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Conceptualizing urban adaptation to climate change. Findings from an applied adaptation assessment framework

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SUMMARY Urban areas have particular sensitivities to climate change, and therefore adaptation to a warming planet represents a challenging new issue for urban policy makers in both the developed and developing world. Further to climate mitigation strategies implemented in various cities over the past 20 years, more recent efforts of urban management have also included actions taken to adapt to increasing temperatures, sea level and extreme events. Through the examination and comparison of seven cities, this paper identifies the various levels of administrative adaptation planning, the tools and information used in making policy choices, and the roles of governance and finance in urban adaptation to climate change. Lessons learned from these seven cases are presented to better inform the next generation of cities adapting to climate change.

Keywords: Cities, urban areas, adaptation, climate change, governance

Table of Contents

Introduction

Climate change policies focused on urban areas have several specific justifications: cities, or more precisely the activities they contain, contribute considerably to global greenhouse gas emissions and therefore to climate change. For this reason, cities have become the focus of numerous initiatives for the reduction of emissions. Furthermore, urban areas will be particularly affected by the impacts of climate change due to the concentration of population, values, and assets; this is worrisome as their ability to function is often crucial for the wellbeing of national economies. One benefit of this concentration of population and activities within cities is the strong potential for innovation and policy action, so that cities can serve as privileged laboratories for experimenting and developing new policies and strategies for the reduction of emissions and adaptations to the impacts of climate change. The importance of a greater attention towards the adaptation of cities to climate change has been underlined by reports and recommendations of agencies and institutions that are active in the less developed countries, where, as the fourth report of the Intergovernmental Panel on Climate Change (IPCC) Working Group on adaptation states, the most vulnerable city centers are concentrated. It has been confirmed moreover by the activities and decisions of the Conference of the Parties (COPs), as for instance the Nairobi Work Programme and the Cancun Decision on a framework for adaptation.

The most dramatic impacts from climate change are expected to manifest themselves in low-lying coastal areas, where an estimated 23% of the world population lives and the majority of the world's metropolises are located. Of the world's urban population, 13% live less than 10 meters above sea level (McGranahan et al. 2007). Vulnerabilities considered in relation to urban areas are therefore principally those of flooding from sea level rise and extreme events. Categories commonly used to define the types climate risks in cities include sea level rise, storm surge, flood, drought, freshwater quantity and quality issues, heat and heat waves, air pollution, disease, fire, and biodiversity loss (Schauser et al. 2010; EU 2011).

Many of the risks and hazards confronting cities as a result of climate change are modifications in scale of existing risks and hazards, or the result of a combination of climate dependent and climate independent impacts (Nicholls et al. 2008), so urban areas that are unable to cope with the challenges they face today will have even greater difficulty overcoming future challenges imposed by climate change (IFRC 2010). For instance, in the case of many coastal cities, ongoing natural and man-made processes of subsidence frequently exacerbate the menace of rising sea levels. For this reason, rather than referring to global or mean level levels of impacts, adaptation planning needs to take into account very specific local conditions; by considering "relative sea level rise" the specific contribution of local processes are accounted for in assessments of future impacts (Nicholls et al. 2008). A similar idea holds true for floodplains, as urban growth is sprawling into areas that are already prone to flooding. Urbanization of flood prone areas, together with changing climatic conditions, is resulting in an increasing numbers of flash floods. Flooding is exacerbated by a high rate of surface sealing in urbanized areas where rainwater is not able to penetrate into the ground and is instead conveyed into lower lying areas of the city. Also, the urban heat island effect and increasing incidence of heat waves in cities result from a combination of increasing mean temperatures and other effects from high-density, built-up areas.

Successful adaptation policies are often based on a consolidated and coordinated approach for addressing risks and projected climate impacts at the local scale. Not only are people directly affected by climate-induced impacts at this level, but it is also appropriate for introducing institutional solutions to target a wide number of people (Jabeen et al. 2010). Cities have the potential to concentrate adaptive capacities – economic resources, diversified food resources, a range of income generating opportunities, material and immaterial networks that can serve as transmission mechanisms for early warning systems,

and efficiencies of scale for emergency response (IFRC 2010), and knowledge generation for innovative solutions. Grounding climate change at the local, urban scale provides the benefits of making the associated risks or opportunities more relevant to the public and private agents responsible for designing and implementing responses (Hunt and Watkiss 2010).

Adaptation to many of the impacts from climate change can be achieved within traditional urban policies, like those connected to risk prevention in relation to extreme events, as well as to physical planning principles, which can mitigate negative impacts from sea level rise, flood risk, and urban heat island effects. The ability to adapt and level of resilience differ largely between cities, depending on the institutional and managerial capacities to decide on and implement policies, as well as on the economic wealth and the character of the social relations needed for the implementation process. The same holds true for the vulnerability and adaptive capacity of different social groups within cities, which are exposed at different degrees to climate change impacts and have different capacities for adaptation and resilience, mainly depending on their economic and social position.

The policy initiatives supporting urban adaptation, either within networks among cities or within funding programs by donor institutions, are developing mainly along two preexisting trajectories: those connected to urban poverty and issues of urban development as part of more comprehensive economic development policies, and those aimed at increasing urban sustainability, on the wake of Agenda 21 initiatives, making evident the potentialities and responsibilities of urban areas for the reduction and mitigation of global environmental impacts. Since the beginning of the nineties, after the 1992 Earth Summit in Rio, an increasing number of networks and initiatives among cities and local administrations have been established with the objective to increase urban sustainability. Further networking initiatives arose after 2005, with the Kyoto Protocol entering in force, focusing more specifically at climate change mitigation and emissions reduction. These initiatives aim at reinforcing and/or substituting urban to national activities for the reduction of emissions of greenhouse gasses. Some of these initiatives focused on climate protection have extended their activities towards adaptation strategies over the last few years.

The intent of this paper is to provide an overview of the latest and most advanced practices in urban adaption to climate change. Conclusions are drawn from a comparative review of the adaptation plans and studies of seven cities, specifically regarding the level of administrative planning, the tools and information used in making policy choices, and the roles of governance and finance in urban adaptation to climate change. The information collected from literature is analyzed following an assessment framework, which allows for the comparison of adaptation strategies across different urban and national contexts. It has been created based on a review of the adaptation plans of several cities whose strategies are at the forefront of urban climate change adaptation, and furthermore informed by a review of the state-of-the-art articles and background papers addressing urban adaptation to climate change. The conclusions drawn from the application of the framework and supporting evidence from recent literature are presented herein.

Levels of administrative adaptation planning are discussed in the first section of the paper, while the second section presents the tools and information employed in making policy choices, with specific consideration of the role of climate scenarios, adaptation measures, and uncertainty in urban adaptation. Next, issues of governance are discussed on several different levels. Topics ranging from who needs to adapt and when, to public leadership and the policy process, to the involvement of private actors are examined. Fourth, aspects of finance for adaptation planning and measures are considered in terms of the costs and benefits, sources of funding and associated implications, as well as public-private partnerships and innovative ways of finance. Conclusions and lessons learned are drawn from these seven cases to better inform the next generation of cities adapting to climate change.

Methods

A framework is used organize the pertinent information for each city's adaptation plan into several categories regarding best practices, policymaking, and financing to guide the analysis. Basic information including the size and socio-economic position of the urban area, and time horizon and status of the plan are listed first. The next section on risks and adaptation strategies identifies the climate scenarios used to anticipate or model potential impacts, relevant climate risks, types of adaptation measures, and specific adaptations taken to address climate change. The third section on policy mechanisms considers external inputs into the policy making process, political leadership for adaptation, the process for creating adaptation policy, the integration of adaptation policy into other urban policies, barriers and constraints in adapting to climate change, and the modes of government to design and implement policy. The final section on finance identifies any economic assessment of impacts or adaptations, the projected costs of climate change, the source and amount of funds for adaptation, the investment strategy or target, and the types and costs of investments made or recommended.

The framework is structured in a way to highlight drivers of adaptation to climate change in urban areas. Examples are drawn from the application of the framework to seven case studies: New York City (NYC), Metropolitan District of Quito (Quito), Greater London (London), Tunis, eThekwini Municipality (Durban), Ho Chi Minh City (HCMC), and Bangkok. These cities were selected for analysis based on their comprehensive but diverse city adaptation strategies and coverage in the literature. The term "adaptation plan" is interpreted for this research in a broad sense, including physical, organizational, and economic plans for urban adaptation planning, taking into consideration single impacts (e.g. urban flood protection in the case of HCMC), public infrastructures (Tunis), or prescriptions or guidelines for private adaptation activities. The adaptation initiatives considered are relatively recent, as each of the seven plans or studies has been created within the past five years. All of the cities, excluding Quito, are coastal cites, representative of the majority of the world's urban areas located along coasts. The adaptation plans of NYC, London, Durban, and Quito have been created within local or national authorities, driven by the goals and political leadership of the local authority itself. Conversely for HCMC and Tunis, adaptation plans are preliminary studies conducted by external agencies; which in the case of Tunis comprised three additional North African urban areas (including Casablanca, Bouregreg Valley, and Alessandria). Bangkok has an adaptation plan created by the local authorities with the support of an external agency, as well as a study carried out entirely by external agencies.

The "character" of an adaptation plan is as diverse as its institutional origin. The plan for London, made by the Authority for the Greater London area, addresses several policy goals and defines time horizons for achievement. The more sector oriented plans made by local authorities for Durban and Quito address several projects for single urban adaptation issues. The report analyzed for the case of NYC consists of a set of guidelines formulated by a panel of climate experts for the management of the process of urban adaptation. Both Bangkok and NYC explicitly advocate employing a risk management approach to adaptation. While the NYC plan is more of guide to the adaptation process, Durban, Quito, and London have already implemented specific adaptation measures within several sectors of their municipalities. Tunis and Bangkok have not yet implemented any adaptation measures, but do appear to have the capacity to do so. In all cases, with the exception of Tunis, there is an evident lack of information regarding the costs of impacts and adaptations to climate change, with only some stand-alone examples of these costs; Tunis is the only one among the seven plans considered that quantifies costs and potential losses from a broad range of future hazards potentially affecting the urban area. Only London is undergoing the adaptation process without financial support from external donors, while all other cities have had some assistance in adaptation assessment or in funding adaptations. None of the seven adaptation plans provide an in-depth strategy on how to finance adaptation measures, but most advocate, at least implicitly, to link climate initiatives to existing operating and

rehabilitating cycles. General findings from the application of the framework to NYC, Quito, London, Tunis, Durban, HCMC, and Bangkok are discussed throughout the remainder of the paper.

Adaptation Planning as Policy Innovation

Planning for climate change adaptation is a new task for urban planners and managers. Further to social and economic development, changing environmental conditions have important impacts on living conditions in urban areas. The innovative character of this new task is reflected by the finding that none of the urban adaptation plans or studies considered in this paper were created under the guidance of established instruments or implementation strategies. Adoption of plans for adaptation can thus be considered an innovative practice in urban management and schemes to analyze innovative policy approaches can be applied.

In terms of the phasing of innovation, cities that have already activated adaptation planning are the pioneer cities (Kern et al. 2007) and institutions designing adaptation plans are considered “early adopters”. These cities are freely experimenting and shaping new tools, whereas later adopters are more likely to accept common practices (Westphall, 1997, cited by Marsden et al. 2010). Of the seven cases considered here, only London has already reached the next step in the policy innovation process, where mandatory policy requirements drive the adoption of new practices. In fact, local authorities in the UK need to report to the central government, inter alia, on their efforts in climate change adaptation. Nevertheless, the London plan was birthed as an initiative of an early adopter, from the former major Ken Livingston, who is among the promoters of world networks for urban climate policies. He has created the resources and procedures for adaptation planning within the Greater London Council, however was unable to complete the adaptation plan during his mandate. London’s adaptation activities were taken over by his successor, Boris Johnson, in a situation when adaptation planning was no longer an option but an obligation for local authorities. The important role of individuals acting as “political entrepreneurs” within public administration when promoting adaptation policies (Marsden et al. 2011) is confirmed by the analysis of case studies such as this one. Cases like those of London (and Durban) demonstrate how individuals used both their external networks and their knowledge of internal institutional mechanisms for promoting adaptation planning initiatives within their administrations.

Administrative Level of Adaptation Planning

Administrative levels at which decisions on adaptation planning are taken correspond to the position of actors (individuals and institutions) who initiate action for adaptation. This fact is of some importance as it has emerged in the case studies that single actors, often well connected to international policy networks, frequently have a decisive role in starting innovative urban policies like adaptation planning. The range of actions they are able to trigger with their initiative is to a certain extent connected to their proper institutional framework. The scale of adaptation actions correspond to level of planning competences that authorities responsible for policy design or urban planning at the local level have.

Depending on the level of the actor within the administrative hierarchy, the level at which adaptation is planned varies from specific adaptation actions made within an urban context for the realization of single projects (for instance protection measures) to city-wide adaptation frameworks or concepts for the assessment of adaptation needs. Plans are designed to be overarching and generic, comprehensive but infrastructure oriented, or sectoral. Some studies, such as those for Tunis, HCMC, and Bangkok, are implementation oriented and discuss precise infrastructure measures with strategic recommendations on planning and bylaws. Conversely, the NYC and London plans, for example, provide more

strategic ideas and processes to be followed during the adaptation process, outlining how best to adapt while working within the confines of a certain sector.

The administrative levels involved in planning range from urban local governments, including single sectors of urban governance, to state authorities. An example of a local government providing an overarching framework or concept for an adaptation plan is provided by London, which calls for the integration of different types of measures at different policy levels and sectors. The plan is based on a cross-sector strategy for mainstreaming adaptation actions into existing urban management activities, including land use planning, transportation, water, and environmental policy. The strategy provides the framework for the identification of climate risks, setting of priorities, competences, and definition of actions. Within this framework a list of adaptation actions are defined for implementation within the short to medium term. The plan provides mainly strategic indications for climate adaptation actions to be undertaken by other administrations (boroughs, service providers, etc.). The activities to be undertaken by the Greater London Authority are limited mainly to studies, lobbying, and collaboration with local authorities (boroughs) and sectoral administrations (DEFRA, Health sector, etc.), as proper activities to be undertaken directly by the GLA are almost inexistent in this plan (GLA 2011a).

In a similar sense, the New York City Panel on Climate Change (NPCC) has created an Adaptation Assessment Guidebook with the intent to organize adaptation planning. The NYC initiative does not provide specific adaptation recommendations, but rather details the process that adaptation should follow, giving guidelines for decisions on specific adaptation measures for each sector. Measures considered are intended to assist public and private actors to understand the adaptation process and to begin to create inventories of at risk infrastructure and create appropriate adaptation strategies through an eight-step process in line with the Flexible Adaptation Pathways concept.

A local authority has prepared Bangkok's climate change assessment report with international assistance. Recommended adaptation activities are general, without specific indications on how or where they should be implemented. Adaptations are categorized as community infrastructure and operations, business and commercial, or residential health and general population. A separate external consultancy has conducted a cost assessment of risks due to flooding in Bangkok, and has recommended several infrastructure-based adaptations for the city. No specific means of implementation are discussed in either the city's adaptation plan or the study on flood risk.

Focusing on infrastructure, adaptation actions have been proposed for Tunis on the basis of an extended cost-benefit analysis, involving public actors from different administrative levels (local as well as national). Specific adaptation measures are proposed for the identified risks that the city is facing, in relation to both climate change and geophysical hazards. The adaptation measures considered focus mainly on improvement of infrastructure, whereas urban planning and management activities focusing on land use, building prescriptions, and expenditure for public health systems are mentioned but not accounted for in the assessment study.

Financed by an external donor, the adaptation study for HCMC was formulated by a group of experts who worked with representatives of the local city council (People's Committee for the City) and the city department for Natural Resources and Environment. The report proposes implementation arrangements for adaptation recommendations addressing the specific identified climate risk of river flooding. While predominantly focused on structural and technical measures, some non-technical and non-structural responses are also identified. Adaptation recommendations include engineering options, social response options including relocation, economic instruments, natural system management, sector specific practices, and traditional responses taken by communities exposed to increasingly frequent flooding. Furthermore, an external consultancy conducted a study on the costs of

impacts and adaptations for flooding in HCMC, which provides specific information for an infrastructural-based approach to adaptation.

The plan for Quito develops comprehensive policies leading to the implementation of adaptation and mitigation measures to address climate change. It was initiated by the Metropolitan Authority, which helps to coordinate the actions taken by local authorities in the area. This is achieved by generating methodologies and management tools for research and the provision of timely information. Actions are divided into four axes: information generation and management; use of clean technologies and good practices for mitigation and adaptation; communication, education, and citizen participation, and institutional strengthening and capacity building. Specific adaptations are further focused within the five sectors of ecosystems and biodiversity, drinking water provision, health, infrastructure and providing systems, including hydroelectric power, and risk management.

In Durban, the head of the city's Department of Environmental Management initiated action on climate change. After a first attempt to mainstream climate adaptation into the activities of all of city departments proved unsuccessful, a second more sector focused approach, which provided specific adaptation plans for the health, water, and disaster management sectors, has succeeded in spurring local action. The sector specific plans align adaptation measures with existing business plans, development objectives, funding, and skills. Activities in Durban are very much focused on the involvement of local the authority's officials and staff in order to integrate climate adaptation into local public policies.

Tools and Information for Policy Choices

Urban adaptation strategies derive recommendations for local authorities and public and private entities to address climate risks based not only on perceived changes, but also on the findings of preliminary vulnerability or impact assessments. The review of adaptation reports and relevant literature reveals that the methods and scenarios used in making climate projections vary based on available resources, while the types of adaptation measures and underlying sources of uncertainty are similar in many cases.

Climate Projections and Scenarios

The definition and implementation of successful adaptation strategies at the local level requires detailed knowledge about climate change impacts – information focused at a very local scale with projections over a long time horizon. At present, information of this kind is hardly available even in developed countries and is completely lacking in most parts of the developing world. However, adaptation can be more efficient with more precise information on the character and range of impacts (especially with respect to sea level rise).

One way to cope with the scarce availability of sufficiently precise data, which has been used for instance in the case of Tunis, is to limit time horizons to a relatively near future (in this case 2030) in order to keep confidence in projected changes at a relatively high level and to increase credibility and consensus for adaptation policies. In the case of Tunis, the availability of funding has furthermore allowed researchers to employ downscaling techniques, based on an ad-hoc exercise of regional downscaling models created in the framework of the study. The projections used for the Tunis study are based on two different downscaling approaches, the ENSEMBLES model, and an application of the ARPEGE-Climate model (Egis BCEOM International / IAU-IDF / BRGM 2011a).

Like Tunis, climate projections for Quito and HCMC are available only at the global level, thus limiting the possibility of deriving precise indications for the dimension of potential local impacts. The HCMC study focusing on flood risk for the city (the principal local impact) uses global climate change scenarios to force localized river-flood models, deriving three levels of flood intensity (1-in-10 year, 1-in-30 year, and 1-in-100 year), while also considering

additional scenarios including land subsidence, sea-level rise, and storm surge (The World Bank 2010).

On the contrary, assessments for London and NYC refer to elaborated climate projections with low scale grids, which are able even to reproduce spatial differences within the single urban region and to consider different socio-economic and climate scenarios. Modeling exercises fulfilling these requirements were either preexisting, as in the UK case where the government started a climate information system at national level in support of adaptation activities, or have been established as part of the planning process, as exemplified by the NPCC in NYC. The regional projections are based on GCM output from the single land-based model grid box covering NYC and its surrounding region (Horton and O'Grady 2009). The London strategy refers to the UK Climate Projections 2009 (UKCP 2009), which provide probabilistic projections for a number of atmospheric variables (such as temperature, rainfall and humidity) covering different temporal averages (month, season, year), and spatial resolutions (25km grid, or administrative regions, for example, London) (GLA 2010). In the modeling exercises for NYC and London, the creation and institutionalization of the process by the specific local competences will facilitate future modeling activities and allow for the provision of updates for climate projections at the local level.

Type of scenarios considered

With the exception of London, all climate projections used in the local applications refer to the global SRES scenarios defined in the context of the IPCC assessments. Projections for Quito and HCMC are based on the A2 (also B2 for HCMC) scenarios (Zambrano-Barragán et al. 2010). The study on flooding in Bangkok uses three climate scenarios (current, the most optimistic SRES B1, and the very pessimistic A1FI scenario) (The World Bank 2010). The adaptation plan for NYC uses GCM simulations driven with IPCC projected greenhouse gas emissions according to the more optimistic B1 and the less optimistic scenarios A2, A1B scenarios. The study for Tunis uses downscaling models referring to A1B (ENSEMBLES) and again A1B alongside with A2 and B1 scenarios for the ARPEGE model. The London plan is the only one to use proper national Climate Projections (UKCP 2009), which provide different future scenarios in overlapping 30-year time slices, starting with 2010-2039. Thus among the cases considered, there is some convergence on the use of the less optimistic A2 scenario (Quito, HCMC, Tunis, and NYC), and the more optimistic B1 scenario (Bangkok, Tunis), whereas the very pessimistic A1FI scenario is employed only in the HCMC flood study.

In Durban, climate projections are based on research undertaken by the University of Pretoria, University of KwaZulu Natal-Pietermartizburg and the University of Cape Town, using a regional downscaling model (CCAM nested within CSIRO MK3 AOGC). Data were also obtained from the South African Navy in order to project possible sea level rise, as part of the Global Sea Level Observing System project. The reference to IPCC SRES scenarios for 2070 to 2100 is generic, as no families of the SRES scenarios are indicated as references, and global atmospheric changes are referred to in terms of range of temperature variation. Based on the physical indications from modeling, four integrated scenarios for the future development of Durban were designed in a participated process as a tool for communicating with decision makers (Naidu et al. 2006).

Despite the advantages of their high scientific quality, ad-hoc modeling exercises do have some disadvantages. Although they are the only solution in cases where complex downscaling exercises do not exist, they do not provide continuity in climate change information and do not easily allow for updating and future elaboration of localized climate simulations.

Types of Adaptation Measures

An important criterion for the design of climate change adaptation activities is the timing of implementation. Planned or anticipatory adaptation measures are the result of deliberate policy decisions made by public agencies in anticipation of a climate event to proactively preserve and protect resources. Reactive measures are implemented after climate change impacts have occurred, and can further be categorized into two types: responses that are designed prior to events but implemented only once impacts are observed, and ad hoc responses to impacts taken after they have been observed. Managers select the appropriate option based on the available information on the risks and reversibility of the negative consequences and costs associated with acting now versus later (U.S. EPA 2009). Autonomous adaptations, which can occur on both time scales, are taken by private actors and are triggered by market or welfare changes (USAID 2009), or following public incentives, but without explicit planning.

Urban policies commonly used to facilitate adaptations include land-use zoning, building and building codes, natural resource management, transportation, changes in the management of urban utilities such as waste and water (OECD 2009), and protection infrastructures like dikes and erosion prevention. Evidence from urban adaptation strategies and relevant literature indicates that most adaptations fall in one of the following categories:

- Technical (hard infrastructural or soft non-structural),
- Land use planning,
- Contingency planning,
- Education and awareness raising,
- Research and monitoring.

Proposed adaptation measures are often synergistic with existing urban policies (Ligeti et al. 2007), as most climate impacts are not entirely new (Schauser et al. 2010), but require the modification of parameters and decision making criteria already implied for traditional urban policies, like land use planning, infrastructure dimensioning, and urban greening and housing (Prutsch et al. 2010). Nevertheless, more recent or less established types of policies, like preventive disaster management, also play an important role in the prospective of increasing risks from extreme events as these policies are able to reduce the socio-economic vulnerability to (climate change induced) hazards (Jabeen et al. 2010), and to increase the resilience with respect to the expected damages. Policies in Durban and Quito are mainly resilience-focused interventions aimed at improving development and service delivery objectives (Roberts 2010), whereas the Tunis (and the other northern-African cities) and HCMC studies consider mainly infrastructure measures and the improvement of early warning systems.

Among the case study cities, Tunis, London, and HCMC have already implemented or are proceeding with the realization of measures that can be considered adaptations to climate change. Like the Thames River flood protection scheme for London, put in place in the second half of the last century and presently monitored for adaptation to future sea level rise, or measures for coastal protection in Tunis and river flood protection measures in HCMC, which are under planning (HCMC) or already being implemented (Tunis).

Coastal or river flood protection was one of the predominant issues to be tackled by the case study cities. Options for climate change adaptation policies in these cases include soft protection and retreat and accommodate strategies, or on the other side, an increasing reliance on technologies to develop and manage information, and an enhanced awareness of the need for coastal adaptation to reflect local natural and socio-economic conditions (Nicholls et al. 2007).

With respect to coastal areas, reference is generally made to three kinds of adaptation strategies: protect, accommodate, or retreat (Klein et al. 2001), all having anthropogenic purposes. In reference to urban areas, the concept of protection is generally

prevailing, as the high costs characterizing this strategy correspond to high values of assets exposed to the risk. Nevertheless, some consideration regarding accommodation strategies are included in the Tunis study with regards to existing and planned settlements in flood-prone areas, proposing building measures (retrofitting, increase of building standards and reorganization of uses in ground floors), zoning with no-construction zones, and insurance schemes. The London strategy states that even urbanization of flood prone areas will need to be considered in some cases, assuming that individual developers will provide flood resistant buildings in these cases (GLA 2011a). Alternately, the Bangkok plan lists coastal protection phased retreat as an option for business and commercial entities to adapt to sea level rise. The recommendations of the study on HCMC also consider ecosystem based adaptation strategies for agriculture[1].

Specific physical measures (beyond classical infrastructure measures for flood protection such as dyke building and prevention and mitigation of erosion) are proposed in nearly all adaptation plans considered. These include, for example, initiatives related to urban greening, including greening of roofs and street profiles, in order to reduce urban heat island effects, creation of permeable surfaces reducing run-off and thereby mitigating impacts from of extreme precipitation, and reserving flood prone areas from urbanization in order to reduce potential losses from river and urban flooding. Some of these measures represent, to some extent, a trade-off between the objectives of adaptation and mitigation, as they imply lower urban densities, contradicting the aim of "compact" cities with less need for individual car transport.

One fundamental condition for adaptation planning in urban contexts appears to be the availability of a good planning capacity, including the knowledge and participation base needed for informing decision making for the urban future.

Uncertainty

One of the primary, fundamental challenges associated with the use of scientific data at the urban level is the issue of downscaling of future climate projections; a technique used by several cities considered. A cascade of uncertainty arises when conducting climate change impact assessments for the purposes of making long-term adaptation strategies at a very detailed, urban level, as uncertainties accumulate throughout the various levels of assessment (Dessai and der Sluijs 2007). The process of moving from a global scale model, with inputs based on uncertain natural and socio-economic assumptions, to a regional model where impacts can be derived at the city level is extremely complicated and highly uncertain. Expected climate change impacts vary by metropolitan region due to many factors, including geography, location, population, and level and pattern of development. Adaptation measures to address potential impacts are impeded by uncertainty of the nature of the impacts due to these factors (OECD 2009).

The type, level, and timing of the adaptation strategies chosen to address (uncertain) impacts also contain uncertainties in their outcomes, as the ancillary benefits and distribution of costs and benefits across stakeholders are often unknown until an adaptation is implemented. It is clear that adaptation to climate change is not only made based on uncertain projections, but also has uncertain results, insofar that market responses to planning measures cannot in all cases be foreseen, and can take forms and cause impacts which differ from those anticipated in the planning documents.

[1] The fact that urban agriculture is considered a relevant sector in the urban economy is an interesting exception among the case studies considered. The consideration of agriculture is justified, besides its physical role in ensuring permeable surfaces in the city area considered also in other case studies, with reference to the role it has for ensuring livelihoods for the poorest segments of the population (ADB 2010).

In addition, there are significant uncertainties surrounding the projected costs of impacts and benefits of adaptation, due to the process of valuation, which includes finding future market prices that are consistent with a city's underlying socio-economic scenario, or providing estimates when there are no market values. Furthermore, valuation must account for both direct and indirect economic impacts. Direct impacts are the primary effects from climate change on production or consumption, while indirect impacts are the changes in production or consumption on the whole economy through the effect on relative prices. Most studies consider only direct costs (impacts = price * quantity), as indirect costs are more difficult to calculate and are often not calculated under the assumption that they would be negligible (EEA 2007).

The most controversial aspect of valuation is the treatment of discounting in climate change economic assessments[2]. Discounting is used to directly compare the economic costs and benefits at different times by expressing all costs at a base year, or in "present value". The choice of a discount rate dramatically affects the estimated economic costs of climate change: a higher discount rate implies lower economic costs now (often discussed in terms of investment in mitigation), while a lower rate calls for more investment and higher costs now (because the future is valued nearly as much as the present is valued). The issue of discounting is connected to both economic and ethical assumptions about how the rights and preferences of future generations are taken into account, and in turn provides a great deal of uncertainty to decisions on when and how much to adapt to climate change or to shift potential costs of damages to future generations.

The discussion over discounting relates to the choice of a time horizon in assessing impacts and designing adaptation measures. Climate change impacts involve long time scales and should therefore be considered over a long time horizon. However, projections going out further into the future are more uncertain than projections made on a short time scale. Additionally, information on uncertain and irreversible events that may occur in the climate system is unavailable and unknown. This raises the issue of tipping points, and when to apply the precautionary principle. Ambitious adaptation supports risk aversion and thereby increases the economic costs of adapting to climate change (EEA 2007). The issue has been extensively discussed in the studies for Tunis and the other Northern African cities, where economic assessment outcomes are presented for a range of different discount rates from 1 to 5% (Egis BCEOM International / IAU-IDF / BRGM 2011a). In the Bangkok study on flooding, three separate discount rates are used (8%, 10%, and 12%) in the economic analysis, resulting in different economically efficient protection levels for flood infrastructure (The World Bank 2010). Conversely in the HCMC study only one standard discount rate of 10% is applied (The World Bank 2010; Egis BCEOM International / IAU-IDF / BRGM 2011a).

Governance

Elements shaping the fundamental components of adaptation policy at the urban level include the development status of a city, timing of initiatives, political leadership and government support, integration of adaptation into the existing policy structure, involvement of private actors, as well as institutional barriers and constraints. Additionally, affiliation to climate change policy networks can be seen as a further confirmation of specific sensibility for activities connected to climate change policies, rather than as a triggering element. Once an affiliation has been established, climate networks may provide valuable assistance and advice for the transfer of policy models or approaches. At this local level, design of climate change policies and implementation of adaptation plans require political support and effective governance, and must overcome various obstacles in the process.

[2] This issue is covered extensively in the literature, particularly relating to the debate over the low discount rate used in the Stern Review. The debate cannot be presented here in breadth, nevertheless a brief consideration of the implications in terms of uncertainty is considered.

Socio-Economic Considerations

Adaptation to climate change is an issue for cities in developed as well as in less developed countries, but baseline conditions are quite different in these cases, and low-income economies will face the most financial burden as they are proportionally more affected by the impacts of climate change (Aggarwala et al. 2011). Economic impacts may be lower at an absolute level in developing countries, beyond the losses of human lives, which are anticipated to be greater than for cities in developed countries, but will likely be more incisive in relation to the entire volume of economic activities (UN-Habitat 2011). Conditions for poverty and marginality are recognized as key contributors to vulnerability, and low-income households are expected to be those which will suffer most from climate change both in developed and in developing countries (UN-Habitat 2011). Adaptation must take into account the particular circumstances of the urban poor by supporting slum and squatter upgrading, and reconsidering zoning, planning, and building regulations (IFRC 2010).

Climate change, having different impacts on groups and individuals based on wealth and access to recourses, is expected to exacerbate existing social divergences especially in low-income countries (UN-Habitat 2011). Concerns in developed countries focus on the fact that climate change is anticipated to exacerbate pre-existing gender dimensions of vulnerability, as age, gender, and literacy influences vulnerability to the consequences of climate change (IFRC 2010). The London Climate Adaptation Strategy adds further characteristics to this vulnerability profile, such as disability, proficiency of spoken English, living alone or not having a support network, and low income and inadequate insurance coverage. It states, furthermore, that with respect to flood risk, the poorest ten per cent of Londoners are more likely to live in areas of tidal flood risk (GLA 2011a). The HCMC adaptation plan also identifies low-income groups as being more vulnerable to flood risk (ADB 2010).

Timing

Time horizons for the manifestation of severe impacts from climate change are rather long, but physical assets and structures of urban areas have similar or even longer lifecycles, so accounting for climate change in decision-making on physical urban assets will need to take the future climate into consideration. On the other hand, current time horizons in public decision making processes are shorter than those for climate change scenarios; this can be attributed, at least in part, to the difficulties in taking into account future social and economic changes, which are difficult to anticipate in the long term. For this reason, for example, the time horizons adopted in the study for risk management in Tunis have been limited to 2030, arguing that the social implications of decisions on longer terms would be too difficult to be shared, although relevant levels of climate change impacts are expected to manifest themselves over a longer time frame.

Planning and management of urban adaptation thus needs to account for the consistent differences in time horizons between credible anticipations of future development and relevance of time horizons for climate change impacts (Egis BCEOM International / IAU-IDF / BRGM 2011a). If economic assessments are part of the decision making criteria, then the time horizon chosen for the assessment of future damages and investment costs, and the translation of future costs and benefits into present values (i.e. discounting) represent important issues to be tackled.

Also from a financial point of view, knowledge of the time frame in which climate risks are anticipated to occur and when adaptation strategies should be implemented is crucial for maximizing benefits. The study for Tunis, which bases decisions for adaptation measures on a cost-benefit analysis, uses three time steps for categorizing proposed actions (short-term actions (to be implemented within 2 years), medium-term (to be implemented within 5

years) and long-term activities which should be implemented within the next 10-15 years (Egis BCEOM International / IAU-IDF / BRGM 2011b).

With a slightly longer time horizon than the Tunis study, the cost assessment for impacts and adaptations to flooding in Bangkok are made for the year 2050, a moderate selection. Conversely, Quito and Durban make projections over a much longer time frame. Quito's plan discusses a temperature change that is predicted over the next hundred years, and timelines are set for specific and sectoral adaptations (Zambrano-Barragán et al. 2010). In Durban's adaptation plan, climate projections were made for 2070 to 2100 and associated impacts were identified for each sector, providing a basis for adaptation options that should be implemented (Hounsome and Iyer 2006).

One option for planning adaptation is to temporarily subdivide decision making, postponing some decisions until more precise knowledge is available in the future, or planning for the revision of decisions in light of any newly available information. Thus following principles of adaptive management (Tompkins and Adger 2003; Birkmann et al. 2010), some of the cities' plans recommend that adaptation should be approached as an iterative and constantly evolving process (Rosenzweig et al. 2010). For instance, the London strategy, which has scarce direct implications in terms of investments and public infrastructures, does not explicitly differentiate time horizons, but defines precise, generally short-term, deadlines for planned activities, and furthermore contains generic indications for the definition of time lines and tipping points[3]. The NYC study conceives a process of eight steps, which follow the cyclical concept of Flexible Adaptation Pathways, providing an iterative process for continual reassessment and adaptation action (Rosenzweig et al. 2010). This strategy of adaptive management can be implemented in relation to slow onset phenomena like sea level rise, yet if extreme events like flooding and flash flooding are concerned, uncertainties should be taken into account and decisions on the necessary level of protection must be subject to political decision making. A time horizon of 30-40 years has been adopted for the Tunis study as a compromise between uncertainties connected to long time horizons and realistic assumptions about investment and lifecycles of measures to be adopted, for instance infrastructure and urban development regulations (Egis BCEOM International / IAU-IDF / BRGM 2011b).

Climate Change Network Affiliations

External inputs into local policy processes frequently stem from international climate change networks. A number of cities benefit from the opportunity to share ideas and experiences through networks, seminars, and conferences (Carmin et al. 2009). This is true both for networks formed by international agencies established in support of donor programs (e.g. Resilient Cities program, and the North African cities program by the World Bank), and for independent international networks created among cities focusing on sustainable urban development, like ICLEI – Local Governments for Sustainability (Brugmann 2011) or the Covenant of Mayors and C40 Cities initiatives. A second relevant impetus for the definition of urban adaptation policies found in some of the case study cities comes in the form of reports and technical advice for vulnerability studies and action programs financed by external donors.

The example of Durban is emblematic for the role of international networks: in this case ICLEI initiated climate action in Durban when the association asked the city to participate in the Cities for Climate Protection campaign. A further input for activities subsequently was provided by an international program for financing urban climate policies, when the Head of Durban's Environmental Management Department was invited by the Rockefeller Foundation to serve on the advisory committee for the Asian Cities Climate

[3] The publication of revised projections on sea level rise is actually not a real tipping point, nevertheless the change in prospective on future sea levels is one of the key criteria for triggering a review of the strategy.

Change Research Network (ACCRN). The Rockefeller Foundation "compensated" the city with funding to jumpstart their Municipal Action Plan (MAP) for adaptation to climate change (Carmin et al. 2009). In NYC, the New York City Panel on Climate Change (NPCC), the expert committee advising the Adaptation Task Force for decision-making in adaptation, was again created with external funding from the Rockefeller Foundation.

The climate risk assessment and adaptation study for Tunis (conducted as part of a series of studies on the North African coastal cities of Casablanca, the Bouregreg Valley in Morocco, and Alexandria, Egypt) was financed by a group of international donors including The Marseille Centre for Mediterranean Integration (CMI)[4], The World Bank, and other organizations (Egis BCEOM International / IAU-IDF / BRGM 2011d). The purpose of these studies is to provide public administrations with advice and assessments that can potentially be used for the design of adaptation plans.

The external inputs in the London case are less evident. The London strategy for climate change adaptation was initiated by the former Mayor of the Greater London Authority (GLA), Ken Livingston, who was also the initiator of one of the major networks for urban climate policies - the C40 Initiative. In this case, further to responding to national policy inputs, the local adaptation process appears as a showcase for public policies.

Public Leadership for Climate Adaptation

In many cases of adaptation planning, as in other innovations for (urban) policies, a single concerned official or agency, sometimes without defined legislative mandates or significant financial or human resources, drives the response to climate change within cities (Solecki et al. 2011). The examples of London and Durban highlight the sometimes-vital role of individual figures. Former London Mayor Ken Livingston proved to be particularly concerned about climate change as he initiated the C40 network and commenced the London adaptation plan. The redaction of London's adaptation program was delayed for a period of two years following the election of the new mayor in 2008. During Livingston's mandate, climate change policies had been introduced among the statutory tasks of the GLA[5]. The adaptation activities started in 2006, one year before the institutional change occurred and the new statutory act entered into force (Collingwood Environmental Planning 2010). The change in the municipal leadership appears to have slowed down the deliberation process on the adaptation strategy (Collingwood Environmental Planning 2010), and there is some evidence that actions have been emptied of direct incisiveness in the final version of the plan, which was completed in 2011.

In Durban, the Head of the Environmental Management Department, Debra Roberts, set the adaptation process in motion after she attended a climate focused environmental course at a United States university. Upon her return to Durban, Roberts lead the initiative to develop and implement a municipal climate protection program, which commissioned an analysis of climate impacts and subsequent citywide and sector-specific adaptation plans.

Policy Process

Adaptation planning is not (yet) part of the traditional set of urban policies, and the initiatives triggering the creation of local adaptation plans are quite various. International donors have initiated several of the plans and studies considered here (i.e. Tunis, HCMC, and Bangkok). Some studies made by external agencies are driven by global impact assessments identifying cities with particular vulnerabilities. For example, studies conducted

[4] The CMI was established in 2009 by the World Bank, the European Investment Bank, and the Government of France followed by the Governments of Egypt, Jordan, Lebanon, Morocco and Tunisia as well as the City of Marseille. http://www.cmimarseille.org accessed in July 2011.

[5] http://www.london.gov.uk/who-runs-london/greater-london-authority/about-gla

for Bangkok and HCMC were financed following the recognition that both are among the top ten cities in the world (based on population) likely to be exposed to flooding due to climate related risks by 2050 (The World Bank 2010). Often this external donor influence triggers a top-down approach to the involvement of stakeholders, as exemplified by the case of Tunis and the other North African cities, where stakeholders involved in the assessment process mainly include representatives from public authorities, but none from the economic sector or civil society. Consequently, the Tunis study gives precise indications with regards to investments in public infrastructures and provides some advice with regards to land use planning, but lacks consideration of issues related to private initiatives for adaptation and risk preparedness, only mentioning them among further recommended activities.

When local planning authorities create adaptation plans the consideration of a bottom-up or participatory view, which is an established practice in urban planning, has a greater importance (see Quito and London). Although it is generally stated that climate change impacts are going to evolve in the future, the sensation that climate is changing, created for instance in Durban by a series of extreme events, has contributed to an enhanced consensus towards local adaptation policies. It is explicitly noted that the feeling that climate is already changing is helping to spur public consensus for adaptation measures in Durban (Roberts 2010).

Level of Integration with Existing Urban Policies

The formulation of urban adaptation plans spans between two levels of integration into current urban policies. At the one end there is a dedicated action plan that relies on institutional structures and on specific financial resources providing support for adaptation activities in all relevant sectors of urban policies. At the other end stands the ideal mainstreamed policy, where the aims of climate change adaptation strategies are developed and implemented as part of each sectoral urban policy. In reality, most plans fall somewhere between these two poles, given that an autonomous action of each of the sectoral areas of urban management would not even be desirable, and a completely autonomous “department of adaptation” would nevertheless depend on specific knowledge and competence for intervention held by the urban sectoral administrations.

Disaster management mainstreaming and development planning mainstreaming are the two most common ways that climate change adaptation is incorporated into existing frameworks to link climate change to broader issue agendas. The rate and success by which mainstreaming can occur are governed by the commitment of local government officials, the use of adaptation as a filter for new initiatives, the degree to which adaptation and development goals are linked, and the allocation of local resources to advance climate change adaptation (Carmin et al. 2009). One of the most promising ways to effectively mainstream climate adaptation is to link initiatives to development goals. However, given that funding is generally limited, this will inevitably lead to contradictions and the need to make trade-offs between different priorities. Some of these trade-offs are advancing risk reduction strategies versus affordability, promoting stricter residential building regulations for disaster resistance safety versus flexible standards for incremental housing development by the urban poor, and self-help community development of infrastructure versus adherence to universal standards of water and sanitation services designed to avert risks of contamination in crisis situations (McCarney 2009).

The importance of integrating considerations of different risks and needs for action in planning for adaptation is evidenced by Durban’s experience. The Headline Climate Change Adaptation Strategy (HCCAS) advocated a comprehensive, citywide initiative, but had little or no effect on the sectoral administrations that should have implemented the recommended measures. After realizing the inefficacy of the comprehensive plan, the local authority decided to create sector specific, interconnected Municipal Action Plans (MAPs) aligned with the existing business plans, development objectives, funding, and skills of the departments responsible for implementation. With respect to the HCCAS, sector administrations

perceived outlined risks too generic and distant to be of concern for the everyday activities of municipal sectoral administrators. The subsequent sector-focused approach provided detailed indications for climate change issues with respect to individual sectors and for cross-sectoral synergies. The health (clinical health, environmental health, communicable disease control and social development), water (water and sanitation, coastal, storm water and catchment management, and coastal policy), and disaster risk management sectors were chosen as pilot projects to test the approach. They were selected because of their particular vulnerabilities to climate change, their importance to the city's development agenda, good working relationship with the Environmental Planning and Climate Protection Department, and because water and health are affected by similar climatic factors. Both sectors require adaptations engaging a broad range of stakeholders responding to a variety of risks (McCarney 2009).

The adaptation plan for NYC links to larger sustainability activities, so that climate change is considered as part of a broad range of future trends, rather than as an isolated phenomenon. Climate change adaptation in NYC was initiated with the release of the city's sustainability plan (PlaNYC), which adopted climate change as one of its ten sustainability goals. The first initiative was to create an interagency Climate Change Adaptation Task Force (Task Force) to determine adaptation strategies to protect the city's critical infrastructure. The mayor subsequently convened a panel of experts, the New York City Panel on Climate Change (NPCC), to advise the Task Force on issues related to climate change and adaptation, and to ensure that the city's adaptation efforts are based on sound science and a thorough understanding of climate change impacts and adaptation. The NPCC has provided an analysis of expected climate change hazards for NYC, studied impacts on the critical infrastructure, and developed a risk management framework for adaptation planning. The NPCC has also developed a planning tool to help guide Task Force members through the processes of identifying climate risks to critical infrastructure and creating adaptation plans, while considering the regulatory environment for climate change adaptation. The development of an evolving dynamic process for a risk management approach to climate change through the use of Flexible Adaptation Pathways is considered one of the highlights of the adaptation strategy. Through this initiative, multiple layers of government, public agencies, private organizations, and experts build crucial partnerships for coordinated adaptation strategies. The Mayor's Office of Long-Term Planning and Sustainability provides leadership to this on-going coordination and helps facilitate the application of Flexible Adaptation Pathways (Rosenzweig et al. 2010).

The adaptation study for HCMC proposes specific implementation arrangements to the city departments responsible for the adaptation measures. This is a more generic form of mainstreaming as the plan intends for adaptation initiatives to be integrated within the city departments normal work responsibilities. For example, the Department of Planning and Investment is advised to integrate climate change adaptation into the 2011-2020 HCMC Socio-Economic Development Plan, and the HCMC Environmental Protection Agency is advised to prepare adaptation monitoring and audit guidelines to keep track of adaptation performance, amongst other recommendations.

Resilience Building

Resilience involves redundancy, flexibility, the capacity to reorganize, and the capacity to learn (IFRC 2010). There is a general consensus that cities must become resilient to a broad range of shocks and stresses in order to best prepare for climate change. This can be done effectively by linking efforts to foster climate resilience with efforts to promote urban development and sustainability (Leichenko 2011). Building resilience in this way requires the involvement of many stakeholders, including civil society organizations, the private sector, the academic and research community, and the local government (IFRC 2010). The NPCC in NYC's adaptation process exemplifies this idea, as it is composed of more than 40 public and private stakeholders including experts from regional academic

institutions, as well as engineering, legal and insurance industries. In a similar manner, the London adaptation plan provides for actions aimed at “raising individual and community level awareness and capacity to cope and recover” indicating resilience building measures related to participation in early warning schemes and community flood risk planning (GLA 2011a).

Creating resilient cities is the goal of both climate change adaptation and disaster risk reduction, as both reduce the socio-economic vulnerability to hazards or the effects of climate change. Common goals are to lessen the impacts of extreme events and increase urban resilience to disasters, particularly among vulnerable urban populations. Both recognize the importance of combining multiple sources of knowledge, and rely on analyses of the underlying causes of exposure and vulnerability, seeking to integrate findings into planning, management, and action (IFRC 2010). In Durban, the link between disaster risk management and adaptation is explicitly realized in adaptation planning as the Disaster Management Unit (DMU) was chosen to be one of three pilot sectors in which to implement a Municipal Adaptation Plan. As climate change is recognized as a risk requiring action, the DMU is responsible for creating early warning systems and ensuring that resiliency is build into construction processes to reduce the probability of infrastructure failure and enhance recovery after an extreme event, as well as relocating people and critical infrastructure in vulnerable areas. The DMU is intended to serve as an effective element for comprehensive, cross-sectoral adaptation planning in Durban (Roberts 2010; Carmin et al. 2009).

Governance of adaptation

Public authorities are able to promote adaptation in urban areas using four main channels. The predominant role of public authorities is the provision of specific infrastructures, such as flood protection measures, to protect private investments from damages, typically using public funds. With regards to the wider range of infrastructures supporting urban activities, municipalities act as investors, for instance in physical infrastructures, and need to protect investments against climate change impacts to prevent damages and losses in order to ensure their function in the long-term. A third role of public authorities concerns the regulation of private activities to prevent conflicts and ensure long-term sustainability of urban uses. Lastly, local authorities are most active in the field of enabling, communicating climate change information, and building awareness of potential impacts amongst stakeholders and decision makers (OECD 2009, 2010; Carter 2011).

This complexity and heterogeneity within urban areas poses particular challenges to the governance of adaptation. Especially in the case of urban areas in developing countries, vulnerabilities to climate change impacts are concentrated in those areas that have not been reached by regulative interventions of public authorities, lacking both infrastructures and forms of institutional assets, which could be used for disaster management. If governance represents a problem for developed countries like the UK, where public administrations are able to deliver policies, then there is major concern with regards to developing countries, where governance structures and institutional assets actually prove unable to provide for infrastructure provision and management of urban growth under present conditions.

Land use planning

Local authorities typically engage in activities relating to the regulation, planning, and provision of urban infrastructures, so a consolidated set of instruments like land use plans, zoning rules, and by-laws are readily available for use in the adaptation of urban areas. However, these instruments are oriented more towards the regulation and management of urban expansion, as they provide indications for new development. The adaptation of existing urban areas will instead require more sophisticated instruments that are able to efficiently influence private decisions with regards to investments in existing assets.

With respect to future developments, the adaptation study for Tunis presents detailed considerations and recommendations for land use policies and urban development. These include opportunities to take climate change impacts into account when designing and

developing new areas, as well as consideration of urban density. With regards to existing urban areas, adaptation can be based only on a small range of infrastructure measures, such as drainage, and other activities to increase resilience (Egis BCEOM International / IAU-IDF / BRGM 2011b). Conversely, the London adaptation plan acknowledges the increasing flood risk associated with urban growth, and anticipates this threat to be compounded by future urbanization of already flood prone areas.

Adaptation of existing urbanized areas to new climate conditions presents a particularly difficult issue when retreat strategies must be implemented, as the protection of assets is considered too expensive, and parts of urbanized areas must be forfeited (infrastructures and public facilities no longer maintained). These kinds of policies are already creating conflicts, for instance in some UK coastal zones, where managed realignment projects are creating equity problems for private owners (Turner 2007; Hallegatte et al. 2008). Policy concepts for properties affected by public adaptation strategies and solutions for extreme cases of abandonment of urban land have not yet been developed, as major obstacles are expected in urbanized areas (Shih and Nicholls 2007) and are still only somewhat conceptualized in the adaptation debate (de Perthuis et al. 2010).

Involvement of Private Actors

Whereas traditional adaptation strategies following the “protection” philosophy (Klein et al. 2001) rely mainly on public action, resilience-oriented adaptation strategies will need the support of private activities and investments to increase preparedness for climate change impacts. Although knowledge about expected climate change impacts appears to be quite widespread, private action, for instance in terms of investment in adaptation measures to protect buildings from future impacts, is still rather rare. A background study connected to the London adaptation strategy attributes the gap between knowledge about climate change impacts and implementation of adaptation measures among private house owners to the existence of a form of market failure (LCCP 2009). The explanation given for these market failures, which represent at the same time justification and logic of public intervention, include inadequate or asymmetric access to information, externalities not included in cost-benefit analysis (LCCP 2009), or divergence of time horizons for climate change which are, albeit consistent with investment cycles for buildings, beyond the “normal” human perception.

Institutional Barriers and Constraints

Research needs and barriers to effective action for climate change adaptation include information and data deficiencies, administrative and governance constraints, funding limitations, and the need to define metrics of progress (Solecki et al. 2011). The adaptation plan for Durban exemplifies several problems encountered in this context, most of which hold true for all cities adapting to climate change. Six specific governance constraints have been identified, several of which have contributed to a lack of response from sectoral administrations, compelling the city to change its strategy for mainstreaming adaptation into urban policies. First, the long time scale of climate change is not compatible with the short political and budgeting cycles at the local level. Second, cities have historically been planning for a constrained set of predictable futures, and lack flexibility in planning for uncertain futures. Third, climate change has been stereotyped as an environmental issue, while it is actually a developmental challenge, inhibiting it from being effectively mainstreamed into planning and decision-making. Fourth, local governments have had limited standing in international climate change negotiations despite their role in adaptation and capacity building. Being recognized as governmental stakeholders at COP16, mainly for mitigation efforts put into place by urban authorities, built momentum for adaptation efforts by ensuring that national governments acknowledge cities as climate change players. This better positioned cities to receive international funds. Fifth, it is extremely difficult for local

governments to access international funds for climate change adaptation. Sixth, it will be challenging for local governments to deal with the residual damages from climate change where adaptation is neither economic nor feasible (Rosenzweig, Solecki, and Hammer 2011).

HCMC, on the other hand, evidences how barriers can exist in the interactions and conflicts between different adaptation strategies. One goal of the plan is to provide all residents with safe and affordable land as a means of social development, yet where that land is located and how relocation would occur are unknown. Additionally, there is a lack of provision of public infrastructure and constraints on the planning process in urban development that hinder proposed strategies such as improved building codes and better land use planning. Furthermore, there are negative consequences or externalities associated with some structural measures, for instance related to the implications of building dikes and relocating people, that are not discussed, but will have tremendous implications for the people (Birkmann et al. 2010).

In presenting and assessing a program of measures, the consultants for the study on Tunis considered constraints and barriers at the level of the single measures proposed, including real estate values and uncontrolled urbanization (in relation to flood protection measures), and difficulties in creating and using urban green areas, such as avoiding soil sealing etc. (in relation to passive adaptation measures). At the more general level, the consultants also considered administrative and cultural barriers against any kinds of change.

Finance

Potential costs of climate change impacts and adaptations are particularly important to cities, as The World Bank estimates that more than 80% of the overall annual global costs of adaptation to climate change will be borne by urban areas (Huhtala et al. 2010). Adaptation costs, however, only account for a fraction of the overall baseline costs of ordinary urban development. While categories of adaptation costs are similar for all urban areas, the techniques used in cost benefit analysis, the costs of impacts and adaptations, the sources and implications of funding, the role of public-private partnerships, the use of risk management and insurance, and use of resilience upgrading to lower private losses differ significantly across cities.

The United Nations Framework Convention on Climate Change (UNFCCC) assessment reports address the costs and benefits of adaptation measures relevant for urban areas in a chapter (Chapter 7 AR4) dedicated to Industry, Settlement and Society (Wilbanks et al. 2007). Urban areas are furthermore considered in the context of coastal systems, as many of the major urban areas are situated in low-lying coastal areas (Nicholls et al. 2007). The estimated damages for coastal zones are connected to raising sea levels, considering inundation resulting from storm surges and as backwater effects from rivers, salt-water intrusion in ground and surface water, and morphological changes in terms of wetland losses and erosion. The DIVA model (Hinkel and Klein forthcoming), which is based on an optimization approach to coastal protection (assuming that only valuable land will be protected by dykes or beach nourishment), takes into account a big share of urban adaptation efforts, as dykes are build generally for the protection of urbanized areas. Global assessments of adaptation costs have difficulties in taking into account specific issues connected to relative sea level rise, such as subsidence of urban areas (although partly addressed in more recent versions of the DIVA model that provided some input in the assessments), or different security levels chosen for adaptation solutions.

The costs for adapting to rising sea levels, as estimated by the UNFCCC, range from $4 to $11 billion per year to be spent on engineering solutions for coastal protection, assuming a planning horizon of 50 years and no adaptation deficits (Nicholls et al. 2007). Further costs of $ 1-2 billion/year will be incurred due to residual damages from coastal

flooding and land loss. These costs are underestimated, as they neglect to account for existing infrastructure and adaptation deficits (which can be rather important even in cities of developed countries, like New Orleans), additional adaptation needs related to infrastructures for growing urban areas (Satterthwaite and Dodman 2009), and other climate change impacts on coastal systems, such as increased storminess and coral reef degradation (Nicholls 2009). Furthermore, most damage assessments only account for private losses insofar as insurance payments for similar extreme events could be considered, without consideration of the livelihoods of those lacking access to disaster loss insurances – nearly the entire urban community in developing countries (Satterthwaite and Dodman 2009).

The usefulness of these global figures is mainly related to the debate on funding of adaptation and development policies, rather than being significant for the implementation of adaptation strategies in a specific location. Considering adaptation as an activity put in place by urban and national institutions, the range of financing needs for addressing adaptation costs at the city level include: (1) upstream planning for the provision of public services; (2) prefeasibility, feasibility, and analysis of investments; (3) support for climate change adaptation and disaster risk management at the city level; (4) the design and construction of investments; (5) maintenance and repair; and (6) monitoring, evaluation, and reporting (following Huhtala et al. 2010).

Techniques used in Cost-Benefit Analysis

Assessments of the economic costs of climate change are helping to inform the policy debate on adaptation. In the local context, prior to the formulation of an adaptation strategy, an impact assessment is often conducted to identify the greatest vulnerabilities to climate change. National, state, and local governments have begun to conduct impact and vulnerability assessments to identify the sectors, infrastructure, and populations most at risk, ensuring that adaptations are focused on the most significant threats. Generally, these assessments consider costs of inaction in terms of damages that will be incurred due to climate change impacts on natural ecosystems, coastal zones, agriculture, energy, tourism, human health, water, and the built environment (EEA 2007). Not only does this process highlight the potential socio-economic and environmental losses due to the impacts of climate change, but it also helps prioritizes the risks and need for adaptation, providing a timeline and estimation of costs and benefits to show where adaptation will have the greatest effect. Information on the anticipated impacts of climate change, and the associated costs and benefits of adapting, provides a basis for assessing the effectiveness of adaptation policy.

Cost-benefit criteria were used to compare the expected costs of climate change impacts (and natural disasters like earthquakes in the Tunis study) with adaptation costs and residual losses in the cities where international donors have financed adaptation studies done by external experts, including HCMC, Tunis, and Bangkok. Results of these exercises reveal the political implications of fundamental assumptions on discounting. In the case of Tunis, discounting was based on a fixed rate for the short term, with a decreasing discount rate for the remainder of the investment cycle (up to 100 years according to the lifetime of the investment) (Egis BCEOM International / IAU-IDF / BRGM 2011b).

The HCMC adaptation study does not undertake a cost-benefit assessment of potential or foreseen adaptation measures, but does assess the costs of impacts using two alternative methods; one aggregates the losses in land values due to regular and extreme flooding (assuming that the impact of present flooding due to climate variability has already been capitalized in land values, possible losses in land values due to additional flooding events are estimated). The second assessment bases the estimation of annual losses on the number of persons affected by flooding in relation to the GDP per capita and the expected number of days of flooding (ADB 2010).

In The World Bank's study on flooding in Bangkok, consideration is given to both the direct and indirect costs of flooding on buildings, industry, and commerce; transportation and related infrastructure; public utilities such as energy and water supply and sanitation services; and people, income, and health. Direct impacts from flooding involve costs from loss in the stock of infrastructure, tangible assets and inventory, agricultural and environmental goods, and injuries and life loss. The indirect impacts of flooding are a result of a loss in the flow of goods and services to the economy. The Bangkok study calculates present value of future losses using 8%, 10%, and 12% discount rates for assessment of adaptation investments. Using the results from the preliminary evaluation and applying Thailand's standard 8% discount rate for public investments (The World Bank 2010), the study finds that flood infrastructure should be designed to protect against a 100-year return period flood, as it provides a higher net return (NPV=$0.4 billion). Such an investment will be economically efficient given an A1FI climate change scenario, however, if a discount rate of 10 % is applied, Bangkok should opt for the adaptation project aimed at a 30-year return period.

Costs of Impacts and Adaptation

Studies conducted by international donors generally provide evidence on cost-benefit relations for proposed actions and investments. This holds true in the cases of Tunis, HCMC, and Bangkok, where economic assessments represent a central element for the consideration of adaptation options (see above). The study on Bangkok estimates the net present values of structural adaptation investments, for an A1FI climate scenario, of approximately $1.06 billion for a 30-year return flood protection project, and of $1.5 billion for 100-year return flood protection. Total annual operation and maintenance costs for a 30-year return flood are $17.5 million, with average annual benefits of reducing flood damages reaching $132 million. For protection against floods with 100-year return periods, annual operation and maintenance costs are $26 million, with average annual benefits of reducing flood damages totaling $177 million (The World Bank 2010).

In the Tunis case, annual costs of impacts from natural hazards up to 2030 are estimated at 140 MDT, and are further considered in relation to the number of inhabitants (49 – 57 DT/person/year) and the GDP for the area of Grand Tunis (0,77% in relation to present GDP or 0,29% in relation to the GDP estimated for 2030) (Egis BCEOM International / IAU-IDF / BRGM 2011a). In a second phase, the costs and benefits of adaptation measures were again estimated with a revised time horizon (2020-2050), finding total annual costs of 612 MDT, and benefits of 870 MDT, of which 438 MDT are due to measures related to the risk of urban flooding (Egis BCEOM International / IAU-IDF / BRGM 2011c). The study underlines the fact that benefits expected from adaptation measures are slightly exceeding 21% of the overall damages attributed to climate change during the first phase dedicated to the vulnerability assessment, and are thus more than compensating the impacts from climate change. The value of benefits estimated corresponds less than 5 % of the GDP (Egis BCEOM International / IAU-IDF / BRGM 2011c p. 212).

The study on HCMC provides an estimate of the viability of a proposed $750 billion dollar flood protection project to be completed by 2025 to offset the impacts of climate change. Annual impact costs range from $6.5 to $50 billion for regular flooding and from $0.42 to $6.69 billion for extreme flooding. Based on the assessment of GDP losses, the damages could be reduced by 35% by adapting (corresponding to the decrease in the number of inhabitants exposed) (ADB 2010; The World Bank 2010).

On the other hand, comprehensive cost-benefit analyses have not been a primary concern to local administrations preparing adaptation plans on their own initiative. For example, impact and adaptation costs are currently unavailable for NYC and London, as economic assessments were not conducted as part of the cities' initial adaptation planning process. The NYC plan does however recommend an analysis of the economics and financing of adaptation based on the findings of the NPCC's report. Although an economic

assessment has not yet been conducted for NYC, a statewide report was released in 2011, including a cost analysis of impacts and adaptations (see Leichenko et al 2011). Concerning NYC, the report finds that the coastal zone will face the greatest economic impact of any region due to its exposure and vulnerability, and the high concentration of residences, businesses, and infrastructure along the shore. Also, urbanized areas will incur higher public health costs due to the urban heat island effect (Rosenzweig, Solecki, DeGaetano, et al. 2011).

Similarly for Quito, there has not yet been a comprehensive cost assessment of climate change conducted for the city. One example of the costs of adaptation comes from an economic analysis of the impacts of glacial retreat in the Andes (done by several researchers and members of The World Bank), which found that rapid glacial retreat will disrupt the water cycle in Quito, requiring an increase in the current investment costs for future water supply of approximately $100 million (Vergara et al. 2007). Additionally, several adaptation investments have already been made in on-going activities in the water supply and sanitation sector; $110 million and $190 million have been invested in separate strategies within the Water and Sanitation Master Plan. Approximately $40 million have been invested in the Hillside Management Program, and the Fund for the Protection of Water holds $6.6 million (Zambrano-Barragán et al. 2010).

In Durban, plans have been set in place to capture the full costs of implementing the three pilot MAPs to determine the costs and benefits of adaptation for early adapters. Findings will reveal whether this type of adaptation work is viable in the long term without external funding (Roberts 2010). An expert in climate change adaptation and economics has helped EPCPD develop the terms of reference for a cost-benefit analysis, and the EPCPD MAP website currently states that a call for economic assessment project proposals will be posted in the near future. Nevertheless, sector oriented assessments have been prepared for some areas; a multi-criteria assessment of the health and water MAPs is provided in the final report of the plans. It uses “broad judgment” for considering the cost-benefit ratio of the various interventions (high cost: low benefit or high benefit: low cost) (Constable and Cartwright 2009), and finds that out of the 47 interventions considered, 33 are high benefit: low cost, 12 are neutral, and 2 are deemed high cost: low benefit.

Sources of Funding

A significant portion of the funds that currently support climate change adaptation comes from general sources[6] dedicated to development funding, recognizing the fact that development deficits and poverty are bound to increase vulnerability to climate change. Multilateral development banks and bilateral development agencies also provide financial assistance for adaptation. These multilateral development banks usually issue loans, often accompanied by grants or concessional funds, to support infrastructure investments in middle-income countries. National governments and development banks are also negotiating development policy loans to support climate adaptation budgets, and climate change aspects are increasingly integrated (mainstreamed) into donor policies (Burton 2005). The adaptation studies analyzed here can be considered, at least in part, preparative studies for applications for these kinds of loans.

For cities in industrialized countries, potential sources of finance depend more on national or local budgets. National or local level finance typically comes from taxes, and fees and charges (Huhtala et al. 2010), but only a part of municipal government has actually the power to change levels of taxes or to borrow money (Aggarwala et al. 2011). Fiscal incentives represent a challenge for adaptation finance, as creating incentives for private

[6] Such international sources of finance include the Global Environmental Facility, Adaptation Fund, Global Fund for Disaster Risk Reduction, Climate Investment Funds (Pilot Program for Climate Resilience, Clean Technology Fund, and Scaling up Renewable Energy Program in Low Income Countries), Reduced Emissions through Deforestation and Forest Degradation, and International Development Association.

action can contradict the aim of raising funding for public action at the local level, and can potentially have a negative impact on individual cities' positions in inter-municipal concurrence for inhabitants and productive investments. According to an OECD survey, city revenues from taxes range from 5 % to approximately 70% (OECD 2010). Taxes are related to real estate values, so variation of taxes should be able to affect land use. Although recent discussion on the use of fiscal instruments in the context of climate policy has concentrated on mitigation strategies, for example proposing property taxes in order to favor compact city development (see for instance Viguié and Hallegatte 2010), they might become an instrument for promoting and financing of adaptation.

One of the first steps in the process of adapting to climate change is to plan an adaptation strategy, so initiatives taken at the level of studies and surveys can be considered part of urban adaptation. Within this perspective, HCMC, Tunis, and Bangkok exemplify cases of international donors supporting initial studies for climate change adaptation planning. The HCMC study was co-financed by the governments of the United Kingdom and Japan under the Asian Development Bank's regional technical assistance project, Promoting Climate Change Adaptation in Asia and the Pacific, and conducted by the International Centre for Environmental Management and the HCMC Department of Natural Resources and Environment (ADB 2010). Similarly, the background studies on Tunis and the other North African cities were conducted by a group of French experts who provided advice to the responsible local and national authorities for the design of a strategy to enhance the urban resilience of the four cities. The studies, developed in parallel, follow the same approach to vulnerability assessment and advice for the definition of action plans, involving stakeholders mainly from local and national authorities, and considering almost exclusively hypotheses of public investments in infrastructures. The adaptation plan for Bangkok was initiated by UNEP as one of the outputs of the UNEP's capacity-building program to assess major environmental developments and trends, implemented under the Global Environmental Outlook process, which conducts assessments from the global to city level (Bangkok Metropolitan Administration, 2009). The approach to adaptation planning has been to identify sectors at risk and provide delegated agencies with plans to address the risks. This type of an approach requires relies on agents having sufficient technical and financial capacity to make the necessary interventions and investments, with an effective system of oversight and control (UN Habitat 2011).

International donors have provided funding for stand-alone adaptation initiatives as well. For example, The World Bank is supporting Quito's Youth Action on Climate Change (Zambrano-Barragán et al. 2010; Brugmann 2011). Additionally, The World Bank and GEF provide some funding for the Andean Regional Project for Adaptation to Climate Change (Carmin et al. 2009). The Fund for Water Protection (FONAG) was created in 2000 with support from the Andean Regional Project for Adaptation to Climate Change, the Nature Conservancy (who gave a $2000 contribution when the project began (The Nature Conservancy 2011)), and several local corporations , and continues to provide funding for climate change adaptation (Carmin et al., 2009). In Quito there are also local sources of funding, such as Quito's Water Supply and Sanitation Company, which gives 1.5% of its billing amount to FOANG, contributing greatly to the current holding of $6.6 million, which is used to promote programs and projects related to reforestation in watersheds, education and environmental monitoring (Zambrano-Barragán et al. 2010). Nearly $1 million is being disbursed each year to conservation projects in the watershed (The Nature Conservancy 2011).

Durban has not felt any pressure to pursue adaptation associated with direct foreign investment or official development assistance. The city has however been successful in obtaining grants to finance climate related projects. For example, Roberts presented her work to the Rockefeller Foundation and then was invited to serve on the advisory committee for the ACCCRN (Carmin et al. 2009). The Rockefeller Foundation "compensated" the city with a $65,100 grant to jumpstart the municipal adaptation plans (MAP) work in 2008 (The

Rockefeller Foundation 2008a). Additional funds for the MAPs work come from within the sectors themselves, as the adaptation plans are mainstreamed into existing business plans, development objectives, and available funding, and skills (Roberts 2010).

The NYC's Panel on Climate Change, which provides scientific advice for the definition of the city's adaptation plan, was funded by a $350,000 grant from the Rockefeller Foundation's Climate Change Resilience Program (The Rockefeller Foundation 2008b). For longer term financing, the NYC adaptation plan explicitly recurs on the strategy of mainstreaming adaptation finance by asking stakeholders to link adaptation planning to their proper investment and rehabilitation cycles. In fact, by incorporating climate risk management into long-term infrastructure management and operations, the plan succeeds in integrating climate adaptation measures into current capital and operating budgets with less specific efforts (which are existent, but not quantified). The financing strategy advocated in the NYC plan represents the outcome of effective mainstreaming of climate change adaptation into urban policies, as adaptation measures are to be adopted, as far as possible, in synchrony with investment cycles for public infrastructures, once the infrastructures require maintenance or substitution. A significant cost savings is anticipated when adaptations are scheduled to coincide with planned maintenance, operations, and policy changes (Major and O'Grady 2010).

The Greater London Council financed the London adaptation plan, as part of its institutional tasks, along with a range of stakeholders from the wider GLS GROUP. The plan provides general policy indications, which do not necessarily imply direct expenditure from public budget. The personnel costs of implementation will be shared by GLA (50%) and the larger GLA group. Single measures are based either on private contributions to public infrastructures (flood defenses), completely private initiatives (water saving, climate proofing of buildings, urban greening), or on public procurement (urban greening and climate proofing of public buildings). Nevertheless, single sector studies quantify potential needs for financial incentives in order to (start) private adaptation efforts, such as green roofs, water efficiency or private flood defense. In these cases the study indicates potential sources of funding located in the area of national housing finance, as well as European Union funding and participation of service providers that will receive benefits from private adaptation efforts, for instance in terms of storm-water management. In terms of cost-benefit considerations, the level of envisaged incentives is aimed at the same level as environmental benefits quantified (LCCP 2009).

The Tunis study explicitly focuses on activities that depend on public funding. If private investments are considered, the assumption of public assistance (for example regarding insurance scheme or specific building norms for areas vulnerable to flooding) is explicitly questioned. Possible strategies for funding are indicated in a generic manner, stating that it will not be possible to meet investment needs from national and local public budgets in Tunis, thereby highlighting the need to solicit international aid (Egis BCEOM International / IAU-IDF / BRGM 2011b p. 229). The necessity of private adaptation efforts (with regards to seismic security, one of the issues tackled in this study further to climate change impacts, and with regards to rearrangement of private properties for flood security) is recognized and quantified in monetary terms, but not discussed in the study as it is defined as being a topic "of political kind and thus beyond its reach" (Egis BCEOM International / IAU-IDF / BRGM 2011b p. 200).

Implications of the Source of Funding

The source of funding is to some extent related to the types of adaptation strategies implemented and the types of climate risk targeted. The origin of funding determines to some extent the direction of decision making, whether it is a top-down approach where decisions on adaptation measures are taken according to national or international standards and financed mainly by national or international funds, or bottom-up approaches where the direction of funding and decision making may be more differentiated and oriented towards

the local needs. The proposals for adaptation strategies for Tunis and the other North African cities, based on studies financed by the World Bank, represent an example for a top-down approach, where the structure of the study was decided by an international donor (albeit finance for adaptation measures is not provided in the actual stage) (Egis BCEOM International / IAU-IDF / BRGM 2011d).

Lessons from urban greenhouse gas (GHG) mitigation are informing the need for a more broad and integrated bottom-up approach to urban climate change adaptation. Analogous to the range of unanticipated additional benefits that were observed when bottom-up methodologies were employed to cost and target local GHG emission reduction investments, adaptation measures may cost less and create greater economic benefits at the local level than top-down estimates suggest. Adaptation measures planned at the local level have the potential to be designed and implemented in a way that could address systemic inefficiencies, increase institutional or geographic performance, improve local amenities, and generally upgrade urban conditions. Moreover, like the bottom-up work on mitigation has shown, local adaptation will provide the opportunity to experiment with new financial instruments (Brugmann 2011).

Mainstreaming adaptation finance can be achieved by integrating risk reduction and sustainability into design and requirements for construction or infrastructure projects or investments (Brugmann 2011). Considering the long life cycle of investments in urban assets, cities can take advantage of the fact that most of the infrastructure that will exist in the next 40 to 50 years has not yet been built by avoiding non-climate-resilient infrastructure in new development (Huhtala et al. 2010). The NYC adaptation plan explicitly recurs on this strategy when asking stakeholders to link adaptation planning to their proper investment and rehabilitation cycles (Major and O'Grady 2010), as noted above.

Although investment in climate change and urban sustainability policies can also produce co-benefits, such as increased accessibility and greater attractiveness of the city, these investments will present an additional burden on most cities' budgets (OECD 2010 p. 241). Climate risk reduction is therefore best achieved when integrated with other catastrophic and systematic risks facing urban areas; likewise, risk-related investments are more efficient and effective when integrated fully with performance related development improvements to infrastructural systems. It follows that the best approach to climate change adaptation is creating projects with the purpose of improving an area's or system's total performance, rather than investing in single interventions within a system (Brugmann 2011). The Tunis study considers, further to climate related impacts, risks arising from natural hazards, for instance seismic risks, so that climate related impacts account for a share of about 20% of the overall damages considered in the study to be tackled by specific urban policies.

Public-Private Partnerships

Public-private partnerships (PPPs) have been intensively discussed and to some extent experimented with in connection to the delivery of urban services in both developed and developing countries. Thus far, PPPs have mainly been used in association with housing policies and the construction of infrastructure, as well as the creation of infrastructure involving self-help initiatives. These discussions involve both developed (see for instance Knox 1988) and less developed cities (Jain 2003).

PPPs could potentially play a crucial role in enabling cities to meet their climate finance needs. Strategic investments can be made with public funds to attract private investment in a certain area. Direct equity investment can be made in specific companies or projects, or indirect investments made through financial institutions that support climate change goals (Huhtala et al. 2010). Nevertheless, no examples of precise implementation of these partnerships have been found in the case study cities in the context of urban adaptation to climate change, and only Quito's adaptation plan calls for improved interaction

with the private sector so that resources invested in climate action can be optimized (Zambrano-Barragán et al. 2010). The only exceptions are PPPs that have been implemented in relation to insurance schemes, for instance in the case of the compulsory building insurances against seismic risks in Turkey (Gülkan 2002; Egis BCEOM International / IAU-IDF / BRGM 2011b). This implies the need for innovation, in order to be able to use private funding dedicated to private assets in support to public policies (e.g. adapting private housing to new climatic conditions), as well as into public activities by (co-) financing public assets like infrastructures or services. Financing mechanisms need to be broadened to allow for more private investments in addition to existing global climate funds. Climate financing requires more innovation to draw in investors and maximize returns. The proposed approach for transforming financing mechanisms to attract investors includes making local climate actions measurable, reportable, and verifiable to allow cities to identify which climate actions are most efficient and effective (Brugmann 2011).

Risk Management and Insurance

There are several new risk management and market instruments that are being used for climate finance. Risk management instruments refer to insurance schemes and guarantee instruments. The World Bank has developed the MultiCat Program, a catastrophe bond insurance platform that allows governments to use a standard framework to buy parametric insurance at an affordable rate. If a natural disaster does occur, then the insurance pays based on the severity of the event. Similarly, another program called Global MultiCat is used to reduce insurance costs through diversification – a number of cities or regions and risks are selected and identified donors and cities pay the insurance premiums. Capital market investors buying the Global MultiCat are paid an insurance premium for providing coverage to the entire pool. Guarantee instruments are credit enhancements supported by multilateral development banks to facilitate government access to credit, specifically partial credit guarantees, where the guarantor shares the risk of debt service default with lenders on a predetermined basis (Huhtala et al. 2010).

Considering existing adaptation strategies, the main focus of risk management is placed on urban infrastructures, together with activities related to land use planning and the reshaping of building codes. In some cases private equity is also considered if indications for actions to be taken by insurances are explicitly listed in order to assure long-term insurability of climate risks, as in the case of NYC. The risk management approach undertaken by the NPCC provides opportunity for the private insurance industry to have a role in the Flexible Adaptation Pathways by transferring and mitigating risk. The NYC assessment strategy considers, inter alia, working with the insurance industry to facilitate the use of risk-sharing mechanisms to address climate change impacts. The following are ways in which the insurance industry can contribute to adaptation (Rosenzweig et al. 2010):

- Maintaining long-term insurability and providing incentives for adaptation through risk based premium pricing;
- Using insurance risk-evaluation tools to help policymakers and adaptation planners better understand and assess the financial implications of climate change;
- Encouraging research aimed at making global climate model output more useful to insurance underwriters and adaptation planners;
- Supporting government adaptation efforts;
- Providing educational information on climate change related risks and increasing awareness among customers.

Resilience Building and Private Losses

Adaptation efforts will not be able to prevent all losses, so residual losses need to be taken into account, both for public and private properties. With regards to private property, a new focus is being placed on urban resilience upgrading, which calls for the implementation of a set of financially justified risk reduction measures that increase the reliability of

investment returns and asset values, where adaptation strategies create the institutional, planning and policy frameworks, business practices, and financing instruments. In this way resilience is proposed as a more attractive objective for city leaders and investors than adaptation alone because it is aligned with the primary, underlying drivers for urban growth (Brugmann 2011). Resilience upgrading leverages adaptation funds with other public or private investment in urban upgrading within existing systems, i.e. slum upgrading, green building, urban regeneration, etc. (ICLEI 2011). Along with financial innovation, some instruments to support resilience upgrading include tax-increment financing, insurance and re-insurance, catastrophe bonds, social impact bonds, securitization and structured finance. Other risk measures can be integrated or mainstreamed into investments that are already serviced by conventional financial methods. The remaining need for adaptation funding, which will be not be addressed by market-based financing, will require public sector funds or support from new adaptation funds (Brugmann 2011).

Emerging Themes

The issue of finance enters the process of planning for urban adaptation in a twofold manner: external finance can trigger policies, as in the case of HCMC, or can facilitate the planning process by creating institutions that add value to the process, as in the case of NYC where the NPCC provided scientific input for the formulation of the city plan. The analysis of these seven case studies evidences the crucial role of external finance, which has been provided by a still small number of donors with particular engagement for climate policies.

The importance of external funding invested in the policy process indicates that adaptation planning at urban level is still in its infancy, and has not yet been mainstreamed into all urban policies. This fact is furthermore connected to the economic status of most (but not all, see NYC) of the cities that have benefited from these types of finance, like HCMC, Tunis and the other North African cities, Bangkok, Durban or Quito. Except for Durban, the urban adaptation policies seem to have been introduced from outside local government but accepted as any other support provided for the management of their urban areas.

The implementation of adaptation measures requires various types of finance; finance for the implementation of specific protection or prevention measures, for the adaptation of existing infrastructures, or for the loss of assets in case of climate induced events. With regards to developing countries, assistance for adaptation planning and for the implementation of measures is apparently becoming a new form of development assistance.

The focus on urban infrastructures, together with activities related to land use planning and the reshaping of building codes, is common to all strategies; but in some cases private equity is also considered if, for example as in the case of NYC, indications for actions to be taken by insurances are explicitly listed in order to assure long term insurability of climate risks. Problems of private equity will become more predominant, especially in developed countries, when set-back strategies will need to be implemented at larger scale, posing questions like those regarding the extent to which public infrastructures will be maintained in order to preserve the value of private assets.

With regards to less developed countries, the potential of market based strategies to improve resilience (e.g. insurance) will meet different challenges, especially with regards to the urban poor who are generally more exposed to climate change impacts including flooding. Although the losses faced by these households may be low in absolute economic terms, the impact on the household economy may nevertheless be severe. The capacity to participate in economic prevention schemes must take into account a household's available funds and priorities in expenditure; a lesson that has emerged from a recent study on impacts of micro credit (Karlan and Zinman 2011).

Conclusions

This paper presents the findings of an urban adaptation assessment framework applied to the cases of New York City (NYC), Metropolitan District of Quito (Quito), Greater London (London), Tunis, eThekwini Municipality (Durban), Ho Chi Minh City (HCMC), and Bangkok. A comparison of these seven plans reveals similarities and points of diversion in the current practices of urban areas adapting to climate change, specifically highlighting the level of administrative planning, the tools and information used in making policy choices, and the roles of governance and finance. The main findings and lessons learned include the following:

- Cities in all socio-economic situations and in all locations face a broad range of climate risks and are vulnerable to the various impacts of climate change. Losses from climate change impacts in urban areas are bound to be particularly important due to the high concentration of people, values, and assets.
- The administrative level of institutional actors involved in urban adaptation planning determines the range, scope, and capacity to trigger implementation.
- Cities situated in coastal zones and along rivers are particularly vulnerable to temporary flooding and permanent inundation, which are among the most relevant climate impacts for cities, and the highest economic losses will be experienced in these areas.
- **Climate science (1)**: Sound climate science is useful for projecting future climate conditions and anticipating climate impacts, however adaptation is needed even in the presence of uncertainty. In terms of cost effectiveness, more detailed (i.e. downscaled) climate information allows urban planners and policy makers to invest in areas and sectors facing the greatest impacts within a relevant timeframe. It is furthermore beneficial to have the climate modeling done by a research center or agency within the city itself, so that it can be updated and easily transferred to decision-makers. In the absence of sound science or political support for climate change, no-regret adaptation can be made to improve the overall resilience of a city.
- **Climate science (2):** The use of ad-hoc modeling exercises in the realm of preparative studies has some disadvantages in adaptation studies, despite the advantages of their high scientific quality, as they do not allow for updating and future elaboration of localized climate simulations.
- **Networking:** Links with climate change networks open up doors for funding opportunities, whether they are small grants for a stand-alone adaptation measures or grants large enough to facilitate the entire adaptation processes. By aligning with these types of institutions, cities not only show their commitment to addressing climate change, but also get the opportunity to attend conferences and meetings to share ideas and to learn from other cities in similar situations, and furthermore to take advantage of any funding opportunities that come down these channels.
- **Governance (1)**: Strong political leadership and support for the climate agenda are essential for effective action. Without a city government that is willing to implement adaptation measures, the creation of an adaptation study or cost assessment is worthless. It is also difficult for urban governments to act without greater support from the region or country where they are located.
- **Governance (2)**: It is evident that integrating climate adaptation measures at the sectoral level within existing policies is the most effective way to ensure funding and implementation. Promoting resilience building or disaster risk reduction (in the presence of uncertainty or lack of consensus on climate change) also functions as an adaptation initiative, as these things share many of the same underlying goals.

- **Private actors**: Involvement of private action is of primary importance, but not yet very well developed, as climate risks, albeit theoretically well known, are still not translating into effective private action, likely due to some form of market failure. Private action must be mobilized to compliment public adaptations.
- Although there are no examples of **public-private partnership** in urban adaptation finance to date, this will surely be a key issue in the future considering the high level of public investments needed.
- Risk management and **insurance** schemes can be used to incentivize people to live in less vulnerable areas, etc. Considerations on the introduction of an insurance scheme or the improvement of existing schemes are part of different adaptation concepts, although their success appears being related to relative economic wealth or the implementation of compensating or assisting measures for lower income groups among the urban inhabitants.
- **Costs of adaptation**: Although impacts and potential economic losses are important, local authorities are apparently less concerned about cost-benefit criteria for decision-making in urban adaptation. Among those taken into consideration, no local authority that has prepared local adaptation plans has based the choice of measures on cost-benefit considerations, but rather they rely on the need to ensure basic functions for the future of the city. One reason for the scarce consideration of economic efficiency criteria could be found in the limited acquaintance of local authorities to this kind of criteria and their prevailing commitment to other types of considerations, such as security, social wellbeing and economic development rather than efficiency of investments and policy measures.
- International donors on the other hand rely principally on **cost-benefit studies** for advocating adaptation efforts; studies sponsored by international donors use considerations on economic viability as fundamental criteria for the assessment of measures. Furthermore, it is difficult to assess the cost of impacts and adaptations to climate change due to the numerous variables, including socioeconomic and climate projections, processes of valuation and discounting, etc., that are required to carry out a proper cost-benefit analysis. Additionally, expertise, time, and money are required to calculate these costs. For these reasons, most local authorities have not (yet) carried out an economic assessment of climate change.
- International donors are contributing a significant amount of funds to support urban adaptation to climate change. This type of financial support leads to more top-down decision making, which may not be as well received or effective as allowing locals to be involved in the adaptation process.

The most significant research gap identified in this paper is the lack of clarity on the economics and financing of urban adaptation. Through this assessment it is made evident that issues of public infrastructure, urban transformation (i.e. land use changes), and private adaptation are largely unexplored and not yet well understood. Additional research on urban adaptation should probe further into these economics aspects, with specific consideration of methods to assess adaptation options, the mitigation potential of adaptation measures, and sources and strategies of funding. A quantification of costs and benefits has only been covered in a limited number of cases, related to isolated projects. Although benefits of adaptation in the urban context cannot be easily quantified, a more comprehensive view on cost efficiency of adaptation measures could provide additional insight into conditions for adaptation policies.

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Appendix: Urban Adaptation Assessment Framework

The purpose of this assessment framework is to categorize the information regarding best practices, policy mechanisms and finance presented in the plans and studies of urban areas adapting to climate change, in order to standardize variables to allow for a comparison of adaptation strategies across different cities. It has been created based on a review of the plans and studies of several cities who are at the forefront of climate change adaptation, and furthermore informed by a review of the state-of-the-art articles and background papers on urban adaptation. The Appendix provides a description of the Assessment Framework, with an explanation of the information recorded during the assessment process, followed by the application of the framework to the cases of New York City (NYC), Metropolitan District of Quito (Quito), Greater London (London), Tunis, eThekwini Municipality (Durban), Ho Chi Minh City (HCMC), and Bangkok. Categories are omitted where relevant information is lacking for a particular city.

City: Name of the city or urban area.

Name of plan or study: Title of the city adaptation plan, report presenting an adaptation study, or paper discussing adaptation in an urban area.

1. **Size and socio-economic status:** Population and development level of the city or urban area.
2. **Dates and time horizon:** The date when the plan was initiated, or the time frame in which climate risks are anticipated to occur, and when adaptation strategies should be implemented to achieve the greatest benefits.

Policy mechanisms

The design and implementation of an adaptation plan or study is largely influenced by affiliation with climate change networks, the type and level of government involvement, the political process for creating and implementing adaptations, the level of integration with existing policy, the type of policies employed to address adaptation deficits, the barriers to adaptation, and the modes of government designing and implementing the policy. These factors are at the core of urban adaptation, driving adaptation action forward.

3. **Network affiliations:** The climate or urban focused groups or networks that the city is involved with, and their role in the city's adaptation process.
4. **Political leadership:** The local authority championing the adaptation effort.
5. **Policymaking process:** The steps through which adaptation has entered the city's policy agenda.
6. **Level of integration:** The extent to which adaptation policies are incorporated into existing structures and strategies, versus calling for the creation of new plans, institutions, or agencies to implement the proposed adaptation measures.
7. **Types of policy:** The traditional urban policies or new policies used to facilitate implementation of adaptations.
8. **Barriers and constraints:** Factors inhibiting successful adaptation or implementation of adaptation measures.
9. **Modes of governance:** The ways in which the government influences, designs, and implements policies supporting adaptation, including public investments in protection measures, incentives for private adaptation efforts, defining rules, or increasing awareness.

Best practices

Each city's adaptation strategy makes recommendations to address the most threatening climate impacts and vulnerabilities. Background literature and a comparison of

several cities' reports show similarities in the source of climate projections, categorization of climate risk, types of adaptation, and specific adaptation measures.

10. **Climate projection data source:** The climate modeling tools used to forecast future changes in climate, and the associated impacts.
11. **Climate risks:** The ways in which anticipated climate impacts will affect the urban area.
12. **Types of adaptation measures:** Full management plans or initiatives, or individual actions designed to remedy a specific impact.
13. **Specific adaptation activities:** The individual adaptation actions.

Finance

Additional funds needed for urban areas adapting to climate change are anticipated to be substantial. At the city level, economic assessment of impacts and adaptations are often conducted to find the projected costs of climate change. The source of funds, investment strategies and targets, and types and costs of investments are all particularly relevant to the process of financing adaptation.

14. **Economic assessment of impacts and adaptations:** The methods used to calculate the costs of impacts and adaptations of the city's relevant climate risks, and the findings of the assessment.
15. **Projected costs of climate change:** The anticipated cost of impacts and adaptation interventions, as well as the economic benefits of adaptation.
16. **Source and amount of funds:** The benefactor, or ways in which the city is able to pay for adaptation, and how much money there is to invest.
17. **Investment strategy:** How and where the funds are spent or invested to support and facilitate adaptation initiatives.
18. **Types and costs of investments:** The costs of specific adaptation measures.

New York City (NYC)

Climate Change Adaptation in New York City: Building a Risk Management Response

Size and socio-economic status: NYC is approximately 305 square miles[7] and has a population over 8 million[8].

Dates and time horizon: Climate change adaptation began in 2007 when the Mayor's Office of Long-Term Planning and Sustainability created the city's sustainability plan (PlaNYC), which named climate change as a sustainability goal. Adaptation initiatives under PlaNYC are continually evolving. Adaptation planning is focused on strategies for responding to near- and mid-term incremental changes (e.g. temperature and precipitation changes) as well as long-term low-probability, high-impact events (e.g. catastrophic storm surges exacerbated by sea level rise. Early win-win adaptation strategies, such as those that have near-term benefits or meet multiple goals (greenhouse gas mitigation, emergency planning, etc.), are advocated (Rosenzweig et al. 2010).

Policy mechanisms

Network affiliations: As an initiative of PlaNYC, an interagency Climate Change Adaptation Task Force (Task Force) was created to investigate climate change adaptation strategies to protect the City's infrastructure. The Mayor convened the New York City Panel on Climate Change (NPCC), a panel of experts to advise on issues related to climate change and adaptation, to assist the Task Force in working to ensure that the city's adaptation efforts are based on sound science and a thorough understanding of climate change impacts and adaptation. The NPCC was created with external funding by the Rockefeller Foundation. Furthermore, Mayor Michael Bloomberg is currently the chair of C40 Cities Climate Leadership Group, and the Urban Climate Change Research Network Secretariat is presently sponsored by and housed at Columbia University.

Political leadership: Mayor Michael Bloomberg's Office of Long-Term Planning and Sustainability created the City's sustainability plan, PlaNYC, which named climate change as a sustainability goal. Mayor Bloomberg is particularly supportive of urban adaptation, as evidenced by his role as the chair of C40 Cities Climate Leadership Group.

Policymaking process: Adaptation to climate change began when the Mayor's Office of Long-Term Planning and Sustainability created PlaNYC in 2007. The first initiative under the climate change theme was to create an interagency Task Force to consider climate change adaptation strategies to protect the city's infrastructure. The Mayor then convened the NPCC, consisting of more than 40 public- and private sector stakeholders, to provide scientific expertise to the Task Force. The NPCC has analyzed climate change hazards, studied impacts on the critical infrastructure, and developed a risk management framework for adaptation planning, as well as made climate projections and developed planning tools to help guide stakeholders in their adaptation planning and strategy-creation process, and examined how the regulatory environment influences infrastructure-related decision making. This work is presented in the NPCC's adaptation plan, *Climate Change Adaptation in New York City: Building a Risk Management Response*, and is intended to guide Task Force members through the process of identifying climate risks to their critical infrastructure, creating adaptation plans, and considering the regulatory environment for climate change adaptation (Rosenzweig et al. 2010).

Level of integration: NYC's adaptation plan links to larger sustainability activities, such as PlaNYC, so that climate change is considered as part of a broad range of future trends, rather than in isolation. Through this initiative, multiple layers of government and a wide

[7] http://home2.nyc.gov/html/dcp/html/landusefacts/landusefactshome.shtml

[8] http://www.nyc.gov/html/dcp/html/census/census_2010.shtml

range of public and private stakeholder experts build crucial partnerships for coordinated adaptation strategies. On-going coordination among the city and other levels of government, public agencies, private organizations, and experts, with overall leadership, as currently provided by the Mayor's Office of Long-Term Planning and Sustainability, helps facilitate the application of Flexible Adaptation Pathways (Rosenzweig et al. 2010).

Types of policy: Generally, the adaptation plan advocates the revision of existing standards and codes to meet climate challenges, or of the development new codes and regulations to increase the city's resilience to climate change. The focus however is building climate change adaptation into systems that are already in place wherever possible, including incremental changes linked to infrastructure rehabilitation cycles. Some legal and regulatory measures are proposed to foster adaptation in the areas of land use and zoning, environmental impact statements, energy, transportation, communication, water, air quality, hazardous waste, and emergency preparedness. The adaptation plan also recommends establishing a climate change monitoring program to track and analyze key climate change factors, impacts, and adaptation indicators in NYC, as well as to study relevant advances in research on related topics (Rosenzweig et al. 2010).

Modes of government involvement: The NPCC assists the Task Force to advise the government and ensure that the City's adaptation efforts are based on sound science and a thorough understanding of climate change impacts and adaptation. The NPCC advocates the creation of a mandate for an on-going body of experts that provides advice and prepares tools related to climate change adaptation for NYC, including updates to climate change projections, improved mapping and geographic data, and periodic assessments of climate change impacts and adaptations for NYC to inform a broad spectrum of climate change adaptation policies and programs (Rosenzweig et al. 2010).

Best practices

Climate projection data source: One of the four specific tasks of the NPCC is to produce climate projections for the NYC region. Researchers at Columbia University and NASA GISS, both located within NYC, have produced the climate change scenarios and implications for NYC. They used GCM simulations driven with IPCC projected greenhouse gas emissions scenarios A2, A1B, and B1 to generate model-based probabilities for temperature, precipitation, and sea level rise. Results from the simulations of sixteen GCMs are used for temperature and precipitation and 7 for sea level rise. To project sea level rise, both the IPCC methods (including global thermal expansion and melt water from glaciers, ice caps, and ice sheets, as well as local land subsidence and local water surface elevation) and a rapid ice-melt scenario were used. Extreme events of temperature and precipitation were also projected. The regional projections are based on GCM output from the single land-based model grid box covering NYC and its surrounding region. All projections are expressed relative to the baseline period from 1971-2000 (2000-2004 for sea level rise), and projections are centered around a decade to give an indication of the climate normals for those years (Horton and O'Grady 2009).

Climate risks: Identified climate risks include heat and heat waves, sea level rise and storm surge, droughts and floods.

Types of adaptation measures: An Adaptation Assessment Guidebook was created by the NPCC and is intended to guide Task Force members through the process of identifying climate risks to critical infrastructure and creating appropriate adaptation strategies through an eight step process in line with the Flexible Adaptation Pathways - strategies that can evolve through time as climate risk assessment, evaluation of adaptation strategies and monitoring continue (Rosenzweig et al. 2010):

1. Identify current and future climate hazards
2. Conduct inventory of infrastructure and assets
3. Characterize risk of climate change on infrastructure

4. Develop initial adaptation strategies
5. Identify opportunities for coordination
6. Link strategies to capital and rehabilitation cycles
7. Prepare and implement Adaptation Plans
8. Monitor and reassess

Finance

Economic assessment of impacts and adaptations: An analysis of the economics and financing of adaptation is recommended as a further study based on the findings of the adaptation plan. Although there has not yet been an economic assessment of the costs of impacts and adaptations to climate change in NYC, a statewide economic assessment has been conducted as part of the project *Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation*. Concerning NYC, the report finds that the coastal zone will face the greatest economic impact of any region due to its exposure and vulnerability, and the high concentration of residences, businesses, and infrastructure along the shore. Also, urbanized areas will incur higher public health costs due to the urban heat island effect (Rosenzweig, Solecki, DeGaetano, et al. 2011).

Source and amount of funds: The NPCC was funded by a $350,000 grant from the Rockefeller Foundation's Climate Change Resilience Program (The Rockefeller Foundation 2008b).

Investment strategy: The NYC adaptation plan explicitly recurs on the strategy of mainstreaming adaptation finance by asking stakeholders to link adaptation planning to their proper investment and rehabilitation cycles. If climate risk management is incorporated into infrastructure management and operations, then these plans can be integrated into capital and operating budgets. The financing strategy advocated in the NYC plan represents the outcome of effective mainstreaming of climate change adaptation into urban policies, as adaptation measures are to be adopted, as far as possible, in synchrony with investment cycles for public infrastructures, once the infrastructures require maintenance or substitution. A significant cost savings is anticipated when adaptations are scheduled to coincide with planned maintenance, operations, and policy changes (Major and O'Grady 2010).

Regarding private equity, the adaptation plan indicates actions to be taken by insurances in order to assure long-term insurability of climate risks. The risk management approach provides an opportunity for the private insurance industry to have a role in the Flexible Adaptation Pathways by transferring and mitigating risk. The adaptation plan encourages the NPCC to work with the insurance industry to facilitate the use of risk-sharing mechanisms to address climate change impacts in the following ways (Rosenzweig et al. 2010):

- Maintaining long-term insurability and providing incentives for adaptation through risk based premium pricing;
- Using insurance risk-evaluation tools to help policymakers and adaptation planners better understand and assess the financial implications of climate change;
- Encouraging research aimed at making global climate model output more useful to insurance underwriters and adaptation planners;
- Supporting government adaptation efforts;
- Providing educational information on climate change related risks and increasing awareness among customers.

Metropolitan District of Quito (Quito)

Quito's Climate Change Strategy (QCCS)

Size and socio-economic status: The City of Quito is located within the Metropolitan District of Quito; both are governed by the Illustrious Municipality of the Metropolitan District of Quito (Municipality), and covered by QCCS. The Metropolitan District of Quito has a total population 2.1 million, with 1.6 million inhabitants located in the urban area. Quito has a population density of 118 people per hectare, and 43.5% of the population lives below the national poverty line (Zambrano-Barragán et al. 2010).

Dates and time horizon: QCCS falls under Executive Decree 1815, which mandates the State Policy of climate mitigation and adaptation. QCCS was adopted in 2009, and adaptation measures are currently on going or planned to commence in the future. The main objective of QCCS is "to develop comprehensive policies that guarantee the implementation of adequate, crosscutting and equitable adaptation and mitigation measures to climate change," through generating methodologies and management tools for research and the participation of stakeholders and decision makers (Zambrano-Barragán et al. 2010).

Policy mechanisms

Network affiliations: QCCS initiatives were presented by the authors at ICLEI's 1st World Congress on Cities and Adaptation to Climate Change.

Political leadership: The Municipality, governed by a Municipal Council and Metropolitan Mayor, is responsible for implementing adaptation measures under QCCS in response to current and projected impacts of climate change (Zambrano-Barragán et al. 2010). One member of the Metropolitan Council, Gonzalo Ortiz, initiated the call for action on climate change in early 2007 when gave a presentation to his colleagues on the necessity of designing a climate change strategy for Quito based on the scientific evidence of rising temperatures and shrinking Andean glaciers, which gained support from (then) Mayor Paco Moncayo and the Council (Carmin et al. 2009).

Policymaking process: QCCS was developed in response to the experienced and projected impacts of climate change (Zambrano-Barragán et al. 2010). Several months after Metropolitan Council member Ortiz gave his presentation of the impacts of climate change, he and Metropolitan Councilor Carmen Elena De Janon asked the Directors of the municipal water and sewage corporation, the municipal air monitoring corporation, the Metropolitan Office of the Environment, and the Strategic Research Unit to establish an Inter-Institutional Commission to prepare a draft climate change strategy for the city (Carmin et al. 2009). Various stages of consultation and revision took place to help to improve the quality of the draft. Municipal agencies, attendees at the Clima Latino conference (held in Quito in 2007), and an environmental NGO, which engaged the local population, participated in the consultation process (Carmin et al. 2009). In 2008, the QCCS was finalized (Carmin et al. 2009), and a Climate Action Plan for implementing the QCCS was planned to be finalized by 2010 (Zambrano-Barragán et al. 2010). The Municipality and several international agencies are advancing the adaptation agenda at the city and local level. Stakeholder participation and community involvement are also fundamental components of QCCS.

Level of integration: Ecuador ratified the UNFCCC in the 1990s and developed a National Policy and Strategy for Climate Change in 1998 (Carmin et al. 2009). Executive Decree 1815 mandates the state policy of climate mitigation and adaptation. At a more local level, QCCS is being used together with the city's ecological footprint planning tool (Zambrano-Barragán et al. 2010).

Types of policy: Policies are currently focused on water supply and sanitation, as these sectors face challenges in the provision of services due to both populating growth and climate change (Zambrano-Barragán et al. 2010).

Modes of government involvement: Two mechanisms have been developed at the institutional level to ensure coordinated action supported by science and local knowledge: the channeling of financial and technical resources at the required scale, and avoidance of duplicated efforts. The mechanisms include Quito's Panel on Climate Change (QCCP), a scientific and expert committee to advise the Municipality on climate change action, and the Metropolitan Climate Change Committee, consisting of representatives of local institutions (Zambrano-Barragán et al. 2010).

Best practices

Climate projection data source: Climate projections for Quito are based on the IPCC SRES A2 scenario (Zambrano-Barragán et al. 2010).

Climate risks: Fragile ecosystems, water scarcity and drought (resulting from higher temperatures, less precipitation, and glacier disappearance; with consequences for sanitation and hydroelectric generation), human health, and food security are considered at greatest risk from climate change (Zambrano-Barragán et al. 2010).

Types of adaptation measures: QCCS actions are divided in four axes: (1) information generation and management; (2) use of clean technologies and good practices for mitigation and adaptation; (3) communication, education, and citizen participation, and (4) institutional strengthening and capacity building. They are focused on five sectors including ecosystems and biodiversity, drinking water provision, health, infrastructure and providing systems, including hydroelectric power, and risk management (Zambrano-Barragán et al. 2010).

Specific adaptation activities: On-going and future actions in the water supply and sanitation sector, undertaken by the Municipality and the Water Supply and Sanitation Company, include (Zambrano-Barragán et al. 2010):

- Research and information
    - The Water and Sanitation Master Plan (2010-2040) considers win-win adaptation measures
- Risk management and climatic events
    - The Hillside Management Program (1997-) aims at minimizing the threats of landslides and mudslides that the slopes around Quito impose on the city through integrated management
- Mitigation and adaptation
    - Control and Reduction of Unaccounted Water Plan (2007-)
    - The Integral Plan for reduction of water consumption, a three stage process including the development of a baseline, then designing consumption reduction strategies, and implementing the plan
    - Funds for the Protection of Water-FONG (2000-) for watershed conservation
    - Climate Change Research on the impacts of climate change on the retreat of glaciers and the role of highland ecosystems in water supplies for Quito, conducted by the Municipality, the Company, the French *Institut de Recherche pour le Développement*, and the Regional Project for Adaptation to Climate Change in the Andes
- Future proposals
    - The Management of Storm water Runoff Program is planned for managing urban storm water runoff in order to optimize the drainage system and allow for its active management; construction of artificial depressions to minimize flooding, gardens, and green roofs are planned
    - The Metropolitan Municipality plans to promote the construction of eco-neighborhoods – new buildings that will incorporate innovative concepts in water management, energy, and solid waste

The World Bank and the Municipality are currently implementing a project focused on citizen involvement and stakeholder participation. Quito's Youth Action on Climate Change is aimed

at strengthening the local youth's actions on climate change through capacity building workshops in risk-prone neighborhoods, strengthening the political agenda of youth movements, and funding risk management and adaptation initiatives. Thus far, approximately 1,000 students have been trained and are anticipated to have a multiplying effect by facilitating subsequent workshops. The Municipality and its partners made two calls for adaptation and risk management project proposals, and selected projects were to be implemented by November 2010 (Zambrano-Barragán et al. 2010).

Quito is working with the UN Habitat to create a Manual for Local Climate Change Management that will help other municipalities in Ecuador develop local climate change adaptation strategies. Additionally, Quito is implementing the Ecuadorian Local Environmental Authorities' Network, which has a focus on climate change, to standardize tools and methodologies (GHG inventories, vulnerability assessments, adaptation strategies, etc.), create an experiencing-sharing platform, and promote the development of joint adaptation activities (Zambrano-Barragán et al. 2010).

Finance

Projected costs of climate change: An economic analysis of the impacts of glacial retreat in the Andes (done by several researchers and members of the World Bank) found that rapid glacial retreat (consistent with upward shifts in the freezing point of the isotherm, coinciding with a warming troposphere) will disrupt the water cycle (particularly the supply of potable water) in Quito, requiring an increase in the current investment costs for future water supply of approximately $100 million (Vergara et al. 2007).

Source and amount of funds: Several internal sources of financing are available to Quito. The Environment Fund, created within the Environmental Office in 2005, is dedicated to protecting the natural resources and environmental quality of the district. Furthermore, QCCS calls for improved interaction with the private sector so that resources invested in climate action can be optimized (Zambrano-Barragán et al. 2010).

Some international donors are funding stand-alone climate adaptation initiatives in Quito related to the overall adaptation concept. For example, The World Bank is facilitating capacity building by supporting Quito's Youth Action on Climate Change (Zambrano-Barragán et al. 2010). Additionally, The World Bank and GEF provide some funding for the Andean Regional Project for Adaptation to Climate Change (Carmin et al., 2009).

The Fund for Water Protection was created in 2000 with support from the Andean Regional Project for Adaptation to Climate Change, the Nature Conservancy (who gave a $2000 contribution when the project began (The Nature Conservancy 2011)) and several local corporations, and continues to provide funding for climate change adaptation (Carmin et al. 2009). Quito's Water Supply and Sanitation Company contributes 1.5% of its billing amount to The Fund for Water Protection, contributing greatly to the current holding of $6.6 million, which is used to promote programs and projects related to reforestation in watersheds, education and environmental monitoring (Zambrano-Barragán et al. 2010). Nearly $1 million is being disbursed each year to these conservation projects in the watershed (The Nature Conservancy 2011).

Investment strategy: Investments are directed towards public infrastructure, activities, services and planning in the water supply and sanitation sector. Investments are made in existing and new infrastructure, for risk management, and to support stakeholder driven initiatives.

Types and costs of investments: While no comprehensive cost estimate is provided, several investments have been made in on-going activities in the water supply and sanitation sector. $110 and $190 million have been invested in separate strategies within the Water and Sanitation Master Plan. Approximately $40 million have been invested in the Hillside Management Program, and the Fund for Water Protection holds $6.6 million (Zambrano-Barragán et al. 2010).

Greater London (London)

The draft climate change adaptation strategy and the final report **Managing risks and increasing resilience, The Mayor's climate change adaptation strategy**

Size and socio-economic status: London is administered by the Greater London Authority (GLA) and has approximately 7.75 million inhabitants. It is part of the territory of the London Metropolitan Area, which is inhabited by 12-14 million, people (GLA 2011b).

In a study dating from 2002, the London Metropolitan Area's GDP was £168.6 billion, corresponding to 20.3% of the national GDP. At that time the workforce was approximately 3.5 million people, 32% of which are in business and financial services, 19% in the public sector, 16% in retail, 7% in manufacturing, and 6% hotels and restaurants. The urban economy is furthermore related to the national economy having "imported" in 1998 goods and services for UK £89 billion – and supported a further 4.7 million jobs outside the capital (LCCP 2002 p. 152).

Dates and time horizon: Climate change projections are considered for the time horizons of 2050 and 2080, in order to provide an adequate time frame for long-term decisions like spatial planning. Despite these long-term projections considered, the implementation strategy, called Roadmap to Resilience, is based on an action plan that sets out single actions to be implemented mainly on a short-term time horizon (2011 - 2013); flood risk mapping, and integration of flood risk management into local plans, drought preparedness planning and feasibility studies are among these short-term measures. The action plan considers only few infrastructure measures, such as increasing the percentage of green areas, river restoration, and investments into the improvement of water efficiency of private households. In these cases, longer time horizons are considered, with timelines varying between 2030 and 2050.

Since 2008, the GLA, which has planning and environmental policy competences over the London Metropolitan area, has been drafting a climate change adaptation strategy. In the final version of the plan, published in 2011, precise indications of occasions triggering the review of the plan, which were specified in the draft version (among these, further to institutional changes such as the appointment of a new mayor, the revision of climate projections, sea level rise scenarios or the manifestation of other significant climate change impacts), have been cancelled in favor of a generic "regular appraisal and review." This incidence is connected to new institutional obligations related to the reform of local authorities, which should be the occasion for integrating the strategy into the remaining environmental plans that are yet to be established (GLA 2010, 2011a).

Policy mechanisms

Network affiliations: Former Greater London Authority Mayor Ken Livingston, who was also the Initiator of the C40 Network, commenced the climate change adaptation plan. London is furthermore member of ICLEI.

Political leadership: The metropolitan administration of London (Greater London Authority, GLA) was among the first urban administrations to plan for climate change mitigation. The modification of the founding act of the GLA in 2007 enhanced competences of the urban administration and defined a series of statutory themes, among these sustainable development, health and health inequalities, also climate change adaptation and mitigation.

The Greater London council has planning competence over the area of London in terms of spatial planning, environmental and housing and social policies. Local authorities (boroughs) need to adjust their plans and management strategies according to the Greater London Authority's plan, and are responsible for the execution of parts of the measures foreseen as improvements in water efficiency, flood risk management and planning, and maintenance of infrastructures (roads, drainage).

Policymaking process: The climate change adaptation plan for the Greater London Area is connected to a national policy framework (Climate Change Act 2008). The GLA, like all institutions managing vital infrastructures, was called to report to the central government on its efforts in terms of climate change adaptation in 2010 and 2014/15. This compulsory reporting mechanism related to the National Indicator 188, was abolished in 2010[9].

The first planning document was published in February 2010, starting a three months period of public debates with citizens. The final version was published in October 2011 (GLA 2011a). The document identifies, for each of the actions to be undertaken, the responsible institutions, such as national and local authorities, water services, etc. and departments of the GLA.

Former GLA Mayor Ken Livingston initiated the activities on the adaptation strategy in 2006. Shortly after, but still during his mandate, the statutory act of the GLA was modified and the issue of climate change was among the topics that the administration must address, although adaptation activities had commenced a year before the new statutory act even entered in force. Later changes in the municipal leadership have apparently slowed down the deliberation process on the adaptation strategy and there is some evidence that actions have been emptied of direct incisiveness in the final version of the plan (Collingwood Environmental Planning 2010).

Nevertheless, the plan is based on some previous studies addressing specific climate impacts and/or specific sectors interested, including an initial scoping study concluded in 2002 (LCCP 2002). This scoping study comprises a section on economic impacts, with estimates of potential costs and losses due to interruptions of infrastructures, like interruptions of traffic lines, overheating of urban areas and underground facilities, and energy networks and economic activities (insurance and banking sector, manufacturing, environmental services and tourism). Subsequently, the study on the insurance and banking has been amplified, turning it into a proper study on climate change impacts on this sector.

Furthermore, a study on possible options for incentives for private adaptation measures has been redacted focusing on a hypothesis of incentives for green roofs, water fittings increasing water efficiency, and private flood defense. The study is based on indicative cost benefit considerations, which draw quantifications of benefits (in terms of reduction of urban heat islands effect, storm water run off, and greenhouse gases) derived from international studies. The result of the cost-benefit consideration consists of a quantification of an incentive, which is determined by the value of environmental benefits generated.

Possible fonts of funding are indicated, pointing to innovative funds for housing and a specific EU funding program for green roofs. Furthermore, it is recommended to include utility companies in the funding because of the benefits they receive in terms of storm water management and energy saving with regards to private flood defense measures; a national flood defense program is indicated as possible source of funding (LCCP 2002).

In parallel to the climate change adaptation strategy, the document for the land use planning has been revised and published. The adaptation plan makes reference to the report when discussing issues with spatial relevance, such as the location for central heating cooling facilities and indications for building, and local area development for flood risk protection and reduction of urban heat island effects.

Level of integration: On the policy level, the plan represents a stand-alone initiative, where adaptation strategies are partly integrated with mitigation strategies. The plan profiles itself as a leading initiative based on the national framework for climate change adaptation. From a sectoral prospective, the initiative provides a crosscutting vision on relevant urban policy and management issues. In 2008, a national framework for climate change policies was adopted, requiring the design of a national adaptation plan, and asking for regular reporting

[9] http://www.defra.gov.uk/environment/climate/sectors/local-authorities/ (last accessed march 2012)

from involved authorities. Mayors from sub-units (boroughs) are requested to report, inter alia, on local vulnerability against flooding.

Types of policy: The plan focuses on preparation and strategic planning for extreme events and climate change in an attempt to reduce potential losses. The plan is based on a cross-sector strategy for mainstreaming adaptation actions into existing urban management activities, including land use planning, transportation, water and environmental policy. The strategy provides the framework for identification of climate risks, setting of priorities, competences and definition of actions. Within this framework a list of actions of adaptation are defined for implementation within the short term/medium period. The plan provides mainly strategic indications for climate adaptation actions to be undertaken by other administrations (boroughs, service providers, etc.). The activities to be undertaken by the GLA are limited mainly to studies, lobbying and collaboration with local authorities (boroughs) and sectoral administrations (DEFRA, Health sector, etc.)

Adaptation recommendations for flood defense, prevention of impacts from urban overheating in the building sector, and advocacy in favor of insurance and early warning systems can be interpreted as strategies for increasing resilience. The actions proposed are classified as “no regret”, or as “reversible” measures with regards to recommendations for building bans or special flood resistant building techniques for flood prone areas.

Modes of government involvement: The process relies on the involvement of stakeholders at various levels, involving public authorities, relevant service providers (transport, health care, environmental agency, etc.), and small and medium enterprises in the extended area. Citizens are involved using a web portal, public discussion groups, etc. and are solicited for suggestions and initiatives for private action in an ongoing participative process (GLA 2010).

The strategy furthermore provides for coordination among the single local authorities responsible for the London boroughs, which have statutory duties in vulnerability assessment according to the national policy framework.

Best practices

Climate projection data source: Climate scenarios provided by the national program for climate change (UKCP 2009). A region specific vulnerability assessment was based on a Local Climate Impact Profile (LCLIP, tool developed by UKCIP) for the whole area of London.

Climate risks: Direct climate risks include intense precipitation, drainage and flash flooding, drought and water efficiency, heat waves/urban heat islands, river floods, and wind/storm damage. Indirect impacts include biodiversity loss, migration/differential social impacts, and increased health and disease problems. Water quality issues, as well as water scarcity and drought are also of some concern.

Types of adaptation measures: The framework character implies the integration of different types of measures at different policy levels and sectors.

- Public Infrastructures:
    - Tidal flood barrier (already in place)
    - Improve and adapt sewage system (on-going)
- Public procurement:
    - Increase of greening /green roofs on public spaces and buildings
    - Investigate the feasibility and cost of incorporating rainwater-harvesting systems in the city's operational properties, gardens and large open spaces
- Regulation:
    - Promoting water saving, limit for per capita water consumption
    - Require that new developments are set back from flood defenses (land use planning, bye-laws and building codes)
- Involvement of private initiative:

    - Promote the use of SuDS such as green roofs as part of new developments, redevelopments, major refurbishments, and street enhancements
    - Require developers building in areas of flood risk to contribute to the development and maintenance of a local flood emergency plan
- Governance for adaptation:
    - Collaboration with the Thames Water Utilities to create a drought strategy, and initiative and costs of planning shared with the Environmental authority (DEFRA) for river restoring.

Specific adaptation activities: Flood risk management is supported by improvements in understanding and management of surface water flood risk. Increases in the quality and quantity of green space and vegetation in London are helping to buffer the city from floods and hot weather. Water and energy efficiency efforts in private buildings are increasing resilience.

Finance

Economic assessment of impacts and adaptations: The strategy does not refer to economic assessment exercises. With respect social inequalities and exposure to flood risk it does however state that the poorest 10 % of households are more likely to live in flood prone areas (GLA 2010).

As part of the preparative process, some specific studies were made exploring particular impacts (flooding), sectors potentially interested by impacts (business sector), and strategies (incentives for private adaptation measures). In this context, also (rudimentary) cost benefit considerations are made, defining for instance the optimal level of incentives for green roofs considering installation/building costs and benefits. One scoping study (LCCP 2002) assessed potential impacts of climate change on key sectors (transport, energy, workforce) and main economic activities (financial services, insurance, manufacturing, public administration, tourist/creative, environmental business sectors and functions), providing mainly qualitative assessments of severity and amenability to adaptation rather than quantification of potential damages and costs of adaptation measures.

Although designed as a strategic plan, the adaptation report does not specify sources of funding. With regards to private actors, it advocates individual adaptation strategies (flood risk preparation, insurance, and modification of building standards) without quantifying expected expenditures or indicating potential sources of funding.

Source and amount of funds: The GLA and a range of stakeholders from the wider GLS GROUP have funded the planning phase. The personnel costs of implementation will be shared by GLA (50%) and the larger GLA group. Single measures are based either on private contributions to public infrastructures (flood defenses), completely private initiatives (water saving, climate proofing of buildings, and urban greening), or on public procurement (urban greening and climate proofing of public buildings).

Investment strategy: The principal actions undertaken thus far consist of planning and studies; no indications on the financing of initiatives such as green roofs initiative and tree planting are given.

Tunis

Plan d'adaptation et de résilience Tunis *(Adaptation and résilience plan for Tunis)*

The territorial reference for the study area is represented by the Tunis agglomeration, covered by the **2009 master plan (Schéma Directeur d'Aménagement)**. This extension was chosen in order to refer also to existing planning documents and development programs.

Size and socio-economic status: The Agglomeration of Tunis comprises the governorates of Manouba, Ariana, Tunis, and Ben Arous. The area covers 300,000 hectares, of which 20,000 are urbanized, with 2.5 million inhabitants. Tunis is the capital of Tunisia, which is considered a transition economy.

Dates and time horizon: The document provides advice to urban and national policymakers for the definition and implementation of an action plan to increase resilience to climate change impacts and disaster risks. The vulnerability analysis in the first part of the study refers to a time horizon of 2030, whereas the subsequently defined action plan refers to a time frame 2020-2050. The suggested actions are grouped according to time frame: short-term actions (to be implemented within 2years), medium-term (to be implemented within 5years) and long-term activities that should be implemented within the next 10-15 years.

Policy mechanisms

Network affiliations: As far as the action plan is concerned, memberships in specific climate change networks are not mentioned as being relevant. Tunisia is member of the Marseille Centre for Mediterranean Integration (CMI), funded by The World Bank, the European Investment Bank, and the French Government. The CMI program "cities for climate change" is the reference for the consultancy for the action plan.

Political leadership: The study has been financed by The World Bank as part of a project addressing the vulnerability and resilience of cities in the MENA region; parallel studies with the same goals and methodologies have been prepared by the same group of consultants for Alexandria (Egypt), Casablanca and Bouregreg Valley (Morocco). The study was presented by a consortium of French research organizations (EGIS-BCEOM, IAU-ile de France, BRGM).

Policymaking process: The study was elaborated in two phases, a first focuses on vulnerability analysis and the second one providing policy advice based on the previous analysis. Results from both phases have been presented to and discussed with local stakeholders during dedicated workshops.

Level of integration: The vulnerability analysis addresses all areas related to natural risks affecting urban areas and identifies those areas that are most relevant for the case study. Actions proposed for the action plan are articulated according to the risk considered, the administrative level involved (national/regional/local), and the time horizon to be considered for implementation.

Types of policy: The adaptation measures considered focus mainly on urban planning and management activities based on public activities for land use planning, improvement of infrastructure, adaptation of buildings through building prescriptions, and expenditure for public health systems.

Barriers and constraints: Potential difficulties in implementation are assessed in the description of proposed activities, and are classified as weak, medium, high, or very high.

Best practices

Climate projection data source: The vulnerability analysis is based on regional downscaling of the IPCC Scenario A1B using ENSEMBLES model, and A1B, A2 and B1 scenario downscaled using ARPEGE-Climat model.

Climate risks: Specific risks include flashfloods resulting from a combination of increased urbanization (in terms of increase of sealed surfaces) and increased intensity of events, with frequency doubling by 2030. Additionally, risks associated with extreme events (increased frequency of heavy rainfall, drought, heat-waves, coastal flooding) and coastal erosion as a consequence of sea level rise are considered. Climate independent seismic risk is assumed to be constant.

Specific adaptation activities: Actions proposed on the basis of an extended cost-benefit analysis are provided according to the relevant climate risks:

- Multiple risks: coordination, planning measures for early warning system, adapting urban planning and building legislation, insurance schemes, and land use zoning;
- Coastal flooding: change of national laws for coastal property, early warning system for tsunamis, coastal management, and specific erosion measures for single areas;
- Flash floods: early warning systems, hydraulic management in vulnerable areas, specific measures for future urbanization and limits to urban sprawl in order to limit the increase of soil sealing, specific protection measures for vulnerable areas (city center, catchments), definition of building rules, and dyke maintenance and management;
- Water resources management: controlling and optimizing water consumption;
- Heat waves: proposal of application of bioclimatic principles on building and urban planning rules.

Finance

Economic assessment of impacts and adaptations: Annual costs of impacts from natural hazards up to 2030 are estimated at 140 million Tunisian Dinars (MDT), and are further considered in relation to the number of inhabitants (49 – 57 DT/person/year) and the GDP for the area of Grand Tunis (0,77% in relation to present GDP or 0,29% in relation to the GDP estimated for 2030) (Egis BCEOM International / IAU-IDF / BRGM 2011a). In a second phase, the costs and benefits of adaptation measures were again estimated with a revised time horizon (2020-2050), finding total annual costs of 612 MDT, of which 438 MDT were due to measures related to the risk of urban flooding, and benefits of 870 MDT (Egis BCEOM International / IAU-IDF / BRGM 2011c). The study underlines the fact that benefits expected from adaptation measures are slightly exceeding 21% of the overall damages attributed to climate change during the first phase dedicated to the vulnerability assessment, and are thus more than compensating the impacts from climate change. The value of benefits estimated corresponds less than 5 % of the GDP (Egis BCEOM International / IAU-IDF / BRGM 2011c p. 212).

Projected costs of climate change: The estimated need for investment is 654 MTD to be spent over the entire time horizon considered. According to time horizons considered, costs are: 339 MTD in the short term (< 5 years), 2 MTD in the very short term (< 2 years), 337 MTD within 5 years, and 315 MTD in the medium term (< 10-15 years).

The adaptation actions have been chosen on the basis of an extended cost-benefit analysis, with a discount rate fixed for the first year, and decreasing in the long-term. The short-term rate of discounting is fixed according to the Ramsey-Keynes condition ($x = \delta + \gamma \mu_{\pi}$), taking into account the fact that a public investor is considered. Here δ is estimated at 0.5 and 1.5%; γ between 0.5 and 2; and μ_{π} estimated at a fixed rate of 4%. The result is a preferred rate of 7%. The time horizon for the first years of discounting is limited to 20 years. The second period that uses a decreasing discount rate is assumed to be 100 years. As many of the investments considered actually have a shorter lifetime, this value is adapted to the actual expected lifetime (Egis BCEOM International / IAU-IDF / BRGM 2011b).

The final assessment of interventions is based on calculation of the NPV of investments and a ratio of costs and benefits regarding the specific type of vulnerability addressed; cost/benefit relations are quantified for different discount rates (0-10%).

Source and amount of funds: The action plan explicitly focuses on activities with public funding. If private investments are considered then the hypothesis of public assistance (for instance regarding insurance scheme or specific building norms for areas vulnerable to flooding) is explicitly questioned.

The study does not indicate possible strategies for funding.

Investment strategy: Only public investments are considered, and the question of funding is explicitly posed wherever private investments are envisaged.

Types and costs of investments: The study quantifies the amount of investment needed for climate proofing and improving urban infrastructures. Total annual costs of climate change are 612 MDT; benefits total 870 MDT, of which 438 MDT are due to measures related to the risk of urban flooding (Egis BCEOM International / IAU-IDF / BRGM 2011c).

eThekwini Municipality (Durban)

The **Headline Climate Change Adaptation Strategy** (HCCAS) and subsequent sector specific **Municipal Adaptation Plans** (MAPs)

Size and socio-economic status: Durban has a population of approximately 3.5 million people and covers an area of 2,300 kilometers. Due to the apartheid development in the region, Durban is racially structured and highly fragmented, with sprawling and poorly integrated urban form. Unemployment plagues 34.4% of the working age population, spurring high rates of poverty and crime. Furthermore, approximately 140,000 urban households do not have access to public services such as water, sewer, or electricity (Carmin et al. 2009).

Dates and time horizon: Climate action was initiated in Durban in 2000 when the city was asked to participate in the Cities for Climate Protection campaign led by ICLEI – Local Governments for Sustainability. The campaign focused primarily on mitigation activities, and provided little momentum for climate action due to a lack of information on climate science and impacts. In 2004, the eThekwini Municipality, responsible for planning and managing Durban, began working on the development and implementation of the Municipal Climate Protection Program (MCPP) (Carmin et al. 2009; Roberts 2010) In 2006, the HCCAS was launched, addressing projected climate change impacts for 2070-2100 (Hounsome and Iyer 2006). Sector specific MAPs were later initiated in 2008. Adaptation in Durban is an iterative and on-going process, with three MAP pilot projects completed.

Policy mechanisms

Network affiliations: Durban participated in an ICLEI climate protection campaign in 2000. Additionally, Debra Roberts, Head of Durban's Environmental Management Department (EMD) presented the city's work on climate change to the Rockefeller Foundation and then was invited to serve on the advisory committee for the Rockefeller Foundation's Asian Cities Climate Change Resilience Network (ACCCRN) (Carmin et al. 2009).

Political leadership: The early efforts of Roberts set the adaptation process in motion. Furthermore, city officials have accepted the idea that climate change adaptation is worthy of being placed on the municipal agenda, and many incentives and ideas have supported adaptation activities (Carmin et al. 2009). The municipal government is the primary agency facilitating research and interventions to address the climate risks facing Durban (Roberts 2010).

Policymaking process: The development and implementation of the MCPP began in 2004 under the guidance of Roberts, who had just returned from a climate focused environmental course at Brown University. Roberts commissioned the EMD to conduct an initial analysis of climate impacts. Following the completion of the initial impact analysis in 2006, titled *Climate Future for Durban*, the HCCAS was developed, initiating the adaptation work stream in the MCPP. The objective of the HCCAS was to identify the municipal sectors that would be impacted by climate change and to recommend adaptation options. Water, health, infrastructure, the coastal zone and biodiversity, tourism and business, and food security and agriculture were identified as the most vulnerable, and a number of specific adaptations were recommended for each. This information was published as a set of general guidelines, the *Headline Adaptation Strategy*, however was not put into action by most municipal departments due to lacking institutional capacity. While some sectors, such as water, were already involved in work that had ancillary adaptation benefits, other sectors had a limited awareness of climate change, or were unable to take effective action due to structural limitations (Roberts 2010). Furthermore, the *Headline Adaptation Strategy* did not specify *how* to implement the suggested adaptations, but only provided more general information, such as the climate change impacts in the sector, stakeholder feedback and initiatives,

research needs and opportunities, and adaptation options (Carmin et al. 2009; Roberts 2010).

The biodiversity sector was the only sector to stimulate new adaptation actions, likely because the department responsible for overseeing the EMD and the HCCAS, the Environmental Planning and Climate Protection Department (EPCPD), is also responsible for biodiversity planning (Carmin et al. 2009; Roberts 2010).

The HCCAS had little or no impact on the sectoral administrations that should have implemented them, so the local authority decided to create sector-specific, interconnected MAPs aligned with existing business plans, development objectives, funding, and skills. With respect to the first initiative, sector administrations perceived outlined risks too generic and distant to be of concern for the every-day activities of municipal sectoral administrators. A sector-focused approach instead provided detailed indications for climate change issues with respect to chosen sectors and for cross-sectoral synergies. The health (clinical health, environmental health, communicable disease control and social development) and water (water and sanitation, coastal, storm water and catchment management, and coastal policy) sectors were chosen as pilot projects to test the sectoral approach. They were selected because of their particular vulnerability to climate change, importance to the city's development agenda, good working relationship with the EPCPD, and because water and health are affected by similar climatic factors. Both sectors require adaptations engaging a broad range of stakeholders responding to a variety of risks (Carmin et al. 2009; Roberts 2010).

Additionally, an MAP was created for the disaster management sector, as the HCCAS process highlighted the role of the Disaster Management Unit (DMU) in adapting to climate change. Through the HCCAS process it became evident that structural limitations prohibited the DMU from taking action. Although the DMU regarded climate change as a risk requiring attention, it had no capacity to address the problem because the unit typically functions in a reactive rather than proactive way, focused on short-term relief and welfare. The HCCAS identified the need for the DMU to prioritize proactive and strategic interventions, to create early warning systems and to ensure that resilience is built into construction processes to reduce the probability of infrastructure failure, enhancing recovery after an extreme event, and relocating critical infrastructure and people in vulnerable areas. Additional findings included the need for the DMU to plan new developments in less vulnerable areas, ensure community empowerment, increase human capacity and skills within the DMU, and develop a local disaster management plan. The central role of the DMU in effective cross-sectoral and comprehensive adaptation planning was not however realized until the subsequent development of an MAP adaptation work stream. Then it was finally realized that the disaster management system serves as an effective element for cross-sectoral and comprehensive adaptation planning, which is essential to achieving local level resilience (Carmin et al. 2009; Roberts 2010).

Monitoring of implementation of the three pilot plans show that most actions in the water sector have been effectively mainstreamed into the work programs of the department, but the health sector has made little progress implementing the adaptation plan, largely due to leadership change. Limited progress has been made in the DMU. Future work will focus on community-based adaptation and responding to slow onset disasters, as well as research into the costs and benefits of Durban as an early adapter to climate change (Carmin et al. 2009; Roberts 2010).

Level of integration: Resilience based adaptations in Durban provide development related co-benefits in the context of poverty and underdevelopment; this is a significant factor influencing the acceptance and success of adaptation initiatives. The underlying idea of the MAPs is to mainstream adaptation into a municipal environment with many competing objectives, which has so far has been successfully achieved in the water sector pilot project.

Furthermore, city leaders realize that development of new institutional partnerships is useful in advancing the climate change adaptation and resilience agendas (Roberts 2010).

Types of policy: Policies are mainly resilience-focused interventions that aim to improve development and service delivery objectives (Roberts 2010).

Barriers and constraints: Past experience suggests that the initial failure of the HCCAS process was likely due to a number of factors, including the high level and generic nature of the study, pre-existing heavy workloads of municipal agents, shortages of skills and funds, and the perception that other challenges were more urgent, and that climate change is a distant and unlikely threat. Lack of skilled and experienced personnel has also been a barrier to adaptation, especially in the DMU (Roberts 2010).

The Urban Climate Change Research Network's (UCCRN) First Assessment Report on Climate Change and Cities (Rosenzweig et al. 2011) highlights six climate-specific governance challenges in Durban's adaptation process. First, the long time scale of climate change is not compatible with the short political and budgeting cycles at the local level. Second, cities have historically been planning for a constrained set of predictable futures, and lack flexibility in planning for uncertain futures. Third, climate change has been stereotyped as an environmental issue, while it is actually a developmental challenge, inhibiting it from being effectively mainstreamed into planning and decision-making. Fourth, the local government has had limited standing in international climate change negotiations despite their role in adaptation and capacity building. Being recognized as governmental stakeholders at COP16 helps cities from a governmental perspective to ensure that national governments acknowledge them as climate change players. This puts cities in position to receive international funds. Fifth, it is extremely difficult for local governments to access international funds for climate change adaptation. Sixth, it will be challenging for local governments to deal with the residual damages from climate change where adaptation is neither economic nor feasible.

Best practices

Climate projection data source: Projections for the impact and adaptation assessment are based on research undertaken by the University of Pretoria, University of KwaZulu Natal-Pietermartizburg and the University of Cape Town, using a regional downscaling model (CCAM nested within CSIRO MK3 AOGC). Data were also obtained from the South African Navy in order to project possible sea level rise, as part of the Global Sea Level Observing System project. The reference to IPCC SRES scenarios for 2070 to 2100 is generic, as no families of the SRES scenarios are indicated as references, and global atmospheric changes are referred to in terms of range of temperature variation. Based on the physical indications from modeling, four integrated scenarios for the future development of Durban were designed in a participated process as a tool for communicating with decision makers (Naidu et al. 2006).

Climate risks: Climate change is anticipated to lead to increases in vector borne diseases, increases in the frequency and intensity of floods and droughts, extinction and changes in the geographical distribution of plants and animals, increases in infrastructure damage, increases in erosion of coastal areas, decreased food security and water availability, increases in heat stress, higher energy consumption (i.e. due to increased use of air conditioners), increases in economic losses due to property damage, and decreases in tourism revenue. These impacts will be the result of sea level rise, increased frequency of extreme weather events, increased frequency and intensity of short duration heavy rains, prolonged periods with no rain and heat waves, and increased daily maximum and minimum temperatures (Hounsome and Iyer 2006) .

Types of adaptation measures: Education and awareness raising, policy, land use planning, contingency planning, and research and monitoring were the main types of adaptations recommended in the HCCAS. After HCCAS was deemed unsuccessful, a

sector-by-sector approach has been taken in adapting to climate change, beginning with the water, health, and DMU sectors. The best adaptation responses are considered those that engage a broad range of actors and respond to a spectrum or risks and threats. The water sector adaptation plan is focused on improving water and sanitation, coastal, storm water and catchment management, and coastal policy. The health plan focuses on clinical health, environmental health, communicable disease control, and social development and food security. Additionally, five interventions to improve institutional capacity are detailed in the disaster management MAP: (1) implementation of the disaster risk management framework, (2) comprehensive citywide assessment, (3) securing additional human resources for the DMU, (4) revision of contingency plans for key risk areas, and (5) hosting a disaster management summit (Roberts 2010).

Finance

Economic assessment of impacts and adaptations: Plans have been set in place to capture the full costs of implementing the three pilot MAPs to determine the costs and benefits of adaptation for early adapters such as Durban. This will reveal whether such adaptation work is viable in the long term without external funding support (Roberts 2010). An expert in climate change adaptation and economics has helped EPCPD develop the terms of reference for a cost benefit analysis. The EPCPD MAP website currently states that a call for economic assessment project proposals will be posted in the near future.

Additionally, a multi-criteria assessment of the health and water MAPs is provided in the final report of the plans. It uses "broad judgment" for considering the cost-benefit ratio of the various interventions (high cost: low benefit or high benefit: low cost) (Constable & Cartwright 2009), and finds that out of the 47 interventions considered, 33 are high benefit: low cost, 12 are neutral, and 2 are deemed high cost: low benefit.

Source and amount of funds: There has been no pressure to pursue adaptation associated with direct foreign investment or official development assistance. Durban has, however, been successful in obtaining grants and using them to finance climate related projects. For example, Roberts presented her work to the Rockefeller Foundation and then was invited to serve on the advisory committee for the ACCCRN (Carmin et al. 2009). The Rockefeller Foundation compensated her with a $65,100 grant to jumpstart the MAP work in 2008 (The Rockefeller Foundation 2008a).

Further funding for the MAPs often comes from within the sectors themselves. The adaptation plans are mainstreamed into existing business plans and development objectives, and utilize available funding and skills (Roberts 2010).

Investment strategy: The MAPs call for investments in public activities, services and planning. Investments are focused on research and building capacity and resilience into existing things. The plan is not a focused on investing in new infrastructure or large-scale changes.

Ho Chi Minh City (HCMC)

Ho Chi Minh City Adaptation to Climate Change - Summary Report *(Reporting the results from the risk and vulnerability assessment for Ho Chi Minh City prepared for the Asian Development Bank by the International Center for Environmental Management in collaboration with HCMC People's Committee and Department of Natural Resources and Environment. The donors intended the study to provide the basis for a "HCMC's structural approach to climate change adaptation" which will need to be defined by local authorities.)*[10]

Climate Risks and Adaptation in Asian Coastal Megacities *(Conducted by The World Bank in 2010, referencing the ADB study.)*

Size and socio-economic status: HCMC has a large and growing population of more than 6.3 million (ADB 2010). It is the largest city and most important economic center in Vietnam, with 7.5% of the country's population, accounting for 20% of GDP (WWF 2009).

Dates and time horizon: The adaptation studies conducted by The World Bank and ADB were released in 2010. The purpose of these reports is to assist the People's Committee in adapting to climate change, considering a timeframe up to 2050.

Policy mechanisms

Political leadership: The risk assessment represents an example of external leadership in adaptation planning, as the initiative and finance for the study were provided by international development banks (The World Bank and Asian Development Bank) in recognition of the high level of risk with respect to coastal and river flooding. Local authorities supported and collaborated in the preparation of the adaptation study and declare to be "interested in a climate change adaptation plan for the city" (ADB 2010).

Policymaking process: The assessment was made as a study promoted and financed by external donors, intending to trigger more adaptation planning at local level by making local policy makers aware of future climate risks. The final chapter of the ADB study proposes implementation arrangements for study recommendations (ADB 2010).

Level of integration: HCMC is currently planning major drainage and dike works, which will occur in three stages, to enclose the city and divert floods, rainwater, and high tides to the Thi Vai River. Many of the works are part of the Irrigation Plan for Flood Control for the HCMC Area up to up to 2025 (ADB 2010). There is a ''one area, one plan'' framework for development in HCMC, so many adaptation measures are already being implemented in the city and need only to be adjusted, intensified, and applied in a coordinated way in the context of climate change (ADB 2010).

At the country level, the National Target Programme to Respond to Climate Change has a plan to account for the 30-cm SLR projected to occur by 2050 (Birkmann et al. 2010). Furthermore, a Climate Change Office has been set up within the Ministry of Natural Resource and Environment, and the Science, Technology and Environment Committee of the Parliament has started to examine the impacts of climate change on the national development sustainability (WWF 2009).

Types of policy: Urban development, land use planning, and zoning are advocated to achieve reductions in both poverty and vulnerability to climate risks such as flooding. Integrated water resource management is intended to help mediate current and future water

[10] The Study was co-financed by the governments of the United Kingdom and Japan under the Asian Development Bank regional technical assistance project Promoting Climate Change Adaptation in Asia and the Pacific (TA 6420-REG, approved 21 November 2007), and conducted by the International Centre for Environmental Management (ICEM) in close cooperation with the HCMC Department of Natural Resources and Environment (ADB 2010).

resource problems, and climate proofing and contingency planning of urban infrastructures are intended to increase flood preparedness.

Barriers and constraints: Several barriers exist in the interactions and conflicts between different adaptation strategies. One goal of the plan is to provide all residents with safe and affordable land, yet where that land is located and how relocation would occur are unknown. Additionally, there is a lack of provision of public infrastructure and constraints on the planning process in urban development that hinder proposed strategies such as improved building codes and better land use planning. Additionally, there are negative consequences or externalities associated with some structural measures. The implications of building dikes and relocating people are not discussed, but will have tremendous implications for the people (Birkmann et al. 2010).

Best practices

Climate projection data source: The HCMC study uses the IPCC SRES A2 and B2 scenarios in order to define the most extreme emission pathways, with downscaling to the level of the city/watershed in the cost assessment in the Asian Coastal Megacities report (The World Bank 2010).

Climate risks: HCMC has been named one of the top ten cities in the world with populations most likely to be severely affected by climate change (ADB 2010). Moreover, flood, drought, heat, and sea level rise and storm surge are anticipated to have severe consequences for transportation, industry, agriculture and natural ecosystems, energy, and public health sectors (ADB 2010). Climate change is also expected to contribute to occurrences of saltwater intrusion, ground and surface water salinization, erosion, flash floods, landslides, typhoons, tropical cyclones, and habitat destruction of mangroves and salt marshes (WWF 2009).

The poor will be more exposed to flooding by 2050 than others living in the city. Living in a low-income area implies vulnerability to climate change because there are limited resources for dealing with negative economic shocks such as flooding events. The urban poor are vulnerable to climate change because of their geographic location in the city and associated poor housing and environmental conditions (ADB 2010).

Types of adaptation measures: HCMC requires actions to simultaneously manage flooding and reduce poverty, including livelihood diversification, as well as social protection and health insurance schemes. Detailed adaptation planning is key to ensuring urban resilience in HCMC. Balance in adaptation is recommended through the implementation of engineering options complemented by natural system rehabilitation, economic and social policies and programs, and integrated urban planning to achieve the goal of ‘’one area, one plan’’ (ADB, 2010). The study recommends many types of adaptations, primarily focusing on engineering options, social response options including relocation, economic instruments, natural system management, sector specific practices, and traditional responses taken by communities exposed to natural hazards. Although predominantly focused on structural and technical measures, some non-technical and non-structural responses are identified, such as strengthening coping capacities (Birkmann et al. 2010).

Specific adaptation activities: Several different types of adaptations are advocated to address flood risk: research and monitoring to better predict and create early warning systems for storms, tides, and droughts; flood management contingency planning to ensure that when floods do occur they pass quickly with minimal damage; flood management and drainage systems to improve sanitary conditions and reduce disease risk; land use planning and zoning controls to keep settlements out of vulnerable areas (including resettling of populations located in the most vulnerable areas); more strict construction requirements and building codes in low income areas; and research and development of semi-permeable surfaces for the city landscape (ADB 2010)

The following are included among the study's specific adaptation recommendations (ADB 2010):

- Review and revision of infrastructure design standards for the transportation sector;
- Integration of climate change into adaptation of industrial systems through spatial development planning and developing effective policy instruments to encourage resilience (e.g. planning and the use of economic instruments to keep business development and industrial zones outside of vulnerable areas; further developing an understanding of climate change effects on productivity and the impact of industry on vulnerability; and retrofitting and protecting vulnerable infrastructure, when cost effective);
- Ecosystem-based adaptation to provide a coordinated and comprehensive approach to address the vulnerabilities in agriculture and ecosystems;
- Protection of the availability of energy resources, the efficient operation of energy infrastructure, and management of the changes in seasonal patterns of demand.

Finance

Economic assessment of impacts and adaptations: The ADB adaptation study does not undertake a cost benefit assessment of potential or foreseen adaptation measures, but provides an estimation of the viability of an existing $750 billion dollar flood protection project to be completed by 2025. The assessment strategies is based on two alternative assessments: one based on the losses of land values, the other on GDP losses related to the number of inhabitants interested by flood events. Based on the assessment of GDP losses, adaptation would reduce damages by 35% (corresponding to the decrease in the number of inhabitants exposed) (ADB 2010).

Projected costs of climate change: The report on Asian Coastal Megacities finds that the annual costs of flooding in HCMC up to 2050 are $6.5 to $50 billion, in present value. The costs of adaptation for 2010 to 2050 are calculated to be between $6.12 to $49.5 billion for ordinary flooding and $0.42 to $6.9 billion for extreme flooding from 1-in-30 year events (The World Bank 2010).

Potential impacts are quantified in terms of the length and surface of flooded of land, using two strategies. Discounting is applied only to GDP values (annual discount rate of 10%), whereas land values are assumed representing already the capitalization of a discounted future income stream. The methods for quantifying impacts include (The World Bank 2010):

- Assessing the decline of land values in function of the amount of time (number of days per year) that areas are flooded. This includes the value of infrastructures lost or damaged as land values represent a capitalization of infrastructures.
- Assessing the decline of GDP in relation to the area flooded; losses of GDP are calculated in proportion of the duration of flooding, assuming a complete loss of productivity for the duration of flooding. The amount of GDP is assessed as a function of population density in the flooded area, assuming an average GDP per capita for the area.

Source and amount of funds: The ADB adaptation study was co-financed by the governments of the United Kingdom and Japan under the Asian Development Bank regional technical assistance project, Promoting Climate Change Adaptation in Asia and the Pacific, and conducted by the International Centre for Environmental Management and the Ho Chi Minh City Department of Natural Resources and Environment (ADB 2010).

Investment strategy: Many of the proposed adaptations require new investments to protect against floods, SLR, salinization, droughts, and storms, for example in building dikes, resettling populations, creating new institutions, researching new crop varieties, etc.

However, the adaptation report does not provide specific suggestions for economic instruments that could be used to promote business development out of vulnerable areas.

Types and costs of investments: The Prime Minister has approved the Irrigation Plan for Flood Control for the HCMC Area up to 2025, with an investment of about $650 million (ADB 2010).

Bangkok

Bangkok Assessment Report on Climate Change *(Bangkok Metropolitan Administration, UNEP, and Green Leaf Foundation, 2009, adaptation report for the Bangkok Metropolitan Region)*

Climate Change and Adaptation for the Bangkok Metropolitan Region *(Panya Consultants Co. Ltd., 2009, commissioned by The World Bank to inform the Coastal Megacities report – focuses only on the City of Bangkok and the shoreline of the Province of Samut Prakarn along the Gulf of Thailand, which are directly affected by sea level rise)*

Climate Risks and Adaptation in Asian Coastal Megacities *(The World Bank, 2010, contains a synthesis of the Panya report)*

Size and socio-economic status: The current population of the city of Bangkok is estimated to be about 10 million. The Bangkok Metropolitan Region (BMR) includes Bangkok and five provinces, namely Samut Prakarn, Samut Sakhon, Nonthaburi, Pathum Thani and Nakhon Pathom, and covers an area of 1,569 square kilometers (The World Bank 2010).

Dates and time horizon: The Bangkok Metropolitan Administration released the Bangkok Assessment Report on Climate Change in 2009 for the BMR. Separately, in estimating costs, the Asian Coastal Megacities study on Bangkok examines direct and indirect tangible damages associated with potential floods under 16 scenarios. Damage costs are evaluated for the base year of 2008 and for 2050. The scenarios include three climate change scenarios (current climate, B1 and A1FI), three levels of flood intensity (1-in-10 year, 1-in-30 year, and 1-in-100 year), and additional scenarios that include land subsidence, sea-level rise, and storm surge (The World Bank 2010).

Policy mechanisms

Network affiliations: Bangkok is affiliated with UNEP and The World Bank, but does not appear to have any other significant network associations that have factored into their adaptation process.

Policymaking process: At the country level, the Office of Natural Resources and Environmental Policy and Planning, under the Ministry of Natural Resources and Environment, is (in the process of) creating a strategy to address climate change issues as they relate to Thailand. The strategy will outline the mechanisms and measures that will have to be undertaken by various agencies of the government. Such measures will include those for reducing greenhouse gas emissions and enabling the country to adapt to the adverse impacts of climate change (Bangkok Metropolitan Administration et al. 2009).

At a more regional scale, the Bangkok Assessment Report on Climate Change (2009) is an output of UNEP's capacity-building program to assess major environmental developments and trends, implemented under the Global Environmental Outlook process (Bangkok Metropolitan Administration et al. 2009).

Level of integration: The approach to adaptation planning has been to identify sectors at risk and provide delegated agencies with plans to address the risks. This type of an approach relies on agents having sufficient technical and financial capacity to make the necessary interventions and investments, with an effective system of oversight and control (UN-Habitat 2011). However, the recommended adaptations have not yet been translated or integrated into urban policies.

Types of policy: Policies advocated in the plan relate to both planning and infrastructure development, and include actions for risk management and assessment, infrastructure upgrades/adaptations, health and health care, and other general adaptations (Bangkok Metropolitan Administration et al. 2009).

Barriers and constraints: No barriers or constraints to adaptation have emerged yet, as adaptation planning has only been initiated from outside local or national administrations (i.e. UNEP's capacity-building program). However, official statistics accounting for approximately half of the existing population indicate that implementation of urban policies may encounter some difficulties with respect to unplanned urban settlements.

Best practices

Climate projection data source: SRES A1FI and B1 scenarios were used in the Asian Coastal Megacities study of Bangkok, along with downscaling form 16 GCMs. A1FI and B1 scenarios were chosen because they represent the high and low brackets, respectively, of the estimated global temperature increases. For flooding, commercially available software was applied to develop the hydrologic models (The World Bank 2010).

Climate risks: Relative sea level rise in Bangkok will be accelerated by local land subsidence, primarily caused by the over pumping of groundwater and the nature of the thick, soft clay on which the city is built. On this background, intensification of precipitation and the increasing occurrence of storm events will further increase already existing drainage problems and lead to flooding of huge urban areas, especially those lying below sea level. Furthermore, droughts and flooding events will accentuate problems of fresh water availability because of contamination of ground water, air pollution and the occurrence of infectious diseases will increase due to heat waves, and rising temperatures will impact on agricultural production changes in growing seasons (Bangkok Metropolitan Administration et al. 2009).

Types of adaptation measures: A risk management approach is used to assess the potential consequences of climate change and to identify appropriate responses. Adaptation measures include policy-based, infrastructural, and environmental responses, which advocate capacity-building activities, improved communication between scientists and officials, development of climate change risk at the local level, and awareness raising in homes and communities (UN-Habitat 2011). Adaptations for climate-proofing the city include improving the local public health infrastructure and disease surveillance and prevention programs; creating early warning systems for extreme weather events; and implementing stricter zoning and building codes to minimize damage from storms and sea level rise (Bangkok Metropolitan Administration et al. 2009).

Specific adaptation activities: Adaptations are categorized as community infrastructure and operations, business and commercial, or residential health and general population. While numerous specific adaptations are proposed under each of these headings in the Bangkok Metropolitan Administration report (specifically to address the threats of long term temperature increase, ground and surface water quantity and quality, sea level rise, extreme weather events, increased frequency and intensity of short duration heavy rains, heat waves, droughts and smog episodes), some additional adaptation areas to be addressed by the city include (Bangkok Metropolitan Administration et al. 2009):

- Policy measures
    - Water and energy conservation;
    - Reviews of standards, codes, and regulations to promote best practices;
    - Emergency preparedness and response;
    - Early warning systems for severe weather and pollution;
    - Improving disease surveillance and prevention;
    - Education and awareness raising, especially for local health professionals and the public about health risks associated with climate change;

    - Implementing a heat watch/warning system and creating emergency shelters for the most vulnerable citizens;
    - Staying updated on climate change in the BMR, and translating new knowledge into local policies and practices.
- Measures of urban planning
    - Implementing stricter zoning and building codes to minimize storm damage;
    - Using structural measures to prevent contamination of potable supplies;
    - Improving the local public health infrastructure.

Separately, the Asian Coastal Megacities study proposes some infrastructural adaptation measures based on the assessment of flooding in Bangkok, including dikes, pumping capacity improvements, canal improvements, and coastal erosion protection (The World Bank 2010).

Finance

Economic assessment of impacts and adaptations: A cost assessment of flood related impacts and vulnerabilities in Bangkok is presented in the Asian Coastal Megacities report, based on the Climate Change Impact and Adaptation Study for the Bangkok Metropolitan Region (Panya Consultants Co. Ltd. 2009). The report considers the direct and indirect costs of flooding on (1) buildings, industry, and commerce; (2) transportation and related infrastructure; (3) public utilities such as energy, water supply, and sanitation services; and (4) people, income, and health. Direct impacts from flooding involve costs from loss in the stock of infrastructure, tangible assets and inventory, agricultural and environmental goods, and injuries and life loss. The indirect impacts of flooding are a result of a loss in the flow of goods and services to the economy. The Bangkok study presents results using 8 percent, 10 percent, and 12 percent discount rates for assessment of adaptation investments (The World Bank 2010).

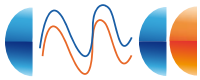
Projected costs of climate change: Damage costs from flooding in 2050 range from $1.5 billion to $7 billion under the different climate and land use scenarios. Increased costs associated with the net impact of climate change (under the A1FI scenario, which assumes the highest range of impacts globally, considering storm surge and sea-level rise, but not land subsistence) from a 1-in-30-year flood are THB 49 billion ($1.5 billion), or approximately 2% of GRDP. The actual costs of a 1-in-30-year flood, accounting for both climate change and land subsidence, will be nearly $4.6 billion in 2050. As the Bangkok study shows, land subsidence, if not stopped, will eventually contribute a greater share of damage costs from floods than a projected change in climate conditions (The World Bank 2010).

Damages assessed were mainly due to losses in the commercial and industrial sector, resulting from income losses from business suspension during flooding (value-added income losses are estimated at 22 and 10 billion baht ($0.63 and $0.29 billion USD) by 2050 in the commercial and industrial sectors respectively (Panya Consultants Co. Ltd. 2009)).

Investment strategy: Using the results from this preliminary evaluation and applying an 8% discount rate for public investments, as is standard policy for Thailand (The World Bank 2010),, the Asian Coastal Megacities study finds that flood infrastructure should be designed to protect against a 100-year return period flood, as it provides a higher net return (NPV=13.4 billion THB, or $0.4 billion). Such an investment will be economically efficient given an A1FI climate change scenario, however, if a discount rate of 10 % is applied, Bangkok should opt for the adaptation project aimed at a 30-year return period (The World Bank 2010).

Types and costs of investments: The Asian Coastal Megacities study finds that structural adaptation investments for the A1FI climate scenario will be approximately 35.3 billion THB ($1.06 billion) for a 30-year return flood protection project, and 49.5 billion THB ($1.5 billion) for 100-year return flood protection. Total annual operation and maintenance costs for 30 and 100-year return floods are estimated to be approximately 584 ($17.5 million) and 874

million THB ($26 million), respectively. Average annual benefits of reducing flood damages are estimated to be 4.4 ($132 million) and 5.9 billion THB ($177 million) for protection against floods with 30 and 100- year return periods, respectively (The World Bank 2010).



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