Real Options Analysis in Climate Change Adaptation Decision under Uncertainty

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Uncertainty Issues in Risk Assessment of Climate Change

- **Climate Change Prediction with Scenario** (IPCC, 2014)
- **Flexibility & Robustness** – Thames Barriers in London, DELTA Project in Netherlands, New York City Panel on Climate Change
- **Non-Stationary State** – Transition in probability over time
- **Cost-Benefit Analysis** – Common approach in most of countries

Characteristics of Real Options Analysis

- **Real Options Analysis** is developed from financial issues for investment decisions on energy, stocks, plants, etc. (Dixit and Pindyck, 1994)
  - Addressing **Future Uncertainty**
  - Incorporation of **Flexibility** – Waiting, Future Growth/Shrink or Abandonment
  - Stochastic Process – the description of **changes in probability**
  - Evaluating an option with flexibility in **monetary terms**, etc.

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Cost-Benefit Analysis vs Real Options Analysis

Characteristic	Cost-Benefit Analysis(CBA)	Real Options Analysis(ROA)
Perspectives to future	Deterministic 'The current knowledge is the best'	Probabilistic 'The future is uncertain but we can explore the future with scenarios'
The types of decision	Now or Never	Now, Never or Later
Uncertainty	Not Resolved in calculation	Resolved in calculation
Flexibility	Not incorporated	Incorporated and Monetized
Results	Net Present Value (NPV)	NPV, Optimal Investment time, Real Option Value (ROV)
Procedure	Complicated	More complicated

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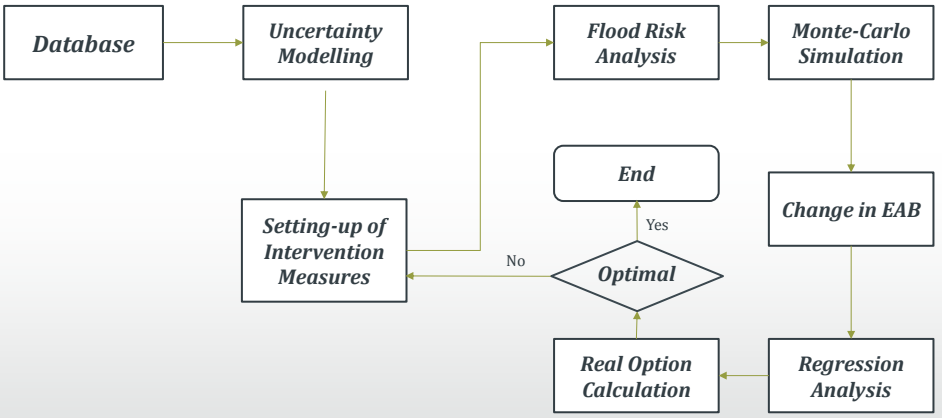
Framework of Real Options Analysis in Climate Change Adaptation (Developed on the basis of Dixit and Pindyck, 1994 and Yang, 2007)



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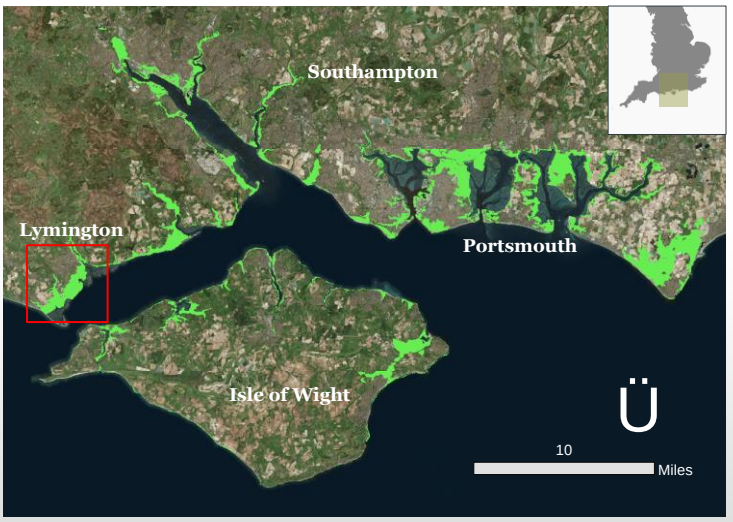
The Case Study Area of Lymington, the Solent (Wadey et al., 2012)



Areas at risk of 1-in-1000-year coastal flooding

* Image source: BBC (Coastal Flooding, 2003)

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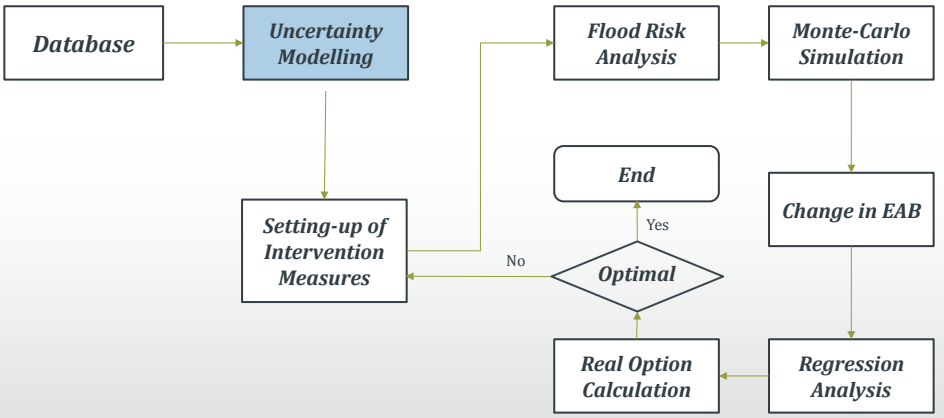

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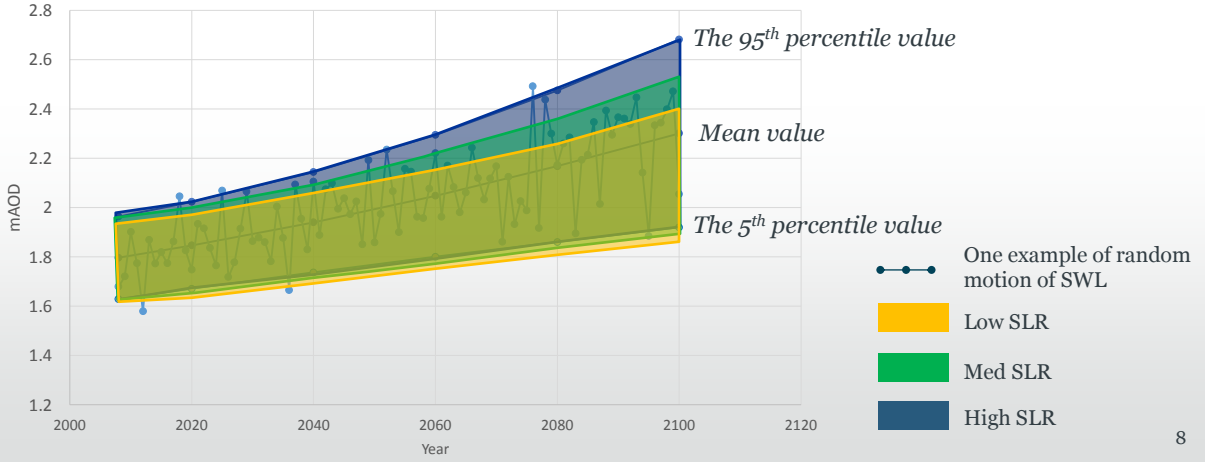
Changes in Still Water Level (SWL + SLR) over time

(Data source: UKCP09, McMillan, 2011)

The probabilities of Still Water Level and Sea Level Rise were combined by Monte-Carlo Simulation for each of some selected years – 2008, 20, 40 ,60, 80 and 2100



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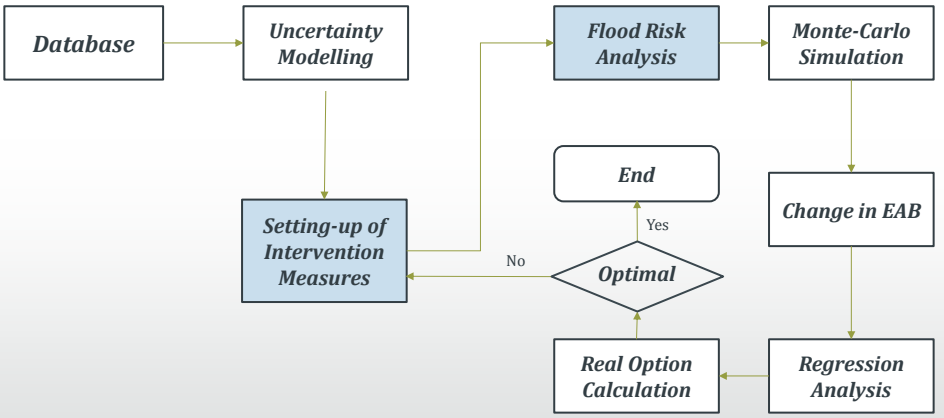
Flow of Real Options Analysis in Climate Change Adaptation



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The Extents of flood risk area at different SWLs (LISFLOOD-FP)

(a) No intervention

(b) Intervention

*Map Source: Arc-GIS

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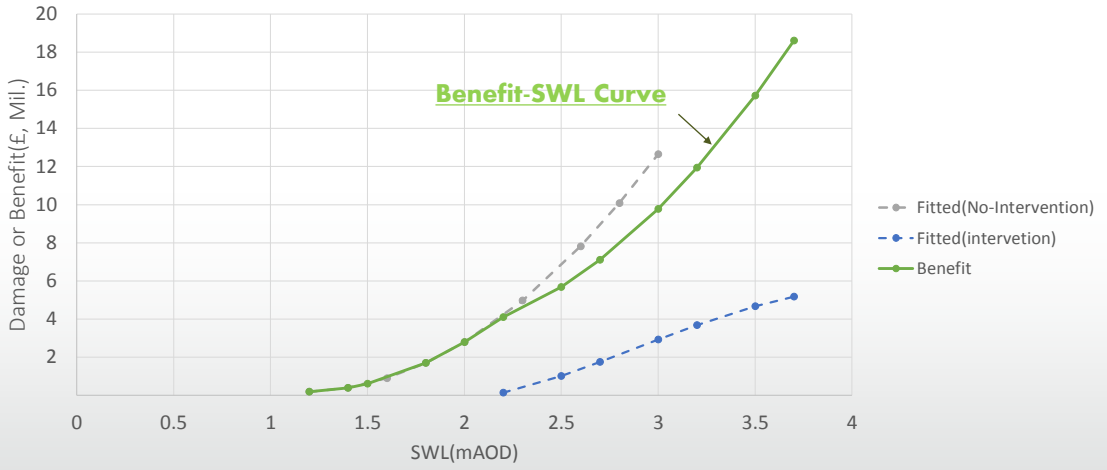
Damages or Benefit(£) - SWL Curve at Lymington

(Data source: Multi-Coloured Manual by Penning-Roswell et al., 2010)



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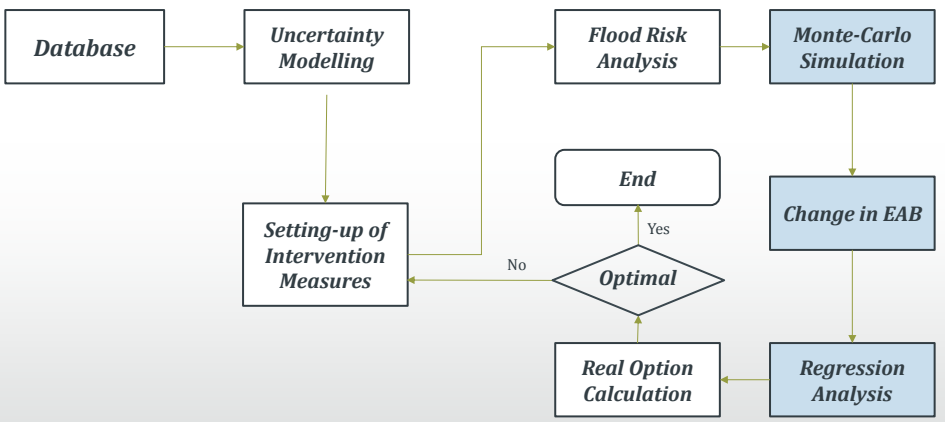

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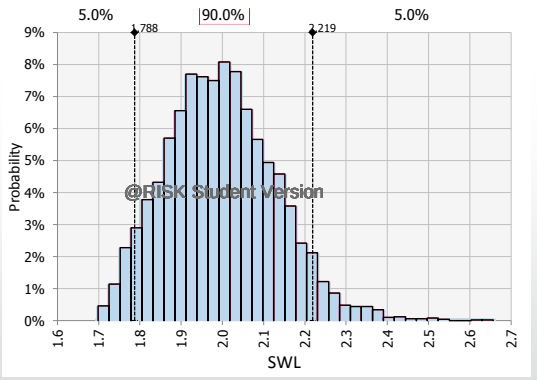
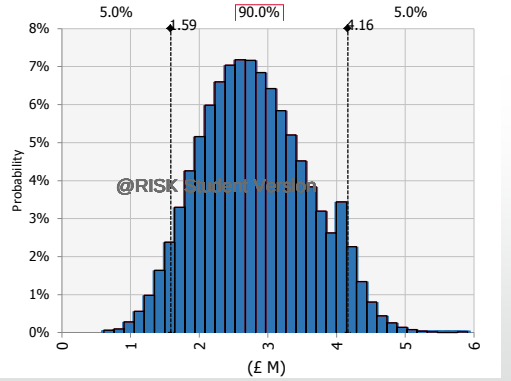
Conversion of SWL to EAB (Expected Annual Benefits)

- Monte-Carlo Simulation (5,000 runs per simulation) for each of selected years (e.g. 2020, 40, 60, 80 and 2100) has been applied through @Risk



(a) SWL at 2060 for Medium Scenario



(b) Benefits at 2060 for Medium Scenario

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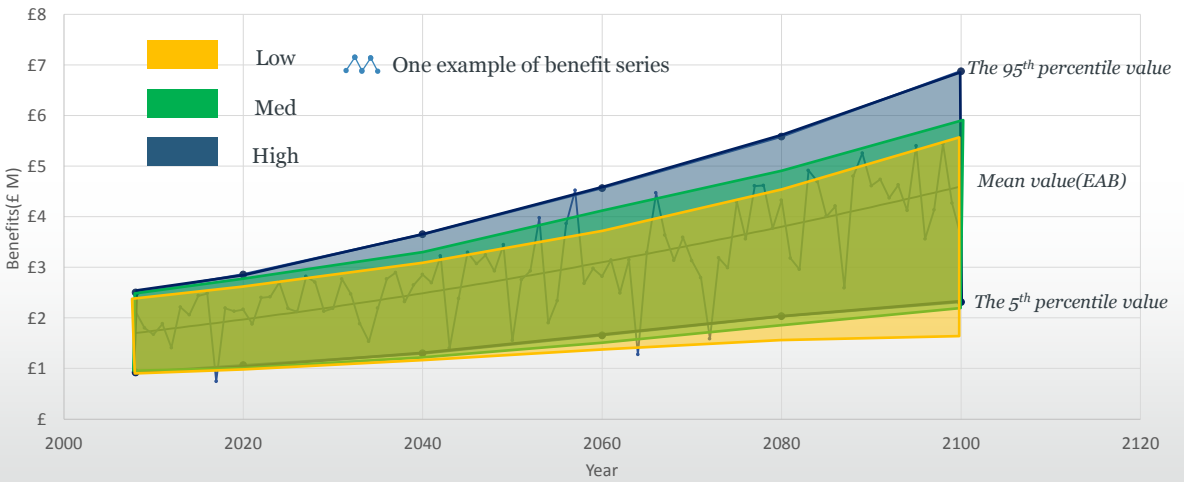
Changes in Expected Annual Benefit(EAB) with Likely Ranges



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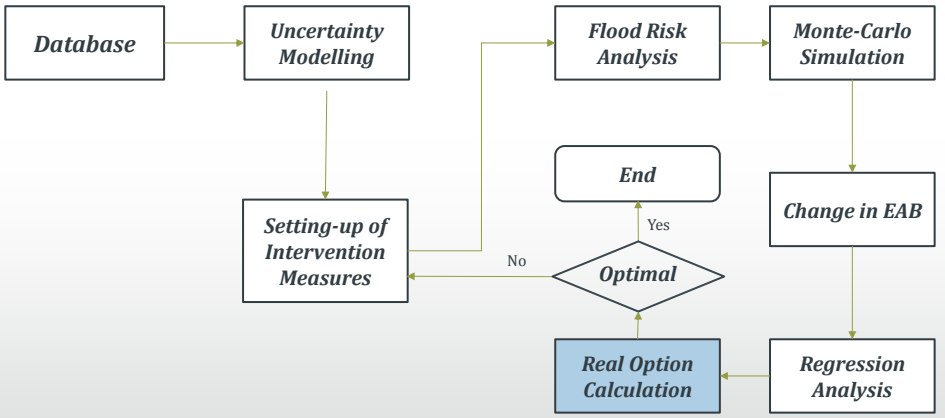

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Calculations of Real Options (Dixit & Pindyck, 1994)

- A real option with flexibility for each year has two values;
  - Termination Value (when an option is implemented)
  - Continuation Value (when an option is deferred)

$$F_t = \max\left[V_t - I, \frac{1}{1+r} E_t[F_{t+1}]\right]$$

Where, F_t: Real Options Value at time t

V_t: Project Value when invested at t yr

I : Investment cost

$E_t(F_{t+1})$: Expected Value of F_{t+1} at t yr

r: Discount rate

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The Conditions of Lymington for real options analysis

- Investment cost: £ 61.56 M
- Time Period: 2100 year
- SLR scenario after 2100 is assumed to increase at the rate of 10 to 2.5 mm/yr depending on Scenario
- Discount Rate (HM Treasury, 2011) : 3.5% for 30 years,
  3.0% for 31 to 75 years and
  2.5% thereafter

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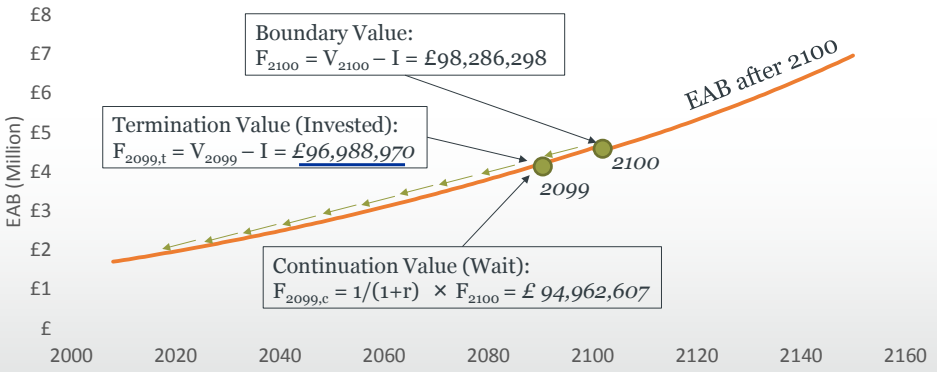
Examples of Real Options Calculation at High SLR Scenario



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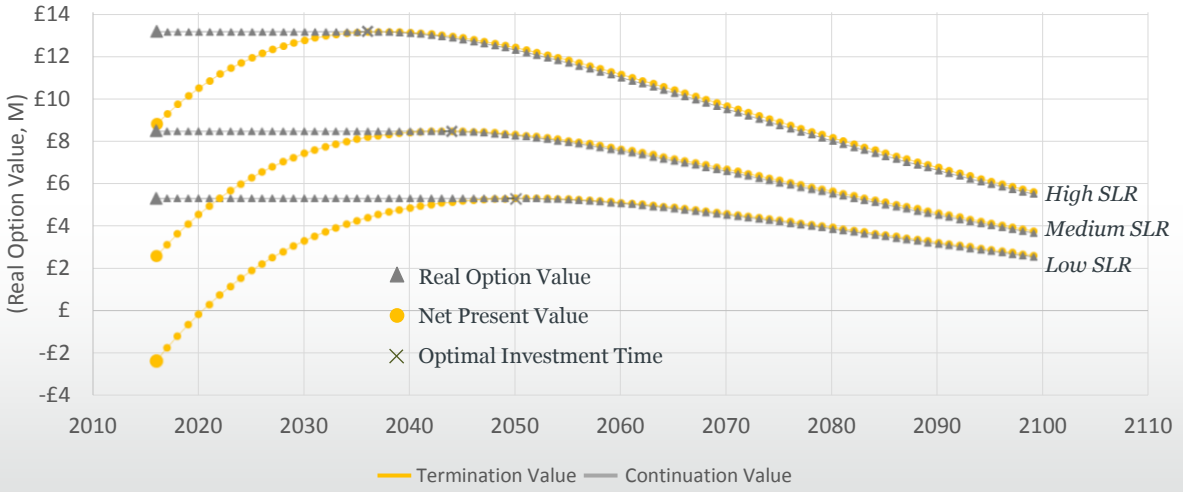
Real Option Value for each of SLR Scenarios



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Results of Real Options Analysis according to SLR scenarios

Scenarios	Low	Medium	High
Investment cost	£61,600,000	£61,600,000	£61,600,000
Optimal Investment time	2051	2044	2036
NPV[1)]	-£2,300,000	£2,600,000	£8,800,000
ROV[2)]	£5,400,000	£8,500,000	£13,100,000

Note: 1) NPV (Net Present Value) is an option value when the investment is made at 2016
2) ROV (Real Options Value) is an option value with flexibility considered in its calculation

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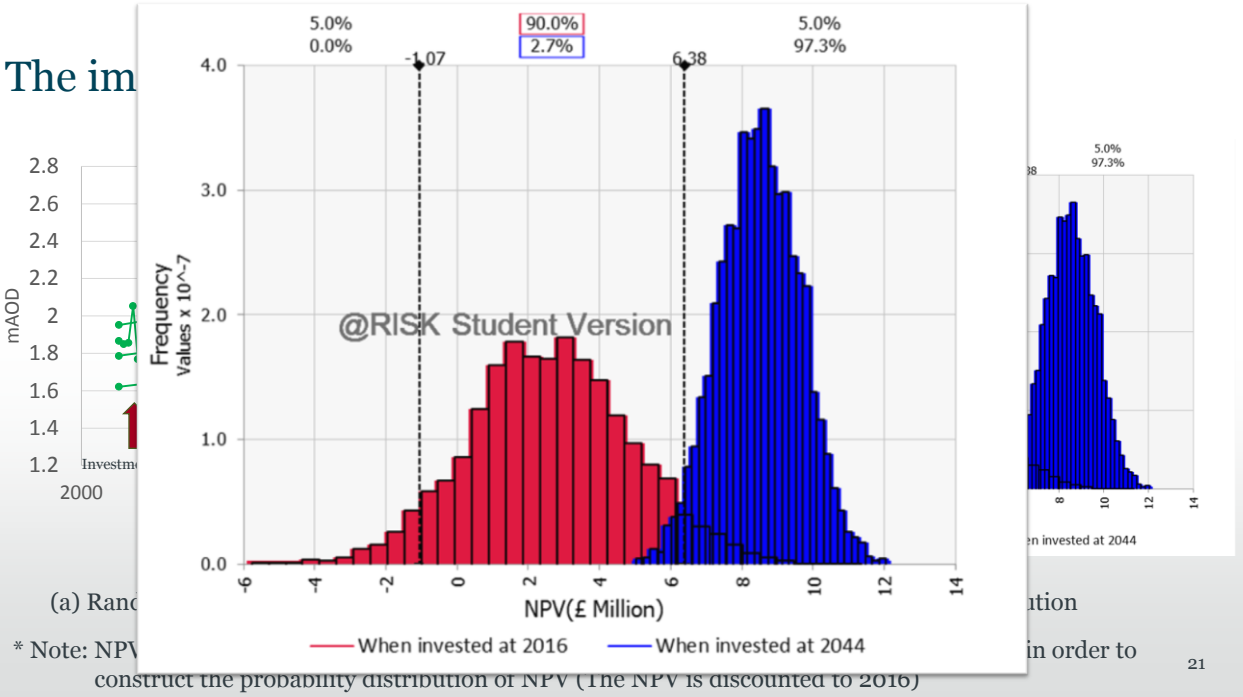

(a) Ranc ution

* Note: NPV in order to construct the probability distribution of NPV (The NPV is discounted to 2016)

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Conclusions

- Through the case study of Lymington, Real Options Analysis provides **Optimal Investment Time** and **Real Option Value** for an intervention measure according to climate change scenarios
- When invested at optimal investment time, **the investment criteria are satisfied even under the uncertainty of future**.
- Real Options Analysis **can give additional results other than a conventional analysis does** (e.g. cost-benefit analysis)
- Thus, Real options analysis can be applied **as a complementary tool for cost-benefit analysis** in climate change issues or policies related to uncertainty

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Thank you

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