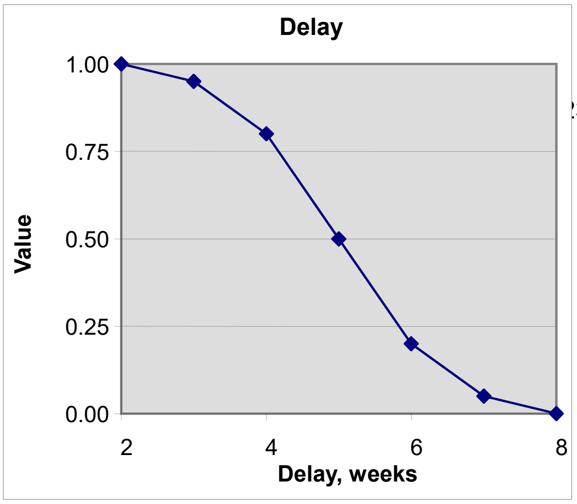
Calculated Values	
Years	Value
3	0.09
15	0.75
20	0.93
28	1.00



Piecewise Linear Value Function: Natural Scale, Decreasing Preference

Input	
Delay	Value
2	1.00
3	0.95
4	0.80
5	0.50
6	0.20
7	0.05
8	0.00

Calculated Values	
Delay	Value
2	1.00
3.9	0.82
6.1	0.19
7.6	0.02



5) Weight the Attributes - Swing Weights (Decision Weights)

- Previously we used weights for the purpose of helping to create alternatives that would bring us "value"
  - Direct Assessment (rank order, assign weight between 0 and 100, normalize)
- Now the purpose of the weights changes to that of choosing between the alternatives
  - for which we need the decision-makers relative preferences between the objectives
- Direct assessment problem
  - Say Profit is very important in an investment decision.
  - What if there is not much difference between the profits of the investment alternatives?
  - From the perspective of choosing between alternatives, profit should have a lower weight

5) Weight the Attributes – Swing Weights

- Consider a hypothetical Alternative that has lowest score on all Attributes.
  - If just one attribute could be "swung" to the best level, which would it be?
  - Repeat for remaining Attributes to develop rank order based on these "swings"

	Attribute Scores					Hypothetical Alternatives		Swing Rank
	A	B	C	D	E	Worst	Best	Rank
First Oil, yrs	3	2	2.5	4	2	4	2	2
Reserves, MMSTB	100	350	180	290	400	100	400	1
Profit, $MM	110	115	100	120	110	100	120	4
Safety, score	4	3	5	3	5	3	5	3

5) Weight the Attributes – Swing Weights

- Consider a hypothetical Alternative that has lowest score on all Attributes. If just one attribute could be "swung" to the best level, which would it be?
- Repeat for remaining Attributes to develop rank order based on these "swings"
- Then proceed as in Direct method by assigning relative importance to the rank ordered list

Objective	Worst	Best	
Reserves	100mbbl	400mbbl	0 ———— 100
First Oil	4yr	2yr	——— 90
Safety	3	5	—— 60
Profit	$100m	$120m	— 30

- Combine weights back up the value tree and check for consistency at higher levels

Example: 5. Weight the objectives

1. Context: Buy a car
Decision: Choose specific make & model.

Objectives			Alternatives				
Name	Wt	Norm Wt	Pajero	Jeep	Prado	Path-finder	Tribute
Min Purchase Cost	60	0.18	40	10	0	80	100
Max Build Quality	100	0.29	70	0	100	60	30
Max Size	40	0.12	100	40	90	30	0
Max Comfort/features	30	0.09	90	80	100	0	70
Max Safety	90	0.26	60	100	50	40	0
Min Operating Cost	20	0.06	40	80	0	90	100
Total Score	340	1.0					

(NB weights based on Values, not Scores)

6) Determine Overall Value for Each Alternative then Rank them

- For alternative j, sum the weighted values for

$$V_j = \sum_{i=1}^{N_A} w_i v_{ij}$$

Where
V_j = Overall Value of Alternative j
N_A = Number of Attributes (Objectives)
w_i = weight of Attribute i
v_{ij} = value of Alternative j for Attribute I

- Provisionally choose Max V_j

j

i

Att	w_i		v_{ij}		w*v
1	.21	X	40	=	8.2 +
2	.35	X	60	=	21 +
3	.04	X	80	=	3.2 +
4	.11	X	100	=	11 +
5	.29	X	30	=	8.7 =
	Total Score				521

Example: 6. Overall Scores

1. Context: Buy a car
Decision: Choose specific make & model.

Objectives			Alternatives				
Name	Wt	Norm Wt	Pajero	Jeep	Prado	Path-finder	Tribute
Min Purchase Cost	60	0.18	40	10	0	80	100
Max Build Quality	100	0.29	70	0	100	60	30
Max Size	40	0.12	100	40	90	30	0
Max Comfort/features	30	0.09	90	80	100	0	70
Max Safety	90	0.26	60	100	50	40	0
Min Operating Cost	20	0.06	40	80	0	90	100
Total Score			65.6	44.6	61.8	51.2	39.0
Rank			1	4	2	3	5

Multi-Objective Decision-Making Prosess

Overview
Framing
Modeling
Analysis
Simplifications

7) Trade-offs: Handling conflicting objectives

3. Alternatives (Choices)

5. Weights C_1 C_2 C_3 C_4 C_5

4.score alternatives

2. Objectives Hierarchy

O_1

O_2

O_3 W_3 V_{31} V_{32} V_{33} V_{34} V_{35}

Classify some objectives (attributes) as **desirable** – benefits, returns, … and sum the weighted scores for this subset

O_4

O_5

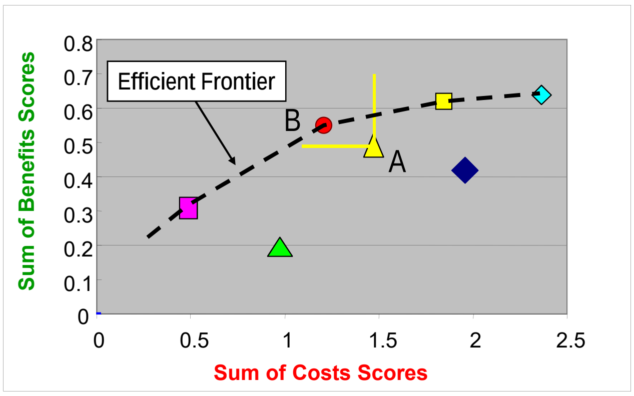
O_6

Classify other objectives (attributes) as **undesirable** – costs, risks, .. and sum the weighted scores for this subset

6. V_1 V_2 V_3 V_4 V_5

7) Assess Trade-offs

- Identify Classes of objectives to trade-off
  - e.g. Costs v Benefits, Risk v Return
- Derive a combined Class score for each Alternative by adding the scores for each Attribute of that class, and plot



A is “dominated” by B

The set of all non-dominated points is called the “efficient frontier”

Reject all alternatives not on the efficient frontier

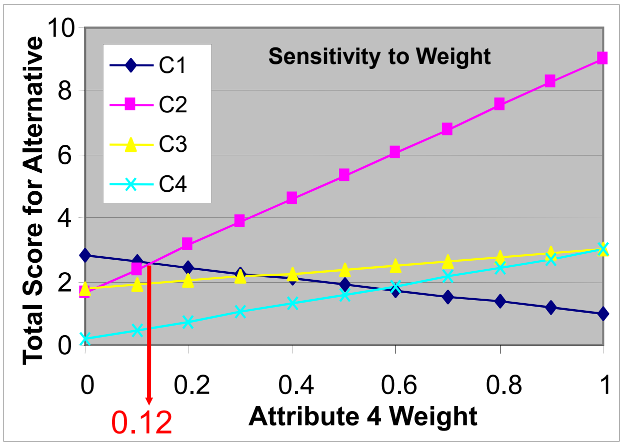
8) Sensitivity Analysis

- Sensitivity analysis answers the questions:
  - What matters in this decision?
  - How do the results change if one or more inputs change?
  - How much do the inputs have to change before the decision changes?

  Ultimately, leading to
- How accurately do I need to know the inputs (eg probabilities) to make a decision?

- Specifically for VoI and VoF
  - How accurately do I need to know the uncertainties
  - How accurately do I need to know the reliability of the proposed information

8) One-Way Sensitivity Analysis (to attribute weight)

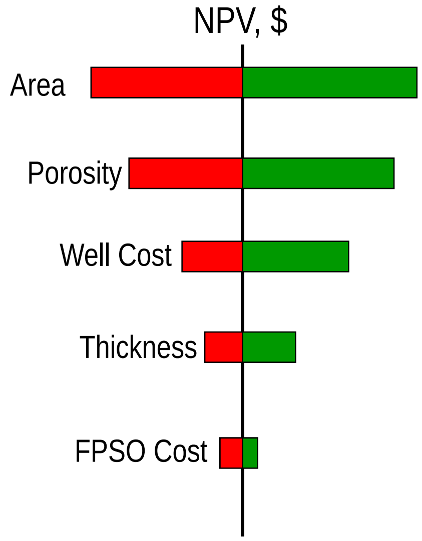


1. Choose an attribute weight to vary.
2. Vary this weight between 0 and 1
3. Pro-rate the other weights so they still all add up to 1
4. Plot total score for the alternative at each weight level

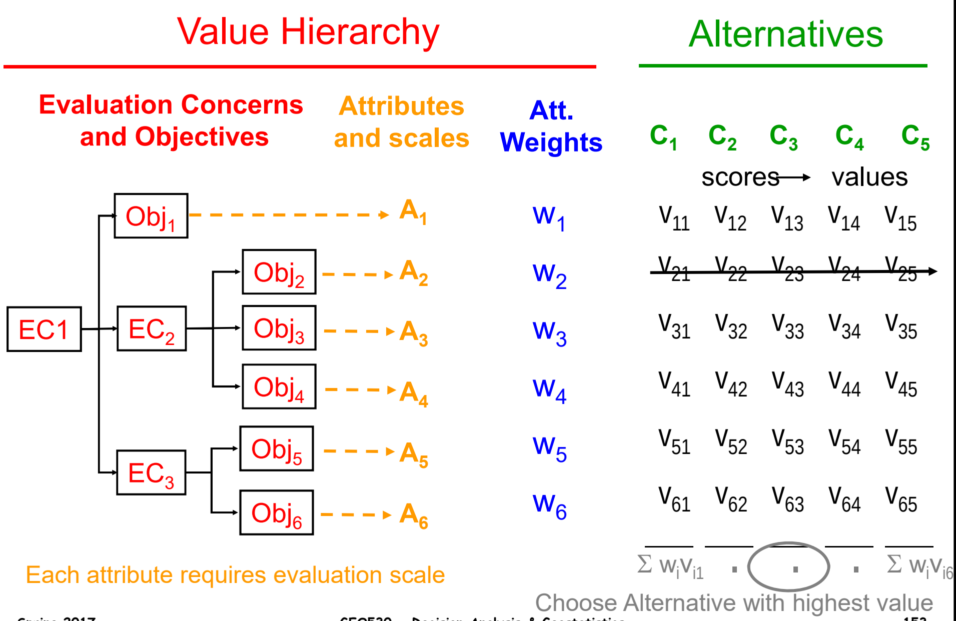
- Weight greater than 0.12 => C2 is the best alternative
- Weight less than 0.12 => C1 becomes the best alternative
- Choice is insensitive to weight, if it is greater than approx 0.2

Deterministic Sensitivity Analysis: Tornado Plots

- Shows the change in a decision criterion (eg NPV) as input variables are changed, one at a time, by a certain amount (often 10%)
  - arranged from highest to lowest impact on decision criteria – hence "tornado"
  - easy to implement by modifying a spread-sheet model
- Does not reflect uncertainty in decision criterion as a function of uncertainty in input variables
  - unless input variable uncertainty is uniformly distributed
- Does not reflect uncertainty in decision criterion as a result of several input variables changing at the same time



Summary of Core of Process (Steps 2 – 6)



Incorporating Uncertainty

3. Alternatives (Choices)

4. Use Expected Values

2. Objectives Hierarchy	5. Weights	C_1	C_2	C_3	C_4	C_5
O_1	W_1	e_{11}	e_{12}	e_{13}	e_{14}	e_{15}
O_2	W_2	e_{21}	e_{22}	e_{23}	e_{24}	e_{25}
O_3	W_3	e_{31}	e_{32}	e_{33}	e_{34}	e_{35}
		e_{41}	e_{42}	e_{43}	e_{44}	e_{45}
		e_{51}	e_{52}	e_{53}	e_{54}	e_{55}
O_6	W_6	e_{61}	e_{62}	e_{63}	e_{64}	e_{65}
	6.	$\bar{V}_1$	$\bar{V}_2$	$\bar{V}_3$	$\bar{V}_4$	$\bar{V}_5$

Or put risk as an objective (to minimize)

Provisional Best Choice

Multi-Objective Decision-Making Prosess

Overview

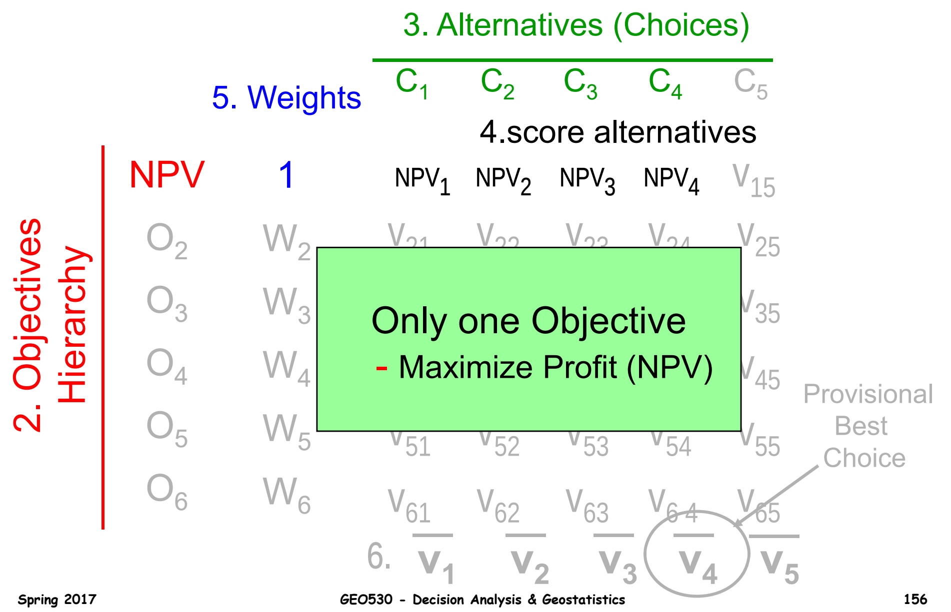
Framing

Modeling

Analysis

Simplifications

Common Reduction of D-M Process: Choose highest NPV



Decisions in minutes: Conversational approach to better decision making

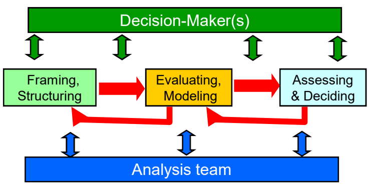
- Get into the habit of structuring decision-making conversations around the three main elements – in this order:
- Objectives:
  - "so what de want to get out of this decision?"
  - "is there anything else, anything we missed?"
  - "what is most important?"
- Alternatives:
  - "what are our options?"
  - "can't we think of anything better?"
- Information:
  - "what do we know about how each option will satisfy our goals?"
  - "are we sure of these predictions?"
  - "what is the evidence for our opinions?"

Example

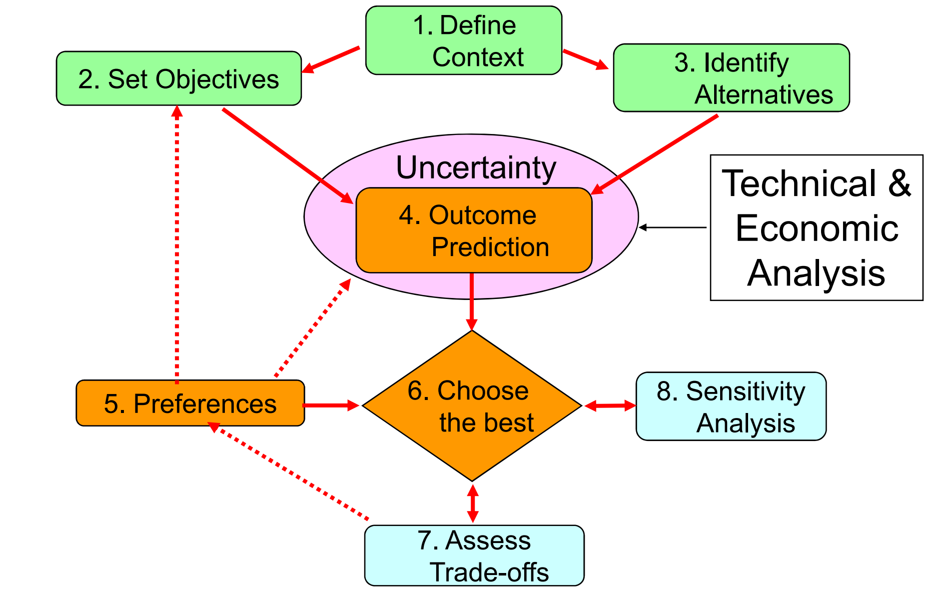
Hire a Replacement Geologist

Overview of multi-objective decision process

1) Identify the decision context
2) Construct a Value Hierarchy (Tree)
   - Determine Attribute Scales
3) Identify/Develop Alternate Courses of Action
4) Score Alternatives/Choices against Attributes
   - Transform Scores to Values
5) Weight the Attributes
6) Determine Overall Value for Each Alternative
7) Trade-off Costs v. Benefits
8) Perform Sensitivity Analysis



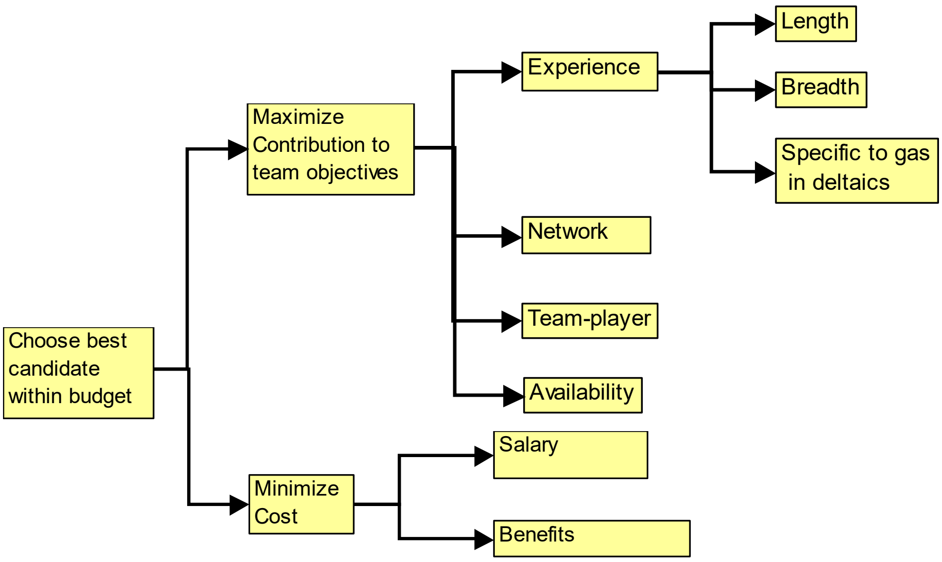
High Level Decision-Making Process



Whole Process Example: Hire a replacement geologist: Decision Context

- You are leader of an asset team managing production of gas from a deltaic reservoir.
- Tracy, involved in several on-going projects, is your most experienced geologist and has left the team for another job. You need to replace her and are restricted to making an internal hire.
- There are 7 candidates who are available.
  - Ahmed
  - Beth
  - Carlo
  - Dave
  - Ed
  - Fariba
  - Gaomin

Hire a replacement geologist: Value Tree



Hire a replacement geologist: Attributes

	"Leaf" Criteria	Objective (Adjective)	Attribute (Noun)
1	Exp. Length	Longer	Time in Industry, years
2	Exp. Breadth	Larger	Past-Job Variety, score
3	Exp. Specific	More Direct	Past-Job Relevance, score
4	Network	Bigger	Network Scope, score
5	Team Player	More Favorable	Team Apptitude, score
6	Availability	Shorten	Time to start, weeks
7	Salary	Minimize	Salary, $ per year
8	Fringe Benefits	Minimize	Benefits, $ per year
9			Att 9
10			Att10

Hire a replacement geologist: Attribute Scales

	Attribute (Noun)	Scale Type	Min	Max	Cost/Bene
1	Time in Industry, years	Natural	0	30	b
2	Past-Job Variety, score	Constructed	-2	2	b
3	Past-Job Relevance, score	Constructed	-3	0	b
4	Network Scope, score	Constructed	-1	3	b
5	Team Apptitude, score	Constructed	-2	1	b
6	Time to start, weeks	Natural	2	16	b
7	Salary, $ per year	Natural	80	130	c
8	Benefits, $ per year	Natural	15	40	c
9	Att 9		0	1	
#	Att10		0	1	

Hire a replacement geologist: Constructed Attribute Scales

Past-Job Variety, score

Scale	Description
-2	One only - no variety
-1	Done 2 different
0	Done 3 Different
1	Done 4 Different
2	More than 4
2	
2	

Past-Job Relevance, score

Scale	Description
-3	None
-2	Gas
-1	Deltaics
0	Gas & Deltaics
0	
0	
0	

Hire a replacement geologist: Constructed Attribute Scales

Network Scope, score

Scale	Description
-1	Restricted to within the company
0	Other O&G companies, locally
1	Locally across industry sectors (operators, service companies, academia)
2	Internationally with operators
3	Internationally across all industry sectors
3	
3	Not comprehensive - limited by applicants resumes

Team Apptitude, score

Scale	Description
-2	Tends not to interact with team
-1	Interacts, but concerned more about self than team
0	Sometimes has conflicts between what is best for team and self
1	Concerned only with team success
1	
1	
1	

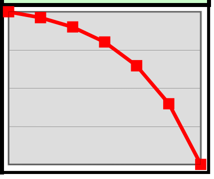
Hire a replacement geologist: Scoring

	Attributes	Ahmed	Beth	Carlo	Dave	Ed	Fariba	Gaomin	Alt 8	Alt 9	Alt 10
		Alternative Scores									
1	Time in Industry, years	7	10	9	19	23	14	11			
2	Past-Job Variety, score	-2	-1	0	1	2	0	0			
3	Past-Job Relevance, score	0	-1	-1	-2	-3	-1	0			
4	Network Scope, score	1	2	0	2	3	1	1			
5	Team Apptitude, score	1	0	1	1	-2	0	1			
6	Time to start, weeks	4	10	6	12	12	8	6			
7	Salary, $ per year	100	80	80	110	120	110	115			
8	Benefits, $ per year	20	26	25	35	30	30	30			
9	Att 9										
10	Att10										

Hire a replacement geologist: Value functions – expressing preferences

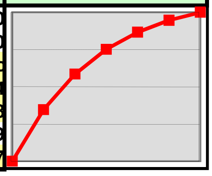
Time to start, weeks	
Exponential	
Min	2
Max	16
Mono	Dec
Rho	5
Mid-V	10
GS 0.5	0.74405
Ints	7

Value Function



Time in Industry, years	
Exponential	
Min	0
Max	30
Mono	Inc
Rho	13.5974
Mid-V	8
GS 0.5	0.49979
Ints	7

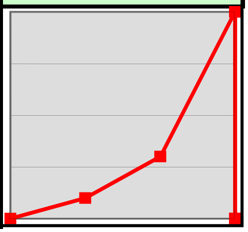
Value Function



Team Apptitude, score

Piecewise x	V(x)	Description
-2	0.00	Tends not to interact with team
-1	0.10	Interacts, but concerned more about self than team
0	0.30	Sometimes has conflicts between what is best for team and self
1	1.00	Concerned only with team success
1		
1		
1	1.00	

Value Function



Hire a replacement geologist: Values

Attributes	Ahmed	Beth	Carlo	Dave	Ed	Fariba	Gaomin	Alt 8	Alt 9	Alt 10
	Alternative Values									
Time in Industry, years	0.37	0.50	0.46	0.78	0.88	0.64	0.54			
Past-Job Variety, score	0.00	0.10	0.20	0.50	1.00	0.20	0.20			
Past-Job Relevance, score	1.00	0.66	0.66	0.33	0.00	0.66	1.00			
Network Scope, score	0.60	0.80	0.30	0.80	1.00	0.60	0.60			
Team Apptitude, score	1.00	0.30	1.00	1.00	0.00	0.30	1.00			
Time to start, weeks	0.97	0.74	0.92	0.59	0.59	0.85	0.92			
Salary, $ per year	0.89	1.00	1.00	0.76	0.50	0.76	0.65			
Benefits, $ per year	0.96	0.87	0.89	0.50	0.76	0.76	0.76			
Att 9										
Att10										
Total	5.80	4.98	5.44	5.26	4.72	4.77	5.67	0.00	0.00	0.00
Rank	1	5	3	4	7	6	2	8	8	8

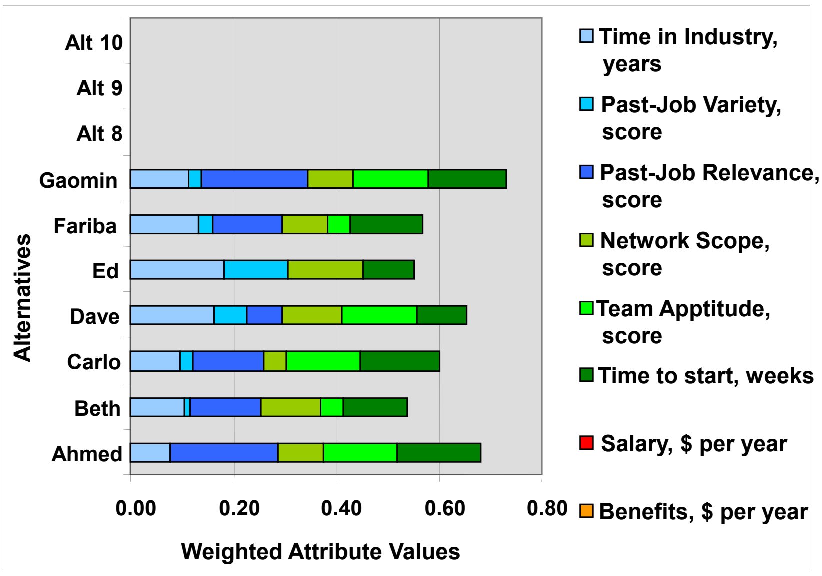
Hire a replacement geologist: Benefit Weights

	Attribute (Noun)	Min	Max	Cost/Bene	Weights: Rank	Weights: Score	Weights: Normalized Weight
1	Time in Industry, years	0	30	b	1	100	0.21
2	Past-Job Variety, score	-2	2	b	4	60	0.13
3	Past-Job Relevance, score	-3	0	b	1	100	0.21
4	Network Scope, score	-1	3	b	6	70	0.15
5	Team Apptitude, score	-2	1	b	5	70	0.15
6	Time to start, weeks	2	16	b	3	80	0.17
7	Salary, $ per year	80	130	c	0	0	0.00
8	Benefits, $ per year	15	40	c	0	0	0.00
9	Att 9	0	1				0.00
#	Att10	0	1				0.00

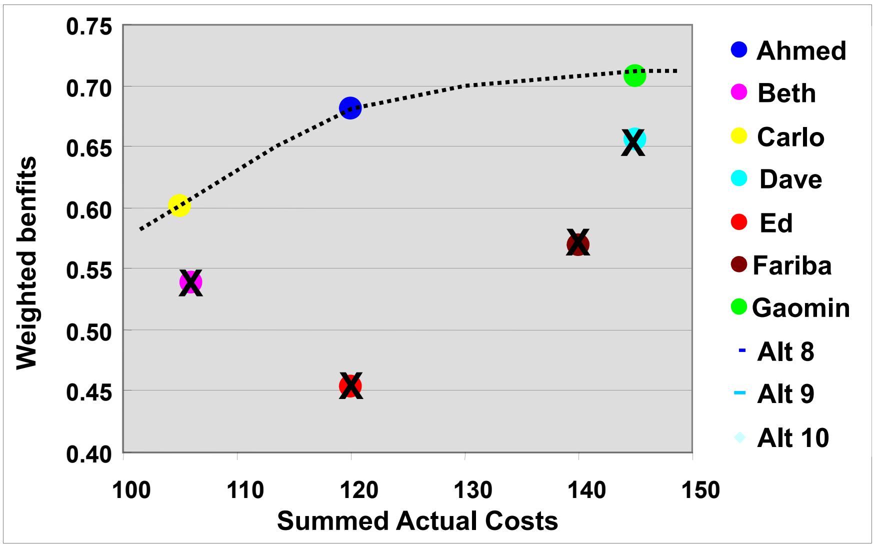
Benefits

Costs

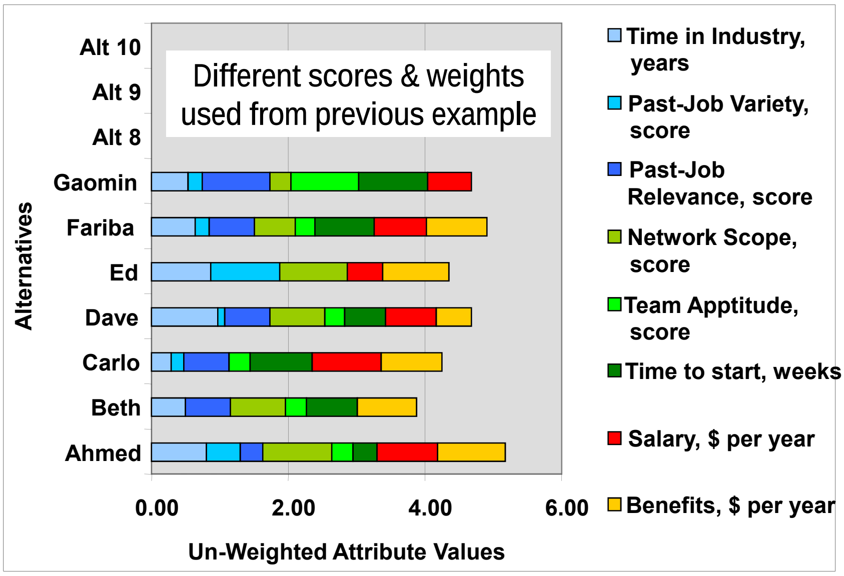
Hire a replacement geologist: Weighted Values of Benefits Only



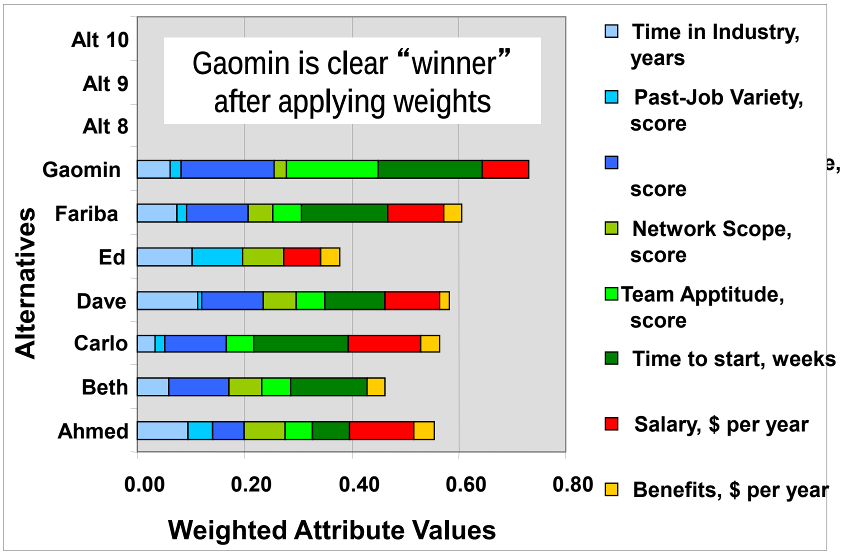
Hire a replacement geologist: Trade-off between Weighted Benefits and Sum of Actual Costs



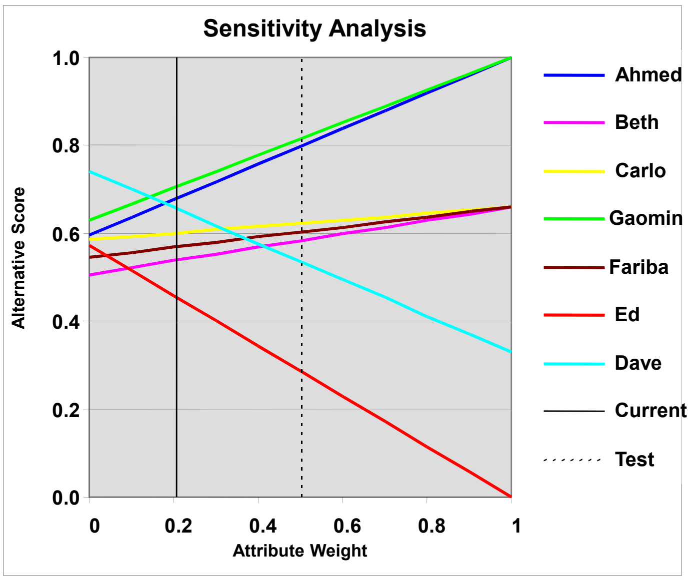
Hire a replacement geologist: No Trade-off Un-weighted Values (cost & benefits considered together)



Hire a replacement geologist: No Trade-off Weighted Values (cost & benefits considered together)

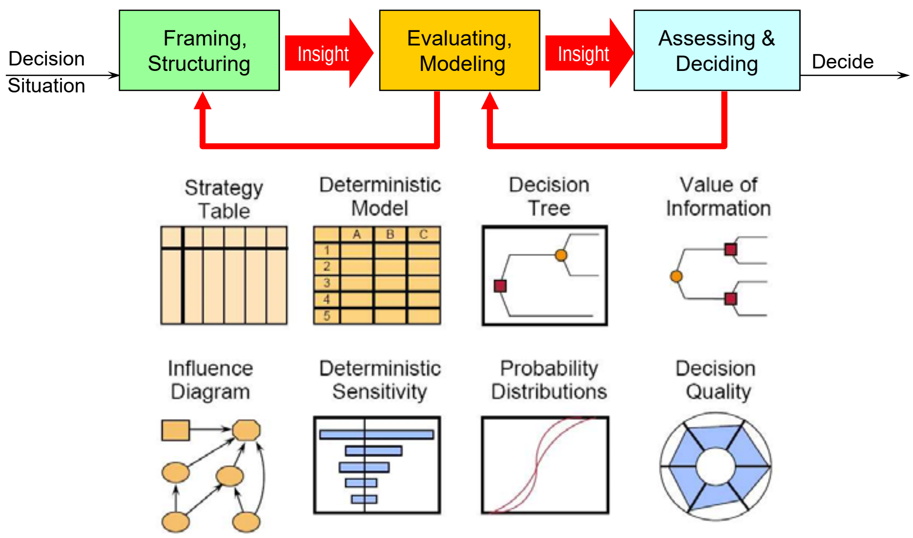


Hire a replacement geologist: Sensitivity to Attribute 3 (highest ranked) weight



Conclusions

Decision analysis draws on a number of different models and tools ...



… however, the main value of decision analysis is *not* in the specific numbers that are generated in the process but in the …

- Structured thinking and insight that the process engenders.
- The resulting transparency and record.

Decision analysis is about how to achieve clarity of action in making decisions and, even more fundamentally, how to achieve clarity of thought.

Howard

… however, the main value of decision analysis is *not* in the specific numbers that are generated in the process but in the …

- Structured thinking and insight that the process engenders.
- The resulting transparency and record.

…the real problem in decision analysis is not making analyses complicated enough to be comprehensive, but rather keeping them simple enough to be affordable and useful.

Howard

Decision Quality - What are the important questions to ask?