04 - PRACTICAL APPRAISAL TECHNIQUES FOR VALUING ADAPTIVE CAPACITY IN FLOOD RISK MANAGEMENT

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Abstract

There are many sources of uncertainty and drivers of future change that communities and decision-makers could be better prepared for by adopting more adaptable plans to manage flood and erosion risks. It may not be possible to reduce uncertainty, at least in the short term, but recognising and accepting uncertainty and being better able to manage it can save money and time.

Flood Risk Management has always faced the challenge of decision-making in the face of multiple uncertainties relating to the climate, the economy and society. Traditionally, these have been addressed by adopting a precautionary approach; however, a managed adaptive approach can offer advantages. The benefits include improved resilience to negative changes, enabling opportunities to arise from positive changes and greater cost-effectiveness.

The absence of clear methods and tools to value adaptive approaches has also been recognised as an obstacle to wider adoption. In this paper a staged approach to building in adaptive capacity is proposed, which systematically analyses uncertainties, identifies opportunities to incorporate adaptability, and appraises the benefits through analysis of decision trees. The methodology is set in the context of an appraisal processes operated within a framework of cost-benefit analysis. The approach is transferable to other situations where future options on water management require decision-making based on quantified assessment of costs and benefits. The work should help decision-makers to fully appraise the benefits of building in adaptive capacity and make the economic and technical case for adaptive flood risk management in the context of an uncertain future.

This paper is based on a Guidance Note commissioned by OPW to support the CFRAM Programme and in particular ensuring climate change adaptation is taken account of in option selection. The techniques adopted in the OPW Guidance Note were development during research led by JBA Consulting for the Environment Agency in this area. Use of Decision Trees to clearly identify critical spatial and temporal decision points and prompt an alternative and adaptive response in the design of flood relief schemes have been adopted in highly vulnerable communities. This will allow a proactive adaptive strategy to be set out within the Flood Risk Management Plan.

1 INTRODUCTION

There are many sources of uncertainty and drivers of future change that communities and decision-makers could be better prepared for by adopting more adaptable plans to manage flood and erosion risks. It may not be possible to reduce uncertainty, at least in the short term, but recognising and accepting uncertainty and being better able to manage it can save money and time.

The capacity of organisations, institutions and individuals to adapt to changes in their wider environment varies considerably between and within sectors. This paper focuses upon improving the adaptive capacity of the Flood Risk Management (FRM) industry in Ireland through the CFRAM programme, through the development of practical approaches to support the appraisal of managed adaptive approaches. The characteristic time-scales for investments in flood risk management are of the order of 10 to 100 years. Over these timescale, uncertainties surrounding climatic and socio-economic changes can have a significant influence on the benefits that investment in FRM can be expected to accrue. In fact the uncertainties may be so great that it is hard to make the case for major investments now, other than by adopting a 'precautionary' approach, which may incur excessive costs. Alternatively, decision-makers may seek to adopt an adaptive approach which builds in flexibility and helps them to react to future uncertainties as they materialise during the life of a project.

The **managed adaptive approach** to FRM promotes an holistic and long-term approach which reinforces existing climate change policy by promoting actions that also support other socio-economic objectives and longer term adaptability. The approach advocates flexibility in responses, meaning that they are capable of addressing uncertain future challenges and opportunities as they arise.

The adaptive approach differs from the more traditional approach to FRM – the **precautionary approach** – in which assumptions are made of what might happen in the future and a fixed investment programme is planned accordingly. When uncertainties are severe, a precautionary approach may involve excessive upfront investment, which could prove to be unwarranted, or, if change is faster than anticipated, may result in an unacceptable level of risk.

Managed adaptive and precautionary approaches are not mutually exclusive; to a large degree, the adaptive approach is precautionary in that it ensures options are open for future change rather than applying locked-down solutions.

Accepting and managing uncertainty is not easy and, while there are few arguments against the benefits of affordable and flexible investment plans, there can be difficulties with their justification, development, valuation and implementation. Previous research (Defra 2009b) has identified specific barriers to the development and appraisal of adaptive approaches, namely:

- a lack of systems thinking involving narrow problem definition
- a focus on the status quo; risk and uncertainty aversion
- an inability to value the benefits of adaptation and the costs of not adapting
- a lack of evidence explicitly identifying examples of adaptive approaches or evidencing their efficiency, effectiveness and general improved performance.

To address the challenge of climate change, the OPW, as lead agency for flood risk management in Ireland, has adopted an approach in relation to assessing and providing for the potential impacts of climate change for the Flood Risk Management Programme (FRMP). This approach is aimed at the effective and efficient provision for the potential impacts of climate change in the management of existing, and particularly potential future, flood risks.

The approach requires that the possible impacts of climate change, and the associated uncertainty in projections, shall be considered at all stages of activity under the national Flood Risk Management Programme, and the development, design and implementation of all policies, strategies, plans and measures for, or related to, flood risk management must be sustainable and should adopt an adaptive or, where appropriate, an assumptive (precautionary) approach with respect to such impacts.

2 WHICH APPROACH IS APPROPRIATE AT THE STRATEGIC CFRAM LEVEL

The approach that brings these future challenges into a strategic context is known as the **managed adaptive approach** to flood and coastal risk management. This involves planning and investing now in actions that manage today's risks, monitoring the change in risk over time and managing these changes. The managed adaptive approach, therefore, involves planning for multiple interventions and investments in the future, although the future choices and the timing of these interventions will be uncertain.

If the rate of climate (or other) change diverges from our present-day expectations, then a managed adaptive approach offers flexibility to respond to its impacts and hence provide greater resilience. However it may be that there are also costs associated with maintaining this flexibility.

Traditionally, uncertainty has been managed by adopting a precautionary assumptive approach, for example by applying additional freeboard to a design crest level or preventing development in flood prone areas. These approaches are still relevant and relatively straightforward to appraise. However, it is now recognised that a wider and whole systems approach to a broader suite of uncertainties is required in order to achieve better value for money and greater sustainability and flexibility in the measures to address flood and coastal erosion risks. It is also acknowledged that in some circumstances a highly precautionary response may still be appropriate, where an identified limit to the flexibility of the solution is acknowledged.

The important driver is to ensure that a full examination of these uncertainties is undertaken as early as possible in the FRMP process, well before preliminary options are considered. From previous research examining options for managing climate change at the point of design and implementation is often too late and a less efficient process, which often leads to less adaptable solutions. In this design based optimisation approach where the preferred solution is "checked" as to whether it is adaptable to climate change, it is possible that the search for preferred option has to revert back to re-examine adaptable options through a revised screening process. This is both time consuming and will not build trust with the communities we are working with.

Climate change adaptability is included in the Multi Criteria Analysis (MCA) process adopted to support the selection of options for the FRMP. However, adaptability should be a guiding factor in considering the overall long term-strategy for flood risk management for an area and be an overriding criteria against which the strategy should be tested. This is criticality associated with ensuring our decisions are robust when climate change enhanced events occur. The ADAPT project published by EPA and UCD has some useful background to the science of Real Options Appraisal (ROA), which is the foundation for the proposed approach in this note.

There are some potentially significant advantages of a managed adaptive approach – less intense capital programme, communities starting to take more responsibility and planning for future provision of FRM measures and FRM become more aligned to the spatial planning cycle.

3 PREPARING FOR THE ASSESSMENT OF ADAPTABLE CLIMATE CHANGE FLOOD MANAGEMENT OPTIONS

3.1 Screening

Real Options Appraisal is a viable but challenging technique that can be applied to decision making where significant uncertainty exists. It is therefore important before these techniques are applied across the CFRAM programme, appropriate screening is undertaken so that ensuring adaptive options is focused on the most vulnerable communities. This screening delivers:

- ROA is challenging and reserved for key areas
- Understanding the scale of the impact and the challenge in managing these impacts
- Assessment of drivers of uncertainty and a timeline for these drivers to be triggered or decisions to be made
- Screening of the most appropriate approach to be applied in the FRMP so that adaptability to climate change is addressed through strategic choices or a defined approach to the design of flood management measures.

The screening will typically identify two alternative routes to the assessment of options. The CFRAM is broken down into Areas of Further Assessment or AFAs (arising from the Preliminary Flood Risk Assessment carried out by the OPW in 2010). Where the vulnerability of the community within the AFA is high to climate change and the absolute change is significant (and hence could justify a large increase in investment to manage that risk) a Decision Tree should be constructed to assist with the appraisal. Also where changes to the AFA are planned that are external to the FRMP, i.e. large scale regeneration this would also trigger a Decision Tree. However, if the change in flood risk is relatively benign and existing measures can be adapted as necessary then climate change adaptation can be dealt with through the standard FRMP Multi-criteria analysis approach.

3.2 Understanding the scale of the challenge

3.2.1 Setting and checking boundaries

Boundary setting is an important stage for capturing the extent of the flood risk management problem. Adaptation to climate change is a social and economic issue and this stage needs to identify boundaries not only in terms of flood cells and catchment areas, but also the implications for economic well-being on a wider development plan area basis. The CFRAM process requires a consideration of current risks and future risks. A detailed appraisal of managed adaptive solutions require more detailed consideration of future risks and benefits, which may involve modelling impacts of future uncertainties including climate change scenarios and scenarios linked to other variables such as economic growth and regeneration or population change. These can be done in a simplistic manner by scaling current results, for example use a 20% uplift in Annual Average Damages (AAD) to reflect enhanced economic value in a flood cell.

Where the risks and the potential solution are predicted to extend beyond the “economic” flood or coastal cell then the geographic extent of the appraisal should be extended. Including ‘space for water’ concepts can then be considered, which may help to identify a true community response to how future uncertainties could be managed in the long term.

3.2.2 Assess extents and economic damages (AAD’s) for climate change scenarios

The output of the CFRAM modelling will provide an appreciation of the extent, revised depths and velocities arising from the climate change scenarios.

A scoping assessment, as an indication of how climate change will influence the FRMP, is required at this early stage. This should be done on an absolute and percentage basis so that climate change impacts can be assessed locally but also within a national context. The mapped and modelled water levels and extents will inform the modeller when reviewing the AFA that either the scale of the flood risk will change significantly under future scenarios or that the change in risks will be modest. Importantly new areas of risk may be identified and that the typical response may have to alter to manage the climate change impacts (higher wall, replace of bridge deck etc).

Where climate change will be manageable within existing defence provision and requires a moderate increase in investment it is recommended that the final assessment of climate change adaptability is undertaken at preferred option stage, and is a retrospective check. This will follow the Adaptive Approach within the design process and does not need to be analysed any further. However, it should be noted that there is a potential to conclude that the preferred option does not lend itself to a managed adaptive approach. This is not uncommon to come to this conclusion late in the process, and reinforces the need to select not only adaptable measures but also adaptable options, and for these to be retained with the short listed options.

Where climate impacts are looking significant then the full process should be followed with the use of Decision Trees to help in choosing an adaptable solution.

4 CONSTRUCTING DECISION TREES

4.1 Assess drivers for change

The future is uncertain. Some aspects of the future can be directly influenced by the flood or coastal erosion manager whilst others are wholly outside of their control, and are referred to as ‘autonomous’.

Before risk modelling commences, it is important to think broadly, with stakeholders, about the impact uncertainties could have on the local community. At this stage, there is a need to:

- Identify the drivers of future change and sources of uncertainty
- Quantify the nature of change and the time period over which it takes place
- Assess the likely impacts of the specific changes and their scale on the locality in question
- Identify potential trigger points and key decisions; for example, whether or not a regeneration scheme is being promoted in the local development framework.
- Collate the supporting evidence.

The exploration of the drivers of change should be as broadly based as possible, covering a full range of relevant issues and stakeholder interests. It is also important to consider how these uncertainties could play out in future and what the impacts are likely to be over specific time periods and on specific areas.

4.2 Identify adaptive measures/options

If we are to break from a legacy of traditional engineered responses to flood risk then our thinking needs to be different.

The question list in Figure 6.1 is designed to help identify low- or no-regrets measures, or measures that deliver multiple benefits regardless of future change.

Potential options

1. Reducing vulnerability
a: Have all reasonable opportunities to reduce vulnerability been taken?
b: Have steps been taken to limit future increases in vulnerability?
c: Has a full examination of the range of futures identified the potential for a significant increase in risk requiring a radical approach to managing the receptors?

2. Making space for water and function
a:Have opportunities to make space for water and function been maintained/enhanced?
b: In making space for water can the scale of receptors at risk be reduced?

3. Delivering co-benefits and co-funding
a: Have opportunities for present day co-benefits and co-funding been enhanced?
b: Have opportunities for future benefits been maintained/enhanced?

4. Building in flexibility
Does the option include potential for future modification?

5. Deferring, removing or abandoning
a: Could it be removed/stopped with minimum impact (on resources and on the environment)?
b: Can investment be delayed without an intolerable build-up of risk or foregoing present opportunities?

Adaptive options

Figure 4.1*: Considerations to enable the development of adaptive options*

The list of questions is intended to highlight the following attributes:

1. **Reducing vulnerability** – reducing the consequences should a flood occur is often more easily effected than managing the probability of flooding through structural interventions in the pathway or indeed the source of the flood waters. Actions taken to reduce vulnerability through improved preparedness, warning and evacuation are typical non-structural responses that can be easily modified or involve minor structural responses that are easily changed or moved. A focus on reducing vulnerability is promoted as it is (typically) more adaptable than efforts devoted towards reducing probability. Lowering the vulnerability of an area by changing the utilisation of land use is highly effective, although should be considered carefully. In addition, options should be taken to ensure that future vulnerability is not increased.

2. **Making space for water and function** – options that contribute additional, or do not restrict, space for water and function are more likely to perform well under different futures than those that do not. Such options can contribute additional space either at source (through source control) or throughout the pathway (set back, defence lines, preferential flood routes, wetland recreation etc). They radically reduce the vulnerability of the receptors previously at risk.

3. **Delivering co-benefits** – Integrated solutions to flood risk. These types of schemes will tend to look at wider agendas and will facilitate discussions concerning solutions that are

changing the status quo. This is likely to result in the introduction of adaptive options that are in alignment with the wider aims of the area.

4. **Building in flexibility** – alternatives that enable future modifications or decisions to be implemented more readily within minimum resources and impact (social, financial and ecosystem) characterise adaptability. For example, land banking for future defences, foundation strengthening or widening for future crest raising etc. By proactively developing staged approaches, decision makers are better able to respond to future change. Effective and flexible modification is often supported by implementing measures in smaller, more frequent increments, than traditionally is the case. For example, roll back or beach nourishment (i.e. to maintain the higher foreshore level) as opposed to defence height increases to maintain the overtopping performance of sea defences.

5. **Deferring/removing or abandoning** – alternatives that can be either deferred until later or removed, if structural, or stopped, if non-structural, with minimum disruption and impact (social, financial and environmental).

5 USING DECISION TREE ANALYSIS

The purpose of option appraisal is to enable shortlisted options to be evaluated in more detail and the preferred investment choices to be made. This appraisal is undertaken on a whole life basis, using discounting to calculate the present values when considering costs and benefits of these options. Decision trees can be constructed at workshops and frame the time based adaptive approaches that are possible at each AFA. They are seen as best practice in option identification.

The guidance presented below uses a decision tree approach to represent the range of future choices and then considers external uncertainties by appraising the performance of **each decision pathway through the tree** for alternative futures (Figure 5.1). The approach set out below is straightforward in principle, but from experience of undertaking the case studies can prove to be complex in practice. A proportionate approach is recommended relating to the complexity of the problem or opportunity being addressed and degree of uncertainty faced.

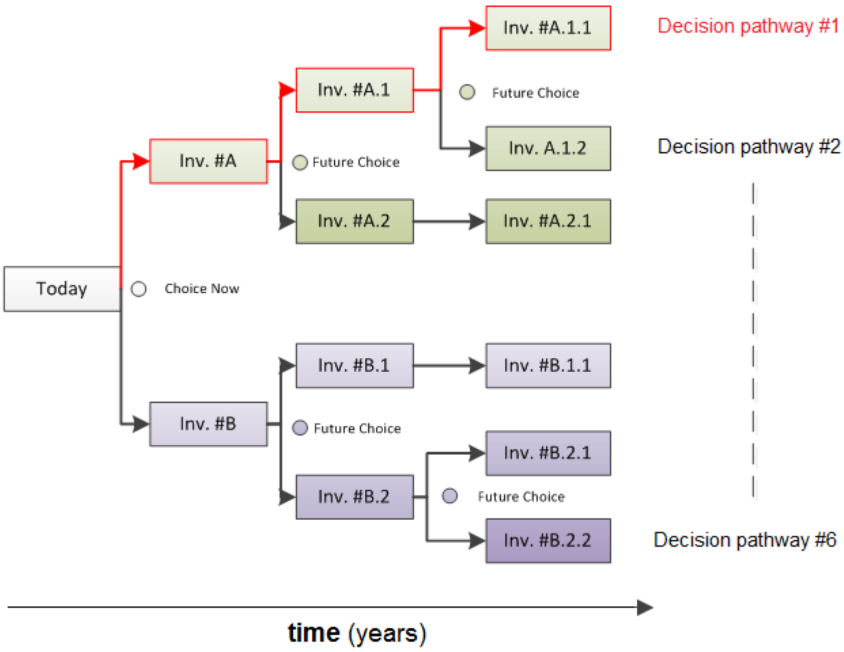

***Figure 5.1**: Illustrative decision tree representing six decision pathways and the associated choices that the FRM manager may make, both now and in the future*

Decision pathways represent a key addition to the existing option appraisal processes so that each option are still evaluated as in existing guidance and entered as an annual stream of values into Multi Coloured Manual (MCM) spreadsheets to generate Net Present Values (NPVs). However, additional performance measures are introduced to value the flexibility, robustness and opportunity lost through making particular decisions. The decision tree analysis proposed here can, and should, be approached with a varying amount of rigour depending on the type of application being considered. It is suggested that the full method set out in this paper is particularly applicable and highly recommended for circumstances in which it is advantageous to build future flexibility into an investment plan.

5.1 Required inputs

The decision tree analysis requires information on:

- Future uncertainties described through autonomous futures, with associated weights where these have been derived,
- Investment costs associated with each of the short-listed options,
- Investment timings associated with each of the short-listed options,
- Benefits associated with each of the short-listed options, evaluated with respect to each future uncertainty.

The background and scoping to derive this information should have been undertaken during the scoping stage. It is important that the planning of any appraisal, especially one where managed adaptive approaches are being considered, involves the early identification of key (trigger) points on the decision tree via discussion with stakeholders.

5.1.1 Define a suite of futures for use in the Decision Tree

At the end of this stage a suite of 5-7 alternative and autonomous futures will be determined. They will be used to test the performance of each decision pathway. These are **only** required if quantitative analysis of option performance is to be undertaken through the decision tree.

An example set of alternative autonomous futures is set out below in Table 6.2. Each future is described as a combination of climate change and economic change and potentially could extend to cover funding change drivers. Together these three aspects describe one future. In this situation economic growth underpins the local authority's development aspirations and national funding could have a significant impact on successful delivery of the scheme.

5.2 What can the decision tree show

Using this guidance should assist practitioners in:

- appraising different options/pathways within decision trees,
- appraising multiple options under future uncertainty,
- evaluating and comparing options using performance measures to provide tangible evidence and promote decision making,
- measuring the adaptive capacity of multiple decision pathways.

An example Decision Tree is shown in Figure 5.2

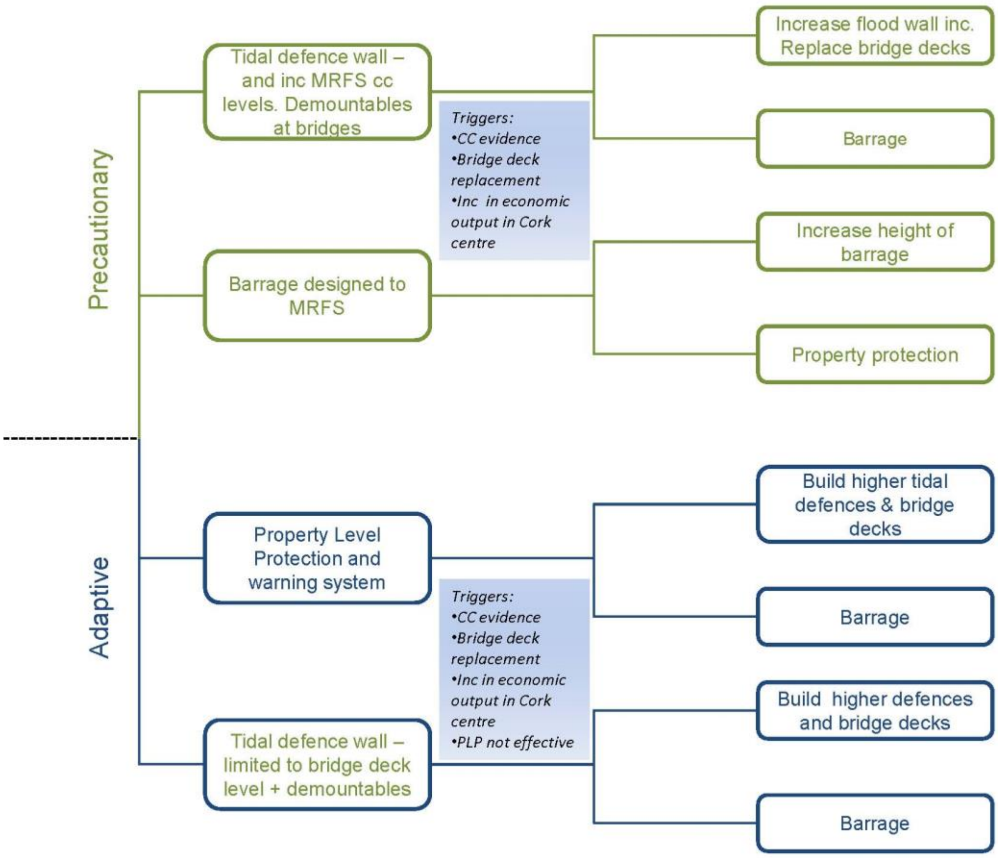

***Figure 5.2:** Example Decision Tree from the Lower Lee FRS*

6 MEASURES OF PERFORMANCE

Performance metrics are required to evaluate quantitatively how well each branch of a decision tree will perform under future uncertainty. The following metrics are applicable whether or not the decision tree is being assessed using probabilistic weighting of the alternative futures:

1. **Flexibility**: the number of future options that remain open following any investment choice (a measure of foreclosure).
2. **Robustness**: the proportion of possible futures in which a given option has the highest performance.

When probability weights are available for alternative futures, it is possible to report a further metric. The CFRAM will adopt an equal probability weight for each scenario, however this metric is not being used in the CFRAM:

3. **Expected performance**: an average of the economic performance over all defined futures.

6.1 Step by step example

Evaluation of the performance metrics is illustrated below using a simplified decision tree for a case where three autonomous futures have been defined. The data are hypothetical and for illustrative purposes. A standard discounted cash flow analysis is assumed, as per Department Finance guidance (the figures represent hypothetical NPV calculations in this case). Benefits would be defined as the risk avoided in terms of annual flood damages with respect to a baseline representing the conditions that would exist without the investment.

6.1.1 Evaluation of the tree with no weightings for alternative futures

In the decision tree presented in Figure 6.1, there are four available decision pathways before the practitioner has chosen to make either decision A or decision B, and the **flexibility** therefore equals 4. For either choice A or B, the flexibility reduces to 2.

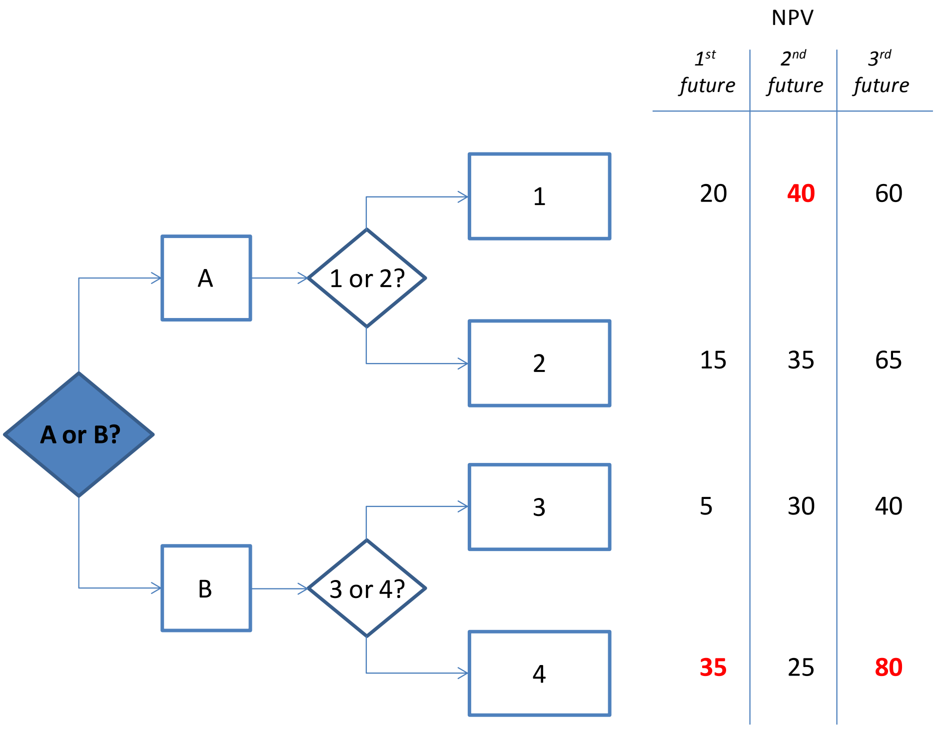

Figure 6.1: *Example decision tree with example NPVs used to determine performance measures*

In the example, the decision faced now is a choice between strategic options A and B. In each case, there are trigger points reached in future leading to a further decision. Because it is not known at present which future will materialise, each of the four possible sequences of choices (decision pathways through the tree) should be_evaluated using costs and benefits. In this illustration, the outcomes are assumed to be expressed in terms of NPV. The best outcome performance for each future is shown in bold red text. This data can then be used to determine the metrics described above:

Robustness is evaluated by determining how well a given sequence of decisions would perform under each future. In this case, choice B offers the best performance in 2 out of 3 of the identified futures. Its robustness is therefore 2/3. The robustness of A is 1/3. Clearly option B would be preferred based on consideration of the robustness. However, should the second future be realised, both of the decision pathways available in B would be out-performed by both of the decision pathways available in A.

A regret table for choices A and B can be constructed (Table 6.1) assuming that by the time the future trigger points are reached, there will be enough additional knowledge available to ensure that the best available subsequent choice (1, 2, 3 or 4) will be taken.

Table 6.1: Regret table for options expressed in the decision tree assuming that future decisions will be taken so as to achieve the best possible outcome

	1st Future	**2nd Future**	**3rd Future**
Option A	35 – 20 = 15	0	80 – 65 = 15
Option B	0	40 – 30 = 10	0

The largest regret that would result from making the initial investment choice B is therefore 10. This represents the maximum **lost opportunity** from choosing B now and hence being able subsequently to choose between the future options 3 and 4, but forgoing future options 1 and 2 (which are only available if we make the initial choice A).

7 CONCLUSIONS AND PRACTICAL RELEVANCE

Understanding and managing future uncertainty is complex and therefore developing the approaches to assess the value of responses to such uncertainty requires a clear, structured approach. The development of the supplementary guidance to be applied to the CFRAM Programme represents significant progress in providing approaches which assist decision-makers and practitioners in developing and appraising managed adaptive approaches. This is achieved by providing clear guidance on where there is a need to fully value adaptive approaches, offering a measured step forward in illustrating how strategies can be expressed as decision trees and facilitating the development of multiple futures and identifying situations where climate uncertainties can be given probability weightings based on (arguably) objective science and also deep uncertainties where this may be inappropriate.

8 ACKNOWLEDGEMENTS

The research on which this paper is based was from project SC110001 'Accounting for adaptive capacity in FCERM options appraisal' commissioned as part of the joint Environment Agency/Defra Flood and Coastal Erosion Risk Management Research and Development Programme. The project was led by JBA Consulting; with a wider consortium of partners included Professor Jim Hall, Paul Sayers, Professor Zoran Kapelan, University of Exeter and Royal Haskoning DHV.

Mark Adamson commissioned JBA Consulting to write the Guidance Note under the CFRAM Programme. Mark was very active in formulating the approach and how it would integrate with the CFRAM output.

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