PPSDM Jakarta, October 30th, 2017

Company decision-making for geothermal projects

(GEOCAP course 1.07)

Topic: Decision Analysis / Decision Quality

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What information do decision-makers need?

- "Nothing is more difficult, and therefore more precious, than to be able to decide" (Napoleon Bonaparte)

Involvement in decision-making / decision analysis of your lecturer:

- *Ref. many conferences and publications on oilfield development planning, uncertainty, economics, decision-making, training on these subjects, etc.*
- *Norwegian Forum for Forecasting and Uncertainty (FUN), best practice uncertainty evaluation and decision-making in the E&P industry*
- *Executive Master course TU Delft (NL) MPBE: Master of Petroleum Business Engineering*
- *Various industry courses (Norway, Russia,….)*
- *MSc Petroleum Geology, Suriname, course module "Petroleum Economics & Mgt"*
- *Board member of EDPN = European Decision Professionals Network (www.edpn.org)*

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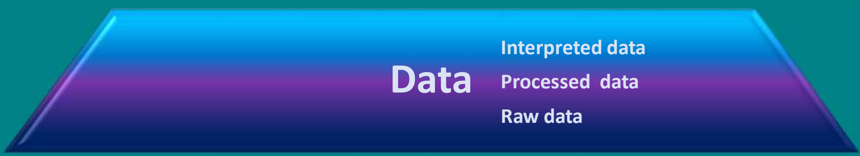
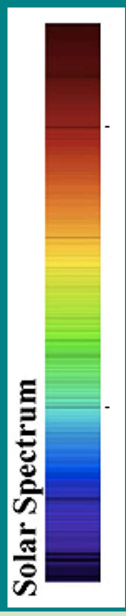
The knowledge pyramid





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What is a Decision?

A decision is:

- An irrevocable allocation of resources
  - Irrevocable in the sense that it is impossible or extremely costly to change back to the situation that existed before making the decision.
  - A decision is not just a mental commitment to follow a course of action, but rather the actual pursuit of that course of action.

- Ref. Howard, R.A., "*Decision Analysis: Applied Decision Theory*", Proceedings of the Fourth International Conference on Operational Research, Wiley-Interscience (1966).

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What is Decision Analysis?

- DA is the discipline comprising the philosophy, theory, methodology, and professional practice necessary to *address decisions in a formal manner*.
- DA includes many procedures, methods, and tools for identifying, clearly representing, and formally assessing *important aspects of a decision*.
- DA helps in systematically *comparing decision alternatives*, and *recommending a course of action* following a conditional optimization of the 'utility' of a well-formed representation of the decision.
- Ultimately, this formal representation of a decision and its corresponding recommendation is translated into *insight for the decision-maker* and other stakeholders.
- Study and technological innovation can add value to a possible course of action by improving its expected utility (e.g. the mean of the NPV-distribution) and/or reducing the possible range of bad outcomes.

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What is a 'good' forecast?

Exercise

- For Decision Analysis, *forecasts* of the uncertain future need to be made.
- All participants to write down their suggestions for defining a "good" forecast.
- Then speak up in class
- Plenary discussion of your suggestions

- Paper Bos&Arkley (2012): "A good forecasting method, in our opinion, results in actual being consistently bracketed by the predicted range. For example, a good forecasting method is a method that, when applied to many different cases, results in 80% of actuals being bracketed by the forecast P90–P10 range, after having retroactively corrected the forecast range for any change in controllable assumptions (i.e., operational interventions or settings not taken into account at time of forecast)".

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What is fundamental to DA?

- To distinguish a "good decision" from a "good outcome".
- DA is in first instance not about the outcome, but when applied consistently to a large quantity of projects (decisions), DA should result, on the long run, in excellent performance.

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Processes & methods to be discussed

- **Decision Gate process** – project maturation from brainwave to bankability to FID
- **DA process** – Decision Analysis, to be updated at various 'Decision Gates'
- **Framing** – Part of DRA process: defining uncertainties, decision alternatives, models, decision criteria
- **DTA** – Decision Tree Analysis: setting up a logical structure for Decisions and Scenarios
- **T2B** – Technical-to-Business: modelling technique to couple physics/technical/economics (and HSE)
- **Basic Statistics** – understanding how to model uncertainties, 'Frequentists' vs. 'Bayesians', preventing bias / psychology
- **MC** – Monte Carlo, probabilistic sampling technique for modelling KPI-uncertainties, incl. correlations
- **SA** – Sensitivity Analysis: understanding main high-impact uncertainties + what to do about it
- **Robustness** – definition of robustness: how to use this when recommending a decision?
- **CAPM & WACC** – Capital Asset Pricing Model & Weighted Average Cost of Capital: how to use in DCF?
- **DCF** – Discounted Cash Flow analysis: understanding the underlying assumptions of DCF analysis
- **HGT** – Host Government Take, tax, royalty, levies, depreciation, ring-fencing
- **MCA** – Multi-Criteria Analysis: understanding how to optimize the future in case of multi-criteria
- **VoI** – Value of Information: understanding when to propose new data acquisition
- **VoF** - Value of Flexibility: understanding when to propose flexibility-options in an engineering design
- **MPT** – Modern Portfolio Theory: better understanding the nature of risk and how the portfolio of projects determines how to assess individual project risk.
- **MSA** – Multi-Stakeholder Analysis: understanding how to make a Multi-Stakeholder project fly
- **DQ** – Decision Quality: a way to measure and monitor the quality of the decision-making process

Many other methods, e.g.
- **Real Options Valuation**
- **Complexity theory**
- **Agent-Based Modelling**
- **System Dynamics**
- **Bifurcation theory**
- **Resilience testing**
- **Etc. etc.**

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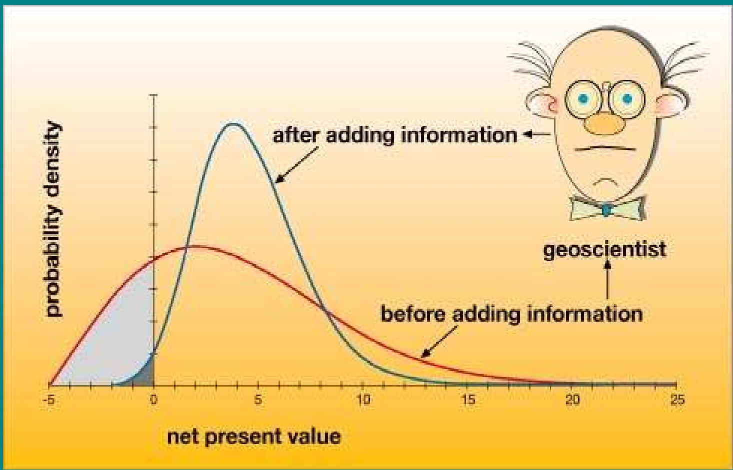
Added value of new information (through research / study)



- Both the mean of the NPV and the risk have been significantly improved (compare the areas below the two curves at NPV<0).

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DA, ref. Ron Howard (Stanford U)

The Discipline of Decision Analysis

Prof. Ron Howard, Stanford University

A systematic procedure for transforming opaque decision problems into transparent decision problems by a sequence of transparent steps.

Opaque:

- hard to understand, solve, or explain; not simple, clear or lucid

Transparent:

- readily understood, clear, obvious

In other words, decision analysis offers the possibility of *replacing confusion by clear insight into a desired course of action*.

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Exercise: What is a good decision?

1. Form groups of 4-5 participants
2. Discuss what you consider defines a ‘good’ decision
   - Also discuss what information a decision-maker needs
   - Also discuss what common beliefs should NOT be part of this definition.
3. Report back to plenary group

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Expert brainstorm

Our Thoughts about What Managers Need to Make Good Decisions

- They need to know that the team looked a range of different alternatives.
- For each alternative they need to understand
  - The value and its top drivers
  - The risk and its top drivers
  - What combination of outcomes would cause them to change their choice.
- Need to believe that uncertainty range reasonably captures the range of possible outcomes.
- They need to have confidence that their **decision** is robust under a range of possible outcomes.
- They want to know that all projects have been evaluated on consistent basis.

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Ref. Bickel & Bratvold (SPE-ATW 2006)

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Stanford Decision Analysis Process

ref. Ron Howard

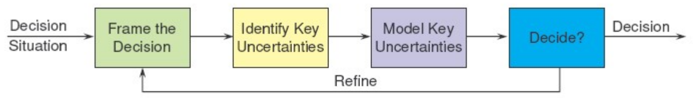
- Clear articulation of the decision to be made
- Framing
- Recognition of a decision hierarchy
- Development of alternatives
- Identification of uncertainties
- Valuation, including probabilistic analysis
- Sensitivity analysis
- Interpretation and communication
- Assessment of decision quality

DA process: establish Decision Quality (DQ)

- Establishing Decision Quality is the last step in the Decision Analysis process.
- Look-back on the decision process to assess whether it had sufficient quality:
  - *appropriate frame*
  - *meaningful reliable information*
  - *creative alternatives*
  - *clear values and tradeoffs*
  - *logically correct reasoning*
  - ***fostering learning and working towards "best practices"***
  - *commitment to action*

DA process

The decision analysis cycle serves to focus uncertainty quantification.



Frame: What decision are we working on? What are the alternatives?

Identify Key Uncertainties: What are the key drivers of value and risk? These might fall in a range of areas (e.g., subsurface, rig rates, oil and gas prices, schedule, capex, opex, etc, etc).

Model the Key Uncertainties: Build fit-for-purpose probabilistic models.

Decide: Is the best alternative clear? Based on sensitivity analysis (or value of information), could refinements to the probabilistic models change our decision?

Decision framing is the most critical step, as it constrains all that follows, yet companies spend the least amount of time in this phase.

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Ref. Bickel & Bratvold (SPE-ATW 2006)

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Requirements for good decision-making

Requirements for good decision making ...

- **The decision context should define the scope and scale of the uncertainty modeling.**
  - The goal is to provide *insight* to the decision makers so that *they* can make a good decision. The answer is not a number or even a distribution!
- **The decision model is complete when further refinements would not change the recommendation.**
  - I can be clear about what I should do, but still not be certain of what will happen.
  - Improved uncertainty characterization does not necessarily improve decision making.
- **Maintain a focus on adding detail as needed to determine the best alternative.**
  - There is no stopping rule when trying to make a prediction or a forecast; I can always make it a little bit better.
  - The stopping rule from a decision perspective is clear; stop when further refinements would not change the decision.

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Ref. Bickel & Bratvold (SPE-ATW 2006)

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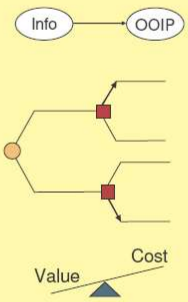
Criteria for new information to have added value

There are three criteria that information must meet in order to be worthwhile (or value creating).

Information = Further analysis, modeling, testing, etc.

Three Criteria of a Worthwhile Information Gathering

1. **Relevant.** The information must change your beliefs about another uncertainty.
2. **Material.** The information must have the ability to change decisions you would otherwise make.
3. **Economic.** The cost of the information must be less than its value.



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Ref. Bickel & Bratvold (SPE-ATW 2006)

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Some obvious messages

The takeaway…

- **Quantifying uncertainty creates no value in its own right.**
  - In fact, it only has value to the extent that it holds the potential to change decisions that might otherwise be made differently.
  - If the best course of action is clear, it is a waste of resources to further improve uncertainty estimates.
- **Reducing uncertainty creates no value in and of itself.**
  - Reducing uncertainty only creates value to the extent that it changes decisions.
  - The goal is not to reduce uncertainty. Rather, the goal is to make good decisions.
  - This could imply that no further modeling to reduce uncertainty is warranted even though it is possible.

The is nothing so inefficient as to very efficiently do the wrong things.
-- Peter Drucker

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Ref. Bickel & Bratvold (SPE-ATW 2006)

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Expert results of discussion (1)

What information do E&P managers need to make good decisions?

Workshop Results

- CDF (or PDF) of some economic measure (P50-P90). Includes full life-cycle economics. Include KPIs and key constraints (e.g., capital, cash flow). Include EMV.
- Tornado diagrams (sensitivity analysis); reputation, safety, environment, goodwill are important value measures and should be included.
- Information that can be used for the global portfolio.
- CDF (or PDF) for reserves, production, etc.
- Explicitly list constraints (gov, safety, environmental, human resources, etc)
- Risk assessment (safety, environment)
- Provide information for each alternative that was considered.
- For each alternative, highlight flexibility or options that can be taken.
- Detail on the costs (capital, opex)
- Be clear about the decision we are trying to make
- What are the key risks? What could go wrong?
- Provide some information regarding the quality of the modeling/decision process and how it has worked in the past.
- Strategic fit

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Ref. SPE-ATW 2006 workshop results

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Expert results of discussion (2)

How do the tools/concepts we have discussed during this workshop address these needs? Where should we focus our future efforts?

Workshop Results

- Tools that can make things understandable and simple. Some tools are available, but require much effort.
- Change management (change workflows and processes)
- We need to drive top-down thinking into the culture
- Focus on the decision and spend time on what is important.
- Education
- Proper uncertainty consolidation methods (different projects to the portfolio level)
- Brainstorm different alternatives, be creative
- How to combine expert knowledge.
- Have an integrated team (doors should be open)
- Implement the concepts (we have had them for at least 10 years)
- Define what we mean by fit-for-purpose. Propose models for different decision situations.
- Increase the size of the teams, instead of reducing them.
- Lower the threshold to using new tools and workflows.
- Better educate people in the field how to use the existing tools.
- Focus on tools that integrate the tools and disciplines we have seen during the workshop
- Need to focus on framing the problem and involving the right people.
- Risk and uncertainty management after the initial decision.
- A decision making forum

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Ref. SPE-ATW 2006 workshop results

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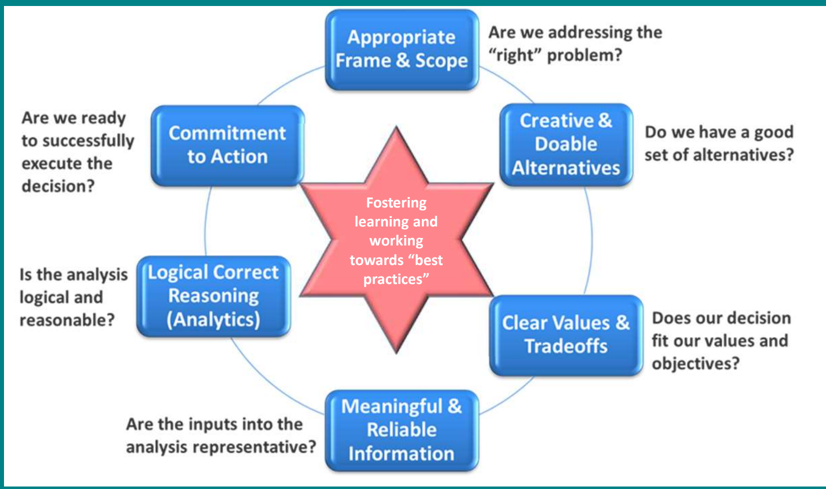
Summary DA / DQ

- Establishing DQ is the last step in the DA process.
- Look-back on the decision process to assess whether it had sufficient quality
  - ref. criteria →
- Note: DQ ≠ decision outcome!



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Summary what is a 'good' decision?

My personal suggestions

- A good decision is a decision that has been taken according to a *precise* process that is *consistently* applied to different cases / different alternatives within a case
  - **Precise**: unambiguous, repeatable
    - Little room for subjective, haphazard process steps, nor for omitting steps
    - Beware: process should not become a "box-ticking exercise" & should continuously invite critical thinking / innovation so as to improve corporate learning
  - **Consistent**: this allows *corporate learning* (signal-noise ratio)
- A good decision is *not* a decision that resulted in a good (or acceptable) outcome!
  - Certainly not in case of large uncertainties! Being lucky is not same as being good.
  - But when applied consistently, process should lead to **excellent** *average outcome*
- Staff should not be rewarded based on outcome, but on having properly applied the agreed process
  - And on proposing process innovations
    - Staff should not be rewarded for being lucky!

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Wrap-up

- A good decision (forecast) ≠ a good outcome (forecast)
- Decision Analysis (DA) comprises many methods and processes
- DA is at the core of how a company conducts its business
- DA and DQ are a company's critical success factors
- Detailed knowledge and skills can only be acquired over many years, but growing personally in this domain can be very rewarding

Application to geothermal asset valuation

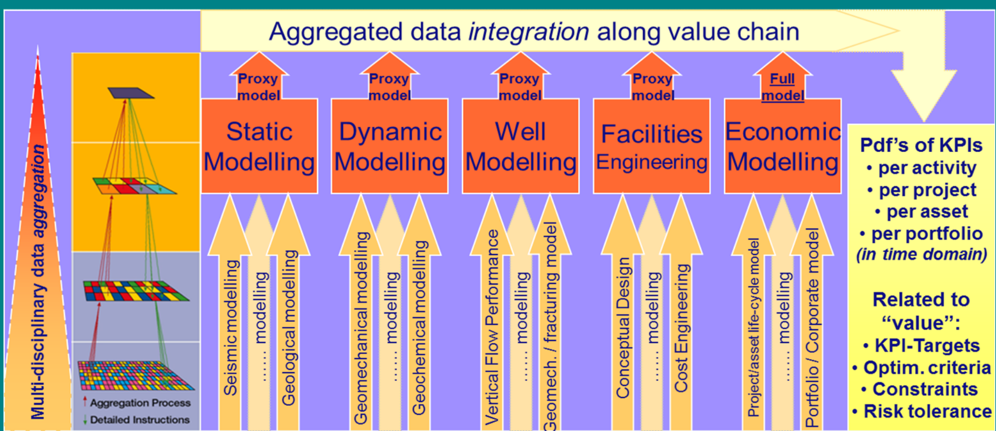
- For all types of well stimulations techniques, i.e. conventional hydraulic fracturing & acidizing, Cyclic Stimulation, Multi-stage Stimulation, Chemical Stimulation and Thermal Stimulation, we need a methodology that allows a consistent evaluation and comparison between the various stimulation alternatives.
- This method must also include uncertainty and risk analysis, as de-risking (risk reduction) is often a primary driver for deciding whether or not to invest in some opportunity.

➢ *Give examples of model input variables (to be expressed as probability density functions) that impact on the decision criteria of a stimulation job*.

DA for stimulation of geothermal wells

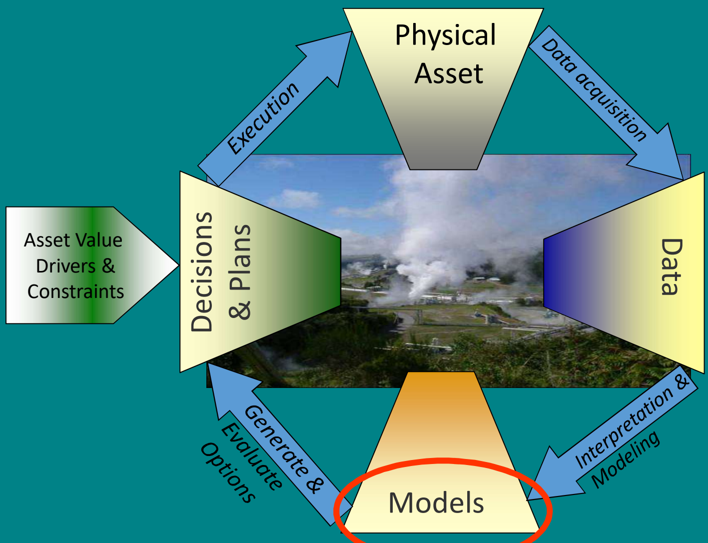
Class	Input variable (pdf)
Δtime and/or Δcost	License application time and costs, including delays and cost overruns due to social acceptance problems
	Stimulation job duration and costs
	Required post-stimulation job remedial action (additional costs and time, including the probability of a mandatory cessation of activities, e.g. due to induced seismicity)
	Required monitoring equipment
Reservoir performance	Reservoir geological volumetric and flow parameters
	Post-stimulation average reservoir permeability reduction rate due to area-wide chemical precipitation upstream of cold water front
Well performance	Skin improvement per type of job and per type of well
	Post-stimulation skin build-up rate
	Scale build-up inside well and impact on workover frequency-costs-duration
	Pressure and temperature losses from the completion of the well to the wellhead

Integrated Asset Model to assess geothermal wells



- Supply pdf's and relationships that can be used by IAM

The 'Value Loop' (Shell)©



XL exercise stimulation of geothermal wells