2. The central conundrums of policy formulation: ill-structured problems and uncertainty

Sreeja Nair and Michael Howlett

INTRODUCTION: ILL-STRUCTURED POLICY PROBLEMS AND THE CHARACTERIZATION OF UNCERTAINTY

The concept of uncertainty has been widely interpreted and studied in diverse disciplines that influence public policy. These include the physical sciences, social sciences, mathematical sciences, engineering, economics, philosophy and psychology. The theoretical basis, historical context, relevance, and tools and methods for addressing uncertainty are thus often grounded within specific discourses originating in different disciplines (Walker et al., 2012).

Historically, policy scholars studying problem solving in policymaking – such as Churchman (1967), Rittel and Webber (1973) and Simon (1973) – typically thought about uncertainty in a purely 'objective' sense – that is, whether the problem's causes and solutions were known or unknown. Bivariate concepts of 'wicked' and 'tame' or 'well-structured' and 'ill-structured' problem contexts introduced by these authors have dominated thinking in the area. These, however, form only part of a larger group of policy problems that become intractable owing to several kinds of uncertainties. An ill-structured problem in this sense is one 'whose structure lacks definition in some respect' (Simon, 1973, p. 181). 'Wicked' problems can be considered to comprise a subset of ill-structured problems, generally characterized by lack of agreement regarding the nature of the problem as well as potential solutions (Rittel & Webber, 1973). A major challenge in formulating strategies to deal effectively with uncertainty has been the inadequacy of various schemes and models used to classify different levels and types of uncertainty and to assess their impacts. A seminal paper by Knight (1921) addressed ill-structured problems, usefully distinguishing between uncertain futures in which there is a reasonably quantifiable probability distribution (Knightian risk) and those in which there is not and such distributions are unknown (Knightian uncertainty).

Morgan and Henrion (1990) in an oft-cited text underscored the importance of properly classifying the types and sources of uncertainty in policymaking so that they can be effectively addressed. They argued against Knight that a classification of uncertainty as centered on known/unknown probability makes it difficult to proceed from analysis to 'real-world decision-making'. Instead, they argued for a subjectivist or Bayesian approach which classified uncertainty in terms of the different kinds of sources from which it can arise. This includes statistical variation owing to random measurement errors, 'linguistic imprecision' (that is, cases where the quantities being studied or measured are not well specified or characterized), variations over time and space, randomness, subjective judgement, disagreement between experts, and differences between the real and approximated value of the quantity (Morgan & Henrion, 1990). This analysis was useful in noting that while uncertainty often arises due to imperfect information, including wrong information

or missing information, all existing information is also prone to ambiguity – including multiple interpretations and diverse perspectives (Jones & Baumgartner, 2005). Uncertainties surrounding the choice of policy options and their consequences, and levels of confidence regarding available information and values of multiple stakeholders (including decision-makers) are also significant (Hansson, 1996).

While Morgan and Henrion's classification focused on uncertainty in quantitative policy analysis, Koppenjan and Klijn (2004) extended this analysis further in presenting a classification focused on the interactions among actors and knowledge (or information)-related uncertainty needed to resolve complex policy problems. Some of these uncertainties overlap with the analysis of Morgan and Henrion, for example, those related to decision variables and value parameters and related uncertainties. Koppenjan and Klijn's classification, however, also includes: (1) substantive uncertainty that arises due to a lack of relevant information related to the nature of the complex problem, or the different interpretations of information coming from different 'frames of reference' of the social actors; (2) strategic uncertainty that arises due to the unpredictability of strategies deployed by different actors based on their perception of the problem and strategies likely to be deployed by other actors; and (3) institutional uncertainty that arises owing to the complexity of interaction of different actors guided by institutional frameworks (that is, rules and procedures of the organizations they represent). Similarly, Brugnach et al. (2008) present uncertainty as involving an object(s) of perception or knowledge, various actors including the decision-maker, and the relationships that bind the object(s) and the actors. They consider ambiguity as uncertainty of a third kind, separate from the uncertainty inherent in a system (ontological uncertainty) and that arising due to lack of knowledge (epistemic uncertainty).

Both kind of uncertainty affect policymaking at both the level of objective knowledge of problems as well as at the level of the relative nature of decision-makers' knowledge of that 'knowledge base'. The 'wicked' problem space, again, can be seen in this view to itself be a superset of several other interconnected problems spanning multiple policy domains and levels of government, and requiring a high degree of deliberation and cooperation for effective problem solving (Jentoft & Chuenpagdee, 2009).

In addition, such problems are also 'relentless', that is, they are not typically able to be solved permanently, thus making it important to ensure a 'continuous transfer, receipt and integration of knowledge' over time (Weber & Khademian, 2008, p. 336). Such problems rank high in terms of their complexity, uncertainty regarding problem characteristics and solutions, and divergence of perspectives (Head, 2008; Table 2.1).

Usefully synthesizing these approaches, Walker et al. (2010) identify five policy-relevant

Table 2.1 Characteristics of wicked problems

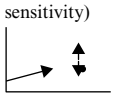
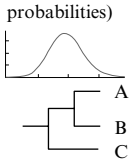
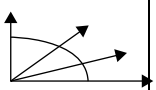
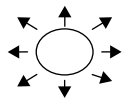
	Degrees of difficulty		
Complexity of elements, sub-systems and interdependencies	Low	Moderate	High
Uncertainty in relation to risks, consequences of action and changing patterns	Low	Moderate	High
Divergence and fragmentation in viewpoints, values, strategic intentions	Low	Moderate	High

Source: Modified from Head (2008).

levels of uncertainty. These include the 'Level I' 'shallow' or parameter uncertainties where alternative states of a system within specific probabilities exist but in some scenarios may be well known and established. Policy problems characterized by parameter uncertainty are not very difficult problems to handle – at least in theory – and are likely to be resolvable by standard treatments.

These can be distinguished from 'Level II' medium or fuzzy uncertainty, where multiple alternatives exist within a specific scenario but can be ranked based on the 'perceived likelihood' of their occurrence. 'Level III' situations are then those where different possible overall scenarios exist but these can still be ranked in terms of their likelihood. 'Level IV' uncertainty represents a more complex form of Level III uncertainty in which multiple plausible alternative scenarios exist but cannot be ranked in terms of their perceived likelihood. Finally, in the most complex 'Level V' situations, it is not feasible to present or agree upon a full range of alternative scenarios and there is a very real 'possibility of being surprised' by events occurring outside of normal boundary conditions and solutions (Walker et al., 2013a; Figure 2.1).

This multi-level model is useful because it allows for the identification of policy

Complete certainty	Context	Level I	Level II	Level III	Level IV	Level V	Total ignorance
		A clear enough future (with sensitivity) 	Alternate futures (with probabilities) 	Alternate futures (with ranking) 	A multiplicity of plausible futures (unranked) 	Unknown future 	
	System model	A single system model	A single system model with a probabilistic parameterization	Several system models, one of which is most likely	Several system models, with different structures	Unknown system model; know we don't know	
	System outcomes	Point estimates with sensitivity	Several sets of point estimates with confidence intervals, with a probability attached to each set	Several sets of point estimates, ranked according to their perceived likelihood	A known range of outcomes	Unknown outcomes; know we don't know	
	Weights on outcomes	A single estimate of the weights	Several sets of weights, with a probability attached to each set	Several sets of weights, ranked according to their perceived likelihood	A known range of weights	Unknown weights; know we don't know	

Source: Walker et al. (2013a).

Figure 2.1 Different levels and orders of uncertainty

responses that can effectively 'adapt' to match with the rate and level of current as well as projected uncertainty in policy environments and impacts. Level I and II problems, for example, as noted above, can be anticipated and factored into predictions of future events and trajectories. Level III problems are more complex, as different alternative scenarios are possible, a number of tools could be used in each scenario and the complexity of accurately forecasting changes over time (Taeihagh et al., 2013), but can still be dealt with reasonably efficaciously.

The final two situations of multiple, contested scenarios, however, fall into a category that Walker et al. (2001) refer to as 'deep' uncertainty. These are the worst-case problems with multiple perspectives regarding the nature of the issue or problem at hand as well as multiple potential solutions whose prospects for success are unknown (Rittel & Webber, 1973). As Maxim and van der Sluijs (2011) note, for example, most policy typologies are focused on the 'producer' of information and ignore uncertainty related to process and communication between the producer and the end-user (that is, the decision-maker). These uncertainties can relate to 'qualification of the knowledge base' or the degree of agreement upon or the absolute size of the evidentiary support for models. Uncertainties can also arise owing to the 'value-ladenness' of policy choices, which includes different actor perspectives on the value of the knowledge and information being utilized for decision-making and arguments concerning preferred policy alternatives pathways (Mathijssen et al., 2008).[1]

Both of these types of uncertainty are well beyond calculations of risk and involve a much higher ratio of ignorance and ambiguity, requiring a very different type of policy response and design (Stirling, 2010), ones which incorporate the real possibility of surprise into actions which embody possibilities for flexibility, adaptiveness and change.

Becker and Brownson (1964) argue that even at a relatively simple level, when knowledge is available on a subject, policymakers may not be aware of it and thus may undertake decision-making on the basis of uninformed ignorance rather than informed awareness. This tendency is worsened when collective or absolute knowledge of a subject or phenomenon is not as readily available. Decision-makers may be aware of this gap and function with an attitude of prudent awareness or, when they are unaware of their ignorance, with a hubristic attitude or over-confidence (Table 2.2).

UNCERTAINTY AND CHALLENGES TO POLICY FORMULATION

All of these kinds of ill-structured problems have been studied in the context of various policy issues. Recent studies, for example, have dealt with policies pertaining to environmental health (Kreuter et al., 2004), development of genetically modified foods (Durant & Legge, 2006), fisheries and coastal governance (Jentoft & Chuenpagdee, 2009), organizational learning (Crul, 2014), educational research (Jordan et al., 2014) and global environmental issues such as climate change.

Levin et al. (2012) argue that problems such as climate change have certain problematic features which illustrate a special class of 'super-wicked problems'. These include, firstly, that as action towards addressing a problem (climate change in this case) is delayed, it gets more difficult to solve; secondly, that the problem is exacerbated since those

Table 2.2 Policymakers' knowledge and comprehension matrix

		Nature of existing collective knowledge of a phenomenon	
		Aspects of a problem and possible solutions are known	Aspects are unknown
Nature of decision-makers' awareness of existing knowledge of a phenomenon	Aware	Known-Known: Key policy actors are aware of the known aspects of a phenomena (INFORMED AWARENESS)	Known-Unknown: Key policy actors are aware that certain aspects of the phenomenon are unknown (PRUDENT AWARENESS)
	Ignorant	Unknown-Known: Key policy actors are unaware of known aspects of a phenomenon (UNINFORMED IGNORANCE)	Unknown-Unknown: Key policy actors are unaware that certain aspects of the phenomenon are unknown (IMPRUDENT IGNORANCE)

Source: Based on Becker and Brownson (1964).

responsible for causing the problem and who possess the means to solve it lack any clear incentive to act; and thirdly, that there is no legal institutional framework to sufficiently address the impacts of a problem such as climate change spread over time and geographic scales.

This is a good case to illustrate the many policy-relevant problems associated with this level of uncertainty. For example, uncertainty in climate assessments can emerge for a number of reasons: lack of data or lack of agreement on results; choice of statistical methods; error of measurement; use of approximations; subjectivity in judgement; uncertainty in human behaviour; errors in model structure; errors in values of parameters; changes in parameters from historical values; differences in concepts and terminology; choice of spatial/temporal units; and assumptions taken. In climate projections and impact assessments, uncertainty gathers and often magnifies through a 'cascade of uncertainty' or an 'uncertainty explosion' (Schneider & Kuntz-Duriseti, 2002). This refers to the process whereby uncertainty accumulates throughout the process of climate change projections and impact assessment. The cascade also implies that in a causal chain such as climate impact assessments, the characteristics of the aggregate distribution might be very different from the individual components themselves.

Additionally, climate change is a global phenomenon with local impacts, and there is a time delay when these impacts are manifested (Schneider & Kuntz-Duriseti, 2002). And apart from empirical and methodological challenges, there may be uncertainty owing to institutional barriers for garnering consensus, combining expert judgement and integrating multiple perspectives (Webster, 2003).

Dealing with such high levels of uncertainties requires a different kind of policy than might be adopted when only lower level issues exist. The focus of policy design under low levels of uncertainty, on the other hand, is to either reduce uncertainty where possible or,

in other cases, to assess the range of uncertainty and then identify policy measures that are expected to be 'robust' within this range (Bredenhoff-Bijlsma, 2010).

Day and Klein (1989) suggest that while most government policies are crafted in response to events that are 'reasonably predictable', policy events at higher levels of uncertainty can also be: (1) unpredictable, 'unforeseen' and 'unprojectable'; (2) catastrophic; and (3) where the interpretation of uncertainty signals is convoluted because of associated moral and social issues.[2] As an example of the third category, Day and Klein (1989) discuss the spread of AIDS in Britain in the 1980s. In the specific case of strategies designed to reduce vulnerability to climate risks, policies that do not consider the existence of the diversity of risks, impacts and responses in a system can end up as 'policy misfits' (Bunce et al., 2010) or may become counter-intuitive or 'maladaptive' as they increase risks in the long run (Barnett & O'Neill, 2011). That is, if environmental degradation and change lead to certain 'thresholds' being crossed, current policy responses may not be as effective (Kwadijk et al., 2010).

Under conditions of deep uncertainty, policies should be prepared to deal with worst-case scenarios, allow for quick recovery and be ready for potential reforms in policy design (Walker et al., 2010). On climate change, for example, Smith et al. (2010) argue that current decision-making on adapting to the impacts of climate change focuses on 'adjustments' to current activities, leaving the possibility of a potential transformation in social and political regimes largely unaddressed (Pelling, 2011; Smith et al., 2010). If policymakers assume that certain policy choices are 'no-harm' or 'no-regret' in the short term, they may overlook their possible adverse (sometimes irreversible) effects in the long run and thus delay timely preventive action. Policymakers must learn to recognize early warnings or changes, especially as new knowledge emerges (European Environment Agency, 2001).

However, adequate reflection of on-the-ground realities remains a key concern; for example, a lack of awareness on climate change issues among decision-makers can lead them to rely on a largely expert-driven approach for climate change adaptation planning that may not reflect reality (Bisaro et al., 2010). The World Resources Report (2011) highlights the need for decision-making under uncertainty to be flexible to accommodate conditions of change, robust to withstand multiple future scenarios, and/or enable decisions to withstand long-term change.

Hallegatte et al. (2012) argue that it is difficult to define a 'best solution' for climate change and other deep uncertainties, and instead suggest that 'a menu of methodologies' (p. 36) and tools is needed, together with some indications on which strategies are most appropriate in which contexts. The idea of 'policy packaging' is gaining attention in this area as implementing a combination of measures (rather than individual ones) or 'policy bundling' can enhance synergies and reduce inconsistencies among the measures (Howlett & Rayner, 2013; Taeihagh et al., 2013).

However, how to arrive at such policy mixes is an issue for formulators and requires complex implementation and formulation technologies. Conventional forecasting methods like Monte Carlo simulations and other kinds of statistical analyses, for example, can cover low levels of uncertainty or parameter uncertainty by providing likelihood estimates and probabilities (Brugnach et al., 2008; Walker et al., 2010). However, unexpected events or 'wild-cards' (Wardekker et al., 2010) can still impact policymaking and have significant social and political implications.

DEALING WITH UNCERTAINTY IN POLICY FORMULATION

Failure to address 'deep uncertainty' hampers the effectiveness of policies designed for the long term (Lempert et al., 2003). Both top-down and bottom-up methods have different strengths and weaknesses in dealing with such situations (Dessai & van der Sluijs, 2007). Decision theory also provides useful tools for decision-making when the information base is sufficient, but these tools may not be as robust when there are uncertainties, including information gaps. Such tools may be combined with other methods such as scenario planning (Polasky et al., 2011) or threshold approaches considering critical limits beyond which policy effectiveness can cease (Kwadijk et al., 2010) – especially useful in cases where crossing such thresholds can have long-term, irreversible consequences (World Resources Report, 2011).

Eckles and Schaffner (2011) also argue that public opinion plays a role in affecting policy outcomes and knowledge of uncertainty and risks, in turn, are important in forming public opinion. Based on a model for uncertainty management, Herian et al. (2012) found that using public perceptions on policy planning to inform government initiatives, such as budgetary planning, can enhance public support for the government and its decisions under uncertainty.

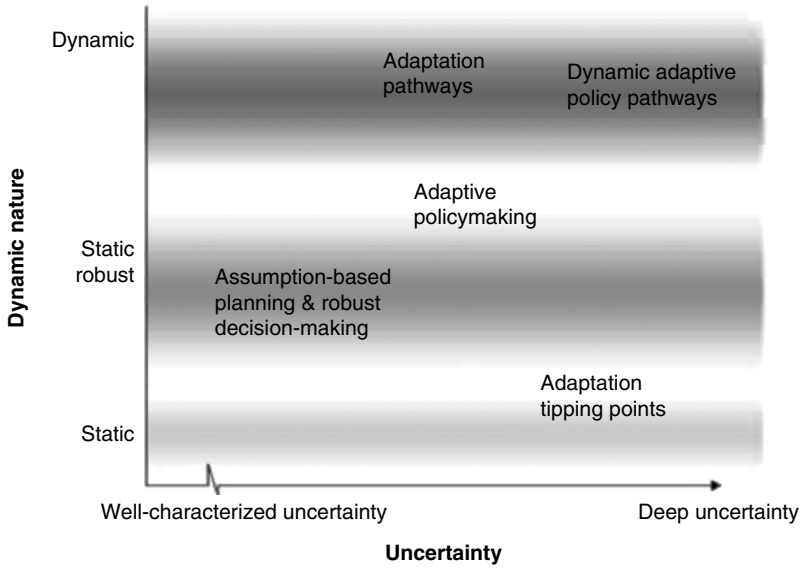
For long-term policies, including environmental issues such as climate change, policymakers also grapple with uncertainties in the policy formulation stage owing to an incomplete understanding of the biophysical and social systems affecting and being affected by the environmental processes. This incomplete knowledge may lead to an overestimation or underestimation of the policy problem. This is a major problem in relation to investments, for example. In order to boost investment in innovative environmental technology, policymakers often have to ensure and/or create a 'stable' facilitating environment for such innovation to occur and dispel investor concerns pertaining to the risks of failure that are associated with innovations (Janicke & Jorgens, 2000).

Uncertainty also relates to the problem definition, nature and extent of the problem, and the extent to which policymakers are dependent on scientific information to formulate the policy (Brown, 2000). Problems that are likely to manifest themselves fully only in the future call for alternative mechanisms for agenda setting and policy formulation. In such cases an appropriate measure to deal with uncertainty is to facilitate learning over time, as and when new knowledge regarding the policy problem becomes available. This is a central characteristic of 'open, flexible and adaptive institutional environments', which further depend on the nature of the governmental regime (Arentsen et al., 2000).

The next subsections present three approaches that have been found to resonate with policy scholars and practitioners alike in dealing with different levels of uncertainty in policy formulation: adaptive policymaking, strategic foresight and policy experimentation.

Adaptive Policymaking

The concept of adaptive policies dates back to John Dewey's (1927) proposition that 'policies be treated as experiments, with the aim of promoting continual learning and adaptation in response to experience over time'. One of the most cited pieces on policy uncertainty in the last decade has been that of Walker et al. (2001), which presents a spectrum of uncertainty moving from determinism to total ignorance. Adaptive policymaking is a model specifically suited to higher-level problems.



Source: Walker et al. (2013b).

Figure 2.2 Approaches for developing adaptive policies

That is, conventional forecasting methods such as Monte Carlo simulations and quantitative methods using statistical analyses are not adequately equipped to deal with such situations (Brugnach et al., 2008; Walker et al., 2010). Walker et al. (2013b) thus map the possible approaches towards adaptive planning (Figure 2.2) based on their dynamics – that is, the degree to which they vary over time – and on the level of uncertainty. The level of uncertainty can range from low to deep uncertainty, as identified in Walker et al. (2001). The dynamic nature of adaptive policies is represented on the y-axis in Figure 2.2, moving from static (indicating that changes over time are not considered in policy functioning), to static robust (indicating that changes or adaptation in the policy are anticipatory in nature) to dynamic (indicating that adaptation of policy can be anticipatory, simultaneous and reactive (*ex post*) over time).

The various approaches highlighted in Figure 2.2 include:

- Assumption-based planning which aims at planning to protect an existing plan from failure in the event that any of the key assumptions of the plan were to change.
- Robust decision-making which can be used to develop a new static plan that is robust, that is, functions well across a range of plausible futures.
- Adaptive policymaking which focuses on monitoring and adapting to changes over time to prevent the static plan from failure (thus 'static robust').
- Adaptation tipping points is a static approach that helps identify the conditions and time frame beyond which current policies/plans do not continue to function effectively.

- Adaptation pathways is a dynamic extension of the adaptation tipping point approach that generates an alternate route for continuation of the policy/plan in a new form to achieve the initial intended objectives.
- Dynamic adaptive policy pathways combine the adaptation pathways and adaptive policymaking approaches to identify alternative options over time across a range of plausible futures.

The central objective of these planning approaches is to avoid failure. By deploying these approaches, policymakers to some extent accept the 'irreducible character' of future uncertainties and aim to reduce uncertainty about policy performance despite these uncertainties. Many of these approaches are supported by computer models which may be unavailable or impractical in developing country contexts – for example, robust decision-making, which relies heavily on computer runs. There are some quicker and simpler policy models that could also be deployed if the policymakers believe it's better to be 'roughly right than precisely wrong' (Walker et al., 2013b, p. 972).

Drawing a parallel between evolutionary biology and policies for sustainable development (both operating under conditions of change), Rammel and van den Bergh (2003) argue that 'every successful adaptation is only a temporary "solution"' to changing conditions and that diversity of adaptation options and flexibility to deploy these options can contribute to long-term stability. The discussion of adaptive policies is also pertinent to issues that face natural variations, for example, management of fisheries, which is prone to natural cyclical patterns as well as uncertainty related to harvesting. The adaptive policymaking process in such cases can be passive (that is, operating on available 'best' scientific information until new knowledge emerges) or active (that is, consciously experimenting with policy alternatives to identify better strategies as new conditions emerge) (Walter, 1992).

In recent years, adaptive policies have been discussed widely in the context of decisions for long-term infrastructure planning and climate change (Buurman et al., 2009; Gersonius et al., 2013; Giordano, 2012; Ranger et al., 2013). These research papers explore the impacts of climate change on long-lived infrastructure and the influence of uncertainties on infrastructure policies and plans. Giordano (2012) highlights the importance of introducing flexibility and adaptiveness from the initial stage of planning. Similar to the adaptive policymaking concept, policies that are designed to be 'robust across a range of plausible futures' are preferred in this context rather than those aimed at being 'optimal', as they can respond to changes over time and accommodate learning in this process. The adaptive policy approach can also be applied in the case of transboundary air pollution, which is a complex policy issue with uncertainties related to the long-range forecasting of emissions, economic costs of abatement and political concerns (Kelly & Volleburgh, 2012).

Swanson and Bhadwal (2009) present seven tools that can be used to design adaptive policies that can deal with a range of anticipated and unanticipated future conditions. For example, adaptive policies can anticipate future conditions using:

1. Integrated and forward-looking analysis, including scenario planning.
2. Multi-stakeholder deliberation to identify potential drawbacks and unintended impacts.
3. Monitoring key performance indicators to activate automatic policy adjustments.

In addition, adaptive policies can function effectively when faced with unanticipated conditions through:

4. Regular and systematic policy review and improvement.
5. Enabling self-organizing and social networking in communities.
6. Decentralizing decision-making to the lowest accountable unit of governance.
7. Promoting variation in policy responses.

However, there is little evidence or detailed guidance on the operationalization of these tools.

There are a number of institutional challenges in actually implementing these policies primarily owing to the increased costs and time needed for adaptive policies as compared to 'traditional static approaches'. This makes it difficult for policy practitioners to justify such adaptive policies, even if the benefits might offset the costs in the long run. In addition, the complex nature of the adaptive policy product also makes it difficult for a policymaker to present or defend. As a result, its uptake and usability is rather limited as compared to conventional straightforward policy planning approaches. Additionally, robust and adaptive policies might require significant changes to the original policy design, which may not be politically or socially desirable.

Van der Pas et al. (2012) also draw attention to the need to evaluate adaptive policymaking, which could differ based on the criteria for evaluation and whether the evaluation is of the plan itself, the process of drafting the plan or the product, that is, the outcomes of the plan.

Strategic Foresight

Strategic foresight is one of the ways 'to broaden the boundaries of perception and to expand the awareness of emerging issues and situations' in medium levels of uncertainty (Major et al., 2001, p. 93). Strategic foresight attempts to integrate multiple perspectives and methods to identify current and emerging issues and trends and help assess policy options for attaining a desired future. Based on experiences from the United Kingdom, Singapore and the Netherlands, for example, Habegger (2010) identifies a number of elements of successful foresight exercises. These include having a scientific edge in specific foresight methods and processes, allowing for innovation, fostering iterative interactions between stakeholders, and obtaining the trust and support of top bureaucrats to support the idea of exploring futures that may be quite different from present conditions.

Foresight can be instrumental for environmental planning, for example, by providing insights about a range of futures of social-ecological systems and critical thresholds, and thus aid in anticipatory planning to avoid adverse impacts (Bengston et al., 2012). It can also inform policy by enhancing the knowledge base for policy design. This can be done by 'increasing the bandwidth' to allow a greater volume of information to be shared with policymakers; 'optimizing the signal', that is, improving foresight content by ensuring better quality, relevance, usability and timing of foresight studies; and 'improving reception', that is, enhancing the receptivity of policymakers for foresight (Da Costa et al., 2008). Given the short-term focus of many policy cycles, foresight can also help in identifying current policy gaps to deal with longer-term issues such as climate change.

Foresight may also be used as a signalling device by policymakers to indicate to the public that they are using objective scientific processes in making policies. Under conditions where policymakers are hesitant to openly share their policy strategies, foresight may help to engage citizens in a shared vision process via instruments such as transition management (Da Costa et al., 2008; Loorbach & Rotmans, 2010).

Policy Experimentation, Including Pilots

Policy experimentation is a predictive tool deployed by various agencies, including the government, to pre-test different programmes and policies for their likely impacts, process of implementation and stakeholder acceptability in advance of launching them at a larger scale. Experimental projects are generally small-scale, highly exploratory 'risky ventures' whose benefits are often realized through the 'acquisition of knowledge' (Rondinelli, 1993) and are well suited to dealing with lower levels of uncertainty. Through knowledge acquisition and with experience, policy experiments can help reduce uncertainty and aid decision-making for the future (Cooney & Lang, 2007). The goal of policy experiments is to get an indication of the outputs, outcomes and challenges that can be expected when these programmes and policies are implemented fully.

Policy pilots are a common and important form of policy experimentation and are instrumental for evaluating new programmes at a 'controlled small scale' before introducing them as full-scale programmes (Weiss, 1975). Policy pilots can be used to test the likely effects of new policies and their early outcomes (impact pilots), or to explore the implications of specific ways of implementing a policy, or assess the best methods of delivery (process pilots) (Cabinet Office, 2003). Pilots can thus aid in policy appraisal (Turnpenny et al., 2009) and provide useful insights for dealing with complex policy issues and high uncertainty (Vreugdenhil et al., 2010).[3]

Experiments have helped policymakers diversify their policy responses and thus spread risks. Experiments have also been useful as a source of evidence for policymaking. Under high levels of uncertainty, societal change or transitions may be required, and these can be facilitated by experiments. Under conditions of uncertainty, experiments can help test the design, suitability and acceptability of plausible policy solutions. Policy designers, however, need to recognize the level of uncertainty in the policy environment and consider the role of continual monitoring and social learning over time. Towards this end, in recent years, the literature on experimentation has shifted its focus to the process of experimental policy design, including the role of various stakeholders, compared to the earlier focus on the content of the experiments itself (Van der Heijden, 2014). Also referred to as 'experimentalist governance', this new wave involves 'provisional goal setting' that is redefined in an iterative manner based on the learning from trying out alternate modes of goal achievement in different contexts (Sabel & Zeitlin, 2012).

While the benefits of policy experiments to address situations of uncertainty and ambiguity are many, there are also challenges in their application. The first set of challenges relates to the political aspects of experimentation in terms of the design, implementation and evaluation of pilots. At times, pilot projects may be used as tools to avoid conflict rather than enhance evidence-based policymaking. In addition, if pilots address issues that are politically contested, they may be delayed until more favourable political conditions ensue (Jann & Wegrich, 2007). A contrary situation may also exist: there can be

pressure to expedite evaluations to obtain timely 'positive' evidence to support certain decisions (Sanderson, 2002) or to rapidly scale up pilots once initial positive results are observed. This is problematic, however, for two reasons: firstly, it is important to ensure sufficient capacity to properly conduct and sustain a pilot (PHR, 2004) and secondly, initial results may need to be monitored to ensure that the positive results are sustained over time before moving to the scaling-up phase. Scholars have used results from laboratory and field experiments to provide policymakers and practitioners with evidence of the impacts of selected experimental interventions as well as their feasibility and acceptability by key stakeholders, including the intended beneficiaries. Behavioural variables at the level of the individual are thus key factors in influencing the overall outcomes of such policy experiments. While behaviour can be regulated to some extent with incentives, there are limits on how much local observations can indicate the overall success or failure of a scaled-up experiment.

The second set of challenges relates to the evaluation of policy experiments. Policy pilots are usually conducted as 'one-off evaluations' to measure success (Stoker & John, 2009). In sectors that are rapidly changing or for those projects with a longer gestation period between the start of a new experiment and the realization of its benefits, it may be necessary to conduct repeated evaluations over time (Cabinet Office, 2003).

The third set of challenges relates to the scaling up of experiments. Positive results from smaller-scale experiments may not be observed when the experiments are scaled up or applied in a different context (Simmons et al., 2007). The context dependency of pilots and related dynamics means that pilots may not accurately predict the impact of diffusing the project in a different context or scaling it up. In such cases, policy experiments should be considered as an early evaluation of how specific policies or programmes might work under certain conditions in certain settings.

CONCLUSIONS AND SCOPE FOR FUTURE RESEARCH

The historical context and theoretical background of treatment of uncertainty is a subject of some interest to policy scholars. Uncertainties broadly emanate from both the quantities considered in policy models and the structure of those models themselves. Policies can embody varying levels of uncertainty along this spectrum, from limited knowledge to deep uncertainty or 'unknown unknowns'.

As set out above, policy design under uncertainty is rather complicated in the case of wicked problems, such as climate change, that have no clear agreement on causes or solutions. As uncertainty rises, the level of knowledge about the system decreases, and this alters the suitability of policy solutions to address specific policy problems. Efforts to seamlessly integrate knowledge between the academic and policymaking communities are also impeded by the presence of different perspectives, timescales and vocabularies for concepts and processes, which make the transmission of knowledge difficult. A faulty policy design owing to uncertainty can further hamper the effective functioning of policies and the realization of intended policy goals and objectives.

For long-term policies that address complex and dynamic policy problems, there is a need to constantly monitor and evaluate whether the policies continue to meet their intended goals and objectives (Ramjerdi & Fearnley, 2013).

Adaptive policy-making, scenario forecasting and policy experiments hold immense potential to aid policy designers under uncertainty and ambiguity. Policy experiments can be used to test many policies that are being deployed to deal with complex policy issues and rapidly changing policy environments. Under normal conditions of uncertainty and ambiguity, policy experimentation offers three major contributions to policy formulation: promoting variation and diversification of risks; supporting evidence-based policymaking to prepare societies for transitions; and fostering social learning. Higher levels of problems, however, require alternative formulation aids, such as scenario analysis and adaptive policies.

NOTES

1. In tracing how uncertainty has been considered by policy scholars from the modern to post-modern era in the context of policy analysis and application, Bredenhoff-Bijlsma (2010) highlights that while modernism focused on the 'positivist' notion of using objective knowledge for policy analysis, post-modernism focused on the 'socially constructed nature of scientific knowledge' that emphasizes the role of actor interactions (an idea central to network theory).
2. The concept of 'surprise' or unexpected changes has largely been used in the ecological context (Lindenmayer et al., 2010), but offer little or no scope for the decision-maker to respond from history or experience (Lempert et al., 2003; Walker et al., 2010). Under such high levels of uncertainty, there is little agreement on the choice of variables that should be included in models and it is difficult to assign probability distributions to possible future scenarios with any confidence (Lempert et al., 2003; McInerney et al., 2011; Walker et al., 2010).
3. In the development sector, policy experiments are frequently used to assess alternative courses of action. These include (1) projects that focus on problem definition itself; (2) projects that focus on problems which are partly or wholly undefined; (3) projects that explore the most effective way of achieving pre-set policy goals; (4) projects that aim to identify gaps and barriers in situations where problems and goals are already well known; and (5) natural experiments that occur over a period of time without conscious intervention (Rondinelli, 1993).

REFERENCES

Arentsen, M.J., Bressers, H.T.A. and O'Toole, L.J. (2000), 'Institutional and policy responses to uncertainty in environmental policy: a comparison of Dutch and U.S. styles', *Policy Studies Journal*, **28** (3), 597–611.

Barnett, J. and O'Neill, S. (2010), 'Maladaptation', *Global Environmental Change*, **20** (2), 211–13.

Becker, S.W. and Brownson, F.O. (1964), 'What price ambiguity? Or the role of ambiguity in decision-making', *Journal of Political Economy*, **72** (1), 62–73.

Bengston, D.N., Kubik, G.H. and Bishop, P.C. (2012), 'Strengthening environmental foresight: potential contributions of futures research', *Ecology and Society*, **17** (2), 10.

Bisaro, S., Hinkel, J. and Kranz, N. (2010), 'Multilevel water, biodiversity and climate adaptation governance: evaluating adaptive management in Lesotho', *Environmental Science and Policy*, **13** (7), 637–47.

Bredenhoff-Bijlsma, R. (2010), 'Policy development under uncertainty. A framework inspired by cases of water management', PhD Thesis, Gildeprint, Enshede, the Netherlands.

Brown, M.L. (2000), 'Scientific uncertainty and learning in European Union environmental policymaking', *Policy Studies Journal*, **28** (3), 576–96.

Brugnach, M., Dewulf, A., Pahl-Wostl, C. and Taillieu, T. (2008), 'Toward a relational concept of uncertainty: about knowing too little, knowing too differently, and accepting not to know', *Ecology and Society*, **13** (2), 30.

Bunce, M., Brown, K. and Rosendo, S. (2010), 'Policy misfits, climate change and cross-scale vulnerability in coastal Africa: how development projects undermine resilience', *Environmental Science and Policy*, **13** (6), 485–97.

Buurman, J., Zhang, S. and Babovic, V. (2009), 'Reducing risk through real options in systems design: the case of architecting a maritime domain protection system', *Risk Analysis*, **29**, 366–79.

Cabinet Office. (2003), *Trying it Out: The Role of 'Pilots' in Policy-making*, Report of a Review of Government Pilots, Strategy Unit, Government of the United Kingdom.
Churchman, C.W. (1967), 'Wicked problems', *Management Science*, **14** (4), B141–B2.
Cooney, R. and Lang, A. (2007), 'Taking uncertainty seriously: adaptive governance and international trade', *European Journal of International Law*, **18** (3), 523–51.
Crul, L. (2014), 'Solving wicked problems through action learning', *Action Learning: Research and Practice*, **11** (2), 215–24.
Da Costa, O., Warnke, P., Cagnin, C. and Scapolo, F. (2008), 'The impact of foresight on policy-making: insights from the FORLEARN mutual learning process', *Technology Analysis & Strategic Management*, **20** (3), 369–87.
Day, P. and Klein, R. (1989), 'Interpreting the unexpected. The case of AIDS policymaking in Britain', *Journal of Public Policy*, **9**, 337–53.
Dessai, S. and van der Sluijs, J.P. (2007), *Uncertainty and Climate Change Adaptation – a Scoping Study*, Report NWS-E-2007-198, Department of Science Technology and Society, Copernicus Institute, Utrecht University.
Dewey, J. (1927), *The Public and its Problems*, New York: Holt and Company.
Durant, R.F. and Legge, J.S. (2006), 'Wicked problems, public policy, and administrative theory: lessons from the GM food regulatory arena', *Administration and Society*, **38** (3), 309–34.
Eckles, D.L. and Schaffner, B.F. (2011), 'Priming risk – the accessibility of uncertainty in public policy decision making', *Journal of Insurance Issues*, **34** (2), 151–71.
European Environment Agency. (2001), *Late Lessons from Early Warnings: The Precautionary Principle 1896–2000*, Environment Issue Report No. 22. Luxembourg: Office for Official Publications of the European Communities.
Gersonius, B., Ashley, R., Pathirana, A. and Zevenbergen, C. (2013), 'Climate change uncertainty: building flexibility into water and flood risk infrastructure', *Climatic Change*, **116** (2), 411–23.
Giordano, T. (2012), 'Adaptive planning for climate resilient long-lived infrastructures', *Utilities Policy*, **23**, 80–9.
Habegger, B. (2010), 'Strategic foresight in public policy: reviewing the experiences of the UK, Singapore, and the Netherlands', *Futures*, **42**, 49–58.
Hallegatte, S., Shah, A., Lempert, R., Brown, C. and Gill, S. (2012), 'Investment decision making under deep uncertainty – application to climate change', *Policy Research Working Paper Series* 6193, World Bank.
Hansson, S.O. (1996), 'Decision making under great uncertainty', *Philosophy of the Social Sciences*, **26** (3), 369–86.
Head, B. (2008), 'Wicked problems in public policy', *Public Policy*, **3** (2), 101–18.
Herian, M.N., Hamm, J.A., Tomkins, A.J. and Pytlik Zillig, L.M. (2012), 'Public participation, procedural fairness and evaluations of local government: the moderating role of uncertainty', *Journal of Public Administration Research and Theory*, **22**, 815–40.
Howlett, M. and Rayner, J. (2013), 'Patching vs packaging in policy formulation: assessing policy portfolio design', *Politics and Governance*, **1** (2), 170–82.
Janicke, M. and Jorgens, H. (2000), 'Strategic environmental planning and uncertainty: a cross-national comparison of green plans in industrialized countries', *Policy Studies Journal*, **28** (3), 612–32.
Jann, W. and Wegrich, K. (2007), 'Theories of the policy cycle', in F. Fischer, G.J. Miller and M.S. Sidney (eds), *Handbook of Public Policy Analysis: Theory, Politics, and Methods*, Boca Raton, FL: CRC Press, Taylor & Francis Group, pp. 43–62.
Jentoft, S. and Chuenpagdee, R. (2009), 'Fisheries and coastal governance as a wicked problem', *Marine Policy*, **33** (4), 553–60.
Jones, B.D. and Baumgartner, F.R. (2005), *The Politics of Attention*, Chicago, IL: University of Chicago Press.
Jordan, M.E., Kleinsasser, R.C. and Roe, M.F. (2014), 'Wicked problems: inescapable wickedity', *Journal of Education for Teaching*, **40** (4), 415–30.
Kelly, J.A. and Volleburgh, H.R.J. (2012), 'Adaptive policy mechanisms for transboundary air pollution regulation: reasons and recommendations', Working Papers No. 2012.32, Fondazione Eni Enrico Mattei.
Knight, F.H. (1921), *Risk, Uncertainty, and Profit*, Boston, MA: Hart, Schaffner and Marx, Houghton Mifflin Company.
Koppenjan, J. and Klijn, E.H. (2004), *Managing Uncertainties in Networks. A Network Approach to Problem Solving and Decision Making*, London and New York: Routledge.
Kreuter, M.W., De Rosa, C., Howze, E.H. and Baldwin, G.T. (2004), 'Understanding wicked problems: a key to advancing environmental health promotion', *Health Education and Behaviour*, **31** (4), 441–54.
Kwadijk, J.C.J., Haasnoot, M., Mulder, J.P.M. et al. (2010), 'Using adaptation tipping points to prepare for climate change and sea level rise: a case study in the Netherlands', *Wiley Interdisciplinary Reviews Climate Change*, **1** (5), 725–40.
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*, Santa Monica, CA: RAND.

Levin, K., Cashore, B., Bernstein, S. and Auld, G. (2012), 'Overcoming the tragedy of super wicked problems: constraining our future selves to ameliorate global climate change', *Policy Sciences*, **45**, 123–52.
Lindenmayer, D.B., Likens, G.E., Krebs, C.J. and Hobbs, R.J. (2010), 'Improved probability of detection of ecological "surprises"', *Proceedings of the National Academy of Science of the United States of America*, **107** (51), 21957–62.
Loorbach, D. and Rotmans, J. (2010), 'The practice of transition management: examples and lessons from four distinct cases', *Futures*, **42** (3), 237–46.
Major, E., Asch, D. and Cordey-Hayes, M. (2001), 'Foresight as a core competence', *Futures*, **33** (2), 91–107.
Mathijssen, J., Petersen, A., Besseling, P., Rahman, A. and Don, H. (2008), *Dealing with Uncertainty in Policymaking*, The Hague/Bilthoven/Leiden: CPB/PBL/Rand Europe.
Maxim, L. and van der Sluijs, J.P. (2011), 'Quality in environmental science for policy: assessing uncertainty as a component of policy analysis', *Environmental Science and Policy*, **14**, 482–92.
McInerney, D., Lempert, R. and Keller, K. (2011), 'What are robust strategies in the face of uncertain climate threshold responses?', *Climatic Change*, **112**, 547–68.
Morgan, M.G. and Henrion, M. (1990), *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis*, Cambridge: Cambridge University Press.
Pelling, M. (2011), *Adaptation to Climate Change: From Resilience to Transformation*, London: Routledge.
PHR (Partners for Health Reformplus). (2004), *The Role of Pilot Programs: Approaches to Health Systems Strengthening*, Bethesda, MD: PHRplus, Abt Associates Inc.
Polasky, S., Carpenter, S.R., Folke, C. and Keeler, B. (2011), 'Decision-making under great uncertainty: environmental management in an era of global change', *Trends in Ecology and Evolution*, **26** (8), 398–404.
Ramjerdi, F. and Fearnley, N. (2013), 'Risk and irreversibility of transport interventions', *Transportation Research Part A*, **60** (issue C), 31–9.
Rammel, C. and van den Bergh, J.C.G.M. (2003), 'Evolutionary policies for sustainable development: adaptive flexibility and risk minimising', *Ecological Economics*, **47**, 121–33.
Ranger, N., Reeder, T. and Lowe, J. (2013), 'Addressing deep uncertainty over long-term climate in major infrastructure projects: four innovations of the Thames Estuary 2100 Project', *European Journal of Decision Process*, **1**, 233–62.
Rittel, H.W.J. and Webber, M.M. (1973), 'Dilemmas in a general theory of planning', *Policy Sciences*, **4** (2), 155–69.
Rondinelli, D. (1993), *Development Projects as Policy Experiments: An Adaptive Approach to Development Administration*, 2nd edn, New York: Routledge.
Sabel, C. and Zeitlin, J. (2012), 'Experimentalist governance', in D. Levi-Faur (ed.), *The Oxford Handbook of Governance*, Oxford: Oxford University Press, pp. 169–83.
Sanderson, I. (2002), 'Evaluation, policy learning and evidence-based policymaking', *Public Administration*, **80** (1), 1–22.
Schneider, S.H. and Kuntz-Duriseti, K. (2002), 'Uncertainty and climate change policy', in S.H. Schneider, A. Rosencranz and J.-O. Niles (eds), *Climate Change Policy: A Survey*, Washington, DC: Island Press, pp. 53–88.
Simmons, R., Fajans, P. and Ghiron, L. (eds) (2007), *Scaling up Health Service Delivery: From Pilot Innovations to Policies and Programmes*, Geneva: World Health Organization.
Simon, H.A. (1973), 'The structured of ill-structured problem', *Artificial Intelligence*, **4**, 181–201.
Smith, M.S., Horrocks, L., Harvey, A. and Hamilton, C. (2010), 'Rethinking adaptation for a 4° C world', *Philosophical Transactions of the Royal Society*, 369, 196–216.
Stirling, A. (2010), 'Keep it complex', *Nature*, **468** (7327), 1029–31.
Stoker, G. and John, P. (2009), 'Design experiments: engaging policy makers in the search for evidence about what works', *Political Studies*, **57** (2), 356–73.
Swanson, D. and Bhadwal, S. (eds) (2009), *Creating Adaptive Policies: A Guide for Policymaking in an Uncertain World*, New Delhi and Ottawa: Sage and International Development Research Centre.
Taeihagh, A., Bañares-Alcántara, R. and Givoni, M. (2013), 'A virtual environment for the formulation of policy packages', *Transportation Research A*, **60**, 53–68.
Turnpenny, J., Radaelli, C.M., Jordan, A. and Jacob, K. (2009), 'The policy & politics of policy appraisal: emerging trends & new directions', *Journal of European Public Policy*, **16** (4), 640–53.
Van der Heijden, J. (2014), 'Experimentation in policy design: insights from the building sector', *Policy Sciences*, **47** (3), 249–66.
Van der Pas, J.W.G.M., Kwakkel, J.H. and Wee, B.V. (2012), 'Evaluating adaptive policymaking using expert opinions', *Technological Forecasting & Social Change*, **79**, 311–25.
Vreugdenhil, H., Slinger, J., Thissen, W. and Ker Rault, P. (2010), 'Pilot projects in water management', *Ecology and Society*, **15** (3), 1–13.
Walker, W.E., Rahman, S.A. and Cave, J. (2001), 'Adaptive policies, policy analysis, and policy making', *European Journal of Operational Research*, **128**, 282–289.

Walker, W., Marchau, V. and Swanson, D. (2010), 'Addressing deep uncertainties using adaptive policies', *Technological Forecasting and Social Change*, **77** (6), Special Section 2, 917–23.
Walker, W.E., Lempert, R.J. and Kwakkel, J.H. (2012), *Deep Uncertainty*, Delft and Santa Monica, CA: Delft University of Technology and RAND.
Walker, W.E., Lempert, R. and Kwakkel, J.H. (2013a), 'Deep uncertainty', in S.I. Gass and M.C. Fu (eds), *Encyclopedia of Operations Research Management Science*, New York: Springer Science, pp. 395–402.
Walker, W.E., Haasnoot, M. and Kwakkel, J.H. (2013b), 'Review. Adapt or perish: a review of planning approaches for adaptation under deep uncertainty', *Sustainability*, **5**, 955–79.
Walter, C.J. (1992), 'Perspectives on adaptive policy design in fisheries management', in K. Jain and L.W. Botsford (eds), *Applied Population Biology*, Dordrecht: Kluwer Academic Publishers, pp. 249–62.
Wardekker, J.A., de Jong, A., Knoop, J.M. and van der Sluijs, J.P. (2010), 'Operationalising a resilience approach to adapting an urban delta to uncertain climate changes', *Technological Forecasting and Social Change*, **77**, 987–98.
Weber, E.P. and Khademian, A.M. (2008), 'Wicked problems, knowledge challenges and collaborative capacity builders in network settings', *Public Administration Review*, **68** (2), 334–49.
Webster, M. (2003), 'Communicating climate change uncertainty to policy-makers and the public', *Climatic Change*, **61** (1–2), 1–8.
Weiss, C. (1975), 'Evaluation research in the political context', in E.L. Struening and M. Guttentag (eds), *Handbook of Evaluation Research*, Los Angeles, CA: Sage, pp. 13–26.
World Resources Report. (2011), *Decision Making in a Changing Climate*, Washington, DC: World Resources Institute.