Risk Analysis and Exploration Economics

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The Concept of Risk

• Risk = Uncertainty + Undesirable Consequences

• Risk = Downside potential at a certain Probability Level
Rent vs. Risk

• Most of the exploration possibilities are unsuccessful

• The Profit Margin for the Oil Companies must be large enough to accommodate failures
Risk- & Non Risk-Takers

• Fiscal Terms must account for the large Risk in the Oil Business

  – **Oil Companies are High Risk Takers** Companies can reduce risk by diversification

  – **Governments are Low Risk Takers** Governments can reduce risk by introducing a Regressive tax system (Bonuses and Royalties)
Probability concept

- Fundamental rules
  Probability = 1 - Risk
  P=1.0 means 100% certainty
  P=0.0 means 0% certainty
Risk vs. Probability

Risk Tranches

Increasing Level of Knowledge

Increasing chance of Failure

Increasing chance of Success

Increasing Level of Knowledge

Chance of success

Chance of failure

No Knowledge

Probability

0

0.2

0.4

0.6

0.8

1

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Geological & Technical Risks

• Exploration
  – Existence of Hydrocarbons
  – Magnitude of Discovery
  – Type of Hydrocarbon

• Development
  – Technical Risk
  – Reservoir Development
Other Risks

- Fiscal
  - Changes in fiscal terms
- Economic
  - Exploration and development costs
  - Hydrocarbon prices
- Political
Profitability and the risk
Technological uncertainty
…costs overruns in Norwegian Projects 1998

Change in CAPEX from PDO estimates to summer 1998

Source: MIE
Political Risk

• Nationalisation
  – Not illegal after international law
  – Company gets compensation

• Policy and Rule Changes
Country Ratings

![Country Ratings Graph](image)

- Norway
- Indonesia
- Namibia
- Libya
- Russia
- Algeria
- Angola
- Gabon
- Congo
Oil Price - the only relevant Risk?

- The ROR for international Oil companies follows the oil price

![Graph showing oil price and ROR trends from 1977 to 1990.](from Energy Information Administration, USA)
Risk Management

• Risk Avoidance
  • Avoid opportunities with too large risk

• Loss Prevention
  • Understand and analyse the risk to prevent loss

• Risk Transfer
  • Farmouts, Joint Ventures, Diversification

• Insurance
  • Price dependant on risk
    – E.g. MIGA
      » Currency Transfer
      » Expropriation
      » Breach of Contract
      » War and Civil Disturbance
Decisions under Uncertainty

• The Consequences of a Decision is only unfolded in the uncertain Future

• Decision Analysis Methods are tools for manoeuvring in normal Business Environment
Decision Process

1. Understand Alternatives and the risk these alternatives involve

2. Evaluate the potential Consequences perceived in the Situation

3. Assess the uncertainties involved in the Decision

4. Recombining the judgements to develop a consistent Strategy
Risk Analysis Methods

Technical estimates of volume and production

Political Risk Analysis

Discounted Cash Flow Analysis

Technical Risk Analysis

EMV Analysis

Invest or Not?

Utility Theory

Gamblers Ruin Theory

How Much?

Yes

No

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Expected Monetary Value

- EMV = (R*POS) - (RC*(1-POS))
  - EMV = Expected Monetary Value
  - R = Reward = Net Present Value (NPV)
  - POS = Probability of Success
  - RC = Risk Capital = Bonuses, Dry Hole Cost, G&G etc.
Total Success Probability

- POS = $P_{expl.} \times P_{dev.} \times P_{fiscal} \times P_{pol.} \times P_{econ.}$

- Example:
  - POS = 0.5*0.9*1.0*0.8*0.6
  - POS = 0.22
Geological risking

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>P(play)</th>
<th>P(pros)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocarbon source [%]</td>
<td>80.0</td>
<td></td>
</tr>
<tr>
<td>Timing [%]</td>
<td>90.0</td>
<td></td>
</tr>
<tr>
<td>Migration [%]</td>
<td>90.0</td>
<td></td>
</tr>
<tr>
<td>Potential reservoir facies [%]</td>
<td>80.0</td>
<td></td>
</tr>
<tr>
<td>Trap occurrence [%]</td>
<td></td>
<td>70.0</td>
</tr>
<tr>
<td>Effective porosity [%]</td>
<td></td>
<td>80.0</td>
</tr>
<tr>
<td>Hydrocarbon accumulation [%]</td>
<td></td>
<td>70.0</td>
</tr>
<tr>
<td>&gt; Marginal play probability [%]</td>
<td></td>
<td>51.8</td>
</tr>
<tr>
<td>&gt; Conditional prospect probability [%]</td>
<td></td>
<td>39.2</td>
</tr>
<tr>
<td>&gt; Unconditional probability [%]</td>
<td></td>
<td>20.3</td>
</tr>
<tr>
<td>&gt; Dry hole risk [%]</td>
<td></td>
<td>79.7</td>
</tr>
</tbody>
</table>
Geological risk

Expected size before licensing (mil Sm³ o.e.) vs Size of discovery

From NPD
POS (Geological risk only)

**Probability of success = 0.50**
This is the typical probability of success of a step out or delineation well, or of an adjoining structure

**Probability of success = 0.20 - 0.30**
This is the typical range of probability of success of exploration in an area with many similar plays and structures and for an exploration well which is in such a structure not too far from existing discoveries

**Probability of success = 0.10 - 0.20**
This is the typical range of probability of success of exploration in a well explored area with a variety of different plays and on a new location

**Probability of success = 0.02 - 0.05**
This is the typical range of probability of success of exploration in a poorly explored area or a new geological basin in which previously no wells have been drilled or only dry holes have been drilled
EMV - Example

• Assumptions
  • NPV = 120 million USD
  • RC = 15 million USD
  • POS = 22%

• EMV = (R*POS) - (RC*(1-POS))
• EMV = (120*0.22) - (15*(1-0.22))
• EMV = 26.4 – 11.7
• EMV = 14.7 million USD

  – Break-even POS = RC/(NPV+RC)
  – Break-even POS = 15/(120+15)
  – Break even POS = 11.1% (EMV=0)
Success Capacity

• How many dry wells can a discovery carry?

Success Capacity = (1/break-even success ratio) - 1

Example:

Success Capacity = (1/0.111) - 1
Success Capacity = 8

One success well can carry 8 dry wells and still have a positive NPV
EMV curve

- EMV curve
- Reward (NPV)
- Break even POS
- Calculated EMV
- Calculated POS
- Risk capital
EMV example

<table>
<thead>
<tr>
<th></th>
<th>Capital</th>
<th>POS</th>
<th>EMV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome 1</td>
<td>120</td>
<td>22.0%</td>
<td>26.4</td>
</tr>
<tr>
<td>1-POS</td>
<td>-15</td>
<td>78.0%</td>
<td>-11.7</td>
</tr>
<tr>
<td>Total EMV</td>
<td></td>
<td></td>
<td>14.7</td>
</tr>
</tbody>
</table>

Break-even POS 11.1%

Success Capacity 8.0
EMV Exercise
Two outcome decision tree

- **Don’t drill**
  - EMV = 0 $  
  - NPV = 0 $  
  - POS = 0.22  
  - 1-POS = 0.78

- **Drill**
  - EMV = 14.7 MM$
  - Discovery
    - NPV = 120 MM$
    - EMV = 26.4 MM$
  - Dry hole
    - RC = -15 MM$
    - EMV = -11.5 MM$

**Chance node**

**Decision node**
An expanded tree

<table>
<thead>
<tr>
<th></th>
<th>Capital</th>
<th>POS</th>
<th>EMV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome 1</td>
<td>240</td>
<td>5.0 %</td>
<td>12</td>
</tr>
<tr>
<td>Outcome 2</td>
<td>120</td>
<td>7.0 %</td>
<td>8.4</td>
</tr>
<tr>
<td>Outcome 3</td>
<td>60</td>
<td>10.0 %</td>
<td>6</td>
</tr>
<tr>
<td>Total Capital</td>
<td>120</td>
<td>22.0 %</td>
<td></td>
</tr>
<tr>
<td>1-POS</td>
<td>-15</td>
<td>78.0 %</td>
<td>-11.7</td>
</tr>
<tr>
<td>Total EMV</td>
<td></td>
<td></td>
<td>14.7</td>
</tr>
</tbody>
</table>
Multi outcome decision tree

Drill
EMV=14.7 MM$

Don’t drill
0 $

Large Discovery
NPV1 = 240 MM$
EMV1 = 12 MM$
POS = 0.05

Med. Discovery
NPV2 = 120 MM$
EMV2 = 8.7 MM$
POS = 0.07

Small Discovery
NPV3 = 60 MM$
EMV3 = -6 MM$
POS = 0.10
1-POS = 0.78

Dry hole
RC = -15 MM$
EMV = -11.5

Total EMV = 14.7

Chance node
Decision node
Exercise
## Analyzing Political Risk

<table>
<thead>
<tr>
<th>Event</th>
<th>Capital</th>
<th>POS</th>
<th>EMV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discovery and moderate unrest</td>
<td>100</td>
<td>5.0 %</td>
<td>5.0</td>
</tr>
<tr>
<td>Discovery and large unrest</td>
<td>40</td>
<td>7.0 %</td>
<td>2.8</td>
</tr>
<tr>
<td>Expropriation during production</td>
<td>-60</td>
<td>10.0 %</td>
<td>-6.0</td>
</tr>
<tr>
<td>Unsuccessful Exploration</td>
<td>-15</td>
<td>78.0 %</td>
<td>-11.7</td>
</tr>
<tr>
<td><strong>Total EMV</strong></td>
<td></td>
<td></td>
<td>-9.9</td>
</tr>
</tbody>
</table>
Gambler Ruin Analysis

- Gambler's ruin occurs when a risk taker with limited funds goes bankrupt due to continuous failures.
- Will the company survive if worse come to worse?

**Flowchart:**
- **Technical estimates of volume and production**
- **Technical Risk Analysis**
- **Political Risk Analysis**
- **Discounted Cash Flow Analysis**
- **EMV Analysis**
- **Utility Theory**
- **Gamblers Ruin Theory**
- **Invest or Not?**
  - Yes
  - No
Probability of one success

- What number of wells would be needed to be sure of at least one discovery at a certain confidence level?

The probability of at least one success = 1 - the probability of all failures

\[ CL = 1 - (1 - \text{POS})^n \]

- CL = Desired confidence level
- POS = Success probability
- 1-POS = probability of failure
- N = No. of Exploration wells
Combined Probability of Success

Combined POS

Number of wells

Combined POS

Number of wells

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Utility Theory

- EMV curve
- Utility curve

Risk capital
Utility Break even SP

Reward (NPV)

Break even SP

Technical estimates of volume and production
Political Risk Analysis
Discounted Cash Flow Analysis
Technical Risk Analysis
EMV Analysis
Invest or Not?
Gamblers Ruin Theory
How Much?
Utility Theory

-40 -20 0 20 40 60 80 100 120 140
0 1 0 0 02 03 04 05 06 07 08 09
Probability of Success (%)
Million USD

EMV Analysis
Utility Theory
Gamblers Ruin Theory
How Much?

No
Yes
EMV Exercise

• An oil company have mapped a prospect and concluded that the resources may be as high as 100 million barrels and the probability of success is estimated to 10%. The data acquired, the interpretations and the cost of the exploration well will amount to 20 million USD. If a discovery is made, the NPV will be 90 million USD.

  – Calculate the expected monetary value.
  – Find the break even POS
  – Will you recommend this project to your Management?

• The company decides to shoot a 3D seismic survey before the first well. The budget for the survey is 5 million. The structure is confirmed and estimated even bigger than before and the geologists now estimates the POS to 20% and the economists calculate an NPV of 120 million USD

  – What is the new EMV?
  – Was the decision to shoot the 3D correct?
  – How many dry wells can be drilled for the project to still be positive if a discovery is made?
## Exercise B

<table>
<thead>
<tr>
<th>Capital</th>
<th>POS</th>
<th>EMV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome 1</td>
<td>90</td>
<td>10.0 %</td>
</tr>
<tr>
<td>1-POS</td>
<td>-20</td>
<td>90.0 %</td>
</tr>
<tr>
<td>Total EMV</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Break-even POS: 16.7 %
Success Capacity: 5.0

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Outcome 1</td>
<td>120</td>
<td>20.0 %</td>
</tr>
<tr>
<td>1-POS</td>
<td>-25</td>
<td>80.0 %</td>
</tr>
<tr>
<td>Total EMV</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Break-even POS: 17.2 %
Success Capacity: 4.8
EMV Exercise without 3D

1. Drill
   - EMV = -9 MM$
   - POS = 0.10
   - 1-POS = 0.90

2. Don’t drill
   - 0 $

- Discovery
  - NPV = 90 MM$
  - EMV = 9 MM$

- Dry hole
  - RC = -20 MM$
  - EMV = -18 MM$

Chance node
Decision node
EMV Exercise with 3D

POV = 0.20
Discovery
NPV = 120 MM$
EMV = 24 MM$

Drill
EMV=4 MM$

1-POV = 0.80
Dry hole
RC= -25 MM$
EMV=-20 MM$

Don’t drill
0 $

Chance node
Decision node
Multi outcome exercise

• An oil company has analyzed a prospect and have concluded that there may be three possible outcomes with related probabilities as given to the right in million usd

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Capital</th>
<th>POS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome 1</td>
<td>150</td>
<td>5.0%</td>
</tr>
<tr>
<td>Outcome 2</td>
<td>100</td>
<td>10.0%</td>
</tr>
<tr>
<td>Outcome 3</td>
<td>50</td>
<td>10.0%</td>
</tr>
</tbody>
</table>

• The exploration cost is calculated to be 20 million usd

• Draw a multi branch decision tree which illustrates all outcomes

• Collapse the multi branch tree into a two branch tree and draw an illustration
## Multi outcome exercise

<table>
<thead>
<tr>
<th></th>
<th>Capital</th>
<th>POS</th>
<th>EMV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome 1</td>
<td>150</td>
<td>5.0 %</td>
<td>7.5</td>
</tr>
<tr>
<td>Outcome 2</td>
<td>100</td>
<td>10.0%</td>
<td>10</td>
</tr>
<tr>
<td>Outcome 3</td>
<td>50</td>
<td>10.0%</td>
<td>5</td>
</tr>
<tr>
<td>Total Capital</td>
<td>90</td>
<td>25.0%</td>
<td></td>
</tr>
<tr>
<td>1-POS</td>
<td>-20</td>
<td>75.0%</td>
<td>-15</td>
</tr>
<tr>
<td>Total EMV</td>
<td></td>
<td></td>
<td>7.5</td>
</tr>
</tbody>
</table>

- **Break-even POS**: 11.8%
- **Success Capacity**: 7.5
Multi outcome exercise

Drill
EMV = 7.5 MM$

Don’t drill
0 $

POS = 0.05
Large Discovery
NPV1 = 150 MM$
EMV1 = 7.5 MM$

POS = 0.10
Med. Discovery
NPV2 = 100 MM$
EMV2 = 10 MM$

POS = 0.10
Small Discovery
NPV3 = 50 MM$
EMV3 = 5 MM$

1-POS = 0.75
Dry hole
RC = -20 MM$
EMV = -15$

Total EMV = 7.5

Chance node
Decision node
Collapsed multi-branched tree

- **Drill**
  - EMV = 7.5 MM$

- **Don’t drill**
  - 0 $

- **Discovery**
  - NPV = 90 MM$
  - EMV = 22.5 MM$

- **Dry hole**
  - RC = -20 MM$
  - EMV = -15 MM$

- **POS = 0.25**
- **1-POS = 0.75**

<table>
<thead>
<tr>
<th>Capital</th>
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<th>EMV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Capital</td>
<td>90</td>
<td>25.0 %</td>
</tr>
<tr>
<td>1-POS</td>
<td>-20</td>
<td>75.0 %</td>
</tr>
<tr>
<td>Total EMV</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Two outcome decision tree

- **Decision node**: Drill
  - EMV =
  - Discovery
    - NPV =
    - EMV = 24
  - Dry hole
    - RC =
    - EMV =

- **Chance node**: Don’t drill
  - 0 $
  - POS =
  - 1-POS =
Multi-branch decision tree

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Chance node

Decision node

Drill

EMV=

Don’t drill

0 $

POS =

Large Discovery

NPV1 =

EMV1 =

POS =

Med. Discovery

NPV2 =

EMV2 =

POS = 0.

Small Discovery

NPV3 =

EMV3 =

1-POS =

Dry hole

RC =

EMV=

Total EMV = 7.5