Decision Support Methods for Climate Change Adaption

3

Robust Decision Making

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 **Robust Decision Making (RDM)**. RDM aims to identify robust options or strategies, i.e. those which perform well over a wide range of futures. It aims to support decision making under conditions of *deep uncertainty*, i.e. when little or no probabilistic information is available.

- RDM has been widely applied as analytic, scenario-based approach for decision support. The formal application is undertaken in a computer modelling interface that adopts data sampling algorithms to analyse strategies over very large ensembles. However, the concepts of the approach can also be used in a simpler application, which tests how options or strategies perform against climate uncertainty.

- RDM has high relevance for adaptation, and aligns strongly with the concepts of adaptive management, by targeting policies or options that are robust rather than optimal.

- The review has considered the strengths and weakness of the approach for adaptation. The key strength is the quantitative analysis of robustness, and the fact that the method can be applied when future uncertainties are poorly characterised or probabilistic information is limited or unavailable. The approach can also work with quantitative or economic data.

- The potential weaknesses of the formal application relate to the high data and resource needs (for quantitative information, computing power, stakeholder engagement and analysis) and the associated expert input required. The data and scenario inputs can also be somewhat subjective, influenced by stakeholders' perception. However, many of these aspects can be overcome with informal applications of the approach, particularly when focused on climate uncertainty alone.

- Previous applications of ROA for adaptation have been reviewed, and adaptation case studies are summarised. Most of the recent adaptation applications have focused on water management, and these include both formal and informal examples.

- The review and case studies provide useful information on the types of adaptation problem types where RDM might be appropriate, as well as data needs, resource requirements and good practice lessons. RDM is particularly applicable under situations of high uncertainty, where probabilistic information is low or missing. The approach can use physical or economic information, thus it has broad applicability from detailed economic appraisal through to the consideration of non-market sectors where valuation may be challenging. It has high potential for identifying low and no regret options, and near-term adaptation strategies that enhance long-term resilience.

- Ideally the approach should be used to consider multiple sources of uncertainty, but this increases the resources needed. The application to climate change uncertainty alone therefore provides a 'lighter-touch' approach to test options for climate robustness. In such applications, the larger the climate uncertainties explored, the better. Where resource constraints are high, such exercises can prove valuable for helping to identify robust solutions and move towards adaptive management.

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 a 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 analytical hierarchic processes, 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 3*) provides a summary of **robust decision making**. 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

Robust Decision Making (RDM) is a decision support tool that can be used in situations of deep uncertainty. RDM is premised on the concept of "robustness" rather than "optimality". The approach was developed to help policymakers make more informed near-term decisions which have long-term consequences.

RDM involves testing near-term strategies across a large number of plausible future states. The primary aim is to help policymakers anticipate or mitigate the negative impacts of possible future surprises resulting from the interaction of factors (exogenous uncertainties) outside of their control, with measures that are within their control. This is described as decision making under situations of *deep uncertainty*, i.e. when little or no probabilistic information is available.

The approach can be applied when traditional risk information (e.g. well-defined probability distributions) is not available, when there is no agreement on the conceptual models to use, or how to evaluate the desirability of alternative outcomes. RDM aims to help decision makers to take robust or resilient decisions today, despite imperfect and uncertain information about the future.

RDM has developed as an analytic, scenario-based approach for strategic decision-making. The formal application of the approach involves the combination of both qualitative and quantitative information through a human and computer-guided modelling interface (Lempert et al, 2003: Groves and Lempert, 2007). This powerful combination surpasses the analytical power of traditional qualitative and quantitative decision support tools. This computer based analysis allows RDM to evaluate how different strategies perform under large ensembles, often of thousands or millions of runs, which reflect different plausible future conditions (Lempert et al, 2003). Iterative and interactive techniques are then applied to "stress test" different strategies, identifying potential vulnerabilities or weaknesses of proposed approaches (Dessai et al., 2009). The formal application of the approach is characterised by the use of data mining algorithms which carry out vulnerability-and-response-option analysis (Groves and Lempert, 2007).

The formal application of RDM involves a series of steps, set out in Figure 1 below (Groves et al., 2008). RDM analysis begins by structuring the problem, but instead of characterising key uncertainties (or more accurately, risks) as a prelude to optimally ranking strategies, the analysis proposes alternative strategies. Uncertainties associated with the parameters defining these strategies are then characterised, assigning a range of uncertainty values for each variable using stakeholder consultation or other approaches.

Each strategy is then assessed over a wide range of (computer-generated) scenario futures. Combinations of uncertainty parameters that are most important to the choice between strategies are statistically derived and a summary of key trade-offs among promising strategies developed (Groves et al, 2008).

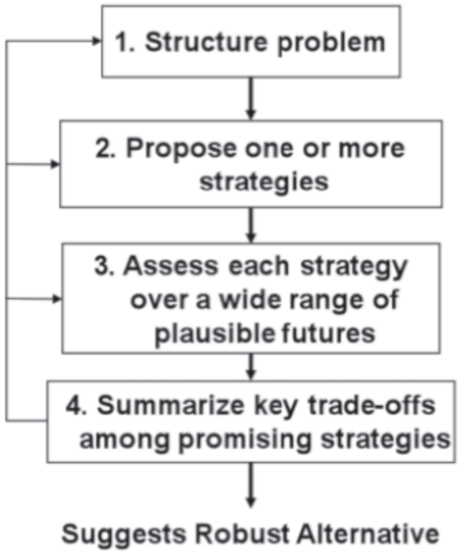

Figure 1. The RDM process

Source: Groves et al., 2008

The analysis of strategies across the scenario futures is measured with performance measures, which are used to measure pre-selected, desirable outcomes. Ideally, an RDM analysis helps to identify a robust strategy – one that performs well over a very wide range of scenario futures. In the event that a robust, well performing strategy is not identified, the iterative process of strategy reformulation begins again with stakeholders.

The formal application of RDM tests many strategies against computer-simulated future scenarios, considering exogenous factors (outside the decision maker's control) and policies or options (within their control), linking these with functional relationships, and assessing strategies against the performance measures in quantitative terms. The former method involves application of statistical or data-mining algorithms.

The Application to Adaptation

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 MEDIATION project has reviewed this potential application.

RDM seeks strategies (or policies or options) that are robust ('good enough'). It therefore offers an alternative to a conventional cost-benefit analysis, which identifies optimal options on the basis of economic efficiency (in the case of climate change adaptation, using impact assessment in a predict-then-optimise framework).

It provides an alternative tool for decision-support which incorporates uncertainty explicitly, minimising regret (in contrast to maximising expected utility), and can play a role in translating the theoretical concepts of adaptive management into quantitative actions, by selecting options that are robust across a wide-range of plausible (climate) futures. This is particularly valuable in cases where the climate model projections are highly uncertain, as is the case for precipitation changes (see briefing note 1.).

The formal application of the approach can also be used to consider wider uncertainty (e.g. in relation to socio-economic future, impact uncertainty) and thus is a potential powerful tool for full uncertainty analysis. The formal approach can also be used with interim performance (measurement) review or evaluation, which aligns it more closely to the iterative adaptation management concepts of monitoring, research, evaluation and learning. The informal application for adaptation focuses on analysing climate uncertainty only, i.e. surrounding climate model projections or climate information.

Strengths and Weaknesses

A key part of the MEDIATION project has been to identify the strengths and weaknesses of different approaches. A summary of these is presented below.

The main strength of the approach is that it helps make informed adaptation decisions possible without relying on probabilistic predictions of future climate change. Indeed, it is particularly valuable where future uncertainties are poorly characterised and/or probabilistic information is limited or not available.

In such cases RDM provides a structured way of assessing performance and identifying robust options in the face of uncertainty, which conventional approaches do not allow. The formal method provides the analytical power to test many strategies and sources of uncertainty and identify trade-offs, synergies and robust decisions.
The approach can assess robustness (i.e. performance) using various metrics, including physical effectiveness or economic efficiency. It therefore offers greater flexibility in assessing market and non-market sectors, and can avoid valuation of benefits enhancing applicability where valuation is difficult or contentious (e.g. ecosystems).

The potential weaknesses relate to the lack of quantitative probabilities associated with scenarios, which can make the analysis a more subjective decision, influenced by stakeholders' perceptions.

The (formal) application of the approach also involves very high demands for quantitative information and computing power for modelling and analysis, and requires high expert input.

Some of these aspects can be overcome by more informal applications of the approach, particularly when limited to the analysis of robustness against climate model projections, though this then negates the benefits of considering wider uncertainty and identifying comprehensive robustness (and a result, key vulnerabilities (particularly those that accumulate or are cumulative) may go undetected.

Case Studies

The MEDIATION study has reviewed existing literature examples that have applied Robust Decision Making to a number of adaptation case studies.

A number of these case studies are summarised in the box below, including an example of one formal and one informal application.

Key strengths

The strength of the RDM lies in the analytical power of testing many options or strategies and in the identification of robustness.

Applicable under situations of uncertainty, where probabilistic information is low or missing, or climate uncertainty is high.

Can work with physical or economic metrics, enhancing potential for application across non-market sectors.

Potential weaknesses

The lack of quantitative probabilities can make it more subjective, influenced by stakeholders' perceptions.

The formal application has a high demand for quantitative information, computing power, and requires a high degree of expert knowledge.

Box 1. Formal Application of Robust Decision Making to Adaptation

A comprehensive, formal application of RDM was undertaken by Lempert and Groves (2010) for Southern California's Riverside County Inland Empire Utilities Agency (IEUA).

This study examined how climate change might affect IEUA's 2005 Urban Water Management Plan (UWMP), a static 25 year plan to meet projected demand based on central projections of supply and demand, looking at uncertainty related to climate change and also the region's growth and socio-economic development trends using RDM.

The analysis followed the step by step process outlined earlier, i.e.:

In collaboration with IEUA stakeholders, it selected key performance measures (e.g. annual water demand, cost of supply, etc.) and then developed alternative management strategies. The latter included *static strategies* considering existing and augmented IEUA 2005 plans, as well as *adaptive strategies* based on a decision-tree framework within a Water Evaluation And Planning (WEAP) model environment (a water balance and management model).

The study then identified significant uncertainties. These included six key areas:

1. Future climate change (temperature, precipitation);
2. Future water demand;
3. Impact of climate change on imported supplies;
4. Response of groundwater basin to urbanisation and changes in precipitation patterns (percolation);
5. Achievement of management strategies (recycling program and groundwater replenishment);
6. Future costs (annual cost increases in imported supplies and efficiency).

The strategies' performance across scenario futures and uncertainties was modelled using WEAP, starting with the original strategy, and working through a succession of 5-year signpost periods. The signposts evaluated the average difference between projected supply and demand to determine if the strategy should adopt an alternative course of actions, i.e. adopting an iterative approach.

The outputs were then input into the Computer Assisted Reasoning (CARs) program and analysed to determine the relative performance of various strategies over time. Performance was measured using projected present value (PV) costs in USD billions against PV shortage costs.

Based on the results of the CARs analysis, key trade-offs between the various strategies were summarised and robust alternative strategies recommended for consideration by stakeholders.

The analysis highlighted that a number of uncertainties would increase operating costs significantly (large declines in precipitation, larger-than-expected impacts of climate change on the availability of imported supplies and, reductions in percolation of precipitation into the region's groundwater basin). In response, RDM analysis identified eight response strategies, four static and four adaptive. In each of the scenarios explored, it was found that the adaptive strategy leads to fewer vulnerable states than the static version.

The findings also showed that accelerating efforts in expanding the size of one of the agency's groundwater banking programs and implementing its recycling program, while monitoring the region's supply and demand balance and making additional investments in efficiency and storm-water capture if shortages are projected provides a promising robust adaptive strategy — and eliminates more than 80% of the initially-identified high-cost outcomes.

Case Study 2: Robust Decision Making for Climate Uncertainty

Dessai and Hulme (2007) present an example of the application for RDM to look at climate uncertainty for water supply in one of the driest regions in England, the East Suffolk and Essex (ES&S) Water Resource Zone (WRZ).

This area is vulnerable to future climate change, and a potential drying signal, with potential impacts on water security, as measured by the average available headroom (the difference between water available for use and demand) relative to target headroom (the minimum buffer allowed between supply and demand).

The analysis focused on the implications of uncertainty from climate change on proposed adaptation actions at a local/regional level, focusing in on water resource supply (not demand), and assessing the robustness of the existing 25 year plan (which had already built in adaptation to climate change using ensemble mean projections for alternative emission scenarios). The aim was to systematically assess the plan against the range of climate change projections and other uncertain parameters. The study included stakeholder consultation with local water managers.

The analysis focused particularly on isolating the threat that uncertain climate related parameters posed to supply-side security. They considered a series of climate uncertainties, including GHG emissions, climate sensitivity, carbon cycle, ocean diffusivity, aerosol forcing, regional climate response and climate impacts, looking at the potential effects one at a time (rather than in combination as in formal RDM and the previous case study, where interactions between uncertainties are explored).

This allowed quantification of the uncertainty introduced by the parameters sampled in the assessment. In turn, this was used to analysis whether the existing adaptation options identified were robust to the range of climate uncertainties.

Overall the findings indicated that the existing water plan was robust, primarily because it had already built in climate change considerations using one of the drier climate models available at the time of plan development. The analysis also strongly indicated that the largest uncertainty introduced into adaptation planning came from the regional climate response.

Some additional analysis was undertaken to look at the potential interaction of different factors, i.e. the cumulative uncertainty. This highlighted that under extreme conditions, further investments would be needed.

The analysis did not take into account the uncertainty around other factors, such as from the loss of groundwater supplies due to pollution, borehole deterioration, leakage, etc. which are important in looking at overall robustness, but it provides an useful case study into the consideration of climate robustness.

Discussion and Applicability

The review and case studies provide a number of practical lessons on the application of robust decision making to adaptation. They provide useful information on the types of adaptation problem types where RDM might be appropriate, as well as data needs, resource requirements and good practice.

RDM is particularly applicable under situations of high uncertainty, where probabilistic information is low or missing.

This is reflected in its use for water resource studies, where the uncertainty is often large (even in terms of the sign of future precipitation changes) from the climate models, combined with other major uncertainties in relation to supply and demand.

The RDM approach can use physical or economic information, that it has broad applicability from detailed economic appraisal through to the consideration of non-market sectors where valuation may be challenging. The potential for stakeholder inputs also allows application where quantitative information is low.

RDM has a particular application in identifying low and no regret options, i.e. in relation to near-term adaptation strategies that are also likely to enhance long-term resilience (through the analysis of robustness). Indeed, the case studies highlight that these low regret options often emerge from the application. It also has potential to consider how near-term infrastructure investment performs against long-term future (uncertain) scenarios.

Ideally the approach is used to consider multiple sources of uncertainty, not just climate change, but this does increase the level of analysis, and the formal approach (using computer interfaces) is technically complex and data and resource intensive, requiring a high degree of expert knowledge.

The application to climate change alone therefore provides a 'light-touch' and enables the testing of options against climate uncertainty. In such applications, which reduce the approach into quantitative scenario testing, the greater the degree of climate model uncertainty explored, the better (i.e. multi-model and multi-scenario analysis, including issue of downscaling, and including variability as well as trends). Where resource constraints are high, such exercises can prove valuable for helping to identify more robust solutions and moving towards adaptive management under high uncertainty.

References

Dessai et al., 2009. Climate prediction: a limit to adaptation? In Adapting to Climate Change: Thresholds, Values, Governance, eds. W. Neil Adger, Irene Lorenzoni and Karen L. O'Brien. Published by Cambridge University Press. Cambridge University Press 2009.

Dessai S; and Hulme M (2007) Assessing the robustness of adaptation decisions to climate change uncertainties: A case study on water resources management in the East of England, Global Environmental Change, 17, pp.59-72. doi: 10.1016/j.gloenvcha.2006.11.005.

Groves, D. G., Lempert, R., Knopman, D., and Berry, S. (2008a). "Preparing for an Uncertain Future Climate in the Inland Empire – Identifying Robust Water Management Strategies." DB-550-NSF, RAND Corporation, Santa Monica, CA.

Groves, D.G., Knopman, D., Lempert, R.J., Berry, S.H., and Wainfan, L., 2008b. Presenting uncertainty about climate change to water-resource managers: a summary of workshops with the Inland Empire Utilities Agency. RAND, 2008.

Groves, D. G. and Lempert, R. J. (2007): A new analytic method for finding policy-relevant scenarios. Global Environmental Change. 17: 73-85.

Lempert et al., 2003. Shaping the next one hundred years: new methods for quantitative, long-term policy analysis. Robert J. Lempert, Steven W. Popper, and Steven C. Bankes. RAND, 2003. Santa Monica, CA. ISBN 0-8330-3275-5.

Lempert and Groves, 2010. Identifying and evaluating robust adaptive policy responses to climate change for water management agencies in the American west. Technological Forecasting & Social Change, 77, 960-974.

Lempert, R. J., Popper, S. W., and Bankes, S.C. (2003), Shaping the Next One Hundred Years: New Methods for Quantitative, Long-term Policy Analysis, RAND, Santa Monica, CA: i-187.

Further Reading and Reference Sources

MEDIATION Policy Briefing Note 1: Method Overview.

Further information

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007- 2013) under grant agreement n° 244012.

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

For further information on the MEDIATION project: contact Rob Swart at
rob.swart@wur.nl

For further information on economic decision support tools, contact Paul Watkiss
paul_watkiss@btinternet.com

Citation: Watkiss, P. and Dynzynski, J (2013). Robust Decision Making: Decision Support Methods for Adaptation, MEDIATION Project, Briefing Note 3. Funded by the EC's 7FWP

First published May 2013

The MEDIATION project is co-ordinated by Alterra, Stichting DLO and involves 11 teams from across Europe

SEVENTH FRAMEWORK PROGRAMME

Mediation