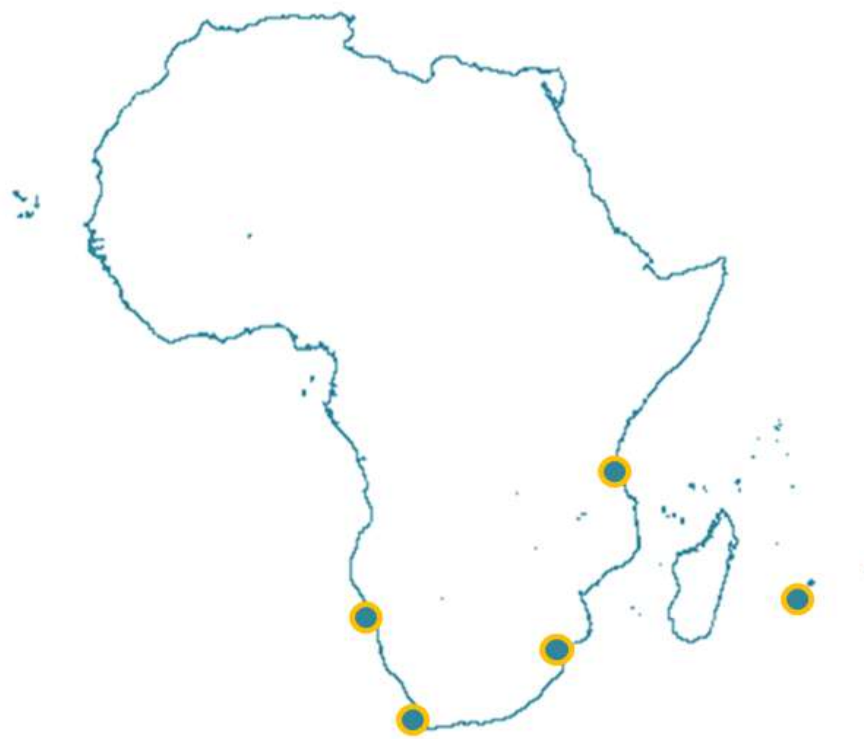
Sub-Saharan African Cities:
A Five-City Network to Pioneer Climate Adaptation through Participatory Research and Local Action

Risk Concept



ICLEI Local Governments for Sustainability

CITIES ADAPT

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Preamble

The official mandate of ICLEI Africa is to work with local authorities towards sustainable development in Sub-Saharan Africa. The “Five City Network” project for which this report was written aims to meet some of the “knowledge, capacity and network gaps” that hinder the ability to plan for and adapt to climate change in five African cities.

The first phase of the project aimed to, “identify [climate change] risks and impacts at the local level”. It is against this context that this paper seeks to produce a consistent and in-depth analysis of the concept of climate change risk and management that can be applied at the local scale.

1. Introduction

Accounting firms are not usually prone to exaggeration or the melodramatic. So when the international accountants Ernst and Young ranked climate change second of all risks confronted by governments and the public sector globally, it is probably worth taking note (Ernst & Young, 2011). What exactly is meant by climate change risk? The use of risk in comparing different threats represents an implicit attempt to prioritise. For this prioritisation to be useful, risk has to be applied in a consistent and comprehensive manner.

Risk, as applied in this analysis, refers to threats to people and the things they value (following Kasperson and Kasperson, 2001). Risk is a part of everyday life but most people are risk averse and the reduction of risk is assumed to be a common good.

Between 1970 and 2004 the global emission of greenhouse gases increased on average by 1.6 per cent per annum, most of which was due to population and economic growth (Rogner *et al*., 2007). Atmospheric concentrations of carbon dioxide have risen from 280 parts per million prior to the industrial revolution to 400 parts per million in 2012. The corresponding increase in atmospheric and ocean temperatures and altered climate system is being called the greatest risk confronting humanity (Stern *et al.*, 2006) and has been compared to a terrorist attack (King, 2004; Tahir and Robinson, 2011), global water scarcity (Iglesias *et al.,* 2007; Orr *et al.,* 2009; Krechowicz and Fernando, 2009), the current financial crises (WEF, 2011) and the HIV pandemic (Barkemayer, 2010).

Risk is both a psychological construct and an economic cost, and as such it links: i) the finance sector; ii) the material economy; and iii) social and institutional theory (including behavioural economics). As such it spans the full range of literatures and vested interests that define our understanding of climate change and its “solutions”. Most people have an intuitive understanding of risk and risk management – and its familiarity is central to its conceptual utility. In addition, risk has fewer political and ideological connotations than concepts such as “vulnerability”, “resilience” and “sustainability”. The growing use of risk in climate analyses, then, should be welcomed (McKinsey, 2009; Jones & Preston, 2010; Yoh *et al*., 2011, Dietz, 2011). The reality, however, is that many utterances on climate change risk do not stand up to scrutiny (Jones, 2001; Carter *et al*, 2007, Jones, 2010) and because the concept is both familiar and widely-used, the manner in which it is applied varies greatly. The risks of a terror attack and climate change share the common feature that it is difficult to assign a probability to their occurrence, but in most other ways they are not comparable.

This paper expounds key features of climate change risk with the intention of supporting effective and systematic measures of climate risk reduction at the city-scale.

2. The unprecedented nature of climate risk

All risk is a function of perceptions and as such is subjective, but climate change risk is particularly subjective. Climate change risk is also particularly multi-dimensional; it manifests via multiple pathways, generating what Leichenko & O'Brien (2002) refer to as "multiple exposures" over extended periods of time.

An array of estimates put the cost of climate change for developing countries between US $4 billion and US $109 billion per annum over the next twenty years (Parry *et al.,* 2009). The range is indicative of the uncertainty over how a generally warming atmosphere will translate into impacts and the difficulty in quantifying these impacts in monetary terms This innate uncertainty is a central attribute of climate change risk. Aggregated cost estimates provide a potential proxy of climate change risk, but they also conceal important information on the nature of this risk at the local level.

Climate change risk is unusual and unprecedented in a number of very specific ways and this makes it difficult to manage. Diakoulaki & Grafakos (2004) point out, "People do not have well-ordered preferences for unfamiliar objects ……" and as a result conventional actuarial approaches to quantifying climate change risk tend not to produce satisfactory results. Similarly, conventional pollution economics approaches involving markets for risks and price disincentives to polluters, tend to offer incomplete solutions (Edenhofer *et al.,* 2011).

Understanding the specific and peculiar dynamics of climate change risk is important in assessing the threat of climate change, and to the formulation of appropriate risk management approaches. These dynamics include:

- The lag between emissions and the manifestation of climate risks in the form of impacts, complicates and frustrates efforts to mobilise timely risk reduction responses. The world is already almost 0.8°C warmer than the long-term average (IPCC, 2007) but few people realise that even if emissions stabilise at their current level (which is highly unlikely, given the increasing trend) atmospheric temperature is likely to reach 2.2°C above the long-term mean (Parry, 2009[1]). The lags between emissions, temperature increases and associated impacts is attributable to the energy transfer between the atmosphere, the oceans and land and the ability of the ocean to retain CO_2 over thousands of years (Archer, 2005). The implication is that by the time climate change impacts are considered serious enough to warrant definitive intervention, it may be too late. At the same time, mobilising action against a risk that will only manifest at some unknown date in the future, is not something that most societies do well. On the contrary, the ability to react urgently to immediate danger (predators and dangerous circumstances) and to discount future risks has proven an important survival strategy up until now (Gardner, 2009) but is acutely inappropriate in the context of climate change. The thermo-dynamics behind climate change generate a risk that people are poorly equipped to address.

- Climate change is a global phenomenon caused by individual actions. No single individual or country can remove climate change risk in isolation, necessitating a cooperative risk management strategy. Deciding what should be done about climate change and the extent of current sacrifice (or cost) that should be made to secure a solution, is a function of how severe the risk is understood to be. That understanding, however, depends on individual value systems, including how individuals value the future, and it varies across individuals. As Kenneth Arrow has shown, there is no consistent means of aggregating individual preferences into a single definitive social policy that reflects the preferences of those individuals (Arrow, 1963). The difficulty in garnering the extent of required cooperation and collaboration and in apportioning responsibility is evident in attempts to reach the required global consensus on a solution. The institutional economics, and resulting "market failures" (Stern *et al.*, 2006) that define responses to climate change compound the problems created by the thermo-dynamics and unfamiliar attributes to this risk.

[1] Martin Parry IPCC Working Group 2, speaking at the Zurich gathering of the "Economics of Climate Change", Ruschlikon Centre, July 2009.

- Climate change is accompanied by high levels of uncertainty about: i) the probability of events; ii) the nature and impact of events (what Walker *et al.* (2011) called "predictive uncertainty): and iii) the socio-institutional responses to events (Lempert and Schlesinger, 2000; Willows and Connell, 2003; Kandlikar *et al*., 2005). In theory, "risk" refers to outcomes for which the probabilities are known and "uncertainty" to outcomes for which the probabilities are unknown (Tversky and Kahneman, 1992; Camerer and Weber, 1992). In the context of climate change risk, however, outcomes are both risky and uncertain, and much of the risk is itself a product of uncertainty (Willows and Connell, 2003). For example, the risk of disasters can be reduced by increasing the accuracy of climate prediction (Tebaldi and Knutti, 2007) but the climate systems that are being perturbed by trapped irradiation are complex and it is not possible to predict exactly how global warming will manifest in altered weather patterns, and even less possible to anticipate how people and institutions will respond to altered (and most probably more hostile) weather (Dessai *et al.,* 2009). The inability to establish a definitive "damage-cost function"[2] or to define climate change risk in a strict actuarial sense, renders efforts to mobilise financial and other resources subject to conjecture and contestation. Cities in particular find it difficult to manage for uncertainty or to plan for urban futures that are distinctly different from their pasts.

- Uncertainty and the associated climate risk is further amplified by the possibility that the 9 billion tons of CO_2 that is currently released into the atmosphere annually from the burning of fossil fuels will end up being only a small portion of annual global emissions. As warming releases greenhouse gases from what have, until recently, been considered long term vaults in the permafrost, soil and ocean, there is the possibility of "run-away climate change" – a situation that would see temperatures accelerate towards 5°C or 6°C above pre-industrial levels and beyond the control of human intervention. It is not possible to predict where these "tipping points" (Lenton *et al.,* 2008) will occur, but there is growing concern around the altering of the West African monsoon systems, the Greenland and West Antarctic ice-sheets, the El Nino/ Southern Oscillation, thermohaline circulation in the Northern Atlantic (the system that drives ocean currents which themselves play a role in thermoregulation) and the interactions between

[2] "Damage-cost function" in economic and insurance parlance, refers to the costs of climate change impacts as a function of temperature increases.

CO_2 sequestrated in forests and tundra and atmospheric temperature (Hansen, 2009, Rockstrom et al, 2011). The possibility of radical and sudden change in these large and important systems is near-impossible to model (Parry *et al.*, 1996) and difficult to manage, particularly at the local scale.

- The accelerating emission of greenhouse gases since the 1850s has its origins deep within – and across - the socio-economic structures that underpin notions of development and progress. Tracing and attributing the origins of the risk is complex and easily contested, as is the allocating and enforcing of responsibility for remedial action. As a result, changing the structural socio-economic origins of climate change requires new types of collaboration and co-operation and is difficult. This is particularly so when the change is considered to have punitive consequences on development and progress, and therefore involves sacrifice.

- The world in 2012 continues to exist in the wake of a severe financial crisis. While this crisis has slowed economic growth and emissions in most countries, it has also undermined the multilateralism and flow of investment into the technologies and process that will ultimately reduce climate change risk. Analysts agree that the short-term offers a once-off opportunity to reconfigure the global economy so as to reduce emissions and build adaptive capacity (Stern *et al*., 2006; Greenpeace, 2008[3]; Heal, 2009). The technological solutions to climate change require immediate large investments in long-lived capital. That the current period is defined by low levels of investment, and a new wave of economic polarisation between developed and developing countries is problematic.

It is the particular and peculiar nature of climate change risk that underpins many aspects of the repeated failed attempts to reach a binding and effective international agreement to reduce this risk. Cities are already experiencing climate change impacts and will ultimately depend on such an agreement. In a further attempt to estimate the cost of climate change, the World Bank recently calculated the cost of adapting to a 2°C warmer world by 2050 to be between US $70 – 100 billion per annum, with 80 per cent of this cost being borne by cities in developing countries (World Bank, 2010).

[3] In January 2008 Greenpeace scientists estimated that there remained “100 months to save the planet”.

Confronted with the increasing risks and the possibility of an inadequate globally-negotiated response to climate change, many cities (including the five African cities that form the focus of this project) are managing their local climate change risks proactively. Indeed cities are becoming the centres of climate change action (Bicknell *et al.,* 2009; Bulkeley *et al.*, 2010; ARUP, 2011). This study has confirmed the findings of Walker *et al* (2011); beginning an effort to manage climate change can constitute the most difficult step and typically requires the input of what Walker *et al* call "long-term institutions" (such as ICLEI) in order to transcend short-term priorities and immediate benefits.

In the five African cities that constitute the focus of this study, managing climate change risk is part of a much larger urban challenge that includes extending services, providing houses and infrastructure and ensuring access to a safe and healthy environment across generations. The challenge, and opportunity, is to address these issues simultaneously. For cities that get this right, there is the potential to not only safeguard their assets and inhabitants, but to advance local development and competitiveness and to draw down some of the finance and donor support that is emerging for countries and municipalities that are seen to be pro-active against climate change.[4]

3. Disaggregating climate change risk

That climate change risk is understood to be unprecedented and particularly problematic represents a necessary point of departure, but it does not reveal much about how the concept of climate risk might be useful in managing climate change in African cities.

Risk is a human construct – a function of personal perceptions. That the concept is familiar to a "broad church" of stakeholders is constructive. So too is the ability of risk, as a concept, to allow people and institutions to draw connections between climate events and their well-being. This ability to connect events with individual well-being is crucial if climate change risk management is understood to be a "socio-institutional process" (Downing and Dyszynski, 2010). The same feature, however, introduces

[4] The Adaptation Fund http://www.adaptation-fund.org/ is just one of the newly launched resources available to developing countries looking to address climate change. The fund draws on 2 % of CDM transactions and is disbursed through National Implementing Entities or Multilateral Implementing Entities. In Africa, only South Africa, Senegal and Benin have registered National Implementing Agencies as of September 2011. The Special Climate Change Fund (SCCF) and the Least Developed Country Fund (LDCF) are among the other UNFCCC resources available to African countries as a complement to existing Official Development Assistance (ODA). The Green Climate Fund was launched at COP17 in Durban and aims to distribute US $100 billion per annum when fully resourced.

personal biases on the severity of the risk. Levitt and Dubner (2005) compare the deaths caused by kitchen germs and Bovine spongiform encephalopathy (BSE) disease, and domestic swimming pools and privately-owned weapons respectively, and quote Peter Sandman[5] in noting that the "risks that scare people and the risks that kill people are very different".

As with any risk – and particularly the highly subjective climate change risks that impact upon the five cities in this study – the insight required for effective responses is supported by detailing "risk of what", "risk for whom" and "risk when".

3.1 Risk of what:

What is meant by climate change risk? Climate cannot be observed or experienced. It is only the manifestation of climate in weather that is experienced. Similarly, nobody will have "climate change" recorded as the cause of their death, and yet through its impacts the anthropogenically perturbed climate system is already causing deaths and inflicting economic losses, and has the potential to impose increasing harm (Stern *et al.*, 2006). What is it, then, that is considered risky? Growing concentrations of greenhouse gases, warmer mean temperatures, higher maximum temperatures, the increased frequency of "natural" disasters or the increased probability of death? Approaches to risk management will vary depending on the perceived "threat".

There are no definitive answers to these questions. Whilst initially it may be a single issue such as sea-level rise, flooding or increased temperature that focuses attention on the need for intervention, in most African cities climate change manifests through a complex combination of slow changes and acute impacts (Table 1). What is critical is that analyses need to be explicit about the type and location of the climate change impacts that they are responding to, and the timeframes over which they seek to study these impacts and mobilise a response. At the city-scale, vague and generic references to climate change risk can be unhelpful and can confound attempts to mobilise appropriate response efforts (Grubler and Nakicenovic, 2001).

Table 1: Climate impacts in the five cities network

[5] See http://psandman.com/index.htm.

City	Focus impacts	Known indirect impacts
Cape Town/ Mamre	Temperature	Heat stress and winter ailments. Low labour productivity. Crop and livestock losses. Fire damage. Algal blooms on main water resources. Heat damage to bitumen roads. Increasing use of scarce energy for cooling and refrigeration.
Dar es Salaam	Extended drought and more intense flooding	Damage to infrastructure and mobility. Loss of pasture and crops. Food insecurity. Lack of electricity from hydro-electric power sources. Contamination of groundwater. Water use conflicts. Mudslides and inundation damage transport routes. Increasing urbanisation places strain on city infrastructure.
Maputo	Coastal and terrestrial flooding	Implications for sanitation sector. Power outages for Mozal Smelter. Loss of tourism revenue. Saline intrusion of aquifers. Damage to transport infrastructure.
Port Louis	Wind (increasing intensity of tropical cyclones) and flooding	Loss of tourism. Water quality impacts. Damage to infrastructure. Damage to energy infrastructure and power outages. Difficulties in transporting goods and people. Siltation of water courses. Health impacts from contaminated water.
Walvis Bay	Sea- level rise and flooding	Water quality and contaminated fish exports. Loss of harbour industries including oil imports. Saline intrusion of groundwater in the Kusieb Valley. Threats to the road between Swakopmund and Walvis Bay, with implications for the movement of goods and people.

The conventional approach to estimating risk from environmental catastrophes is to focus on the easily identifiable economic and social impacts (Willows and Connell, 2003). Typically these take the form of damage estimates: losses of infrastructure, losses to agriculture and occasionally losses of human life. The approach – of which there are many examples – is problematic on a number of accounts:

- It assumes a static social state in which people do not adapt in any way – what Schneider (1997) term the "dumb farmer" assumption, but which is not unique to agriculture. We know that people do, with varying degrees of capacity and success, seek to anticipate and respond to changed climate conditions so as to reduce their risk (Rosenberg, 1992; Smit and Lenhard, 1996). The IPCC (2007) itself defines adaptation as "the adjustment in natural or human systems ....which moderates harm or exploits beneficial opportunities". Ignoring adaptation fails to distinguish between potential and net impacts, and tends to over-report climate change risk. Indeed understanding how individuals and communities cope with the risk of death and material losses arising from climate change, is a critical component of formal and informal risk management strategies (Harrison *et al.,* 1998; Adams *et al.,* 1999). Factoring in adaptation, and differential capacity for adaptation, further allows the identification of opportunities that might arise from effective climate change adaptation, and while these are sometimes inflated, the principle that adaptation is a reality, even in the poorest of communities, remains important. This is not to suggest that "self-help" and coping are substitutes for access to public safety nets and commercially based insurance, but only that ignoring all forms of adaptation (including self-help and coping) over-reports the risk.

- It assumes a monotonically increasing damage function (see Figure 2 for example) in which the harm caused by climate change increases proportionately with mean atmospheric temperature, which itself increases linearly as the concentration of greenhouse gases in the atmosphere increases. The reality is that damaging events are often stochastic, non-linear and difficult to predict, making analysis and projections almost intractable as explained with reference to tipping points above (Dietz, 2011). Sea-level rise could have almost no impact on the Walvis Bay harbour and adjacent activities until the sand spit that protects the harbour is breached, at which point it will have dramatic and sudden impacts.

- It focuses on visual impacts. The common notion of a climate change risk involves images of floods, windstorms and droughts; events that are readily identifiable as "disasters" and confined to a particular location at a particular time (see Brauner, 2002; Warner *et al*., 2009). Many climate change risks are, however, not easily captured in this manner. Increases in temperature (particularly night temperature) alter plant respiration rates relative to photosynthesis progressively reducing crop yields (Hansen et al., 1994; IPCC, 2001), rising river temperatures increases the microbe count in this water, increased wind speeds increases the energy of wind-driven chop on the ocean and raises the amount of money required to maintain sea-defences. These types of impacts tend to manifest over longer periods and often over wider geographical ranges. Estimating the extent of the damage can be difficult and attributing this damage to climate change even more so – the longer the period of impact the greater the influence of confounding (non-climate) influences. The increasing frequency and intensity of these impacts is, at least in part, attributable to climate change and should be included in analyses of climate change risk.

- It ignores indirect impacts. Climate change has its origins in complex socio-economic systems and its impacts are felt throughout these systems. Most analyses focus on short-term physical impacts, but these impacts have knock-on effects that present risks of their own – especially once social and institutional impacts are included (see Figure 1). The climate change threats identified in the five African cities that form the focus of this study have both direct and indirect impacts. For example, drought in Dar es Salaam causes loss of life and agricultural value, but also disrupts the supply of hydro-electric power to the city which itself causes widespread harm. Similarly, disaster risk management efforts in the wake of Maputo floods in the 1990s and early-2000's diverted fiscal resources that could have been spent on the countries growth and development. In Mozambique, Tanzania and Namibia floods and famines (the intensity and frequency of which is increasing under perturbed climates in certain regions) accelerate urbanisation and compound the urban challenges faced in Maputo, Dar es Salaam and Walvis Bay respectively. In the face of these amplified challenges, institutions and governments face new reputational risks that have the potential to induce expedient and short-term strategies which inadvertently make the problem worse (Orr *et al.,* 2009) – what some people have called mal-adaptation (Burton, 1997; Adger *et al.*, 2005; Doria *et al.,* 2009). In addition there is a growing body of evidence showing that the anxiety associated with anticipating and dealing with emergencies imposes health risks. Among those affected by the Asian tsunami in 2005, for example, the World Health Organization estimates the likely prevalence of psychological distress to be in the order of 20 per cent to 90 per cent among the affected populations, with approximately 20 per cent to 40 per cent expected to suffer mild distress and 30 per cent to 50 per cent expected to suffer moderate to severe distress. Mental illness is a feature of many African urban societies and already over-burdens the resources available to cope with the problem.

The over-arching point is that direct, easily identifiable climate change impacts give rise to a series of less easily attributable secondary and tertiary impacts in what Blakie and Brookfield (1987) refer to as, "spirals of degradation". Ignoring these spirals tends to lead to under-reporting of the actual risk.

- In one sense climate change imposes risk regardless of whether it is happening or not. The simple possibility that climate change harm might occur requires companies, government and individuals to consider their future in the light of this possibility (Lowry, 2011). The increased uncertainty created by the possibility of climate change, compounds the uncertainty created by increasingly rapid social and technological changes in African cities, making long-term planning and investment difficult.

"Risk of what", then, is not as simple as is often assumed in climate change studies. The process followed by this study illustrates as much; the project began by looking at discrete, high-profile, easily visible biophysical risks in five African cities (see Table 1) and has had to expand that brief to include a more complex suite of impacts at each location as awareness and insight has developed. For the purposes of understanding climate change risk it is important to note that any analysis that excludes

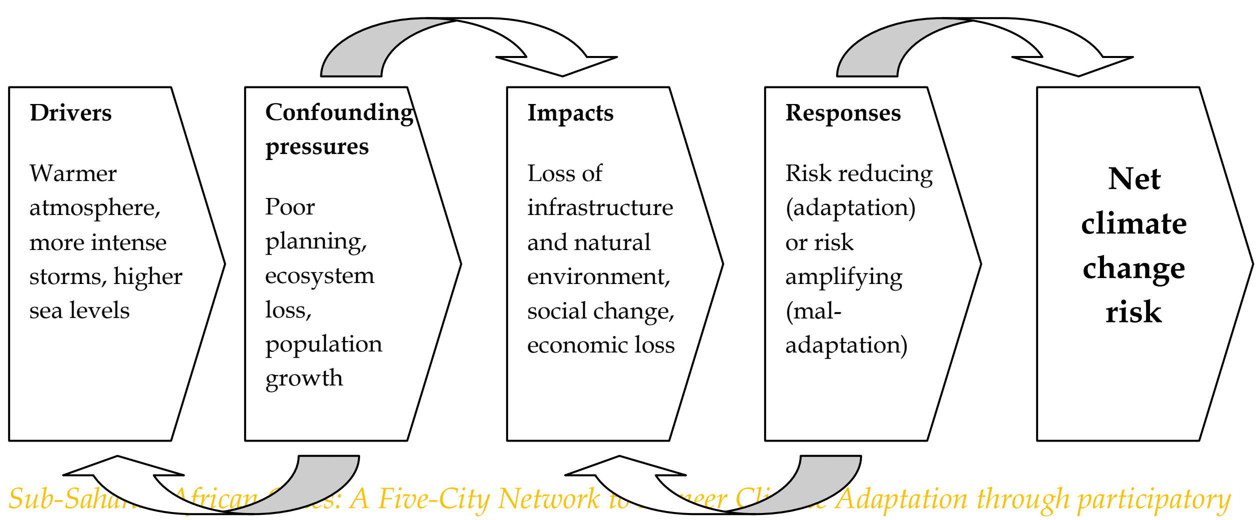

Figure 1: Climate change risk is the product of biophysical and socio-institutional interactions. Dealing with climate risk systemically involves understanding these risk pathways and their multiple feedbacks.

both direct impacts and their knock-on effects will tend to truncate and under-report the full extent of the risk. Whilst there may be an analytical case for doing this, it should be noted in the process of being explicit regarding "risk of what". For example, if a study of climate change risk is only interested in a specific location or a particular time period, it should stipulate this with the understanding that it only represents a part of the total climate risk.

3.2 Risk for whom:

In many ways risk is a social construct containing psychological, financial and economic explanations of human behaviour in the face of uncertainty. Climate change risk analyses are accordingly, anthropocentric (Kasperson and Kasperson, 2001) even when they factor in ecosystem or environmental value[6]. The same climate change event has the ability to present different risks, and different levels of risk, to different people depending on their level of risk aversion. Accordingly, it is necessary in any climate risk analysis to establish, "risk for whom?" with the understanding that the risk to an individual might be very different to the risk for a society or a company and that certain stakeholders will be more vulnerable to a given climate change impact than others.

Equally, different people or institutions will be exposed to different aspects of climate change risk. For a farmer the danger may be back-to-back years of below average rainfall, for the owner of a nuclear power plant the risk may be a short-term but sudden spike in ambient temperature, for exporters the risk might be policy changes to account for carbon intensity that will impact trade and competitiveness, while for governments the risk may be social discontent and loss of electoral support.

As a rule economists assume that poorer people tend to be more risk averse than affluent people (Vickrey, 1945; Arrow, 1965). Poor communities live with risk as a matter of course (Collins *et al.*, 2009) but not out of choice – the same climate change event tends to have a disproportionately larger impact

[6] Even when adopting an anthropocentric perspective, climate change risk analyses should acknowledge the risk to people of ecological damage. Expanded risk analyses may go further and include ecological damage as a risk in its own right (Naess, 1973; Leopold, 1949).

on poor people's utility relative to wealthy people. Transferring a quantum of risk from affluent people to poor people will, in this sense, increase the risk.

The ability of climate change risk to manifest subjectively makes it imperative for such assessments to be explicit regarding who is assumed to be impacted by the risk being assessed, or whose perspective on the risk is being adopted. Too many climate change risk analyses assume people are affected equally, or worse, do not distinguish between variable impacts on different groups. Apart from misrepresenting the manifestation of climate change risk, such approaches also miss the opportunity to identify target communities or members of communities that will receive priority in adaptation efforts. It may be, for example, that HIV (which itself has a gender bias) positive city-dwellers are most exposed to deteriorating water quality in Cape Town, that small-scale fishermen are disproportionately affected by increased wind speeds in Port Louis or that industries with fixed capital (such as the national oil import industry) are more exposed to sea-level rise impacts in Walvis Bay than those without fixed coastal capital. Stipulating affected communities and distinguishing between the effects on communities makes for better understanding of climate change risk and better inference from risk analyses.

3.3 Risk when:

Acknowledging that a single climate change hazard can impose harm over an extended time-frame (coastal storm surges can undermine coastal tourism revenues indefinitely, the need to cope with a famine can destroy investments in educations and skills accrual) is important for a good analysis of climate change risk. For most analyses, however, an indefinite timeframe makes calculations intractable (or un-helpful), and it is necessary to state both the period during which risk is analysed, and the process of converting economic value to a present value – most commonly via discount rates. Certainly such stipulations are a pre-requisite for risk comparisons. The comparison of risks that manifest at different times or over different timeframes leads to incommensurate results and is poor analysis, leading to inappropriate interventions.

Even where timeframes are stipulated and discount rates are applied, the reduction of climate change risk to a net present value makes the assumption that the value of money (and the relative price of goods and services) will remain proportionate over the period of analysis. Walker *et al* (2011) point out climate change has the potential to reconfigure the culture through which people value things, rendering such analysis wholly inadequate.

4. Risk Measurement

That climate change risk is essentially an artefact of individual perception makes it difficult to quantify systematically. Levitt and Dubner (2005) note that risk could easily be depicted as "hazard plus outrage", and that effective risk communication involves increasing or attenuating outrage depending on the agenda, so as to alter perceptions.

Conventionally risk is calculated by multiplying the probability of a hazard occurring by the cost of the damage (or "insult") caused by that hazard. From the discussion above it should be clear that climate change risk analyses benefit from details around what is being assessed and who is being impacted and when it is being impacted. Even when this information is provided, however, the application of the standard risk calculus remains problematic on a number of accounts:

- Probabilities are difficult to assign. As a minimum, risk calculations should pronounce on their expectations of the future and (as has been adopted by the IPCC) entertain the notion of different types of future in putting numbers to the harm caused by climate change events. For many dangerous weather events both the frequency and the intensity is expected to increase as result of climate change, increasing the probability of damage (see Figure 2). One in one hundred year floods may become one in twenty year floods and then one in five year floods. Extreme storm surges will become more frequent at many coastal cities, rainfall events will become more intense. Whilst the general direction of the change in frequency and intensity have become more and more certain, anticipating exactly when the impacts will be felt remains speculative.
- "Insult" or damage is often difficult to ring-fence over time and space, particularly once indirect impacts are considered. The expanding brief of this study itself illustrates that while initial climate change attention is often focused on a specific impact, it is the knock-on effects of this impact that are often most critical. Flooding is a concern at Walvis Bay due to the damage it causes to infrastructure, but flooding is also associated with deteriorating water quality and

energy outages which has already had an impact on the health-status of fish and other exports that rely on water quality from Walvis Bay. Sea-level rise and associated storm surges has damaged coastal infrastructure at Walvis Bay, Maputo, Dar es Salaam, Port Louis and Cape Town. This impact is relatively easy to evaluate, but much more difficult to quantify is the impact of damaged coastal infrastructure and the risk of storm surges on the local tourism industry of those cities over the long term or the gradual salination of groundwater aquifers.

In attempting to incorporate direct and indirect impacts of the risk of climate change induced sea-level rise, a study conducted by the City of Cape Town used coastal property and infrastructure for direct impacts and foregone tourism revenue for indirect impacts. Projections of foregone tourism revenue are clearly assumption dependant, but the approach is more accurate than simply ignoring this impact.

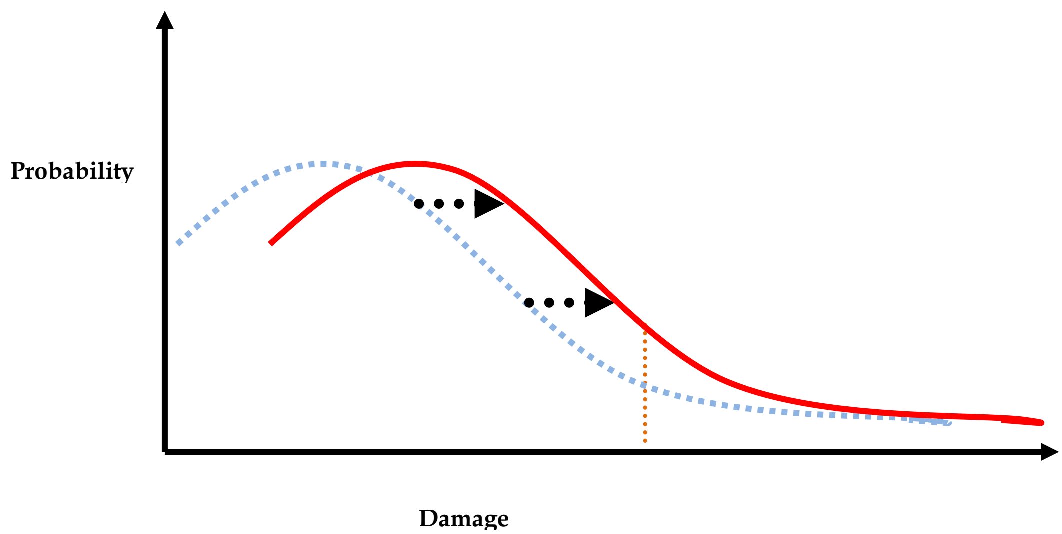

Figure 2: The general impact of climate change is to move the damage curve right (from blue to red), increasing the frequency of high impact low probability events and increasing the probability of damage.

- Attribution represents a further quantification dilemma. Climate change imposes direct risks, but it also exposes existing "faultlines" or weaknesses in the environment, society and institutions. Grin *et al* (2010) take this to its extreme in their recent study of transformation by suggesting that the climate crisis itself is simply a manifestation of a deeper pre-existing crisis of "values and their expression in [consumerist] lifestyles". The reciprocal point is that climate change risk will expose multiple crises, (of inequality, poverty and scarcity) some of which predate perturbed climates. If this is the analytical lens, then distinguishing between climate change risks and other risks is impossible and quantifications become even more difficult. Funders and technocrats have become pre-occupied with the concept (borrowed from the climate change mitigation sector) of "additionality" – trying to distinguish between "business as usual" impacts and climate change impacts. In practice this remains extremely difficult, especially at the city scale. It is also frequently counter-productive, especially as (following Grin *et al's* logic) many of the best means of reducing climate change risk involve addressing its systemic under-pinnings such as poverty, poor infrastructure and environmental exploitation.

- In quantifying "insult" or "damage" it is further important to note that globally the risk of environmental damage has increased over time as the value of property, infrastructure and people (as measured by their contributions in the labour market) has increased (Brauner, 2002). Very often insurance industry pay-outs are used as proxies in damage quantification (Warner *et al*., 2008). The trend of increasing damage is important, but it is necessary to distinguish between the increase caused by inflating values (or increased insurance cover) and the increase caused by increasing climate impacts. The value and extent of coastal property, for example, has increased dramatically around the world over the past thirty years and to a certain extent this has driven the increased value of damage by sea-storms (Yoh *et al.,* 2011).

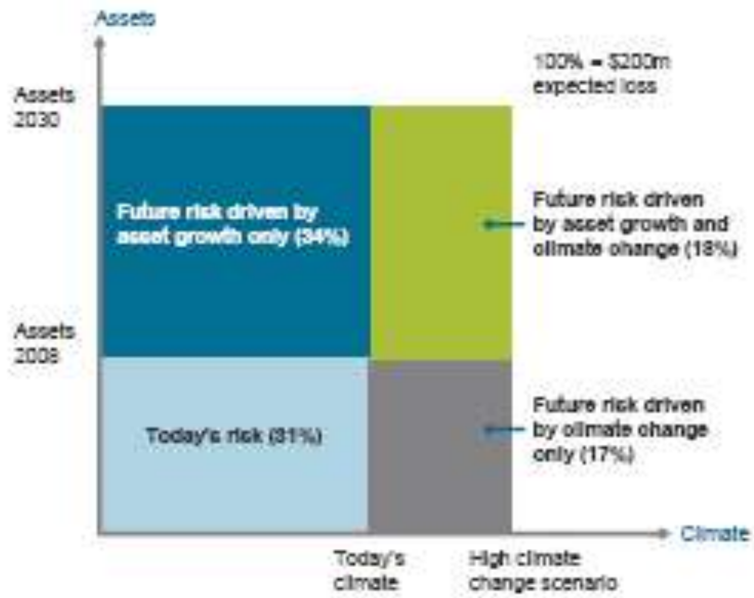

Figure 3: In this study of Guyana the risk assessment distinguished (albeit with artificial precisions) between the risk increment caused by increasing climate change and the risk increment caused by increasing asset value (Source, McKinsey, 2009).

- The relationship between ecological degradation and climate change risk is endogenous, and the value of ecological assets and the cost of their degradation should be central to climate change risk analyses. Ascribing value to ecological assets, however, is always subjective and often contested. This difficulty does not comprise a reason to ignore the value of the environment (Vatn and Bromley, 1994) - in developing countries, in particular, ecological systems provide buffers against climate change risk - it does, however, complicate climate risk measurement.

Quantitative risk assessments of climate change impacts are, due to subjectivity, uncertainty and the lack of data, rarely objective processes that lead to an unambiguous preference. Quantitative estimates do, complications notwithstanding, serve a purpose as long as inference from these estimates remains cognisant of the difficulties in putting numbers to climate change risk and as long as comparisons between quantitative estimates factor in how these estimates were derived.

- Quantifications can be particularly useful in highlighting the need to avoid risks that many people assume are unlikely but which would be catastrophic. If, for example, it is anticipated that climate change could end civilisation as we know it (Hansen, 2007) – i.e. impose extremely high damages, then no matter how small the probability of this event is anticipated to be, the estimate of risk is likely to prove significant. As Oxfam point out, "Climate change offers humanity no second chances" (Oxfam, 2009)[7]. A very low probability multiplied by a very large damage number will still produce a very large number. It is managing these "low probability-high impact" events that is so difficult for policy makers, but climate change risk estimates suggest that major efforts to this end could be justified.
- Quantifications can be useful in providing a sense of scale and in reiterating the idea that climate risk has economic consequences.
- Risk quantifications can illustrate the economic importance of early action as opposed to the more expensive "wait and see" alternative (Stern, *et al*., 2006).

The process of calculating risk can itself be important. Where arriving at the assumptions and processes for calculating complex climate change risk draws on experts from a wide range of disciplines and contexts, it can contribute to what McKinsey (2009) term a "risk consensus" - a general agreement on the nature of City-scale risks and how this risk should be most appropriately shared in the context of other development goals. Where shared insight and agreement is fostered by the process of risk calculations, this can be useful in risk management.

It is not necessarily the case that risk quantifications be expressed in monetary terms, although this is the norm. In developing country contexts where money is sometimes a poor indicator of well-being, climate risks may be better quantified in terms of loss of life, loss of arable land, increases in infant mortality or reductions in life expectancy.

5. Managing risk

The demand from policy quarters for increasing risk analysis is motivated by a desire to compare climate risk with other risks and to motivate for climate change interventions as part of a fiscally efficient

[7] http://www.oxfam.org/sites/www.oxfam.org/files/bp128-hang-together-separately-summary-0906.pdf

approach. Indeed, risk analysis is only really helpful if it leads to risk management and reduction. Climate change risk management involves exploring, making and acting on decisions under conditions of uncertainty, with the assumed intention of reducing risk (Jones and Preston, 2010).

In theory, markets for risk transfer and reduction – principally insurance markets - should ensure that everyone in the world lives with a level of risk that is acceptable to them (Yoh *et al.*, 2011). But as is pointed out above, climate risk is unusual and complex, and beyond the scope of conventional pollution economics and its reliance on either taxation or cap-and-trade schemes. Climate change risk markets, perhaps more than other markets, are prone to failure. When risk markets fail in the context of climate change, they prevent access to weather related insurance for people who cannot afford it, they charge extortionist prices for risk that cannot be easily quantified, they transfer risk from the affluent to poor people and they result in people living with untenable amounts of weather related risk. Risk markets have an important role to play in reducing climate change risks, but leaving the quantification and reduction of this risk to current actuarial approaches and existing markets will not reduce the risk adequately. Risk markets are only likely to be helpful if they are supported by policies and public safety nets that remove systemic risk (through adaptation, mitigation and climate smart infrastructure planning and zoning), incentivise the behaviour changes that reduce risk and prevent the default of climate risk being dumped on poor households.

It is important in this context to distinguish between risk reduction and risk transfer. Risk transfers from risk averse people or institutions to less risk averse people or institutions do represent one means of reducing risk. The default, however, is for risk transfers to flow the other way; that is to be regressive. For example, the building of a sea-wall to protect a valuable coastal property, will transfer wave energy, erosion and damage to an adjacent property the owners of which might not have the resources to protect themselves. The irrigating of previously dryland crops so as to prevent damage from more intense and frequent droughts is one option available to those that can afford in Dar es Salaam and its surrounds, it but leaves less water for alternative uses and users. The transfer of risk, in many instances, involves trade-offs between different ecosystem goods and services.

A planned and shared approach to climate change risk management within cities will necessarily draw on certain aspects of conventional risk management theory in constructing solutions. These include distinguishing between risk reduction and risk transfer. Risk transfer and risk reduction are not necessarily exclusive concepts; where risk is transferred to people or institutions that are better able to manage that risk, such transfers reduce risk and as such may form a deliberate part of the risk management strategy. Unless pro-actively managed, however, the more typical outcome of risk reduction strategies is to simply transfer risk. Where these transfers are regressive they increase the damaging impact of climate change risk. Risk management theory further suggest that systemic risks – and almost all climate change risk is systemic in the sense that it impacts in direct and indirect ways over wide temporal and spatial scale - require systemic solutions; what McKinsey Inc has termed "total climate risk" (McKinsey, 2009). Piece-meal solutions to managing climate change risk that are focussed on discrete projects tend to be less effective than programmes that remove risk from the system. The obvious example involves the collaborative global effort to reduce greenhouse gas emissions, but systemic risk can be removed through adaptation measures as well. At its best, climate change risk management is a socio-institutional learning process (Adger, 2000; Downing and Dyszynski, 2010) involving a combination of technology, markets, education, legislation and improved living standards so as to remove the source of the threat, move people away from the impact of the hazard and equip people to better cope with the hazard.

There are, in addition, principles that are specific to managing climate change risk:

- Identify the components of the risk, including the direct and indirect components. All climate change risk is caused by increased concentrations of greenhouse gases, but the manner in which this risk manifests within cities is often defined by location, poverty, urban-rural bias or a lack of legislation. Identifying the pathways through which climate change risk manifests in the five African cities that form the focus of this study will enable systemic risk management.
- Identify the parties to the risk. The advantage of risk as a concept is that it appeals to a "broad church". Identifying and gathering the full set of stakeholders affected by risk or able to affect the risk, within a particular urban context is necessary for systemic risk management. Whilst each of these parties is likely to have a different exposure and response to the risk – that is the nature of subjective risk – arriving at some form of risk consensus can be useful. Once the

community of affected parties has been identified, it is possible to select specific parties to deal with specific aspects of the risk. Very few cities have a mandate to generate electricity or reduce energy related emissions for example – this is more typically a national competency – but across all three spheres of government it is possible to produce coherent and complementary approaches to reducing emissions and managing the impact of high emissions. The insurance and re-insurance industry, where informed, are frequently a key agency in ensuring scaled responses to climate risk management. By pricing climate risk into home, life and corporate insurance packages, insurers can influence perceptions of and responses to climate change risk and can incentivise behaviour changes that avoid and reduce risk. Similarly, local agencies, such as funeral companies and micro-lenders can act as levers of scaled climate risk reduction.

- Recognise the link between ecological degradation and climate change risk, but in many places human behaviour unrelated to climate change represents a more acute pressure on ecosystems. Acknowledging the role that ecosystems play in buffering urban people from climate change impacts and reducing climate change risk is essential, especially in developing country contexts where these buffers are often more valuable and often more cost-effective in risk reduction than infrastructural and social programmes (Blignaut, 2012, Roberts et al., 2012). Avoiding an increasing risk spiral in which both climate change and responses to climate change destroy the ecological buffers that reduce climate change risk is critical. Equally, investing in the protection of the same ecological buffers can represent highly effective and no-regret risk management.
- Avoid mal-adaptation. There is the distinct possibility for (often well-meaning, but) mis-informed attempts to reduce risk to have the opposite effect. This is particularly true for climate change risk. As a principle, efforts to reduce climate change risk should be clear not to inadvertently increase that risk through mal-adaptation. A recent editorial in Global Environmental Change identified four distinct pathways through which mal-adaptation could arise, namely options that relative to alternatives: (1) increase emissions of greenhouse gases, (2) disproportionately burden the most vulnerable, (3) have high opportunity costs, (4) reduce the incentive to adapt, lock-in to "path dependency" (Barnett and O'Neill, 2010). The risk of lock-in warrants further exposition.

- Avoid lock-in to path dependency. Given the high level of uncertainty, climate risk management strategies that reduce adaptation options are particularly prone to mal-adaptation and risk amplification. Conversely city programmes or projects that retain options while permitting policy and decision making flexibility (even reversibility) are likely to prove more valuable as the inherently unknowable future unfolds and uncertainty increases. As uncertainty increases risk reduction options that are effective across a wide array of possible futures become valuable (New and Hulme, 2000; Dessai *et al.*, 2009).
- Recognise the legitimacy of "coping". Neither the UNFCCC nor any government or local authority is likely to produce the definitive climate risk removal intervention for Africa's cities. In the interim people around the world are dealing with the consequences of hostile and increasingly unusual climates – the climate "residual" that is not being addressed by either mitigation or formal adaptation. The reality is that even people in the poorest communities seek to reduce the risk of climate change through a range of formal and (more commonly) informal measures. Some of the most effective adaptation involves "coping". Peasant farmers diversify their crop selection so as to survive droughts, people in flood prone areas raise the floor of their home's floors on plastic beer crates, residents in informal settlements contribute to community support funds and funereal schemes in the hope that these will support them (or the family that survive them) in difficult times, city residents keep livestock on the urban edge as an insurance against fluctuating employment fortunes and communities lobby for the attention of government and donors in the hope that access to these networks will offer some reprieve in the face of acute cleat risk. By identifying, validating and supporting effective coping, there is the potential to reduce systemic risk on scale, without an exclusive reliance on top-down programmes and their associated propensity for ineptitude.
- Set the aim of "good enough" risk reduction. It is not possible, at the city-scale, to remove climate change risk. Neither is it possible, given the complexity of climate change risk and the subjective manner in which it manifests, to optimise for risk levels. The goal for climate change risk management should be a consensus around "good enough" risk reduction.

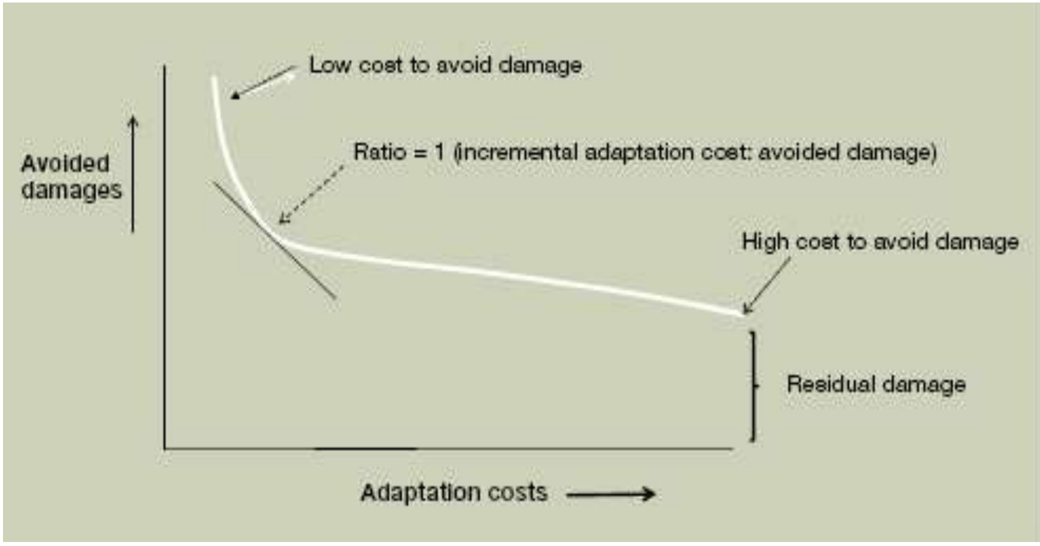

Figure 4: The application of economic instruments to decisions regarding the prioritisation of adaptation options allows the identification of options that, if implemented, save money (top left) and those options that are costly relative to the damage that they save (bottom right). Effective application of cost-benefit analysis includes a wide range of costs and benefits in the analysis and further includes the costs arising from the consequences of the "residual damage". (Source: Adjusted from World Bank 2010).

6. Conclusion

There is a growing awareness that Africa's cities are at a severe risk from climate change. This risk manifests alongside many other transitions, most obviously urbanisation – the "spatial nexus of multidimensional change" (Peter, 2011). Climate change alters the threats and opportunities available to society and as such city decision-makers need to consider the consequences of climate change when making decisions about the future. In doing so, they face a range of options and a range of uncertainties, which combine to pose risks.

It is important in discussions of climate change risk to remember what is at stake: how to prevent the death, harm, loss of property and value and loss of development options in the face of an increasingly hot and unstable climate. While this goal should remain the focus of climate change risk analyses, the risk itself can manifest via a multitude of complex pathways that link global warming, climate change and harm.

Accurate estimates of climate change risk in Africa's cities necessarily look at the changed probability of different impacts and multiply this probability by the cost (either financial or economic) of the physical, biological, institutional and social and economic impacts over time and space. This should include direct costs as well as costs that arise because of the direct costs. Failure to capture both the direct and the wide range of indirect costs tends to under-report climate change risk. What is very difficult to calculate effectively is the impact of low probability high impact events, but these need to feature in a thorough analysis or, as a minimum, be noted as an omission (Dietz, 2011). Equally, distinguishing between the baseline and the additional probability of that event occurring due to climate change is not an exact science but requires careful consideration in any calculation.

Calculating climate change risk has both advantages and limitations, and these both need to be understood if the approach is to be applied effectively. Risk analyses are useful in raising profile and in mobilizing resources, but can be easily abused. In ensuring that risk is a useful concept in managing climate change impacts on Africa's cities it is important that:

- Risk reduction efforts should first focus on not making things worse. By intervening in the wrong way or at the wrong time, risk management can amplify the original risk. Efforts that undermine local willingness or ability to manage risk can themselves amplify risk.
- Risk transfers can be successful if progressive – i.e. if they transfer risk to people who are better equipped to cope with the risk. The norm, however, is for affluent, networked and well capacitated people to transfer risk to less well resourced (and vocal) – a step which increases risk.
- Risk reduction is the goal of climate risk management, and is a useful yardstick in assessing climate change adaptation measures. It is usually difficult for one town or region on its own to reduce the probability or intensity of an event, but it can reduce the impact of an event thereby reducing risk.
- Efforts that aim to deal with the systemic origins of risk tend to be the most effective. Typically these efforts do not focus on a discrete location or event. Effective climate risk management is necessarily participatory and inter-disciplinary

References

Adams R.M, McCarl, B.A and Sergerson K. (1999) Climate Change and U.S. Agriculture: Some Further Evidence. Submitted to Agricultural and Resource Economics Review.

Adger, W. N. (2000) Social and ecological resilience: are they related? *Progress in Human Geography* 24(3), pp. 347-364.

Adger, W.N., Arnett, N. and Tompkins, E. (2005) Successful adaptation to climate change across scales. *Global Environmental Change* 15, pp.77–86.

Adger, W., Agrawala, S., Mirza, M., Conde, C., O'Brien, K., Pulhin, J., Pulwarty, R., Smit, B. and Takahashi, K. (2007) Assessment of adaptation practices, options, constraints and capacity. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (eds Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E.). Cambridge University Press, Cambridge, UK, pp. 717-743.

Archer, D. (2005) Fate of fossil fuel CO2 in geologic time. *Journal of Geophysical Research* (110). Accessed online at http://geosci.uchicago.edu/~archer/reprints/archer.2005.fate_co2.pdf
October 2011.

Arrow, K. (1963) Social Choice and Individual Values. Cowles Foundation Monographs Series. Yale University Press, second edition. Pp?

Arrow, K. (1965) The theory of risk aversion, in *Aspects of the Theory of Risk Bearing*, by Yrjo Jahnssonin Saatio, Helsinki. Reprinted in: Essays in the Theory of Risk Bearing, Markham Publ. Co., Chicago, 1971, pp. 90-109.

ARUP. (2011) *Climate Action in Megacities*. ARUP C40 Climate Leadership Group. June 2011.

Barkemayer, R (2010) Developed world at risk of forgetting about AIDS pandemic. *Science Daily*. Available at: http://www.sciencedaily.com /releases/2010/11/101129203334.htm

Barnett, J and O'Neill, S. (2010) Maladaptation. Editorial to Global Environmental Change (20) pp. 211-213.

Brauner, C. (2002) Opportunities and Risk of Climate Change. SwissRe Working Paper.

Bicknell, J., Dodman, D. and Satterthwaite., D (2009). Adapting Cities to Climate Change: understanding and addressing the development challenges. London, Earthscan.

Blaikie, P and Brookfield, H (1987) Land degradation and society. Methuen. London.

Blignaut, J. (2012) How Eco-system Based Adaptation Can Yield a Double Dividend of Adaptation to Climate Change and Enhancement of Ecosystem Services. ENEP DEPI Ecosystem Services Economics (ESE) Working Paper Series, Paper No. 18.

Bulkeley, H., Schroder, H., Janda, K., Zhao, K., Armstrong, A., Yi Chu, S. and Ghosh, S. (2010) 'Cities and climate change: The role of institutions, governance and urban planning', report prepared for the 5th Urban Research Symposium: Cities and Climate Change – Responding to an Urgent Agenda, Marseille, France, June 28–30 2009.

Burton, I. (1997) Vulnerability and adaptive response in the context of climate and climate change. Climatic Change 36, 185–196.

Camerer, C. and Weber, M. (1992). Recent developments in modeling preferences: Uncertainty and ambiguity. *Journal of Risk and Uncertainty*. 5, 325-370.

Carter, T.R., Jones, R.N., Lu, X., Bhadwal, S., Conde, C., Mearns, L.O., O'Neill, B.C., Rounsevell, M.C.A., Zurek, M.B. (2007). New Assessment Methods and the Characterisation of Future Conditions. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E. (eds). Cambridge University Press, Cambridge, United Kingdom, pp 133-171.

Collins, D; Morduch, J; Rutherford, S and Ruthven, O (2009) Portfolios of the Poor; how the world's poor live on $2 a day. Princeton Press, New York.

Dessai, S., Hulme, M., Lempert, R., Pielke, R.Jr. (2009). Climate prediction: a limit to adaptation? In: Living with climate change: are there limits to adaptation? Adger, N.W., Goulden, M., Lorenzoni, I. (eds). Cambridge University Press, Cambridge.

Diakoulaki D., Grafakos S. (2004). Treatment of uncertainty in weights elicitation through the disclosure of the hidden monetary values assigned to sustainability criteria. 15th Mini-EURO Conference: Managing Uncertainty in Decision Support Models. Coimbra.

Dietz, S (2011) High impact, low probability? An empirical analysis of risk in the economics of climate change. Climate Change 108: 519-541.

Doria, M., Boyd, E., Tomkins., E and Adger, N, (2009)Using expert elicitation to define successful adaptation to climate change. Environmental Science and Policy: 12., pp. 810-819.

Downing, T.E., Olsthoorn, A.A. and Tol, R.S.J. (1999) *Climate, change and risk*. Routledge,

Downing, T.E. and Dyszynski, J. (2010) Frontiers in Adaptation Economics: Scaling from the Full Social Cost of Carbon to Adaptation Processes,. Oxford: Global Climate Adaptation Partnership.

Edenhofer O, Pietzcker, R, Kalkuhl, M and Kriegler, E (2011) Tax Instruments for reducing Emissions: an overview in Fan Gang *et al*., The Economics of Climate Change in India: towards a low carbon economy. Earthscan, London.

Ernst & Young (2011) Turn risks and opportunities into results. Exploring the top 10 risks and opportunities for government and public sector. Ernst & Young, London.

Gardner, D (2009) Risk: the science and politics of fear. McClelland and Stewart Ltd, Toronto.

Grin J, Rotmans, J and Schot J (2010) Transitions to sustainable development; new directions in the study of long term transformative change. Routledge, London.

Grubler, A. and Nakicenovic, N. (2001) Identifying dangers in an uncertain climate. *Nature*, 412, 15-15.

Heal, G (2009) The economics of climate change. A post-stern perspective. Climate Change, 96. pp. 275-297.

Hansen, J., M. Sato, and R. Ruedy (1994), Long-term Changes of Diurnal Temperature Cycle: Implications about Mechanisms of Global Climate Change, Atmospheric Research, Vol. 37, pp 175-209

Hansen, J. (2007). Scientific Reticence and Sea-level Rise. IOP Environmental Research Letters. Available at http://www.iop.org/EJ/article

Hansen, J (2009) Storms of my grandchildren; the truth about he coming climate catastrophe and our last chance to save humanity. Bloomsbury Press. New York.

Harrison, S., Jolly, D., Laarif, A., Abe-Ouchi, B., Dong, K. Herterich, C. Hewitt, S. Joussaume, J.E. Kutzbach, J. Mitchell, N. de Noblet and P. Valdes, (1998) Intercomparison of simulated global vegetation distributions in response to 6 kyr BP orbital forcing. Journal of Climate, 11, pp. 2721-2742.

Iglesias, A., Garrote, L., Flores, F. and Moneo, M. (2007). Challenges to manage the risk of water scarcity and climate change in the Mediterranean. Water Resources Management.

IPCC (2001) Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881pp.

IPCC (2007) *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the IPCC. Geneva: Intergovernmental Panel on Climate Change.

IPCC (2007) *Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Geneva: Intergovernmental Panel on Climate Change.

Jones, R (2001) An environmental risk assessment/management framework for climate change. Natural Hazards (23) pp. 197-230.

Jones, R (2010) A risk management approach to climate change adaptation. In: Climate change adaptation in New Zealand: Future scenarios and some sectoral perspectives. Nottage, R.A.C., Wratt, D.S., Bornman, J.F., Jones, K. (eds). New Zealand Climate Change Centre, Wellington, pp 10 - 25.

Jones, R.N. and Preston, B.L. (2010) Adaptation and Risk management. Climate Change Working Paper 15, Centre for Strategic Economic Studies Victoria University Melbourne
May 2010.

Kandlikar M, Risbey J and Dessai, S (2005) Representing and communicating deep uncertainty in climate-change assessments. Geoscience 337, pp. 443-455.

Kasperson, J and Kasperson, R (2001) Global Environmental Risk. United Nations University Press and Earthscan Publications Ltd, London.

King D. A. (2004) Climate Change Science: Adapt, Mitigate, or Ignore, Science, 303, pp. 176.

Leopold, A (1949) A sand county almanac. Oxford University Press. London and New York.

Krechowicz, D and Fernando, H (2009) Emerging Risk: Impacts of key environmental trends in emerging Asia. World Resources Institute. Washington.

Leichenko, R & O'Brien, K (2002) The dynamics of rural vulnerability to global change: The case of southern Africa. Mitigation and Adaptation Strategies for Global Change (7), pp. 1-18.

Lempert, R.J. and Schlesinger, M.E. (2000) Robust Strategies for Abating Climate Change. *Climatic Change*, **45**, 387-401.

Leopold, A (1949) A Sand County Almanac. Oxford University Press.

Lenton T, Held, H, Kriegler, E, Hall j, Lucht W, Rahmstorf, S and Schellnhuber H-J (2008) Tipping Elements in the Earths's Climate Science. Proceedings of the National Academy of Sciences 105 (6) pp, 1786-1793.

Levitt S and Dubner, S (2005) Freakonomics. Penguin Press. New York.

Lowry, R (2011) Is risk itself a climate related harm? Climate Change 106, pp. 347-358.

Melbourne, 18 pp.

McKinsey (2009) Shaping Climate Resilient Development: A Framework for Decision-making. Report of the Economics of Climate Adaptation (ECA) Working Group, McKinsey and Company, New York.

Næss, A (1973) The Shallow and the Deep, Long-Range Ecology Movement. Inquiry 16, pp.95-100.

New, M. and Hulme, M. (2000) Representing Uncertainty in Climate Change Scenarios: A Monte Carlo Approach. Integrated Assessment 1 (3) pp. 203-213.

Orr, S, Cartwright, A & Tickner, D (2009) Understanding Water Risks: a primer on the consequences of water scarcity for business and government. *WWF Water Security Series* 4.

Parry, M. Arnell, M. Berry, P. Dodman, D. Fankhauser, S Hope, C. Kovats, S. Nicholls, R. Satterthwaite, D. Tiffin, R. Wheeler, T (2009) 'Overview of Conclusions' in Assessing the Costs of Adaptation to Climate Change: A review of the UNFCCC and Other Recent Estimates', Grantham Institute for Climate Change and International Institute for Environment and Development (IIED), London, pp. 6-18.

Peter, C (2011) Urbanisation and transition to the future, in Tavengwa *et al* Cityscapes: rethinking urban things 1, 2011. p. 18.

Roberts, D., Boon, R., Diederichs, N., Douwes, E., Govender, N., Mcinnes, A., Mclean, C., O'Donoghue, S. and Spires, M. (2012). Exploring ecosystem-based adaptation in Durban, South Africa : " learning-by-doing " at the local government coal face. Environment & Urbanisation, 24(1), 1-29.

Rockström, J; ,Steffen1, W, Noone K, Persson,; Chapin, A; Lambin, E; Lenton, T; Scheffer, M; Folke, C; Schellnhuber; H; Nykvist; B; de Wit, C; Hughes, T; van der Leeuw, S; Rodhe, H; Sörlin,, S; Snyder, P; Costanza, R; Svedin, U; Falkenmark, M; Karlberg, L; Corell, R; Fabry, V; Hansen, J; Walker, B; Liverman, D; Richardson, K; Crutzen, P and Foley, J (2011) A safe operating space for humanity. *Nature*, 461, pp. 472-475.

Rogner, H.-H., D. Zhou, R. Bradley. P. Crabbé, O. Edenhofer, B.Hare, L. Kuijpers, M. Yamaguchi (2007). "Executive Summary". In B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer. Introduction. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Print version: Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Rosenberg, N (1992) Adaptation of agriculture to climate change. Climate Change, 21 (4), pp.385-405.

Schneider SH (1997) Integrated assessment modeling of global climate change: transparent rational tool for policy making or opaque screen hiding value-laden assumptions. Environ Model Assess 2: pp.229–249.

Smit, B., Lenhart, S., (1996) Climate change adaptation policy options. Climate Research 6:pp.193–201.

Stern, N., S. Peters, V. Bakhshi, A. Bowen, C. Cameron, S. Catovsky, D. Crane, S. Cruickshank, S. Dietz, N. Edmonson, S.-L. Garbett, L. Hamid, G. Hoffman, D. Ingram, B. Jones, N. Patmore, H. Radcliffe, R. Sathiyarajah, M. Stock, C. Taylor, T. Vernon, H. Wanjie, and D. Zenghelis (2006), *Stern Review: The Economics of Climate Change*, HM Treasury, London.

Swiss Re (2009) Influence of Global Warming on Extra-Tropical Storms. Climate Change Facts Compiled by ProClim. Available online at: http://www.swissre.com/resources/

Tahir, R & Robinson, N (2011) Crisis and risks in tourism: death takes a holiday – debunking the myth of terrorism and its psychological impact on the tourism industry. International Journal of Tourism Policy, 2010; 3 (4): 348.

Tebaldi, C. and R. Knutti (2007), The use of the multimodel ensemble in probabilistic climate projections. Philosophical Transactions of the Royal Society.

Tversky, Amos & Kahneman, Daniel, 1992. " Advances in Prospect Theory: Cumulative Representation of Uncertainty," Journal of Risk and Uncertainty, Springer, vol. 5(4), pages 297-323, October.

Vatn, A & Bromley, D (1994) Choices without prices, without apologies. Journal of Environmental Economics and Management 26, pp. 129-148.

Vickrey, W (1945) Measuring Marginal Utility by Reactions to Risk, *Econometrica*, Vol. 13, No. 4. pp. 319-333.

Walker, D; Liebl, S; Lewis, G; LaGro, J; Nowak, P and Sullivan, J (2011) Adapting to Climate Change: Why Adaption Policy is More Difficult than we Think (and what to do about it). Adaptation Working Group, Wisconsin Initiative on Climate Change Impacts. October.

Warner, K, Afifi, T., Dun, O., Stal, M., Schmidl, S., and Bogardi, J. (2008). Human security, climate change, and environmentally induced migration. In Climate Change: Addressing the Impact on Human Security. Hellenic Foundation for European and Foreign Policy (ELIAMEP) and Hellenic Ministry of Foreign Affairs, 2007-2008. Greek chairmanship of the Human Security Network. Athens.

Warner, K, Ranger, N, Surminski, S, Arnold, M, Linnnerooth-Bayer, J, Michel-Kerjan,E, Kovacs, P, Herweijer, C (2009) Adaptation to Climate Change: Linking Disaster Risk Reduction and Insurance. United Nations International Strategy for Disaster Reduction Secretariat (UNISDR). Geneva.

WEF (2011) Water Security. The water-food-energy nexus. Available at: http://www3.weforum.org/docs/WEF_WI_WaterSecurity_WaterFoodEnergyClimateNexus_2011.pdf

Williams, M and Teasdale, J (1982) Facilitation and helplessness: the interaction of perceived difficulty and importance of task. Journal of Behavior Research and Therapy 20, pp. 161-171.

Willows, R. and Connell, R. (2003) Climate Adaptation: Risk, Uncertainty, and Decision making. UK Climate Impacts Programme, Oxford. Working Paper No. 15, Centre for Strategic Economic Studies, Victoria University.

World Bank (2010) The Economics of Adaptation to Climate Change. A Synthesis Report', Final Consultation Draft - August 2010, World Bank, Washington, D.C.

Yoh, G; Knee, K & Kirshen, P (2011) On the economics of coastal adaptation solutions in an uncertain world. Climate Change 106, pp. 71-92.