Long term investment strategy – An independent review of the 2014 assessment
Jim Hall
Environment Agency Long Term Investment Scenarios

Flood and coastal erosion risk management
Long-term investment scenarios (LTIS) 2014
What LTIS has achieved

- A scientific and economic basis for resource allocation
- More complex than any equivalent assessment worldwide
- Based on a legacy of flood risk assessment research, dating back at least to 2002
Noteworthy achievements

- A national flood risk assessment model has been combined with a deterioration model, scenario assumptions and economic appraisal in 3000 flood systems.
- This has been integrated in to a national optimisation of investment, comparing risks and costs.
- The study takes a long term perspective and integrates current investment plans with longer term scenarios.
- Surface water flooding has been considered alongside river and coastal flooding.
- The major sensitivities (in the effect of climate change, floodplain development and the underlying risk estimate) have been analysed to explore and demonstrate the robustness of the results to uncertainties and assumptions.
Table 1 Properties at risk from flooding

<table>
<thead>
<tr>
<th></th>
<th>Rivers and the sea (thousands) From National Flood Risk Assessment (NaFRA)</th>
<th>Surface water (thousands) From flood map for surface water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Residential</td>
<td>Non-residential</td>
</tr>
<tr>
<td>High</td>
<td>153,000</td>
<td>91,000</td>
</tr>
<tr>
<td>Medium</td>
<td>350,000</td>
<td>153,000</td>
</tr>
<tr>
<td>Low</td>
<td>1,274,000</td>
<td>329,000</td>
</tr>
<tr>
<td>Very low</td>
<td>72,000</td>
<td>21,000</td>
</tr>
<tr>
<td>Total</td>
<td>1,849,000</td>
<td>594,000</td>
</tr>
</tbody>
</table>
Optimising future expenditure

Optimal risk $\hat{r}$ is achieved at cost $\hat{c}$, yielding adaptation benefit $\hat{r} - r_0$.
Choosing the future: how much should we invest in flood defence?
Optimal investment level

- The optimal ‘long-run’ investment in FCERM (at around £860 million per year) is 15% more than the current investment level.
- This is lower than one might have thought given that schemes funded at the moment typically have a benefit-cost ratio (BCR) of ~8:1.
- The objective function near the optimum is quite flat, so not too much should be read into the second significant figure.
- Marginal investments near the optimum (i.e. with a BCR just greater than 1.0) are unlikely to compete with other public infrastructure investments.
- Given the uncertainties in costs and benefits, in order to avoid the possibility of uneconomic investments it would be wise to focus upon investments with BCR robustly greater than 1.0.
- As long as investment is cost-beneficial it does not detract from the optimum.
Flood risk need not increase significantly in future, even in a changing climate.

The flood defence system can be adapted to changing future conditions.
Changing risk profiles

![Graph showing changing risk profiles](image-url)

- **Current situation**
- **(1) 2060s with optimum investment (baseline scenario)**
- **(2) Amended for current uptake of property level resistance**
- **(3) With 50% uptake of resistance**

**Properties at Risk**

- **Thousands**

**Legend**

- **High (above 1:30)**
- **Low 1 (1:100 to 1:200)**
- **Medium (1:30 - 1:100)**
- **Low 2 to Very Low (below 1:200)**
Optimal investment will lead to a profound shift in the risk profile

In future there will be:

- Relatively frequent flood damage to 0.3 million high risk properties where community protection is not affordable or justifiable in economic terms.

- Occasional catastrophic flood damage and disruption to urban areas and infrastructure networks when flood defence levels are exceeded.

Property level protection is an important strategic instrument for dealing with residual risk.
Critical assumptions

- Baseline risk estimate
- Timing of investment
- Exclusion of major disruption
- Cost reduction (10% efficiency saving 2015-2021)
- Effect of maintenance on deterioration
- Managed retreat
Recommendations for future development

- Reconfiguring NaFRA so that it can simulate the damage associated with specific (spatial) flood events
  - Validation
  - Construction of the full damage-probability distribution
  - Evaluate costs and benefits of options for insurance/reinsurance.
- Moving towards a global optimisation that incorporates:
  - Optimal timing of replacement
  - The benefits of maintenance
  - Property-level protection for management of residual risk.
- Periodically review the optimum long-term investment analysis to incorporate the effect of investments that are undertaken to reduce flood risk
Concluding remarks

- LTIS has helped to convince Treasury that the EA is proceeding in a responsible way in allocating public resources
- The results contain very significant assumptions and sensitivities
  - The baseline risk estimate (direct damage)
  - Wider economic impacts
  - The decision rule
- The analysis has provided some important insights:
  - It is feasible to adapt to increasing flood risk
  - It is not feasible to reduce flood risk much
  - Residual risk will continue to need to be managed
  - Cost savings are very important for the business case
- Next steps
  - Addressing assumptions and improving sensitivity analysis
  - Opening up to scrutiny and innovation
Real options analysis: examples from flood risk management
Jim Hall
Real Options Analysis

- Provides a framework to incorporate uncertainty and the value of flexibility into decision making
- A “Real Option” is an alternative or choice that becomes available through an investment opportunity or action.
- e.g. designing an activity with the flexibility to upgrade in the future provides an option to deal with more (or less) severe climate change.
Options we might wish to consider

- Option to expand
- Option to contract
- Option to switch resources
- Option for phased stage-gate and sequential investments
- Option to delay
- Option to abandon
Real “in” and Real “on”
Wang and De Neufville (2005)

- Real options “on” systems:
  - Focus on the external factors of a system and management of an investment portfolio

- Real options “in” systems incorporate flexibility into the structural design of the system
  - Incorporates flexibility into the structural design of the system
Stochastic versus probabilistic

- Stochastic formulation
  - closed form (e.g. Black-Scholes) or discrete (e.g. binomial lattice) models

- Probabilistic formulation
  - Decision trees, subject to scenarios of exogenous uncertainty
  - Several studies of engineering adaptation decisions:
    - Flood defences (Linquiti and Vonortas, 2012; Woodward et al. 2013, Hino and Hall in prep)
    - Water supply systems (Zhang and Babovic, 2011)
    - Marine protection systems (Babovic, 2009)
  - May also embed stochastic processes in a two-layer (aleatory-epistemic) uncertainty characterisation (e.g. Harvey and Hall, 2011)
### HM Treasury Green Book example: Option to expand

<table>
<thead>
<tr>
<th>Probability</th>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wall</td>
<td>Upgradeable wall</td>
</tr>
<tr>
<td></td>
<td>Cost</td>
<td>Benefit</td>
</tr>
<tr>
<td>Low climate change</td>
<td>0.5</td>
<td>75</td>
</tr>
<tr>
<td>High climate change</td>
<td>0.5</td>
<td>75</td>
</tr>
<tr>
<td>Expected benefit</td>
<td></td>
<td></td>
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</table>

#### Box 6: Appraisal using a Real Options approach

Consider a proposal for investing in infrastructure protecting against the impacts of flooding due to climate change. There are two options: invest in a wall, or invest in an upgradeable wall which has the option to upgrade in the future. The standard wall costs £75, and has benefits of £100 from avoided flooding. The upgradeable wall costs £50, the upgrade costs £50 and would give benefits of £200 from avoided flooding.

The information can be set out in a decision tree:

The expected value of investing in the standard wall is a simple NPV calculation, calculating the expected costs and benefits of the investment. The NPV is $(0.5 \times -75) + (0.5 \times 100) = -25$. This suggests the investment should not proceed.

Flexibility over the investment decision allows the possibility to upgrade in the future if the impacts of climate change are high. The expected value of this option can be calculated.

If the impacts of climate change are high enough to warrant upgrading, then the value of the investment is £120. If the impacts are low, then upgrading is not justified since the payoff is negative (£-40). Since the investment costs of the upgrade are not realised in practice in the low outcome, they are therefore not incorporated into the NPV. The expected value of investing now with the option to upgrade in the future is $(0.5 \times 120) - 50 = +10$.

Comparing the two approaches shows an NPV of -25 for the standard approach, and +10 for the Real Options approach. Flexibility to upgrade in the future is reflected in the higher NPV, and switches the investment decision.
Option to expand revisited

- 6 climate change scenarios
- 3 socio-economic scenarios
- Evolving in 20-year time steps

Do-nothing damage-probability function
Option to expand revisited

Upgrade triggered at BCR > 5
Option to expand revisited

\[
\text{Expected Option Value} = \sum_{CC=1}^{6} \sum_{SE=1}^{3} w_{CC,SE} \sum_{t=0}^{T} \frac{1}{(1 + s)^t} \left((B_{\text{Adapt}} - C_{\text{Adapt}}) - (B_{\text{Fixed}} - C_{\text{Fixed}})\right) = £1,480k
\]

Yellow: Phase 2 is built in the adaptable strategy
Alternative options to expand:
Preventing floodplain development

**Phase 1**
- Base case: Development is permitted. No flood protection
- Develop: Development is permitted. Initial protection is constructed
- Buy: Development is not permitted

**Phase 2**
- No flood protection upgrade
- Flood protection upgrade
- No additional flood protection
- Flood protection is built
Lessons learnt

- Real options analysis seems to have become a shorthand for options appraisal under uncertainty with future flexibility.
- The instances in which one has to justify expenditure now (i.e. via a positive option value) in order to retain future options are less common.
- Calculation of expected option values is “the weakest link”: it often relies on probabilistic information about scenarios which may not be available/justifiable.
- Extended sensitivity analysis of decision pathways under a wide range of uncertainties is of value even in the absence of probabilistic information.
- Introducing optionality enhances robustness: choices today are less sensitive to future uncertainties.