Research Methods for Understanding and Supporting Decision Processes in African Cities

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About FRACTAL working papers

This series is funded by the UK's Department For International Development (DFID) and the Natural Environment Research Council (NERC) through the Future Resilience for African Cities and Lands (FRACTAL) project, within the Future Climate For Africa (FCFA) multi-consortia programme. The overarching objective of FCFA is to generate fundamentally new climate science focused on Africa, and to ensure that this science has an impact on human development across the continent. FRACTAL's main aim is to advance scientific knowledge on regional climate responses to global change, and to enhance knowledge on how to integrate this information into decision making at the city-region scale in Southern Africa. These products have been developed to share initial findings from research in the hope of fostering dialogue, and eliciting feedback to strengthen the research. The opinions expressed are therefore the author(s) and are not necessarily shared by DFID, NERC or other programme partners.

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Executive Summary

This Working Paper reviews 12 decision-making methods to explore how different approaches may lead key people working in cities and surrounding urban areas of Southern Africa to make better-informed decisions about adapting to climate change. The review covers both decision-making *process* methods – that is, those that describe and provide insights about empirical cases of decision-making- and decision-making *support* methods – those that analyse normative dimensions of how a decision could be made.

The review provides information for Future Resilience for African CiTies and Land (FRACTAL), which aims to address the challenge of providing policy-makers in the region with accessible, timely, applicable and defensible climate information. FRACTAL is designed to work across disciplines within the both natural and social scientific communities, and to foster strong collaboration between researchers, city government officials, ministers and other key decision makers in southern Africa. As a result, this review provides guidance for selection of methods that may enhance outcomes, and lead to greater understanding of decision-making processes at the city-regional level within Africa - for the benefit of FRACTAL partners, designated researchers embedded in cities, and, ultimately, Africa's people, who are, by definition, increasingly urban dwellers.

The review presents key conceptual and theoretical insights drawn from multiple disciplines. The analysis frames the broader discussion in the context of both the use of relevant knowledge, and the prevailing policy-science interface in decision making. The report argues that three themes increasingly characterise the nature of contemporary decision-making:

- the increasing complexity of problems – the rise of so-called "wicked" problems.
- the necessary shift away from linear models of decision-making.
- the rise of "risk" as a central concept for dealing with uncertainty.

Many of the 12 reviewed methods link closely to one or more of these themes. The analysis here offers observations, and raises questions for further investigation. Key points include:

1. Although the included methods have been applied to a very wide range of decision types, it is notable that many have not been used in urban contexts or only in limited cases.
2. Many of the methods reviewed are participatory and iterative in nature, and therefore, psycho-social constraints may affect the accuracy, reliability, and credibility of information used in decision-making processes.
3. Many methods are time- and resource-intensive. Analyses that require considerable investments of financial resources, technological capacity and human capital, should be used only where necessary, to ensure better-targeted decision support.
4. The learning outcomes from the methods reviewed are diverse, and would require further investigation were they to be used as a basis upon which to select a decision method.
5. The use of multiple methods is a possible approach, although this should be balanced with the potentially increased costs (e.g., for data collection), especially if stakeholders are involved, and the additional burden falls on them.

In addition, the working paper considers how these decision-making methods can contribute to the expanding field of climate services. Interestingly, the authors find a lack of medium- to long-term climate services applicable to the urban African context: thus, this is an important gap that FRACTAL can fill. The paper provides examples of possible decision-making methods that might address existing FRACTAL research questions. The findings offer concrete next steps for FRACTAL as it moves forward.

1. Introduction

This report examines decision-making methods that may be incorporated into climate-resilient planning and development in southern Africa's urban regions. It explores the strengths and weaknesses of various decision-making approaches in the context of climate change and its related challenges. The report addresses:

- How the availability and type of climate information can influence the choice of the decision-support mechanisms.
- The degree to which methods can be inclusive, robust, cost-effective, context-relevant, and informed by climate information.
- The limits of using climate information in different decision-support contexts.

This review was undertaken for Future Resilience for African CiTies and Lands (FRACTAL), a four-year project that aims to advance 'decision-relevant' scientific knowledge about climate change to support medium- to long-term planning and development in southern Africa's cities and urban regions. The review offers guidance for selection of methods to better understand African city-region-level decision-making processes, for the benefit of FRACTAL partners and designated researchers embedded in cities.

The review addresses broader FRACTAL aims, including:

- Building the evidence base for 'good practices' on climate-informed decision-making – particularly related to how water, energy and food issues are likely to unfold over the next 40 years.
- Fostering strong collaboration between researchers, city government officials, ministers and other key decision makers in southern Africa.
- Working across disciplines within the both natural and social scientific communities,
- Improving decision-making, engaging with decision-makers, and supporting the monitoring and evaluation of relevant policy-making issues that arise in the climate change context[1][2].

The review covers both **decision-making *process* methods** and **decision-making *support* methods** that are multidisciplinary in scope, and that have been applied in both the public and private sector to ensure a broad range of methods are considered that might be useful for application in the FRACTAL project. We make a distinction between the two types of methods as follows: ***Process* methods** aim to analyse empirical cases of decisions that have been made or are being made (either retrospectively or in real-time) in order to describe and better understand how decisions were reached. By contrast, ***support* methods** aim to provide analyses of how a decision between various options could be made (i.e., prospectively): these are methods that typically use rigorous and tested, formal approaches.

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1 The project is funded by the UK's Department for International Development and the Natural Environment Research Council, and is coordinated by the Climate Systems Analysis Group at the University of Cape Town.
2 The wider FRACTAL objective is based on Task 2.3 - Review and test decision-support tools and climate services for decision-making in African cities and sub-task 2.3.3: Plan and carry out review of methods for i) understanding the process of decision-making, and ii) for supporting adaptation decisions.

Process methods relate mainly to the development and testing of descriptive decision theories (e.g. the prospect theory model of Tversky and Kahneman, 1992). Support methods derive from prescriptive decision theories, based on normative models yet recognizing the limitations of human judgement and practising rationality in a complex world (e.g. the subjective expected utility model of Savage, 1954; Edwards et al., 2007).

This remainder of this paper is organized as follows:

Section 2 details the review methodology.

Section 3 provides the context for the reviews by introducing some of the main philosophies, arguments and tensions surrounding selecting and using research methods for 'actionable knowledge,' as knowledge that is used in making decisions is sometimes called. It frames the broader discussion through the lenses of the increasing complexity of problems, the necessary shift away from linear models of decision-making, and the rise of 'risk' as a central concept for dealing with uncertainty. This sets the stage for looking at each individual method.

Section 4 provides short summaries of 12 methods chosen for the review, and provides a relevant set of references for each. Following a wide search, the methods were selected through discussion amongst the co-authors, with the ambition to go beyond the field of climate change adaptation and to include multi-disciplinary methods, applied in both the public and private sectors, that address particular needs or offer potential usefulness. The overall goal is to explore how different approaches may lead key people working in cities and surrounding urban areas of Southern Africa to make better-informed decisions about adapting to climate change.

This section also presents summary tables (Tables 1 and 2) that compare the main features of each method and their potential constraints.

Section 5 draws overall lessons emerging from the reviews, and discusses the constraints and enablers to the uptake of climate data in decision-making – with the medium- to long-term climate data equivalent to FRACTAL ambitions specifically in mind. It also addresses the advantages and disadvantages of combining methods, as well as the potential for decision-making methods to contribute to the improved design of climate services.

Section 6 concludes, summarising how the lessons learned from this review may be applicable to further work in the decision-making research cluster within FRACTAL. We discuss the reviewed, candidate decision-making methods that could also help address FRACTAL cross-cluster research questions. Finally, we examine the next steps for testing these methods in the FRACTAL project.

2. Methodology

We conducted a literature review of twelve methods that we considered potentially useful for supporting and understanding decision making. The scope for inclusion was intended to

allow both normative/prescriptive concepts (support methods) and descriptive approaches (process methods) to be considered. Following a wide search, the methods were selected through discussion amongst the co-authors, with the ambition to go beyond the field of climate change adaptation and include multi-disciplinary methods, applied in both the public and private sectors, that address particular needs or offer potential usefulness. For example, criteria included the relevance for data-poor contexts, such as is often the case in southern African cities; the potential to identify salient entry points for climate science-informed support for decision-making; and the feasibility of testing a given method's potential for use within the constraints of the FRACTAL project.

Certain methods (Backcasting, Scenario Planning and Adaptation Pathways) can be considered examples of one of the other methods, Foresight. However, reviews suggested that there are sufficient differences: each have widespread recognition and established protocols that they can be considered separately as methodological tools.Several decision support methods have been reviewed in detail by the authors in earlier work[3], so this review is not exhaustive. Indeed, many conventional formal methods are not included. These methods have already been reviewed specifically for climate change adaptation elsewhere (eg. Watkiss and Hunt, 2013; Nay et al. 2014). Ultimately, methods were included here based on their potential utility in the FRACTAL project, with the expectation that each method brings different opportunities for learning.

Extensive reviews were then developed for each method using a common template, and were shared for discussion. Subsequently, condensed versions of around 500 words were made by one of the authors. Each (condensed) review provides as an introduction to the method, and information on its background and origin, relevance to climate change research, application examples and findings, as well as a relevant set of references. This information was then supplemented in two tables giving access to summary information showing the main features of each method and their potential constraints. It should be recognised that decision-making methods are difficult to compare directly because they incorporate different assumptions, concepts, terminology and outlooks. However, we envision such summary tables (Tables 1 and 2) could serve as a checklist or part of a screening exercise when identifying or choosing between appropriate methods.

Table 1 summarises the decision types (problem types and decision objectives as well as particular sectors where these decisions occur) and investigates the potential entry points where research methods could get traction in decision processes. It also identifies the main participants in decision-making, the resources and data required to conduct the research, and the likely learning outcomes, recognising that this will look different for process methods and for support methods because of differences in objectives, i.e. *understanding* versus *supporting* adaptation decisions.

Table 2 summarises the constraints to the use of the selected methods, following the focus of Jones et al. (2015), and looking at four areas of constraints. These include, firstly, uptake of climate data in decision-making methods and their treatment of uncertainty information. Secondly, technical capacity constraints refer to the capacities of of the analysts conducting

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3 European Commission Seventh Framework Programme projects MEDIATION - Methodology for Effective Decision-making on Impacts and AdaptaTION and IMPACT2C.

the research, for which an indicative level is given. Thirdly, political and institutional constraints are summarised. Finally, psycho-social constraints, which relate to the perception/acceptance of the decision outcome and basis for trusting the process. The information in the two tables is discussed in the subsequent sections.

In parallel to the review of methods, we reviewed 'framing' papers in a separate section which aims to provide an essential background to wider thinking on decision methods. In this section the authors subjectively identified the three themes of 1) complexity and wicked problems, 2) the decision-first approach as opposed to science-first and the shift away from linear models of the process, and 3) the rise of concepts of risk in the literature. The themes were linked with particular methods in Table 1. Superscripts are used in Table 1 to show the significance of themes and their relevance are further discussed in the later sections, in addition to the overall lessons emerging from the reviews.

3. Framing Decision Processes

This section includes work that does not discuss particular methods, but looks at decision-making more broadly, and for this reason is important for understanding and framing the selected methods conceptually. By including work that is more theoretical rather than methodological - in contrast to the main part of the review - this section shows that many aspects of decision problems encountered in policy and planning are actually more universal than imagined.

Disciplines such as urban planning, environmental policy, climate change, as well as decision science all introduce key framing concepts. For example, in their introduction to *Advances in Decision Analysis*, Edwards et al. (2007) provide a useful reminder of the importance of clearly distinguishing between normative, prescriptive and descriptive decision theories. Normative decision theories provide arguments based on rational choice to guide decision-making (how to make better decisions); descriptive decision theories focus on how real people make decisions based on actual behaviour (how decisions are made). Prescriptive theories combine elements of the other two; rational models applied with awareness of the limitations and possible biases of human judgement in the context of complexity of decision problems (ibid. p.5).

This section is organized according to three themes that have emerged from literature on framing decision-making that have contributed significantly to our theoretical understanding and are most relevant to the consideration of decision-making in the context of climate adaptation in cities. The overall aim is to emphasize that policy problems are often difficult; that this has strong implications for decision-making; and that there are different ways to find solutions underpinned by thinking across many scientific disciplines.

Further, differences between decisions and decision-making in the public and private sectors also lead to different conclusions. In the context of climate adaptation in cities, research often gives more attention to public-policy problems and decision-making processes because of the partnership with local government. However the private sector is becoming increasingly important at city and regional scales. Thus, there are great opportunities to learn from how various methods and theories have been developed and tested in either a private setting, in a government setting, or in some hybrid between the two.

i) The increasing complexity of problems

A seminal work on the characterization of policy problems originated in the field of urban planning. Rittel and Webber (1973) used the term "wicked" to describe complex policy problems that are not amenable to simple answers or optimal solutions. They contrasted these with earlier policy problems, where decision-making had been very successful: "…the streets have been paved, and roads now connect all places; houses shelter virtually everyone; the dread diseases are virtually gone; clean water is piped into nearly every building; sanitary sewers carry wastes from them; schools and hospitals serve virtually every district; and so on." (op.cit.: 155).

The authors argue that while societies are becoming increasingly heterogeneous and differentiated, and more variations of (policy) options present are theoretically possible, these diverse values/preferences mean that "'what satisfies one [group] may be abhorrent to another" (op.cit.: 169). They note that "there are no 'solutions' in the sense of definitive and objective answers". At around the same time, systems thinker Russell Ackoff developed the idea of "messy systems" where "every problem interacts with other problems and is therefore part of a set of interrelated problems, a system of problems" (Ackoff, 1974: 427), which he argued, could not be understood through a reductionist approach. Ackoff suggested four planning principles are needed in the context of messy systems: participative; coordinated, in that "all aspects of a system should be planned for simultaneously and interdependently;" integrated (i.e., across levels of scale); and continuous, by which he means "updated, corrected and extended frequently" (op.cit.: 435).

Rayner (2006) argues that contemporary environmental policy issues are ones that have been identified by science, but are in many cases difficult to understand and are not directly understood by the public or by politicians. For instance, using climate change as an example, he argues that the problem is not straightforward; that deeper questions underlie the uncertainty; and that fundamentally incommensurable views (internally consistent, logically argued, and immune to falsification) combine to create a "wicked" climate problem. Building on these ideas, climate change has been characterized as a "super-wicked" problem (Levin et al., 2012): that is, having additional complexities compared to standard-issue, wicked problems. Thus, from the point of view of the spectrum of wicked problems and messy systems, climate change adaptation (CCA) should be undertaken in a way that is consistent with Ackoff's articulation of four principles of planning.

ii) The shift away from linear models of decision-making

Millstone (2008) discusses how the role of science vis-à-vis policy making has shifted by focusing on how different decision models have conceptualized the science-policy bridge, and by explaining how and why this shift in thinking has come about. The portrayal of decision-making is a central theme. For example, one insight into different "decisionist" linear models separates the work of experts/scientists and policy-makers, and the development of risk perspectives around scientific uncertainties.

Millstone then critiques circular models (IRGC 2006; FAO 2006, cited in Millstone, 2008).which have gained in popularity among public authorities but, which, he suggests, are

both overly complicated and more difficult, particularly in terms of offering a way to identify starting points. Arguably this point of view may understate the knowledge of policy-makers, who are likely to understand the entry points for change better than anyone - whereas scientists struggle to understand how and whether their work can have an impact. Finally, Millstone argues that up-stream normative considerations for public policy must frame the work carried out by scientists and advisors. He shows that recent thinking on the use of science for policy is set out by the idea of risk assessment policy (RAP) - a process for framing the assumptions (upfront) for the use of science for policy. Another view on locating entry points is that understanding potential adaptation options serves as an important initial reality check for any scientific study of (and provision of support for) decision problems[4].

Watkiss (2015) discusses how the framing of adaptation (and therefore climate information needs) has changed over the years. The new framing proposes a "decision-first" (policy-led) as opposed to a "science-first" (impacts-led) approach. This aligns with the argument put forward by Millstone (2008), and also with the conclusions of several political economy based analyses (e.g. Tanner et al., 2015; Tanner & Mitchell, 2008).

The "decision-centric" process has been developed in the context of the Thames Estuary 2100 Project (Reeder and Ranger, 2011; Ranger et al., 2013). According to the authors, decision-centred approaches frame the analysis as a choice between options to reduce vulnerability predicated on a strong understanding of the decision problem itself, rather than by focusing on climate projections. Hence, in this project, one innovation resulted in the creation of long-term scenarios designed specifically to inform particular decisions, based on understanding of the characteristics of the decision problem (i.e., long-lived infrastructural investments with high stakes, high uncertainty and complexity). An "adaptation pathways" approach was used to identify adaptation options timed to maintain flexibility while keeping risk below acceptable levels. This type of dynamic adaptive planning, also known as "iterative risk management," leads us to our final framing theme.

iii) The rise of "risk" as a central concept for dealing with uncertainty

The importance attached to risk management represents an important principle in the new framing. Millstone (2008) discusses the development of risk perspectives, starting in the 1970s, which emerged as a response to criticisms that scientific uncertainties were not being addressed. The new approach recognized epistemic uncertainty surrounding an issue, based on the lack of theoretical understanding, or inadequate information or insufficient data describing the system, i.e., incomplete knowledge.

Millstone describes sequential stages of science-based risk appraisal, starting with the scientific stage of "risk assessment,"' followed by the policy-making stage of "risk management" where other non-scientific economic, social and political factors should be taken into account (op.cit.: 298-299). Thus, this model portrays the scientific appraisal as entirely independent of policy-making. A third stage called "risk communication"' can

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See the companion paper (FRACTAL Deliverable 2.3.5: Review of adaptation options applicable to each city) for examples of this approach.

involve scientists, but also typically involves other specialized actors such as knowledge brokers, journalists, and other communicators.

Writing about the science-policy interface for climate issues, Dessai and Wilby (2011) contrast a "predict-then-act" framing of planning with an "assess-risk-of-policy" framing in terms of how climate uncertainty is managed. The former "focuses heavily on characterising and reducing uncertainty of climate and climate impact projections" whereas the latter "starts with the decisions and works its way backwards to assess how much uncertainty a given portfolio of decisions is capable of handling" (ibid. p. 2). Assuming a risk-based approach is taken, the authors advise a range of methods and tools (including stakeholder assessments) should be used depending on the availability of data and resources.

Watkiss (2015) discusses climate adaptation strategies for the tea sector in Rwanda, by suggesting the need for early interventions, starting with the identification of relevant development objectives, followed by the prioritization of actions emerging climate finance should target. This framework envisages three types of interventions i.) immediate actions that address the current adaptation deficit, and also build resilience for the future, ii) the integration of adaptation into immediate decisions or activities with long lifetimes, such as infrastructure or planning, and iii) early planning for the future impacts of climate change, noting uncertainty (Watkiss, 2014; DFID, 2014: IDRC, 2015). A similar approach has been established by the IPCC (cf. AR5, IPCC, 2014) applying the concept of "iterative risk management".

The popularity of the three above themes across many areas of literature, and the application as framing concepts to many types of decision problems are striking. Yet in view of different schools of thought reviewed here, there are no simple conclusions. The question of what is the "best" decision-making model or framework in a given situation is not easily answerable. Different valid frameworks are available. Each can shed some light on decision problems, and each may have a role to play. A further factor - hardly mentioned so far but key both to framing concepts and choice of methods is whether the decision-making process or the decision analysis includes stakeholders.

In general, we can distinguish between **expert-driven** versus i**nclusive, participatory** modes of decision processes or methods. Expert methods are undertaken by an analyst (or team of analysts) with a high level of training and methodological knowledge. The activity is thus consistent with an established theoretical background and principles (which could also be seen a mixed blessing due to the *a priori* assumptions built in) and professional standards that ensures good documentation of the process. It also lends a certain "authority" to the result. On the other hand, participatory methods usually involve a range of stakeholders, and therefore different types of knowledge. Results could therefore have a greater "legitimacy" for some audiences. This can sometimes also include "expert judgement,"' which, as well as including sectoral and disciplinary experts could include wide participation and different types of expertise (e.g., local or cultural knowledge), but should not be confused with expert methods (i.e., decisions based on analytical expertise).

Thus, the choice between expert-driven and participatory-decision processes may involve a key trade-off between legitimacy and authority. It is important to mention, however, that

increasing the number of participants, or the number of different expert perspectives does not necessarily mean that a decision is easier to make, a problem is easier to solve, or the outcomes are any better (Rittel and Webber, 1973).

Many of the methods we discuss in the section 3 also reflect on this trade-off between legitimacy and authority. For example, the review on "'indicator assessments" contrasts more technical approaches (using scientific data) with more subjective approaches (based on participatory methods and stakeholder opinion). Of course, there are several other dimensions of decision-support methods (formal vs. informal methods, black box vs. transparent methods, computer-supported or not, etc.) to consider for adaptation decision-making, and this itself probably reflects the degree of complexity inherent in adaptation problems. The main distinction we are considering in this review is the distinction between **process methods** and **support methods**.

In section 3 we review several approaches/methods for their potential usefulness, and we include a table (Table 1) summarizing these methods. The table lists: the types of decisions that the methods address, whether entry points to decisions can be identified, the main participants that use the method, the inclusion of climate information (which is the focus of the FRACTAL project), the resources required to apply the method, and the learning outcomes that typically result.

3. Research Methods

This section introduces short reviews of twelve research methods of two different types. In this typology, **process methods** aim to analyse empirical cases of decisions that have been made or are being made (either retrospectively or in real-time) in order to describe and better understand how decisions were arrived at. By contrast, **support methods** aim to provide analyses of how a decision between various options could be made (i.e. prospectively): these are methods that typically use rigorous and tested formal approaches.
Each review covers the relevance of the method to climate change research, a description of the method, a discussion of its strengths and weaknesses, examples where the method has been applied, recommendations for further methodological development and key references.

The main characteristics of these methods are summarized in Table 1. The potential constraints of each method are summarized in Table 2. It is hoped that providing reviews of each method, key characteristics and potential constraints in their application may help to identify the most suitable methods for various research questions being explored in the FRACTAL project.

Reviews - Decision-making process methods

Theories of Collective Action

Collective action in practice is the development of joint strategies that allow communities to manage natural resources, over many generations. Theories of collective action developed in the economic and political sciences, were based mainly on the theory of rational choice, especially game theory. A seminal contribution was made by Ostrom and colleagues (1990, 1992, 1998) in developing the *theory of human behaviour* for better understanding social dilemmas and the governance of the commons through collective action. This work addressed the claim that open access resources - referred to as common-pool resources (CPRs) - cannot be managed over long periods of time without building trust and enforcement of sanctions when contractual agreements are broken by individuals. This body of work is largely synthesized in two books, *Governing the Commons* (1990) and *Understanding Institutional Diversity* (2005) (but see also shorter articles such as Ostrom et al., 1992; Ostrom, 1998).

One of the greatest contributions of Ostrom's work to the study of collective action and institutions is the development of the Institutional Analysis and Development (IAD) framework, which proposes 'universal components' to study the diversity of regularized social behaviour organised at multiple scales. The framework incorporates multiple levels of analysis to understand the effects of rules on human behaviour and the outcomes of their interactions. This multi-level approach recognises that human decision-making starts with many layers of internal processing at the individual level, on top of which are structures composed by groups of individuals (e.g. families, industries, nations, etc.), themselves composed by even larger structures (Ostrom 2005).

The focal level in the IAD framework is the 'action arena' where different human participants interact in an 'action situation' constrained by rules and other exogenous variables. The interaction produces outcomes that in turn affect the actors and the action situation. Because the IAD framework is conceived as a multi-tier conceptual map, the representation of an action arena can be further unpacked, as many times as needed. Seven broad types of rules that can affect the structure of an action situation were proposed, ranging from rules about what 'position' participants hold, what actions are assigned to each position, and how benefits and costs may be distributed (i.e. payoffs). Note that, unlike many other decision-analytic methods, IAD is not necessarily a participatory research method. It can be used to guide a participatory exercise, but it can also be used to guide a desk-based study based on literature review or interview data.

Since the two books mentioned above were published (1990; 2005) many empirical studies have shown that cooperation levels for social dilemmas far exceed the predicted theoretical levels: individuals systematically engage in self-regulated collective action to provide public goods or manage CPRs without an external force that induces pressure for this. More importantly, they have also shown the diversity of rules designed and enforced by human participants themselves to change the structure of social-dilemma situations and self-organise. Most sustainable common pool regimes involved clear mechanisms for monitoring rule conformance and graduated sanctions for self-enforcing compliance (Ostrom 1990, 1998). This was found to depend heavily on trust levels and communication to sustain cooperation over time.

IAD was applied to more than five hundred case studies - including irrigation systems in Nepal (Joshi et al. 2000), and fishery management and forest ecosystems (e.g. Gibson et al. 2000) - allowing researchers to record a common set of variables. IAD and its theory of collective action has also greatly contributed to the analysis of social-ecological systems (SESs). Ostrom developed a multi-tier SES framework, which looks at how humans interact with resource systems and ecological dynamics, suggesting a set of relationships between the variables in the SES framework to understand CPR management. New updates of the SES framework have been recently published

(e.g. Epstein et al. 2013, Vogt et al. 2015) emphasizing the need to strengthen the ecological dimension. In urban settings, there are fewer applications of the SES framework. It has been applied to study governance of urban social-ecological commons such as peri-urban lakes in India (Nagendra and Ostrom 2014).

Foresight

Foresight encompasses a wide range of methods and approaches to help people think about and prepare for a range of possible futures. It aims to help decision-makers explore and anticipate, in a participatory way, what might happen in the future. By considering all possibilities foresight is better able to handle the nonlinear nature of complex, uncertain and "wicked problems" (Rittel and Webber, 1973: 155), to more quickly detect the impacts of long-term decisions than traditional planning. It is often used to explore interactions between multiple systems, such as energy, transport and food systems. It promotes early detection and fast recovery and often involves systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building processes (e.g. see Backcasting) to uncover a range of possible alternative future visions (in similarity to the Adaptation Pathways approach). Key foresight methods include horizon/environmental scanning, strategic conversation, visualization, roadmapping, storytelling and scenario building.

Foresight is a promising approach for rethinking public policy when wider/ radical change, including technological and social innovations, need to be considered. The method can draw on a wide array of actors' knowledge to create a broad range of scenarios (see also Scenario Planning). This involves developing qualitatively different future scenarios - as opposed to changing quantities while the qualities remain the same (forecasting). Foresight methods are also seen as compatible with implementing a shift from vertical to horizontal approaches to decision-making. This, combined with making transparent normative views and potential conflicts of interest and barriers, can facilitate "soft coordination" of policy networks (UNDP, 2014).

An example application in South Africa is the national Neighbourhood Development Programme (NDP), which was introduced into local government planning processes to plan the future of townships. This resulted in a strong communicative planning and visioning basis for uniting and aligning multiple local stakeholders. The municipality was able to establish credible long-range development plans and secure political support and cooperation from stakeholders previously opposed to the plan and also access required resources. The process also garnered interest in replication of the process from other municipalities. A democratic, participatory process supporting the collaborative development and ownership of a long-range vision and strategy, helped guide critical decision-making and ensure stakeholder alignment. The long-term nature of foresight also helped to create a "safe" platform for an otherwise difficult engagement (Karuri-Sebina and Rosenzweig, 2012: 38).

Multiple Streams Framework

The Multiple Streams Framework (MSF) is a theoretical framework for analysing policy-making processes, which emerged within political science in the mid-1980s through the work of John Kingdon (Kingdon, 1984). The MSF proposes that policy-making can be understood as consisting of three streams, each composed of various institutional, perceptive and procedural elements: the problem stream; the policy stream (consisting of proposed interventions or solutions); and the political stream (including the 'national mood' and public interest).

There are several other core concepts of the MSF framework. 'Policy entrepreneurs' are important actors because they are instrumental in leveraging opportunities that emerge in 'policy windows'. 'Coupling' is said to be achieved between three streams when a policy problem and a policy solution (with agreed responsibilities and governance arrangements) are made sufficiently compelling to receive political attention and resources. Without this coupling, no policy can emerge and no policy decision is taken, such that problems remain unresolved, solutions may exist and be promoted by stakeholders but there is no receptivity for them (Ridde, 2009). The concept of 'spillovers' suggests that a window of opportunity occurring in a given policy area and being utilized by a policy entrepreneur could increase the probability of another window opening in a related area.

MSF has mainly been used to study agenda-setting under conditions of complexity and ambiguity within the policy-making process, but has been extended to also look at questions of policy implementation. There are already some early applications of the framework in the climate field, mainly relating to energy (Brunner, 2008; Carter and Jacobs, 2014) and forest (Storch and Winkel, 2013) policies. While also used at local and supranational levels, it is more often at the national level in sectors such as emergency management (Henstra, 2010); health (Odom-Forren and Hahn 2006; Ridde, 2009); transport (Weber, 2014) education (Lieberman, 2002; DeJaeghere et al. 2006; Chow, 2014); and foreign aid policy (Travis and Zahariadis, 2002). There are relatively few studies that apply the framework in an African context, with the exceptions of DeJaeghere et al. (2006) and Ridde (2009).

The framework has been critiqued for a lack of clarity on what constitutes a stream, for being too heavily based on or tied to the political system of the United States, and for having limited (or even non-existent) explanatory capacity. Responding to many of these criticisms, Winkel and Leipold (2016) suggest complementarity and possible integration between MSF and policy discourse analysis (especially Hajer's version of it), which links strongly with other tasks and analysis being undertaken in FRACTAL.

Processual Analysis

Processual case research - or processual analysis - has been developing within the field of organization studies since the 1970s (Hinings, 1997). According to Pettigrew (1997: 337 & 340), one of the method's originators and developers, it aims "to capture the dynamic quality of human conduct in organizational settings" and "to account for and explain the what, why and how of the links between context, processes and outcomes".

Processual analysis has both theoretical and empirical bases. It is associated with the development of process theories that suggest various kinds of temporal relationships, either in the form of deterministic phases or models with interactions, feedback loops, parallel paths, nondeterministic branch points and reversals (Langley, 2010). Data collection methods tend to be a mix of observation, interviewing and reviewing archival documents (Dawson, 1997).

Processual analysis goes beyond mere storytelling, describing events and constructing case histories, although these are indeed crucial building blocks in applying the method (Pettigrew, 1997). Outputs can also include chronologies and graphical visualizations of patterns and linkages.

Langley (1999) has proposed seven strategies for deriving from process data theoretical insights that are accurate, parsimonious, general and useful. The seven strategies are: (1) developing case narratives or thick descriptions as referred to in the ethnographic literature; (2) quantifying incidents and applying statistical methods; (3) testing alternative theoretical templates; (4) grounded theorizing from inductive bottom-up coding of data; (5) visual mapping and graphical representations; (6) temporal decomposition and bracketing of time periods within processes; and (7) case comparisons across time periods within a case, across processes (i.e. between cases) and between cases and a priori conceptual frames (Langley 1999 and 2010).

This method has been applied to analyze and understand strategic change and competitiveness within organizations, mainly private sector firms in Europe and North America but there are also some studies on public sector organizations (e.g. Pettigrew, 1992 and Allison, 1971). It has not yet been used within the field of climate research, but holds promise for better understanding patterns of decision-making that do, could or should include climate considerations, the mechanisms shaping these patterns, and how the sequencing of actions and changes in context interact to produce different outcomes.

Some of the key challenges noted in the literature are that the method requires considerable time commitment to the research process (i.e. there is no quick and dirty option) and that it is easy to get lost in, and overwhelmed by, a mass of data. Related to this, Pettigrew (1997) notes that poorly performed process research stops at presenting a case history without developing analytical themes linking the empirically derived patterns with wider theoretical debates. Langley (2010) surfaces a common concern with or critique of processual case research as being the limited generalizability (within the positivist paradigm) or transferability.

Applied behaviour analysis and organizational behaviour management

Applied Behaviour Analysis (ABA) is a method based on the application of behavioural principles – as originally articulated by psychologist B. F. Skinner in his book Science and Human Behavior (1951) – to change 'socially significant' behaviour to a meaningful degree (Reitman 2005). Interestingly, since then it has developed much further as a method within the private sector (Dickinson 2000), where it is better known as Organizational Behavior Management (OBM).

Instead of focusing on theory testing, ABA concentrates on evaluating the utility of procedures (i.e. practical strategies or interventions) in changing behaviour (Wilder et al. 2009). This is done through direct and systematic observation of behaviour in the setting where it occurs (Reitman 2005). Observational data are collected on responses made by individuals to specific interventions to determine if progress is being made (i.e. in reaching the target behaviour) or not. If no progress is observed under a particular intervention, then the procedure has to be re-evaluated and modified.

Conceptually, ABA relies on relationships between stimulus control, and reinforcement and punishment. Stimulus control is said to occur when an intervention (stimulus) increases the probability that a given behaviour will occur. It may come about when a stimulus is repeated several times - and through reinforcement or punishment - the behaviour is married to a consequence. Reinforcements can include a range of procedures - they can simply be events that are 'pleasant' such as positive feedback or can be rewards of objects of value to the individuals. Punishment-based procedures aim to reduce the frequency of 'problematic' behaviour, and are used only in restricted critical situations given the associated ethical implications (ibid).

The application of ABA to clinical activities is very broad. It has focused on children and adults with developmental difficulties, but has also been used to facilitate changes at a broader level, for example to address vocational problems (e.g. unemployment or underperformance), to accelerate medical rehabilitation (e.g. compliance with physical therapy, to manage pain, to improve memory performance), and promote socially desirable behaviours, such as reducing energy consumption, unsafe driving, and illegal use of drugs (Reitman 2005).

OBM similarly applies behavioural principles to individuals and groups in business, industry, government, and human service settings. Its focus is on organizational problems, such as under-performance or poor productivity, lack of knowledge and skills, occupational injuries and safety, and quality deficits. Although the applications of OBM are more diverse, this field builds on the principles of ABA to isolate, analyse, and modify the environmental/ context events that most directly affect observable or verifiable (generally not self-reported) business/ employee performance (Bucklin et al. 2000). In OBM, a cost-benefit analysis is also common practice to calculate return-on-investment figures based on observable changes, which are relevant in a business environment.

An important difference between ABA and OBM is that OBM interventions are sometimes classified into two categories: antecedent-based interventions and consequence-based interventions. According to Wilder et al. (2009) examples of the former include task clarification, equipment modification, goal setting, prompting, and training. On the other hand, consequence-based interventions included feedback, praise, as well as monetary and nonmonetary incentives (reinforcement stimulus). Based on a set of reviews, feedback seems to be by far the most common intervention used in OBM to change target behaviour in an organizational setting.

Adaptation pathways approach

The adaptation pathways approach focuses on the sequencing of decisions to select and implement climate adaptation measures, accounting for uncertainty and avoiding unacceptable risk and wasteful expenditure (Reeder and Ranger, 2011; Haasnoot et al., 2013; Rosenzweig and Solecki, 2014). It is primarily used in a forward looking sense at what future adaptation actions may be deemed technically robust and socially acceptable under future scenarios, over decadal timescales (thus having similarities with foresight methods). Future scenarios must include uncertainties in the evolution of the climate system as well as economic, political, technological, demographic and other environmental trends (Haasnoot et al., 2013). Unlike other approaches reviewed in this paper, adaptation pathways has been developed specifically for addressing various climate risks. However, by combining technical approaches of risk management with social dimensions of decision-making and governance, it also lends itself well to transdisciplinary research on climate adaptation.

Wise et al. (2014) draw attention to the complexities and uncertainties inherent in decision contexts for adaptation. They argue that the following aspects particularly need to be considered: (1) knowledge of the system in question (e.g. stormwater infrastructure system or forest ecosystem) that is being developed, managed and adapted; (2) the goals of any policy or actions; and (3) the distribution of power in decision-making and implementation. They suggest it is useful to distinguish between: (1) incremental actions within the prevailing governance regime that address proximate causes of vulnerability or developmental needs, and (2) transformative adaptation that entails changing the rules and values that frame decisions and assign power in the decision process. Building on this work, Gorddard et al (2016) suggest that it is insufficient to only focus on decision-making processes. Rather, they argue, the broader decision context needs to be understood by analyzing the social systems and structures affecting the framing of problems and the agency of different decision-makers and stakeholders in a decision-making process, that in turn limit or create the ability to innovate and change.

Pathways is a powerful metaphor that works across multiple contexts to explain navigating change. It can be used as a foresight and planning tool, as well as a retrospective analytical tool. When used in planning, it can help identify decision triggers and tipping points such that new options can be selected with sufficient lead times when existing options no longer limit risk to an acceptable level. On the other hand, by considering past decision-making, referred to as an 'antecedent pathway', as a basis for charting future pathways, the method can assess institutional preparedness for climate adaptation. In all cases, considerable time and commitment from stakeholders is needed to fully apply the method. The approach has been used to address sea level rise and flooding in the Thames Estuary in the UK (Reeder and Ranger, 2011; Ranger et al., 2013) and in the Rhine Delta in the Netherlands (Haasnoot et al, 2013). It has also been used in the context of sea level rise, storm surge and flood risks in Lakes Entrance, Australia (Barnett et al 2014) and droughts, floods, salinity, and overexploitation risks in the Murray-Darling Basin, Australia: (Abel et al 2016). It has not been used as a decision tool at the city scale in an African context, with the exception of Taylor (forthcoming), who uses the pathways framework to analyse adaptation decisions made in managing stormwater in the City of Cape Town.

Reviews - Decision-making support methods

Robust Decision Support

The Robust Decision Support (RDS) method was developed based on the Robust Decision Making (RDM) theoretical framework. The theory underpinning RDM stems from a research programme on strategic decision making under conditions of deep uncertainty led by the RAND Corporation (Lempert et al. 2003) [5]. However, development of scenarios for planning under uncertainty should also be credited to work at Royal/Dutch Shell in the 1970s (see Scenario Planning). RDS emphasises a quantitative modelling approach to long-term policy analysis (LTPA). It evaluates potential impacts (positive and negative) associated with different adaptation actions. The method not only incorporates external factors such as climate change in the analysis, but also other factors such as population growth and economic development. The implementation of the RDS method usually follows 8 steps organised into the 'preparation phase' and the 'investigation phase'.

The 'preparation phase' generally takes around 12-24 months to complete. This phase is designed to involve all relevant stakeholders and decision makers and give them an opportunity to participate in the critical problem formulation and analytical design process. Once the modelling platform has been constructed and calibrated (based on historical climatic and hydrologic data sets), and potential future scenarios have been defined, the process continues with the 'investigation phase'. In this phase, which takes approximately 12 months to complete, the models are run for each of the several adaptation strategies articulated by the key actors, considering different climate and non-climate scenarios.

The RDS has been applied in the context of water and watershed management where climate change was an important factor in the decision-making (Escobar and Purkey 2016). The participatory approach adopted for these applications responded directly to the Integrated Water Resource Management (IWRM) demand for participatory water and watershed planning. In a water management application of RDS, the model construction was based on the Water Evaluation and Planning (WEAP) system developed by the Stockholm Environment Institute. The WEAP model runs generate a range of future scenarios linked to different trajectories of change and climate projections, as well as different adaptation management options. To support evaluation of model results, data visualization tools were used with participants, and this contributed to a process of co-learning amongst key stakeholders regarding promising adaptation actions (Escobar and Purkey 2016).

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5 Along with its contributions to the field of RDS and scenario planning, Edwards et al. (2007, p.4) remarks that the first conference on "decision processes" was held at RAND Corporation in 1952.

Structured Decision Making

Structured Decision making (SDM) is a systematic approach to identifying and evaluating possible options that focuses on engaging stakeholders, experts and decision makers in productive dialogue and decision-oriented analysis. The aim is to identify and agree on decisions that are optimal with respect to management objectives, multiple interests and forms of knowledge of the issue at hand. Many analysts categorize decisions according to the degree of structure involved in the decision-making activity; they describe a structured decision as one in which all three components of a decision—the data, process, and evaluation—are determined. In business and in government sectoral planning, where many decisions are made on a regular basis, it makes sense to place a comparatively rigid framework around the decision and the people making it.

SDM concepts and tools have been applied in many policy contexts to help advance clear, creative and pluralistic decision processes, particularly in the area of resource management. Decision support tools such as objective networks and influence diagrams are useful for structuring these complex decision problems involving linkages across scales and irreducible uncertainties. In practice, the stages of SDM are often introduced as a series of steps, during a series of workshops, worked through in a largely linear way (Gregory, 2012). This guidance identifies six steps to follow: (1) Clarify the Decision Context, (2) Define Objectives and Evaluation Criteria, (3) Develop Alternatives, (4) Estimate Consequences, (5) Evaluate Trade-Offs and Select Options, and (6) Implement and Monitor.

During step (1), stakeholders are recruited to contribute to participatory workshops. Throughout the process SDM follows a 'participant-friendly' method. This often involves stakeholders in civil society processes that employ both decision analysis and discourse (Arvai et al., 2001; Renn, 2003). It places emphasis on the multiple perspectives on values, and multiple perspectives on technical judgements, as a basis for creating more widely attractive alternatives, and understanding the implications of diverse views. Structured decision-making can be seen as building on formal decision analysis, but with an emphasis on stakeholder involvement for pluralistic decision processes rather than involving a single decision-maker. Therefore it is essential to gather a broad representative group of stakeholders in both the clarification stage (1) and when planning the participatory workshops.

Applications of SDM to climate change adaptation or mitigation problems are still rare, but there are many examples related to natural resource management, for example in land-use change. One application concerns landowner decisions to address private forest management and parcelization in North Carolina (Ferguson et al., 2015). Another example found that stakeholder-based advisory groups were remarkably successful in balancing economic, environmental and social objectives in water management for reservoir operations on 22 British Columbian river systems (McDaniels et al., 1999; Gregory and Failing, 2002). This process was implemented in part because of regulatory pressures to find new approaches that could avoid litigation, build stakeholder support, and use values and technical information effectively to address conflict. Another example using SDM with a stakeholder advisory group investigated integrated resource planning at British Columbia Gas (Hobbs and Horne, 1997; Keeney and McDaniels, 1999). More recently, Cartwright et al. (2012) provide relevant discussion of the SDM method in relation to climate change decisions in cities and

give an example of sea-level rise for the City of Cape Town. The authors argue that suitable outcomes of decision structuring (e.g. a range of climate change adaptation options) can be identified for specific needs using multi-criteria support instruments e.g. cost-benefit analysis, value function analysis and analytical hierarchical processing.

Decision Scaling

Decision Scaling also known as "Climate Informed Decision Analysis" (CIDA), is a methodology for determining which (investment) decision options are robust to a variety of *plausible futures* using expert judgement (Hallegatte et al., 2013). It involves the integration of methods for climate risk assessment and robust decision analysis in situations characterised by "deep uncertainty"[6]. Climate change information is incorporated by first identifying which sets of climate changes would affect the project and then determining the likelihood of those sets. Stakeholder priorities are also mapped to observable indicators and used to define thresholds of acceptable versus unacceptable performance of investment alternatives. In this way, it connects "bottom-up" vulnerability analysis with "top-down" climate model information, and retains the strengths of both approaches - this is one of the ways in which Decision Scaling differs from Robust Decision Support (RDS).

The "bottom-up" vulnerability assessment component (see also the review of indicator approaches) involves producing a *decision/risk map*, identifying each decision's performance under a wide range of different future climate possibilities. The method then uses GCMs, stochastic modelling, or expert judgment to determine *plausibility* (subjectively derived probability) of the (uncertain) climate projections. Decision options are based on application of decision-to-climate performance to relative climate plausibilities.

Benefits of the approach include: it allows alternative visions of the future (including information about likelihoods) to be incorporated into the decision; it is able to handle poorly-characterized climate change uncertainties; it applies GCM information late in the process, reducing the impacts of GCM uncertainties on the decision as a whole; and it allows for easily updated analysis when better information becomes available.

Decision Scaling has been applied in water system planning and river basin management in a range of contexts from Niger (Brown, 2010) to the Upper Great Lakes in North America (Brown et al. 2011; Moody and Brown 2012, 2013).

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6 A situation in which analysts do not know or cannot agree on (1) models that relate key forces that shape the future, (2) probability distributions of key variables and parameters in these models, and/or (3) the value of alternative outcomes (Hallegatte et al., 2013).

Backcasting

Backcasting is an approach to futures studies designed for planning situations where existing trends or strong inertia seem to be a barrier to achieving important societal goals, such as environmental degradation or the potentially negative impacts of climate change. As such, backcasting can be useful to help planners free their mind of present entrenchments in order to find novel solutions for the long-term and thus to overcome factors such as goal conflicts, lack of resources, uncertainty and preoccupation with short-term problems (Carlsson-Kanyama et al., 2013).

To apply the method, participants start by looking some 20 years or more into the future to envisage a society where radical goals are realised or a pervasive problem is solved, or at least dealt with in an efficient way. Then one or several paths may be sought that link the present state to the future vision(s) in terms of policy measures. The aim of this approach is not to suggest a rigid 20-year plan, but to widen the conception of what is possible to achieve in the long-term as an input to planning and discussions in society. It may suggest new perspectives on a problem where we seem to be entrenched by the present framing of the problem. For example, to discuss multiple visions of the future that stakeholders *wish to have* or *wish to avoid,* one could ask:

> *What will our city look like in the year 2030, when climate and society have changed, but services are better than today?*

In a workshop, participants can: i.) come up with proposals, which are ii.) clustered, iii.) voted on, and iv.) prioritised, based on the focal question.

Van der Voorn et al. (2015) suggest that once a common vision (or several) is identified, it is valuable to discuss whether: (i) it includes transformative elements that articulate the perceived gap between the present state and the desired future state (ii) the vision clearly translates into goals and guiding targets for stakeholders to put into action.

Most frequently, backcasting is used within particular sectors such as transport, urban development, water management and sustainable energy use. Some examples in the water sector are (i) the Breede–Overberg Catchment Management Strategy in South Africa, (ii) The New Orleans Horizon Initiative Water Management Strategy in the United States and (iii) The Rhine-Meuse Estuary sub-programme of the Dutch Delta Programme in the Netherlands in (Van der Voorn et al., 2015). The method has also been applied to climate change by the IPCC (Metz et al., 2001).

Much application of backcasting to date has focussed on mitigation, focussing on a decrease in carbon dioxide emissions. In contrast, it has not been used very often to analyse adaptation to climate change. Carlsson-Kanayma et al.'s (2013) literature survey found only one clear case where backcasting was used for climate change adaptation. However, it is suggested that backcasting and other normative vision-oriented approaches are suitable for climate change adaptation because of their applicability at various scales, their compatibility with various tools and methods and their ability to support various forms of stakeholder engagement (Van der Voorn et al., 2015).

Scenario planning

Scenario planning has its origins in military intelligence when, during the Second World War, the RAND Corporation developed what it called "future - now" thinking (Kahn ,1940). Later the Hudson Institute along with the Shell corporation started developing energy scenarios helping them anticipate the devastating impacts of oil prices following 1973 Arab–Israeli War. Today there is much greater emphasis on decision-making processes and ensuring that scenarios have practical value and can involve the key decision makers, as 'owners' of the problem. Meaningful scenario planning is thought to be enhanced if participants can bring imagination, expert knowledge, experience and judgement to complement their analysis of empirical data. Scenarios can provide a useful 'hypothetical' to engage stakeholders about the uncertainties of the future, especially in the context of a wider regional planning and visioning exercise (Low Choy, et. al., 2012).

In the climate change adaptation context, a scenario planning tool has been developed in the Climatools Programme (Carlsen and Dreborg, 2008; Carlsen et al., 2009). The programme is designed to assist local decision makers in adaptation planning in Swedish municipalities. It shares many characteristics with other frameworks for the utilisation of socio-economic scenarios in the impacts, adaptation and vulnerability communities, e.g. UK Climate Impacts Programme (UKCIP, 2001; Berkhout et al., 2002) and the Finnish project FINADAPT (Carter et al., 2005). However a key difference in Climatools is the construction of a unique set of scenarios specifically tailored for each planning situation. By doing this collaboratively with the municipality, a clear link between the scenarios and the stakeholders' own concerns can be established. In this way, the Climatools approach addresses a common shortcoming of scenario planning.

A case study from Climatools programme examined the impacts of climate change on drinking water from The Tullinge water aquifer, near Stockholm (Baard et al., 2012). The Tullinge study exemplifies different resource uses, needs and interests; the objective was to consider future threats from climate change including damage to water distribution networks, microbial and chemical contamination, increased saltwater intrusion, and algal blooms in freshwater lakes and aquifers. The study included participatory processes involving planners from different municipal sectors.

Another example of using participatory scenario planning is Transformative Scenario Planning (TSP). This is being applied in the Adaptation at Scale in Semi-Arid Regions (ASSAR) project to bring stakeholders with different, often conflicting, perspectives together around pressing sets of problems. Stakeholders build stories that illustrate a range of potential futures that could come from taking different paths for dealing with those issues. By doing this, the stakeholders learn more about their present situation and about what dynamics in that situation are serving to help or hinder progress toward a more equitably beneficial future (Kahane et al. 2012).

Cobb and Thompson (2012) describe a qualitative case study using an in-depth evaluation of the scenario planning process, and an exploration of factors influencing its use as an environmental decision-making model. The authors explore how decision-makers and scientists within the National Park Service (NPS) in the United States used scenario planning to negotiate the social and scientific uncertainty associated with climate change through the lens of systems innovation

theory and organizational resilience. Further examples are the MAJI project (More Action for Just Initiatives for Climate Change Adaptation in Southern Africa) conducted with communities in Malawi to collaboratively plan for climate change (Waylen and Martin-Ortega, 2015), and the exercise carried out with eThekwini officials and others about the urban development in Durban (Khan et al, 2015).

Indicator approaches

Indicator approaches are very popular in applied research as they provide methods useful for working at the interface of science and policy. A considerable amount of literature has been published on applying indicators to better understand climate impacts, vulnerability and adaptation (IAV). Indicators are also used in conducting assessments, which may be used for informing policy making (e.g. setting priorities, allocating resources). Whilst further work has developed around 'adaptive capacity' indicators and resilience, there are also lessons from application of indicators in environmental assessment and in development generally to support decision-making (see Fussel, 2010: pp9-17).

Concepts like vulnerability to climate change, adaptive capacity and resilience cannot be measured directly. However, they are important to consider in any climate change assessment. Measureable quantities/qualities need to be found that can be used as surrogates for these concepts. Such 'indirect' indicators are used for describing less tangible factors. Often, sets of indicators are used together to measure the phenomenon of interest - a common approach has been to aggregate the individual indicators into a single overall numerical score, referred to as an index.

Composite indices combine large amounts of information and are a helpful format for communicating scientific results to policymakers, which may be preferable (OECD, 2008). However, such indices need to be carefully constructed, with a clearly defined methodology - including the procedure for selecting the best available indicators, and for aggregating (including weighting procedure). Examples have shown that a mixed approach, integrating qualitative and quantitative indicators can provide a more comprehensive assessment. There are also different modes for carrying out indicator assessments: contrast more technical approaches (using scientific data) with more subjective approaches (based on participatory methods and stakeholder opinion).

Examples discussed here are drawn from multiple areas of IAV. Fussel (2009) reviews climate change vulnerability indicator approaches and their potential application to decision making. The author argues that "existing indices of vulnerability to climate change show substantial conceptual, methodological and empirical weaknesses including a lack of focus [...] and hiding of legitimate normative controversies" Fussel (2009; p28). He also emphasises the diversity of decision contexts and purposes they serve. He suggests that national-level vulnerability can inform two types of international adaptation funding decisions: a) classifying countries into vulnerability categories, and b) determining fair allocations for eligible countries. On the other hand, Hinkel (2011) identified six purposes that might be served by vulnerability indicators. His verdict is that indicators may only be used to identify particularly vulnerable people, regions or sectors (at local scales, where exposure units are narrowly defined by a few variables).

Gupta et al. (2010) developed the Adaptive Capacity Wheel for assessing how institutions - broadly understood to be rules, roles, and social practices - foster adaptive capacity. Their 22 'criteria' function as indicators across six 'dimensions', including variety, learning capacity, room for

autonomous change, leadership, availability of resources, and fair governance. The tool has been used to 'score' policy instruments for their ability to promote the adaptive capacity of society (cf. Grothmann et al., 2013).

Institutional capacities - of the organisations involved in climate governance and adaptation planning - is the focus of the Climate Capacity Diagnosis and Development (CaDD) software tool and method (see http://climatesense.eu/). CaDD uses the concept of 'response levels' to indicate the level of development in each pathway. Thus, it is an example of a qualitative indicator approach. The tool has been used with development organisations, local authorities, sector and industry groups, and CSOs. An example is the Adaptation Strategies for European Cities (ASEC) project, which included 21 European cities.

Indicators of adaptive capacities have also been developed for more specific purposes such as use in integrated assessment modelling (Tinch et al, 2015) and to develop climatic and socio-economic scenarios (see the scenario planning). Brooks and Fisher (2014) discuss indicators in their paper on monitoring and evaluation frameworks for adaptation. Their approach includes vulnerability, adaptive capacity and regular development indicators. They identify the problem that changing risk contexts might distort 'before and after' assessments that are based on regular development indicators. Adaptation will by definition take place against a shifting climatic, social and environmental baseline, which may act as a confounding factor in the assessment of development and adaptation interventions.

Becker et al. (2015) review indicator-based approaches for assessing community resilience. Finding that many approaches rely on similar methods and indicators as have been used in vulnerability assessments they argue for integration of this work into resilience assessment. Their core set of 14 indicators were identified as most significant based on project case studies and local research. Another promising example is the self-assessment tool developed by UNISDR that is part of the 'Making Cities Resilient' Initiative (UNISDR, 2012). This tool, the Disaster Resilience Scorecard for Cities (UNISDR 2014), is designed to enable communities to monitor changes and communicate their priorities with city councils in other processes of governance. The scorecard integrates many criteria - including qualitative and quantitative information - across multiple categories.

Table 1: Comparing decision process methods and decision support methods

Name of process method	Decision types	Potential to identify entry points	Main participants	Resources and data required	Learning outcomes for the participants
Processual Analysis	Strategic change within public and private organizations	Yes, by investigating processes in context	Private sector firms in Europe and North America	Moderate (data input) High (time and number participants required)	Decision-making patterns and mechanisms, sequencing of actions
ABA & OBA	Interventions for behavioural change in individuals, communities or organisations	Through observation of behaviour in situ	Health and education sectors and business sector	High (learning and communication intensive)	Measurement, to help assess the attribution of outcomes.
Foresight[a]	Long-range vision and strategy	Emphasises innovation opportunities	A wide range of actors can be involved	Moderate	Uncovering future visions, early detection of impacts
Theories of Collective Action[a,b]	Management of common pool resources	Yes, through 'action situations'	Individuals or private sector actors	Difficult to estimate	Participants learn new heuristics, norms, rules
Mutiple Streams Framework[b]	Policy agenda setting across many sectors	Potentially when the streams come together	Government and the private sector	Medium time to achieve rigour	How policy process works in a given context
Adaptation pathways[b,c]	Sequenced decisions to address climate risks.	All elements in the sequence are discussed	Decision-makers, technical experts	High commitment from stakeholders	Acceptable CCA options, capacity assessment
Name of support method	Decision types	Potential to identify entry points	Main participants	Resources and data required	Learning outcomes for the analyst/participants
Backcasting[b]	Addresses barriers to acheiving goals (long-term)	Novel solutions for the long term	Planners, esp. in transport and urban sectors	Moderate (incl. workshop costs)	Novel solutions to overcome goal conflicts, lack of resources, uncertainty and preoccupation with short-term problems
Decision scaling[b,c]	Medium-long term investments, where exact probabilities are unknown (e.g. water sector)	Through mapping stakeholders concerns to indicators	Water planners. Uses expert judgement	High (time, computationally intensive and number participants required)	Performance of decision options using weighted plausible future climate scenarios
Structured decision making[b,c]	Natural resource management, decision making at a range of scales	Decision options identified around a common problem or issue	Landowners, public, government, planners, environmental groups, companies	Moderate (data input) High (time and number of participants required)	Multiple perspectives on values and technical judgements leading to identification of options
Robust decision support[c]	Long-term policy	May be based on	Private sector actors and	High (computationally	Potential impacts

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	analysis, where exact probabilities are unknown (e.g. water sector).	scenarios defined by decision makers	modellers, using a participatory approach	intensive)	associated with different adaptation options
Scenario planning[c]	Socio-economic development, local adaptation planning	Synergies for mainstreaming CCA into other policy	Planners from different sectors	Moderate (low number of participants, but can be time consuming)	Dynamics in the present situation that help or hinder progress toward a more equitably beneficial future
Indicator approaches[c]	Diverse, but especially in setting priorities and allocating resources	Identifying vulnerable people, regions or sectors; adaptation planning	Can be participatory; can include various stakeholders	Highly data intensive	Better scientific understanding of climate impacts; climate risk assessments of interventions

Framing themes relevant to methods are indicated by the superscripts a) the increasing complexity of problems; b) decision-first emphasis and the shift away from linear models; and c) the rise of "risk" as a central concept for dealing with uncertainty.

Table 2: Comparing constraining factors in decision process and decision support methods

Name of process method	Limitations to including climate information and uncertainty	Technical capacity constraints	Political and institutional constraints	Psycho-social constraints
Processual Analysis	Possible but no precedents	Low	Moderate (embedded researchers in FRACTAL- may be able to observe and interview actors and access documents required). Can be sensitive to political cycles.	Observations can be localized, dependent on the observer; interviews - restricted by moods, memory lapses and quality of rapport
ABA & OBA	Moderate - The method can be applied to different contexts, however it does not deal well with uncertainty. The setting where the experiment is conducted has to be under controlled conditions.	Low	Moderate - method encourages learning, but requires commitment and persistence. If economic and institutional context is unstable or changing, it would not be suitable.	An external observer is needed to be able to record change in behaviour.
Foresight	Low - method is flexible enough to incorporate scenarios of future threats and hazards	Moderate	Moderate - these methods are very participatory in nature, so the economic and institutional setting can	Low and probably well suited to address different perceptions of risk, trust and credibility

Name of support method	Limitations to including climate information and uncertainty	Technical capacity constraints	Political and institutional constraints	Psycho-social constraints
			have high influence.	
Theories of Collective action	Low - explicitly accounts for how much and what type of information is used in the action-situation.	Low	Moderate - highly influenced by the institutional context, as it is mainly used to assess institutions. Can be sensitive to political cycles	Difficult to estimate
Multiple Streams Framework	Not really applicable as the method does not use climate information but rather could be used to analyse decisions that are climate sensitive	Low	Seeks to identify what these constraints and enablers are (rather than the method being affected by these constraints). As such, the method can be sensitive to political cycles	Moderate
Adaptation pathways	Low	Moderate	Moderate - can be used to assess institutional preparedness for climate adaptation	Low
Name of support method	Limitations to including climate information and uncertainty	Technical capacity constraints	Political and institutional constraints	Psycho-social constraints
Backcasting	Low - this method is flexible and can be implemented with different levels of information.	Low	Moderate - this method is very participatory in nature, so the economic and institutional setting can have high influence.	Low - should be overcome through participatory approach
Decision scaling	Low - Designed to incorporate climate information	High	Moderate - this method is somewhat participatory in nature, so the economic and institutional setting can have high influence.	Moderate - uses expert judgment and combines with climate model outputs late in the process
Structured decision making	Low - this method is flexible and can be implemented with different levels of information.	Moderate	Moderate - this method is very participatory in nature, so the economic and institutional setting can have high influence.	Low - should be overcome through participatory approach
Robust decision support	Low - Designed to incorporate climate information	High	Moderate - this method is somewhat participatory in nature, so the economic and institutional setting can have high influence.	High - emphasises a quantitative modelling approach to long-term policy analysis, incl. climate change, population growth, economic development data etc
Scenario planning	Low	Low	Low (suitable for medium to long range strategic planning)	Low (good at helping diverse users and decision makers identify and plan for the most uncertain and most concerning drivers of change)
Indicator approaches	Low	Moderate	Low	Low (information is expected to be

	considered credible and trusted)

4. Discussion

Having reviewed twelve candidate decision-making methods, there are several observations and recommendations that we can make about methods that may be useful and relevant for understanding and informing decision-making in African city contexts. Exploring the constraints and enablers to the uptake of climate data in decision-making, following Jones et al. (2015), has also provided insights about which of the methods reviewed may be suitable for addressing FRACTAL research questions.

What framework is appropriate for the decision space?

Some approaches are less individual research methods, but more conceptual frameworks for designing research and analysing data. As we have seen, framework approaches such as Institutional Analysis and Development (IAD, see Theories of Collective Action above) and Multiple Streams Framework (MSF) can be very useful in private institutions with multi sector cooperation, but they may also introduce compatibility issues with current and on-going framings in the decision space e.g. structures in place for decisions bridging several national ministries. They may be difficult to apply if contradictory with epistemological and ontological assumptions.

Considering costs

Most methods listed in Table 1 are highly resource intensive. This is reported in terms of economic costs, time/commitment costs and other specific costs such as data costs, computational costs and workshop costs. Some methods require the involvement of many actors (e.g. **Processual, Decision Scaling**); some are intensive regarding communication and learning activities (**ABA** and **OBA**) and others are data collection and analysis heavy (**RDS**). Resources have to be managed to avoid a case study application getting overambitious or losing relevance for users. This can happen if, for example, a data-intensive bio-physical impacts model includes climate projections that introduce such a high level of uncertainty, that they limit the usefulness of the results from impacts model. It has been argued that the decision-first approach mentioned in Section 2, as opposed to a science-first approach, can lead to a reduction in resource-intensity. Ranger et al. (2013) explain that resource-intensive analyses are used only where necessary, to compare specific attributes of options, and in such cases analyses tend to be more streamlined, targeted and less sensitive to uncertainties.

Urban applications

The methods reviewed have been applied to a very wide range of decision types, with regard to time scale, geographical scale, sectors and actors (Table 1). Whilst this is to be expected, it is also worth noting that, many have not been used in urban contexts or

only in limited examples. Those identified as having been applied in a city context include **Foresight**: in South Africa in the national Neighbourhood Development Programme (Karuri-Sebina and Rosenzweig, 2012: 38); **Structured Decision-Making** in relation to climate change decisions in cities (Cartwright, Cohen and Liddell (2012); **Adaptation Pathways** in the Thames Estuary in London (Reeder and Ranger, 2011; Ranger et al., 2013) and managing stormwater in the City of Cape Town (Taylor (forthcoming); **Backcasting** has been used for planning in urban environments (Van der Voorn et al., 2015); scenario planning in Durban and **Indicator approaches** (Khan et al, 2015) for which a tool has been developed for the 'Making Cities Resilient' Initiative (UNISDR, 2012).

Typology of learning

The reviewed methods are quite disparate in terms of their learning outcomes (Table 1). A useful next step would be to develop a typology of learning (e.g. the reader could be directed to identify if the aim is to acquire new knowledge/modify existing knowledge/synthesise knowledge or transfer knowledge) and key dimensions (for example 'entry points' and 'resource intensity') could be used to map the approaches graphically. There is also a companion working paper[7] on example adaptation options, from non-FRACTAL projects, in urban contexts in Africa. This contains structured summaries of adaptation options applied in a range of city case studies to encourage the transferability of lessons learned between cities. These structured practical examples could contribute to such a "typology of learning".

Uncertainty

Limits to climate information use and inherent uncertainty is a direct concern for all decision processes (Table 2), particularly for decision-making around risk management. It is a motivation behind many of the methods. **Scenario Planning** for example is a method that embraces uncertainty, rather than trying to reduce or eliminate it. It can help those addressing future uncertainty to generate creative approaches to planning for climate change challenges, thinking outside the historical or most obvious trends to incorporate uncertainty as a factor in prioritizing management or planning actions. **Structured decision-making** also acknowledges the role of uncertainty in decision-making, identifying that good decision-making processes will confront uncertainty explicitly, and evaluate the likelihood of different outcomes and their possible consequences. The iterative nature of this approach also allows for knowledge accumulation and communication and on flexible decision outcomes, and cautions against the lock-in of specific decision and associated infrastructure and technology (Kemp and Weehuizen, 2005).

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7 FRACTAL Deliverable 2.3.5: Inspiring climate action in African Cities. Practical options for resilient pathways. FRACTAL Working Paper No. 4. (Butterfield et al., forthcoming).

Being aware of the governance context

Political economy and institutional constraints (Table 2) may be a barrier to the use of medium to long term information (particularly climate) in decision-making due to the timescale of political cycles (typically 4 or 5 years) and higher priorities in the decision context of other development challenges or agendas. This reinforces some of the issues with the conceptual frameworks as the participatory nature of those reviewed here, can mean they are very sensitive to institutional dynamics and changes in the actor space, which can result in high costs.

Capacity needs

Although many of the conceptual frameworks reviewed here tend to have moderate to high costs, as they often require a significant level of stakeholder engagement and are sensitive to changes in the institutional context, they are more accessible in terms of the level of skill required to implement them compared to formal decision support methods. Technical capacity constraints limit the use of climate data in decision-making processes and will directly affect which decision methods might be employed (Table 2). Since this includes limited scientific capacity, conceptual frameworks or less formal approaches, such as backcasting as opposed to robust decision-making for example, may be easier to apply.

Information perception

Psycho-social constraints refer to differing levels of risk perception and a perceived lack of accuracy, reliability and credibility in climate information (Jones et al., 2015). Many of the methods reviewed suggest a low likelihood of this risk, as their participatory and iterative nature is designed to address these issues. Participatory research has the potential to make climate science more transparent and understandable and to increase legitimacy and trust in the outcomes. The most formal methods, with arguably the least stakeholder engagement are those where the risk of reduced "ownership" of the process may result in a mistrust of the information presented. However, there are diverse applications of the RDS and decision scaling methods, where the level of stakeholder participation varies and there may be instances where the perception of information is positive. E.g. the recent development of RDS data visualization tools that support participatory and dynamic exploration of model outputs to encourage co-learning amongst key stakeholders regarding promising adaptation actions (Escobar and Purkey, 2016).

Practicalities

Beyond the scientific justification, practical issues and dependences of the twelve methods are not discussed. Some methods are ready to apply and some will take a much

longer time to prepare for. Key aspects are the size of teams, disciplines involved, the scale of application, the existence of entry points, and so on. To address this, testing of methods is required to see if they are sufficiently substantial for understanding particular urban decision issues and robust enough to be recommended for future decision-making.

Some of the most promising methods will be tested in the FRACTAL project, either in the "Learning Labs' or in "Dialogues" (meetings organised by project research clusters/across clusters in the time period between Learning Labs). These will provide opportunities to fulfil a range of FRACTAL research objectives - including co-exploring "burning issues" with stakeholders in the city to understand existing decision priorities and applying selected methods reviewed here to help address particular research questions. This will include methods that allow an understanding of decision-making processes within each city and as well as methods to identify and appraise different adaptation options.

The selection of methods always depends on the research questions, the data availability, opportunities for stakeholder engagement, matching timescales with decision-making, expertise of the researchers and not least the resources required. Validation issues for the application of methods also need to be explored and better understood.

Mixed method approaches

Using multiple methods in the same study is quite common in social research (e.g. Crossley 2010; Forrester et al 2015). According to the research design, methods may be tightly dependent on each other - where each method occupies a particular functional role in the study; or they might separately and independently address the same phenomena - in which case cross-validation may be useful. Use of multiple methods should contribute to complementary aims. However, the interdisciplinary breadth of the multiple methods used, may mean that this is difficult - each one incorporates different assumptions, concepts, and outlooks.

For example, **RDS** and **Decision Scaling** are similar, and **Backcasting** and **Scenario Planning** can be considered examples of **Foresight** methods. Comparing the reviews of RDS and Decision Scaling methods, readers will notice that the RDS method does not use likelihoods, *plausible scenarios or thresholds* used in the Decision Scaling method and instead defines indicators. However, both methods are useful where exact probabilities are unknown (e.g. many climate-sensitive decisions in the water sector). The difference is that decision scaling uses expert judgment to assess the *plausibility* of different climate scenarios to identify the least likely, whilst RDS tests the interdependencies of scenarios, priorities, options and objectives using a participatory approach (Shrestha et al., 2014).

There are opportunities for combining methods that are conceptually quite similar and recognising similarities and differences in this way can reveal the strengths and weakness of a particular method for a particular decision context. Comparing two methods can in some cases allow for the application of more than one method to the same decision problem, building on the particular strengths and applicability of each method to the case at hand, where no one method is a completely good fit (see Box 1).

For example, Van der Voorn et al. (2015) propose a "mixed" methodology approach - combining backcasting (BC) with the adaptive management[8] (AM) principles of adaptiveness, flexibility, policy implementation and monitoring. They describe BC and AM as complementary approaches for climate change adaptation and have combined these in the Backcasting Adaptive Management (BCAM) methodology. We suggest that there are good links between backcasting and the Adaptation Pathways method. Backcasting searches for novel solutions to pervasive problems and the achievement of radical goals, whilst the adaptation pathways method allows the planner to identify decision triggers and tipping points such that new options can be selected with sufficient lead times (when existing options no longer limit risk to an acceptable level). In a similar vein, Winkel and Leipold (2016) suggest complementarity and possible integration between Multiple Streams Framework and policy discourse analysis, which links strongly to the urban governance tasks being undertaken in FRACTAL.

However, there are also constraints to the use of two or more methods. Returning to our previous point, resource intensity of decision methods is an important factor, particularly with methods involving data collection and stakeholder-intensive work. Questions such as: Is the method justified in terms of increased use of resources? Is there a greater risk of stakeholder fatigue? need to be asked. Combining approaches that are less intensive and that do not require high levels of data and stakeholder input e.g. development of conceptual frameworks rather than application of more participatory approaches is a consideration. To this end we consider the potential for combining IAD and MSF frameworks (see Box 1).

Box 1: Combining frameworks - an example of a "mixed methods" approach

Although it has been widely applied, the Multiple Streams Framework (MSF) has been criticised for ambiguity on determining what a stream and a policy system entail, and hence for having limited explanatory capacity. On the other hand, the Institutional Analysis and Development (IAD) framework - which has contributed to collective action theory in institutional economics - provides a way of conducting structured analysis of an action situation. By clearly defining the boundaries of an action situation, its geographical features and common resources, as well as the institutional system and policy dilemmas, IAD unpacks and represents the structure of a social situation. Could

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        Defined as systematic strategies for improving management policies and practices by learning from the outcomes of previous management actions.

this type of structured analysis also provide explanatory capacity within the MSF?

Although the IAD framework considers rules as artefacts that can be changed, they are analysed as static components that can be categorized into seven broad types (Ostrom 2005). This limitation of the IAD framework could be strengthened by the MSF, which explicitly considers the dynamics of multiple streams interacting and influencing a system. Seen in this light, there may be potential for combining the MSF with the IAD framework so that the latter provides the structure to define and explain the system to be analysed, and the former provides the approach that captures the multiple and dynamic influences that determine the interactions and structure of that situation. Combining frameworks/complementary approaches is a promising area for further research, and when used together in more than one study can be innovative.

Methods in relation to framing themes

The three framing themes discussed earlier illuminate the difficulties in city adaptation decision problems and also resonate with decision methods reviewed. For example, the theme of *complexity* and wickedness of problems is an important premise for the Foresight method's use of non-linear thinking and modelling. Systems concepts are employed in the Institutional Analysis and Development (IAD) framework, as well as work on "nexus" issues, for example. Apart from these examples, many other participatory methods also aim to deal with wicked problems using workshops, dialogues, modelling and mapping activities.

The theme of *decision-first* and the shift away from linear models is central to Structured Decision making (SDM). This method employs a circular model which emphasises rational/optimal decision making. It is applied in policy contexts, but it is not always clear how it includes upstream normative considerations. Theories of Collective Action also criticises simple models of human interaction; it investigates polycentric governance and provides examples showing how 'good' decisions are supported by institutional diversity and participation of multiple actors. Backcasting has a decision-first aspect (it is normative and can support various forms of stakeholder engagement) as does the Multiple Streams Framework (it details the roles of scientists, policy makers and other actors within different streams and how policy decisions emerge when coupling is achieved). The Adaptation Pathways method is also decision-first; it emphasises dynamic, iterative planning which will provide flexibility for selecting new options when circumstances change.

The theme of *risk framing* of decisions is also important to Structured Decision making (SDM). This method determines focal areas of uncertainty to include in the analysis and estimates the performance of each alternative. Similarly, RDS and Decision Scaling are both underpinned by the theory of planning/decision-making under deep uncertainty which is often associated with concepts of risk (see above *Uncertainty* section). RDS also uses assessment of probabilities, whereas Decision Scaling also reflects a context- (or decision-) first approach. Scenario Planning is another method concerned with

uncertainty. It can incorporate uncertainty into scenarios (eg. Moore et al., 2013) and use multiple scenarios to illustrate a range of potential futures. Indicator approaches also often have a risk framing (by including risk assessment information in indicators), and can support integrated climate risk management (Brooks and Fisher, 2014).

Although these themes are do not encompass all of the 12 selected methods, they clearly are already integrated into them to some degree. On the other hand, such emerging themes could be important to bear in mind when designing future Climate Services.

Links to climate services

There are also opportunities for decision methods, such as those reviewed here, to contribute to the expanding field of climate services. Climate services involve the timely production, tailoring, translation and transfer of climate information, ensuring that the most relevant knowledge is effectively communicated, easily accessed and interpreted, to develop policies and evaluate adaptation and mitigation strategies. Decision support is considered as an integral part of climate services (Miles et al. 2006; DeGaetano et al., 2010), and climate services ideally rely on the co-production of knowledge and draw on a variety of sources: ranging from scientific research and meteorological and climate models, to practical experience - an important aspect of FRACTAL.

However, as discussed at the outset, methods discussed here come from different disciplines, many have not been used in city contexts and this is also true of the climate services. It is interesting to note that the authors looked for examples of medium to long-term time scale Climate Services that would be relevant to decision-making processes in cities and city regions in Africa, but we could not find suitable candidates for review. In our view this gap in climate services design (using innovative decision methods at different stages in the decision-making support process) could be an important area that FRACTAL could address.

As such, it is suggested that the design of climate services could potentially be improved by a bottom-up consideration of decision methods reviewed here. Decision methods, when used in combination, can address some of the drawbacks identified of individual decision process and support methods and increase their relevance to city scale decisions.   In line with the objectives of FRACTAL, climate services involve not only the process of co-producing knowledge but also building the necessary skills and capacity of different user groups, both to guide the production and tailoring of the information (to meet context-specific needs) and to be able to apply this information to reduce the negative impacts of climate change and enhance benefits.

5. Conclusion and recommendations

The aim of the FRACTAL project in supporting decision makers to integrate climate and other scientific knowledge into climate-sensitive decisions has provided a frame for this review. We have found that whilst many of the methods have been applied to a very wide range of problem types, time scale, geographical scale, sectors and actors, many here have not been tested widely in African city decision-making contexts and may not fit with current decision-making frameworks, development priorities, or with political timescales. In addition, many methods are economically, technologically and time intensive and as noted, it is important to ensure resource-intensive analyses are only used where necessary, to ensure more targeted decision support. Whilst some methods embrace uncertainty, it is key to understand the sensitivity of the decision to climate information and to choose methods that do not introduce unnecessarily increased levels of uncertainty.

The learning outcomes from the methods reviewed are diverse and would require further investigation were they to be used as a basis on which to select a decision method. The technical capacity constraints of the decision analyst are key in the choice of method as this limits the use of climate data in decision-making processes and will directly affect which decision methods might be applied. Conceptual frameworks, though sensitive to cost and the institutional context are often more accessible in terms of the level of skill required to implement them compared to formal decision support methods. Psychosocial constraints (Jones et al., 2015) are an important factor in choosing a method, though even the most formal approaches can be tailored to include participatory components to enable more ownership and trust in the decision-making support process.

The use of multiple methods is a possible approach, although this should be balanced with the potentially increased costs (e.g. data collection), especially if stakeholders are involved, and the additional burden on them. Furthermore, the increased interdisciplinary breadth needed in the use of more than one method, may make it difficult to validate the results that the decision methods provide as each one incorporates different assumptions, concepts, and outlooks.

The review has assessed several methods for their suitability for application in a range of decision-making contexts. This has provided information that will be potentially useful for the next stages of the FRACTAL project. Although FRACTAL research questions have been explored in this review, such as the **limits of using climate information in different decision support methods** and **how the availability of climate information can influence the decision support method used**, other decision-making cluster and cross-cluster research questions remain. These may be addressed by applying some of the methods in this review. Some existing FRACTAL research questions and possible decision-making methods that might address them are:

1. How does the current *management and decision-making structure* across the system integrate or fail to integrate and thereby increase system vulnerability? *(Decision Scaling)*
2. What urban development decision making processes take place, what are the outcomes, and how are these integrated with climate change, water and energy sectors? How is climate change factored into decision-making processes on urban water and energy infrastructure development? *(Multiple Streams Framework)*
3. What are the physical/environmental/infrastructure systems involved in the supply of potable water to the city regions and what institutions are responsible for management and decision making? *(Processual Analysis)*
4. How has (or could) the pathway of decision-making evolved given the availability of climate information that is more applicable/context-relevant/accessible throughout the timeline of the project? *(Backcasting & Adaptation Pathways)*
5. How much uncertainty in climate information can cities tolerate? *(RDS, Decision Scaling)*

Once decision methods have been selected to help explore burning issues in each city, a further area that requires investigation is **how *changes* in decision-making in FRACTAL will be identified and tracked over time**. Whilst FRACTAL Embedded Researchers will be key to this process, it will also be important to capture such changes in the FRACTAL Monitoring, Evaluation and Learning framework.

The following are concrete next steps for FRACTAL:

1. The framing of this review has discussed the importance of a non-reductionist systems thinking approach (Ackoff, 1974) when dealing with "messy systems" and the ability of some conceptual frameworks to alleviate the resource-intensive nature of certain more formal methods, depending on their level of stakeholder engagement. In line with this, the Nexus cluster is developing a heuristic systems model using a participatory process of system diagramming or modelling with stakeholders. Levels of acceptable risk, decision trigger points and thresholds in this systems model could be usefully explored in upcoming Learning Labs using **scenario planning** approaches for example.

2. The combination of technical approaches of risk management with social dimensions of decision-making and governance, mean that the **adaptation pathways method** is particularly well suited to the transdisciplinary nature of the climate adaptation research that is being conducted in FRACTAL. As such, application of a range of **foresight** methods, such the **backcasting** and **adaptation pathways** methods may work well in combination with the Climate Narratives approach currently being undertaken in the Learning Labs (which starts with a hypothetical end situation, and maps from there to the current state, identifying critical events and actions).

3. The above methods could also be a precursor to the application of more formal methods such as **Decision Scaling** once an understanding of thresholds and

acceptable levels of risk are understood. Further participatory methods can be used in an iterative way to validate the results of these formal methods.

4. Policy discourse analysis is being undertaken in FRACTAL and Winkel and Leipold (2016) suggest complementarity and possible integration with the **Multiple Streams Framework**. This could be a useful consideration in FRACTAL in helping explore some of research questions above.

This review has suggested that a "typology of learning", selecting key dimensions that were reviewed to be graphically mapped, could be a useful next step. This could be linked to the learning potential identified in the companion FRACTAL working paper No. 4[9], which contains structured summaries of adaptation options across 14 African cities.

We have found a lack of (medium to long term time scale) Climate Services applicable to the urban African context. In our view innovative choices in decision methods could result in the better design of climate services and thus an important gap that FRACTAL can fill.

Finally, where decision methods reviewed in this study, have been applied to specific cases to appraise adaptation options, they will form part of online guidance illustrating which method is appropriate to apply in which context for different decision types, time scales, geographical scales, sectors and actors.

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      FRACTAL Deliverable 2.3.5: Inspiring climate action in African Cities. Practical options for resilient pathways. FRACTAL Working Paper No. 4. (Butterfield et al., forthcoming).

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