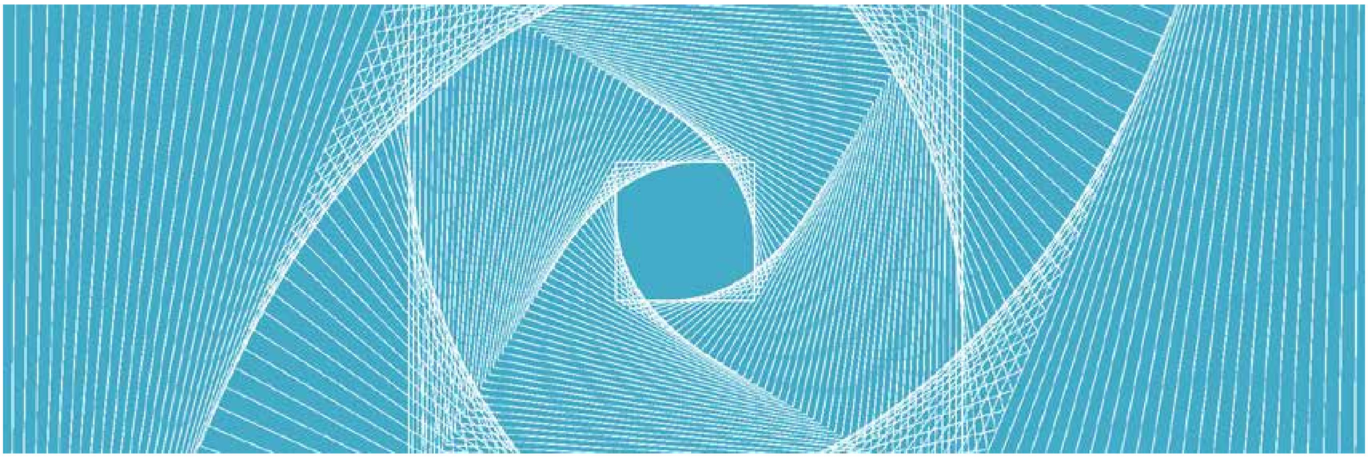
cecan
Centre for the Evaluation of Complexity Across the Nexus

Note No. 9
Spring 2018

Managing deep uncertainty: exploratory modelling, adaptive plans and decision support



Decision making on complex systems has to come to grips with irreducible, or deep, uncertainty. Such uncertainty has three sources: intrinsic limits to predictability in complex systems; a variety of stakeholders with different perspectives on what the system is and what problem needs to be solved; and, generally, dynamic change that can never be completely understood. Dealing with deep uncertainty means that evaluation should be linked to forward-looking analyses.

What is deep uncertainty?

Deep uncertainty occurs when:

- Various parties to a decision do not know or cannot agree on how the system works, how likely various possible future states of the world are, and how important the various outcomes of interest are.
- It is possible to enumerate possible representations of the system, plausible futures, and relevant outcomes of interest, without being able to rank order them in terms of likelihood or importance.

Making decisions under deep uncertainty implies shifting from optimizing expected outcomes for a single future state of the world, to robustness to many plausible future states of the world:

- A plan is robust if its expected performance is only weakly affected by the various uncertainties.
- Alternatively, a plan can be understood as being robust if no matter how the future turns out, there is limited regret about implementing the plan.

What are the key ideas behind decision-making under deep uncertainty?

Many of the technical terms used in DPS are derived from the methods of cluster analysis and qualitative comparative analysis.

Decision-making under deep uncertainty rests on three key ideas:

- **Exploratory modelling:** in the face of deep uncertainty, one should explore the consequences of the various presently irreducible uncertainties for decision-making. Because of the intrinsic complexity of the system under study, and the combinatoric explosion due to the various uncertainties, this exploration uses computational scenario-based techniques for the systematic exploration of a very large ensemble of plausible futures.
- **Adaptive planning:** decision robustness is achieved through plans that can be adapted over time in response to how the future actually unfolds.
- **Decision support:** instead of identifying the optimal choice, decision analysis focuses on exploring the consequences of alternative courses of action over the many uncertainties, and maps the trade-offs that the decision-makers are facing.

What is exploratory modelling?

Exploratory modelling involves:

- The use of computational experimentation with one or more simulation models to systematically explore the impact of uncertainty on various outcomes of interest for alternative courses of action.
- A set of computational experiments that is plausible or interesting in a given context generated by the uncertainties associated with the problem of interest, and constrained by available data and knowledge; the various uncertainties together span a space of possible experiments.

However

- A single experiment in this space is not a prediction. Rather, it is a computational 'what-if' experiment that reveals how the real world system would behave if the various assumptions made in this particular experiment about the various uncertainties were correct.
- A single 'what-if' experiment is typically not that informative, other than suggesting the plausibility of its outcomes. Instead, exploratory modelling aims to support reasoning and decision-making on the basis of large sets of experiments.
- Exploratory modelling involves searching through the space of possible experiments using (many-objective) optimization algorithms, and sampling over the space using computational design of experiments and global sensitivity analysis techniques. By searching through the space, one can identify which (combination of) uncertainties negatively affect the outcomes of interest. In light of this, actions can be iteratively refined to be robust with respect to these uncertainties.

What is adaptive planning?

Adaptive planning:

- Means that plans are designed from the outset to be altered over time in response to how the future actually unfolds. In this way, modifications are planned for, rather than taking place in an ad hoc manner.
- Requires a wide variety of futures to be explored in order to identify the uncertainties for which flexibility is needed, and the shape this flexibility should take. Insight is needed into which actions are best suited to which futures, as well as what signals from the unfolding future can be monitored in order to ensure the timely implementation of the appropriate actions.
- Involves a paradigm shift from planning in time, to planning conditional on observed developments.
- Results in plans that have the flexibility needed to achieve robust decisions

Actively monitoring whether the performance of the plan is on track, and implementing pre-specified contingency actions if the plan deviates is a crucial success factor.

What is the role of decision support and joint sense making?

Decision making on uncertain complex systems generally involves multiple actors who have to come to an agreement. In such a situation, planning and decision-making requires an iterative approach that facilitates learning across alternative framings of the problem, and learning about stakeholder preferences and trade-offs, in pursuit of a collaborative process of discovering what is possible.

Decision support:

- Can be used to enable a constructive learning process amongst the stakeholders and analysts.
- Must shift away from the a priori agreement on (or imposition of assumptions on) the probability of alternative states of the world and the way in which competing objectives are to be aggregated, with the aim of producing a preference ranking of decision alternatives. Instead decision analysis must shift to an a posteriori exploration of trade-offs amongst objectives and their robustness across possible futures.
- Should move away from trying to dictate the right choice, and instead aim at enabling deliberation and joint sense-making among the various parties to the decision.

circumstances than by the single currency.08 crisis.

What examples of approaches for decision-making under deep uncertainty are available?

Notwithstanding the many technical differences that exist between the various approaches and techniques, there is an increasing emphasis on what is shared. Also, in practice, people are increasingly adopting aspects from multiple approaches in order to offer context-specific support for making decisions under deep uncertainty.

The three ideas of exploratory modelling, adaptive planning, and a posteriori decision support underpin a variety of specific approaches:

- (Many-objective) robust decision-making was first put forward by the RAND Corporation. It involves the iterative refinement of candidate strategies on the basis of exploratory modelling. Recently, it has been complemented with many-objective search to find a set of initial strategies that represent different trade-offs amongst the various outcomes of interest.
- Dynamic adaptive policy pathways emerged more or less simultaneously in the UK in the context of the Thames Estuary 2100 plan and the Dutch Delta Programme. It emphasizes the design of a plan as a sequence of actions over time. New steps on the pathway are taken if changing conditions necessitate this. It is an effective means for ex ante exploration of possible lock-ins (ie where it is no longer possible to change to a different type of strategy), and future flexibility.
- Other techniques include decision scaling, real options analysis, and info-gap decision theory. Decision scaling is a bottom-up approach to informing climate adaptation decision-making. Real options analysis aims to assign economic value to individual options that make a plan flexible. Info-gap decision theory is an approach for investigating how far the future has to deviate from a reference scenario before the performance of a plan becomes unacceptable.

When are decision-making-under-deep-uncertainty approaches applicable?

Deep uncertainty approaches may be particularly helpful when:

- There are multiple parties involved in the decision-making process, and they have diverging ideas about what the problem is and how it might be resolved.
- There is a sense of urgency about making choices, while the alternatives have long lead times, or might create possible lock-ins.
- The consequences of the decision are sensitive to uncertainties that at the moment of the decision cannot be reduced.

In decision-making under deep uncertainty, evaluation serves the dual purpose of evaluating past decisions as well as suggesting key decisions that have to be made in the foreseeable future.

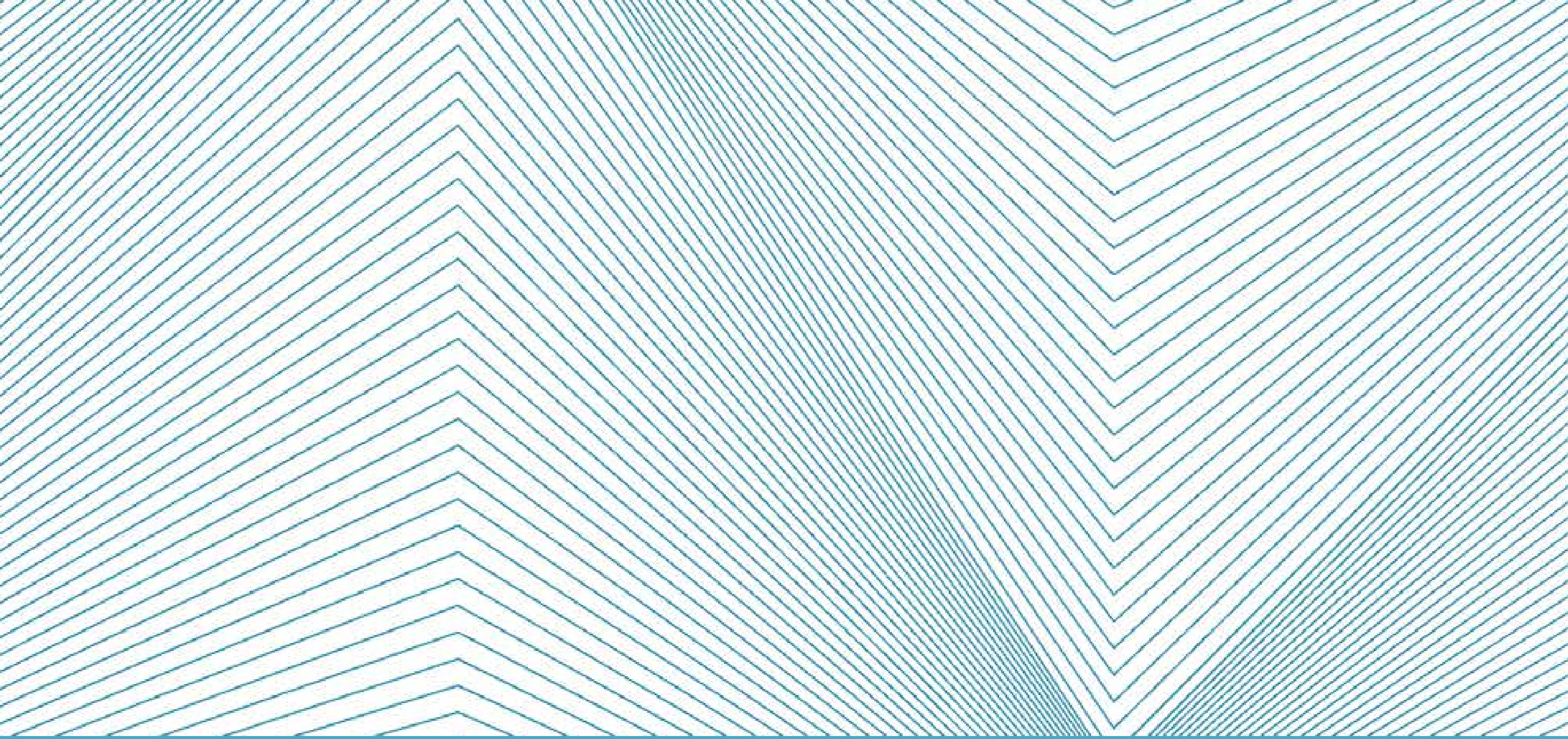
To date:

- Most approaches for supporting the making of decisions under deep uncertainty rely on the use of simulation models. For these approaches to be applicable either one or more models of the system under study should already be available, or there should be a willingness to develop such models.
- Decision-making under deep uncertainty approaches have primarily been used in long-term infrastructure planning, with a particular focus on climate adaptation in the water sector.

What are the main drawbacks or downsides to using a decision-making-under-deep-uncertainty approach?

There are some disadvantages to this approach including:

- The various parties to a decision must be willing to give up the illusion of predictive accuracy.
- Systematic exploration of a large number of futures is time consuming, and can easily create an information overload.
- If models of the system do not yet exist, there is the additional burden of developing these models. If however models do exist, they might constrain the possibility of exploring a wide variety of futures.
- Institutional barriers (eg least cost planning in the water sector in the UK) might limit the application of various approaches, or render the insights generated not applicable.



References and further information

Bankes, S.C., 1993. Exploratory Modeling for Policy Analysis. Operations Research 4(3) 435-449.

Haasnoot, M., Kwakkel, J.H., Walker, W.E., ter Maat, J. (2013) Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. Global Environmental Change 23, 485-498. doi: 10.1016/j.gloenvcha.2012.12.006

Herman, J.D., Reed, P.M., Zeff, H.B., Characklis, G.W., 2015. How should robustness be defined for water systems planning under change. Journal of Water Resources Planning and Management 141(10). doi: 10.1061/(ASCE)WR.1943-5452.0000509

Lempert, R.J., Groves, D.G., Popper, S.W., Bankes, S.C. (2006) A General, Analytic Method for Generating Robust Strategies and Narrative Scenarios. Management Science 52, 514-528. doi: 10.1287/mnsc.1050.0472

Kwakkel, J.H., Walker, W.E., Haasnoot, M. (2016) Coping with the Wickedness of Public Policy Problems: Approaches for Decision Making under Deep Uncertainty. Journal of Water Resources Planning and Management. doi: 10.1061/(ASCE) WR.1943-5452.0000626

Walker, W.E., Haasnoot, M., Kwakkel, J.H. (2013) Adapt or Perish: A Review of Planning Approaches for Adaptation under Deep Uncertainty. Sustainability 5, 955-979. doi: 10.3390/su5030955

cecan
Centre for the Evaluation of Complexity Across the Nexus

www.cecan.ac.uk / cecan@surrey.ac.uk / +44 (0) 1483 682769

The Centre for the Evaluation of Complexity Across the Nexus (CECAN) is a £3m national research centre hosted by the University of Surrey, which brings together a unique coalition of experts to address some of the greatest issues in policy making and evaluation.

This Evaluation Policy and Practice Note was written by Dr. ir. Jan H. Kwakkel, Faculty of Technology, Policy and Management, Delft University of Technology. Contact: J.H.Kwakkel@tudelft.nl.

E·S·R·C Economic & Social Research Council
Department for Environment Food & Rural Affairs
Department for Business, Energy & Industrial Strategy
NERC Science of the Environment
Environment Agency
Food Standards Agency food.gov.uk