SUPPORTING CITY-SCALE DECISIONS IN THE CONTEXT OF CLIMATE CHANGE: THE CASE OF THE CITY OF CAPE TOWN

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INTRODUCTION

How do cities take effective decisions in the management of climate change impacts and in organising their functions, communities and economies so as to reduce emissions? This is not a trivial question. City of Cape Town officials, like their counterparts around the world, are being urged from all quarters to demonstrate pro-activity and leadership in the face of climate change (McKinsey 2009; Stern et al. 2006; UNEP 2010; WWF 2011). However, the process of taking the types of decisions that are effective in reducing climate change risk is poorly defined, prone to lobbying influence and unnerving for officials.

Climate change decisions, because they have far-reaching consequences, inevitably transcend science and become strategic and political; posing the right questions to the right people is as important as getting answers, and more important than getting correct answers to irrelevant questions. De Visser (2010) has identified Cape Town’s ‘overly restrictive’ interpretation of the Municipal Finance Management Act as an impediment to effective decision-making in the context of climate change. The reality is that even when the City’s legal framework permits action, many officials (particularly those who appreciate that climate change decisions require structural change with the potential for political and social consequences) find decision-making in the context of climate change difficult.[1] The inherent uncertainty with regard to future climates makes the guarantee of outcomes tenuous, while effective climate change responses can be costly in the short term. That the City's approach to addressing climate change varies across strategies, policies and departments adds further complications.

In spite of these pressures and complexities, City of Cape Town officials have grappled with which adaptation options to apply, and when, in the face of sea level rise, flooding and drought risk, fire, heat and wind stress, all of which have already been influenced by climate change and the ongoing urban development. It is in this context that the City's Climate Change Think Tank sought to develop a 'decision support framework'. The intention was to remove some of the vagaries of human nature that make for inconsistent decision-taking (Gardner 2009; Reason 1990).

Neo-classical economics assumes that individual preferences are fixed over time and that decisions are rational. Gardiner (2009), however, cites a number of cognitive and perception biases that influence personal and collective decisions: people under-estimate their chance of being killed by things that do not appear in the news; people are more confident about complex projections than simple projections; people tend to discount risks that are familiar and risks that are taken by a group of people relative to the same risk taken by an individual. Moreover, a growing literature suggests that human preferences change over time and vary under particular contextual and framing conditions (Dietz and Stern 1995; Norton et al. 1998; Slovic 1995). The net effect is to make some decision-making 'intuitions' highly irrational. These tendencies converge in relation to global warming – a risk that is unprecedented, complex, shared and which manifests only some time after the causal actions. Limiting the biases that arise from personal and circumstantial influences so as to create climate change decisions that are more replicable, defensible and coherent is one of the core aims of a decision support framework. This chapter presents some of the frameworks and tools that are available for decision-making in the context of climate change, and highlights how climate change questions should be structured so as to ensure reasonable outcomes and avoid common errors.

CLIMATE CHANGE DECISIONS AT THE CITY SCALE

The current rate of anthropogenic warming exceeds anything experienced in the past 120,000 years and certainly anything experienced since the formation of modern society. The result is a suite of difficult-to-predict biophysical and social consequences, and increased uncertainty. The City of Cape Town is already experiencing impacts that are consistent with a rapidly warming climate. Mean sea levels are higher than the long-term average (Brundrit 2008), precipitation events appear to have become more intense (Tadross et al. 2005), the frequency and intensity of 'Black South Easters' has increased in the past 20 years[2] (MacDeevit and Hewitson 2007) and a growing volume of anecdotal evidence supports the notion that the region will be exposed to more intense localized droughts, a greater frequency of fires, and crop stress caused by higher respiration rates (Midgley et al. 2005; Tadross et al. 2005).

In many respects the risk posed by global warming is unlike the conventional risks confronted by the City of Cape Town, and not only because it has the potential to inflict unprecedented damage. When the past no longer represents an adequate proxy for the future, this has profound implications for risk assessment, planning and decision-making (Downing et al. 2001; Lonsdale et al. 2008; Reynolds et al. 2007). The timing and extent of future climate impacts are part of what Downing and Dyszynski (2010) describe as an inherently unknowable future. It is possible to plan for this type of risk and uncertainty, but only if new approaches to decision-making are introduced. The systemic risks generated by climate change cannot be described, analyzed and controlled using traditional City management logic (Max-Neef 2005) or traditional actuarial risk management processes. The origins and impacts of climate change are embedded in complex socio-economic systems, and narrow technical definitions of the problem and solution tend only to add to policy dissonance. Appropriate climate change decision-making needs to be embedded in institutions that can continually absorb a wide range of different knowledge, react quickly, evaluate the impact of decisions and retract or adjust decisions as appropriate. None of this is possible without leadership, but a reliable and consistent method of taking climate change decisions can be considered part of the enabling environment for socio-economic development that South African legislation requires of local authorities (Constitution of the Republic of South Africa, Act No. 108 of 1996).

Whilst the approach to taking decisions and the outcomes of many decision need to change in the context of climate change, many of the actual decisions confronted by the City of Cape Town would exist if climate change was not happening, and are located within existing City planning processes. The City already takes energy planning decisions as part of its medium-term budgeting framework, and already takes decisions on how much money to allocate to disaster relief and the management of coastal protection infrastructure. In addition, a wide range of city-scale decisions affect the ability of residents to cope with flooding, fire and higher temperatures. The influence of climate change is to bring certain decisions forward in the planning process, increasing their priority, and to change the preferred option for certain decisions. Climate change further requires new considerations and information to be introduced into existing decision-making processes. Some of the narrow, short-sighted and technocratic decisions that have characterized the City of Cape Town's planning in the past have not only left the city with a problematic development legacy, but are inappropriate in preparing for climate change (Cullinan 2011; De Visser 2010).

It is a challenge to integrate climate change decisions, with all their peculiarity and complexity, into existing decision-making processes. The decision-making environment in Cape Town is shaped by party politics, a conservative interpretation of financial legislation and a heightened adherence to the extent of 'powers, functions and mandates' vested in local government, and in particular departments within this sphere of government (De Visser 2010; Shearing 2011). As climate change is teaching us, however, in the long run the physical laws of thermodynamics emerge as salient and binding. Unless governance and decision-making perspectives, with all their requisite plurality and flexibility, reflect the underlying biophysical reality, they are destined to fail.

The City of Cape Town's most effective 'policy pioneers' (Bulkeley et al. 2010) have a grounding in the natural and social sciences that allows them to understand the complex biophysical systems that define their responsibilities, but are equally skilled at engaging the City's various decision-making committees and the politics that influence these committees. It is the politicians in Cape Town who ultimately take planning decisions, but the City's policy pioneers use decision support instruments to motivate arguments to politicians for difficult decisions that they believe are in the public interest. This type of sequence of events is not unusual across other progressive cities, but there is an obvious danger in the approach. In first establishing the desired decision intervention and then applying a decision support framework to justify the decision, the potential is created for self-interested or misguided officials to abuse decision support instruments so as to motivate for poor decisions. As a means of mediating the prevailing approach to 'good' environmental decision-making and preventing the opportunistic use, and abuse, of decision support instruments, it is necessary that decision-makers engage in and understand the context and theory of climate change adaptation and mitigation and some theory of structured decision-making, before applying any one of the available instruments.

Conceptually, at least, all climate change decisions constitute part of a broadly defined process of climate change adaptation – responding to climate change – regardless of whether they focus on adaptation or on mitigation. Adaptation to climate variability and change is a socio-institutional process that involves assessing and responding to present and future impacts, planning to reduce the risk of adverse outcomes, and increasing adaptive capacity and resilience in responding to multiple stresses (Adger et al. 2005; Downing and Dyszynski 2010). The emphasis of decision-making under conditions of climate change is, accordingly, on the process. The goal is to be adapting well, not to be well adapted, and 'good enough' is a more likely ambition than notions of 'optimisation' or 'climate proofing'. A 'good enough' process is one in which the path taken to reach the decision reflects the available information and is defensible, auditable and repeatable.

Drawing on climate change adaptation theory it is possible to identify a number of principles of good decision-making process that, if applied, will ensure that decision support instruments have an internal coherence and are not abused:

- **Decisions should take the system into account:** Central to an appropriate understanding of climate change decisions is the perspective of the City as a system. A system, in its broadest definition, is a group of elements which interact to form a whole (Skyttner 2006; Weinberg 2001). Behaviour or properties of the system arise from this interaction. Climate change poses wide-ranging systemic risks, and the best solutions acknowledge as much of the affected system as possible. The best climate change solutions are those that remove risk from the system, as opposed to removing risk from a specific project or asset, and accordingly, in the context of climate change, decision-making processes should be capable of identifying and removing systemic risk.
- **The decision outcome must be implementable:** Decisions that ignore both the institutional complexity of implementation and the capacity available to act on decisions tend to lead to failed or perverse outcomes. While grandiose solutions may capture attention, the range of possible solutions should be limited to those that are within the remit and ability of the City of Cape Town to implement (Cullinan 2011).
- **Decision outcomes should be cost-effective:** Arguably all climate change responses are cost-effective, if it is understood that climate change threatens the existence of all civilization and economic activity. Some climate change responses are more cost-efficient than others, and decision-making processes should be able to distinguish between options based on their cost and benefit, align solutions to the available budget, resources and data, and give priority to those options that remove the greatest amount of risk for the least money.
- **Decision-making should include biological and institutional options:** There is a tendency in decision-making to focus on visible or tangible solutions – infrastructure- and technology-

intensive projects. Some of the best climate change solutions, however, involve the use and protection of biological systems as buffers, the changing of legislation and the creation of institutional capacity for early warning, or support for existing community coping efforts (Hallegatte 2009; Vatn and Bromley 1994). Decision-making processes that do not factor in the potential of environmental solutions because this value is not reflected on ledgers and balance sheets, not only truncate the range of suitable options but risk missing some of the most cost-effective solutions.

- **Decision-making processes should factor in the risk of mal-adaptation:** It is possible for climate change 'solutions' to inadvertently amplify risk, or to transfer risk to people who are less able to cope with it. Poorly designed sea walls can concentrate wave energy, crop improvement programmes can undermine rural livelihoods and revamped disaster management programmes can undermine local risk management solutions. Many climate change responses require the reallocation of either private or public funds, with the resultant opportunity cost. Decision-making processes that do not factor in the risk of mal-adaptation tend to be biased towards highly technical solutions, and often ignore the social origins and impacts of climate change risk that require redress before more technical solutions become effective.
- **Decision-making should draw on available information and science:** Adaptation, especially when it is 'anticipatory' (UNDP 2007), should necessarily make use of the available science to identify the nature and location of expected impacts. At the local scale, there are difficulties in interpreting the volumes of climate data that are available from various sources due to the spatial and temporal scales at which these data are reported (Ziervogel and Zermoglio 2009), but reflecting on local knowledge, local records and those

data that are applicable at the city scale can orient and improve the decision-making process.

Drawing the basic principles of climate change adaptation into climate change decisions grounds these decisions and reduces the scope for expedient or opportunistic use of decision support instruments. The same is true of decision support theory; structured decision-making (Merkhofer 1999) involves a number of pre-identified steps that are useful in understanding climate change decisions. In the context of climate change the decisions taken at each step can be continuously re-evaluated and adjusted, but the presence of a pre-agreed structure for the process is intended to add rigour, by restricting the tendency to focus prematurely on 'the answer' provided by the earliest parameterizations of a threat while data and alternative perspectives are still being collected (Kahneman and Tversky 2000). Structured decision-making includes the following stages:

- **Define decision type:** Decisions differ in terms of the scale at which they are taken, their intended outcome, the level of certainty and information that informs such decisions and the extent to which they are reversible. The structure and type of a decision, in many ways, informs the possible content of the decision, as illustrated by Ziervogel and Zermoglio (2010) (Figure 1).

[insert Figure 1 here]

1. **Type 1** – Type 1 decisions arise from a clear, single view of the available options. This does not imply that all potential drivers of a strategy are predictable, rather that the choices involved in achieving the desired outcome are predictable enough to identify a clear and confident decision. Point forecasts will offer precise enough insights in such cases for a clear

choice to be identified. This is characteristic of information-rich, slow-moving environments.

2. **Type 2** – Type 2 decisions offer a limited set of possible options and the added value of being able to pick the 'right' one, rather than a 'good enough' option.
3. **Type 3** – A bounded range of possible decisions characterizes type 3 options, but what distinguishes these from type 2 decisions is the lack of a single 'right' decision. Rather, the options are contingent upon a set of interrelated factors which cannot be determined with certainty, but are bounded by a set of relatively well defined conditions.
4. **Type 4** – Type 4 decision spaces fall within the category of deep uncertainty, that is, a limitless range of possible future outcomes with no predictive or analytic capacity available to predict the direction or magnitude of actions required. Under conditions of type 4 uncertainty, the challenges of 'acting now' versus 'wait and see' emerge, and decision makers need to select options that are robust against a full spectrum of potential choices.

- **Agree on a system boundary:** Selecting a suitable system boundary – the people, the area and the information that will be considered in taking the decision (Merkhofer 1999) – is one of the most important and, in the context of climate change, most difficult steps in structuring a decision. Both cities and the natural environment represent complex components of the same complex systems, and climate change tends to have wide-ranging impacts. Urban climate change decisions that fail to acknowledge systemic influences, or which do not stipulate how the system boundary has been defined, are prone to naivety. However, as social and environmental considerations are progressively included in city-scale decision-making and planning, so the level of uncertainty in the information increases to the point where it becomes difficult to draw any reasonable conclusions. Simplification of the system to which a decision applies is necessary both to facilitate analysis and as an acknowledgement that people have a limited capacity to assimilate data and to comprehend complexity. Simplification becomes a problem when the simplification itself predisposes the analysis towards certain outcomes,[3] truncates the options set so as to exclude potentially useful outcomes, or is simply inappropriate – as in cases where acknowledging complexity and intractability is central to the type of answer that is required.

Deciding which elements to include and exclude in the analysis involves normative choices that are best taken collaboratively. The system boundary needs to be broad enough to be representative, without the analysis becoming unmanageable. Given the importance of setting system boundaries for decision-making, there is a body of academic literature on how this is done in different fields (Dijkema and Reuter 1999; Parnell et al. 2010; Tillman et al. 1994).

- **Distinguish between public and private decisions:** Distinguishing between public (i.e. the City's) and private decisions forms part of establishing the decision system and its boundary; it is a critical part of the decision-making process but is often ignored. The City's primary responsibilities are the management of public assets and interests and the protection of people who are too poor to protect themselves. Identifying these areas of concern, and the ability of private decisions to influence public interests, is necessary in identifying who should be taking which decisions. Figure 2 illustrates what can happen when this distinction between private and public interests is not properly managed.

[Insert Figure 2 here]

- **Identify a decision sequence:** Most climate change responses involve a sequence of decisions. Establishing the order in which decisions should be confronted is important.

Decision trees can be useful in this regard. Some work has been done on assigning Bayesian probabilities to the threats and options created by climate change (Bromley 2005) but more simply, decision trees can illuminate options and their likely outcomes. Similarly, a sense of appropriate sequence can indicate those decisions that, if pursued, either rule out or retain the option of other decisions. Given the innate uncertainty introduced by climate change, retaining options represents a sensible principle in any management strategy. The building of a sea wall tends to rule out biological and institutional means of managing sea level rise, for example, while many of the same biological and institutional options do not exclude the building of a sea wall at a later stage if they prove inadequate in meeting the threat. Where sequencing assists, in this way, in identifying 'first' and 'last' resorts it can be useful in establishing a decision-making structure (Table 1).

[Insert Table 1 here]

- **Understand the decision goal:** The decision goal is related to the type of decision being taken (see above) and is the determinant of the choice of process and decision-making instrument. Establishing the goal can become a contested process in itself, but it can be generally assumed that the reduction of risk for people who are least able to cope with this risk by their own means should be central to City-level climate decisions.
- **Acknowledge the influence of different metrics and scales:** More specific goals are likely to emerge in the process of decision-making and can be incorporated at that time. It is not, however, common for climate change decisions to result in some form of social optimum, and optimizing is rarely suitable in the context of climate change, although often implicit in quantitative decision support tools. More realistically, climate change decision-making

involves a set of compromises and adjustments so as to reduce risk to an acceptable or ‘good enough’ level.

Many decision support instruments make use of quantitative approaches. Putting numbers to options can be useful in establishing objectivity in decision-making, providing criteria have consistent scales and numeric measures accurately capture expected performance. However, quantitative approaches can also be used to conceal information (Vatn and Bromley 1994). Füssel (2010) points out the algebraic complications, and common errors, that are incurred when an interval-scaled variable (such as average temperature) and an ordinal-scaled variable (such as a vulnerability index or competitiveness rank) are multiplied or divided. O’Neill (1993) distinguishes between ‘strong’ and ‘weak’ commensurability, where ‘strong’ involves a common cardinal scale between the numbers used to reflect evaluation dimensions, while ‘weak’ assumes only an ordinal scale on which different dimensions are gauged. Incommensurability does not imply incomparability. Instead, incommensurability allows for weak comparability between options without their performance being measured on the same cardinal scale. O’Neill’s approach is useful both in identifying a much overlooked problem with multiple quantitative criteria assessments and in proposing a way around this problem.

- **Weighting:** Many of the decision approaches involving multiple criteria require or assume the allocation of weights to different criteria. It is important to realize that weights are not merely numerical values associated with some notion of the relative importance of the criteria, and weighting needs to be allocated within the context of the scales of performance being considered in the decision problem. Various formalized approaches are available for extraction of weights from stakeholders in the context of the decision problem. The most commonly used methods for weight elicitation are the swing weighting method and methods based on cross-attribute indifference judgements (Basson 2004; Belton and Stewart 2002; Von Winterfeldt and Edwards 1986).

- **Recognize the influence of uncertainty:** Uncertainty represents a common area of miscommunication in climate change science and in the taking of climate change decisions. A systematic approach to determining when and where uncertainty matters represents an ongoing challenge and grounds for further research. Climate change increases uncertainty, but does not remove the need for planning or for decision-making. What climate change uncertainty may do is place a greater emphasis on knowledge accumulation and communication and on iterative and flexible decision outcomes, and caution against the lock-in of specific decisions and their associated infrastructure and technology (Kemp and Weehuizen 2005). In terms of structuring decisions, it is better to know that you don't know something than to assume that you do when you don't (or can't) know; in the context of climate uncertainty, decision-making stridency and notions of 'climate proofing' verge on hubris.

Structuring decisions is often time-consuming, with multiple days of workshops potentially being required to establish boundaries, weightings, sequences and uncertainty for a single decision. Structuring itself requires judgement as to whom and what should be included in the process. Failure to invest in decision-structuring, however, can predispose decision support instruments to nonsensical answers. Given the value of investment that is often at risk in climate change decisions, time invested upfront in decision-structuring is critical in ensuring suitable outcomes from decision support instruments, and necessary to generate trust in these outcomes.

MULTI-CRITERIA DECISION SUPPORT INSTRUMENTS

Three decision support instruments capable of considering multiple criteria are discussed below by way of illustration. Each has its own strengths and weaknesses. It is emphasized that the use of instruments does not remove the need for sage decision-takers. As the adage states, ‘No one can think of all the answers that come to fools.’ However, use of such tools within the context of the above discussion reduces the propensity for narrow or inappropriately technocratic application of decision support instruments, providing the basis for replicable and transparent evaluation of a wide array of information, and thus for taking informed and effective decisions.

Cost-benefit analysis

The conventional way of selecting climate adaptation options has involved cost-benefit analysis (Hallegatte 2009; McKinsey 2009; Stern et al. 2006; Van Ierland et al. 2007); the most beneficial options are considered to be those that reduce the greatest extent of risk (often expressed as a cost) for the least expense, and options tend to be ranked in terms of their relative cost to benefit. The appeal of cost-benefit approaches lies in their recognition that climate change is an issue of economic significance. Cost-benefit analysis resonates easily with the understanding that resources are constrained, that trade-offs and transactions are taking place already whether in formal markets or elsewhere, and that providing a decision logic that is easily understood by businesses and economists can provide a means of mobilizing effective resources in response to climate change.

Ideally the determination of costs and benefits should remain broad. ‘Benefits’ should include the value of the avoided risk that can be attributed to an intervention within the decision boundary. Distinction should be drawn between public and private costs and benefits, and benefits should include ecosystemic approaches to addressing climate change. Some of the most effective adaptation options have their foundation in the rehabilitation of ecosystems, and cost-benefit approaches should find ways of evaluating the socio-economic benefits of these options. Crucially, climate change tends to have both direct impacts and knock-on effects in markets and society. Benefit, in a cost-benefit analysis, should seek to capture the avoided impact of both direct and indirect impacts. For the sake of analytical rigour the time frame over which benefits and costs are calculated should be stipulated, as should the assumptions regarding the probability of an event occurring within this time frame, although this probability is often a matter of expert opinion more than quantitative analysis. Social discount rates that reflect uncertainty with regard to future events have a place in cost-benefit analysis, but should be clearly stipulated.

Not all environmental damage is attributable to climate change. In calculating the benefits of climate change adaptation it becomes necessary, but very difficult, to isolate that proportion of environmental damage that is ‘additional’ as a result of anthropogenic climate change. Stipulating how this was achieved permits accurate inference from the cost-benefit analysis. In a recent innovation, and as a means of addressing the innate difficulties in quantifying the economic benefits of avoided climate change damage, the City of Durban has applied a metric involving changes in the number of affected people and the degree to which they are affected as a proxy for ‘benefit’ (Cartwright et al. 2011).

‘Costs’ included in such analyses should reflect the full cost of taking and implementing decisions, including the opportunity cost of diverting funding from other programmes. Effective cost-benefit analysis includes the cost of institutional and policy change options amongst the suite of adaptation options that could be applied. That these options are not easily costed should not see them excluded from the analysis.

Good application of cost-benefit analysis should assist in selecting an appropriate sequence and timing of interventions. As the *Stern Review* pointed out, for example, judicious early mitigation responses save money relative to a ‘wait-and-see’ approach (Stern et al. 2006). There are, however, limitations to cost-benefit analysis and many adversaries of the approach, particularly in its application to environmental issues. The application of cost-benefit analysis can create a predisposition towards market-based solutions to environmental problems, with the assumption that these markets are adjusted for externalities (Ackerman and Gallagher 2005), but as George Monbiot points out, too frequently the market itself undermines the values and mentality required to address the complex origins of environmental damage: ‘As soon as something is measurable it becomes negotiable. Subject the natural world to cost-benefit analysis, and accountants and statisticians will decide which parts of it we can do without’ (Monbiot 2010). More technically, the full set of data required for definitive cost-benefit analysis, and particularly the quantification of a climate change damage function, is not available, and the application of costs and benefits to social or environmental goods that are not traded in formal markets at recognized prices can become contested. In addition, it can be difficult to accurately assess both cost and benefits *ex ante,* especially when the exact nature and timing of the climate change threat is unknown.

In addition, the conflation of risks into numbers can easily conceal information that could be useful in taking an informed decision (Vatn and Bromley 1994).[4] For example, where options are treated as discrete and assigned discrete prices, this should not conceal the possibility of implementing joint options that are frequently the most effective. Perhaps most critically, cost-benefit analysis tends to suggest levels of precision and certainty in decision-making that cannot be justified in the context of climate change impacts. Certainty itself is problematic in the face of the wide range of inherently difficult-to-predict contingencies generated by climate change, but equally problematic is the assumption that the same levels of certainty apply to different events and solutions. In reality very different levels of certainty apply to impacts and the likelihood of decisions to be effective in reducing these impacts, and distinguishing and prioritizing decisions based on the degree of certainty that they offer may itself be desirable. In this sense using cost-benefit analysis to arrive at some form of 'financial optimum' in the face of climate change is inappropriate. As McKinsey point out, '...[cost-benefit analysis] has an important yet narrow objective: to present a practical framework that national and local decision-makers can use to quantify the risk that climate poses to their economies, and to minimize the cost of adapting to that risk' (McKinsey 2009: 14); and even that may prove difficult.

In an exploratory application of cost-benefit analysis to climate change adaptation (McKinsey 2009; see Figure 3) the researchers were caught by many of the pitfalls highlighted above, but did demonstrate that cost-benefit analysis can be useful in distinguishing between climate change adaptation measures that:

- are cost-negative and therefore create savings, many of which are 'no regret' options;
- present economic benefits that outweigh the cost of implementation, and should be considered a prudent investment;

- cost more than they save but may be deemed necessary to protect human life, heritage or biodiversity.

Where cost-benefit analysis can identify options that reduce climate change risk or offer protection from climate change while simultaneously saving money, it can be useful in indicating the most appropriate point of departure for a city such as Cape Town.

[Insert Figure 3 here]

Value function analysis

Value function methods are used to systematically address both information about stakeholders' preferences for different levels of performance in terms of each criterion and information about the relative importance of the criteria – that is, criteria weighting.

Once the problem has been suitably structured, the value function approach is used to compare options and come up with a single score for each alternative. Preference for a particular option is recorded through the definition of partial value functions for each criterion. The value function is used to map performance in a particular criterion onto a zero-one scale. In constructing the value functions, it is necessary to decide on the scale of the x-axis (in other words what maps onto a '0' and what maps onto a '1' score) and the shape of the value function. Examples of selected value functions are shown in Figure 4.

[Insert Figure 4 here]

Both the scale of the *x*-axis and the value function shape reflect aspects of stakeholder preferences. With respect to the *x*-axis scale, a choice is required as to what represents the 'worst' and 'best' values. These may be selected as the worst and best of the alternatives being considered ('local scales'), or may be contextualized in terms of the system in which the alternatives exist ('global scales'). For example, the range may be selected as the worst and best of all available technologies in the market, or the worst and best of all possible solutions to a particular decision.

In terms of value function shape, a linear value function suggests that stakeholders have no preferences across the range of performance being considered on the *x*-axis – so an increase in one unit of performance at the bottom end of the scale has the same value at the top end of the scale. A convex value function suggests that a unit increase at the lower end of the range of performance has more value than a unit increase at the upper end. A concave value function suggests the opposite.

Value functions are typically established through structured facilitated workshops with stakeholders using well established techniques. The relative importance of each criterion is then captured by assigning a weight to that criterion. Weighting has to be done in context – weights cannot be assigned outside of an understanding of the relative performance of alternatives being considered. Weighting, similarly, is ascertained through workshop techniques with stakeholders from a range of disciplines and backgrounds. It may be the case that determining the shapes of value functions, the values used on axes and the weighting takes place as part of the decision-structuring exercise that precedes the actual decision-taking, but the process of ascribing weights and arriving at axis values and value function shapes can be useful in identifying and sharing priorities and establishing interdisciplinary capacity.

Once the value scores for each alternative related to each criterion have been determined, and the weights allocated to each criterion have been ascertained, the overall scoring of the alternative is calculated using the following equation:

$$V(a) = \sum_{j=1}^{n} w_j v_j(a)$$

- where V(a) is the value score of alternative a,
- w_j is the weight given to criterion j,
- and $v_j(a)$ is the value score (between 0 and 1) of alternative ‘a’ in criterion j.

The value score provides a representation of the relative performance of the different alternatives under consideration. However, given that there is uncertainty in all of the data – including both the scores and the weighting – the results should never be taken as single-point values. Uncertainties can be propagated throughout the decision-making process to determine whether they have a significant impact on the ultimate decision outcome.

Structuring value function decisions is often time-consuming, with multiple days of workshops potentially being required to establish the shapes of value functions and weights applied to a single decision. If consensus cannot be reached between stakeholders on any of the aspects of either problem-structuring or analysis such as criteria for inclusion, performance scores or weighting, then the entire analysis can be conducted in parallel with different input values to ascertain whether vastly different results are obtained. It is possible for the same conclusion to be reached by a number of different routes, which itself can be affirming of the outcome. If consensus cannot initially be reached, the decision-makers need to look into whether there are any trade-offs or compensations which can ultimately result in a greater degree of consensus around a preferred option. Once value functions have been suitably structured, the actual decision-making process can be a quick one.

Analytical hierarchical processing

Analytical hierarchical processing (AHP) has been developed in an attempt to remove human error and bias from decisions that incorporate both qualitative and quantitative data. Rather than prescribing a correct decision, AHP helps decision-makers find the decision that best suits their needs and their understanding of the problem, as defined in the structuring process (Ozcan and Musaoglu 2010). The approach is based on the '[i]nnate human ability to make sound judgments about simple problems' (see Saaty 1980)[5] and accordingly tries to reduce larger, more complex decisions to a range of smaller, simpler decisions in a systematic manner that permits inference regarding the overarching, larger decision. For example, people generally make decisions they are comfortable with in choosing between two different menu items, but often express regret when confronted by the full buffet. By reducing the choice from the buffet to a series of choices between items on the buffet, and then using these answers to compile a hierarchy of preferences, AHP allows decision makers to process complex decisions. AHP is especially suitable for complex decisions which involve the comparison of decision elements that are difficult to quantify, or are not directly comparable – social and environmental impacts, for example. AHP requires the decision maker to structure the decision according to a hierarchy of criteria and sub-criteria cascading from the decision objective or goal. Firstly, a hierarchy (ranking) of decision elements (see the example in Figure 5) is built. These consist of the Goal, the Criteria to be applied, and the various Alternatives or Options.

[Insert Figure 5 here]

Decision makers are required to develop priorities to differentiate the importance of the criteria relative to each other. Although the matrix algebra required to solve for the variables is straightforward, increasing the number of criteria and options increases the size of the matrices and makes the calculations laborious. There are a number of software packages that can simplify the process and remove the need for manual processes.

AHP is particularly useful where there are limited or no objective data on which to base a decision, and this may be especially relevant in dealing with issues of climate change. The ability to compare political considerations with issues of cost and risk in a systematic manner makes this approach useful in the multiple-criteria context.

That is not to suggest that AHP is immune from abuse or misapplication. AHP often involves redundant comparisons to improve validity, recognizing that participants may not have perfect data, may be uncertain or may make poor judgements in some of the comparisons (Huo and Saito 2008). This redundancy leads to multiple comparisons that may sometimes result in numerical inconsistencies. For example, if outcome A is deemed as preferable as outcome B, then the pairwise judgements for A and B to any other outcome should be identical. When this does not transpire in the judgement process, inconsistency can arise. Perhaps the greatest threat involves the use of a software program to create seemingly robust and incontestable decisions. For many, the use of software will conceal the underlying value judgements on which the answers produced by the AHP software depend. Whilst it is possible to accommodate a wide range of disciplines and opinions in the construction of decisons for AHP, the instrument can facilitate expediency and undermine the type of transdisciplinary capacity that is considered critical in addressing climate change risks at the city scale.

THE PROCESS OF INTERROGATING MULTIPLE CRITERIA

The process of structuring decisions and evaluating multiple criteria can be useful in its own right, regardless of the results produced. This is particularly the case where the decision-structuring and decision-making process involves collaboration between groups of people that do not typically interact. Where the process of defining the system boundary, allocating weights or taking actual decisions involves interrogating options, interdisciplinary consensus and capacity can emerge. This capacity can be useful in creating awareness and in increasing ability to take future decisions.

In applying a multi-criteria approach to climate adaptation in the eThekwini Municipality (Durban), municipal officials met in workshops to evaluate a number of pre-identified climate change options in terms of the following criteria:

- the extent to which the option would be expected to reduce climate change risk. Although it is acknowledged that it can be difficult to know this precisely in advance, options that are perceived to reduce the greatest amount of risk are obviously more desirable;
- ancillary benefits realized by undertaking the activities. Many of the interventions pursued

under the remit of adaptation would be worth undertaking even if climate change were not taking place, because they incorporate sustainable development benefits;

- the extent to which the option is reversible or flexible, should the nature of climate change turn out to be different from that projected. Reversibility and flexibility come at a premium, given the uncertainty over future climate impacts;
- the extent to which the option either mitigates or exacerbates the release of further greenhouse gases;
- the extent to which the option permits complementary options and reduces or retains the set of options available for responding to climate impacts. The understanding is that those interventions that retain options are more desirable;
- the ease with which an option can be implemented and the related likelihood of it being successfully implemented;
- the institutional complexity related to implementation of the intervention with regard to municipal processes and procedures and the number of departments requiring input;
- the cost : benefit ratio of the intervention. No detailed analysis was undertaken; rather a broad judgement was made with regard to ‘high cost : low benefit’ and ‘high benefit : low cost’ of options;
- the risk of an intervention inadvertently constituting ‘mal-adaptation’ through ill-considered implementation. This criterion is based on the understanding that some options are safer, in terms of unintended adverse impacts, than others.

Participants were asked to score the options using a scale of 1–3 to reflect least desirable to most desirable. The value of the exercise was not in the quantitative results that emerged – the numerical values that emerged were almost meaningless – but in the process of getting people from different disciplines to consider parameters that they do not usually take into account in their day-to-day decision-making (Hallegatte 2009;Van Ierland et al. 2007). Decision takers were forced to consider a more complex city system than they were accustomed to, and in so doing climate change became the platform for an unprecedented and extremely integrated decision-making process. Climate change adaptation theory emphasizes the ability to respond to a wide range of inherently difficult-to-predict contingencies, and the importance of 'socio-institutional learning' (Downing et al. 2001), monitoring, reflexive institutions, ongoing decision-making and iterative progress, all of which can be facilitated by the process of exploring decision structure and decision outcomes collaboratively (Kemp and Weehuizen 2005).

CONCLUSION

Decision support instruments do not provide a surrogate for good decision-making, and do not replace good decision makers or the importance of asking the right questions. But they can assist in creating consistency, rigour and trust in the decision-making process. Where effectively applied, these instruments form an important component of climate change management and can also be useful in creating the type of human and institutional capacity that is ultimately required to take the range of complex decisions that will be necessitated by climate change.

It is critical that the use of decision support instruments take place within the broad context of understanding climate change and understanding decision support theory. Where this is not the case such instruments are easily abused.

All climate change decisions involve multiple criteria. The merits and limitations of cost-benefit analysis, value function analysis and AHP are presented here as just some of the decision support instruments that could find wider application in the context of climate change decisions within the City of Cape Town, and particularly within the special focus committees that take decisions in the City.

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[1] In this discussion 'the City' refers to the local government structures of a city, for example the City of Cape Town, and 'the city' refers to Cape Town itself.

[2] 'Black South-Easter' refers to the conditions created by a cut-off low pressure system over the southern Cape in association with a south Atlantic high pressure system. The tight pressure gradients cause very strong winds and rain over the Cape.

[3] For example, considering only technology-related challenges in the system will result in technological fixes to that system – and may miss out on opportunities for behavioural change or societal restructuring.

[4] In this definitive piece entitled 'Choices without Prices without Apologies' the authors highlight the pitfalls of conflating information in metrics.

[5] The text quoted here is from a lecture by Thomas L. Saaty, 'How to make a decision: the Analytical Hierarchy Process' delivered at the University of Pittsburgh.