Exploration Economics

- **Characteristics**
  - Major gamble.
    - Discovery of an unexpected large field
    - Or no oil or gas at all
  - Sequential decisions.
    - Exploration investments are relatively small considered to further investment in case of success.
    - Investments without further commitments if failure
Exploration Economics

...characteristics – options and sequential decisions

- Information are revealed over time – options and sequential decisions
- Decision trees focus on critical uncertainties and decisions that reveal uncertainties

- Exploration drilling
  - appraisal
    - development
      - too small
    - dry well
  - too small
- 20%
Exploration Economics

- A petroleum exploration project
  - A field development decision
    Cash flow elements and uncertainty
    Decision criteria: Net present value (NPV)
  - An exploration decision
    New cash flow elements and uncertainties
    Decision criteria: Expected Monetary Value (EMV)
Exploration Economics...

- A field development decision
- Cash flow elements and uncertainty

Profitability and the risk
Technological uncertainty

...costs overruns in Norwegian Projects 1998

Change in CAPEX from PDO estimates to summer 1998

Billion NOK

<table>
<thead>
<tr>
<th></th>
<th>Bakder</th>
<th>Varg</th>
<th>Jotun</th>
<th>Oseberg Sør</th>
<th>Oseberg Øst</th>
<th>Visund</th>
<th>Åsgard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source: MIE</td>
<td>60%</td>
<td>23%</td>
<td>20%</td>
<td>10%</td>
<td>8%</td>
<td>15%</td>
<td>22%</td>
</tr>
</tbody>
</table>

Mai 2004
### Field Development Decision

Cash in flow (revenue)

Cash out flow (expenditures)

...to calculate the NPV

\[
NPV = \sum_{t=0}^{N} \left( \frac{V_t}{(1 + r)^t} \right)
\]

\[
= V_0 + \frac{V_1}{(1 + r)^1} + \frac{V_2}{(1 + r)^2} + \ldots + \frac{V_N}{(1 + r)^N}
\]

...where:

- \( V_t \) - the net income in year \( t \)
- \( r \) - discount rate
- \( N \) - total numbers of years (project duration)

### Exploration Economics

Drill a wildcat

- **Yes**
  - **Success**
    - 0.09
  - **No**

- **Failure**
  - 0.91

- Exploration costs
  - **Success**: 2.4 mill US$
  - **Failure**: 0.20

- Net cash flow of a field development
  - 100 mill US$

- Exploration and Appraisal costs
  - 2.8 mill US$
Exploration Economics

- New cash-flow elements:
  - Exploration costs
    - Seismic acquisition
    - Wild-cat well
    - Appraisal wells
  - More uncertainty:
    - Success vs failure
    - The resource size if success

Field development NPV has to include the exploration costs
The development NPV must be discounted to the date for the exploration decision
Consequently the NPV is sensitive to the lead time from discovery to development
Profitability and the risk
Uncertainty in time profile

...to calculate the NPV

...exploration costs and lead time - effect on NPV

- Assume 320 mill $ in exploration costs

<table>
<thead>
<tr>
<th></th>
<th>Pre Development</th>
<th>Pre exploration Lead time 5 years</th>
<th>Pre exploration Lead time 10 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV (7%)</td>
<td>2.131 billion $</td>
<td>1.120 billion $</td>
<td>713 billion $</td>
</tr>
</tbody>
</table>
Exploration Economics

- New cash-flow elements:
  - Exploration costs
    - Seismic acquisition
    - Wild-cat well
    - Appraisal wells
  - More uncertainty:
    - Success vs failure
    - The resource size if success

...probability of success

- The Risk Assessment estimates the probability of success
**Exploration Economics**

...resource assessment

<table>
<thead>
<tr>
<th>Resource size</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>p90</td>
<td></td>
</tr>
<tr>
<td>MEDIAN (p50)</td>
<td></td>
</tr>
<tr>
<td>MEAN (average – &quot;centre of gravity&quot;)</td>
<td></td>
</tr>
<tr>
<td>p10</td>
<td></td>
</tr>
</tbody>
</table>

**EMV = (Reward x P) - (Risk Capital x (1-P))**

**Exploration Economics**

...decision criteria – Expected Monetary Value

- **Reward**: NPV (field dev. minus exploration & appraisal costs)
- **Risk Capital**: Exploration costs

**EMV** = (Reward x P) - (Risk Capital x (1-P))
Two different approaches to calculate the EMV:

- Expected resource size
- Resource distribution

---

**Exploration Economics**

...resource assessment

![Diagram showing resource size distribution](image)

- **Probability**
- **Resource size**
- **p90**
- **p10**
- **MODE (Most likely)**
- **MEDIAN (p50)**
- **MEAN (average – "centre of gravity")**
…Expected Monetary Value

- …expected resource size - an example

- In the simplest model we use \( E(R) \) to represent the full range of possible discovery volumes

- If oil is present, the mean recoverable amount is 48 million bbl.

\[ E(R) = 48 \text{ million bbls} \]

... expected resource size - another example

\[ \text{DRILL} \]

\[ \begin{align*}
\text{Yes} & \quad 0.75 \quad \text{Yes} \quad 6 \text{ mill US$} \\
\text{No} & \quad 0.25 \quad \text{No} \quad -12 \text{ mill US$}
\end{align*} \]

\[ \text{EMV} = (0.75 \times 6) - (0.25 \times 12) = 1.5 \text{ million US$} \]
…Expected Monetary Value

- …expected resource size

- overlook the minimum economic resource - a minimum size below which a discovery would not be worth develop at all.

- assume a straight-line relationship between the size of a discovery and the NPV of development.

---

…Expected Monetary Value

- …minimum economic reserve

![Graph showing Expected Monetary Value](chart.png)

- MER = 25 mbbl
...Expected Monetary Value

...expected resource size - an example

- The minimum economic resource (MER) is 25 million bbl.

If oil is present the probability to find resource outcome higher than MER is 63% (the probability of commerciality).

If commerciality the mean resource outcome is 69 million bbl.

...Expected Monetary Value

...minimum economic reserve

DRILL

Yes

Find

Yes

0.75

Develop

Yes

0.63

(34-12) mill US$

No

0.25

No

- 12 mill US$

- 12 mill US$

EMV = 0.75*(0.63*22-0.37*12) - (0.25 *12) = 4 million US$
The increase represents the value of not being obliged to develop non-economic discoveries.

We improve the analysis by considering the whole resource distribution.

- Minimum economic reserve
- Economic of scale
…Expected Monetary Value

- …economic of scale

- Three-point distribution
- Monte Carlo simulation

\[
\text{EMV} = 0.47(0.3 \times 40 + 0.4 \times 40 + 0.3 \times 30) - (0.53 \times 12) = 11 \text{ million US$}
\]