A New Approach to Evaluating Oil & Gas Investment Decisions

“I would rather be vaguely right than precisely wrong”

John Maynard Keynes

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Outline

• Economic Impacts of Uncertainty & Dependencies
• Stochastic Integrated Asset Model Approach
• Application & Benefits
• Summary & Conclusions
“Growth” of O&G Stock Prices v Indices

- Dow
- O&G Index
- Majors Index
- Independents Index

Drivers for a New Approach: Sub-Optimal Historical Performance

- An industry paradox: Most projects promise returns > 15% but the aggregate company portfolio makes lower returns! Why?
  
  Over-estimating returns, under-estimating risk of loss

- Poor portfolio investment decision evaluations resulting from
  - Failure to optimize for impacts of uncertainty
  - Lack of integrated tools, processes and organization

- Poor project investment decision evaluations resulting from
  - Uncertainties being ignored and/or underestimated
  - Over-simplification of interactions and dependencies
  - Removing time from the analysis
Uncertainties and dependencies are everywhere …..
….. occur at many levels …..

• Uncertainty assessment in each domain must address nested layers/types of uncertainty, eg …..

Interpretation/Model
Parameter / TI
Spatial
Data

↑ Monte Carlo
↑ Geostatistics ($\gamma$ or mp)
↑ Experimental Design & Monte Carlo
↑ Scenario Modeling, Discrete Probabilities

……. with appropriate modeling techniques
….. are frequently under-estimated .....
....and we spend a lot of money without always knowing which ones really matter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Uncertainty</th>
<th>Impact on NPV</th>
<th>Action</th>
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<tr>
<td>Gross Rock Volume</td>
<td></td>
<td></td>
<td>Buy more seismic</td>
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<tr>
<td>Oil Price</td>
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<td>Hedge with futures</td>
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<td>Average Porosity</td>
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<td>Take more core</td>
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<td>Saturation</td>
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<td>Different rock model</td>
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<td>Cheaper Steel Supply</td>
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<td>Rig Cost</td>
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<td>Renegotiate contract</td>
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<td>Net:Gross</td>
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<td>Fiscal Terms</td>
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<td>Fire lawyers</td>
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</tbody>
</table>
Uncertainty matters, even if all you require is a single “best” estimate

- For non-linear processes,
  - reservoir simulation
  - volumetrics with cut-offs
  - development alternatives
  even if only a single, “best” estimate is required, we still need to use complete range of inputs - cannot use an average input

- Also, P10 (P90) results are NOT given by taking P10 (P90) inputs and running them through the model

\[ Y = \frac{X^2}{Z^2} \]

Result
\[ Y = 4 \]
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Uncertainty Matters: sub-optimal portfolios

- Possible portfolios given assets available
- "Efficient" portfolios
Impact of uncertainties & dependencies on portfolio selection

After SPE 63056 Brashear & Becker
# 7: Use All The Assets

![Graph showing Expected NPV ($M) vs Risk ($M) with two lines representing 'Excluding Mature Assets' and 'Including Mature Assets'. The graph illustrates the impact of including mature assets on expected NPV.]
Impact of uncertainty on strategic choices: probability of meeting performance metrics

After Howell, SPE 68576
Options in an Uncertain World

• Ignore uncertainty
  – historical E&P approach (at the decision stage)

• Try to reduce uncertainty
  – value of information

• Take measures to live with uncertainty
  – value of mitigation plans (passive flexibility)

• Exploit the uncertainty
  – Value of active flexibility
Need Holistic Models: Trade-Off
Domain Richness vs. Estimating Uncertainty

Model Richness

Hi

Simplified but uncertainty included

Hi

Too expensive

Lo

Too simple and no inclusion of uncertainty

Lo

Classical E & P models

Uncertainty Estimation (No. of “runs” or Scenarios)

Lo

Hi

Model Richness
Holistic Investment Evaluation using a Stochastic Integrated Asset Model (SIAM)
Implementation of the SIAM approach

Model Scope

Alternatives Considered

Few

Many

Model Detail

Simplified

Detailed

Start

Middle

End

Classical Approach

SIAM-based Approach

Model Scope

Narrow

Broad
SIAM guides appropriate “scalability” of classical models - for different decisions.
The role of “Classical” Modeling

• Uncertainty Estimates of Input Parameters
  – Simple sensitivity studies
• Calibration of simplified models
• Generation of high-fidelity simple surrogates
  – Experimental Design and Response Surface Modeling
Step 1. Run SIAM over range of viable inputs to create complete PDF of output

Step 2. Identify input parameters of the runs corresponding to key percentiles

Step 3. Run parameters through complete models to calculate more accurate results

Step 4. Use more accurate results to calibrate initial PDF
Ties to Classical Models: Generating Simple Surrogates

• Goal is a parametric equation relating output response of interest (e.g. water breakthrough) to inputs which govern it (e.g. porosity, permeability, gross rock volume, Ti_i)

\[ BT = a_1 * f + a_2 * f^2 + b_1 * k + b_2 * k^2 + c * f * k \]

• Experimental design determines limited number of “Complex Model” experiments (different input combinations) needed to determine nature of relationships between input and output

• Response Surface Modeling (multi-variate regression) used to find the coefficients of the equation, or use NN?

• Uncertainty of the response then determined using Monte Carlo Simulation around the surrogate Simple Models (parametric equation) rather than the Complex Model
Applications & Benefits of SIAM approach

• Identification of key uncertainties
  – shows where they can be ignored, mitigated or need to be resolved
  – clarifies business impacts for technical specialists
  – promotes “fit-for-purpose” technical analysis & true asset teams

• Identification of main value levers
  – can be used to optimize investment

• A practical and more transparent approach for leveraging the thinking behind real options analysis
  – quantifies Value of Information (additional data and/or analysis)
  – quantifies Value of Flexibility in development plans to mitigate or exploit uncertainty
  – can value risk from perspective of investor/stockholder

• Promotes consistency for portfolio management
Real Options Valuation

• Accounts for the value of managerial decisions over the life of an investment, for example,
  – the option of waiting for uncertainties to be resolved, or paying for information to reduce them (Value of Information)
  – the option of altering the investment (accelerating, exiting) once uncertainties are resolved (Value of Flexibility)

• Rather than use a single risk-adjusted discount rate, account for the different risks in the different components that make up the cash flow stream

• Value risk from the perspective of the owner, using market data

• Create value from uncertainty
Gaming Analogy

A Lottery Ticket

Investment Decision
Uncertain Outcome

An Option

Example: Poker

Player has right to increase bet (invest) or fold (exit) as each round of cards is dealt (partial reduction in uncertainty in outcome)
Value *Increases as Uncertainty *Increases

- A key (non-intuitive?) result of Option theory/thinking

- Exploits the use of flexibility to bias, on average, towards upside
Creating Value from Uncertainty

PDF accounting for value of flexibility

“Upside” Opportunity

Downside Risk

Probability

0

E(NPV)

New E(NPV)

NPV
Exploiting Price Uncertainty: Mean-Reverting Oil Price Model
Value of Flexibility to Vary Production with Oil Price

NPV $ 21 MM
Value of Flexibility to Vary Production with Oil Price

NPV $ 42 MM
Value of Flexibility to Vary Production with Oil Price

NPV $118 MM
Does it make any difference? Evidence of value of implementing D&RA

Introduction of D&RA

after SPE 65144, Jonkman *et al* and Schroder & Co. Inc.
Does it make a difference?  
Correlation of Performance Measures with Decision Making Sophistication

RoE = Return on Equity (1988)  
PR = Proved Reserves  
EMP = Number of Employees  
MC = Market Capitalization  
TBV = Total Base Value

After Simpson, SPE59455
Summary of SIAM approach

• Holistic
  – represents all key aspects of the “system” about which decisions are to be made

• Dynamic & Adaptive
  – simulates the behavior of the system over time
  – enables updating of uncertainties and decisions

• Simple, Fast, Parametric Models
  – component models are analytic with rich set of input parameters, relatively low on sophistication/rigor and execute quickly

• Complex Relationships
  – contains logic for integrating components
  – captures structural and statistical dependencies
Summary of SIAM approach

• **Stochastic**
  – all uncertain variables can be assigned a PDF and the model executed in Monte Carlo simulation mode

• **Architecturally distinguishes between uncertain and decision variables**
  – Uncertain variables: states of nature or world
  – Decision variables: value levers which we can control

• **Flexible and customizable**
  – modeling “language” to capture unique facets of each investment system and implement dynamics and dependencies
Many managers believe that uncertainty is a problem and should be avoided.....

... you can take advantage of uncertainty. Your strategic investments will be sheltered from its adverse effects while remaining exposed to its upside potential. Uncertainty will create opportunities and value.

Once your way of thinking explicitly includes uncertainty, the whole decision-making framework changes.

Martha Amram and Nalin Kulatilaka in “Real Options”
Conclusions

• Uncertainties and dependencies have a big impact on O&G investment decision evaluations
• Accurate uncertainty assessment should be the primary goal of technical analysis (*reducing* it is secondary)
• We need
  – holistic models to identify key uncertainties and value levers
  – to trade-off domain-specific rigor/precision for accurate representation of dependencies, uncertainties and decision dynamics
  – to keep time in the evaluations explicitly
  – consistent, model-based evaluation of project/asset uncertainties for portfolio management
• Uncertainty is our friend, not foe. It can be used to create value.
For More Info ……

- SPE 71414: SIAM approach
- SPE 77509: Psychological Aspects of Judgment & Decision-Making
- SPE 77586: Value of Flexibility
Not everything is uncertain

“In the long run we’re all dead anyway”

also Keynes!