

# Decision Support Methods for Climate Change Adaption

# 1

## Method Overview



**Summary of Methods and Case Study Examples  
from the MEDIATION Project**

## Key Messages

- There is increasing interest in the appraisal of options, as adaptation moves from theory to practice. In response, a number of existing and new decision support tools are being considered, including approaches that address uncertainty.
- The FP7 MEDIATION project has undertaken a detailed review of these tools, and has tested them in a series of case studies. It has assessed their applicability for adaptation and analysed how they consider uncertainty. The findings have been used to provide information and guidance for the MEDIATION Adaptation Platform and are summarised in a set of policy briefing notes.
- The review has covered a range of traditional and new decision support methods. It has considered the existing tools used in policy appraisal, including cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis, as well as new techniques that more fully address uncertainty, including real options analysis, robust decision making, portfolio analysis, iterative adaptive management / adaptation turning points, and the analytic hierarchy process, as well complementary tools that assist in adaptive capacity and socio-institutional analysis, such as social network analysis.
- The review has analysed the strengths and weakness of these approaches. This provides important insights into the relevance of the tools and their potential use for different types of adaptation problem.
- It has also considered previous applications of the methods to the adaptation context have been reviewed, as well as the findings of the MEDIATION case studies.
- The review work and case studies provide useful information on the types of adaptation problem types where these approaches might be appropriate, as well as data needs, resource requirements and good practice lessons.
- Further guidance is given on each of these techniques in a briefing note, available on the MEDIATION Adaptation Platform.

## Introduction

There is increasing policy interest in the appraisal of options, as adaptation moves from theory to practice. At the same time, it is recognised that the appraisal of climate change adaptation involves a number of major challenges, particularly the consideration of uncertainty. In response, a number of existing and new decision support tools are being considered for adaptation.

The European Commission FP7 funded MEDIATION project (*Methodology for Effective Decision-making on Impacts and Adaptation*) is looking at adaptation decision support tools, in line with its objectives to advance the analysis of impacts, vulnerability and adaptation, and to promote knowledge sharing through the MEDIATION Adaptation Platform (<http://www.mediation-project.eu/platform/>).

To complement the information on the Platform, a series of Technical Policy Briefing Notes have been produced on *Decision Support Methods for Climate Change Adaptation*.

This note, *Policy Briefing Note 1: Method Overview*, provides a summary of the decision support tools, their potential relevance for adaptation and guidance on their potential applicability.

It covers a range of traditional decision support tools (cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis) as well alternative approaches that more fully capture uncertainty (real options analysis, robust decision making, portfolio analysis and iterative risk (adaptive) management, adaptation turning points and analytic hierarchy process). It also includes complementary tools that can assist in adaptation assessment including social network analysis.

Additional information on each of the methods, including case study examples, is included in a series of separate *Policy Briefing Notes* (2 – 9).

## Adaptation Decision Support

With the increased focus in Europe towards adaptation implementation, there is a greater need to consider the approaches and methods for assessing adaptation. However, policy analysts, consultants and researchers are currently confronted with a large number of concepts, methods, frameworks, guidelines and toolboxes to choose from.

The MEDIATION Briefing Note on ‘*Choosing Salient Approaches and Methods for Adaptation*’ provides an overview for the decision support structure used in the MEDIATION Adaptation Platform. This recognises that there are many types of adaptation challenges and problem types, and that there is little to no guidance on which approach is appropriate for each of these different challenges. In response, MEDIATION has developed a more precise and specific language for describing the various challenges and methods for adaptation, and developed a diagnostic framework for problem-oriented adaptation research that matches adaptation challenges to appropriate approaches and methods for addressing them, using a series of decision trees.

The MEDIATION framework identifies five general stages as high-level entry points for adaptation research and practice, shown in Figure 1 below. The approaches and methods salient within each stage, and the empirical and theoretical criteria for choosing them are explained on the Adaptation Platform, and in the overview briefing note.

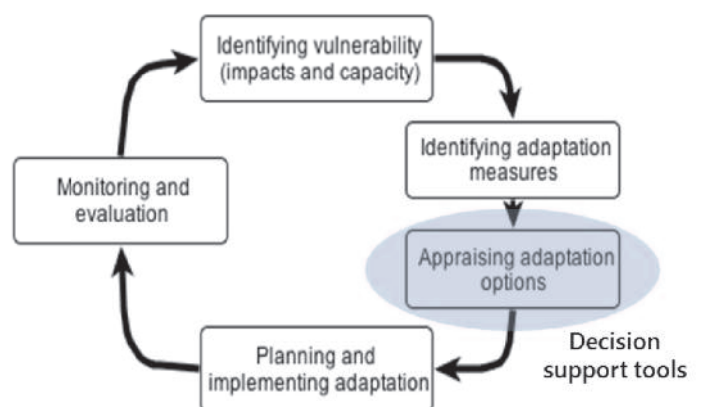


Figure 1. The Stages of Adaptation and the Entry Point for Decision Support Tools.

Stage three relates to the appraisal of adaptation options. This recognises that faced with a list of potential options there is a need to determine the most suitable or best option, noting that this definition will vary with the objectives of the adaptation problem type and the particular application.

Of course the appraisal of options is a standard part of all policy and project analysis, and there are existing guidelines and decision support tools to help in the prioritisation and ranking of options, many of which are focused on economic assessment, especially as policies or projects move towards implementation.

However, the appraisal of adaptation options involves several methodological challenges (EEA, 2007; OECD, 2008; UNFCCC, 2009). These relate to the varied spatial and sector contexts, as well as the timing of adaptation, which raises questions such as how much adaptation is needed (if any) and when action is most appropriate (UKCIP, 2002).

Adaptation also involves a core methodological challenge of uncertainty (UNFCCC, 2009; Hallegatte, 2009). As described in Box 1, future climate outcomes are highly uncertain, because of future alternative socio-economic scenarios, but also because of the differences between climate model outputs (or simulations) for key climate parameters. This uncertainty cascades through to a large range of potential impacts and damage costs, which in turn affect the amount of adaptation that could be needed.

As a result, the most common techniques used in appraisal (and decision support) have limitations in coping with the uncertainty associated with climate change (e.g. see Hunt and Watkiss, 2011). There is therefore a growing consensus that the appraisal of climate change adaptation should incorporate uncertainty, and that this requires extended analysis within existing elements in existing tools or new decision methods that more fully capture uncertainty.

## Decision Support Tools

There are a number of existing decision support tools that are widely used in policy and project appraisal, and which have potential for some conventional adaptation decisions. Three key techniques are used in European policy and

option appraisal, summarised below.

**Cost-Benefit Analysis (CBA)** is the method of choice in most Government economic appraisal or impact assessment. Social cost-benefit analysis (CBA) values all relevant costs and benefits to society of all options, and then estimates a net present value or a benefit:cost ratio. In this regard, CBA is an absolute measure providing the justification for intervention, though it is often difficult to value all the costs and benefits of a particular project or policy.

CBA has been used in some adaptation assessment, usually as part of an impact assessment focused analysis. However, the routine CBA applied in economic appraisal does not fully address many of the complex issues of adaptation (UNFCCC, 2009). In general, the more unique and less routine the decision-making context is, the more difficult the use of CBA will be, and the technique will be appropriate only for some adaptation decision-making contexts, though it can be combined with many of the new techniques below.

**Cost-Effectiveness Analysis (CEA)** is a widely used decision support tool. It compares alternative options for achieving similar outputs (or objectives). In this regard it is a relative measure, providing comparative information between choices (unlike CBA, which provides an absolute measure). It has been widely used in environmental policy analysis, because it avoids monetary valuation of benefits, and instead quantifies benefits in physical terms.

At the technical or project level, CEA can be used to compare and rank alternative options. It does this by assessing options in terms of the cost per unit of benefit delivered, e.g. cost per tonne of pollution abated. This identifies those options that deliver highest benefit for lowest cost (i.e. the most cost-effective). At the project, policy or programme level, where combinations of options are needed, CEA can be used to assess the most cost-effective order of options, and identify the least-cost path for achieving pre-defined policy targets. This is undertaken through the use of marginal abatement cost (MAC) curves, which implement options in order of cost-effectiveness, adding up the cumulative benefits with each additional option. This approach can also identify the largest benefits possible with the available resources, and can be used to help set targets.

## Box 1. Climate Projection Uncertainty

While the appraisal of adaptation involves several difficult aspects, the most challenging is that of uncertainty (UNFCCC, 2009). There are many uncertainties that influence adaptation options, including the climate system, future socio-economic change, impacts, and issues that drive adaptation process such as human and institutional systems, however, the main focus to date has been on climate change uncertainty, which has two key components.

First, climate models require scenarios of future greenhouse gas emissions over time, which are generated from future socio-economic scenarios. These involve very wide ranges of future emission paths, ranging from global stabilisation scenarios consistent with the 2 degree goal, through to high emission scenarios that would lead to 4 to 5 degrees of global temperature change by 2100. At the current time, it is not clear which emission scenario is likely, and this affects future temperature, precipitation and other climate variables, though major differences between scenarios are only likely to emerge after 2035, when the scenarios start to diverge. Second, there are large variations in results from different climate models, even for outputs of the same future emission scenarios. This arises because of structural uncertainty in the models, the level of climate sensitivity (the warming associated with given emission increases), the exact regional and seasonal changes associated with certain changes in global temperature, and the difficulty in projecting complex effects such as precipitation. As a result, different climate models often give very different results even for the same scenario.

These two effects lead to very wide ranges of plausible changes in temperature and precipitation. Indeed, for the latter, different simulations can even differ in the sign of change. Examples are shown in the Figures below. This uncertainty is magnified as subsequent impacts are assessed, leading to an extremely wide range of possibilities for adaptation.

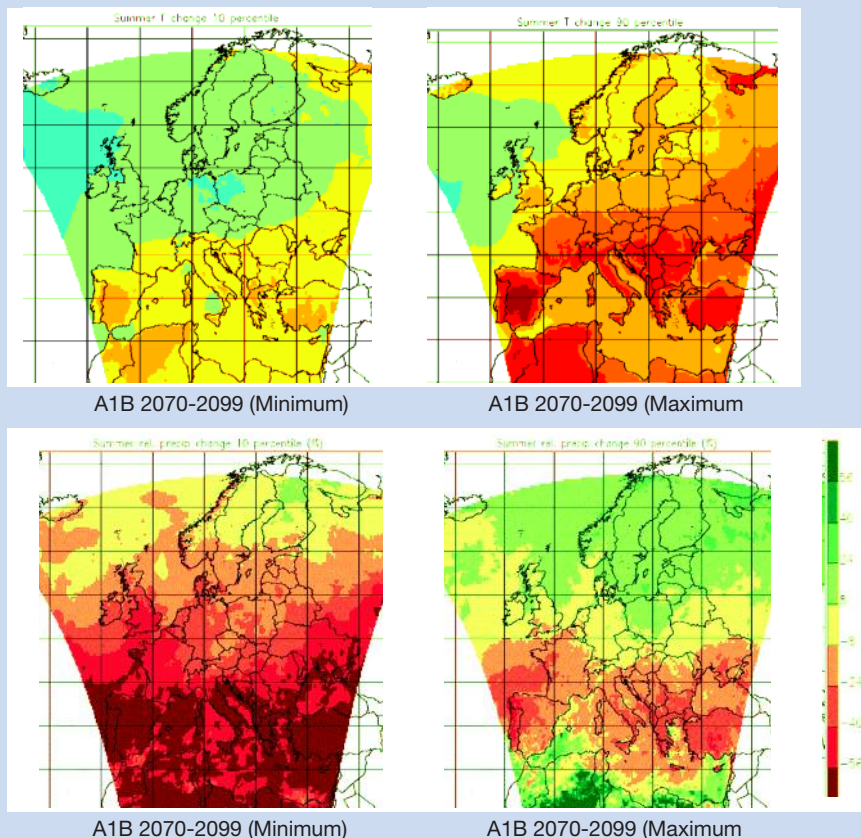


Figure 2 The range of outputs from 11 regional climate model projections for Europe from the ENSEMBLES project (with plots from Christensen et al, 2011), comparing projections for a single SRES scenario (A1B) for late century.

The top two figures show the minimum and maximum temperature projected from the models. This shows the level of temperature across Europe varies enormously between cooler (left, top) and warmer (right, top) models, particularly for the warming level in Southern Europe.

The bottom two figures show the projections for precipitation, with drier (left, bottom) and wetter (right, bottom) models. In this case, even the sign of change is different in many locations, with different models indicating decreases (left) or increases (right) in precipitation from the UK in the north-west to Romania in the east.

Note: Top: Change in surface air temperature (°C) for summer (JJA) (2070-2099 A1B).

Bottom: Change in summer precipitation (%) for summer (JJA) (2070-2099 for A1B). Source of plots, Christensen et al, 2011.

Cost-effectiveness analysis has become the main appraisal technique used for climate change mitigation, as it allows a comparison and ranking of alternative options within and across sectors, using the metric of cost per tonne of GHG abated ( $\text{€}/\text{tCO}_2$ ), and there has also been widespread use of marginal abatement cost curves for mitigation.

However, the lack of a common metric makes a similar cross-sectoral approach impossible for adaptation. Moreover, adaptation is a response to many different local, regional or national level impacts, rather than to a single global burden, and the application of CEA to adaptation is therefore much more demanding, in terms of analysis detail and resources.

CEA also focuses analysis on a single metric, thus omitting a full analysis of all relevant costs and benefits, which reduces the potential for cross-sectoral applications. Nonetheless, cost-effectiveness is already used in many sectors that are relevant to adaptation, such as health (using health impact metrics) and flooding (looking at acceptable levels of risk), and it has some potential for appraising options within a sector, though the approach does not easily lend itself to the analysis of uncertainty.

**Multi-Criteria Analysis (MCA)** is a decision support tool that allows consideration of quantitative and qualitative data together in ranking alternative options. The approach provides a systematic method for assessing and scoring options against a range of decision criteria, some of which are expressed in physical or monetary units, and some which are qualitative. The various criteria can then be weighted to provide an overall ranking of options.

MCA has been widely applied in the environmental domain. It has also been used as a complementary tool to support cost-benefit analysis in appraisal, to consider the performance of options against criteria that may be difficult to value or involve qualitative aspects.

MCA does have considerable potential for adaptation. Criteria can be included to consider uncertainty or various complex elements of good adaptation, and the approach brings the flexibility to work with qualitative information, which is particularly useful given there are often data gaps. As an example, previous adaptation

MCA has considered criteria of robustness, low/no regret characteristics or flexibility, as well as co-benefits and synergies with mitigation (van Ierland et al, 2007). However, the analysis can be somewhat subjective in nature, especially in relation to uncertainty, as it tends to work with individual scenarios, against which options are assessed. This makes it more difficult to incorporate the trade-offs over time and to fully incorporate climate change uncertainty (i.e. how benefits of different adaptation options vary).

## Decision Making Under Uncertainty

While the three techniques above all have potential applications for adaptation, they have relatively low potential for considering uncertainty. However, there is a growing recognition of the need to consider this issue in designing adaptation (e.g. Adger et al. 2006; Dessai and van der Sluijs 2007; Downing, 2012).

At the same time, there has been a shift in the mainstream adaptation literature away from a scenario-based impact assessment framework, where adaptation is assessed on the basis of a predict-then-optimize framework, to a greater focus on adaptation assessment and decision making under uncertainty (Füssel and Klein, 2006; UNFCCC, 2009; IPCC SREX, 2012).

### Definitions of Uncertainty

There are many different definitions of uncertainty.

The IPCC SREX (2012) defines uncertainty as:

*An expression of the degree to which a value or relationship is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. Uncertainty may originate from many sources, such as quantifiable errors in the data, ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures, for example, a range of values calculated by various models, or by qualitative statements, for example, reflecting the judgment of a team of experts.*

This broad definition can be compared with stricter definitions, notably those which seek to separate uncertainty, where it is impossible to attach probabilities to outcomes, from risk, where probability is defined.

As a result there is a growing interest in decision support techniques that can address different elements of uncertainty. A brief description of some of the emerging approaches is presented below.

**Real Option Analysis (ROA)** is an economic decision support tool that quantifies the investment risk associated with uncertain future outcomes. The approach derives from the financial markets, where it has been used to assess the valuation of financial options and risk transfer. The same insights are also useful when there is risk or uncertainty involved with investment in physical assets, hence ‘real’ options.

The approach can be used to consider the value of flexibility. This includes the flexibility over the timing of a capital investment, but also the flexibility to adjust the investment as it progresses over time, i.e. allowing a project to adapt, expand or scale-back in response to unfolding events or from new information (learning). The approach can therefore assess whether it is better to invest now or to wait – or whether it is better to invest in options that offer greater flexibility in the future. ROA can also be used to support initial enabling steps to help secure projects for future development. The most common application of the approach uses decision trees, defining possible outcomes, and assigning probabilities to these, then using expected values to compare alternatives.

Real Option Analysis has been widely cited as a possible decision tool for adaptation, as the concepts of the approach align closely with iterative decision making and adaptive management. It is a powerful decision-support tool with a number of strengths, most notably that it provides information in quantitative and economic terms. However, it is a technical complex and resource intensive, and requires probabilistic (or probabilistic-like) information on outcomes. In practice, the approach is most relevant for particular types of decisions, primarily those that involve large up-front irreversible investments (e.g. coastal protection, large water storage projects), where there is flexibility in the timing, and the opportunity for new information to emerge. The framework is most likely to be supportive of projects that have some combination of substantial near-term benefits, and the ability to scale-up or down in

line with learning regarding potential upside benefits or downside risks.

**Robust Decision Making (RDM)** is a decision support tool that is used in situations of deep uncertainty, i.e. in the absence of probabilistic information on scenarios and outcomes. The key aim of RDM is to seek strategies that are robust over many future outcomes, i.e. that are ‘good enough’ and minimize regret. It therefore offers an alternative to a conventional cost-benefit analysis and the identification of optimal options on the basis of economic efficiency.

The formal application of the approach (Lempert et al, 2003; Groves and Lempert, 2007) uses quantitative models, or scenario generators, with data mining algorithms, to evaluate how different strategies perform under large ensembles of scenarios reflecting different plausible future conditions (using hundreds to thousands to millions of input combinations). The aim is to help policymakers minimise the negative impacts of possible future outcomes. Iterative and interactive techniques are then applied to “stress test” different strategies to identify potential vulnerabilities or weaknesses of proposed approaches.

RDM has many attributes that align with the concept of adaptive management (Lempert and Groves, 2010) and the approach has been widely recommended for adaptation. The approach can assess robustness using various metrics, including physical effectiveness or economic efficiency. It can also be used in an iterative framework (Lempert, 2010) which aligns it more closely to the iterative adaptation management concepts of monitoring, research, evaluation and learning.

It is a particularly useful tool when future uncertainties are poorly characterised and probabilistic information is limited or not available – a key strength for long-term climate change related decisions – though the formal (computer modelling based) application of the approach has a high demand for quantitative information and computing power. As a result, the broad concepts of the approach have also been applied to the climate domain looking at climate uncertainty, to help in selecting options that are robust across a wide-range of plausible (climate) futures.

**Portfolio Analysis (PA)** is a decision support tool that helps in developing portfolios of options, rather than single options. It originated in the context of financial markets to explore the potential for portfolios of financial assets to maximise the financial return on investments, subject to a given level of risk. PA helps in the design of such portfolios. It aims to spread investments over a range of asset types to spread risks at the same time, thereby reducing the dependence on a single asset.

The approach highlights the trade-off between the returns on an investment and the riskiness of that investment, measuring risk by estimating the variance (standard deviation) of the portfolio return: thus a portfolio with a relatively high (low) variance is judged to have a higher (lower) risk (Aerts et. al. 2008). The information on returns and risks is used to identify a portfolio that most closely matches (risk) preferences.

The principles of diversification and the use of portfolios have high relevance for climate change adaptation (including iterative adaptive management, see IPCC SREX, 2012), and the technique can quantify the effectiveness of portfolios of options against climate change uncertainty. In the climate change context, the trade-off is then between the possibility of a high degree of effectiveness in reducing climate risks, and the risk that the adaptation options will fail to be effective over a certain range of climate change. PA allows the selection a set of options that, together, are effective over the range of possible projected future climates, rather than one option that is best suited to one possible future climate.

The main strength of the approach is that it provides a structured way to assess adaptation portfolios in a way that other decision tools do not allow. The approach can be undertaken using various metrics, including physical effectiveness, cost effectiveness, or economic efficiency and this provides flexibility for application to a wide range of applications.

However, the formal application is technically complex, and relies on the availability of data on effectiveness and co-variance, which requires probability, and it can be difficult to apply for some risks, notably where climate attribution is less straightforward, and/or the effectiveness of adaptation is not easily measured.

**Adaptive Management (Iterative Risk Management)** is a long established approach that uses a monitoring, research, evaluation and learning process to improve future management strategies.

The potential for an iterative approach for addressing climate change has been recognised for some time (Tompkins and Adger, 2004) and aligns with the IPCC AR4 Act-Learn-Then act again approach (Klein et al. 2007). The approach has been widely recommended for adaptation, including in the latest IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) (IPCC, 2012).

The approach is less formalised than many of the tools above, but the focus is on the management of uncertainty, allowing adaptation to work within a process of learning and iteration. Recent applications have also used the term 'adaptation pathways' to reflect a shift from predict-and-optimize based approaches to a dynamic pathway that incorporates uncertainty (Downing, 2012).

The most recent applications identify possible risk or impact thresholds (and accompanying indicators) and assess options (or portfolios of options) that can respond to these threshold levels. These are accompanied by monitoring plans that track key indicators, and through a cycle of evaluation and learning, allows the adjustment of plans over time. The appraisal of options within these pathways can be undertaken using some of the tools above, using qualitative or semi-quantitative decision support tools, such as MCA, or more formalised economic appraisal with CBA (though it would also be possible to use the alternative tools above in such a framework). The results of these iterative assessments are often presented as adaptation pathways or route maps. While most applications have been at the project level, notably for sea level rise, there are now examples emerging of more strategic or even national level plans (see Watkiss and Hunt, 2011: Watkiss et al, 2013).

A variation of the approach is to consider major biophysical, human, social or economic thresholds, and the MEDIATION project has developed such assessments using the term '**Adaptation Turning Points**' looking at social-political thresholds (i.e. a formal policy objective or societal preference).



The advantage of the approach is that rather than taking an irreversible decision now about the ‘best’ adaptation option – which may or may not be needed depending on the level of climate change that arises – it encourages decision makers to ask “what if” and develop a flexible approach, where decisions are made over time, and these plans adjusted as the evidence emerges (Reeder and Ranger, 2011). This allows the right decisions are taken at the right time (EA, 2011), such that additional options can be brought forward– or delayed to a later time period – depending on how climate change actually evolves. The disadvantage is that the identification of suitable risk thresholds can be difficult, especially when there are multiple risks or cross sectoral dimensions involved. Like many of the approaches above, it can be time and resource intensive, especially when addressing multiple scenarios in an economic framework.

**Analytic Hierarchy Process (AHP)** is a form of multi-criteria analysis (see earlier) that undertakes pairwise comparisons using expert judgements to derive priority scales (Saaty, 1980). The method allows the analysis of tangible and intangible elements together, allowing these to be traded off against each other in a decision-making process.

The method is applied by making comparisons using a scale of absolute judgements that represents how much one element dominates another for a given attribute. The derived priority scales are then synthesised and the various weighted scores are aggregated. The approach is very flexible and can be adapted to specific contexts. Criteria (or attributes) and sub-criteria can be decided in advance by experts or through a participatory process with stakeholders. There is no upper limit to the number of criteria or sub-criteria, except for the time that is then required to do the comparison.

The approach can be used to choose options, to rank and/or prioritise them, and for resource allocation and conflict resolution. The tool has a particular relevance where important elements of the decision are difficult to quantify or compare, or where different expertise, goals, and world-views are a barrier to consensus-building and communication.

AHP has been used in a wide variety of fields. The approach has high relevance for the

application to adaptation, as it can evaluate options in situations of high complexity, considering different time horizons, uncertainty, multiple and interdependent variables, and subjectivity, all of which requires multi-dimensional trade-offs. It allows the comparison of diverse elements that are often difficult to measure in a structured and systematic way using a scale, though this inevitably involves a degree of subjectivity.

### Socio-Institutional Analysis

Alongside the focus on uncertainty, there is also a growing recognition of the role of socio-institutional issues in climate adaptation. The IPCC special report on extreme events (IPCC, 2012) confirms the viewpoint of adaptation as a socio-institutional process, defining adaptation as a *process of adjustment* to the actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities.

There is an increasing body of research on the role of socio-institutional networks in climate adaptation. Berkhout et al., (2006) found that many of the resources required for carrying out the process of adaptation lie outside the boundary of a particular organization, and Moser and Ekstrom (2010) report that barriers to adaptation often arise from institutional and cognitive constraints. Downing (2012) contrasts a predict-and-provide viewpoint with a process-based understanding of adaptation.

These studies highlight that the inter-relationships between organisations are influential in determining how (and if) adaptation processes will occur. Following from this, it is important to identify the existing socio-institutional landscape and feedback processes in climate adaptation research, to speed up the necessary ‘climate-adapted routines and capability to be developed’ (Berkhout et al., 2006).

These findings have led to an increased interest in adaptation governance, using behavioural and institutional analysis to understand and overcome individual and social constraints. This process-based understanding requires a ‘mapping’ of the problem framing and actors.

One such approach for understanding these issues is **Social Network Analysis (SNA)**. SNA

is a method that analyses social networks and institutional actors (i.e. organizations, individuals, interest groups, etc.) and their linkages and socio-institutional relationships. It allows a mapping of the influence and the exchange of information and can therefore help in assessing adaptive capacity.

SNA explores socio-institutional processes, and identifies the context and governance around decisions. It highlights institutional arrangements and structures, decision framing of actors, their approach to dealing with information, the competence for action, and the laws, regulations, values and norms that are likely to guide decisions.

SNA can be undertaken using qualitative or quantitative methods. The qualitative approach focuses on network mapping and provides visual representations of networks, actors and information flows. This is usually undertaken as part of participatory analysis, revealing insights about these relationships, the various flows between actors and the perceptions of influence and power in the network.

The quantitative analysis is more comprehensive, considering whole networks and undertaking analysis using software and standard statistical tests. This provides a deeper analysis of institutional aspects, providing variety of measures/indicators to help describe the overall relational structure of a social network, as well as the roles of individuals within it.

SNA has high relevance for adaptation, reflecting the growing consensus and the focus on building adaptive capacity. The organisational knowledge, responsibility and strategies can be assessed, and potential barriers to adaptation can be revealed and subsequently negotiated. It can also investigate how actors and organisation address uncertainty, i.e. how decisions are framed and their choice of appraisal tools.

## Strengths and Weaknesses

The MEDIATION project has reviewed the strengths and weaknesses of different approaches. A summary of the key strengths and weakness are outlined below in Table 1.

**Table 1. Strengths and Weaknesses of the Decision Support Tools.**

Tool	Strengths	Weaknesses
<b>Cost-Benefit Analysis</b>	<ul style="list-style-type: none"> <li>– Provides direct analysis of economic benefits, justification for action, and optimal solutions.</li> <li>– Well known and widely applied.</li> </ul>	<ul style="list-style-type: none"> <li>– Difficulty of monetary valuation for non-market sectors and non-technical options.</li> <li>– Uncertainty usually limited to probabilistic risks.</li> </ul>
<b>Cost-Effectiveness Analysis</b>	<ul style="list-style-type: none"> <li>– Benefits expressed in physical terms (not monetary) thus applicable to non-market sectors.</li> <li>– Relatively simple to apply and easily understandable ranking and outputs.</li> <li>– Use of cost curves can assess policy targets with least-cost optimisation.</li> <li>– Used for mitigation, thus widely recognised and resonance with policy makers.</li> </ul>	<ul style="list-style-type: none"> <li>– Benefits can be difficult to identify and single metric does not capture all costs and benefits. Less applicable cross-sectoral / complex.</li> <li>– Works best with technical options, and often omits capacity building and soft measures.</li> <li>– Sequential nature of cost curves ignores inter-linkages and potential for portfolios.</li> <li>– Does not lend itself to the consideration of uncertainty, as works with central tendency.</li> </ul>
<b>Multi-criteria analysis</b>	<ul style="list-style-type: none"> <li>– Combines quantitative and qualitative data, and monetary and non-monetary units, thus applicable where quantification is challenging.</li> <li>– Relatively simple and transparent, and relatively low cost / time requirement.</li> <li>– Expert judgement can be used very efficiently, and involves stakeholders, thus can be based on local knowledge.</li> </ul>	<ul style="list-style-type: none"> <li>– Results need further interpretation and elaboration in more detailed studies.</li> <li>– Different experts may have different opinions, i.e. subjectivity involved.</li> <li>– Stakeholders may have lack of knowledge and can miss important options.</li> <li>– Analysis of uncertainty is often qualitative and subjective.</li> </ul>

**Table 1. Strengths and Weaknesses of the Decision Support Tools (Continued).**

Tool	Strengths	Weaknesses
<b>Real Options Analysis</b>	<ul style="list-style-type: none"> <li>- Assesses value of flexibility and learning, in quantitative and economic terms.</li> <li>- Decision trees conceptualise and visualise the concept of adaptive management.</li> </ul>	<ul style="list-style-type: none"> <li>- Data and resource intensive, with high complexity and expert input.</li> <li>- Data a potential barrier, (probabilistic climate, quantitative and economic information).</li> <li>- Identification decision points often complex.</li> </ul>
<b>Robust Decision Making</b>	<ul style="list-style-type: none"> <li>- Assesses robustness rather than optimisation.</li> <li>- Applicable where probabilistic information is low or missing, or climate uncertainty is high.</li> <li>- Can work with physical or economic metrics, enhancing application across sectors.</li> </ul>	<ul style="list-style-type: none"> <li>- Lack of quantitative probabilities can make more subjective, influenced by stakeholders.</li> <li>- The formal application has a high demand for quantitative information, computing power, and requires a high degree of expert knowledge.</li> </ul>
<b>Portfolio Analysis</b>	<ul style="list-style-type: none"> <li>- Assesses portfolios, which analysis of individual adaptation options not allow.</li> <li>- Measures “returns” using various metrics, including physical or economic, thus broad applicability.</li> <li>- Use of the efficiency frontier an effective way of visualising results and risk-return trade-offs.</li> </ul>	<ul style="list-style-type: none"> <li>- Resource intensive and needs expert knowledge.</li> <li>- Relies on the availability of quantitative data (effectiveness and variance/co-variance).</li> <li>- Requires probabilistic climate information, or an assumption of likelihood equivalence.</li> <li>- Issues of inter-dependence between options.</li> </ul>
<b>Adaptive Management / Iterative Risk Assessment / Adaptation turning points</b>	<ul style="list-style-type: none"> <li>- Process of monitoring, research, evaluation and learning that avoids irreversible decisions and encourages learning to adjust decisions over time.</li> <li>- Uses scenarios to delineate uncertainties not to predict the future.</li> <li>- Is more policy orientated and flexible in objectives and appraisal methods.</li> <li>- Encourages discussion about (un)acceptable change and definition of critical indicators.</li> </ul>	<ul style="list-style-type: none"> <li>- Challenging when multiple risks acting together, or indirect links to CC.</li> <li>- Thresholds are not always easy to identify, especially those that are poorly defined.</li> <li>- Focuses on existing management objectives. Unknown impacts and new challenges may be overlooked / difficult.</li> <li>- Loses simplicity for communication less-well defined thresholds and multiple drivers.</li> </ul>
<b>Analytic Hierarchy Process</b>	<ul style="list-style-type: none"> <li>- Can be applied where elements difficult to quantify or not directly comparable.</li> <li>- Relatively simple approach and produces simple rankings that are easy to communicate.</li> <li>- Does not require information on economic benefits so wide applicability.</li> <li>- Can accommodate a wide range of disciplines, opinions and groups of people who do not normally interact.</li> </ul>	<ul style="list-style-type: none"> <li>- Results change as new options are considered.</li> <li>- Becomes complicated if lots of criteria and options are considered.</li> <li>- Subjective scale can lead to biases.</li> <li>- Trans-disciplinary capacity building can be undermined at the cost of the expediency.</li> <li>- Software can conceal conflicting value judgments.</li> </ul>
<b>Social Network Analysis</b>	<ul style="list-style-type: none"> <li>- Understanding of socio-institutional structures, actors, linkages and decision framing, to improve information and knowledge transfer.</li> <li>- Qualitative SNA quick and easy and encourages participation across diverse viewpoints and actors</li> <li>- Quantitative SNA provides quantitative information and correlations to understand network variables.</li> </ul>	<ul style="list-style-type: none"> <li>- Subjective bias.</li> <li>- Networks have artificial boundaries.</li> <li>- Does not have a temporal or spatial dimension.</li> <li>- Time-consuming, intensive process (quantitative).</li> <li>- Design of process is critical to get as many differing viewpoints as possible.</li> </ul>

## Case Studies

The MEDIATION study has reviewed existing literature examples that have applied these decision support tools to adaptation. It has also undertaken a number of new applications with the Mediation case studies. The examples are reported in Table 2 below.

## Discussion and Conclusions

The various approaches are summarised in the figure below. This outlines the main traditional decision support tools and the new tools that have a greater focus on decision making under uncertainty

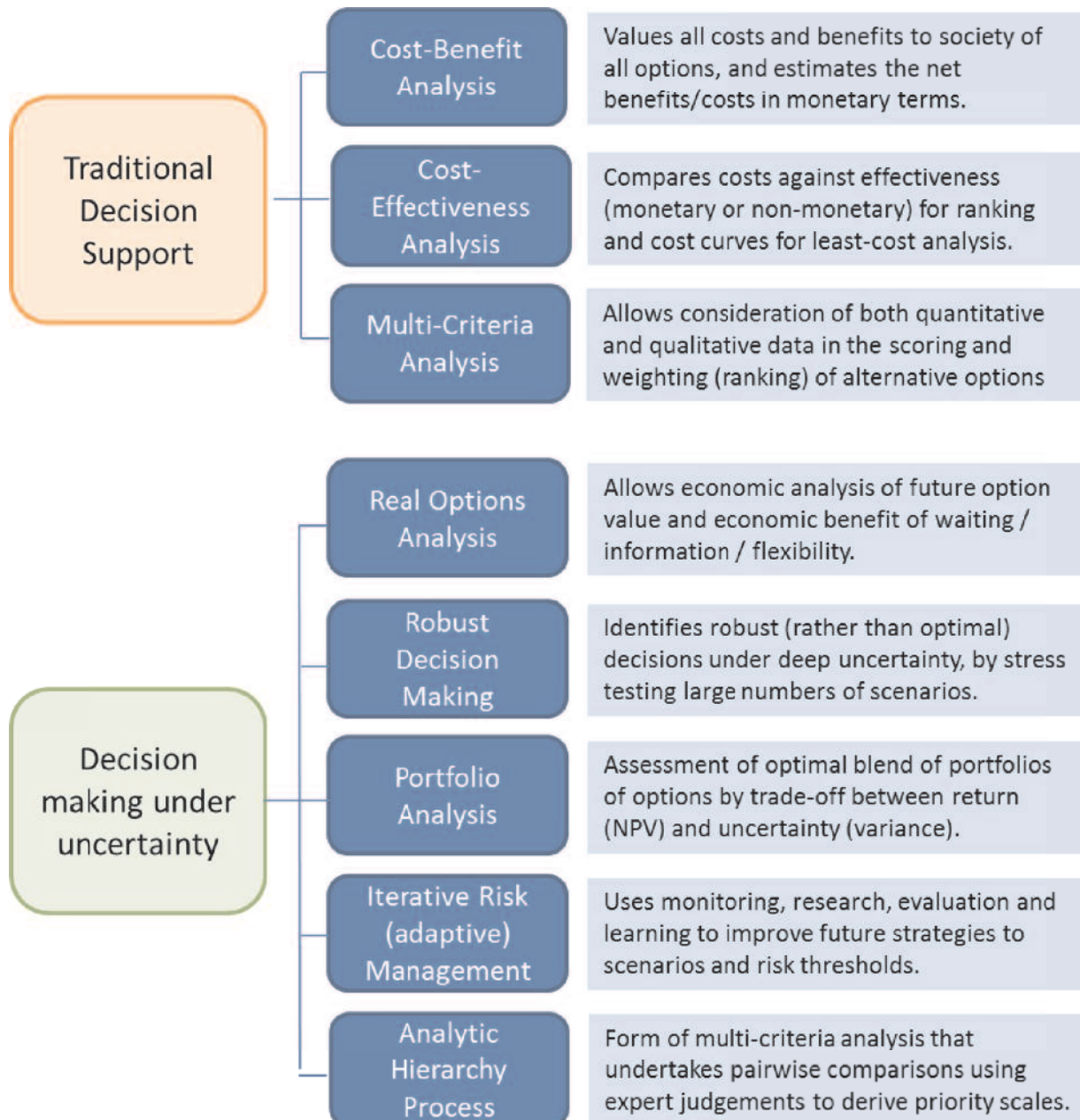


Figure 2. Summary of Tools

Table 2. Examples of the Application of Decision Support Tools to Adaptation.

Tool	Literature applications and Mediation case studies
<b>Cost-Effectiveness Analysis</b>	<ul style="list-style-type: none"> <li>Boyd et al (2006) undertook a detailed application of cost-effectiveness for water resource zones and the potential adaptation response to address household water deficits in the UK.</li> <li>The Mediation case study (Tainio et al. 2013) investigated the cost-effectiveness of alternative conservation measures (adaptation options) that could maintain the biodiversity of Finnish semi-natural grasslands under a changing climate.</li> </ul>
<b>Multi-criteria analysis</b>	<ul style="list-style-type: none"> <li>Van Ierland et al. (2007) (De Bruin et al. (2009)) applied MCA to assess adaptation options for the Netherlands as part of the Routeplanner national study. This used a qualitative MCA, which included various adaptation criteria.</li> <li>A quantitative MCA was used in the Thames Estuary 2100 project (EA, 2009: 2011) as part of a broader study looking at future coastal flood defences for London. The MCA was used to include qualitative criteria (environment, heritage, etc.) alongside formal economic cost-benefit analysis.</li> </ul>
<b>Real Options Analysis</b>	<ul style="list-style-type: none"> <li>HMT (2009) provides a simplified theoretical example of ROA, which is incorporated into supplementary Government guidance on economic appraisal for adaptation.</li> <li>Jeuland and Whittington (2013) applied real option analysis for a water resource planning case study (large water storage projects) in Ethiopia along the Blue Nile.</li> <li>Van der Pol, et al (2013) looked at optimal dike investments under uncertainty with learning about increasing water levels.</li> </ul>
<b>Robust Decision Making</b>	<ul style="list-style-type: none"> <li>A comprehensive, formal application of RDM was undertaken by Lempert and Groves (2010) for Southern California's Riverside County Inland Empire Utilities Agency (IEUA).</li> <li>Dessai and Hulme (2007) present an example of the application for RDM to look at climate uncertainty for water supply management in the UK.</li> </ul>
<b>Portfolio Analysis</b>	<ul style="list-style-type: none"> <li>Crowe and Parker (2008) provide an application of the approach for forests, using portfolio analysis to investigate genetic material that could be used for the restoration or regeneration of forests under climate change futures.</li> <li>Hunt (2009) applied portfolio analysis to a case of flood management at the local geographical scale, for river flood risks in the UK, looking at portfolios of hard and soft options</li> </ul>
<b>Adaptive Management Iterative Risk Assessment Adaptation Turning Points</b>	<ul style="list-style-type: none"> <li>The Thames Estuary 2100 project (EA, 2009: 2011: Reeder and Ranger, 2011) developed a tidal flood-risk management adaptation plan for London using an iterative planning approach and adaptation pathways, with a detailed monitoring and evaluation strategy.</li> <li>The Mediation case study applied the concepts of adaptation turning point to two case studies: turning points for salmon restoration programmes in the Rhine river basin and turning points for wine production in Tuscany, Italy (Werners et al, 2013).</li> </ul>
<b>Analytic Hierarchy Process</b>	<ul style="list-style-type: none"> <li>AHP has been applied to evaluate adaptation options for human settlements and for crop impacts in Australia (Choy et al., 2012: Sposito, 2006), to explore the impacts of storm surge and sea level rise in Canada and Caribbean (Lane and Watson, 2010) and water sector options in China (Yin et al., 2008).</li> <li>The Mediation case studies applied AHP to consider agricultural adaptation options for the Guadiana Basin, Spain and options for viticulture in Tuscany, Italy (Bharwani et al, 2013a).</li> </ul>
<b>Social Network Analysis</b>	<ul style="list-style-type: none"> <li>Turnpenny et al, 2005 applied SNA to map actors involved in climate change policy networks in the UK.</li> <li>The Mediation case studies applied (qualitative) social network analysis in Finland to look at agricultural – conservation networks and to look at adaptation decision-making in the agricultural and water sectors in Spain (Bharwani et al, 2013b).</li> </ul>

The review and case studies provide a number of practical lessons on the application of these tools to adaptation. They provide useful information on the range of adaptation problem types where the various approaches might be appropriate, as well as data needs, resource requirements and good practice.

It is important to stress that the different tools use various metrics, approaches and assumptions, and have potentially different applicability. No one method is right or wrong – different methods may be more or less appropriate according to the adaptation problem and objectives. Furthermore, the methods and tools are not mutually exclusive, and there are several examples where combinations of tools have been used, or where one tool has been used to scope out promising adaptation options from a long-list, which is then subject to detailed appraisal using one of the more complex methods.

Information from the review is summarised in Tables 3 and 4 below. Note that the grading of the resources and expertise required to use these tools are presented in relative terms. Depending on the size or type of adaptation, and the location in the project cycle (from scoping options to detailed implementation analysis) the resources spent on decision analysis may be relatively easy to justify in terms of avoiding mis-allocation and mal-adaptation.

A number of issues are relevant in considering the applicability to different adaptation problem types.

First, the choice of tools depends on the availability of benefits information. As shown below, MCA and AHP have the flexibility to work with qualitative or quantitative information (and even economic data), while other techniques require quantitative data. CBA and ROA work exclusively with economic data only. The availability of data (or the potential for providing monetary estimates of benefits) may therefore constrain the approach, or affect the application to sectors where valuation is challenging.

This also provides relevant information for the sequencing or complementarity of tools. It may be appropriate to use more qualitative scoping tools, such as MCA, early on in the process to identify promising options, followed by more

detailed (economic) appraisal tools to look in detail at a smaller number of options, i.e. as one moves towards implementation

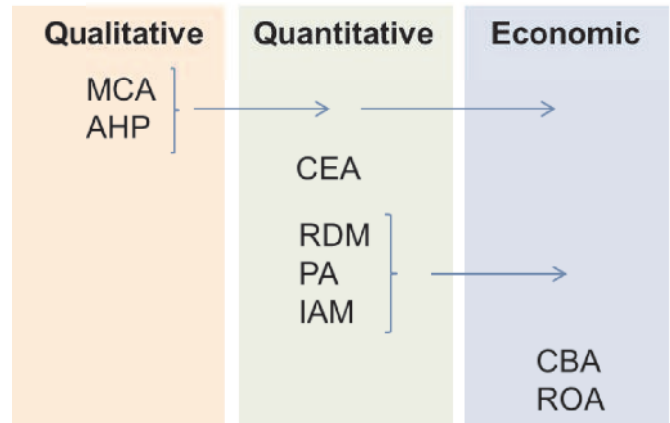


Figure 3. Metrics used in Benefits Analysis.

Similarly, it may be possible to complement some of the more formal economic approaches (such as CBA) with tools that allow the consideration of qualitative information or issues that difficult to quantify (e.g. environmental or social, equity, acceptability).

Second, the nature of the climate information available may also affect the applicability of the tools. Again, tools such as MCA and AHP can work with very general climate (risk) information, whereas quantitative focused tools need more detailed model outputs to allow quantification of benefits. Tools such as RDM (and IAM) are more suitable where there is deep uncertainty (or high climate uncertainty), as compared to tools such as ROA or PA which require probabilistic climate information (or probabilistic like assumptions).

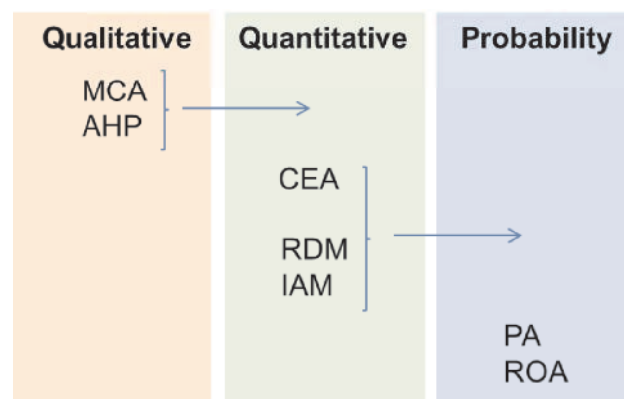


Figure 4. Climate information Needs.

**Table 3. Inputs, Benefit Metric and Resource / Expert Requirements.**

Decision Support Tool	Input requirements	Benefit Metrics	Resources / expertise
<b>Cost-Benefit Analysis</b>	<ul style="list-style-type: none"> <li>– Individual scenario and climate model outputs.</li> <li>– Baseline damage costs from scenario-based IA. Quantitative adaptation effectiveness.</li> </ul>	Economic (monetary).	Medium.
<b>Cost-Effectiveness Analysis</b>	<ul style="list-style-type: none"> <li>– Scenario and climate model outputs and often baseline damage costs.</li> <li>– Effectiveness as reduction in impacts (unit / total).</li> </ul>	Quantitative (but not economic).	Medium
<b>Multi-criteria analysis</b>	<ul style="list-style-type: none"> <li>– Qualitative or quantitative information on climate change.</li> <li>– Effectiveness through expert input or stakeholder consultation.</li> </ul>	Qualitative, quantitative or economic.	Low – Medium
<b>Real Options Analysis</b>	<ul style="list-style-type: none"> <li>– Probability or probabilistic assumptions for climate (multiple scenarios) and decision points.</li> <li>– Baseline damage costs and adaptation effectiveness.</li> </ul>	Economic (monetary).	High.
<b>Robust Decision Making</b>	<ul style="list-style-type: none"> <li>– Multi-model scenario and climate model outputs (more the better).</li> <li>– Formal approach requires uncertainty information for all parameters.</li> </ul>	Quantitative or economic.	High.
<b>Portfolio Analysis</b>	<ul style="list-style-type: none"> <li>– Probability or probabilistic assumptions for climate (multiple scenarios).</li> <li>– Variance and covariance of each option.</li> </ul>	Quantitative or economic.	High.
<b>Adaptive Management / Adaptation Turning Points</b>	<ul style="list-style-type: none"> <li>– Sets of scenario and climate model outputs, but flexible.</li> <li>– Threshold levels for risks.</li> </ul>	Quantitative or economic.	Medium – High.
<b>Analytic Hierarchy Process</b>	<ul style="list-style-type: none"> <li>– Qualitative or quantitative information on climate change.</li> <li>– Effectiveness through expert input or stakeholder consultation.</li> </ul>	Qualitative, quantitative or economic.	Low – Medium
<b>Social Network Analysis</b>	<ul style="list-style-type: none"> <li>– Stakeholder consultation (qualitative)</li> <li>– Survey data and software analysis (quantitative)</li> </ul>	N/A	Low (Qual.) High (Quant.)

**Table 4. Potential Applications of the Tools to Adaptation.**

Decision Support Tool	Potential applicability	Most useful when	Potential uses of approach
<b>Cost-Benefit Analysis</b>	Short-term assessment, particularly for market sectors.	<ul style="list-style-type: none"> <li>– Climate probabilities known.</li> <li>– Climate sensitivity small compared to costs/benefits.</li> <li>– Good data exists for major cost/benefit components.</li> </ul>	Low and no regret option appraisal (short-term). As a decision support tool within iterative risk management
<b>Cost-Effectiveness Analysis</b>	Short-term assessment, for market and non-market sectors. Particularly relevant where clear headline indicator and dominant impact (less so cross sector).	<ul style="list-style-type: none"> <li>– As for CBA, but for non-monetary metrics;</li> <li>– Agreement on sectoral social objective (e.g. acceptable risks of flooding).</li> </ul>	Low and no regret option appraisal (short-term). As a decision support tool within iterative risk management.
<b>Multi-criteria analysis</b>	Project and policy (programme) level. Tool for appraising option, or complementary tool (e.g. to CBA) to consider qualitative or non-market elements.	<ul style="list-style-type: none"> <li>– Mix of qualitative and quantification data.</li> </ul>	Scoping of potential options. Early analysis of uncertainty or other adaptation characteristics of options. Complementary tool to address non-market / non-monetary attributes.
<b>Real Options Analysis</b>	Major project based analysis. Short-term assessment including long-term uncertainty. Comparing flexible vs. non flexible options, or value of information.	<ul style="list-style-type: none"> <li>– Large irreversible capital decisions.</li> <li>– Climate risk probabilities known or good information.</li> <li>– Good quality data for major cost/benefit components.</li> </ul>	Economic analysis of major investment decisions, notably major flood defences, water storage, particularly where existing adaptation deficit, potential for learning and/or potential for flexibility within project.
<b>Robust Decision Making</b>	Project and programme/ strategy analysis especially under conditions of high uncertainty. Near-term investment with long life times (e.g. infrastructure)	<ul style="list-style-type: none"> <li>– High uncertainty of climate change signal.</li> <li>– Mix of quantitative and qualitative information.</li> <li>– Non-market sectors (e.g. ecosystems, health).</li> </ul>	Identifying low and no regret options. Testing near-term options or strategies (e.g. infrastructure) across a large number of futures, or climate projections. Comparing technical and non-technical sets of options.
<b>Portfolio Analysis</b>	Project based analysis of combinations of options, including potential for project and strategy formulation.	<ul style="list-style-type: none"> <li>– Adaptation actions likely to be complementary in reducing climate risks.</li> <li>– Climate risk probabilities known or good information</li> </ul>	Designing portfolio mixes as part of iterative pathways.
<b>Adaptive Management / Adaptation Turning Points</b>	Project and strategy / programme level. To develop adaptation pathways that allow iterative plans.	<ul style="list-style-type: none"> <li>– High uncertainty.</li> <li>– Clear risk thresholds and indicators.</li> </ul>	Flexible, but especially medium-long-term where potential to learn. As an overall iterative framework, within which additional decision support tools used.
<b>Analytic Hierarchy Process</b>	Project and policy (programme) level.	<ul style="list-style-type: none"> <li>– Mix of quantitative and qualitative information.</li> <li>– Mix of qualitative and quantification data.</li> <li>– Need for consensus building.</li> </ul>	Scoping of potential options. Early analysis of uncertainty or other adaptation characteristics of options.
<b>Social Network Analysis</b>	Project to national level for adaptive capacity, socio-institutional aspects and identifying barriers to adaptation.	<ul style="list-style-type: none"> <li>– Adaptation decisions involving many different stakeholders.</li> </ul>	Analysis of adaptive capacity, information and knowledge flows, decision frameworks.



Third, there are some differences in the relevant time periods for application, i.e. between short- and longer-term analyses. The low consideration of uncertainty in conventional CBA and CEA makes them less applicable for longer-term analysis where climate uncertainty is important. Conversely, tools such as RDM, ROA, IAM and PA have the potential to look at both short and longer-term aspects, because they incorporate such aspects.

Finally, many of the new methods that work with decision making under uncertainty (ROA, PA, and to a lesser extent, RDM and IAM) are resource intensive and technically complex. This is likely to constrain their formal application to large investment decisions or major risks, or as part of more detailed appraisal analysis. However, the conceptual aspects for addressing uncertainty in these approaches can be used in 'light-touch' approaches, allowing a wider application in qualitative or semi-quantitative analysis. This can include the use of decision trees from ROA, the concepts of robustness testing from RDM, the shift towards portfolios of options from PA and the focus on evaluation and learning from IRM.

### Further Briefing Notes

Additional information on each of the methods outlined in this note are included in a series of separate *Policy Briefing Notes*.

Note	Decision Support Tool
2	Cost-Effectiveness Analysis
3	Robust Decision Making
4	Real Options Analysis
5	Portfolio Analysis
6	Multi-Criteria Analysis
7	Analytic Hierarchy Process
8	Social Network Analysis
9	Adaptation Turning Points

The notes are available from the MEDIATION Adaptation Platform (<http://www.mediation-project.eu/platform/>).

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To find out more about the MEDIATION project, please visit:  
<http://mediation-project.eu/>

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