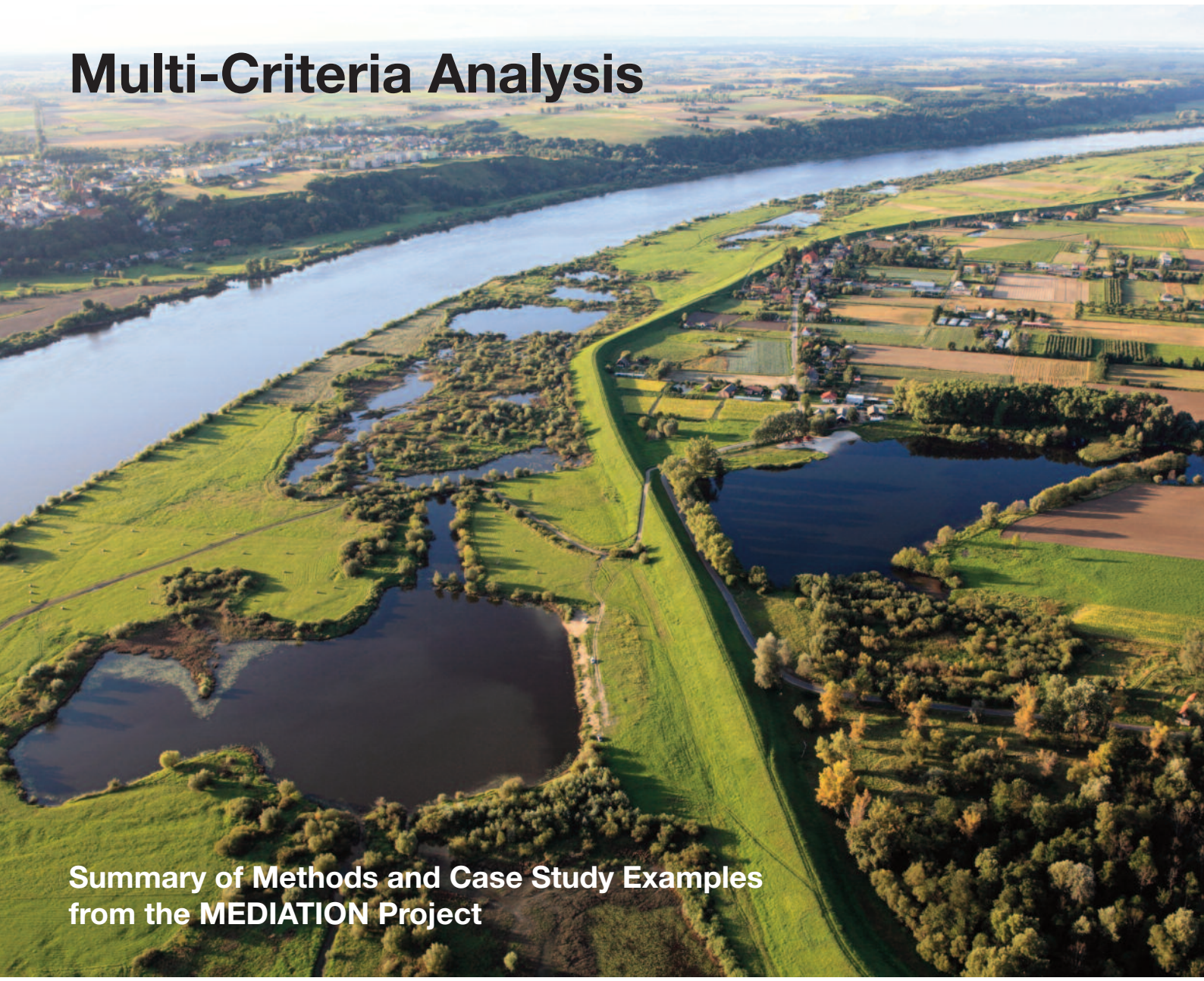
Decision Support Methods for Climate Change Adaptation

6

Multi-Criteria Analysis



Summary of Methods and Case Study Examples from the MEDIATION Project

SEVENTH FRAMEWORK PROGRAMME

Mediation

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 methods 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.
- One of the tools widely recommended for adaptation is **Multi-Criteria Analysis (MCA)**. MCA is an approach that allows consideration of both quantitative and qualitative data in the ranking of 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. These steps are undertaken using stakeholder consultation and/or expert input.
- MCA has been widely applied in the environmental domain. It is also used as a complementary tool to support cost-benefit analysis, to consider the performance of options against criteria that may be difficult to value or involve qualitative aspects.
- The approach has high relevance for adaptation. Criteria can be included to consider uncertainty or various 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.
- The review has considered the strengths and weakness of the approach for adaptation. The main strength is that it allows consideration of both quantitative and qualitative data together, and can compare monetary and non-monetary criteria directly. This allows the consideration of a much broader set of criteria than other approaches.
- The potential weaknesses involve the fact that the scoring and weighting can be quite subjective, influenced by the stakeholders involved in the process. The consideration of uncertainty is also usually more qualitative.
- Previous applications of MCA for adaptation have been reviewed, and adaptation case studies are summarised. MCA has been used as the main decision support tool in early national adaptation policy analysis, but has also been used alongside CBA in adaptation project appraisal to consider broader criteria and aspects.
- The review and case studies provide useful information on the types of adaptation problem types where MCA might be appropriate, as well as data needs, resource requirements and good practice lessons. MCA is particularly applicable in areas where quantification is difficult, or for sectors where broader objectives are important. The approach is considered particularly useful to identify promising options, which can then be subject to more detailed appraisal.

Multi-Criteria Analysis

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 Policy Briefing Notes have been produced on *Decision Support Methods for Climate Change Adaptation*.

An overview of all the decision support tools reviewed is provided in *Policy Briefing Note 1: Method Overview*, which summarises each method, discusses the potential relevance for adaptation and provides guidance on their potential applicability. The methods considered include existing appraisal tools (cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis), as well as techniques that more fully address uncertainty (real options analysis, robust decision making, portfolio analysis and iterative risk (adaptive) management). It also includes complementary tools that can assist in adaptation assessment, including analytic hierarchy process, social network analysis and adaptation turning points. Additional information on each method is presented in a separate *Policy Briefing Notes (2 – 10)*.

This *Policy Brief (Note 6*) provides a summary of **multi-criteria analysis**. It provides a brief synthesis of the approach, its strengths and weaknesses, the relevance for adaptation, how it considers uncertainty, and presents case study examples. It is stressed that this note only provides an overview: more detailed information is available in MEDIATION deliverables, and sources and links on the Mediation Adaptation Platform.

Description of the Method

MCA is an approach that allows consideration of both quantitative and qualitative data in the ranking of 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. These steps are undertaken using stakeholder consultation and/or expert input.

The approach identifies alternative options, selects criteria and scores options against these, then assigns weights to each criterion to provide a weighted sum that is used to rank options (Janssen and Van Herwijnen, 2006). The process allows the weights (for each criterion) to reflect the preferences of the decision-makers and the weighted sum of the different criteria is used to rank the options.

MCA has been widely applied for ranking various alternatives, especially in the environmental domain. It is often included in guidance as one of a number of potential tools for option appraisal (e.g. as for [regulatory] impact assessment, EC, 2005). It can be used for strategy level analysis or for individual projects or investment decisions.

It is also sometimes used as a complementary tool to support cost-benefit analysis, to consider the performance of options against criteria that may be difficult to value or involve qualitative aspects. Such applications include supporting decision analysis for transport appraisal (Dodgson et al, 2000).

A simplified example is included in the box below.

- The approach involves a number of common steps.
- To identify the objectives and important decision criteria.
- To identify potential options. Note that stakeholder consultation is often used to identify the most important options.
- Identify relevant criteria to assess the options against. The number of criteria can range from a few key criteria to twenty or more criteria, though a higher the number of criteria

increases the resources and analysis needed. For each criteria, a scale is needed, either as a quantitative metric (e.g. costs), or for qualitative metrics, a range (e.g. 1 to 5, 1 to 10).

- All options are scored against all the criteria. This process can be undertaken through analysis, stakeholder engagement (and workshops) or through expect elicitation.
- Assess the weighting of alternative criteria. This provides the relative importance of each of the individual criteria in the overall decision. While all criteria can be given equal weighting, it is normal in MCA to give different weightings to different criteria, reflecting their important in the objectives. These weights can also be set through stakeholder engagement or expect elicitation.
- The weighted scores for each option are calculated. This then provides a prioritised ranking of options, though alternative approaches are possible (see later).

Box 1: Multi-Criteria Analysis: Example

A simple example of MCA is illustrated below. This aims to rank three alternative investment projects A, B, and C, based on the criteria (i) profitability, (ii) risk and (iii) whether it is a core activity. The first step is to provide scores for each of the criteria related to these alternatives, as the example below.

Table 1. Scores per criteria per alternative: a hypothetical example

Criteria / Option	A	B	C
i Profitability	5	3	2
ii Safety	2	4	3
iii Core activity	3	1	4

Note: 5=very high 4=high 3=average 2= low 1=very low

We then formulate the weights that we attach to each of the criteria, for instance equal weights of all criteria, i.e. thus 0.333 for each, though different weights are often assigned. This enables us to calculate the weighted scores for each of the alternatives. The weighted scores are then as follows:

– for Alternative A: 0.33*5+0.333*2+0.333*3=3.33
– for Alternative B: 0.33*3+0.333*4+0.333*1=2.664
– for Alternative C: 0.33*2+0.333*3+0.333*4=2.997

Table 2. Table with the weights per criteria, the weighted scores per criteria per alternative, and the total weighted score per alternative based on weighted summation: a hypothetical example

Criterion / Option	A	B	C	Weight
i Profitability	1.665	0.999	0.666	0.333
ii Safety	0.666	1.332	0.999	0.333
iii Core activity	0.999	0.333	1.332	0.333
Total weighted score	3.33	2.664	2.997	

Note: 5=very high 4=high 3=average 2= low 1=very low

Table 2 shows that alternative A would be preferred, because it has the highest total score.

In the implementation of MCA it is important to reflect very carefully on how to score the alternatives and which range of scores should be applied. It is also essential to make sure that the weighted scores can be added, i.e. all criteria should be formulated in positive terms, or all criteria should be expressed in negative terms.

Usually scores are standardized, so that the high and low levels of the scores represent the judgement about the performance of the alternatives as precisely as possible. The weights then need to be made explicit based on the assessment of the decision makers, or for instance starting from equal weights and then according to a set of logical and plausible weights that express the values of various categories of stakeholders.

This ensures that the impacts of the various sets of weights on the ranking can be assessed transparently. The process allows decision makers to learn about the characteristics of the alternatives and the ranking of the alternatives for various sets of scores and weights.

There are many methods to establish the ranking of the alternatives. The most commonly applied is the method of weighted summation. However, alternative methods include pair wise comparison; Analytic Hierarchy Process (AHP) or more complicated mathematical methods. Detailed descriptions of these methods are available from the sources in the further reading list on Multi Criteria Analysis (e.g. Belton and Stewart, 2002).

Details of the Analytic Hierarchy Process approach are provided in a separate *Policy Briefing Note (Nº 7*).

The Application to Adaptation

Multi Criteria Analysis has high relevance for adaptation. The criteria can be included to consider the different aspects of uncertainty as well as other elements of good adaptation. As example, previous adaptation MCAs have considered criteria of robustness, low/no regret characteristics or flexibility, as well as co-benefits and synergies with mitigation.

The approach also allows analysis with qualitative information, which is particularly useful given there are often data gaps in climate change adaptation, and/or because there is often a need to consider additional aspects such as the acceptability, equity or environmental or social performance of options which are difficult to quantify.

Applications of MCA to adaptation use some form of climate change information. In more qualitative studies, this can use climate model information to build up indications of the future impacts of climate change, e.g. in terms of changes in temperature, weather extremes, runoff and sea level rise. Similarly the performance of different adaptation options against these risks can be assessed (i.e. scored). An example of this qualitative type of approach is included in the case study (Van Ierland et al. 2007), which provides an example of the additional characteristics that can be included for adaptation, i.e. importance, urgency, no regret characteristics, co-benefits and mitigation synergies.

It is also possible to undertake MCA in a more qualitative climate scenario framework, using climate model projections and analysis of options (e.g. costs, effectiveness, performance against wider criteria). An example of this approach was undertaken within the Thames Estuary 2100 (TE2100, EA, 2009) project, which looked at future flood defences for London using various sea level rise scenarios. This study used a multi-criteria analysis to complement a formal economic cost-benefit analysis. The MCA was used to consider the data collected as part of the Strategic Environmental Assessment and included the heritage, recreation and habitat sensitivity criteria, as well as landscape character and capacity assessments, alongside costs and benefits within a Multi Criteria Analysis (scoring & weighting).

However, MCA does have some limitations in relation to climate change uncertainty, in that it tends to work with individual scenarios, against which options are assessed. It is more difficult to incorporate the different elements of current and future climate risks (the time dimension), and to include climate change uncertainty (as well as analysing how the benefits of different adaptation options vary against different scenarios), unless multiple runs of the MCA are conducted. The inclusion of criteria for how options perform against uncertainty can be included to address this, but this makes the consideration of uncertainty very qualitative.

Strengths and Weaknesses

A key part of the MEDIATION project has been to identify the strengths and weaknesses of different approaches.

The main strength of multi-criteria analysis is that it allows consideration of both quantitative and qualitative data, and can thus compare monetary and non-monetary units directly. This allows the consideration of a much broader set of criteria than other approaches, as well as elements that may be difficult to quantify. It thus allows application in non-market sectors, and can be broaden out to consider wider attributes (e.g. acceptability, equity) of adaptation options.

The approach also encourages consultation and engagement with stakeholders. This can help in identifying options, bringing in expert knowledge to the scoring process, and understanding stakeholder (and policy-makers) preferences in relation to weighting.

The potential weaknesses relate to the fact that the scoring and weighting exercise can be subjective, depending on the stakeholders or experts involved. This translates through to the consideration of uncertainty, which is often very qualitative in nature.

A summary of the strengths and weaknesses is presented below.

Case Studies

The MEDIATION study has reviewed existing literature examples that have applied Multi-Criteria Analysis to adaptation.

The review has found several relevant applications. This includes application at the national level, for early programmatic analysis of adaptation as part of national strategy development (see case study box below).

It also includes the application of MCA to complement economic appraisal of adaptation at the project level (e.g. EA, 2009), to allow the analysis of a broader set of criteria, particularly environmental and social aspects.

Key strengths

- Can combine quantitative and qualitative data, using monetary and non-monetary units, and can therefore consider a much wider set of criteria, even where quantification is challenging or limited.
- The method is relatively simple and transparent, and can be done at relatively low cost and within a limited time.
- Expert judgement can be used very efficiently.
- It involves stakeholders and can be based on local knowledge.

Potential weaknesses

- Results need further interpretation and elaboration in more detailed studies.
- Different experts may have different opinions and will provide different scores, i.e. there is a degree of subjectivity involved.
- Stakeholders may have lack of knowledge and can miss important options.
- It may be difficult to give consistent scores to the alternatives.
- Analysis of uncertainty often highly qualitative.

Box 1. MCA for Adaptation in the Netherlands

An example of a multi criteria analysis for adaptation in the Netherlands is summarised, based on De Bruin et al. (2009) and Van Ierland et al. (2007).

The analysis started with a typical climate change scenario developed by the Royal Netherlands Meteorological Institute for the period up to 2050 (KNMI, 2006). Adaptation options were identified in workshops for different sectors, namely agriculture, nature, water, energy & transport, housing & infrastructure, health, and recreation and tourism. Experts on spatial planning and adaptation to climate change as well as public and private stakeholders were involved in the identification and ranking of the adaptation options, including representatives from different research institutes, NGOs, universities and Ministries.

The next step was to score and weight these adaptation options. The options (see Table 3 for examples for the agricultural sector) were given scores with respect to the following priority criteria (See Table 4):

(i) the importance of the option in terms of the expected gross benefits that can be obtained;
(ii) the urgency of the option, reflecting the need to act soon and not later;
(iii) the no-regret characteristics of the option (it is good to implement, irrespective of climate change);
(iv) the co-benefits to other sectors and domains; and
(v) the effect on climate change mitigation (for instance through changes in land-use that reduce emissions of greenhouse gases as a side effect).

In defining the criteria we aimed at selecting them as such that they are complete (all relevant criteria have been included), operational (each option can be judged against each criterion), mutually independent (options are independent of each other from one criterion to the next), contain no double counting and are consistent with effects occurring over time (Dodgson et al., 2000; Keeney and Raiffa, 1976). However, not all criteria are completely mutually exclusive, the no-regret and co-benefit criteria are closely related to each other. The scoring is based on subjective expert judgement and has been discussed in a workshop with external experts to validate the scores. We have invited experts with a broad overview of the problem of adaptation to make the ranking because the adaptation options cover many different aspects and sectors of society, and the ranking requires the capability to compare the various options across these sectors. Specialized stakeholders representing a specific sector would not be able to make this comparison across sectors, but of course they were valuable in identifying adaptation options relevant to their sector.

Table 3. Examples of adaptation options for the agricultural sector (based on literature survey and stakeholder consultation).

Nr.	Sector	Adaptation option
1	Agriculture	Adjusting crop rotation schemes and planting and harvesting dates
2	Agriculture	Choice of crop variety and genotype
3	Agriculture	Development and growing of crops for biomass production
4	Agriculture	Soil moisture conservation practices
5	Agriculture	Irrigation
6	Agriculture	Self-sufficiency in production of roughage
7	Agriculture	Water storage on farmland
8	Agriculture	Subsoil drainage of peatlands
9	Agriculture	Insurance
10	Agriculture	Changes in farming systems
11	Agriculture	Water management and agriculture
12	Agriculture	Regional adaptation strategies for the fen meadow area

13	Agriculture	Relocation or mobilization of farms
14	Agriculture	Floating greenhouses
15	Agriculture	Land use change
16	Agriculture	Adaptation strategies to salinization of agricultural land
17	Agriculture	Increasing genetic and species diversity in forests
18	Agriculture	Introduction of southern provenances of tree species and drought resistant species
19	Agriculture	Limiting the import of timber
20	Agriculture	Retention of winter precipitation in forests
21	Agriculture	Acceptation of changes in species composition in forests

The importance (i.e. effectiveness in avoiding damages) of an option reflects the level of necessity to implement the option so as to avoid negative impacts. These options can reduce major damages related to climate change. In principle they generate substantial gross benefits (avoided damages), though potentially at high costs.

The urgency of the option relates to the need of implementing the adaptation option immediately or whether it is possible to defer action to a later point in time. Investments with a long lead time, or investments that have a long life time and conservation of the current situation require early action, and therefore potentially a long delay before implementing the option will make it redundant, much more costly or even impossible. Note that a high score on urgency does not necessarily imply that the option deserves a very high final ranking. It only indicates that postponing action may result in higher costs or irreversible damage.

Table 4. The top ten options for the Netherlands based on ranking with criteria weighting for importance, urgency, no regret, co-benefits and mitigation effect – high scores indicate high priority

Nr.	Sector	Adaptation option	Importance (40%)	Urgency (20%)	No regret (15%)	Co-benefits (15%)	Mitigation effect (10%)	Weighted sum
34	Nature	Integrated nature and water management	5	5	5	5	4	4.9
35	Nature	Integrated coastal zone management	5	5	5	5	4	4.9
40	Water	More space for water – a) Regional water system, b) Improving river capacity	5	5	5	5	4	4.9
41	Water	Risk based allocation policy	5	5	5	5	4	4.9
65	Water	Risk management as basic strategy	5	5	5	5	4	4.9
68	Water	New institutional alliances	5	5	5	4	5	4.9
87	Housing Infra.	Make existing and new cities robust – avoid 'heat islands', cooling capacity	5	5	4	5	4	4.8
75	Energy & Transport	Construct buildings with less need for air-conditioning/heating	5	4	5	4	5	4.7
84	Energy & Transport	Change modes of transport and develop more intelligent infrastructure	5	5	4	4	5	4.7
28	Nature	Design and implementation of ecological networks (The National Ecological Network)	4	5	5	5	4	4.5

Note: high scores indicate high priority to implement the option. Weighted sum of scores for other options are given in Table 6 of De Bruin et al. (2009)

In assessing the economic characteristics of various adaptation options a distinction is made between no-regret options and options with co-benefits. No-regret options are the adaptation options for which non-climate related benefits, such as improved air quality, will exceed the costs of implementation; hence they will be beneficial irrespective of future climate change taking place.

The United Kingdom Climate Impacts Programme (Willows and Connell, 2003) has defined no-regret adaptation options (or measures) as: "options (or measures) that would be justified under all plausible future scenarios, including the absence of human-induced climate change". A no-regret option could be one that is worthwhile, in that it would yield economic and environmental benefits which exceed its cost, and will continue to be worthwhile, irrespective of any benefits of avoided climate damages.

Options that score high on the criterion co-benefit are specifically designed to reduce climate-change related vulnerability while also producing corollary benefits that are not related to climate change (Abramovitz et al., 2002). Co-benefits thus concern external effects which have a positive impact on policy goals unrelated to climate change policy (Metroeconomica, 2004).

Finally, the options were scored according to their effect on mitigation. Certain adaptation options also induce a reduction of greenhouse gas emissions, and thus score very high on mitigation effect (i.e. are strengthening mitigation policies), while other adaptation options actually increase greenhouse gas emissions. Scores were attached for each of the options and for each of the criteria, ranging from 1-5, indicating very low priority (1) to very high priority (5).

To assess the political feasibility of the adaptation options, the options were also ranked according to their complexity, for three categories of complexity: (i) Technical, (ii) Social and (iii) Institutional complexity. This results in a ranking for complexity, which enables policymakers to consider the complications that may arise in the implementation of the adaptation options (See Table 5).

Table 5. Top 10 of complex options: Scoring and ranking of adaptation options regarding feasibility – high scores indicate highest complexity.

Nr.	Sector	Adaptation option	Technical complexity (20%)	Social complexity (40%)	Institutional complexity (40%)	Weighted sum
42	Water	Moving powerplants to coast (cooling water)	4	5	5	4.8
46	Water	Widening the coastal defence area (in combination with urbanisation and nature)	4	5	5	4.8
47	Water	Re-connecting water systems – Overschelde: connection Oosterschelde – Westerschelde	4	5	5	4.8
53	Water	Abandoning of the whole of low-lying Netherlands	4	5	5	4.8
15	Agriculture	Land use change	3	5	5	4.6
43	Water	Spatial planning of locations for powerplants (nuclear in particular)	3	5	5	4.6
44	Water	Construction of additional dikes in low-lying parts of the Netherlands	3	5	5	4.6
52	Water	Reclamation of (part of) southern North Sea	3	5	5	4.6
12	Agriculture	Regional adaptation strategies for the fen meadow area	4	5	4	4.4
40	Water	More space for water – a) regional water system and b) improving river capacity	4	4	5	4.4

Note: high scores indicate high complexity to implement the option, i.e. low feasibility. Weighted sum of scores on complexity for other options are given in Table 6 of De Bruin et al. (2009)

Discussion and Applicability

The review and case studies provide a number of practical lessons on the application of multi-criteria analysis to adaptation. They provide useful information on the types of adaptation problem types where MCA might be appropriate, as well as data needs, resource requirements and good practice.

MCA has broad applicability to adaptation, and can be applied for both project and policy level applications to look at alternative options or choices.

It has very broad sector applicability, though it is particularly useful for sectors which involve non-market elements (e.g. biodiversity), or where there are important criteria for which only qualitative information is available. The potential for stakeholder inputs and their use in a decision framework also allows application where quantitative information is low.

The review identifies that MCA is a very good starting point for identifying and ranking adaptation options for climate change, i.e. to select promising options that can then be subject to more detailed appraisal.

It can also be used to complement more formal economic analysis, i.e. to combine existing economic assessment of costs and benefits within a wider framework that allows other criteria to be directly compared.

The review identifies the importance of stakeholder consultation and engagement, and good practice examples highlight the importance of expert input, and the careful choice of the criteria.

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Further information

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

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SEVENTH FRAMEWORK PROGRAMME

Mediation