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Working Draft

URBAN RISK ASSESSMENTS

AN APPROACH FOR UNDERSTANDING DISASTER & CLIMATE RISK IN CITIES

Urban Development & Local Government Unit
Finance, Economics and Urban Department
The World Bank

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List of Acronyms

AAL	Average Annual Loss
BAP	Bali Action Plan
BBC	Bogardi, Birkmann & Cardona
CAT DDO	Catastrophe Risk Deferred Drawdown Option
CAPRA	Central American Probabilistic Risk Assessment
CCA	Climate Change Adapatation
CDC	Center for Disease Control
CEPREDENAC	Centro de Coordinación para la Prevención de los Desastres Naturales en América Central
COP	Conference of Parties
DEM	Digital Elevation Models
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DSM	Digital Surface Models
DTM	Digital Terrain Models
ESA	European Space Agency
GCP	Ground Control Points
GFDRR	Global Facility for Disaster Risk and Recovery
GHG	Green House Gases
GIS	Geographic Information System
GPS	Global Positioning System
HFA	Hyogo Framework for Action
ICSMD	International Charter on Space and Major Disasters
IPCC	Inter-governmental Panel on Climate Change
LEC	Loss Exceedance Curve
LECZ	Low Elevation Coastal Zone
MDG	Millennium Development Goals
MDR	Mean Damage Ratio
MHCRI	Multi-Hazard City Risk Index
NAPA	National Adaptation Programs of Action
PA	Priority Action
SA	Shelter Associates
UDRi	Urban Disaster Risk Index
UNEP	United Nation Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations Strategy on Disaster Reduction
URA	Urban Risk Assessment
VHR	Very High Resolution
WHO	World Health Organization
WRI	World Resources Institute
WWTB	World Wide Typology of Buildings

Executive Summary

The rapid and often unplanned expansion of cities is exposing a greater number of people and economic assets to the risk of disasters and the effects of climate change. For city governments, increased climate variability imposes additional challenges to effective urban management and the delivery of key services, while for residents it increasingly affects their lives and livelihoods due to a greater frequency floods, landslides, heat waves, droughts or fires. There is an urgent need for cities to consider the issues of disaster and climate change by streamlining assessments of related risks in their planning and management processes and delivery of services.

This paper proposes a framework for carrying out urban risk assessment, and seeks to strengthen coherence and consensus in how cities can plan for natural disasters and climate change. The Urban Risk Assessment (URA) was developed by drawing on lessons from existing efforts to assess risk in cities as well as urban planning literature. It was vetted through a consultative and collaborative process that included international development agencies, the public and private sectors and non-government organizations. It seeks to minimize duplicative efforts, and to bring convergence to related work undertaken by the World Bank and other key partner organizations[1]. The target audience for this report includes: (i) decision makers such as city managers, mayors, and those involved in developing national and local policies related to urban development, (ii) urban practitioners and technical staff at the municipal, regional, and national levels, and (iii) international organizations.

The Urban Risk Assessment presents a flexible approach that project and city managers can use to identify feasible measures to assess a city's risk. It aims to provide key information needed to consider appropriate city-level responses to the risks posed by natural hazards and increased climate variability. The assessment aims to lay the groundwork for collaboration across multilateral agencies, the private sector, and city and national governments to begin benchmarking their own progress towards the reduction of urban risk. The goal is to establish a common foundation upon which urban risk assessments could periodically be performed, with the ultimate objectives being the quantification of risk and monitoring of progress towards improved resilience. The urban risk assessment methodology has been piloted in four cities (Mexico City, Jakarta, Dar es Salaam and Sao Paulo) and will be further refined with the support and guidance of various international agencies as it is rolled out globally.

The proposed assessment methodology focuses on three reinforcing pillars that collectively contribute to the understanding of urban risk: a hazard impact assessment, an institutional assessment, and a socioeconomic assessment. The URA is designed to allow flexibility in how it is applied dependent on available financial resources, available data relating to hazards and its population, and institutional capacity of a given city. Through the URA's sequencing, which is linked to complexity and required investment, city managers may select a series of subcomponents from each pillar that individually and collectively enhance the understanding of urban risk.

[1] The development of the urban risk assessment is part of a Memorandum of Understanding on a joint Cities and Climate Change work program between UN-Habitat, UNEP, and the World Bank, supported by Cities Alliance.

Based on the identified needs and priorities, city governments can select the most appropriate level of risk assessment. At the primary level, the assessment is designed to require only limited financial resources and institutional capacity, and can help cities in identifying hazard prone areas, basic climate change challenges, and capacity for disaster preparedness and response. At the secondary level, the assessment relies on techniques requiring more financial and technical resources to be able to develop actual risk mapping, resilience studies and institutional gap analysis. At the tertiary level, the assessment will require greater resources, institutional capacity and data availability to make use of advanced risk management tools and to undertake detailed disaster and climate change modeling.

The Urban Risk Assessment is intended to assist in decision-making, urban planning, and designing disaster and climate risk management programs. An important step towards this objective is streamlining data acquisition and management into an integrated system which can not only be updated and monitored easily, but that is also accessible to the various entities involved in city management. Recent technological advances, specifically those making the collection and sharing of hazard related information more readily available through open source software, will benefit emerging programs in the four phases of risk management (risk reduction, preparedness, response, and recovery) and the formulation of climate change adaptation programs. The same information can often be valuable to the design of traditional urban projects such as poverty alleviation and housing or infrastructure upgrading.

An ancillary objective of the urban risk assessment is to better position cities to absorb and allocate discrete adaptation funds should they be available. Currently there are no direct linkages between city level actions and National Adaptation Programs of Action (NAPA), and few funding schemes are in place to finance their implementation. When compared to other sectors such as forestry or agriculture that have typically received sizeable allocations for climate adaptation funding, cities have lacked necessary mechanisms and tools to begin addressing climate change and disaster management in a sustainable and unified manner. By identifying risks and vulnerabilities within urban areas, city authorities will be better positioned to address short-term disaster risk reduction as well as the longer term impacts of climate change. National governments will also benefit by being better able to allocate adaptation funding based on multiple assessments across its cities.

This report (i) presents the case for the need to better understand risks related to natural hazards and climate change in cities, (ii) proposes an integrated approach to practitioners for identifying areas, populations and assets most at risk from the effects of disasters and climate change, and (iii) provides preliminary suggestions for risk reduction through quantification of risk and implementation of preventative programs. The report is divided into four chapters: Chapters 1 and 2 are aimed at policy makers with information on why and how to invest in measures that strengthen the understanding of urban risk; Chapter 1 provides background information on the growing importance of disaster risk management strategies at the city level and Chapter 2 provides guidance on how to operationalize and mainstream the Urban Risk Assessment with ongoing urban management and development activities. Chapters 3 and 4 are aimed at practitioners, and provide details on the conceptual approach, components, uses, and monitoring requirements related to the Urban Risk Assessment. This document does not provide a detailed discussion on each methodology presented, but rather an overview with selected resources for those wanting more information on specific approaches. Annexes provide detailed case study examples and other useful resources.

1 The Need for an Urban Risk Assessment

Chapter Summary

- *Cities in the developing world are facing increased risk of disasters and the potential of economic and human losses from natural hazards is being exacerbated by the rate of unplanned urban expansion and influenced by the quality of urban management.*
- *Climate change brings additional challenges with a growing number and variety of impacts on cities, their critical ecosystems and citizens' livelihoods.*
- *New residents and the urban poor living in peri-urban areas and informal settlements are particularly vulnerable due to their tendency of residing in high risk areas and faulty shelters, having limited access to basic and emergency services, and a general lack of economic resilience.*
- *The option of doing nothing can be more costly than proactively identifying and managing risks. If no steps are taken to identify and manage disaster risks and climate change, resulting losses will have severe implications on the safety, quality of life and economic performance of cities.*
- *Better urban management and governance is at the heart of reducing disaster and climate change risks and making cities safer.*
- *Cities can plan and respond better if the location and nature of risk is known, and also if the risk assessment and management processes are mainstreamed in urban development and management programs.*

1.1 Disasters and Cities

Disasters have caused major disruptions in both low and middle-income countries, often wiping away decades of development gains in moments. Major recent disasters in developing countries include earthquakes in Haiti (early 2010) which killed over 220,000 people and in Indonesia (2009) which killed over 1,000, the Nargis cyclone in Myanmar (2008) which killed over 138,000 people, and the Sichuan earthquake in China (2008) which killed over 87,000 people. While the economic losses from disasters tend to be greater in high income countries (in absolute terms) due to higher value of properties and assets, low and middle income countries tend to face higher fatalities and disruptions to hard-earned development gains. On average, around 82,000 people are killed annually by disasters, with the majority of fatalities concentrated in low and middle-income countries.[2]

Urban areas suffer greater fatalities and economic losses than rural areas. Today more than half of the world's population lives in cities, with an additional two billion urban residents expected in the next 20 years[3]. Much of the population growth is expected in small and medium-sized cities in developing countries, yet 1.2 billion urban residents already live in slums, and this too is expected to grow; rural-urban migration can cause low-income settlements to double in size every 5-7 years (Smith & Petley, 2009). Africa and Asia, which have the highest rates of urban growth globally, are also experiencing the fastest rate of increase in the incidence of natural disasters over the last three decades (UN-Habitat, 2007). Not surprisingly, many urban areas sustained heavy losses due to disasters in the last ten years (Table 1). Given these trends, without major changes in the management of disaster risks and urbanization processes, risk to city residents will increase in the future as populations grow. According to a joint World Bank – UN study, population exposed to cyclones and earthquakes will more than double by 2050, to 1.5 billion (Figure 1).[4]

Urban areas concentrate disaster risk due to the aggregation of people, infrastructure and assets, urban expansion and inadequate management. While disasters are considered to be external shocks that destroy development gains, disaster risk is internal to the development process; UNISDR (2009) notes that *'disaster risk is configured over time through a complex interaction between development processes that generates conditions of hazards, exposure and vulnerability'* (Box 1). The settling of communities in high risk areas is oftentimes a result of rapid and uncontrolled urbanization accompanied by increased competition for land, decreased vegetation cover, changes in land use and greater variability in climate. These drivers alter population distribution, relative wealth or impoverishment, and disaster risk over a short time horizon and when combined with inadequate urban management, will continue to exacerbate existing risks to natural hazards (Box 2).[5] Coordinated and strategic action must therefore be taken in the short term to avoid the creation of unmanageable levels of risk to city's built environment_and population. This becomes of still greater importance when considering the impact of small scale or recurrent disasters that impact informal settlements. Such events are

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[2] ISDR (2009) based on EMDAT data. Between 1975 and 2008, 78.2% of mortality in significant natural disasters occurred in only 0.3% of recorded events.
[3] World Bank (2009) "Systems of Cities: Harnessing the Potential of Urbanization for Growth and Poverty Alleviation".
[4] World Bank – United Nations. 2010. "Natural Hazards, UnNatural Disasters: The Economics of Effective Prevention".
[5] World Bank (2003) "Building Safer Cities: The Future of Disaster Risk

rarely recorded and it has been argued that their aggregate impact in cities exceeds losses associated with low-frequency, high-impact hazards that capture news headlines (UN-Habitat, 2007).

The urban poor living in peri-urban areas and informal settlements are particularly vulnerable due to their tendency of residing in high risk areas and faulty shelters, having limited access to basic and emergency services, and a general lack of economic resilience.
The urban poor have to make difficult choices in regard to where they reside. This decision involves trade-offs between proximity to economic opportunities, security of tenure, provision of services, protection from extreme events, and cost. As a result, informal settlements are often located in high risk areas. A household's capacity to cope with the occurrence of a disaster also varies according to income levels, house type, geographic location within the city, and the holding of insurance policies to offset incurred damages.

Box 1: Understanding Disaster Risk

Disasters result from a combination of hazards and the exposure of people and economic assets coupled with their respective vulnerability. Vulnerability, and therefore the disaster risk, can be reduced by improving the resilience, or the capacity to cope of those elements exposed.

Cities are increasingly exposed to a variety of ***natural and manmade hazards*** including droughts, floods, earthquakes, storms and volcanic events. The potential for a hazard to become a disaster depends on the ***degree of exposure*** of a population and its physical or economic assets. Urbanization, migration, population growth and economic development are all factors that increase the concentration of people and assets in high risk areas. The higher degree of exposure and vulnerability of both people and infrastructure within cities is a driving cause behind why natural hazards tend to have greater social and economic impact in urban areas than in rural areas.

Reducing ***vulnerability*** requires the strengthening of coping capacities to minimize the degree of loss emerging from a disaster. Vulnerability can be influenced by physical attributes (e.g., structural qualities of housing or infrastructure) and qualitative attributes (e.g., age, health, poverty). The coping capacity of households and communities to respond to disasters and climate variability is also unequal, with low income urban residents having poor access to information and fewer safety nets.

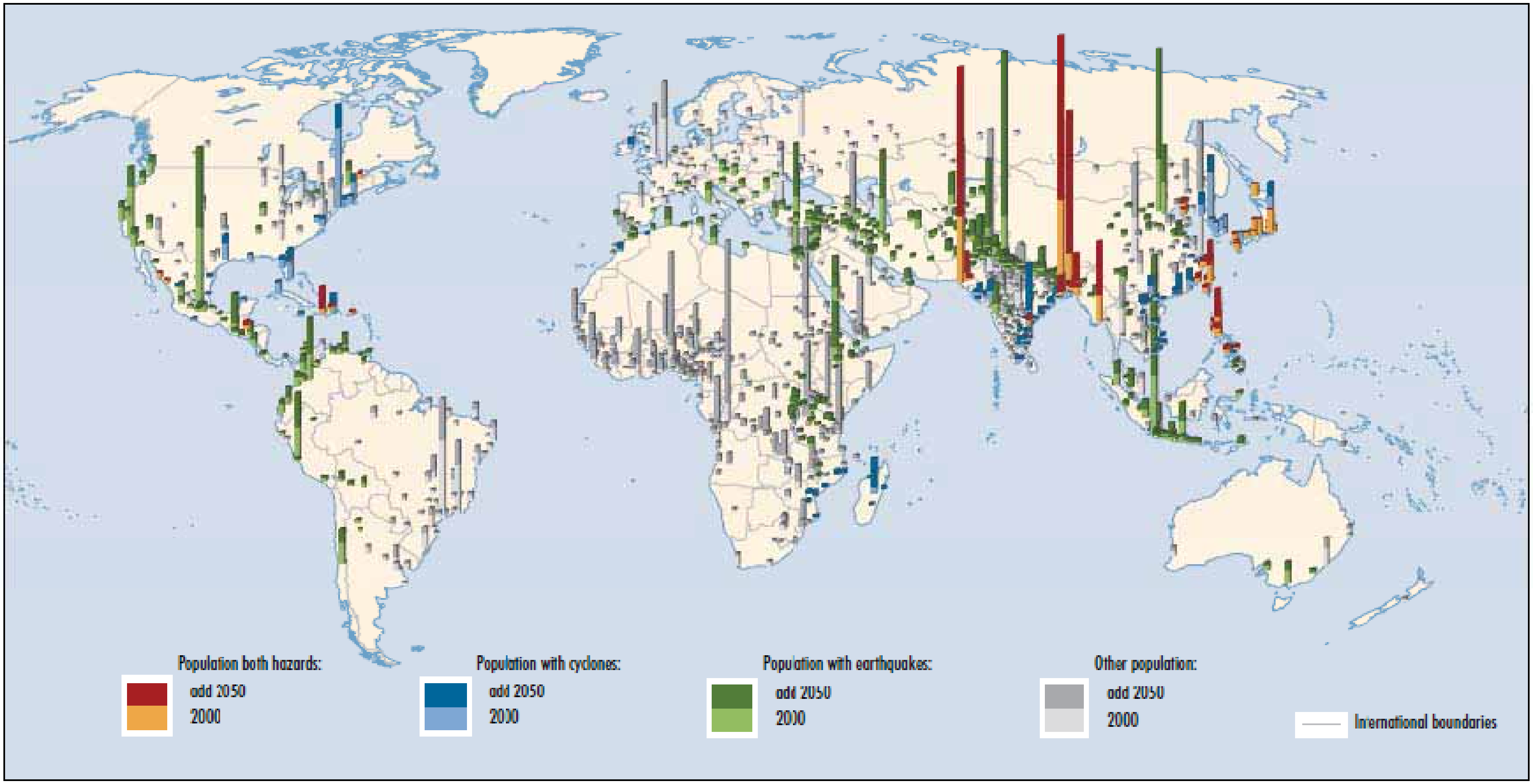
Source: Adapted from UNISDR (2009). Global Assessment Report on Disaster Risk Reduction. United Nations, Geneva, Switzerland.

Table 1: Large Disaster Events from 2001 to 2010 with Major Impacts on Cities

Popular name	Main countries affected	Date of event	Type of hazard	Main cities affected	Total number of deaths	Total number of affected	Total damages US$
Haiti earthquake	Haiti	12 January 2010	Earthquake	Port-au-Prince	222,570	3,400,000	n/a
Sichuan earthquake	China	12 May 2008	Earthquake	Beichuan, Dujiangyan, Shifang, Mianzhu, Juyuan, Jiangyou, Mianyang, Chengdu, Qionglai, Deyang	87,476	45,976,596	85 billion
Cyclone Nargis	Myanmar	2 May 2008	Tropical cyclone	Yangon	138,366	2,420,000	4 billion
Java earthquake	Indonesia	27 May 2006	Earthquake	Yogyakarta	5,778	3,177,923	3.1 billion
Kashmir earthquake	Pakistan	8 October 2005	Earthquake	Muzaffarabad	73,338	5,128,000	5.2 billion
Hurricane Katrina	United States	29 August 2005	Tropical cyclone	New Orleans	1,833	500,000	125 billion
Mumbai floods	India	26 July 2005	Flood	Mumbai	1,200	20,000,055	3.3 billion
South Asian tsunami	Indonesia, Sri Lanka, India, Thailand, Malaysia, Maldives, Myanmar	26 December 2004	Earthquake and tsunami	Banda Aceh, Chennai (some damages)	226,408	2,321,700	9.2 billion
Bam earthquake	Iran	26 December 2003	Earthquake	Bam	26,796	267,628	500 million
European heatwave	Italy, France, Spain, Germany, Portugal, Switzerland	Summer 2003	Extreme heat	Various	72,210	Not reported	Not reported
Dresden floods	Germany	11 August 2002	Flood	Dresden	27	330,108	11.6 billion
Gujurat earthquake	India	26 January 2001	Earthquake	Bhuj, Ahmedabad	20,005	6,321,812	2.6 billion

Source: EM-DAT: The OFDA / CRED International Disaster Database (www.emdat.net), Université Catholique de Louvain and IFRC, 2010

Figure 1: Large Cities Exposed to Cyclones and Earthquakes[6]



Source: World Bank – United Nations (2010) "Natural Hazards, UnNatural Disasters: The Economics of Effective Prevention"

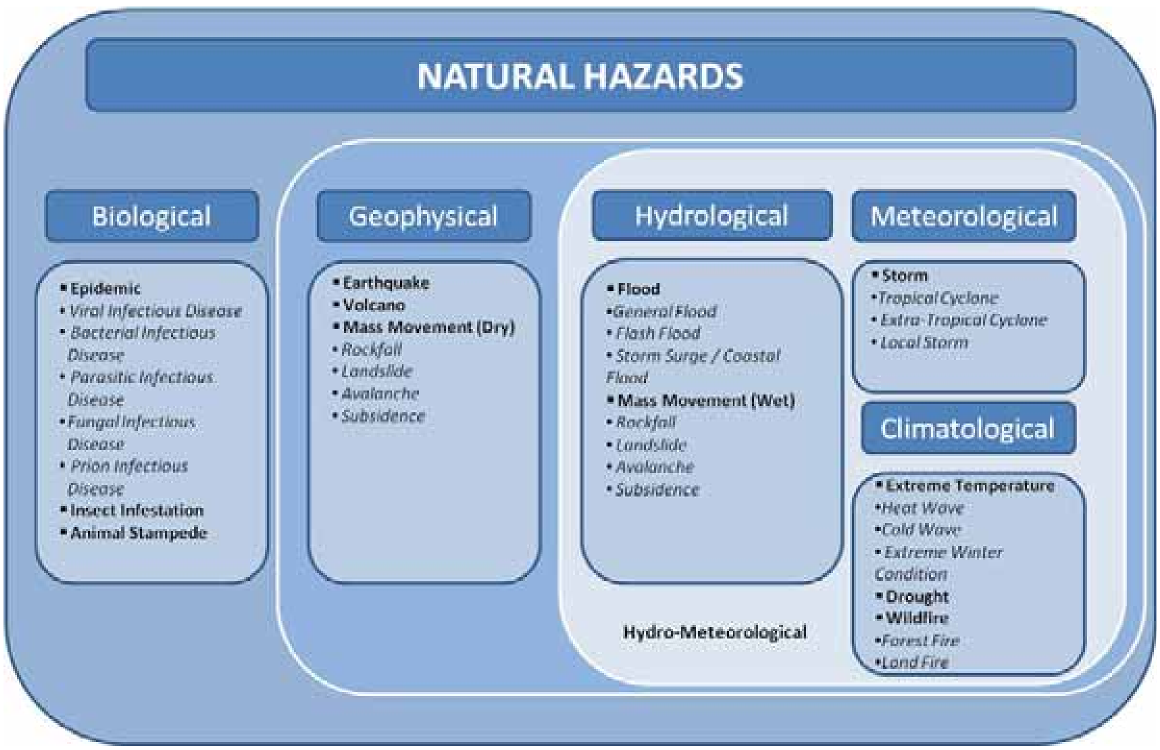
[6]GFDRR (2010). " Natural Hazards, UnNatural Disasters, accessed from http://www.gfdrr.org/gfdrr/sites/gfdrr.org/files/nhud/files/NHUD-Report_Full.pdf

Box 2: Hazard Classification

For the purpose of URA, a hazard is defined as a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Five sub-groups of natural hazards have been defined and include: biological, geophysical, meteorological, hydrological, and climatological (See figure below). While all sub-groups present significant risk to urban areas in developing and developed countries alike, the primary focus of many international development agencies lies in geophysical, hydrological, meteorological and climatological hazards, while agencies such as the World Health Organization (WHO) and the Center for Disease Control (CDC) engaging in the area of biological hazards.

Other hazards such as those originating from technological or industrial accidents, infrastructure failures or certain human activities (e.g., chemical spills, explosions, fires), are becoming more frequent in cities. The distinction between natural and manmade hazards is often subtle; technological events can sometimes trigger natural hazards and vice-versa. While many hazards are of a natural origin, man-made changes can exacerbate the frequency or intensity of the hazard.



Source: CRED (2009)

Box 3: The Economics of Effective Prevention

The future of the disaster prevention landscape will be shaped, in part, by growing cities. The joint World Bank - United Nations publication *Natural Hazards, UnNatural Disasters: The Economics of Effective Prevention* (www.worldbank.org/preventingdisasters) shows that growing urbanization will increase exposure to hazards. By 2050 the number of people exposed to storms and earthquakes in large cities could more than double to 1.5 billion, with the largest concentration of at-risk people living in Asia and the Pacific. But the report also argues that even though exposure will rise, vulnerability need not: much will depend on how cities are managed.

Natural Hazards, UnNatural Disasters focuses not only on the role institutions at all levels play in disaster prevention, but also on individuals and the private incentives or disincentives they face for prevention. Three common threads emerge in the analysis conducted in the report: the role of information, incentives and infrastructure (or the three 'I's).

Information is key: Countries, governments and individuals have to be able to understand the risks they face by undertaking hazard modeling and mapping. But it is not sufficient to just collect risk data. It has to be made public and accessible so as to enable people to make informed prevention decisions.

When information on hazards is made available and markets are allowed to function, prices better reflect hazard risk, guiding people's decisions on where to live and which preventive measures to take. But markets, when smothered, dampen the incentives for prevention. In Mumbai, where rent controls have been pervasive, property owners have neglected maintenance for decades, so buildings crumble in heavy rains. And it is the poor who bear the brunt of the cumulative effects of such distorted policies (skewed tax structure, inadequate city financing arrangements, and so on), which produce only a limited and unresponsive supply of affordable, legal land sites for safer housing. Like rent controls, insecure ownership reduces individuals' incentives to make long-term prevention investments. In Peru, for example, land titling is associated with an almost 70% increase in housing renovation within 4 years. Governments should therefore let land and housing markets work and supplement them with targeted interventions only when necessary.

When provided with the right information and correct incentives, individuals generally make good decisions for themselves. But their preventive actions also depend on the infrastructure and public services that governments provide. Poor households prefer to have easier access to jobs, even though this may imply living in slums on riverbanks prone to flooding or on hilltops subject to mudslides. Governments could greatly expand the choices of the poor: this could include making land available in safer locations—along with adequate and reliable public transport and other services so that people remain connected to their jobs. If they have access to piped water, individuals living in low-lying areas of Jakarta will not need to draw water through bore wells causing the ground to subside. If people have access to reliable and affordable public transportation connecting their job site to safer residential areas, they will be able to avoid locating in hazard-prone areas closer to work.

1.2 Climate Change and Cities

Climate change brings additional challenges to urban management and decision making processes for city governments, and is associated with a growing number and variety of impacts on cities, the surrounding ecosystems and citizens' livelihoods. City governments will need to make their residents aware of the need and methods to adapt to a changing climate characterized by greater frequency and intensity of adverse natural events in an increasingly stressed environment. Moreover, the impacts of climate change and disaster risk in rural areas will influence migration patterns, which characteristically contribute to the growth of low-income urban settlements. It is estimated that 20-30 million of the world's poorest people move each year from rural to urban areas (Smith and Petley, 2009). Table 2 presents a number of potential impacts of climate change on cities[7].

The unique physical, social, economic and environmental composition of a city influences its degree of risk and vulnerability of its residents. While recognizing that the specific assessment of urban risk will differ across cities based on factors such as poverty levels, the pace of urbanization and awareness surrounding disaster risk or climate change, a general typology including coastal cities, dryland cities, and inland and high altitude cities may still be useful in considering the broader issue[8].

- **Large or Mega-cities.** Exposure in large cities to cyclones and earthquakes is projected top rise from 680 million in 2000 to 1.5 billion in 2050 (GFDRR, 2010)(See Figures 1 and 2). The fastest exposure growth will occur in South Asian cities (3.5 percent), followed by cities in Sub-Saharan Africa. Exposure to earthquakes remains high in East Asia: 267 million in 2050, followed by Latin America and the Caribbean (150 million in 2050) and OECD countries. Exposure to cyclones will be high in South Asia by 2050, followed by OECD and East Asia.

- **Coastal cities** are made vulnerable by the low-lying land they are often built on and as such are susceptible to climate change-related impacts such as sea level rise, flooding and coastal erosion. Many coastal cities in the Least Developed Countries are found in tropical areas with hot and humid climates and low-lying land, both of which heighten their vulnerability to extreme events. Only two percent of the world's land is in the Low Elevation Coastal Zone (LECZ) – the area adjacent to the coast that is less than ten meters above mean sea level – but this zone is home to ten per cent of the world's population, 60 per cent of whom live in urban areas. The top ten coastal cities in terms of exposed population are Mumbai, Guangzhou, Shanghai, Miami, Ho Chi Minh City, Kolkata, Greater New York, Osaka-Kobe, Alexandria and New Orleans (OECD, 2008).

- **Dryland cities** suffer from scarce water resources due to extended periods of drought and more frequent sandstorms, the effects of which can be aggravated by poor infrastructure. The effects of drought are widespread but can be particularly severe on drinking water supplies and food prices.

[7] World Bank (2009). "Climate Change Adaptation and Disaster Preparedness in Coastal Cities of North Africa"
[8] Compiled by authors from IIED (2009), GFDRR (2010), and OECD (2005)

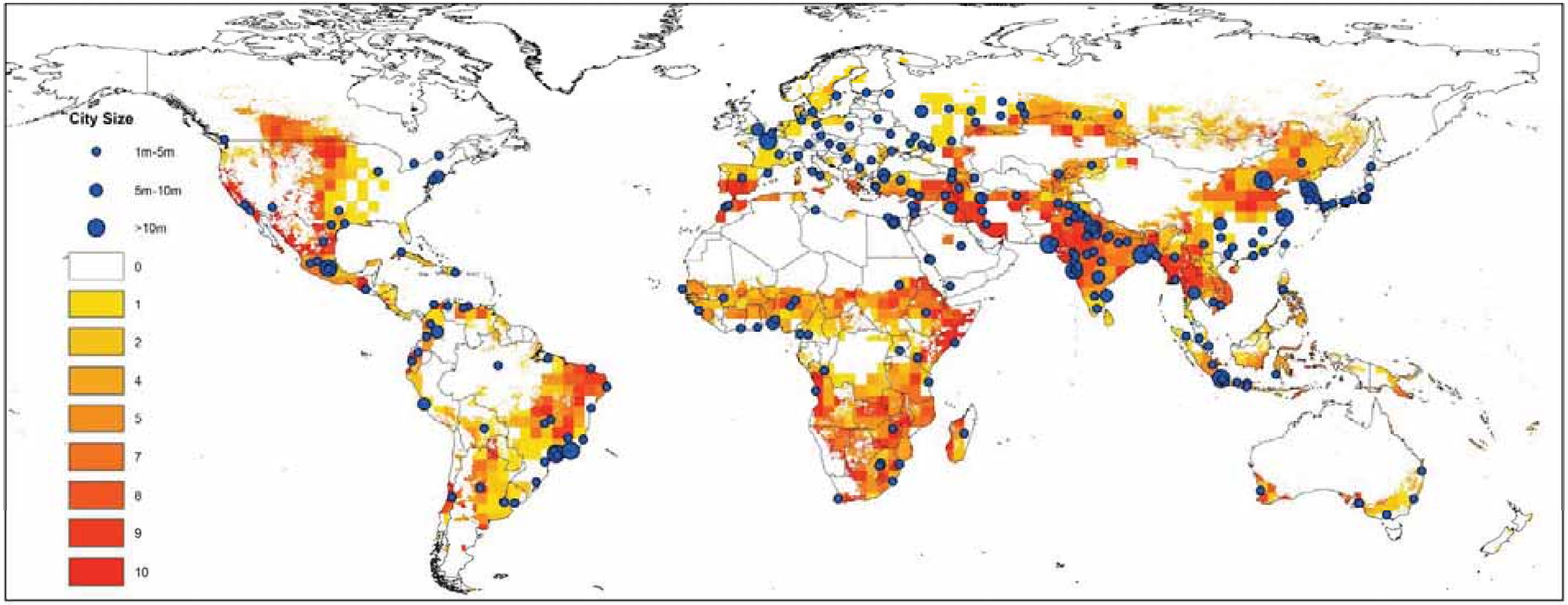
- **Inland and high altitude cities** will be affected by climate change predominantly as a result of changing patterns of precipitation. In many of these cities, minor floods that affect people's lives and livelihoods take place more frequently than major disasters, but these events are seldom reported outside the local area.

Table 2: Urban Climate-Related Hazards

Climate related hazard	Projected impact
Sea-level rise (SLR) and storm surges (SS)	SLR: Erosion and saline intrusion threatens coastal ecosystem infrastructure; dunes, water tables, river water flows and wetlands. SS: Threatens coastal housing and municipal infrastructure; port and trade logistics facilities, highways, power plants, water treatment plants due to increased runoff contaminant and change in population distribution
Extreme rain events	Higher frequency and intensity of flooding, road washouts and landslides may occur in urban areas, threatening vulnerable settlements. Heightened risk of vector borne diseases exists.
Heat waves/Heat island effect	Very high temperatures affect cities more than rural areas given the heat-retaining built environment (buildings, paved areas) and lower air speeds. This considerably reduces night time cooling, and may result in higher than average morbidity and mortality, particularly in older persons. Possible impacts include increased energy demand for air conditioning, water contamination, increased road surface damage, increased water demand.
Water scarcity	Changes in precipitation patterns will reduce reservoir supplies and availability for urban use; runoff contamination increases.
Worsening air quality	Air pollutants from fixed and mobile sources, volatile organic compounds (VOCs) and nitrogen oxides (NOx), react to increasing temperatures with the formation of ground ozone, and surface inversion increases. It particularly affects children and older persons' health.

Source: Adapted from World Bank (2009) Unpublished Project Concept Note on "Climate Change Adaptation and Disaster Preparedness in Coastal Cities of North Africa"

Figure 2: Large Cities in Relation to Current Climate Related Hazards[9]

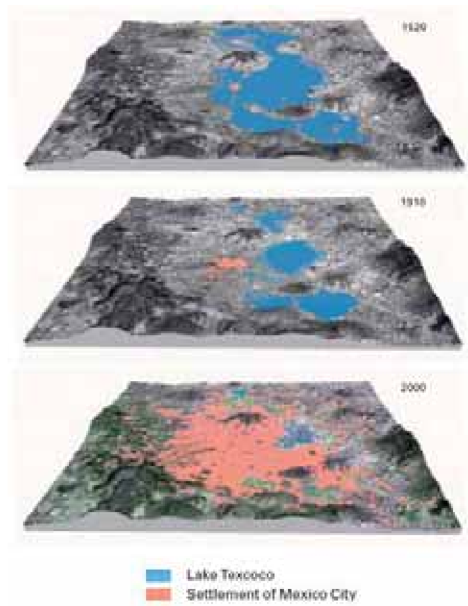


[9] Extracted from Lankoa, P.R. (2008).
Note: The urban areas included in this figure have populations greater than one million. The hazard risk represents a cumulative score based on risk of cyclones, flooding, landslides and drought. "O" denotes "low risk" and "10" denots "high risk". Hazard risk represents a cumulative score based on risk of cyclones, flooding, landslides and drought.
Original source data include: For cities: CIESIN (2006), *Global Rural-Urban Mapping Project* (GRUMP), alpha version. Data available from http://sedac.ciesin.columbia.edu/gpw/.
For hazards: Dilley, Maxx, Robert S Chen, Uwe Deichmann, Arthur L Lerner-Lam and Margaret Arnold (2005), *Natural Disaster Hotspots: A Global Risk Analysis*, World Bank, Washington DC, 132 pages. Data available from http://www.ldeo.columbia.edu/chrr/research/hotspots/coredata.html.

Box 4: City Growth and Increased Urban Temperatures in Mexico City

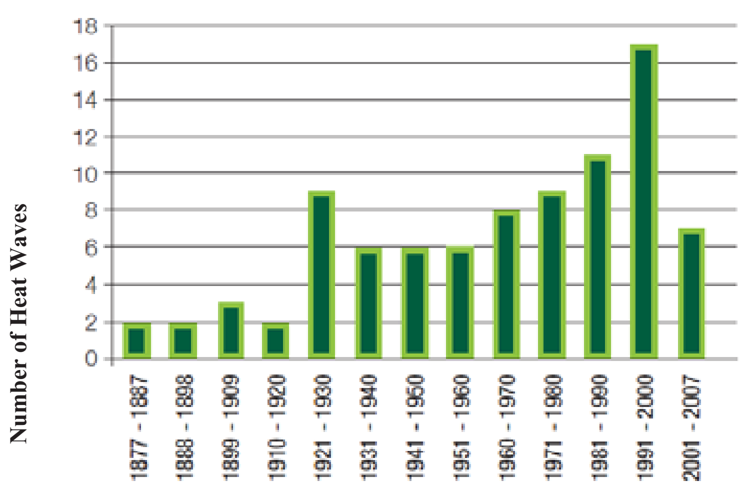
The Mexico Valley is exposed to increases in extreme temperatures which in conjunction with expanding urbanization, has contributed to a significant heat island effect for Mexico City. Projections reveal that the mean temperature is expected to increase by 2 to 3 °C towards the end of the 21st century, and extreme precipitation episodes are expected to increase. Characteristically, rising temperatures are accompanied by an increase in extreme rain events, consequently placing Mexico City at heightened risk of flooding and landslides, particularly in the Western part of the city. Recently released data for Mexico City corroborates the linkages between urban growth, the heat island effect, and rising regional temperatures through a notable rise in the number of heat waves per decade. See Annex 1 for a detailed case study of the urban risk assessment in Mexico City.

Historical Development of Mexico City



Source: Munich Re, 2004

Heat Waves by Decade in Mexico City



Source: GreenPeace, 2010

1.3 Challenges of Managing Disaster and Climate Risk in Urban Areas

Disaster risk management in developing countries is often limited to ex-post disaster response. City management is often reactive to disasters with little consideration given to reducing or managing risk in a comprehensive, preventive manner. In spite of the potential impacts that disasters have on the financial resources of city governments and the functionality of the city as an entity, actions related to the management of disaster risk remains of an ex-post nature, with little attention to preventing or mitigating measures. Although some emergency and disaster response capability may exist, few cities in the developing world are truly prepared to manage disaster events in part due to the day-to-day challenges that most city governments face.

Long term risk reduction and adaptation to climate change has received even less attention. Much of the media and policy debate currently surrounding climate change, particularly within cities, is focused on mitigation. The relevance of adaptation to increasing disaster risks and climate change has received comparatively less attention largely as a result of competing demands placed on city governments such as declining tax revenues, dysfunctional land markets, and the provision of basic services. In addition, city governments are often constrained by a lack of up-to-date, comprehensive, and sufficiently detailed information about hazard and exposure in urban areas, particularly low-income settlements. See Annex L for existing international response for disaster risk reduction and climate change adaptation.

While there is a growing consensus that more investment is needed in upstream risk reduction, prevention, and climate adaptation, cities in developing countries rarely have the technical, institutional, and financial capacity to implement related programs. Those cities in developing countries that have created local units to manage disasters generally have little budget allocation or implementation power. This coupled with centralized administration (in some urban areas), does not usually provide enough independence for the local bodies to amend laws or provide sufficient budgets for innovations in disaster risk management.

Cities can plan and respond better if the location and nature of risk is known, and also if the risk assessment and management processes are mainstreamed in urban development and management programs. However, as previously mentioned, cities in lower and middle income countries rarely consider disaster vulnerability and only a handful have initiated strategies and related programs to increase climate change resilience (Box 4). Even if strategies exist, city management faces challenges in developing, implementing and maintaining risk management activities as a result of:[10]

- ***Limited understanding of climate risks*:** Many city governments lack an understanding of existing sources of risk and potential impact of climate change. The lack of standardized methodology for conducting risk assessments exacerbates this shortcoming and can contribute to haphazard development. Particular attention is also required to assess risk in urban growth area and informal settlements.

[10] World Bank (2010) Unpublished paper on City Primer Application in Middle East and North Africa

- ***Limited institutional capacity and financial resources*:** City governments have finite resources to address urban growth. As such, disaster and climate change risk does not always emerge as a priority for city administration. Cities require technical and financial assistance in enhancing institutional capacities to assess and respond to disasters more effectively.

- ***Absence of standard protocols for disaster risk management and climate change adaptation*:** Currently there are limited examples of cities that have standard procedures for incorporating DRM and CCA activities in city planning.

- ***Monitoring city's performance*:** City managers are keen to learn best practices from other cities and want to know what will work in their own city. Currently there are limited systematic exchanges of information, best practices, and benchmarking city's performance for urban risk reduction.

The option of doing nothing can be more costly than proactively identifying and managing risks. If no steps are taken to identify and manage disaster risks and climate change, the resulting losses can be irreversible and have severe implications on the safety, quality of life and economic performance of cities (Box 3). The impact of the 2010 Chile and Haiti earthquakes illustrates this point. Although Chile's earthquake released 500 times more energy compared to that of Haiti's, the epicenter was further removed from concentrations of population and built assets and its depth was approximately 46km. As a consequence it suffered limited infrastructure and a death toll of just 528 people[11]. In the case of Haiti the epicenter was only 15km southwest of the capital city Port-au-Prince and only 10km below the Earth's surface; these factors caused economic damages and losses equivalent to 120% of GDP[12] and a death toll of more than 200,000 people. [13] The enormous difference in the impact of these two events highlights the importance of investing in territorial planning and building codes with the resulting resilience of infrastructure and housing. Chile has invested in an earthquake response system and has mandated retrofitting of existing structures and earthquake resistant designs for new structures[14]. Conversely, planning, disaster preparedness and earthquake resistant building codes were non-existent or outdated in Haiti.

[11] http://www.unesco-ipred.org/gtfbc_chile/OCHA_Situation_Report_No_4-Chile_Earthquake-20100305.pdf
[12] compared to 2010 GDP (http://www.gfdrr.org/gfdrr/node/320)
[13] GFDRR (2010) "Haiti Earthquake PDNA: Damages, Losses, General and Sectoral Needs. Accessed from http://www.gfdrr.org.
[14] http://www.nytimes.com/2010/10/19/science/19quake.html?_r=2&hpw

Box 5: Understanding Urban Resilience

Resilience describes the ability of a system to withstand or accommodate stresses and shocks such as climate impacts, while still maintaining its function. At an urban scale, resilience will depend on the ability to maintain essential assets, as well as to ensure access to services and functions that support the wellbeing of citizens. This is particularly so, for members of the population lacking access to financial, material, and social capital that can be used to buffer stresses.

Urban populations depend on interrelated and interdependent *urban systems* (infrastructure, ecosystems, institutions and knowledge networks) which support and are supported by a city's actors or *social agents* (individuals, households, and private and public sectors). The resilience of a city depends on both the fragility of the urban system and the capacity of social agents to anticipate and to take action in order to adjust to changes and stresses—recognizing that their ability to act is constrained by access to resources and supporting systems. Cities that may be considered resilient exhibit the following key characteristics:

- **Flexibility and diversity:** The ability to perform essential tasks under a wide range of conditions, and to convert assets or modify structures to introduce new ways of achieving essential goals. A resilient system has key assets and functions distributed so that they are not all affected by a given event at any one time (locational diversity) and multiple ways of meeting a given need (functional diversity).
- **Redundancy, modularity:** The capacity for contingency situations, to accommodate increasing or extreme events, unexpected demand or surge pressures; multiple pathways and a variety of options for service delivery, or interacting components composed of similar parts that can replace each other if one or even many fail.
- **Safe failure:** The ability to absorb shocks and the cumulative effects of slow-onset challenges in ways that avoid catastrophic failures; or where failures in one structure or linkage are unlikely to result in cascading impacts across other systems.
- **Resourcefulness:** The capacities to visualize and act; to identify problems, establish priorities and mobilize resources. Resourcefulness is also related to the capacity to recognize and devise strategies that relate to different incentives and operational models of different actor groups.
- **Responsiveness and rapidity:** The capacity to organize and re-organize; to establish function and sense of order in a timely manner both in advance of and following a failure.
- **Learning:** The ability to learn through formal and informal processes, to internalize past experiences and failures and alter strategies based on knowledge and experience.

Achieving urban resilience requires engaging the capacities of social agents to understand and act upon the urban systems through iterative cycles of *understanding vulnerability* and *building resilience*. Both processes strengthen systems while developing and enhancing the social agents' capacities to intervene effectively in them. External agents such as practitioners, donors, or consultants may play roles as enablers or catalysts in urban contexts.

Source: Adapted from the Urban Resilience Framework developed by Arup International Development and ISET (Institute for Social and Environmental Transition) as part of the Rockefeller Foundation funded ACCCRN project. See www.iset.org/publications or www.arup.com/internationaldevelopmentand the ISET Working Paper Series *Climate Resilience in Concept and Practice*

2 Integrated Urban Risk Assessment as a Tool for Urban Management

Chapter summary

- *This chapter focuses on the structure of the Urban Risk Assessment, its process, uses and challenges in initiating and mainstreaming it.*
- *The urban risk assessment is a flexible approach to assess a city's risks from disasters and climate change.*
- *The assessment builds upon three principal assessment pillars (institutional, hazard impact, and socioeconomic) each associated with three levels of assessment complexity (primary, secondary, and tertiary).*
- *A city can select the appropriate level of risk assessment based on need, resources available, capacity, and its overall goals.*
    - *At a primary level, the assessment requires minimal resources and can help cities identify high risk areas and basic climate change challenges, and plan for disaster preparedness and response.*
    - *At a secondary level, the assessment relies on more advanced techniques requiring more financial and technical resources to develop disaster response capacities and to plan and implement non-structural measures to reduce risk.*
    - *At the tertiary level, the assessment will require greater resources to undertake detailed disaster and climate change modeling to help cities develop superior disaster and climate risk management protocols including structural and non-structural tools to reduce disaster and climate change risk.*
- *The process of assessing risk can be made an integral part of urban planning and decision making processes by streamlining data acquisition and management into an integrated system which can not only be updated and monitored easily, but that is also accessible to all stakeholders involved in city management.*
- *The collection and sharing of hazard related information will benefit emerging programs in the four phases of risk management (risk reduction, preparedness, response, and recovery) and the formulation of climate change adaptation programs.*

2.1 What is Risk Assessment?

Figure 3: Risk as a Process

Source: Villagrán De León (2006)

Risk assessment is an essential component in the disaster risk management and climate change adaptation planning process. The purpose of a risk assessment is to define the nature of the risk, answer questions about characteristics of potential hazards (such as frequency, severity), and identify vulnerabilities of communities and potential exposure to given hazard events. Risk evaluation helps in the prioritization of risk management measures, giving due consideration to the probability and impact of potential events, cost effectiveness of preventative measures, and resource availability.

Risk assessments should be undertaken at a range of scales, from the local to the global. There is great diversity in the target of assessments (people, health, buildings, urban economy), in the sources of data (interviews, existing datasets, satellite imagery or expert judgments) and in the degree to which they are participatory or extractive in collecting data. In all cases, assessments aim to simplify complicated experiences of risk in order to assist in decision-making. The complexities of undertaking an urban risk assessment arise from a number of contributing factors[15] :

- *The multiple hazards to which people are simultaneously exposed.* Recent and frequently experienced hazard types may be more visible to assessors than others at any one moment.
- *The multiple sectors that are at risk.* It is difficult to aggregate vulnerability across sectors such as housing, communication networks, water and sanitation, education, healthcare infrastructure, power networks, etc. Each sector will have different exposure and susceptibility to risk and capacities and resources for coping and recovery.
- *The multiple scales at which risk is felt and responded to.* Risk, in any one place, is an outcome of decision making and action – or inaction – at local, municipal, national and international scales. It is challenging to include all of these scales in the analysis of impacts and capacity.
- *The multiple assets to be accounted for in measuring vulnerability and capacity.* This applies to all scales, from the individual to the urban scale. Some assets will be contingent upon the utilization of others and rarely are different types of assets commensurate.
- *The multiple stakeholders with roles to play in shaping risk.* Stakeholders' actions influence the degree to which they, and others, are placed at risk. This can be hard to pin down – for example, when such actions are part of everyday development processes.

When evaluating urban risk, it is important for city authorities to account for the dynamic character of cities. This supports the notion that risk assessments be undertaken at regular intervals so that the city governments are able to evaluate progress towards risk and vulnerability

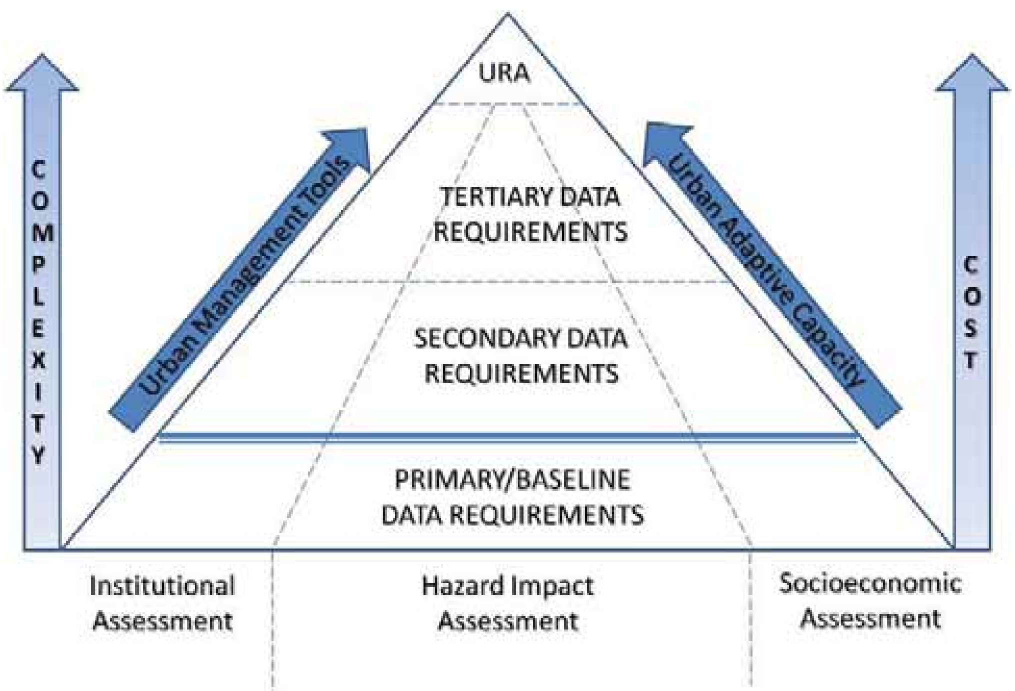
[15] Adopted from UN-Habitat (2007)

reduction. In countries with high population growth and/or high migration from rural to urban areas, planning the risk for cities involves a good understanding of the population dynamics of the country as a whole and the possible scenario of future growth. The role of adaptation to both rapid on-set hazards and those more gradual threats associated with climate change is therefore an integral part of proactive risk reduction planning for cities.

2.2 An Integrated Approach to Assessing Urban Risk

The Urban Risk Assessment is a flexible approach that facilitates improved understanding of city's risks from disasters and climate change. The URA (Figure 4) allows for customization in how it is applied depending on available financial resources, available data relating to hazards and population, and institutional capacity. Through a phased approach where each assessment level is linked to progressively more complex and detailed tasks, city managers may select the appropriate series of components from each pillar that individually and collectively enhance the understanding of risk in a given city. The approach is structured to integrate both rapid on-set events, such as floods or landslides, which are more typically the purview of the disaster risk management community, and slow on-set hazards such as drought or sea level rise typically associated with a longer-term change in climate trends. The specific components of each pillar and level of the assessment are summarized in Table 3 and illustrated in Figure 5.

Figure 4: Urban Risk Assessment Approach



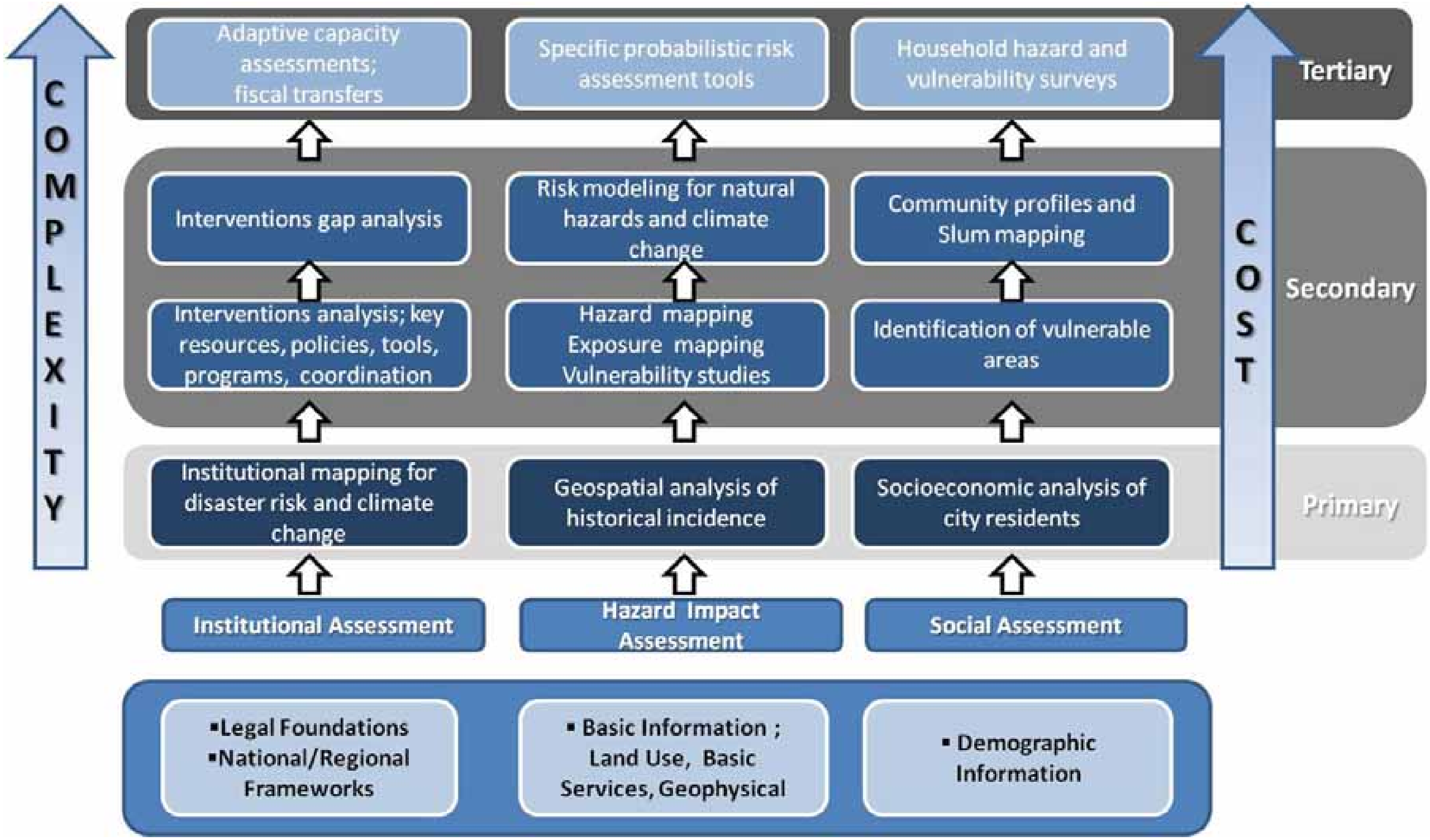
Source: Authors

The assessment is based upon three principal assessment pillars (institutional, hazard impact, and socioeconomic) each associated with three levels of complexity – primary, secondary, and tertiary. The framework is built around a central hazard impact assessment pillar aimed at identifying the type, intensity, and locations of potential losses resulting from future hazards and climate change scenarios. Given that risk is a function of hazards, the relative vulnerability of people and economic assets, and the capacity to respond, the URA takes into account the role of institutions and the socio-economic conditions of city residents in order to (i) understand whether agencies exist that are responsible for managing the risks arising from disasters and climate change, and (ii) identify the most vulnerable populations that are likely to be affected by adverse events, as well as understanding their adaptive capacity. Each pillar is described in further detail in Chapter 3.

The URA allows for undertaking assessments at different levels of complexity based on a city's overall goal and resources available. Each city is unique and will have different needs with regard to increasing resilience to natural hazards and climate change. Their development priorities might be different – some may emphasize improving the built environment while others may seek to improve institutional capacity for disaster risk reduction and planning. Generally, a city's size, available human resources, political autonomy, leadership, and financial condition will drive the priorities and potential directions for city development.

Based on the identified needs and priorities that are defined within a city's fiscal capacity, cities can select the most appropriate level of risk assessment. At the ***primary*** level, the assessment will require minimal resources and can help cities in (i) identifying hazard prone areas and basic climate change challenges, and (ii) planning for disaster preparedness and response. At the ***secondary*** level, the assessment will require more financial and technical resources to facilitate (i) preliminary Early Warning Systems (ii) the ability to estimate losses during a disaster event, (iii) the improved understanding of policy and coordination requirements for disaster risk management, (iv) planning and implementing structural and non- structural tools to reduce the risk, and (v) community based programs for resilience and adaptation. At the ***tertiary*** level, the assessment will require greater resources but will provide for (i) specific probabilistic risk assessment tools to help a city develop advanced disaster and climate risk management policies and programs including cost benefits analysis tools for structural and non-structural investments, (ii) advanced Early Warning Systems, (iii) disaster response capacity, and (iv) large-scale adaptation programs. See Table 3 for additional details.

Figure 5: Levels and Pillars of the Urban Risk Assessment (Source: Authors)



The Primary URA provides city management with an entry point to assess the challenges posed by natural hazards. It is comprised of comparatively straightforward tasks that add only a minimal burden to existing functions of city governments. Cities with limited financial resources and high demand/need for rapid preparation planning may consider beginning with the primary URA which encompasses a mapping of the institutional landscape with respect to disaster risk management and climate change, a geospatial analysis of the historical incidence/trends of hazards across the city, and a broad geo-referenced demographic analysis using census data as a key input. In the long term, the assessment provides information useful to avoid hazard prone areas when planning new city development and when developing policy for areas at high risk of disasters. Assessment of climate change risks, such as sea-level rise or drought, is limited at the primary level and therefore depends on available secondary information to situate cities within broader regional climate trends. Annex E presents a case study incorporating elements of a primary urban risk assessment undertaken in the city of Dakar, Senegal.

The Secondary URA is intended to assist cities in targeting their financial resources and risk reduction programs to the most vulnerable. The secondary level provides for a more refined analysis of each of the principal building blocks of the URA. Institutional strengths and weakness are evaluated and specific mandates, policies and programs assessed for effectiveness and interagency cooperation. City specific hazards and exposure are mapped and urban hotspots identified. Hazard risk can then be modeled along with projected climate change impacts and merged with maps prepared by those communities deemed to be at a high level of risk. Annex F presents a case study incorporating elements of a secondary urban risk assessment undertaken in the city of Legazpi, Philippines.

The Tertiary URA is designed for cities with substantial need, resources and technical capacity to carry out assessments and deliver scaled up programs relating to disaster risk management and climate change adaptation. It is envisioned that these components would be brought together in an internet-based dissemination platform. Annex G presents a case study incorporating elements of a tertiary urban risk assessment undertaken in the city of Sana’a, Yemen.

Table 3: Three Levels of Urban Risk Assessment

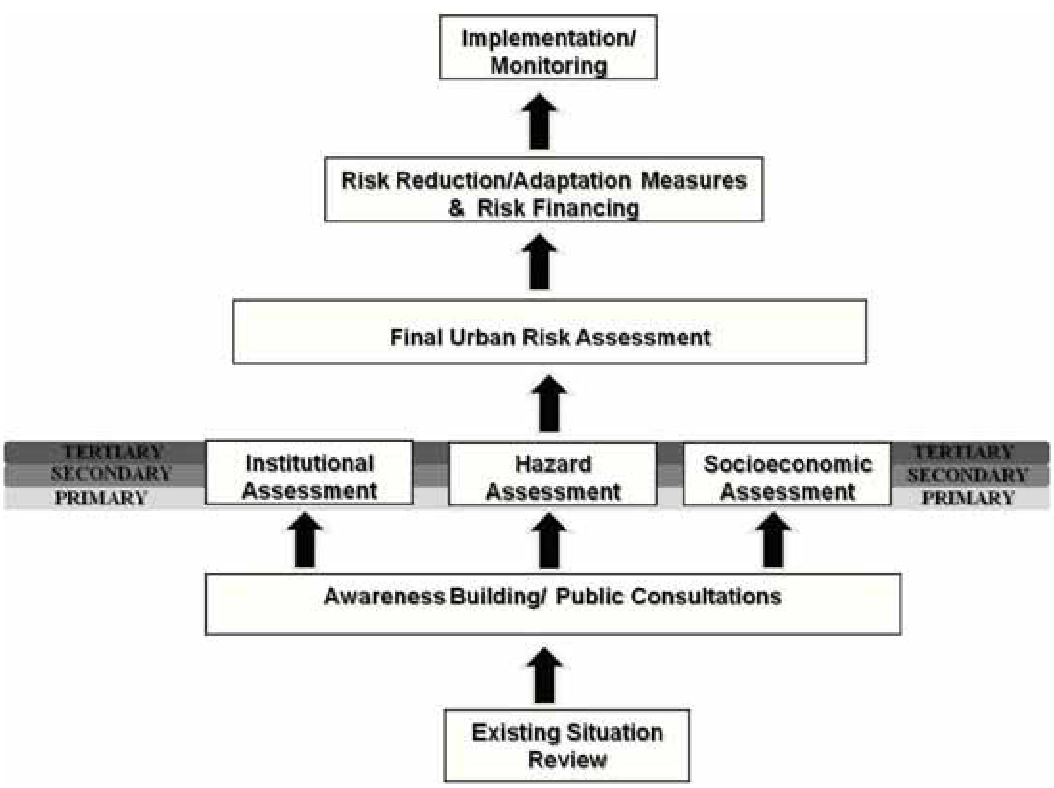
Urban Risk Assessment	Tasks	Link to Climate Change	Objectives / Benefits to local government
Primary	Basic institutional mapping for disaster preparedness and response and climate change Development of a physical base map if one doesn't exist or updating an existing map Historical hazard impact assessment Socioeconomic profile of city	Limited: General identification of climate risks based on available information from regional models	Short term: Planning for disaster preparedness (identification of safe routes and shelters during disasters, protocols for disaster response, accessibility to emergency funds). Long term: Planning new city development to avoid hazard prone areas.
Secondary	In depth institutional analysis for disaster response, risk management and climate change adaptation. Development of hazard exposure maps and scenario-based risk models Identification of infrastructure and populations at risk of disasters and climate change impacts. Socioeconomic assessment and poverty mapping	Risk modeling includes downscaling of regional climate change models; Institutional assessment includes government agencies/ departments with defined roles in adaptation planning	Short term: Planning for disaster preparedness (Early Warning Systems, ability to estimate losses during a disaster event). Improved understanding of policy and coordination requirements for city and necessary interventions for target areas. Long term: Marking yearly budget for disaster risk management, planning new development to avoid hazard prone areas, policy/ attention for target areas (land use, zoning, building codes, etc), structural measures to reduce risk, insurance, adaptation measures in terms of institutional structure, including long term climate change risk in retrofitting infrastructure, livelihood and community based programs for adaptation.
Tertiary	Financial capacity assessment for institutional delivery of resilience building programs Regular assessments and streamlining of web based application showing areas and population at risk (at individual house/building level) Probabilistic risk modeling platform (e.g., CAPRA), detailed house level information on structural vulnerability Household surveys of vulnerable areas	Costs of climate change adaptation defined and prioritized. Adaptation strategies for key affected sectors (e.g., tourism, transportation, etc) and regions of the city developed.	Short term: Planning for disaster preparedness (Early Warning Systems, ability to simulate losses during a disaster event). Improved understanding of city's financial capacity to administer large scale adaptation program. Municipal capacity strengthened in use of output from probabilistic risk assessment software. Long term: Structural and non-structural measures to reduce disaster risk and climate change impacts defined. Well positioned for negotiating fiscal transfers for climate change.

Source: Authors

2.3 Initiating, Undertaking and Mainstreaming Urban Risk Assessment

The urban risk assessment is ideally undertaken as a part of a cyclical process of assessing risk, developing and implementing a risk management plan, and monitoring progress in risk reduction. Through its flexible and scaled approach, however, the urban risk assessment can also be applied in cities without a strategic planning framework. Local governments can initiate the URA in a number of ways: (i) as a part of the urban planning process such as during city planning, formation of city development strategies (CDS), or city planning exercises, (ii) while preparing specific sectoral plans such as transportation, water supply & sanitation, or in the planning of new satellite towns, or (iii) as a standalone activity which is later integrated into CDS or master plans. Cities without a strategic planning framework, such as small cities or urban areas falling under centralized national governments, can work with national or sub-national governments to undertake an URA through specific departments such as those dealing with environment, climate change, water supply/ sanitation, building permits, or emergency response. Ideally the URA may be initiated as a part of strategic urban planning and policy process so that it can be mainstreamed with existing urban management tools and functions. Five steps, each described in turn below, are suggested for carrying out an Urban Risk Assessment (See Figure 6).

Figure 6: Urban Risk Assessment, Risk Reduction Planning and Monitoring Process



Source: Authors

1. Reviewing the existing situation

a) Review any existing national laws and governing framework regarding disaster and climate risk assessment and understand the requirements.
b) Form an institutional framework for undertaking the URA. This may include setting a steering committee consisting of key stakeholders and a team of technical staff that will carry out the risk assessment. Municipal staff members who are already working on land use and other city planning aspects are most suitable to provide technical support in this work.
c) Decide on the objectives and the level of risk assessment (refer to Table 3). For example, a city which is exposed to multiple hazards and that would like to develop an in-depth risk reduction strategy incorporating both structural and non-structural elements, may wish to undertake tertiary level risk assessment. At the other extreme, a city with relatively few hazards and limited financial resources may wish to start with the primary level assessment and later move towards a higher level assessment depending upon needs and resource availability.
d) Determine the extent of city area to be assessed. This may include focusing only on a specific area or the entire urban metropolitan region as well as the fringes or peri-urban area.
e) Evaluate data, financial and technical skill requirements depending upon the level of risk assessment. Also, determine the availability, suitability and quality of data that needs to be collected and identify possible sources.
f) Leverage required financial and technical resources for risk assessment as data collection and analysis can be time consuming and heavily resource dependent.

Data Acquisition and Management

Cities are undergoing fundamental changes to overall data collection and publication as their economic and political stature increases globally. However, for most of the cities in developing countries, collecting reliable and timely data is a challenging task. While the importance of sharing hazard and risk data is increasingly being recognized, there are still many obstacles to achieving this in practice. Commonly cited barriers include the absence of recognized standards and best practices related to sharing, nascent awareness and understanding of the importance and economic value of sharing data, misaligned institutional incentives precluding the sharing of data, inadequate technical expertise, and lack of simple, affordable tools.

In response to the need for reliable data for credible risk assessment and effective policy and decision-making, the World Bank and the Global Facility for Disaster Reduction and Recovery have launched the World Bank's Open Risk Data Initiative (OpenRDI). This recently launched initiative is a commitment to open data to promote transparency, accountability and improved decision making. By working with open source software communities to build the tools necessary to share data, OpenRDI is encouraging and facilitating countries and cities to open their disaster risk data to enable more effective decision-making[16]. An example of OpenRDI is haitidata.org. It is built using the free and open source software platform "GeoNode", and makes risk assessments data produced following the 2010 Haiti earthquake free and open for anyone to download and use. These types of emerging data sharing platforms have a wide array of potential applications for both national and city governments and provide a ready solution to the disparate holding of important data sets for risk reduction.

[16] http://www.gfdrr.org/gfdrr/openrdi

Therefore, the following questions are important to consider:

- Who will collect the data and how?
- When and how many times does the data need to be collected?
- Is it more cost effective to gradually build datasets from existing mechanisms, or to initiate a standalone activity?
- Where should the data be stored so that it is easy to update and is accessible to all stakeholders?

2. Building awareness and public consultations

It is important that city governments recognize the value of involving the public in the URA planning process to strengthen its eventual implementation and monitoring and assist in defining feasible risk reduction programs. Engaging with community groups and non-governmental organizations to provide necessary inputs to an urban risk assessment has importance not only for the data and maps they help generate, but also for the support provided in identifying and acting on risk and vulnerability. Public consultation will support the credibility of the assessment, increase awareness of prevalent risks and help identify potential actions that would contribute to reducing communities' vulnerability. A number of steps are suggested as part of this process:

a) **Sensitize key stakeholders to the basic concepts of disaster risk management and climate change adaptation through a series of workshops and information sessions.** Participants of these meetings would ideally be comprised of a broad range of stakeholders including municipal staff engaged in urban planning and environmental services, disaster preparedness and response, water supply and sanitation services, civil defense, fire departments, and health services. To promote visibility and engagement on these issues, the private sector, insurance companies, university staff, and community leaders should also be included.

b) **Organize training on the linkages between urban growth, disaster risk management and climate change adaptation.** During the training, the various components and steps of the urban risk assessment can be tailored to reflect existing institutional capacity, and availability of pertinent information and financial resources of the city.

c) **Deliver an on-going public information program to promote citizens' awareness of risk and the corresponding work being undertaken by the city government.** The information program may specifically target schools, colleges, hospitals, senior citizen residences, and low-income communities to assist the most vulnerable people in preparing for disasters.

3. Undertaking and disseminating the final risk assessment

The details of selecting the appropriate level of the risk assessment, inclusive of hazard impact, institutional, and socioeconomic components, are explained in Chapter 3. Once there are findings from each pillar, it is useful to disseminate the information to key stakeholders in a user-friendly way.

4. Assessing the level of acceptable risk

Once the risk assessment has been completed city governments can either ignore the risk or decide to manage it by (i) controlling processes and behaviors that generate new risks (e.g., through better zoning and enforcement of building standards), (ii) reducing existing risk (e.g., through infrastructure strengthening, and/or (iii) preparing for an event (e.g., through contingency planning and the strengthening of civil protection mechanisms). Risk management cannot be the responsibility of the city administration alone. Engaging civil society in the development of the URA can help engage city resident in the development of risk management action plans and ensure their buy in. To do this, it is important to create a debate on the level of acceptable risk, as agreements on this matter will affect decision making. The public consultations undertaken in Step 1 of the URA process, as well as city planning exercises, can help in understanding and defining acceptable risks.

5. Implementing and monitoring the URA

Once the URA is developed, it may be necessary to establish legal and institutional arrangements to implement the action plan, including authorizing a body for enforcing and monitoring the action plan. After the end of each planning cycle, or after a disaster, it is useful to review the effectiveness of the action plans so that the policies or action plans can be revised. Risk indicators can be used to review progress in strengthening a city's resilience.

2.4 Challenges in Undertaking the URA

Among the challenges faced by city managers in planning and undertaking an urban risk assessment is the need for various technical skills, financial resources, political support, and the extent to which the information collected actually represents reality. Furthermore, in many cities the collection of needed data, the integrity of that data and the capacity to use/interpret different formats of that data can be problematic. As part of the review exercise described in Step 1, the following challenges should be taken into account:

- **Specialized technical skills:** Although existing technical capacity can be used for undertaking a primary level URA (with some training), specialized technical skills are required for components of higher level risk assessments such as flood or seismic risk assessment.
- **Financial allocation for risk assessments:** While the primary level URA would require minimal financial resources, the associated costs of the tertiary level URA can be over and above a city's current budget for developing urban management tools. Specific resources will have to be identified to initiate and sustain efforts towards risk assessment and risk reduction.
- **Data collection and interpretation:** Collecting reliable, accurate and timely data remains a daunting task in many cities. Even if the data is available, it may be with different organizations/agencies using different data formats.

- **Extent to which assessment methodologies are able to represent the actual situatio**n: Community consultation based assessment (primary level risk assessment) while more cost effective, may not be accurate to plan for structural disaster risk reduction. Available risk modeling and climate change projections also have large uncertainties associated with them.
- **Gaining and maintaining political support:** It may be difficult to gain necessary political support to initiate and mainstream the URA. Priorities may change with a change of leadership, leaders may focus more on other pressing issues such as access to basic services, and there can be vested interests in not disseminating results of a risk assessment to a city's population.

3 Pillars of the Urban Risk Assessment

Chapter Summary

- *This chapter focuses on the three pillars of the Urban Risk Assessment.*
- *The hazard impact assessment focuses on understanding hazard trends, and identifying populations and physical assets at risk of future hazards and impacts from increased climate variability.*
    - *At a primary level, the assessment is based on developing simple hazard impact maps showing locations of historic disasters in a city with current population and assets in those areas.*
    - *At a secondary level, the hazard impact assessment involves estimating impacts for selected hazard scenarios based on simplified loss models.*
    - *At a tertiary level, the hazard impact assessment involves probabilistic risk modeling to show population and economic loss potential resulting from a range of hazard scenarios.*
- *The institutional assessment aims to aid in developing an effective institutional policy for managing disaster and climate change risk.*
    - *At a primary level, institutional assessment involves mapping institutions/ organizations that are explicitly responsible for addressing all the phases of disaster risk management (risk preparedness, disaster response, post disaster reconstruction and risk reduction/ climate change adaptation) and climate risk management. There is a particular focus on those institutions that can provide the inputs to the hazard impact assessment above.*
    - *At the secondary level, the institutional assessment aims to develop an inventory of planning instruments including the technical capabilities of staff, the services and outputs provided from one agency to another, policies, projects, programs, and planning instruments. .*
    - *At the tertiary level, the institutional assessment focuses on undertaking a gap assessment of current city services, management tools, policies and programs.*
- *The socioeconomic assessment focuses on indentifying the geographic location and degree of urban residents' vulnerability.*
    - *At a primary level, the socioeconomic assessment identifies demographic, housing, welfare, human development, and investment variables to understand the impact of poverty, and environmental degradation on disaster and climate change risk.*
    - *At a secondary level, the socioeconomic assessment develops a comparative ranking of specific areas based on a simple qualitative codification of selected variables within specific areas of the city to signify its comparative ranking.*
    - *At the tertiary level, the socioecomomic assessment provides more refined and detailed analysis at the community level based on household surveys on issues of hazards and vulnerability.*

3.1 The Hazard Impact Assessment

The hazard impact assessment focuses on (i) understanding hazard trends, (ii) identifying populations and physical assets at risk of hazards and climate change in a city, and (iii) quantification of potential impacts of future hazard events. The primary level assessment is based on secondary data collection and stakeholder consultations to develop simple hazard impact maps showing the location of where hazards have historically affected a city. At a secondary level, more detailed risk maps are developed, and economic and social loss scenarios are defined based on impact modeling. The tertiary level will involve probabilistic risk assessment modeling. This sophisticated approach uses a series of hazard scenarios representing the location and magnitude of an event, and applies a probability of occurrence to those events to model economic loss for exposed physical assets. Annex I presents a description of each module that is required to construct a probabilistic risk model.

The following preliminary actions form the basis of undertaking the hazard impact assessment:

(i) Defining the study area and time horizon
It is important to define the study area to set limits of the assessment. Depending upon available resources, a city may choose to undertake an assessment of the entire city area, or to focus on only a specific part of the city. The time horizon is equally important to consider. Given that increased climate variability will be accompanied by greater frequency and intensity of extreme events, city governments may consider adopting longer time horizons for the hazard impact assessment (i.e., for infrastructure design which, depending on the asset typically span 50-100 years), over traditional city planning time horizons (which typically span 20-30 years).

(ii) Initiating data collection to identify hazard trends and, when possible, estimating economic (damage to infrastructure and losses) and social (number of people affected) impacts of these events. The assessment should identify the areas where disaster impacts were concentrated within a city, their duration and frequency, and the resulting damages. Supporting data sets may be available from weather stations and/or the appropriate departments of meteorology, the environment, past municipal records, and from city libraries. Detailed case study analysis of past disasters is also useful, and a number of international databases such as EMDAT, DesInventar, and Munich Re's NatCat provide documentation of past events in selected cities. Regional and national databases should also be used to compile any available disaster related information, and in parallel information collected on average annual temperature, rainfall, droughts, or heat waves. The compilation of these various data sets will assist city governments in understanding the extent to which climate change may be contributing to the incidence and frequency of hazards.

Table 4: Characteristics of Hazards, Assessment Data Requirements and DRR Tools

Types	Measurement/ Characteristics	Data Required to Assess Hazard Risk	Disaster Risk Reduction Tools
Floods	Intensity and frequency of floods	Topography (Digital Elevation Model); drainage patterns; built up areas; land use/ landcover, historical rain gauge data	Flood plain management, (including environmental land use regulations), resettlement of vulnerable populations, structural measures to reduce the risk of flooding (e.g., dam, channelization, etc.)
Cyclone and Storm Surge	Maximum sustained wind and radius to maximum wind at landfall, central pressure from water column, height of storm surge waves	Topography (Digital Elevation Model); drainage patterns; bathynetrry, land use/ landcover, historical rain gauge data	Evacuation planning, Coastal zone management. Building Code development for wind and wave loading
Earthquake	Magnitude expressed on Richter scale/ Ground shaking measured based on damages	Information on soil, geology and liquefaction[17] potential to develop geological, seismic and soil maps	Better physical planning (e.g., zoning according to soil stability), building codes that are seismic resistant, retrofitting infrastructure and buildings
Tsunami	Wave height, inundation run-up	Topography of coastal areas (DEM), bathymetry, location and capacity of any flood protection infrastructure	Evacuation planning, Coastal zone management
Drought/ Water Scarcity	Water/ food availability per capita	Surface temperatures Precipitation Reservoir capacity and actual volume stored	Reforestation, water retaining/ground water recharge practices, less water intense agricultural practices, rain water harvesting, better water management
Sea level rise, Tidal Flooding	Wave height / Horizontal pressure from water column	Topography of coastal areas (DEM), bathymetry, tide gauge data, coastal land subsidence data	Coastal zone management
Volcano eruption Lava flow	Pyroclastic and ash fall, explosiveness of volcano, horizontal pressure of lava flow	Topography, Proximity of the volcano from people and assets	Structural measures to block lava flow, moving the population away from possible lava flow areas
Landslides, Mud flows and lahars, Rock and rubble fall	Failure of slopes with mass movements, Horizontal pressure of mud flows, Vertical or side impact of rock debris	Topography (DEM), Geological data, landcover. land use	Structural measures to reduce impacts (e.g., retaining walls); zoning regulations; resettlement of vulnerable populations
Fire	High temperature and combustion	Topography, wind, land use, landcover	Building codes for fire safety, accessible routes for fire trucks/ fire fighters.

Source: Adapted from Ehrlich et al (forthcoming)

[17] Soil liquefaction describes the behavior of soils that, when loaded, suddenly suffer a transition from a solid state to a liquefied state, or having the consistency of a heavy liquid.

(iii) Assessing climate risk
Various tools are currently available to map potential climate change impacts at regional or national levels (Annex M). Although an understanding of climate risk for a city will involve downscaling global and regional circulation models, this down scaling would also require significant improvements in the modeling of the physical processes to make the models appropriate for city level investigation. Given the existing limitations in modeling at a scale that is applicable to cities, as a minimum trends at the national and regional level will provide a useful indication of potential climate change impacts. Therefore, this component of the assessment seeks to respond to the following questions:

- What is the nature and extent of current and future climate risks in the area of interest?
- What is the degree of uncertainty?
- What coping strategies are being used to deal with current climate variability?
- How sensitive and vulnerable are key sectors (such as transportation, tourism, water supply) to changes in climate variables in the study area over the assessment period?

(iv) Conducting focus group discussions or interviews with key officials and citizen groups to identify historical hazard trends and new risks that the city may be exposed to due to its growth pattern. Irrespective of the availability of secondary data on historical hazards and climate trends, a focus group discussion or interview with agencies involved in record keeping of weather information will be useful in understanding the impacts of past disasters, as well as the area and population affected. Information and personal accounts pertaining to the number and intensity of disasters, areas and specific population groups prone to recurrent disasters and other contributing factors should be noted (e.g., whether the event was the result of a natural causes or manmade). The following questions may serve as a guide to these discussions and could include:

i. What is the general trend in temperature and rainfall patterns?
ii. At the city level is hazard risk or climate variability increasing?
iii. Are areas of urban expansion commonly exposed to hazards?

Once specific information on historic and expected future hazard trends has been compiled, the potential hazards that affect the city can be geo-referenced and used as an important input to risk mapping (see Table 4 below for a template).

Table 4: Example of Documenting Historical and Future Hazards in a City

Historical Hazards	Current Affected Areas/ Potential future affected areas	Current Affected Population/ Potential Future Affected Population	Current Affected Physical Assets/ Potential Future Affected assets
Floods	Eastern zone of city	Number of people	Building X, Y; Highway, Port.
Landslides	Western zone of city		Hospital, water treatment plant
Potential Future Hazards			
Coastal surge	Coastal areas on western part of the city		Port

Source: Authors

(v) Assessing exposure of people and physical assets. A review of current urban planning practices, land use changes or the master plan can provide good information on settlement patterns and defining which areas and populations within the city are exposed to hazards or the potential impacts of climate change. Various factors contribute to people settling in high risk areas. Some of these factors include: existing urbanization patterns, land use and zoning policies, in-migration of rural or poor migrants, and the availability of land for developing new settlements. The location of important physical assets such as roads, water supply and sanitation networks, drainage canals, electricity and telephone lines, and hospitals should also be included in this assessment and equally geo-referenced where possible.

(vi) Assessing vulnerability. Building on the historical hazard analysis, the degree of physical vulnerability or the potential damage that an exposed asset or community may incur in a given event can be estimated. As a starting point, city officials may consider determining which areas have a high concentration of people living below the poverty line, which buildings in the city are old or of poor quality, whether the city has an Early Warning System and mechanisms in place to support its effectiveness, and the extent to which the development pattern of the city is avoiding hazard prone areas.

3.1.1 Primary Level: Developing Simple Risk Maps

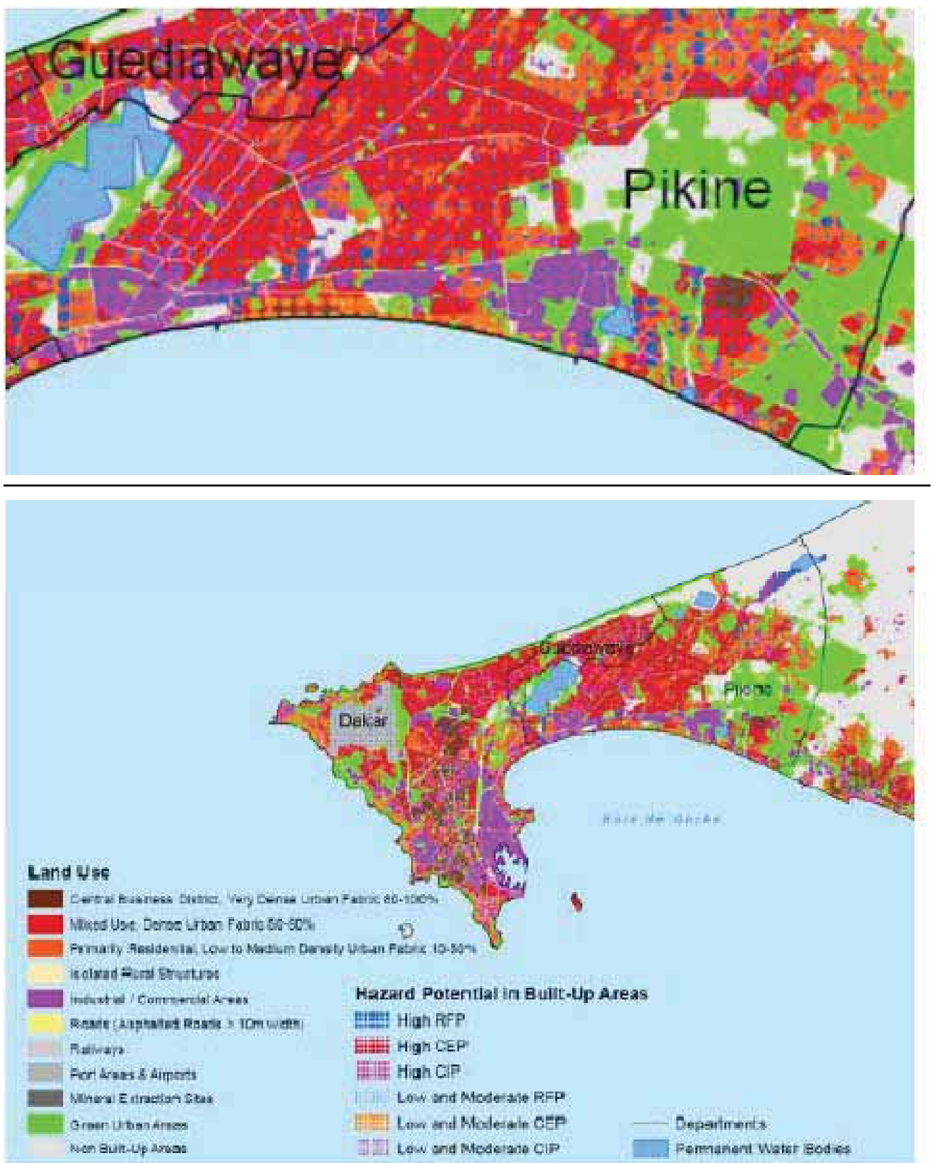
Risk maps identify specific urban areas, infrastructure, and populations at risk of disasters and climate change impacts. The following steps are suggested in their development:

i. Develop (or collect if one exists) a base map showing city boundaries, major infrastructure (roads, water supply, sanitation, sewerage, bridges, docks), land use, major community buildings (religious, markets, historic), critical infrastructure (hospitals, fire stations, police stations, government offices), and major environmental areas (coastline, wetlands, water bodies, conservation areas and brown fields).
ii. Overlay the socio-economic profile on the base map of the city including population density, vulnerable populations (senior citizens, poor households, and women headed households), and economic activities (commercial zones, fishing areas, farming areas, hotels, tourist facilities, cultural heritage sites).
iii. Develop a spatial hazard profile detailing the historical hazard analysis on past disasters and anticipated climate change impacts.
iv. Identify areas within the city where human actions have increased disaster risk. This activity includes identifying buildings located in hazard prone areas (e.g., slopes, or floodplains), their use (e.g., residential, commercial, industrial) and construction quality. Satellite imagery can also be reviewed to identify hazard prone areas and buildings.
v. Overlay the city’s projected growth and development maps (usually available in the master plan) to identify areas of high risk.

Identifying spatial correlation of hazards and elements exposed in these various data layers provides the city government in identifying “hot spot” areas and, depending upon the resolution of the map, critical infrastructure and buildings. The analysis can be undertaken with the aid of paper maps, or in a GIS platform, depending upon the capacity and resources of the municipality.

If Geographic Information Systems or paper maps are not available, community consultation involving urban planners, community groups, and key municipal service employees can be a useful alternative to define land use, environmental features (e.g., river, drainage channels, wetlands), landmark buildings, infrastructure, houses, and other physical assets of the city to develop simple sketch maps. On these more basic maps, areas historically affected by hazards and socio-economic information can still be combined to graphically depict hotspot areas. Land use maps are usually available from city governments, but these are often outdated in many developing cities. Once the hotspot areas are identified, the value of the built environment can be calculated to a rough order of magnitude of possible physical losses as a result of a disaster. Similarly, the number of people affected can be defined based on population densities. See Annex E for an example of this type of assessment in Dakar, Senegal.

Figure 7: Built-up Areas of Dakar Threatened by Hazards (2008)



Source: World Bank (2009) Preparing to Manage Natural Hazards and Climate Change Risks in Dakar, Senegal,

3.1.2 Secondary Level: Developing loss scenarios through simplified impact models

Building on the historical hazard and climate review, this level includes a detailed assessment for each type of hazard that the city is exposed to and identifies the location and characteristics of buildings and other infrastructure that may be damaged during disasters[18]. The following steps are suggested to estimate loss and other impacts from hazard event scenarios:

(i) Undertake built up, landuse/ landcover, building area and building height assessment.
If the city has information on built up, landuse/ landcover, building area and height assessment, it can be used for estimating exposure characteristics of the city and can then be used in combination with appropriate vulnerability models (see next step). If such information is non-existent or old, remote sensing and GIS can be used to assess the built up area, number of buildings, individual building areas and height (see Table 5 below). Importantly, given that remotely sensed data is collected at a distance and is subject to imperfections, results must be calibrated through a process known as ground truthing which supports the accuracy of image data against real features and materials found on the ground of a given location.

Table 5: VHR Satellite Imagery, Remote Sensing and GIS to Develop Built Up Area Maps

Steps to develop building level built up area map	How is it done	Comments
Step 1: Built-up area map The built up area of a city consists of buildings and infrastructure (transportation, drainage, water supply, communication systems, etc).	Urbanized area can be delineated from satellite imagery using automated computer techniques (built-up area index) using Very High Resolution (VHR) satellite imagery at 1:10,000 or larger scales.	Land cover maps provide information at or smaller scale of 1:25,000 scale, Land use and built up area maps provide information at 1:10,000 or larger scale map
Step 2: Assessing the number of buildings Showing building footprints or building as 'points' on a map	Computer algorithms can be used to develop built up area maps. However manual maps have less error than algorithm generated maps. A cartographer can input points for each building seen on VHR imagery or digitize building footprints. The assessment provides an approach to quickly estimate the number of buildings in an area.	Ground verification and other sources of information is required on developing density of buildings, cost of construction per square meter, and building use.
Step 3: Assessing building area and height Building area and volume are important for developing damage scenarios for any hazard.	Building footprint maps (developed in step 2) can be used to estimate density, space between buildings, area of ground floor, and proximity to roads and other visible infrastructure. The area of a building can be derived from the building footprint. The height of a building can be estimated using specialized software to process stereo imagery (two images of the same area, one slightly offset). Alternatively, a building's shadow can provide some indication of height when time of day and date of image acquisition are known, however to date this method has limited accuracy.	Use of ground surveys and old/available maps can be helpful in estimating areas and general heights of buildings in specific parts of the city.

Source: Ehrlich, D., Zeug, G., Small, C., Deichmann, U (forthcoming). Using High Resolution Satellite Information for Urban Risk Assessment. World Bank.

[18] This level is derived from *Elrich, D. et al (forthcoming).*

(ii) Define a building typology and associated vulnerability curves.
The degree of potential damage to a structure can be measured through vulnerability curves, which measure damage percentages at different hazard intensity levels (see Figure 8). To develop vulnerability curves, the city's building stock should firstly be classified using a building typology. Local engineers and architects should be consulted during the process for the definition of building typologies and the development of appropriate vulnerability functions.

There are multiple classification systems of building types that can be adapted to a given city which will ultimately provide a general standardization of types of common construction based on existing information and opinions provided by local working groups (CAPRA). The United States Geological Survey's Prompt Assessment of Global Earthquakes for Response (PAGER) building typology and inventory[19] (see Annex O), for example, was used for urban residential building types in Ethiopia (Table 6). In general, building material, size, height, age, geographical setting, and the settlement's historical growth can provide useful indications for assigning a building's classification[20].

Having defined a building typology, vulnerability curves can be calculated by using a number of distinct approaches, each of which have associated challenges and limitations. The Global Earthquake Model[21] suggests the following four possible approaches for the calculation of vulnerability functions:

- **Empirical:** Uses regression analysis to derive vulnerability functions from past observations of loss experienced by buildings of a particular type. Empirical relationships have a strong degree of credibility and as such this approach provides a high standard of vulnerability functions.

- **Analytical:** Uses first principles of structural engineering to make reliable predictions of outcomes and relate damage and loss to hazard intensity. Analytical techniques can produce valuable insight into the vulnerability of buildings where empirical data is insufficient.

- **Expert opinion:** Uses judgment of recognized experts familiar with the building type of interest to produce a vulnerability function. It is an efficient approach to estimating vulnerability, and can be valuable in the absence of empirical loss data and where insufficient resources are available for the analytical approach.

- **Empirical-national:** In this approach, vulnerability functions are developed for entire countries, or large sub- and supranational regions, without regard to building type, to best fit past loss data.

19 Jaiswal, K.S., and Wald, D.J., 2008, Creating a global building inventory for earthquake loss assessment and risk management: U.S. Geological Survey Open-File Report 2008-1160, 103 p.
[20] See Elrich, D. et al (forthcoming) for full discussion.
[21] http://www.globalquakemodel.org/risk-global-components/vulnerability-estimation/activities

Table 6: Sample Building Classification

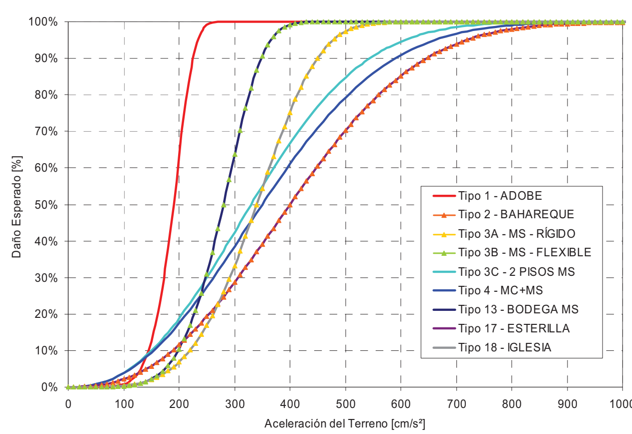
PAGER Label	Description
W2	Wood Frame, Heavy Members, Diagonals or Bamboo Lattice, Mud Infill
RS3	Local field stones with Lime Mortar. Timber floors. Timber, earth, or metal roof.
RS2	Local field stones with Mud Mortar. Timber floors. Timber, earth, or metal roof.
UCB	Unreinforced Concrete Block Masonry, Lime/Cement Mortar
C3	Nonductile Reinforced Concrete Frame with Masonry Infill Walls
INF	Informal Constructions (Pasts of Slums/Squatters)
UFB	Unreinforced Fired Brick Masonry
A	Adobe Block (Unbaked Dried Mud Block) Walls

Source: UN-HABITAT, 2007, Housing in the world- Demographic and Health Survey

(iii) Combine hazard, exposure and vulnerability information to develop indicative loss and damage scenarios for potential hazards.

Vulnerability models that relate the intensity of the hazard with the ensuing damages for specific classes for structures can be developed. The damages are reported on the y-axis and expressed on a ratio scale of 1 to 100%, where the expected loss is a percent of the total value of the structure. A damage ratio of 100% means that the expected loss equals or exceeds that value of the structure. The x-axis shows the range of intensity associated with the hazard and is scaled to capture the minimum damage to the weakest structure to the highest damage to the strongest structure. Using the defined building typology and associated vulnerability curves in combination with hazard and exposure data, a simplified risk map can be developed at varying level of detail. The vulnerability curves for different classifications of building types can then be used to estimate total damage and losses, and based on the percentage of damage to buildings, the exposed population. An important consideration in the damage and loss assessment is the difference between valuation of formal infrastructure, (houses and buildings), versus informally built construction found in low-income settlements. See the case study of Legazpi, Philippines (Annex F) for an example of this approach.

Figure 8: Sample Vulnerability Curves



Source: Cardona (2010)

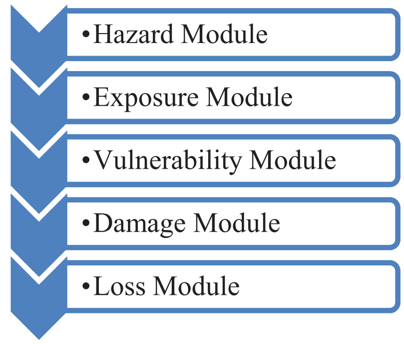
A major shortcoming in disaster risk assessments for many developing countries, however, is the unavailability of vulnerability for different housing typologies and hazard profiles. This problem is largely due to significant proportions of the building stock being informal and to damages not being recorded in a systematic manner. Field visits that record building stock and relative damages in disaster-affected areas can therefore be used to provide an indication of vulnerability of a city's building stock.

3.1.3 Tertiary Level Hazard impact assessment: Modeling Disaster and Climate Risk

Probabilistic risk modeling techniques are widely used by international insurance/reinsurance industry and capital markets to assess risk to asset portfolios to a range of hazards. With advances in computer modeling and GIS technologies, probabilistic risk modeling techniques can be applied to assessing a city's exposure to disaster risk in a meaningful and practical manner. Probabilistic risk models are built upon a sequence of modules that allow for the quantification of potential losses (in financial terms) from a given hazard (Figure 9).

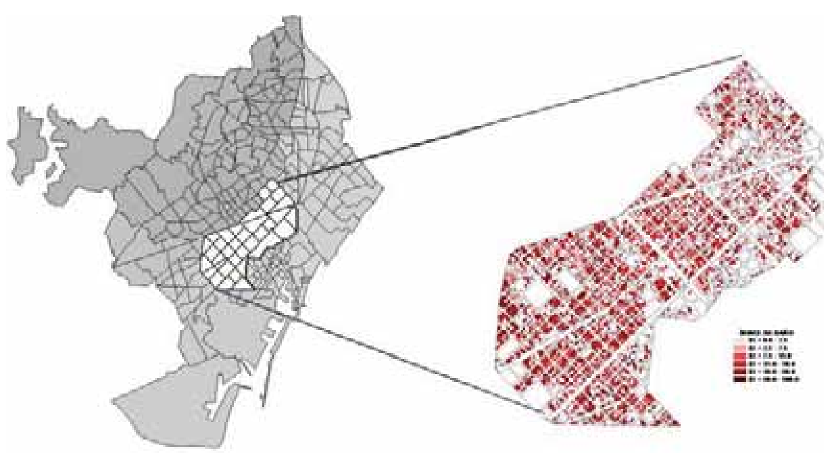
Figure 9: Probabilistic Catastrophe Risk Model

Source: The World Bank (2010)



This component of a risk assessment includes the collection and analysis of underlying hazard data to produce a probabilistic event set and to define the localized/downscaled hazard conditions (e.g., elevation, soil type, bathymetry). With low frequency events such as earthquakes, it is particularly important to engage in a robust probabilistic analysis of the hazard. This will yield a characterization of the hazard that extends beyond the limited or incomplete historical record of observed events. Probabilistic hazard models allow for the quantification of the impacts of climate change on disaster occurrence. Historical event catalogues, such as the information contained in DesInventar, are still important in the hazard modeling process as the source of validation benchmarks. The most valuable validation data are hazard measurements or observation points from historical events which can be used to test downscaling algorithms, which are used to produce event footprints. Key outputs from a detailed hazard analysis are a probabilistic event catalogue defining the frequency and severity of possible events in addition to multiple geospatial datasets defining local site conditions impacting the event footprints

Figure 10: Barcelona Physical Seismic Risk (District of Example)



Source: Cardona, *et al*, (2010).

Using the combination of existing land use datasets, topographic models and improved analysis of land use from satellite imagery, current and future land use scenarios can be evaluated to more accurately define the hazard resulting from a natural event. The value of this capability is the ability to project future land use scenarios and examine the impacts of activities and policies in risk mitigation. Annex I presents a detailed discussion of each module. See the case study of Sana'a, Yemen (Annex G) for an example of probabilistic risk assessment.

Probabilistic Risk Assessment Software: Linking Remote Sensing, GIS and Open Source Platforms

The main objective of introducing an existing software platform for probabilistic risk assessment or creating a city specific program is to provide city management with an analysis tool for risks that can be used to model losses from future events. Such platforms provide the user with various probabilistic risk maps that can be used to identify vulnerable areas dependent on the severity of the hazard. The identified hazard can then be applied to assess damage to structures using vulnerability functions that quantify the expected damage to structures in response to the hazard. See Box 6 for an overview of the Central American Probabilistic Risk Assessment (CAPRA).

To support the evolution of such software, and with a forward looking view of technological advancements in this area, documentation of the source code as well as the functionality of the platform should be available. The following list captures various considerations for the development of probabilistic risk assessment software:

- The platform should be suitable for distribution and future use
- The platform should be designed as a set of modular components for incorporation in a larger risk analysis system to be developed in future
- Develop a simple and uncomplicated user interface
- Outputs should present the results in datasets that can be used in subsequent modeling systems
- Open Source models should be used in the development to the extent possible

Climate Risk Screening Tools

In addition to probabilistic risk modeling, various tools are currently available to map potential climate change impacts at regional or national levels (see Annex M). Although a robust understanding of climate risk for a city will involve the downscaling of global and regional circulation models, obtaining the required spatial resolutions for cities remains a challenge. As a starting point, taking into consideration national and regional trends in which the city is situated will provide good indication of potential climate change impacts. These trends are able to derive projections for 50 to 100 year scenarios and are usually described in terms of average temperatures, intensity and duration of heat and cold waves, total seasonal and annual rainfall, extreme heavy rainfall, drought, and spatial and temporal rainfall distribution.

The use of planning tools can enhance the capacity of city managers or project developers to understand and integrate climate change considerations into future planning. The most effective risk planning tools encourage users to focus on the conditions, assumptions and uncertainties underlying the results of climate models to enable them to estimate the robustness of the information, make an informed assessment of current and future risks, and evaluate the appropriateness of response options. In particular, screening tools are generally able to provide information on some or all of the following aspects: i) current climatic trends and/or projected future climate change in specific geographical areas, ii) vulnerabilities of local natural systems and/or communities to current or projected climate-related impacts, iii) climate-related risks on specific sectors or project activities and iv) possible adaptation options.
(i) vs i

Box 6: The Central American Probabilistic Risk Assessment

The CAPRA initiative started in January 2008. It is a partnership led by CEPREDENAC, in cooperation with the UN ISDR, the World Bank and the Inter American Development Bank. The CAPRA methodology applies the principles of probabilistic risk assessment to the analysis of hurricane, earthquake, volcano, flood, tsunami and landslide hazards. CAPRA's platform integrates software modules related to hazard, vulnerability and risk modeling at different levels and resolutions in accordance with the nature of hazards, the available information and the kind of problems to be resolved.

The platform provides users with a set of tools to analyze magnitude, distribution and probability of potential losses due to each of the defined hazards. These metrics are projected on a Geographical Information System (CAPRA GIS) that allows for visualization and analysis. In absence of such evaluations, governments encounter major obstacles to identify, design and prioritize risk reduction measures.

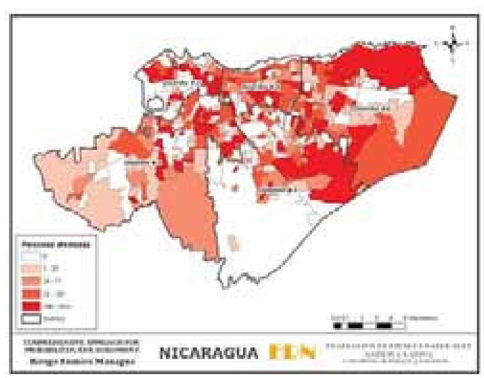
The hazard assessment is carried out by generating a series of stochastic events that: (i) have different magnitudes, (ii) have different frequencies of occurrence, (iii) correspond to historical observed trends of recurrence of the hazard under analysis, and (iv) represent the set of possible events with different intensity in different geographic locations.

At the core of CAPRA is the commitment to be an open and transparent platform. At the data level CAPRA promotes the use of standard data formats established under the Open Geospatial Consortium (OSG), allowing for maximum inter-operability with existing systems. At the software level it allows users to build their own application, using all or part of CAPRA, upon the platform, enhancing the functionality of the software.

CAPRA has strong potential for broad application in cities as it allows for the creation of a dynamic database of exposure of infrastructure, buildings and population (Figure 17). It also contains a library of vulnerability functions (see Section 4.2.1) for a wide typology of structures in each of the six hazards and is capable of assessing the effect on population based on building uses.

Application of CAPRA for Cities

San Juan del Sur, Nicaragua:
500 years return period tsunami run-up height over the coast of the city.



Managua, Nicaragua:
Affected persons based on earthquake modeling of a 6.7 magnitude event with epicenter near the city's airport fault line.

3.2 The Institutional Assessment

Undertaking an institutional assessment is relatively straightforward, but can require substantial data gathering. Understanding a city's institutional landscape with respect to climate change, disaster risk reduction/management, and poverty should be part of the dynamic process of identifying climate change-related vulnerabilities and coming up with the best and most cost-effective approaches to reducing them. This will strengthen a city's understanding of how climate change affects service delivery and ultimately support the streamlining of risk management across municipal agencies. The following steps are suggested as part of the institutional assessment:

Primary level institutional assessment: Institutional Mapping

(i) Identify which institutions/organizations are explicitly responsible for addressing climate change and/or natural hazards, and those that have a more indirect involvement. Given that disaster risk management and climate change adaptation cut across most sectors, an institutional mapping process that takes into account both function and interaction of government and non-government entities is advisable (Table 7). Considering that no city is a territorial, isolated unit, it is relevant to consider the national and regional contexts the city is linked to. In order for a city to understand its institutional landscape, it is important to take into account the existing administrative and political arrangements in which the local government is situated. This requires a closer look to the planning instruments that are in place including policies, programs, plans, and strategies and is further elaborated in the secondary level of the urban risk assessment.

This component of the assessment therefore specifically seeks to respond to the following questions:

- Which agencies are involved in any field of disaster risk management or climate change adaptation?
- How are they involved? What is their function?
- How are the agencies or institutions active in the different fields of disaster risk management and/or climate change related to each other?
- What policies, laws, projects and tools are available to these agencies or institutions?
- Which agency can play a lead role in coordinating all the other agencies involved? Does it have sufficient financial, technical and human resources to undertake such a job? Does it have a legal backing?

(ii) Undertake an institutional mapping exercise that includes all major government agencies within the city and delineate specific responsibilities before, during, and after a disaster. A similar exercise can also be undertaken for climate risk assessments. A sample template for mapping relevant institutions and agencies related to disaster risk management is presented in Table 8. Under the secondary level URA the institutional analysis is further elaborated with a more in-depth investigation of policies, programs and internal structures of concerned agencies to assess effectiveness of coordination across agencies.

Table 7: Suggested Institutions for Mapping

Institution Type	Indicative Function
National Offices and Ministries	Responsible for emergency management, disaster risk management, urban development.
State Offices	Responsible for emergency management and "green" development, industrial parks, parks and recreation, historic conservation offices and finance departments.
City offices	Responsible for climate change and disaster risk management. These may be Sustainability Offices, Works and Engineering, Housing Departments, Water and Sanitation Departments, Emergency Management Departments, Transportation Departments, Energy Offices, and Finance Offices. Departments of Health and Education should also be included for their role in supporting resilience and structural integrity of schools and hospitals.
Private sector	Chambers of Commerce, industrial boards.
Civil society organizations	International nongovernmental organizations and academic/technical support institutions.

Source: Authors

Table 8: Sample Institutional Mapping of Disaster Risk Management Functions

Risk Assessment	**Risk Reduction**		
	Technical[22]	**Early Warning & Response**[23]	**Public Awareness**[24]
Municipality ▪ Identifying flood prone areas	***Municipality*** ▪ Master Plan ▪ Land use/ Zoning ▪ Building Codes ▪ Storm water drainage ▪ Internal roads ▪ Culverts and drainage planning ▪ Implementation and maintenance	***Department of Meteorology & Environment*** ▪ Rainfall and flood forecast	***Civil Defense*** ▪ Early warning to citizens ▪ Flood awareness
Geological Survey ▪ Flood affected areas mapping, Hydrological modeling	***Ministry of Municipal Affairs*** ▪ Approves Master Plan & Budget	***Ministry of Water*** ▪ Flood forecast	***Ministry of Social Affairs*** ▪ Possible role in preparing citizens for floods

[22] Agencies involved in land-use and urban planning, environmental management, maintenance and protection of critical infrastructure and facilities, partnership and networking.
[23] Agencies involved in forecasting, dissemination of warnings, preparedness measures, disaster reaction capacities, and post disaster recovery.
[24] Agencies or institutions involved in public awareness programs and knowledge development including education, training, research and information on disaster management.

Department of Meteorology & Environment ▪ Land use/ Land cover mapping ▪ Environmentally sensitive areas mapping	***Ministry of Transportation*** ▪ Design & construction of flood protection structures ▪ Dams ▪ Major roads	***Civil Defense*** ▪ Early Warning to residents ▪ Fire brigades ▪ Ambulance ▪ Emergency Relief ▪ Post flood – compensation	***Ministry of Education*** ▪ Possible role in flood awareness programs in schools and colleges
Universities ▪ Hydrological modeling ▪ Identification of flood affected areas	***Water Company*** ▪ Water treatment ▪ Water supply ▪ Wastewater treatment ▪ Sewerage	***Red Cross or Crescent*** ▪ Fire brigades ▪ Emergency Response	***Local NGOs*** ▪ Helping residents after floods
		Municipality ▪ Emergency Response ▪ Restoring infrastructure	***Community Organizations*** ▪ Community leaders and organizations helping citizens after floods
		NGOs ▪ Coordination of humanitarian efforts	

Source: Adapted from World Bank (2010) Unpublished report on Jeddah Risk Assessment after 2010 floods

Secondary level institutional assessment: Interventions Analysis

(iii) Create an inventory of relevant planning instruments including existing policies, programs, plans, and projects. This step focuses on the planning documents developed and implemented by the identified institutions/organizations. The exercise will include a stocktaking of both present and proposed government policies and plans that might directly impact disaster risk. This is important to assessing current city management tools such as master planning, building regulations and codes, policies for sectors prone to disasters (cultural heritage conservation, water security, drainage, health care facilities, and transportation systems), and plans related to climate change adaptation. Local government budgets should be identified at this stage, in addition to those budgets already committed to disaster risk management or climate change that can be used for strengthening the city's resilience to disasters and climate change.

Rapid Institutional Assessment of City Management Resources and Tools

The World Bank developed the Climate Resilient Cities Primer (2008), which proposes a set of questions to understand a city's institutional landscape and linkages with the planning instruments. These questions assist in identifying and understanding factors that influence a city's adaptive capacity (Table 9). According to the Primer, factors include, among others, the local institutional policy and regulatory capacity related to disaster risk management and, climate change through issues relating to, land use, building controls, economic strength and diversification, financial resources, infrastructure standards, provision of municipal services, availability of data, and technical expertise in analyzing trends related to hazards. Three question categories that allow for a rapid institutional assessment of city management resources and tools are presented below:

Table 9: Rapid Institutional Assessment Questionnaire

A. Governance structure and disaster risk management in the city	
Appointed head of government (Y or N)	
	a. Term of assignment (Years)
Elected head of government (Y or N)	
	a. Term of elected officials (Years)
Local government office structure: Does it have…	
	a. Disaster risk management department? (Y or N)
	b. Environment, sustainability or CC department? (Y or N)
	c. Are (a) and (b) in the same department? (Y or N)
Other government office structure: Does it have…	
	a. Disaster risk management department? (Y or N)
	b. Environment, sustainability or CC department? (Y or N)
	c. Are (a) and (b) the same department? (Y or N)
B. Responsibilities for disaster risk management and climate change management	
Responsibilities clearly specified? (Y or N)	
Responsibility for CC management established? (Y or N)	
Responsibility for DRM established? (Y or N)	
Authority to contract for services? (Y or N)	
C. Existence, capacity and effectiveness of a city's emergency/disaster response plan	
Does a disaster response system exist in the city? (Y or N)	
Is the response system comprehensive and equipped for all natural hazards specified? (Y or N)	
Is the disaster response system regularly practiced? (Y or N)	
Is the disaster response system regularly updated? (Y or N)	

Source: World Bank (2008)

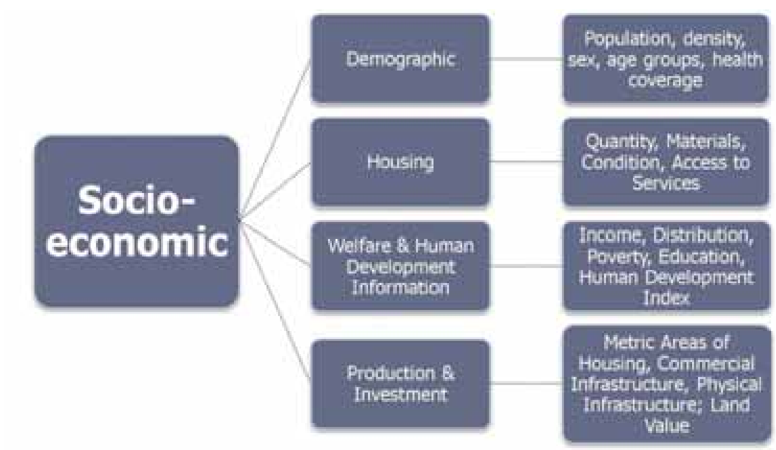
Tertiary level institutional assessment: Interventions Gap Analysis

(iv) Undertake a gap analysis that identifies shortcomings in current city management tools, policies programs, and that provides preliminary recommendations to mainstream risk reduction . A city may then consider undertaking a ranking of appropriate agencies to assess their capacity, both in terms of personnel and financial management, to administer new resilience building programs in the event that discrete adaptation funding were to be made available through National Adaptation Programs of Action (NAPA). Such an assessment better positions city governments to engage national decision making bodies in discussions of effective resource allocation for climate change or to explore possibilities of receiving fiscal transfers for risk financing.

3.3 The Socioeconomic Assessment

The socioeconomic assessment focuses on (i) identifying demographic, housing, welfare, human development, and investment variables, and (ii) developing comparative ranking of specific areas based on a simple qualitative codification. City managers may consider a number of demographic and housing variables that will contribute to a more robust risk assessment (Figure 11). Many of these factors, such as housing characteristics, are important inputs for the hazard impact assessment component of the URA. Collection of housing data should be done in close coordination with the building vulnerability analyses.

Figure 11: Socioeconomic Considerations for Understanding Risk



Source: International Development Research Centre (2008).

Primary level Social Assessment: Analysis of socioeconomic data

For the demographic analysis, the assessment can rely on existing data captured through national censuses and/or household survey information collected through non-governmental organizations or community based groups. Suggested demographic variables that indicate relative resilience of a given household include dwelling occupancy, proportion of children and elderly, gender, disabled persons, household literacy, education levels, and proportion of economically active household members. Suggested housing variables that indicate relative strength and integrity of the building will relate to the ability of walls, floors and roofs to withstand a given hazard, and the building's typical use, e.g., type and number of occupants. A simple qualitative codification can be then be applied to aggregated information geospatially referenced to a specific area of the city to signify its comparative ranking (Table 10).

Table 10: Sample Qualitative Codification of Neighborhood Data

Category	Suggested Indicators	Classification	Value
Neighborhood Characteristics	Construction density Occupant density	Low: Below average	1
		Medium: Equal to average	2
		High: Above average	3
Household Resilience	Proportion of children Proportion of elderly Proportion of disabled Proportion economically active Literacy rate Education level	Low: Below average	1
		Medium: Equal to average	2
		High: Above average	3
Housing Quality	Age of structure Floor material quality Roof material quality Wall material quality	Low: Below average	1
		Medium: Equal to average	2
		High: Above average	3

Source: Adapted from International Development Research Centre (2008).

The collection of *welfare and human development* data at the city level supports an improved understanding of the connection and reinforcement between poverty, disasters, and environmental degradation. Its inclusion in understanding urban risk can contribute to reducing vulnerability at the household level. Because of the economic nature of much of the information, it cannot always be obtained in the desired spatial detail to comply with national data policies. In the absence of detailed data, and using the Human Development Index as a guide, it is suggested that the following variables be considered: average income (per capita or household), median income per capita (which is less affected by extremes of information), life expectancy at birth, and literacy rates (as proxy for education and poverty rates).

In considering variables related to *production and investment* within a city, the built environment often constitutes a major proportion of urban investments and, as such, detailed information is often available. The number of square meters built is a useful indication of investment levels and economic activity; using estimated costs of construction per square meter an approximate value of the built environment can be obtained (Table 11). In addition to the data regarding the built environment, associated land values will play an important role in understanding the degree of exposure to hazards that characterize certain parts of a city.

Table 11: Production and Investment Variables

Unit	Area (m2)	Cost/m2	Value
Dwellings			
Commercial infrastructure			
Trunk infrastructure			

Source: International Development Research Centre (2008).

Secondary and Tertiary level socioeconomic assessment: Community Based Approaches

An approach that incorporates both top-down and bottom-up methods will be more robust, and therefore useful, to city governments than either in isolation. Data collected from ground-based methods through community participation can serve to empower local residents, build social capital, and establish a common foundation for neighborhood level risk assessments. Participatory approaches present opportunities too, enabling communities to have greater control over information and interventions, thereby enhancing their resilience. This in turn generates a debate surrounding whether urban risk assessments should, in fact, be led through bottom-up approaches that place an emphasis on community engagement and household surveys, particularly among the poor or through top-down technological approaches that utilize remote sensing technologies.

There is strong experience in engaging in direct dialogue with the urban poor regarding risk and vulnerability and having them directly involved in risk mapping. Beyond creating critical spatial data about low-income urban areas that would assist in more inclusive city planning, an advantage of this approach is the relatively high accuracy and spatial resolution of data compared to that obtained by aerial or satellite imagery; mapping and enumerations done by federations of slum dwellers have proven to be some of the best inputs to analyzing urban risk. In addition, such experiences have helped to validate the existence of the urban poor and provide valuable shared information to the community and city officials (Box 7).

> **T**o assess the vulnerability of a local population it is necessary to identify the variation of both hazards to which they are exposed and their capacity to cope and adapt. These include settlement variations in terms of the quality of physical capital and homes, the provision for infrastructure, and the risks.
>
> *Source: Moser, forthcoming*

It is important that city governments recognize the value of raising public awareness of climate change and the need for disaster mitigation. Engaging with community groups and non-governmental organizations to provide necessary inputs to an urban risk assessment has importance not only for the data and maps they help generate, but also for the support provided identifying and acting on risk and vulnerability.

Figure 12: Screenshots from iPhone® Application Prototype

Source: ISU, 2009

There are important contributions that community groups can make to the urban risk assessment, each with increasing levels of field work: collection of detailed information regarding the physical condition of neighborhood houses/structures, digital enumeration of slums (‘*heads-up digitizing*’), and household surveys. As described previously, features such as building height, structure material, and roof shape can be challenging to define in densely populated urban areas from remotely sensed data. The engagement of local residents in the collection of this information is therefore an important entry point for collaboration between city governments and community groups.

To facilitate such an approach, the International Space University developed a prototype of an iPhone application that could be adapted to any smart phone and used by community groups (Figure 12). The appeal of this approach lies in the recognition of the extensive reach that cellular telephones have made into slum areas in developing countries. The application allows a user to quickly and easily generate simple reports about individual buildings that include: the current position (provided by the phones built-in GPS), the number of floors, the building type (residential, office, store, etc.), and other optional parameters such as roof material, estimated construction year, and a picture of the building (taken with the phone's camera). These applications can now be delivered very quickly – oftentimes in the span of just a few days – thereby providing an interesting and potentially cost-effective approach for cities to consider for slum mapping.

It has to be taken into consideration that many community residents might have access to a cell phone but not to a smart phone and this is where the integration of SMS capabilities into a community reporting system could be very valuable. This would allow for increased community participation and, although it might not provide detailed reports, it would be the source of relevant information such as the current condition of important infrastructure within the community.

With the rise of freely available software and open source platforms, the potential to streamline slum mapping and include issues of risk and vulnerability in the process have been notably enhanced. The proliferation of handheld Global Positioning System (GPS) devices and open-source technologies that can now be used in mapping, supports the role of communities in data-gathering. Digital enumeration of slums can be undertaken using selected base maps (e.g., Bing Maps) and open source GIS programs which can be downloaded at no cost. The first step would be creating settlement profiles of informal areas which may include: slum address or location, legal status, land ownership, approximate year of establishment, housing conditions, hazards, topography, number of houses, population and population density, services and infrastructure.

One tool that could serve as a useful input for cities in implementing the use of such approaches is OpenStreetMap (OSM), a collaborative project to create a free editable map of the world. OSM was established with the aim of encouraging the growth, development and distribution of free geospatial data. The maps are created using data from portable GPS devices, aerial photography, and other sources such as local knowledge. Both rendered images and the vector graphics are available for download.

As part of the development of the urban risk assessment, the World Bank produced a prototype of this approach for mapping slums and their structures (Figure 13). Although in preliminary stages of development, the prototype application features:

- Slum Sketch (hand sketched plan) which is geo-referenced and visualized over a base map that can be removed or added.
- A set of plotted houses which, when clicked, load a form on which household data can be inputted. Information from the household questionnaire on the incidence of hazards and perceptions of risk (presented in Annex N) would be included in addition to details about the structure/house. Other community features such as manholes, electricity/telephone lines, water stands, and community toilets could be included and, in collaboration with the appropriate city departments GIS base layers (e.g., streets, waterways, topography / hydrology) could be included to give the maps additional context.
- A multimedia option through which the user can view a video clip/ picture of the settlement/household.

Figure 13: Digital Slum Mapping:

World Bank Prototype (Source: Authors)

The process described above for digital slum enumeration could be done in parallel or in sequence to more detailed data collection (both quantitative and qualitative) at the household level on both historical exposure and perceptions of risk. Through focus group discussions and individual/household surveys on historical incidence of small localized disasters and local adaptation measures, this more time intensive step should assist residents of informal areas in their communication and negotiation with city government for necessary investments intended to improve living conditions and reduce vulnerability and risk.

In considering community stakeholders in undertaking an urban risk assessment, it should be recognized that residents of low-income areas of many cities have endured the threat of eviction or destruction of their homes given that they are frequently located on public lands. On the one hand, the use of new technologies to map slums and associated collection of household information may be met with suspicion, and might actually act as a barrier to their participation and support. Yet on the other, the pace of new technology use in city management points to a need for communities to have a central role in settlement mapping which will increase the authenticity of collected data.

Box 7: Field Data Collection and Community Based Approaches

An increasing number of community based organizations and NGOs are making use of very high resolution (VHR) images for slum surveys. One example is the work of Shelter Associates (SA) from Pune, India. For SA, VHR images are one of the most important tools for poverty mapping at the city level. Working in close collaboration with residents of slum communities, SA uses VHR images to digitize slum boundaries and attach fact sheets containing data that has been compiled by quick surveys in slums to register key information about the households, their dwellings and the overall site characteristics. Their Pune slum census covered over 100,000 households in over 200 slum pockets scattered throughout the city. Settlements were mapped by professional agencies using plane table methods to produce large-scale slum maps showing plot and building boundaries, while residents engaged in household surveys, gaining knowledge and skills on data collection and a better understanding of their community's problems, its opportunities and the planning process.

The spatial and socio-economic data is entered into a GIS database and spatially analyzed for direct use by the communities to prepare upgrading plans and to negotiate with local government authorities on policy and developmental issues. The process therefore contributes to community empowerment by enabling them to be fuller partners in settlement upgrading and in the subsequent management of their community. The same approach within the Municipal Corporation of Sangli Miraj Kupwad has led to the initiation of a holistic approach to improve all slum pockets. SA and communities are engaged with the local administration and elected members for drawing up an action plan for slum improvement. As a result of these community based approaches, many slums have been mapped and plans for their improvement have been produced in a cost effective manner.

Source: UN-Habitat, ITC, Ceisin. Expert's Meeting on Slum Mapping.(2008)

4 Concluding Remarks: From Risk Assessment to Action Planning and Implementation

Chapter Summary

- *This chapter highlights the importance of carrying out an Urban Risk Assessment as input to developing adaptation and risk reduction plans in cities.*
- *Pilots of the Urban Risk Assessment in four cities point to key lessons learned about the importance of ensuring that findings are integrated into risk reduction action planning.*
- *The information collected and/or used for an urban risk assessment is useful in many municipal functions such as urban planning and policy, new building/infrastructure approvals, building codes and zoning, infrastructure/building upgrades, and environmental planning.*
- *Climate change adaptation and disaster risk reduction plans are most effective when mainstreamed into urban planning and management efforts.*

4.1 Introduction

Urban risk assessments provide a foundation for building long-term sustainable risk reduction plans that can address a city's vulnerabilities to natural hazards. These assessments are structured to improve the knowledge base and increase the capacity to deal with short and long term hazards that any given urban environment may face. The key to making an URA successful is the transition from the completion of the assessment to the creation and implementation of a risk reduction plan, using the knowledge gained and the catalytic nature of the assessment process. The action plan will ideally address the key risks raised in the URA, while at the same time begin the process of mainstreaming risk reduction in municipal planning and service delivery. Completion of an URA, defining the action plan and mainstreaming risk reduction measures should not be considered as three discrete elements but rather as a process towards a common end objective.

In the context of the Mayor's Task Force on Climate Change, Disaster Risk and the Urban Poor, Urban Risk Assessments have been carried out in Dar es Salaam, Jakarta Mexico City and Sao Paulo in 2010-2011.[25] These risk assessments have identified key issues for the cities, and compiled data related to climate change, disaster risk and vulnerable groups for the first time. Annexes A-D provide a summary of the highlights identified in each of the risk assessments. In each case, the process of action planning has been initiated based on the risk assessment and is currently underway.

The experience from these cases point to several lessons in particular related to the process of carrying out a risk assessment. In all four cities, the process itself has been equally important as the results. Main lessons include:

i) High level support from the mayors and heads of key agencies was essential in giving priority and support to the work. The identification of focal points within the lead agencies was a key element to ensuring accountability and getting the work done.

ii) The analysis carried out through the risk assessments has highlighted the close linkages in the disaster risk reduction and climate change adaptation agendas, particularly in the context of the urban poor and supports the integration of the two fields in urban planning and decision making processes.

iii) In all of the cities, an inter-agency working group was set up to carry out the risk assessments. This included agencies working on urban development, service provision, poverty reduction, disaster management, and climate change. In some cases, this was the first time these agencies worked together which has assisted to create needed synergies for the initiation of adaptation planning. However, it is unclear that these inter-agency working groups will be sustained without a more formal working arrangement.

[25] World Bank, 2011. *Climate Change, Disaster Risk and the Urban Poor: Cities Building Resilience in a Changing World.* Washington, D.C.

iv) In some of the cities there was a disconnect between knowledge at the institutional and community level. This was addressed by involving city officials in site visits to poor neighborhoods, and in two cases, involving stakeholders in the workshops. Communicating in a language that all stakeholders could understand was of fundamental importance. In that regard, producing materials in a simple format and local language was important for communicating results. In Jakarta and Mexico City, short films have been produced for broader dissemination of key messages.

v) Across the four cities, accessing data, maps, and climate projections was problematic. Information was scattered across many different agencies, departments, organizations, and research institutions, and to complicate the process farther, some agencies were reluctant to share data. Enormous effort went into collecting the information that was made available. To benefit from and sustain this effort, setting up a permanent institutional "home" to maintain and update this inter-agency information in each city would be valuable.

vi) The risk assessments were perceived as a useful framework for understanding climate change, disaster risk and impacts on residents. The multidimensional approach to assessing hazard impact, socioeconomic vulnerability, and institutional capacity brought together key issues in a holistic manner. However, this was only the first step. Stakeholder workshops held in all of the cities were useful in discussing key issues, but follow up will be needed to integrate these findings into adaptation and inter-agency risk reduction planning.

4.2 Developing Action Plans: Lessons from Vietnam and New York City

The ability to use an URA to create an action plan is critical to the process of risk reduction, and its value will ultimately be judged through actions on the ground. Developing action plans is an in-depth process involving many stakeholders and can be a complex task. While a full detailed discussion of the steps involved is beyond the scope of this document, the summary included here points to key references.

Vietnam provides an illustrative example where the national government in cooperation with the World Bank has created standard procedures that local officials can use to develop action plans. The approach, the Local Resilience Action Plan (LRAP) is being carried out in the cities of Hanoi, Dong Hoi, and Can Tho.[26] The LRAP is a planning document that helps a city to assess alternative adaptation and risk reduction options, with economic assessment of the costs and benefits of each. The action plan will result in a strategic set of short (less than 1 year), medium (1-3 years), and long-term (more than 3 year) structural and nonstructural measures to increase resilience and reduce disaster risk. Ideally such plans would then be mainstreamed into broader urban planning and management practices.

During the process, stakeholders work to establish priorities, highlighting those actions which are most critical to undertake in relation to the available funding and capacity for implementation. Other factors such as financial feasibility, political and technical complexity,

[26] See World Bank, 2010, A workbook for Local Resilience Action Planning in Vietnam. Washington, D.C.

social issues, and distributional and equity issues are also considered. Once priorities are established and an action plan is developed, detailed plans for each project (ranked by priority) including objectives, cost parameters, and a plan of implementation, are prepared. When considering implementation, the city may decide to treat risks differently in different areas of the city, with the following options: (a) eliminate or avoid, (b) transfer or share (example through insurance), (c) mitigate (through structural interventions), and (d) accept and manage the risk. This plan of implementation ideally addresses issues such as institutional coordination, sequencing of actions, budget, communications for implementation, and monitoring and evaluation.

New York City provides an alternative example of moving from risk assessment to action planning to implementation. In 2008 Mayor Bloomberg tasked the New York City Climate Change Adaptation Task Force with developing a plan to increase the resilience of the city's critical infrastructure. The Task Force was comprised of 40 city, state, federal and private sector infrastructure operators and regulators with the goal of identifying climate risks to the city's critical infrastructure and develop strategies to mitigate these risks.

Once the risks analysis was completed, an extensive process of identifying, developing and prioritizing actions was carried out. The Task Force focused on improving current buildings, amending building design and other regulatory codes as well as the strategic placement of public facilities. It adopted a risk-based approach to climate action, and uses Flexible Adaptation Pathways to address the anticipated risks, compensating for the uncertainty of climate impacts.[27] The Task Force was supported by a panel of technical experts which was also convened by the Mayor.

The City also launched a pilot community engagement and planning process with vulnerable communities. Five workshops were held in partnership with community-based organizations to educate residents about the risks posed by climate change and begin local resilience planning and action. The City's comprehensive sustainability plan (PlaNYC), which is the driving force behind New York City's adaptation actions, will be updated in April 2011 and will build upon the pilot to better inform and engage New Yorkers on climate change issues.

4.3 Key Policy Areas: Lessons from England, Turkey, Kenya, and Colombia

The Greater London Authority released a draft of the London Climate Change Adaptation Strategy in 2010 in response to the evolving nature of risk associated with increased climate variability. With the aim of providing a framework to identify and prioritize risks and then to deliver actions to reduce or manage them, land use planning was placed at the center of the climate adaptation strategy with the objective of incorporating local actors such as municipal governments, community groups and the private sector into the process.[28] Based on scientific projections that southeast England will experience warmer, wetter winters and hotter, drier summers, the strategy identifies three areas of risk that need to be addressed and prioritized

[27] New York City Panel on Climate Change. Climate Change Adaptation in New York City: Building a Risk Management Response. C. Rosnezweig & W. Solecki, Eds. Annals of the New York Academy of Sciences, Vol. 1196, Wiley-Blackwell, May, 2010.
[28] Greater London Authority. The London climate change adaptation strategy, draft report. Greater London Authority, London, 2010. http://www.london.gov.uk/climatechange/strategy

them accordingly: flooding (high risk), drought (medium risk) and overheating (high risk). To address these risks, the following actions were proposed: promote land use planning to improve the understanding and management of flood risk and the development of an urban greening program to help absorb floodwater. To implement this strategy, spatial land use planning will be critical to determine areas where development should not occur, where existing structures should be removed and where relevant development that fits the vision for a given city should be located. In the process of making these decisions it is important that no significant interferences with natural processes should occur.

The Istanbul Metropolitan Municipality created a Strategic Plan for Disaster Mitigation in Istanbul (SPDMI) to reduce seismic risk focusing on building codes and disaster-resistant construction. Regulations that consider the use of proper building materials, building orientation, insulation and ventilation can improve a structure's physical resilience, enhance public health, and increase energy conservation. The SPDMI identified an abundance of bureaucratic obstacles in the construction process, and a lack of coherent building codes, which both encouraged illegal development and substandard construction. In Istanbul, it is estimated that 80% of buildings are occupied without the correct permission, and thus it is highly probable that a certain percentage of buildings in the city have been altered without the necessary legal documentation.[29] Compliance with defined building codes can be facilitated if they are clear, concise and relevant and that they are governed by incentives that make them attractive to administrators, architects, builders, contractors and home owners.

In Kenya the majority of building codes in the 1980's existed from the colonial era, making them outdated in an evolving urban environment. Due to this, a house built to the minimum acceptable level according to the codes was out of reach financially for many of the urban inhabitants and new innovative building designs were not permitted. In 1990, these building codes were redefined through a participatory process: the result was Code 95. This code is performance-based, and permits the use of innovative and popular materials and alternative building technologies.[30] However it should be noted that work is still required to simplify the approval processes and establishing incentives.

The island city of Tumaco, Colombia, is one of the country's most impoverished and vulnerable urban areas. The city is exposed to risks of sea level rise, earthquakes and tsunamis, and ensuing liquefaction from poor soil composition. The city can only be accessed by two bridges at opposing ends of the island, but in recognition of the potential need to evacuate the city, investments were made in widening the shortest bridge to accommodate greater pedestrian and vehicular mobility, and evacuation simulations are run periodically. The case of Tumaco demonstrates that urban planning, or the lack thereof, can play an important role in deciding what is built, where and how and influencing the relative degree of risk faced by urban residents..

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[29] Metropolitan Municipality of Istanbul Planning and Construction Directoriat Geotechnical and Earthquake Investigation Department. Earthquake Masterplan for Istanbul. 2003. http://www.ibb.gov.tr/en-US/SubSites/IstanbulEarthquake/Pages/IstanbulEarthquakeMasterPlan.aspx

[30] The World Bank: Safer Homes, Stronger Communites: A Handbook for Reconstructing after Natural Disasters. Chapter 10. 2010

Figure 14: Tumaco, Colombia

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4.4 Institutions and Governance

As with carrying out an URA, planning for risk reduction covers a range of areas including spatial development and land management, environmental management, economic development, municipal service provision, waste management, and infrastructure development. Institutions and governance therefore play a role in the ability to manage the transition from the completion of the URA and the creation of an action plan to the process of implementing this plan.

No two cities are exactly alike, nor will any two URAs be the same. The transition following the URA will vary from city to city depending largely on the institutional and governance structure of the particular city. The role of other stakeholders such as utilities, the private sector, the urban poor and NGOs also has to be taken into consideration. It is the interplay between all of these actors within the political and legal framework of the city that creates the environment in which the disaster reduction action plan will be created. It is important to take an approach with the aim of the 'development of a single governance framework for risk reduction would seem to offer opportunities for more effective policy implementation and for avoiding duplication and lack of coordination'. [31]

There are also instiutional and governnance issues at the international level in planning for adaptation. Given the scope of needs related to climate change, new funding such as the Green Fund are under discussion within UNFCCC negotiations. How best to allocate this potential funding is not yet defined. At national levels, similar to Nationally Appropriate Mitigation Actions, countries are encouraged to develop National Adaptation Programmes of

[31] Global Assessment Report 2009

Action, NAPA. These NAPAs are supposed to prioritize potential adaptation actions across a country.

A similar intiative at a city level may be warranted. If so, a common framework to aggregate and compare adaptation actions would be needed. These local NAPAs can be predicated on a URA as outlined in this report. Climate change is encourgaing local planning and presentational consistency – a credible URA meets these demands and also enables a city to monitor the impact of efforts to reduce risk.

Aspects of a Good Urban Risk Assessment

- Follows a simple hierarchy (process) and applies consistent terminology
- Combines disaster and climate risk management
- Incorporates multisector inputs from city agencies
- Integrated within overall city functions (and regional circumstances)
- Makes use of community involvement and encourages participation from the urban poor
- Identifies urban areas historically vulnerable to hazards
- Identifies urban areas subject to new and intensifying risks
- Provides detailed inputs to preparation of local resilience action plan
- Makes use of open source and freely available technologies
- Structured to facilitate broad support and engagement from the insurance industry
- Results in enhanced understanding of roles and responsibilities of city agencies and communities

Annexes

ANNEX A: URBAN RISK ASSESSMENT - MEXICO CITY METROPOLITAN AREA, MEXICO

MAP

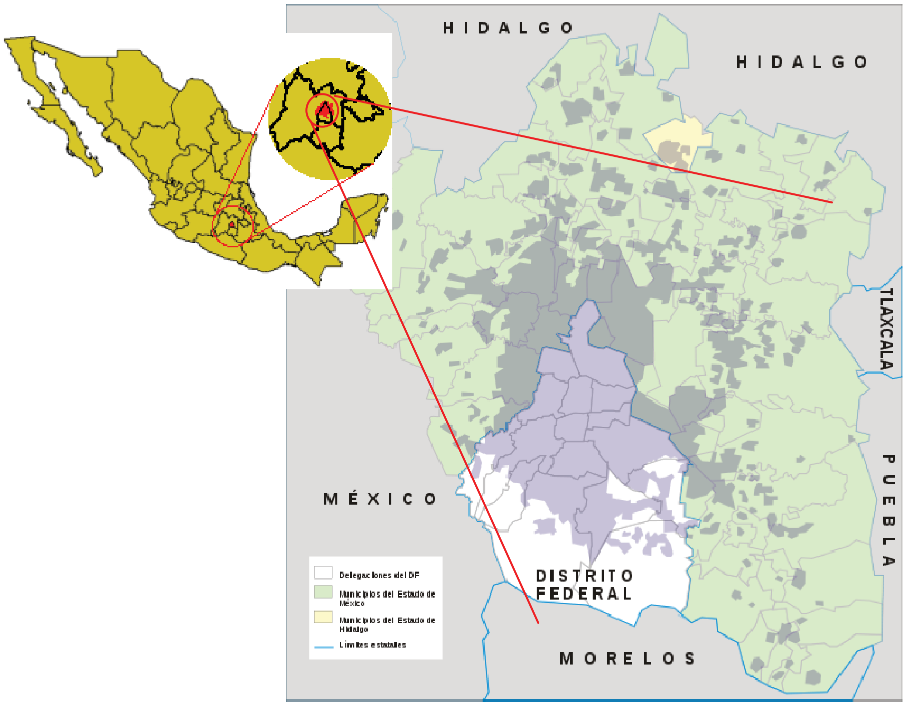


Figure A1: Mexico City Metropolitan Area

CITY PROFILE

The Mexico City Metropolitan Area (MCMA) is one of the largest urban agglomerations in the world. Located in a closed basin of 9,600 km^2, MCMA spreads over a surface of 4,250 km^2 at 2,240 meters above the sea level. The MCMA has a metropolitan population estimated at 21.2 million, concentrates 18 % of country's population and generates 35% of Mexico's gross domestic product on a surface equivalent to less than 0.3% of the national territory. Approximately 8.8 million people, or 42% of the metropolitan population, live in the city proper (Mexico City or the Federal District). The MCMA comprises the 16 boroughs of Mexico City and 34 municipalities of the State of Mexico for a total of 50 geopolitical and administrative units who must coordinate among themselves in terms of urban planning, public services provision, and overall city management (UNDP, 2007).

MCMA has been growing constantly since the 1930s both physically and demographically. The pace of growth of these two dimensions, however, has been distinct. Physical and demographic growth reached its peak in the sixties, and until the 1990s the physical expansion (urban sprawl) formed a continuous

CITY SNAPSHOT

Total Mexico City Population in yr

Federal District: 8.8M (INEG, 2010)
Metropolitan area: 21.2 M

Population Growth (% annual)

3.0.05% (CONAPO 2010)

Land Area (Km2)

Federal District: 1,485 km^2
Metropolitan area: 4,250 km^2

Population density (per Km^2)

5,958 persons/Km2

Country: 57 inh/Km2

Country's per capita GDP (US$)

US$ 9,243 (2010 estimate)

% of country's pop

City proper: 7.87 %

Total number of households

2,388,534 (INEGI 2010)

Dwelling density (per Ha)

23.9 (SEDESEOL)

Avg. household income USD(2008)

53295

GDP per capita USD (2008)

14382

% of Country's GDP

21.8%

Total Budget (US$)

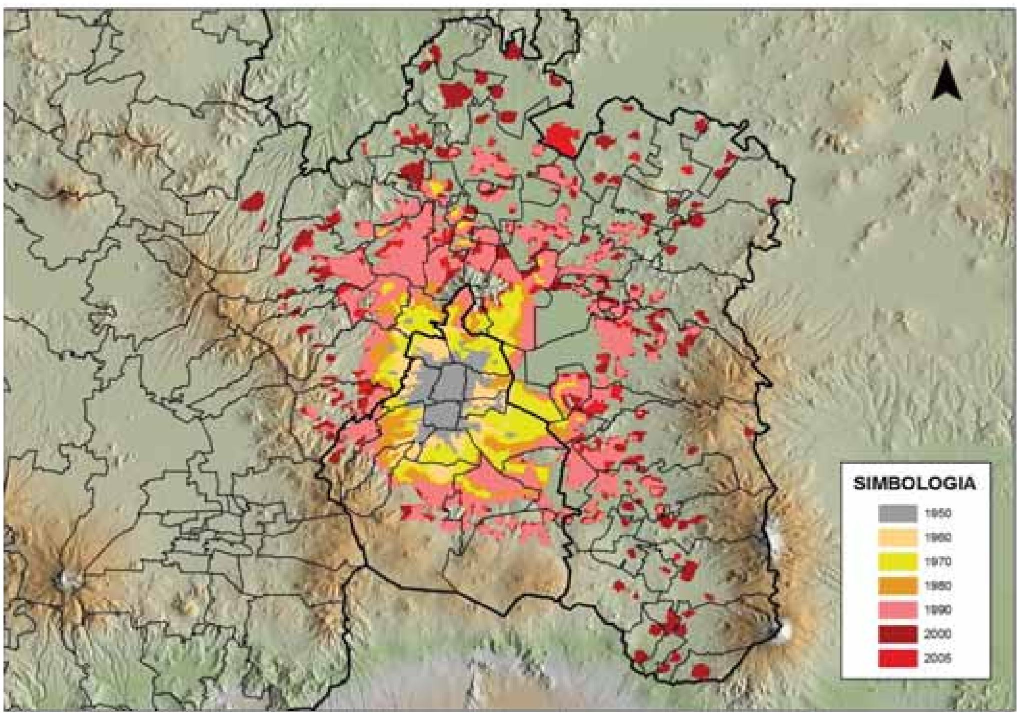
11.7B (2011)

Date of last Urban Master Plan

n/a – multiple MP for different urban sectors urbanized area with gross population density decreasing over time, and spatially increasing with distance from the historical city center. Since 1990 growth has been characterized by a sort of leapfrog expansion and urban spatial continuity was broken. Current land-use now bears limited contiguity to previously urbanized areas. For example, in 2000 the neighboring municipalities located in the State of Mexico represented 52% of the population and grew at an annual rate of 2.4% on average, while the 16 boroughs of Mexico City had a population growth rate of 0.3% annually (UNDP, 2007).[1]

The MCMA is characterized by seismic risk and with no natural drainage for runoff from the surrounding mountains, it is also vulnerable to flooding, particularly in the Western part. The metropolitan area is affected by severe storms, heat waves and droughts. The size of the population in the MCMA complicates the possible impacts of these events as the infrastructure and public services are stretched thin. As a national economic engine, Mexico City's geophysical characteristics and presence of risk of multiple natural hazards underscores the need for the city to implement activities/programs that will increase its physical and social resilience.

Figure A2: Urban Expansion of the Mexico City Metropolitan Areas, 1950-2005



The Built Environment and Basic Service Provision

Mexico City was the first city in Latin America to introduce a local climate action strategy which has been designed to reduce overall emissions by seven million metric tons from its inception by Mayor Marcelo Ebrard in 2008 until 2012.The climate action program is part of a 15-year plan in which Mexico City is investing US$1 billion a year (approximately 9% of the yearly budget). The *Green Plan (Plan Verde)* has seven pillars: land conservation, public spaces, air pollution, waste management and recycling as well as water supply and sanitation, transportation and mobility.

[1] http://inep.org/index2.php?option=com_content&do_pdf=1&id=209

Mexico City has the largest metro system in Latin America which is currently comprised of 200km of subway lines. It is currently being expanded with a 12th metro line stretching 25km which due to be finished in 2012 – an investment of US$2 billion. The Metro which does not extend outside the limits of the Federal District is complemented by a suburban rail system and an extensive network of bus routes. Mexico City's first Bus Rapid Transit line, the Metrobus system, began operation in June 2005. The city has begun construction of a third line for the Metrobus system that will run from the city's North-west to the Central-south over 16 kilometers and with 31 stations.

Water access is a complex problem for Mexico City which has a supply network of some 13,000km of primary and secondary pipelines. Beyond issues of expanding coverage and continuity of water services, the city rests on heavily saturated clay which has been collapsing and causing areas of the city to sink and subsequently endure more frequent flooding due to over-extraction of groundwater. Forecasts to 2015 estimate that water consumption rates will increase by 20% compared to 2000 levels with urban demand reaching 62 m^3/s. Mexico City's climate action program therefore includes measures to invest in water infrastructure, for example the rehabilitation of the city's sewerage system as part of a program of hydraulic works.

Regarding land conservation, 59 per cent of the total land area of Mexico City is designated a conservation area with city's remaining forested areas located in the southern boroughs. These areas are under threat from illegal development, logging and fires, which impact regional rain patterns. At present the city's generation of garbage is increasing at a rate of five per cent a year and the current insufficient rates of its collection have created 'clandestine' fields. Bordo Poniente, one of the world's largest landfill sites, receives 12,500 tons of waste every day. In response Mexico City has initiated a recycling program and is encouraging its citizens to separate trash.

PILLAR 1 - INSTITUTIONAL ASSESSMENT

Institutional Snapshot

Leading agency coordinating Disaster Risk Management effort:

Secretaría de Protección Civil (Secretary for Civil Protection)

Mexico City was the first city in Latin America to launch a local climate change strategy. Given the institutional and political complexities of the Mexico City Metropolitan Area, the Mexico City Climate Action Program (MCCAP) 2008-2012 requires a high level of coordination among multiple agencies and civil society. The MCCAP was developed as part of both the Green Plan and the Environmental Agenda of Mexico City. The Green Plan is a 15-year plan that lays out strategies and actions of sustainable development for Mexico City. The Environmental Agenda of Mexico City is a 5-year plan that defines the city's environmental policy. At the same time, both the Green Plan and the Environmental Agenda are part of one of the pillars of Mexico City's Development Program.

The main objectives of MCCAP are twofold: (i) reduce carbon dioxide emissions by seven million tons (or equivalent) in the period 2008-2012 and (ii) develop a Climate Change Adaptation Program for the Federal District and fully begin its implementation by 2012. To achieve these objectives, the government utilizes various policy instruments including direct investment from Mexico City, regulation, economic incentives, voluntary carbon markets, and education and information campaigns.

The Interinstitutional Climate Change Commission of Mexico City is in charge of coordinating and evaluating the MCCAP. This commission includes representatives from all the administrative units of the Federal District. In addition, three deputies from the District's Legislative Assembly are invited to attend each session. Among its specific responsibilities are: to design, encourage, and coordinate policies to mitigate climate change effects in Mexico City; to evaluate, approve, and disseminate related projects; to develop financial strategies that generate revenue; and to coordinate actions and policies with other programs linked to the MCCAP. To facilitate coordination and provide support to the MCCAP, the Legislative Assembly of Mexico City is working on a proposal for a climate change law (not yet entered into force as of March 2011).

Although the execution of the MCCAP has an estimated cost of approximately US$5 billion, most of which is budgeted for mitigation actions, there has been little translation into monetary transfers. The only instrument that could specifically provide resources for the MCCAP is the Environmental Public Fund, while the remaining identified actions would have to be financed through each respective agency's annual budgets.

The main challenge of the MCCAP is the lack of institutional coordination and cooperation. Even though the program was designed to cut across institutional boundaries, there is lack of ownership and it is mostly considered a program of the Secretary of Environment. Currently multiple agencies are executing a series of actions but with limited communication or information exchange among concerned agencies. Further exacerbating the open exchange of relevant data is that each agency has its own information platform. This signals a strong need to develop a single common interface which all government agencies can use for data storage and use.

Climate Change Adaptation and Disaster Response

The MCCAP's program of adaptation consists of a set of short and long-term actions that aim to reduce risks to the population and economy of Mexico City by taking the potential impacts of climate change into account. The lines of action regarding adaptation are: i) identifying key threats and performing a vulnerability analysis, ii) mainstreaming of adaptation to enhance existing capabilities in Mexico City's Government, iii) implementing adaptation actions.

There are multiple agencies involved in responding to extreme hydro-meteorological events, including: The Water System of Mexico City, the Civil Protection Agency, the Public Safety Agency, the Health Department, the Social Development Agency, the Social Assistance Institute, and the Urban Development and Housing Agency. Their main tasks follow.

Table A1: Institutional Responsibilities Relating to Climate and Disasters

Institution	Headed by/level	Major Function
Water System of Mexico City	Secretary for the Environment	Responsible for public services related to water supply, drainage, sewerage, and water treatment. They also coordinate and operate the "Storm Unit" during high precipitation emergencies in 90 previously identified high-risk locations, with the participation of the Civil Protection Agency, the Public Safety Agency, and the Fire Department.
Civil Protection Agency	Secretary of the Interior	Responsible for coordinating prevention efforts and response to natural disasters, mainly floods and earthquakes, using a "Risk Atlas" that has more than 100 maps depicting multiple hazards. In terms of flooding they have identified critical locations based on past events, but these are not necessarily the same maps used by the Water System of Mexico City. Importantly this agency has mostly focused on prevention, response and capacity building of seismic disasters. They defined and are implementing the Crisis and Immediate Response Action Plan.
Public Safety Agency	It operates in coordination with the Water System of Mexico City and the Civil Protection Agency.	Intervenes when natural disasters occur.
Health Department	In emergencies, the Health Department coordinates with the Civil Protection Agency.	Responsible for periodic monitoring of epidemic prevention and response (including AH1N1 and dengue). In addition to medical attention, it organizes vaccination campaigns.

Social Development Agency	Provides support and responds to emergencies related to heat and cold waves and floods. In addition to operating public dining locations, the agency establishes shelters with food provision and provides psychological assistance.
Social Assistance Institute	Responsible for general social assistance (including psychological support) for the Federal District, but also during emergencies. Through one of its programs, it operates a hotline to provide support to homeless people. It also provides support to families affected by disasters and operates 11 centers for social assistance.
Urban Development and Housing Agency	Responsible for medium and long-term prevention of disasters through urban planning. It is involved in issues related to irregular terrains in high-risk locations. It has plans to develop an information system for Mexico City that will include geographic and urban development indicators.

Ongoing Programs and Projects Related to Disaster Risk Management or Climate Change Adaptation

Climate change adaptation programs focus on Early Warning Systems and medium-term response:

Programs on *Early Warning Systems* and upstream preventative action include the implementation of a hydro-meteorological monitoring and forecasting system for Mexico Valley, an epidemiological monitoring system, and a remote identification and monitoring system for fires. In addition initiatives are in place for management of hillside risk, the protection of native vegetation to reduce erosion, and the establishment of processes to help vulnerable populations.

Regarding *Medium-Term Response* Mexico City is running projects on water and land conservation, land management for agricultural rural areas, reforestation with more resilient species, and green roofing in urban areas. Table 1 shows the goals and key results of the main climate change adaptation projects in the context of CAPMC.

For emergency response in case of landslides or flooding the most relevant agencies are the Department of Civil Protection, Fire and Health, complemented by Brigades of the Ministry of Social Development, to provide shelter, food hot and psychological containment to those affected, on the one hand, and the Ministry of Public Security to control access and prevent vandalism, on the other hand. As a permanent action there are homeless shelters and soup kitchens and attention to patients with severe respiratory or dehydration.

Table A2: Status of Main Climate Change Adaptation Projects

Program – Responsible Agency	Goals	Results
Urban Hillsides Program – Environmental Agency	By 2012, identify 33 hillsides and develop/disseminate their management programs	As of 2009, 9 hillsides identified and 7 programs developed
Dengue Monitoring – Health Department	Determine mortality rate due to dengue	Annual studies made to identify the presence of the virus, risky areas mapped, and household surveys made
Monitoring and Prevention of Health Effects due to Extreme Weather – Health Department	Avoid mortality and mitigate risks and health effects of exposure to extreme temperatures	Information campaigns conducted, serum kits distributed, chlorine in water closely monitored
Epidemiological and Health Monitoring of Climate Change – Health Department	Monitor chlorine in water, water supply systems, sanitary monitoring of food production and distribution, among others	In 2010, over 36 thousand of water samples and 125 of food samples taken for analysis. Over 1900 visits to establishments to evaluate sanitary conditions
Support to vulnerable population during winter season – Social Assistance Institute	Provide support and social assistance to vulnerable people	In 2010, over 200 thousand warm dinners and 15 thousand blankets distributed. Also, over 6 thousand medical consultations provided, among other services
Risk Atlas of Mexico City – Civil Protection Agency	Develop an integrated information system shared by all administrative units	Efforts ongoing
Preventive program for hydro-meteorological risks – Civil Protection Agency	Prevention, mitigation, and response to emergencies due to hydro-meteorological events	260 informational reports disseminated, often daily during the week
Storm Unit Program – Water System of Mexico City	Response to negative effects of precipitation during the rainy season	Between 2008 and 2010, over 6 thousand cases were attended and resolved
Reduction of extreme precipitation impacts in "El Arenal" – Government Secretariat	Mitigate negative impact of extreme precipitation in 14 areas	Food, drinks, blankets, and cleaning products distributed. Equipment installed to speed up the drainage, sewers cleaned, among other
Sustainable housing in the Federal District – Housing Institute of the Federal District	Incorporate green technologies to new housing	Solar water heaters, energy efficiency lamps, and water treatment by re-utilization, among others, incorporated in over 5 thousand new dwellings

Source: Study on Climate Change, Disaster Risk Management and the Urban Poor in Mexico City (2010).

Shortcomings in Current Disaster Risk Management or Climate Change Adaptation Management

Disaster risk in Mexico City is primarily handled in a reactive manner and limited preventative measures have been implemented. The Early Warning System envisioned as one of the priority adaptation measures included in the MCCAP has been delayed in its implementation due to administrative issued that urgently need to be resolved. In addition, there is an evident need to improve the sharing of information among the relevant government agencies, taking as an example the Risk Atlas (elaborated by the Secretary of Civil Protection), to which not all agencies have access.

Leading Agency Coordinating Risk Management Activties

The Secretary of Civil Protection is in charge of the risk management activities in Mexico City, although many other agencies are also involved.

PILLAR 2 - HAZARDS ASSESSMENT

Natural Disaster History

The Mexico Valley is exposed to increases in extreme temperatures, which with expanding urbanization, has contributed to a significant heat island effect for Mexico City. Projections reveal that the mean temperature is expected to increase by 2 to 3 °C towards the end of the 21st century, and extreme precipitation episodes are equally expected to increase. Characteristically rising temperatures are accompanied by an increase in extreme rain events, consequently placing Mexico City at heightened risk of flooding and landslides, particularly in the Western part of the city.

Natural Hazards Snapshot

	Y /N	Date of last major event
Earthquake	X	1985
Wind Storm	X	2010
River Flow		
Floods, Inundations and waterlogs	X	2010
Tsunami		
Drought	X	2011
Volcano		
Landslide	X	
Storm Surge		
Extreme Temperature	X	

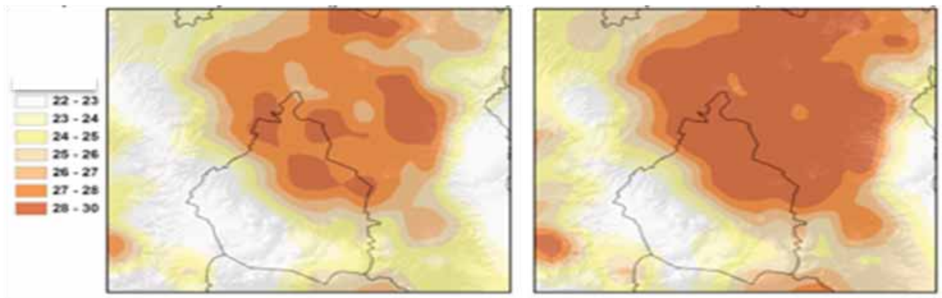
Current Trends and Projections

<u>*Temperature*</u>: The temperature in the Mexico Valley reflects its orography where warmer temperatures are concentrated in the lower elevations and cooler temperatures in the more elevated areas. Nevertheless, with time, the temperature in Mexico Valley has changed due to urbanization, constituting one of the clearest examples of heat island effect in the world. The highest values are observed in the northeast, where the average maximum reaches 30°C. The area with main maximum temperatures over 24°C increased considerably between 2000 and 2007, and the minimum temperature increased by 2°C and 3°C in the north and northeast, respectively, in the same period. While temperature increase in the western part of Mexico City has been lower, the frequency and duration of heat waves in the areas are increasing. For example, the number of heat waves of 3 or more days with 30°C or higher increased from 2 in 1877-87 to 16 in 1991-2000 in the west of the Federal District (Jáuregui, 2000). Simulation exercises for temperature in January show that temperature in the northeast, which is the region that has grown fastest, increased 2°C. Although this temperature rise may in part be the effect of urbanization, some atmospheric conditions may also have had an impact, and this order of magnitude is in-line with those expected this century by models simulating global warming.

To further understand temperature increases associated with urbanization, an analysis was undertaken of temperature trends in areas with rapid urbanization against those in regions that are close to highly vegetated areas. For Mexico City, the trend in the minimum temperature in regions with rapid urbanization between 1963 and 2000 is an increase of about 0.7 °C per decade, while for regions close to vegetated areas the associated increase was about 0.1°C per decade.

Another way to evaluate the effects of extreme events is to analyze the 90th percentile of the maximum temperature using a projection from the Earth Simulator. For 2015-39 the northeast region will have temperatures around 30°C for at least 10% of the year (Figure A3).

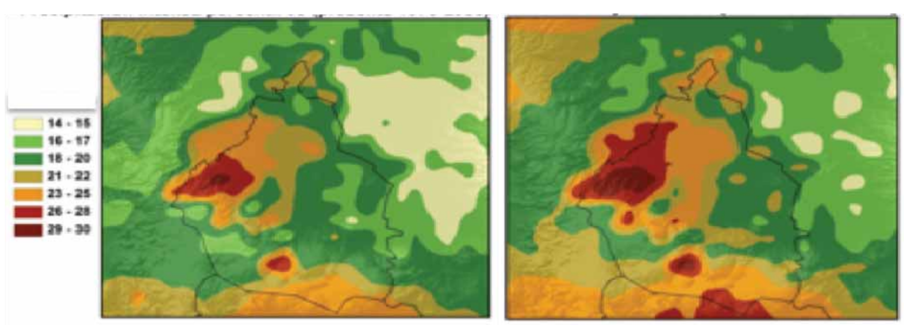
Figure A3: 90th percentile of max temp in °C in 1979-2003 (left) and 2015-39 (right)



Source: Study on Climate Change, Disaster Risk Management and the Urban Poor in Mexico City (2010).

<u>Precipitation:</u> Precipitation projections for Mexico City seem to be consistent with the general projection made by the IPCC in 2007, which states that precipitations will increase in regions with high precipitation and decrease in regions with low precipitation. Particularly, the intensity and quantity of extreme precipitation events is expected to increase in the west of the city, and decrease in the east. In the Mexico Valley the highest precipitation occurs between mid May and early October with the western region receiving most precipitation in August. On average, annual precipitation is between 700 and 900mm (±30%). The highest intensity usually occurs during the afternoon and early evening. The western region presents upward trends for daily precipitation and episodes over 20mm/hour over the past 100 years. During September and October, rain over 30 mm/hour may occur which based on a review of landslides, is the critical threshold for landslides of saturated land. Projected increases in extreme precipitation in term of the intensity and duration are shown in Figure 4. In the west of Mexico City, these increases constitute a significant hazard for vulnerable populations located on hillsides. Additionally, projected increases in extreme precipitation increases the risk of flooding in the west of Mexico City and the southern areas of the Federal District.

Figure A4: 95% percentile of precipitation (mm/day) in 1979-2003 (left) and 2015-39 (right)



Source: Study on Climate Change, Disaster Risk Management and the Urban Poor in Mexico City (2010)

<u>Water Runoff:</u> Climate change projections indicate that with increasing temperature, evapotranspiration increases at the expense of infiltration and runoff. For many urban areas, including MCMA, changes in land use also affect this ratio whereby as urbanization increases less water is naturally absorbed into the ground and more runoff occurs. Assuming 100mm of rainfall and using information about land and vegetation types, the

approximate amount of water runoff was calculated for Mexico Valley[2]. The findings show a noticeable increase in runoff in 2000 when compared with 1980. The increased precipitation and resulting runoff increases flood risk in the city, particularly given the existing drainage system.

[2] Runoff calculation was undertaken the *curve number method*; developed by the USDA Natural Resources Conservation Service.

PILLAR #3 -SOCIECONOMIC ASSESSMENT

Location of the Urban Poor

Vulnerable groups were identified and mapped in terms of population and housing characteristics by doing a cluster analysis with data from the 2000 official census data[3]. In terms of population, vulnerable groups include areas with high concentration of people over 18 years without secondary education, people that moved in the past 5 years, and people with low income. As shown in Table 3, this group includes about 7 million people (or 42% of population of the Mexico City Metropolitan Area) and about 1.5 million dwellings.

In terms of housing, vulnerable groups are concentrated in areas characterized by use of precarious construction materials in walls and ceilings, those without access to basic services, and where formal property ownership/rights are limited. This group includes about 5 million people (or 30% of population) and about 1 million dwellings. Figure 5 presents the location of these groups. The most vulnerable in terms of both population and housing represent about 27% of the population and are located in the peripheral area of MCMA, mostly to the north and east[4].

Table A3: Vulnerability matrix in terms of population and housing

		Population	
		Low vulnerability	**High vulnerability**
Housing	**Low vulnerability**	2,609 PSUs[5] 9,516,901 people 2,329,416 dwellings 54.8% of population	514 PSUs 2,639,058 people 584,547 dwellings 15.2% of population
	High vulnerability	164 PSUs 577,583 people 128,831 dwellings 3.3% of population	1,354 PSUs 4,635,298 people 964,144 dwellings 26.7% of population

Source: Study on Climate Change, Disaster Risk Management and the Urban Poor in Mexico City (2010).

Social Assessment Snapshot

(Information presented is for Mexico unless otherwise stated)

Percentage of city population below poverty line

59.4%

Social inequality (Gini index)

42.8 (2008) CIA factbook

Unemployment (% of total labor force)

6.3%

Percentage of city population living in slums

22 %

Percentage of children completing primary and secondary education: survival rate

57.4 (Mexico City)

Human Development Index

0.75

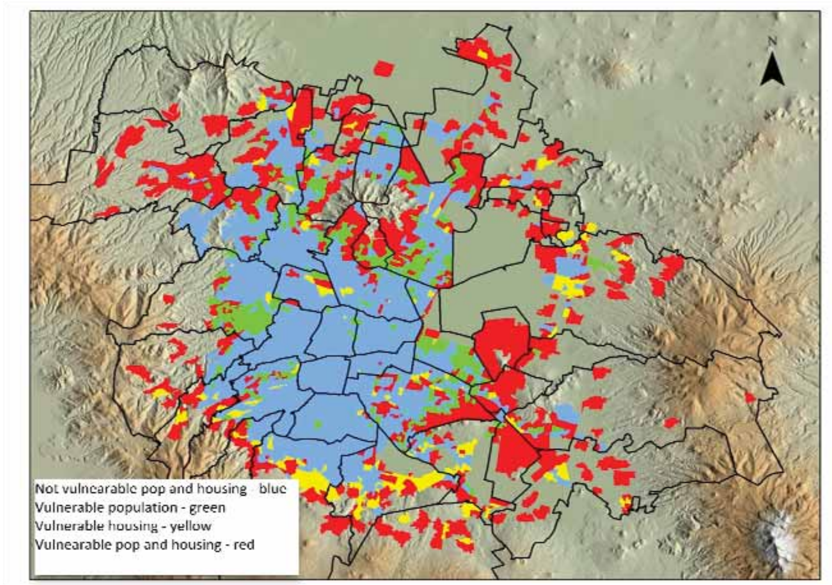
(http://hdr.undp.org/es/datos/mapa/)

3 The Census data are coded, for all variables, in Primary Sampling Units (PSUs) or territorial units called by Mexican official census institution basic geo-statistic areas (AGEB´s which stands for Areas Geoestadísticas Básicas).

4 In addition to those living in low-income neighborhoods, Mexico City also has a sizeable homeless population which is particularly vulnerable to extreme events. Importantly, this segment of the population is not accounted for in the city's calculations of urban poverty, as such information relates to those who possess a dwelling.

5 PSU refer to primary sampling units defined in the context of the 2000 census.

Figure A5: Vulnerable areas in terms of population and housing



Source: Study on Climate Change, Disaster Risk Management and the Urban Poor in Mexico City (2010).

Exposure of the Urban Poor

The information on vulnerable groups was overlaid with information on extreme precipitation and temperature, and locations with steep slopes. A series of maps similar to that presented above were created to observe the location of these groups with respect to high risk zones: current and future extreme precipitation and vulnerable housing; vulnerable population and housing located in zones with high risk of extreme precipitation; vulnerable population and housing located in zones with slopes over 15 degrees; vulnerable population and housing located in zones with risk of heat waves; and vulnerable population and housing located in zones with risk of extreme precipitation and slopes over 15 degrees.

Table 4 shows the distribution of population and housing for each event. Most of the vulnerable population in high-risk zones lives in locations with slopes over 15 degrees (about 1 million people). The total population that lives in high-risk zones represents about 40% of the vulnerable population and about 41% of the vulnerable dwellings. Lastly, it is important to note that about 60% of the vulnerable population and dwellings are not located in high-risk zones.

Table A4: Distribution of vulnerable groups located in high-risk zones

Event	PSUs[6]	%	Population	%	Housing	%
I. Extreme precipitation	48	3.55	179,019	3.86	38,909	4.06
II. Slopes over 15 degrees	288	21.27	1,004,586	21.67	208,546	21.63
III. Heat waves	117	8.64	367,450	7.93	76,771	7.96
I + II	59	4.36	251,118	5.42	53,455	5.54
I + III	1	0.07	39	0.00	10	0
II + III	23	1.70	62,449	1.35	13,175	1.37
I + II + III	0	0.00	0	0.00	0	0.00
Vulnerable in high-risk zones	536	39.59	1,864,661	40.23	390,866	40.54
Total vulnerable	1354	100	4,635,298	100	964,144	100

Source: Study on Climate Change, Disaster Risk Management and the Urban Poor in Mexico City (2010).

Economic Costs of Climate Change: Another important aspect of the socio-economic assessment was the analysis of the economic costs of climate change in terms of GDP for the Federal District. This analysis incorporated four scenarios. The base scenario, named A2, does not include climate change impacts and assumes 1.99% of annual GDP growth, 1.81% of annual GDP per capita growth, and 18% population growth for 2100. The other three scenarios correspond to different goals on reduction of gas emissions considered in international negotiations (i.e. 550, 450, and 350 parts per million (ppm)). The analysis incorporated three discount rates (0%, 1%, and 4%), however, based on the literature on the costs of climate change, the authors recommend using 0% to draw conclusions. Table 5 presents costs for each scenario in terms of GDP reduction and additional number of poor people by 2100 for the Federal District, using a 0% discount rate. It shows the average value, as well as the 95% confidence interval in parenthesis.

Table A5: Costs in terms of GDP and additional poor

Scenario	GDP reduction by 2100 - No. of times	Additional number of poor people by 2100 - thousands
A2	19.10 (5.22, 45.79)	441 (98, 1281)
550 ppm	17.35 (4.52, 43.04)	392 (81, 1176)
450 ppm	10.77 (3.15, 24.38)	213 (51, 560)
350 ppm	6.50 (2.03, 13.70)	104 (26, 249)

Source: Study on Climate Change, Disaster Risk Management and the Urban Poor in Mexico City (2010).

Under the status quo scenario (A2) it is expected that the GDP will be reduced 19 times on average. These results are not too different from those under the 550 ppm scenario. However, if the 350 ppm scenario is

6 PSU refer to primary sampling units defined in the context of the 2000 census.

realized, the benefits could reach 32 times the current GDP (in terms of avoid losses). Also under the A2 scenario, the number of poor is projected to increase to over a million (or about 10% of population in 2100), although the average increase is expected to be 450 thousand. The analysis also pointed that economic losses are not distributed equally among administrative units. Those that will lose the most are those that are currently worse off. In other terms, if the temperature increases by 2 °C, Mexico City could lose up to 7% of its GDP and get 150 thousand additional poor annually.

(Notes: Prepared by Gisela Campillo, Eric Dickson, Cuauthemoc Leon, and Ana Goicoechea)

ANNEX B: URBAN RISK ASSESSMENT - SAO PAULO, BRAZIL

MAP

CITY PROFILE

The metropolitan area of Sao Paulo located in the South East of Brazil, is the largest urban agglomeration in Latin America, and one of the five largest of the world. More than half of the metropolitan population lives in the municipality of Sao Paulo.

CITY SNAPSHOT

(From Global City Indicators)

Total Population in 2010 (Source: IBGE)

11,244,369 (City)

19,672,582 (Metro)

Population Growth (% annual)

0.75% (2000-2010). Source: SEADE

Land Area (Km2), Source: SEADE

1,522.99 (City)

7,943.82 (Metro)

Population density (hab/km^2) Source: SEADE

7.216 (City)

2.469 (Metro)

Country's per capita GDP (US$)

US$ 19,574.67 in 2008. Source: IBGE.

% of country's pop

16.96% in 2010. Source: IBGE

Total number of households

3,039,104 in 2000. Source: SEADE

Dwelling density (per Km2)

Favelas: 1.6%. Irregular lots: 6.32%.

Avg. household income (US$)

US$ 891.37 in 2000.

% of Country's GDP

10.29%

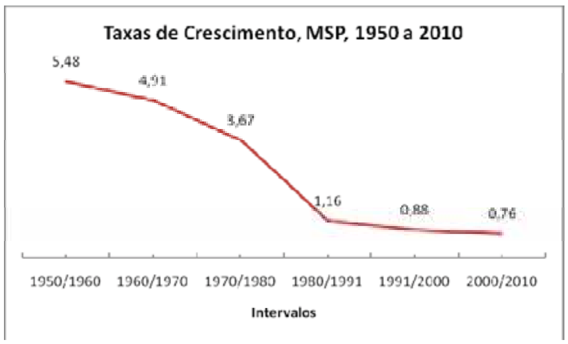
Total Budget (US$)

US$ 15,457,936,496.98

The city of São Paulo is inserted in the compartment of the Atlantic Plateau, having hills disposed between 718 and 720 meters above the sea level. Regional hills climb from large floodplains trough fluvial terraces for interfluvial areas.

Although population in the city area is currently decreasing (in 2010 was of only 0.76% compared to 1.16 in 1990), the number of commuters is increasing. Two million people commute everyday to the municipality of Sao Paulo to access jobs. Furthermore, the rate of population in the periphery is increasing (growing from 4.9 million to 5.5 million from 1991 to 2000), representing 30% of the urban sprawl. The periphery concentrates the majority of the poorer inhabitants (the average housing income there is half the average for the city and the per capita household income is up to 3 times lower than the city rate).

Figure B1: Growing rate for the city of São Paulo. 1950 to 2010.



Source: Habisp.

The life expectancy of the inhabitant of São Paulo is 71.71 years. The mortality rate is of 6.53% for each thousand and the children mortality rate is of 15.83 for each thousand. The city has 4.89% of illiteracy among youth with more than 15 years old. Almost 47% of the population with more than 25 years has less than 8 years of formal education (the primary/basic education is of 9 years and the secondary, 3 years more). The population of Sao Paulo is mainly composed of people from 25 to 59 years (49.6%).

Built Environment and Basic Service Provision

Adequate water supply is provided to 98.62% of the houses in the city (almost 65 m3 per inhabitant/year). Nevertheless, the increase in the number of consumers, scarcity of new hydric resources and the decrease in the water quality of the basins result in higher pressure over the water supply and concerns for the future.

Some statistics point to 87% sewage collection for the city, others to 80%. From all the domestic sewage collected, an amount of 81% receives proper treatment. At slums and irregular housing lots it is more frequent to observe improper sanitation condition and sewage is thrown directly at streams and rivers (almost 48% of the inhabitants of the city´s water basin supposedly protected areas live in slums and irregular housing lots).

Regarding solid waste collection, 99.2% of the houses have the service. In spite of that, there are irregularities on the collection and inspection (with more than 300 clandestine dumping places), and the city suffers with improper disposition of waste clogging culverts and polluting watercourses. The total amount of waste generated by the city daily is ton 5,490,836 and almost 100% of the collected waste goes to regulated landfills. Less than 1% of this waste is recycled.

Energy supply is considerate adequate to meet the demands of the city (99.99% of the houses have energy). It is not unusual for the city to have localized blackouts in certain regions, especially during heavy rains. Illegal connections from energy posts directly to houses are common at poor regions of the city. The industrial, residential and commercial sectors answer more or less equally for the energy consumption of the city (17% of the national consumption and equivalent to 35.3 million megawatts/hour).

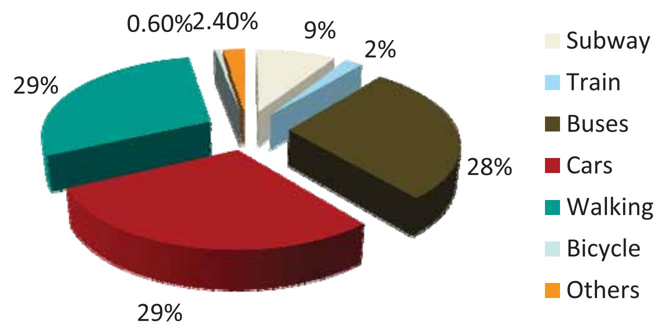


Figure B2: Transport use in SP

The city's fleet is composed of more than 7 million vehicles and traffic conditions are very rough. The public transport system has a railroad is of 61.3 Km, a subway road if of 122.7 Km, and the bus fleet is composed of around 15,000 buses, which circulate through 1,336 Km of road. Each three years it is estimated that the number of bus trips increases by one million. The design and number of routes is considered insufficient to adequately serve all the population.

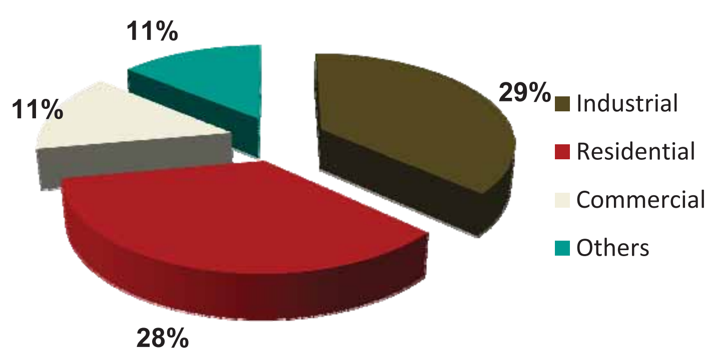


Figure B3: GHG emissions from electric energy use for sector in the city of SP

(Source: Sao Paulo GHG Inventory)

The green area per inhabitant is of 12 m2 and the vegetal coverage is of 74 m2. The city has 511 municipal parks and 10 state parks. São Paulo had, in 2006, only 20% of its original forest coverage.

There are more than 1 million students and 2.360 municipal schools. State schools also attend students, but gradually its attributions are being delivered to the municipality. The central inhabitants spent more time receiving education than those living in the periphery. Bigger literacy rates are found in the central region. In

2000 a rate of 19% of the children with 7 to 14 years old were not doing the basic period of school (Fundamental School). The survival rate for the students with 15 to 17 years was of 62%.

Priorities and Immediate Challenges

The municipality city has a program of goals called "Agenda 2012[7]". This measure was created by law in 2008 and foresees the transparency of the action and priorities carried on by the municipality and should allow the population to follow its development. Each region of the city has its targets that range from health, education, traffic, water quality, sewage piping, quality of parks and leisure areas to safety and transport. More specifically, Sao Paulo faces the following challenges:

- Housing – increase the number of regularization/improvement of slums and allotments and remove families from risky areas;
- Health -Increase the number of attendance of the public services and increase its quality;
- Transport - Increase the coverage of routes of buses, trains and subway, improve bus stops and terminals, remodel electric buses systems and cars, foster public transport, decrease traffic rates, increase traffic safety.
- Education - Improve quality of the public system, decrease evasion rates – specially for the Medium (or Secondary) Education, increase the number of public nurseries (insufficient to attend the growing demand)
- Water Supply - Increase the quality of water and protect water basins
- Sewage -Increase the coverage of the system and avoid illegal disposal of sewage into water courses
- Waste management -Increase inspection of illegal dumping places, decrease waste generation and increase recycling
- Cleaning - Improving the coverage of cleaning culverts and streets services
- Drainage - clean and dredge the river bottoms, clean and increase the existing drainage underchannels, built more "pools" around the city

[7] http://www.agenda2012.com.br/oprograma.

PILLAR 1 - INSTITUTIONAL ASSESSMENT

Agencies Involved in Disaster Risk Management and Climate Change Adaptation

The **Civil Defense Department** acts on the federal, state and municipal levels. Its goal is to plan the actions to prevent and minimize the effects of disasters, either natural or human caused, assist the people affected by them and to rehabilitate or recover the places destroyed by those events. In the city, it is subordinated to the **Municipal Public Urban Safety Secretary,** through the **Municipal Coordination of Civil Defense (COMDEC**). Nonetheless, its personnel are allocated at the 31 decentralized units or "subprefeituras(sometimes creating conflicts of chain authority).

The Municipal Civil Defense acts on Prevention and Recovery, Assistance and Helping and also on Rescue and Search operations, when are assisted by the **Firefighter Department**. At the communities located in risky areas it should exist a Local Group of Civil Defense, or **NUDEC**. It should be composed by community volunteers trained by the Civil Defense to help on emergencies and risky situations, but at the moment the majority of those groups are not created or operating in regular basis.

Institutional Snapshot

Leading agency coordinating Disaster Risk Management efforts

Civil Defense Department subordinated to Municipal Public Urban Safety Secretary

The Emergency Management Center (CGE) is responsible for monitoring and observing meteorological data (there are 180 monitoring stations) and to inform the COMDEC. Then COMDEC alerts the "Subprefeituras" and they can monitor the volume of rain using pluviometers installed at 31 points in the city.

The "**Summer Rain Operation**" is a Plan from the municipality that brings together the **Housing, Transport, Urban Infrastructure, Social Assistance and Subprefeitura´s Coordination Secretaries,** led by the **Civil Defense**, that targets acting towards disasters which occur during the summer (where heavy rain falls are usual). Whenever necessary or from November to April, the municipality organizes its actions to prevent disasters or to timely assist when an emergency takes place, recovering the area after the flood or landslide and providing shelter for those in need.

When a heavy rain approaches, CGE issues an alarming to Civil Defense (COMDEC), but also to the traffic authorities (**CET**), the Health Secretary (**SMS**), **SVMA (Environmental Secretary)** and **Housing Secretary** (SEHAB). Each "subprefeitura" must then act using the Civil Defense agents allocated at the region, following a **POP** – or Standard Operational Procedure. The actions include prevention (evacuating houses at risky places), rescue and saving of people in floods or landslides and further recuperation of the areas.

After the flood or landslide the firefighters rescue possible victims. Water and Sanitation authorities should fix possible broken water pipes and energy agents check the electricity poles. Social assistants must verify housing conditions and if necessary, direct people to provisory shelters while SEHAB arranges for "social rent" or allocates at social housing projects. The Health Secretary, through its Health Vigilance Coordination (COVISA), trains its environmental agents to, before and after the heavy rains, explain to the vulnerable communities about endemic diseases spread by water (such as leptospirosis), its symptoms and the need of medical treatment. The UBS (Basic Health Units) receive folders and posters to distribute to the population on how to avoid leptospirosis and the proper treatment. COVISA also alerts each region of the city about its specific risk of leptospirosis incidence, aiming to prepare the health professionals for the emergence and spread of the disease

Examples of Disaster Related Program or Relevant Decrees

- The "Summer Rain Operation" is an existing Plan from the municipality that brings together the Housing, Transport, Urban Infrastructure, Social Assistance and Subprefeitura´s Coordination Secretaries, led by the Civil Defense. The main project is related to maintaining the actual system for emergency situation: The Municipal Civil Defense acts on Prevention and Recovery, Assistance and Helping and also on Rescue and Search operations, assisted by the Firefighter Department. The Emergency Management Center (CGE) is responsible for observing meteorological data (there are 180 monitoring stations) and to inform the Civil Defense, traffic authorities, the Health Secretary (SMS), SVMA and Housing Secretary (SEHAB). Each "subprefeitura" must then act using the Civil Defense agents allocated at the region, following a POP – or Standard Operational Procedure. The actions include prevention (evacuating houses at risky places), rescue and saving of people in floods or landslides and further recuperation of the areas. There is no information on the updating and testing of the procedures. From the regular citizen point of view, those alarms are not exactly timely or efficient, since they require constant monitoring trough the CGE´s website. At risky areas this is even less likely to occur, since the rate for digitally included in the city in general was of 25% in 2003.
- Civil Defense: Decree 47.534/ 2006 – reorganize the municipal system of the Civil Defense. There are other laws at administrative levels that regulate the Civil Defense and the Operation Procedures. [8]

Shortcomings in Disaster Risk Management and Climate Change Adaptation Management

Civil Defense, as the lead agency on disaster management activities has shortage of agents to act at the risky communities, distributing and teaching the use of the PET pluviometers and water level rulers. CGE also needs resources to train Civil Defense Local agents about informing the population about the risks involving heavy rain. Health Secretary has shortage of medical personnel and adequate facilities to assist citizens on lepstospirosis or climate related diseases. A direct and efficient channel with the community at risky areas must be created to alert on case of emergencies. The same needs to be done to the general population. Prevention measures at risky communities must be strengthened, in order to avoid the need of emergency action. Furthermore, reliable expenditure data on disaster risk management or adaptation programs is lacking.

Estimated Levels of Spending on Pro-Poor Services and Infrastructure

Publicly available data is limited. However, at the begging of 2011, the mayor and the governor of São Paulo launched a joint measure of US$ 5 million investment to fight floods in the city. The measure includes cleaning of the Tietê River, turbines to bomb water from Pinheiros River to the Billings water reservoir, a system of underground channels to dredge the Tietê River and the creation of the Linear Park of the Tietê River (to remove 5ooo families that live irregularly at the margins of the River).

Table B1: Institutional Mapping of Disaster Risk Management Functions

	Risk reduction		
Risk Assessment	*Technical (planning, management, maintenance)*	*Early Warning and response*	*Public Awareness*
• Civil Defense	Civil Defense • Agents and NUDECs	CGE • 18 meteorological stations	CGE • web site

[8] http://www.prefeitura.sp.gov.br/cidade/secretarias/seguranca_urbana/defesa_civil/legislacao/pops__2009/index.php?p=7929

Past Natural Disasters

There is no publicly available systematization of hazards connected to climate events and measure of consequences and losses. This is substantial gap information to be addressed by the municipality. However, other alternative sources of information -an important newspaper of the city - made some registers of rain events in the city:

- *From November 2009 to Mars 2010* heavy rain accounted for 78 deaths and 20,000 houseless. Jardim Romano (a poor neighborhood) was flooded for more than 2 months.
- *Oct 2009* – Tietê and Pinheiros´s rivers overflowed and there were 86 flooding points at the city.
- *February 2008* – In one neighborhood at the east of the city (Mooca) the water flow reached 2 meters. The firefighters were called 53 times to rescue islanded people. Train passengers stayed locked in the wagon for more than 6 hours (due to lack of energy caused by the rain) with 20 cms of water in the floor.
- *November 2006* – the city registers 230 flooding points (doubling the number for the same month one year before)
- *May 2004* – the biggest rain in years (140 mms in a single day) caused 120 flooding points at the city and small rivers over flooded. One person disappeared in a flooded area.

Natural Hazards Snapshot

	Y /N	*Date of last major event*
Earthquake	***NAp***	***NAp***
Wind Storm	***NAp***	***NAp***
River Flow	***Y***	***2009***
Floods, Inundations and waterlogs	***Y***	***2011***
Tsunami	***NAp***	***NAp***
Drought	***NAp***	***NAp***
Volcano	***NAp***	***NAp***
Landslide	***Y***	***2011***
Storm Surge	***Y***	***2010***
Extreme Temperature	***Need available data***	***Need available data***

Table B2: Sao Paulo's hazards, effects and losses

Hazard	Effects	Losses
Heavy rain - more than 30 mms /day	Land slides Floods Stream overflow River overflow Leptospirosis and water transmitted diseases	Lifes Houses and Material goods of residents Cars Health condition
Extreme heavy rain (more than 100 mms / day)	Land slides Floods Stream overflow River overflow Leptospirosis and water transmitted diseases	Lifes Houses and Material goods of residents Cars Health condition
Air dryness	Health problems: respiratory mainly	Health Condition

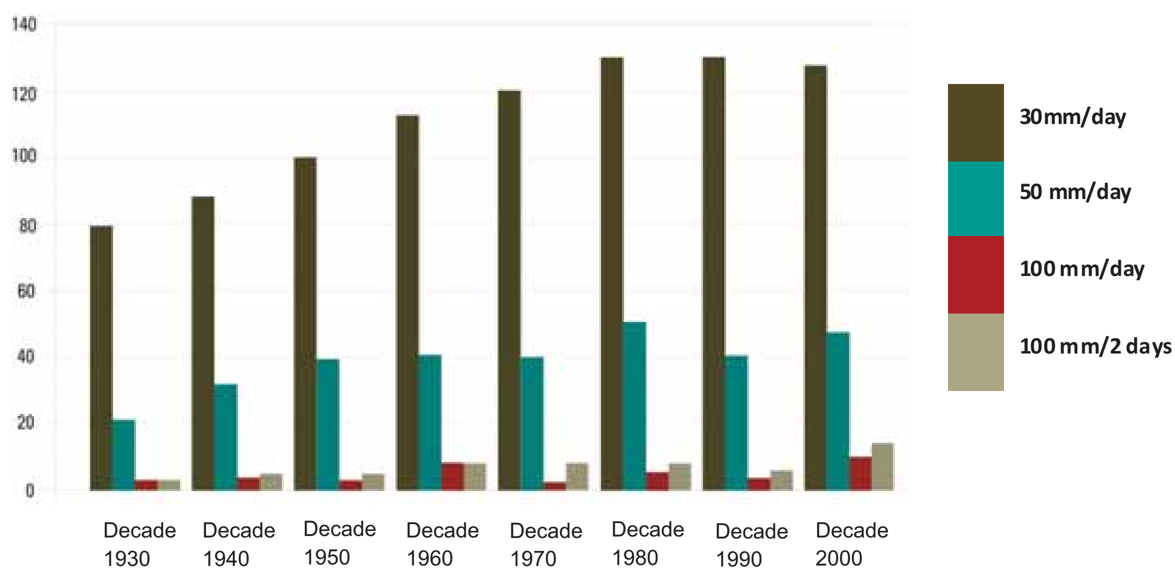
Main Climate Hazards

According to INPE (Institute of Research and Technology, 2009), the city of São Paulo is composed by "pieces" of superficies with different temperatures, forming a mosaic of urban climate. There are heat islands, specific thermic inversion areas, pollution bubbles and local difference in the wind patterns. Therefore it is impossible to plan a single line of action or to precise a unique level of climate event (quantity of rain or degree of heat) that could cause tragedies. Each region has its specific soil, drainage, occupation and permeability conditions and as a result, a different threshold to be met.

That said, INPE produced the chart below, which shows the number of intense rain in São Paulo per decade, from 1933 to 2000, pointing at an increase in the number of days with extreme heavy rain – with more than 100 mms of precipitation in a day or in two days.

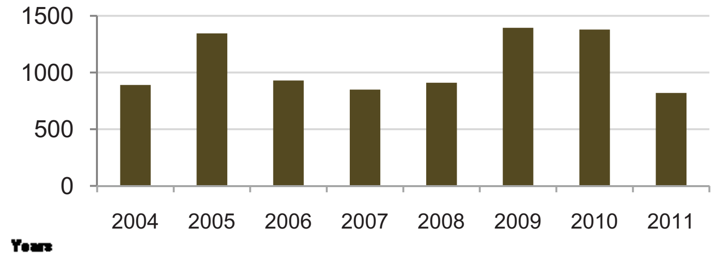
INPE affirms that rains above 10 mms per day are considered heavy, but are not potentially danger. More than 30 mm per day of rain can cause serious floods and inundation, and more than 50 mms can be even more risky for the city (before the 1950´s rain superior to 50 mms was inexistent, but at the present this occurs 2 to 5 times every year).

Figure B4: Days with intense rain per decade



(Source: IAG/USP, Analysis by INPE, 2010)

Figure B5: Flooding points registered by CGE at São Paulo per year 2004 – 2011



(Source: CGE and Mr. Mauricio Maia blog, 2011.

Available at: http://alagamentos.topical.com.br/pontos)

Table B3: Summary of Climate Projections from the regional model Eta/CPTEC for the Metropolitan Region of São Paulo

	present observ	present simulated	2030-40	conf.	2050-60	conf.	2080-90	conf.
Temperature	◥	◥	◥	High	◥	High	◥	High
warm nights	◥	◥	◥	High	◥	High	◥	High
cold nights	◢	◢	◢	High	◢	High	◢	High
warm days	◥	◥	◥	High	◥	High	◥	High
cold days	◢	◢	◥	Average	◥	High	◥	High
heat waves	Unobserved	◥	◥	Average	◥	Average	◥	High
total rain	◥	◥	◥	High	◥	High	◥	High
intense precipitation	◥	◥	◥	Average	◥	Average	◥	High
Precip. > 95th	◥	◥	◥	Average	◥	Average	◥	High
precipitation > 10 mm	◥	◥	◥	Average	◥	Average	◥	High
precipitation days > 20 mms	◥	◥	◥	Average	◥	Average	◥	Average
consecutives dry days	◢	◥	◢	Average	◥	Average	◥	High

(Source: INPE/CEPTEC)

Main Climate Risk Scenarios for the City of São Paulo

Floods - Overflow of river water onto the adjacent lowlands, when the plains along the main watercourses of the Alto Tietê Basin suffer flooding. Despite investments to increase flow capacity of the main watercourses, floods continue to occur due to urban growth and the natural dynamics of floods and major interventions in waterways conducted in the past. The impacts of floods strike: public and private, industrial and commercial activities, urban transport systems and highways.

Heavy Floods - Heavy floods, that is, high water volume and speed. Flooding of this nature may cause destruction of buildings and other urban infrastructure works, material damage of various types and may also endanger the lives of residents of riverine areas. Houses and occupations of people along watercourses subject to this kind of flooding can be seriously affected.

Flash floods with high potential for drag - Several public policies for channeling streams and construction of roads in valleys cause flash flood hazard scenarios along the streets, where there are concentrations of surface water (which also occurs in suburban areas, without paving). This process is characterized by the great power of accumulation of surface water and high destructive power of drag. Hydrological risk scenarios like these expose people and housing to high-risk conditions. The greatest probability of loss of life is found in the periphery regions, and loss of goods in consolidated central neighborhoods. Rainwater runoff concentrated along watercourses or on public roads is responsible for most deaths in hydrological events, when people are dragged and carried by the energy of the water.

Occasional Flooding - The processes of occasional flooding (accumulations of shallow water depths that rarely penetrate the interior of the buildings and affect most public roads) occur widely in various parts of the city, primarily by deficiencies in the drainage system. They are momentary inconveniences for pedestrians and vehicles.

Trash thrown into water courses - A total of 6000 households throw waste directly into waterways in the metropolitan region of São Paulo, a phenomenon that is repeated in city of São Paulo The garbage contributes to siltation and clogging of these waterways, and can be carried by runoff, captured by the river system and taken to lower slopes, where they are deposited. The detention reservoirs of Tiete river are located in these regions of lower slopes and can be damaged by the debris, in case devices that prevent the entry of bottom sediments and trash are not designed.

Landslides on slopes - The slope regions are generally subject to irregular settlements and prone to landslides, which can cause serious accidents and deaths of residents.

More severe rainfall - There is a clear correlation between higher incidence of a seriously heavy rainfall (greater than 100 mm), and more rugged terrains. The climate analysis by INPE indicates that severe rainfall will occur more in some areas of the city, which have concentrations of risk areas for and flooding, increasing the vulnerability of the inhabitants of these places.

Exposure to Hazards

IPT (Technological Research Center) was commissioned by the municipality to map the geotechnical hazardous areas in São Paulo in order to identify sector vulnerabilities to landslides and stream washouts in areas of precarious urban settlements. In this study, hazardous area is defined as one likely to be hit by natural or/and induced processes or phenomena that cause adverse effects. People living in such zones are exposed to physical harm and prone to material losses. Typically, in the context of Brazilian cities, these areas correspond to low-income housing units (irregular precarious settlements).

Risk assessment and analysis factors are simplified, clustered and subject to qualitative analysis of data derived from direct observation in the field. Therefore, the following factors found to be essential for hazard analysis have been assessed: type of process expected, prospect or likelihood of the process occurring; vulnerability of the urban settlements; and damage potential

The analysis included morphological and morphometric features of the terrain; geological materials and profile of the alteration; geological structures; evidence of geological movements**;** ground coverage; and conditions associated with wastewater, pluvial water and subsurface water. A landslide and stream washout hazard zonation has been outlined for precarious urban settlement areas. The method used to map the zonation included the following activities:

- oblique low-height helicopter aerial photography ;
- field work to examine features and limits of hazardous terrains in previously identified hazardous zones;
- assessment of the likelihood of destructive processes occurring;
- assessment of potential consequences with regard to vulnerability of the dwellings;
- estimate of the degree of hazard per sector;
- recommendations for hazard-control interventions; and
- data input into a geo-referenced database, integrated with
- the Secretary of Housing (SEHAB) System

The table below displays the incidence of hazardous areas mapped in the informal/precarious settlements. In like manner as for the data on social vulnerability, slums have the highest incidence rate of landslide and washout hazard areas. About 20% of the land where slums are settled is subject to geo-technical hazard. In the context of a homogeneous distribution of households, slums in São Paulo represent roughly 76 thousand households exposed to hazards. According to the mapping of the city, there are 407 highly hazardous areas located in 26 sub-districts.

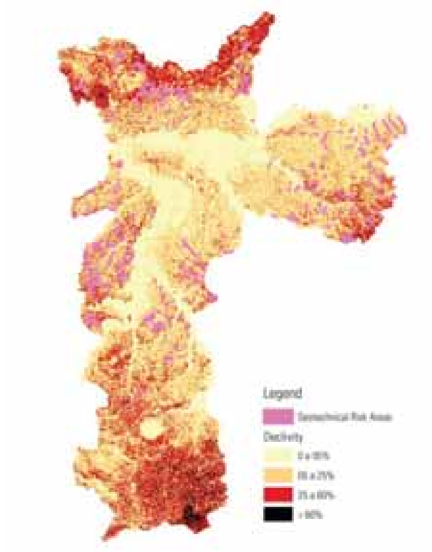
Table B4: Incidence of hazardous areas in precarious/informal settlements, in the Municipality of São Paulo

	Urbanized Centers	Settlements/Allotments	Slums
Landslide Risk Percentage (IPT 2010)	10.43%	3.90%	14.79%
Washout Risk Percentage (IPT 2010)	2.44%	0.68%	5.38%

(Source: HABISP – SEHAB; IPT – 2010)

The figure below displays geo-technical hazard areas overlapping data on steepness. As expected, critical areas are greatly associated with high steepness. Such areas are more prone to be found in the peripheral zone of the city (northern, eastern and southern suburbs). The most critical areas are precisely those where the most precarious settlements are located. Lack of access to a formal land market by the poorest families generated the conditions for these combined factors of social and environmental vulnerability.

Figure B6: Geo-technical Hazard Areas and Declivity Hazard Areas



(Source: IPT, 2010, SEMPLA – Municipal Secretary of Planning)

In addition to identifying hazardous areas, the IPT also ranked them in four levels of criticality. A qualitative hazard analysis has been made on the data obtained from field observation, integrating the analysis parameters into a hazard assessment record card, with the support of aerial imagery. The degrees of hazard were those displayed in Table 5.

Table B5: Degrees of landslide hazard.

Class of hazard	Description of at Hazardous Situations
R1 - Low	Potentially low degree both of geological and geo-technical predisposing factors (steepness, type of terrain, etc.) and of intervention in the sector for the development of landslide and washout processes. There is no evidence of instability processes underway in slopes and drainage banks. It is the less critical condition. If the status remains unchanged, no destructive events are to be expected over one year.
R2 - Medium	Potentially medium degree of both geological and geo-technical predisposing factors (steepness, type of terrain, etc.) and of intervention in the sector for the development of landslide and washout processes. There is some evidence of instability processes underway (yet incipient) in slopes and drainage banks. If the status remains unchanged, there is little probability of destructive events occurring during long, strong rain episodes over one year.
R3 - High	Potentially high degree of both geological and geo-technical predisposing factors (steepness, type of terrain, etc.) and of intervention in the sector for the development of landslide and washout processes. There is significant evidence of instability (ground cracks, sag of embankments, etc.). If the status remains unchanged, destructive events may be expected to occur during long, strong rain episodes over one year.
R4 – Very High	Potentially very high degree of both geological and geo-technical predisposing factors (steepness, type of terrain, etc.) and of intervention in the sector for the development of landslide and washout processes. There is strong evidence of instability, supported by numerous accounts with regard to hazardous conditions (ground cracks, sag of embankments, , wall cracking in houses or retaining walls, tilted trees or poles, slide scars, erosion features, dwellings built near stream banks, etc.). It is the most critical condition. If the status remains unchanged, destructive events are highly probable to occur during long, strong rain episodes over one year.

Source: IPT, Prefeitura do Município de São Paulo

A cross analysis of hazardous areas ranked by their level of criticality and precarious/informal settlements (Table B6) leads to conclude that slums face the most hazardous conditions. In total, more than 5% of slum areas are highly or very highly exposed. This means that these areas are highly prone to be affected by destructive events in the next 12 months. This conclusion only stresses the urgency of taking prevention measures. Furthermore, such hazards can be leveraged by prospective climate conditions, thus potentially increasing the degree of hazard in areas currently ranked as low or medium risk.

Table B6: Cross referencing data: Areas ranked by levels of criticality and precarious/informal settlements in the Municipality of São Paulo.

	Low Hazard	Medium Hazard	High Hazard	Very High Hazard
Slums	2.92%	11.90%	4.11%	1.40%
Settlements/Allotments	0.65%	2.93%	0.97%	0.43%
Urbanized Centers	4.59%	7.62%	0.56%	0.09%

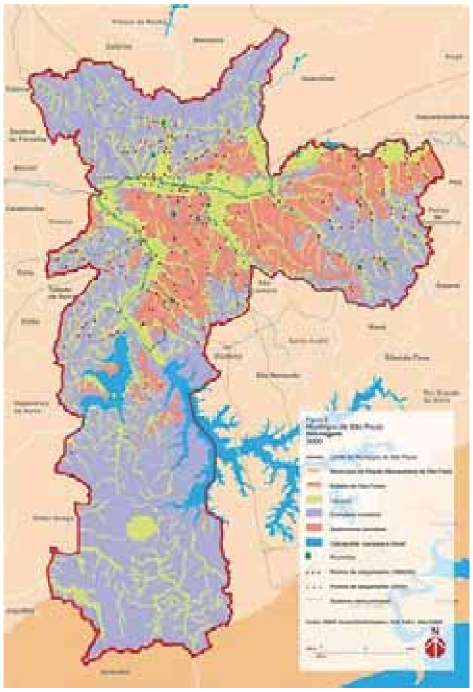
Source: HABISP – SEHAB; IPT - 2010

It is worth stressing that the map made by the IPT does not take into account flood and water logging hazards. While floods are not as lethal as mudslides and landslides, they represent the major hazardous situations to which the population is exposed. These events result in great material damage and may have secondary effects on health by increasing the likelihood of spreading waterborne diseases such as *leptospirosis*. People living near streams or rivers, especially children and elderly, the most vulnerable ones, are also exposed to direct risks such as drowning and physical injury in highly destructive landslides. There is no available data on magnitude, distribution and probability of losses due to each of the most relevant projected hazards.

PILLAR #3 -SOCIECONOMIC ASSESSMENT

The most significant climate hazards for the city of São Paulo are related to floods and landslides. Flooding points have not been mapped by the municipality, only floodable points on streets, which are related to traffic problems (see map below). When dealing with landslides risks, the municipality commissioned IPT to map and rank the critical spots. A qualitative hazard analysis has been made on the data obtained from field observation, integrating the analysis parameters into a hazard assessment record card, with the support of aerial imagery.

Figure B7: Main flooding points of streets (2000).



Source: SVMA, Environmetal Atlas

The followings layers were included in the databank to produce the map:

- Informal/Precarious Settlements in the Municipality of São Paulo (2010):
- Geotechnical Risk Areas (2010): the data consist of the areas mapped by the IPT using in loco verification that presents geotechnical risk of landslide and undermining among water streams. The areas were characterized by four degrees of hazard level, varying from low risk to very high risk.
- Geotechnical Chart (1999): This chart was elaborated in analogical format and contains the mains geomorphologic compartments of the city.

Social Assessment Snapshot

Percentage of city population below poverty line

5.6% in 2000. Atlas DH

Social inequality (Gini index)

0.543 Metropolitan Area. 2006. PNAD

Unemployment (% of total labor force)

12.3% in 2009. SEADE.

Areal size of informal settlements as a percent of city area

7.92% in 2010. HABISP.

Percentage of population living in slums (irregular houses)

0.48%

Percentage of households that exist without registered legal titles

7.9%

Percentage of children completing primary and secondary education: survival rate

Abandon rate for primary: 1.3% and for secondary: 5.4%.

Human Development Index

0.841 in 2000. Source: IBGE.

Predominant housing material

brickwork

- Index of Social Vulnerability (IPVS) by Censuses Tracts (2000). Tracts of the State of São Paulo into 6 groups of Social Vulnerability. The calculation of the IPVS uses basically two different types of information: demographic characteristics and socioeconomic condition of the families.
- Declivity map: Based on the topographic chart of the city developed by EMPLASA, the declivity map is a raster dataset containing classes of declivity for each pixel.
- Transportation infrastructure and public equipment: This data contains the localization of the public equipment of the city such as schools and health unities.
- HAND model: This dataset was produce by the National Space Research Institute for the work about Brazilian megacities and climate change vulnerability. This data was calculated from the topographic chart of the city using spatial analysis techniques. Based on a raster representation obtained from the declivity map, the dataset informs those areas with highest vulnerability to landslide and flooding occurrences.
- Localization of the water reservoir “piscinões”: This data were collected from SEMPLA and corresponds to the localization of the 16 water reservoir constructed in the city to control the flooding occurrences.
- Hydrograph and Drainage System: Corresponds to the watercourses of the city and the natural drainage system.
- Flooding occurrences: This layer contains the points where there were flooding occurrences mapped by the traffic engineering company (CET) responsible for the traffic control in the city.

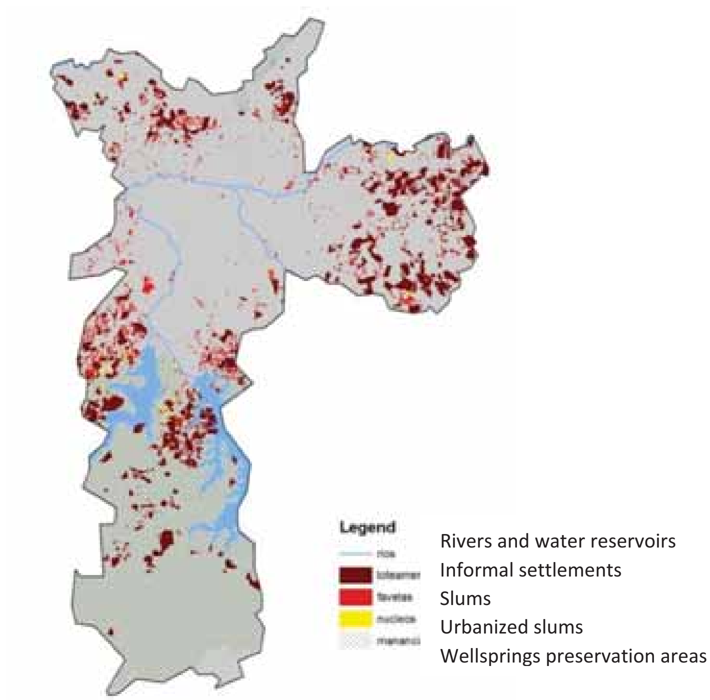
The analytical approach used for the mapping task was based in spatial analysis techniques in Geographical Information System (GIS). All the layers were compiled in an integrated geo referenced databank. The calculations were based on overlay operations applied over the reference layers of Informal Settlements, Slums and Urbanized Slums. Through this operation was possible to calculate the relative incidence in terms of area of geotechnical risk areas and flooding areas. It was also possible to calculate the relative incidence of Social Vulnerability Index in each of the reference layers.

Having calculated both incidences, Social Vulnerability and Geotechnical Risk, it was possible to establish a comparison between all the informal/precarious settlements in the city. The results of the geographical analysis operation were tabulated and organized by themes of vulnerability and hazards. The most vulnerable ones were those settlements which present the higher percentage of areas within highest geotechnical risk and social vulnerability. Finally, thematic maps were generated showing the layers included in the databank allowing the visualization of the critical areas all over the city

Location of the Urban Poor

Most precarious settlements are located in more peripheral areas of the city. Such areas concentrate a number of environmentally vulnerable situations and are the most poorly served with regard to basic services and urban infrastructure. The Study made for São Paulo indicated that observing the relative locations between the risk areas and the informal settlements throughout the city it is possible to observe that there is a high degree of spatial coincidence between them. Nevertheless, this can be a result of the methodology used to primarily identify those sites that received in loco investigation procedures. The map below indicates the location of precarious housing (slums, irregular lots and urbanized slums).

Figure B8: Precarious housing in Sao Paulo



Slum Characteristics

The distribution of the census tracts in the city by groups of social vulnerability clearly discloses the socio-economic macro-segregation pattern that places the central area, and particularly the south-west quarter of the city, as the region with the lowest levels of social vulnerability, as opposed to the peripheral zone, where the highest levels of social vulnerability are recorded. Such more critical situations can be found in southern, northern and eastern periphery of the city. Not by accident, most of São Paulo's precarious settlements are set up in these peripheral areas

According to the municipality, in 2010 there were approximately 890 000 precarious houses at the city. Over 85% of these households are located in slums and irregular settlements, spread across all regions of the city (Image 1). Table 1 displays the distribution of households per type and location in the large administrative regions of the city.

Table B7: Houses by typology of precarious settlements and administrative region of the Municipal Housing Secretariat

	Wellsprings1	North1	South1	Southeast1	East1	Center1	Diffuse2	Total
Slum1	54.886	65.696	117.793	64.980	67.072	10.724	0	381.151
informal settlement1	100.031	60.769	44.953	22.739	154.552	0	0	383.044
urbanized center1	11.193		1.973	1.051	2.640	262	0	24.522
Tenement (cortiços)2 3						11.086	69.303	80.389
/ irregular housing complex1	669	7.403	4.657	2.533	3.056	1.659	0	20.702
Total	166.779	141.996	169.376	91.303	227.320	23.731	69.303	889.808

Slums record the highest proportion of children and youth up to 19 years old (41.7%), which is consistent with the presence of younger responsible for households and a greater number of children. As for household income, most families earn less than three minimum salaries[9]. Although many of them are employed in the formal labor market, low levels of education hinder access to better work opportunities. About two thirds of the heads of household have not completed basic education.[10]

These areas still lack access to urban infrastructure and services supply (Table 2). There are significant deficits in public lighting, paving and urban drainage in slums, urbanized centers and allotments. Likewise, waste disposal and collection services are not available to all households, often because collecting vehicles have no space to circulate. The most critical problem, however, concerns sanitation network. The severity of this situation is mostly evident within the slums, where more than half of the households have no access to sewerage facilities, thus greatly exacerbating environmental problems and exposing inhabitants to diseases and health hazards.

Table B8: Access to urban services and infrastructure in precarious settlements in São Paulo

	Urban Infrastructure			Waste Collection			Sanitation	
	Access to Public Lighting	Paving	Walkways and Culverts	Door to door Collection	Curb Container Collection	Other	No access	With access
Households in Slums	68,30%	67,10%	55,70%	64,90%	20,70%	14,40%	52,30%	47,70%
Households in Residence Centers	86,30%	91,10%	80,80%	67,90%	13,50%	18,60%	8,20%	91,80%
Households in Allotments	92,30%	81,50%	81,20%	91,50%	3,40%	5,10%	20,20%	79,80%
Total	**81,90%**	**75,70%**	**70,40%**	**79,50%**	**11,10%**	**9,50%**	**33,30%**	**66,70%**

Source: Fundação Seade; Secretaria Municipal de Habitação – SEHAB; Pesquisa Socioeconômica em Favelas e Loteamentos no Município de São Paulo, 2007.

A poverty ranking based on the World Bank's poverty threshold criteria (1) reveals the gravity of the situation of the families living in those settlements (Table B9). In the slums and urbanized centers, virtually all families live in poverty or extreme poverty. Again, there is a slight improvement in housing settlements with regard to this indicator; yet about 80% of the families live in poverty or extreme poverty. This finding reinforces the importance of public services supply and policies for those whose ability to fulfill basic needs is extremely low, exposing them to even more critical levels of social vulnerability.

Table B9: Number of precarious inhabitants per level of poverty

	Poverty		
	Indigent	Poor	
Families in Slums	31.90%	66.60%	98.50%
Families in Residence Centers	33.60%	66.40%	100.00%
Families in Settlements	26.10%	53.30%	79.40%
Total	**28.90%**	**59.40%**	**88.30%**

Source: Fundação Seade; Secretaria Municipal de Habitação; Pesquisa Socioeconomica em Favelas e Loteamentos São Paulo, 2007..[11]

[9] The minimum wage established by 2011 is around US$ 325,00.

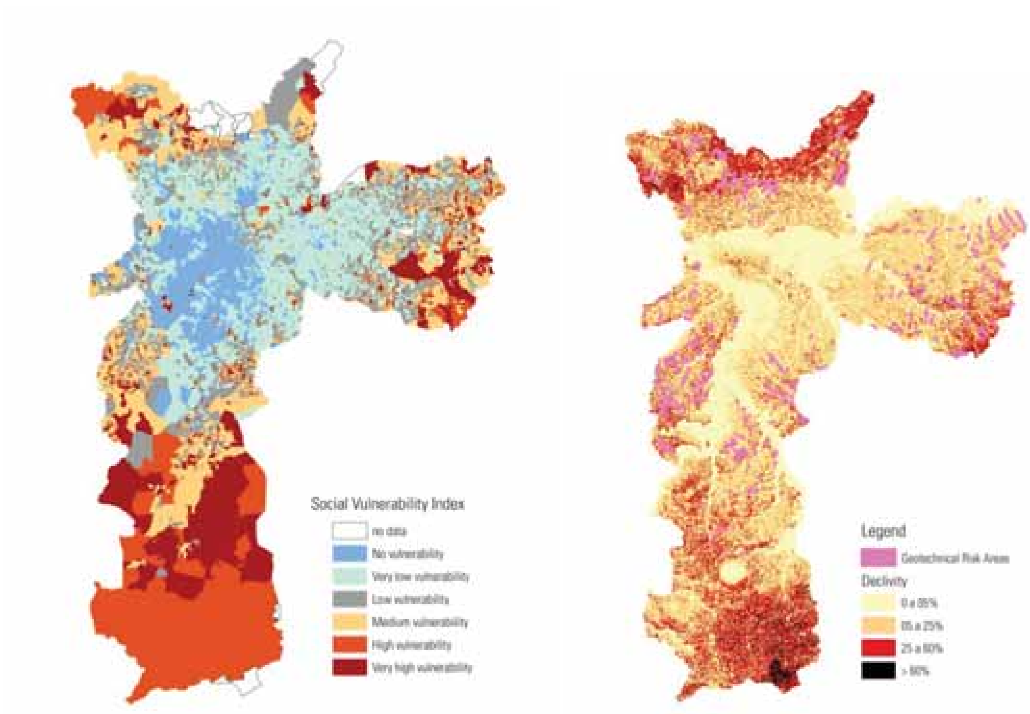
[10] SEADE, 2008.

[11] Social and Economic Research in slums and settlements at the city of São Paulo, 2007.

The situations of social vulnerability disclosed by the data are often associated with exposure to geo-technical and flooding hazards resulting from the occupation of land unsuitable for housing. Moreover, in most cases the dwellings are self-built over long periods. Thus, low technical quality of dwellings associated with occupation of areas unsuitable for housing brings about hazardous situations, often involving imminent risk. Characteristic of these areas are steep slopes and unstable soils or holms and floodway zones naturally prone to flood during rainy periods.

Figure B9 maps the Social Vulnerability City Index (IPVS) for Sao Paulo. It is possible to see the concentration of social vulnerability in the periphery areas of São Paulo. Also, it shows the social vulnerability data (mapped trough IPVS index mentioned before) overlapped with the climate vulnerability (using IPT and INPE data).

Figure B9: Social Vulnerability Index and Social vulnerability overlapped with climate vulnerability



Source: Source: (a) HABISP – February 2010, (b) IPT, 2010, SEMPLA – Municipal Secretary of Planning

Climate Smart Practices

In a joint action with the State of São Paulo (as an environmental compensation measure resulting from the work remodeling Tietê River´s margins), the "Linear Park Varzeas do Tietê" will be implemented in the east region of the city. The program includes the building of the world´s biggest linear park, with 107 km3 of area. Additionally, important environmental areas around drinking water springs will be protected and families living in those irregular areas will be replaced to safer housing projects. Linear parks are also mentioned as an adaptation measure, since it helps to secure the population of risk areas by relocating irregular houses around water reservoirs to safe places at social projects housing units.

This was the policy analyzed by the study that meets both criteria: it is climate smart and also attends the poor population.

Key Lessons in Addressing Poverty in a Climate Smart Way

Some important constrains were found during the study, and a list of them is presents below:

- Lack of personnel from the Civil Defense to be allocated at each vulnerable community, instead of only at the “Subprefeitura”, allowing preparation to emergencies and response quicker and more effective. The same could be said about health agents.
- Lack of mapping and systematization of the city´s entire flooding areas - including housing regions and not only streets - and use this data to prioritize public actions.
- Improve measures to foster public transportation and the use cleaner fuels on them
- Lack of an emergency transport plan to be implemented when there is heavy rain (with use of buses with bi-articulated engines and special corridors for those vehicles to transit)
- Lack of an efficient and comprehensible alert system to the entire population when there is heavy rain, using radio and community channels
- Lack of a plan and studies to analyze and foster the change the city´s growing pattern and land use. To concentrate housing and job opportunities at the same region, and provide it with adequate social equipment such as hospitals, schools, leisure and sports facilities, would avoid large daily dislocation and decrease the traffic and fuel GHGs emission. Another approach is to incentive the occupation of degraded central places, which already have infrastructure but undervalued and concentrates eroded buildings, prostitution and drug use areas.
- Lack of an integrated policy to manage waste issues at the city. Not only the policy should take care of public cleaning, but also deal with waste reduction, inform the population about sustainable consumption and foster recycling.
- Lack of personnel to strengthen existing culvert and streets cleaning policies and enforce inspection measures on improper waste disposal.
- Lack of enforcement and inspection of the Municipal Climate law mechanism of obliging buildings with high concentration or circulation of people (such as malls, large residential condos or commercial building) to install recycling selective facilities and recycling centers.
- Lack of specific procedures related to environmental inspection, epidemiological and entomological control in selected places, aiming the quick discover of biological effects caused by climate change and its treatment.
- Lack of actions to effectively recover areas of permanent preservation, especially those located at floodplains, aiming to avoid or minimize risks caused by extreme climate events.
- Lack of inspection on the law that obliges the new business ventures to reserve a permeable area to absorb water.
- Lack of a an efficient policy to develop energy efficiency measures for the municipality buildings and the city
- Lack of training to public agents to gather information on funding sources for government projects aimed at tackling with climate change adaptation or mitigation and presenting funding projects
- Lack of funding sources for public projects and NGOs projects on climate resilience
- Lack of incorporation by the public agents of the targets and responsibilities given by the climate Law in their daily work (except at SVMA). The law must become part from the daily routine of planning and executing policies in all the related public bodies.
- Lack of unification of the policies and the public data base system. It was noticed in the interviews that it is urgent to integrate policies that addressed climate change, bringing together several organization and public actors. The Climate Change Ecoeconomy Committee is the beginning of this movement, but its role needs to be reinforced
- Lack of civil society participation and planning on climate actions and lack of organized demand for new policies. In order to do that, the society needs to be informed about the topic and their role in it. The

creation of educational campaigns and inclusion of climate change impacts in the school basic curriculum could be important first steps.

- Lack of continuity of the climate policies. As other major policies for the city, they should proceed despite of the changing of the mayor in a new election or the change of Secretary in the middle of the mandate. The policy must be incorporated in the city management and not alter every time the office term ends.

Constraints identified by the consulted communities

- Lack of paved streets on some vulnerable communities, making it difficult for the buses to pass and the people to cross through the mud formed when it rains;
- The lack of an efficient *public transport system* to reach the communities, improving accessibility to other parts of the city and reducing walking distances.
- The lack of quality and coverage of piped water and sewer system, which could rupture during heavy rain and invade the houses and reach rivers or streams.
- The high costs of energy, leading to the use of clandestine connections that are risky when there is heavy rain
- The lack of channeled streams, preventing the death of people who may fall during rains;
- The lack of retaining walls on hillsides at risk;
- The lack of stairways to facilitate commuting for those living in slope areas.
- The lack of or poor quality of garbage collection and inspection of illegal dumpings
- The lack of adequate cleaning of streams and culverts

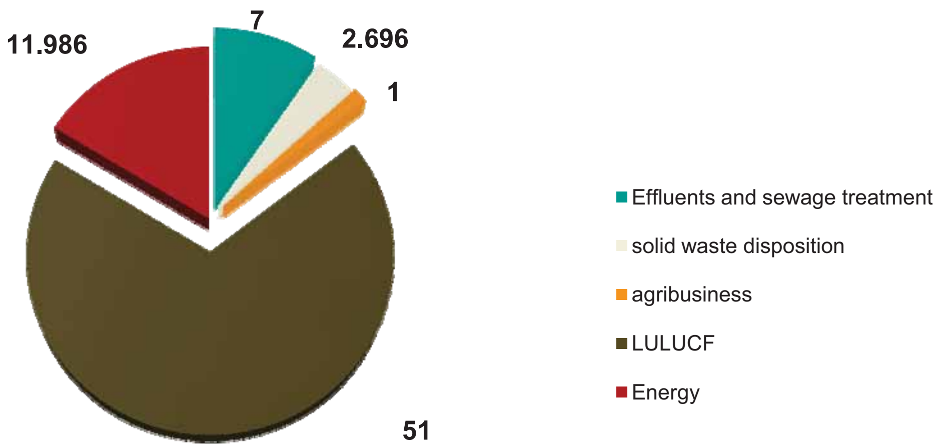
Opportunities promote adaptation strategies.

- Existence of a comprehensive Legal Framework: The legal framework for the city to deal with climate change effects already exists. The Municipal Climate Law sets the foundation for the necessary measures relating to energy, transport, land use, health, building and waste management to be taken by the municipality, private actors and other public bodies. A reduction target was established and the public display of the results is foreseen. Nevertheless, future regulations are needed in some themes, such as payment for environmental services and on inter subnational cooperation.
- Mapping of landslides areas: The risky areas for landslides are already identified and georeferenced by the municipality, allowing the prioritization of prevention actions. The same must be done with flooding spots - what is being measured so far are the flooding points on streets and public pathways, but not at building/housing areas. This data must be produced and shared between Secretaries, in order to be incorporated in their policy planning. If strong preventive projects are implemented, the risks will lower and less need to be spend on emergency action.
- Existence of the beginning of a unified approach to climate issues and policies: The EcoEconomy and Climate Committee was created in an attempt to unite the municipal entities around the subject, and also bring together state and national actors, civil society organizations and public companies. In 2009 the Decree 50.866/2009 inaugurated the Committee´s works. The forum aims to propose, stimulate and follow the adoption of plans, programs and actions that help the fulfillment of the municipal climate policy. It also intends to support actions to mitigate emissions of GHG, promote adaptation strategies, creates seminars and campaigns and suggests the adoption of social and environmental criteria in the process of acquisition of products and services by the municipality. Members of the Committee can help in the identification of technological trends connected to climate change and offer inputs on eventual emends in the municipal climate law. The structure exists and meetings take place regularly, what is needed is to strengthen the Community capacity to propose and implement projects.

Urban Carbon Footprint

According to the 2005 stocktaking[12], the city main source of emission comes from energy, especially from transport (11.986 tons of $GgCO_2eq$).

Solid waste disposal is the second most important source (3.696 tons of $GgCO_2eq$). Liquid effluents (7 tons of $GgCO_2eq$), LLUCF – Land Use, Land Use Change and Forestry (51 tons of $GgCO_2eq$) and agricultural activities (1 ton of $GgCO_2eq$) are not relevant sources in terms of municipal emissions.



In terms of energy, the use of fossil fuels in transport is the most critical issue for the city, since the fleet is composed of more than seven million vehicles (growing each year) and the traffic is heavy (the average of peaks in traffic varied between 80 and 111 kilometers in 2010 and the medium velocity rate was of 16 km/h in 2008)[13].

Although most recent models of cars are "flex" – using both ethanol and gasoline – the majority of the private and public fleet runs on fossil fuel – especially gasoline and diesel (52% of the fossil fuel missions comes from gasoline, 45% from diesel and 3% from natural gas).

A target of 30% reduction on the city´s GHG emission was stated at the law - in relation to emission from 2005. Additional targets should be defined each two years.

Actions such as the settlement of more energy efficient street and traffic lighting and the establishment of the infrastructure and incentives to promote the use of a low-carbon vehicle are being taken, but specialists agree that the city needs to face the problem of planning the use of the land in order of promote shorter journeys between the house and the place of work.

[12] São Paulo´s GHG´s inventory, available at: http://ww2.prefeitura.sp.gov.br/arquivos/secretarias/meio_ambiente/Sintesedoinventario.pdf
[13] http://www.nossasaopaulo.org.br/observatorio/regioes.php?regiao=33&tema=13&indicador=114 and http://infocidade.prefeitura.sp.gov.br/htmls/12_velocidade_media_no_transito_1980_600.html

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ANNEX C: URBAN RISK ASSESSMENT - JAKARTA, INDONESIA

MAP

Administrative map of Jakarta[14]

CITY PROFILE

Jakarta is located on the north coast of the island of Java in the Indonesian archipelago in Southeast Asia. It is the country's largest city and the political and economic hub of Indonesia. The city's built environment is characterized physically by numerous skyscrapers, concentrated in the central business district but also built ad hoc throughout the city, especially in the past 20 years. The rest of Jakarta generally comprises low-lying, densely populated neighborhoods, which are highly diverse in terms of income levels and uses, and many of these neighborhoods are home to varied informal economic activities.

[14] Source: DKI Jakarta

CITY SNAPSHOT

(From Global City Indicators)

Total City Population in yr: 9.6 million in 2010

Population Growth (% annual): 2.6%

Land Area (Km2): 651 km2

Population density (per Km^2): 14,465

Country's per capita GDP (US$): $2329

% of country's pop: 4%

Total number of households (based on registered Kartu Keluarga): 2,325,973

Dwelling density (per Km2): N.A.

GRDP (US$) 10,222

% of Country's GDP: 20%

Total Budget (US$) $3.1 Billion

Date of last Urban Master Plan: 2010

The population of Jakarta is considered wealthy relative to neighboring provinces and other islands, and indeed its GDP per capita is more than four times the national average.

Jakarta is located in a deltaic plain crisscrossed by 13 natural rivers and more than 1,400 kilometers of man-made waterways. About 40% of the city, mainly the area furthest north near the Java Sea, is below sea level. Jakarta is prone to flooding from water draining through the city from the hills in the south, and also from coastal tidal flooding.

The successful provision and management of services by the provincial government is lagging in most sectors. In spite of a booming economy much private-sector property development, Jakarta's spatial planning and infrastructure, as well as service provision – transportation, green space, affordable housing, clean water, healthcare, and education – have not kept pace with demand.

Traffic congestion is a major problem facing the city, with only incremental efforts to relieve congestion through the development of public transportation, most prominently, the TransJakarta Busway. The increasing number of vehicles on the streets of Jakarta is outpacing the development of new roads. Total gridlock in the city is projected to occur as early as 2016 under the transportation Business As Usual scenario.

Lack of piped water provision is driving large multi-use developments and small residential communities alike to drill wells to access groundwater. This extraction of groundwater is causing areas of Jakarta to sink rapidly, particularly in the north of the city. Along with sea level rise, land subsidence is one of the greatest challenges facing Jakarta.

The provision of housing for the poor and lower-middle classes continues to be inadequate relative to demand. With consistent in-migration of people into the city, estimated at 250,000 annually, housing is in constant demand, but costs are escalating. Skyrocketing land prices and rampant private sector development that is under-regulated has resulted in a booming real-estate market that excludes the poor. Large informal settlements have grown over many years along waterways, natural rivers and reservoirs, contributing to the pollution and clogging of these areas.

There is currently no city-wide solid waste management plan for Jakarta. The waste collection mechanisms in the city are largely contracted out to private companies, with wealthier areas paying more, and consequently receiving better and more consistent service. In many areas, waste is collected and picked over by a highly efficient but informal waste picker and recycling community.

PILLAR 1 - INSTITUTIONAL ASSESSMENT

Agencies in Disaster Risk Management and Climate Change Adaptation

The key agencies in Jakarta responsible for coordinated efforts on climate change adaptation and disaster risk management are Badan Pengelola Linkungan Hidup Daerah (BPLHD) - the environmental agency; Badan Perencanaan Pembangunan Daerah (BAPPEDA) - the planning and development agency; Badan Penanggulangan Bencana Daerah (BPBD) - the provincial disaster management agency; Satuan Tugas Koordinasi dan Pelaksana (SATKORLAK) - the national disaster risk management board; and Biro Tata Ruang, the bureau of spatial planning.

- BPLHD is the environmental agency and the key governmental contact for many of the NGOs and other organizations working at the community level. They are involved in a number of greenhouse gas emission abatement programs in Jakarta, including overseeing the development of a greenhouse gas emissions baseline, to be completed in 2011. BLPHD also manages a number of community-level adaptation initiatives and studies in partnership with NGOs and donor organizations.

- BAPPEDA is the development and management body for Jakarta. They manage large infrastructure projects such as sea wall construction in north Jakarta and the building of floodgates along the rivers and major infrastructure projects like the East and West Flood Canals. They manage, finance and carry out the physical management of flood infrastructure along with Pekerjaan Umum - the department of public works.

- BPBD was established as the citywide agency for disaster risk management only at the end of 2010. Until then, disaster response was handled by SATKORLAK, which is a national association based largely in the fire department and acted as more of a committee since it was not anchored in a particular agency or formalized into government structure. The formal empowerment and role of BPBD has yet to be fully developed, integrated and made widely public.

- The Biro Tata Ruang is responsible for the development and management of short-, medium- and long-term spatial plans for the city. Within the plans are specific laws and articles articulating the incorporation of both climate change adaptation and mitigation actions as well as the need for disaster risk management. However, the implementation and enforcement of these laws and articles through BAPPEDA and the Department of Public Works.

Institutional Snapshot

Leading agency coordinating Disaster Risk Management efforts:

Badan Penanggulangan Bencana Daerah (BPBD)

Government staff trained in early warning, preparedness, and recovery:

N.A.

Disaster Risk Management budget: *Actions and programs under different agencies*

Non-governmental organizations involved in Disaster Risk Management:

The World Bank, Institute for Essential Services Reform, Mercy Corps

Relevant Policies and Legislation

Climate change is integrated to a limited extent in the medium and long term city spatial plans, but they relate for the most part to areas of the city which are experiencing the greatest harm from flooding or other problems. The official language in the plans acknowledges the need for climate-change related strategies as well as disaster mitigation and response plans, but does not go into specific detail.(See table below for climate change-related policies in the RTRW 2030 Spatial Plan.)

Adaptation plans to cope with extreme weather events and sea level rise are piecemeal within the plans and agencies. More generally, the governor of Jakarta has made public commitments in the international arena to reducing the city's greenhouse gas emissions.

The plans and policies of BPBD are not yet known, although a city-wide strategy for disaster prevention and response will most likely be developed and managed by this agency. Within the National Action Plan for Disaster Risk Reduction (NAP-DRR), there are a number of listed actions for Jakarta specifically, but they have been developed by different sectors and ministries. The budget numbers included are the requests by the implementing party and have not been allocated or approved.

Table C1: Policies Relating to Climate Change in the RTRW Spatial Plan 2030

i	The Capital Region of Jakarta as other major cities in the world facing global challenges,particularly global warming and climate change, which requires action on climate change, both adaptation and mitigation actions need to be included in spatial planning;
Article 5	5) To realize the integration and control of space utilization as referred to in Article 4, letter e, set the policy as follows: a. implementing nature conservation reserves, nature conservation area, area protection, water resources, and development of green space for urban ecological balance in Jakarta; b. improve the quantity and quality of green space as an effort to improve the quality of Jakarta city life; c. reduction in greenhouse gas emissions in an effort to anticipate global warming and and climate change; and d. establish and maintain areas that have strategic value of the influential on environmental aspects.
Article 5	(8) In order to achieve disaster risk reduction as referred to in Article 4 letter h, set the policy as follows: a. develop infrastructure and facilities for natural disaster risk reduction; b. develop the infrastructure and non-natural disaster risk reduction; and c. promote adaptation and mitigation to prepare for the threat of global warming and climate change and increased risk of another disaster.
Article 10	3) Strategies to implement the policy referred to in Article 5 paragraph (5) c, include: a. implement the carrying capacity of natural resources and environmental capacity for sustainable development; b. apply the concept of environmentally friendly building and the concept of sustainable urban design; c. improve the quality and quantity of green space; d. increase alternative energy e. based waste management technology; f. improving wastewater treatment; g. reduce the use of ozone depleting substances; h. restore the function of mangrove forest; i. improve public facilities, mass transit, and j. improve the control of mobile source emissions and stationary sources.
Article 13	(1) Strategies to implement the policy referred to in Article 5 paragraph (8) letter a, including: a. develop infrastructure and facilities for flood control; b. improve and enhance the drainage system; c. develop a path, region, and disaster evacuation space; and d. build a sea dike in order to anticipate rising sea water.

Article 13	(3) Strategies to implement the policy referred to in Article 5 paragraph (8) c, include: a. direct utilization of disaster areas for cultivation activities that have a high adaptability; b. reducing disaster risk through redesign through the application of technology and engineering in disaster areas; c. mengembangankan North Coast region (northern) as an effort to anticipate changes in climate; d. improve the provision of open space for the anticipated blue intensity rainfall; e. create life side by side with water; and f. Laws refine areas of the building and the environment appropriate hazard threat.
Article 57	(1) The development of energy systems and networks referred to in Article 45 letter d is intended to merjamin supply reliability and continuity of supply of energy for household needs, services, trade, industrial, and transportation with respect to conservation and energy diversification factor. (2) energy conservation factors referred to in paragraph (1) attention to aspects of mitigation of climate change and global warming. (3) Development of energy systems and networks referred to in paragraph (1), include: a. electrical system; b. infrastructure systems of fuel gas and c. infrastructure systems of fuel oil.

[15]Articles found in the RTRW 2030 relating to climate change.

Ongoing Programs in Disaster Risk Management and Climate Change

An important step taken by the DKI government is the establishment of the provincial disaster risk management agency, BPBD. Currently, there is no comprehensive disaster risk management program for the city of Jakarta, or disaster response plan. There are a number of large-scale infrastructure projects, such as the Giant Sea Defense that protects coastal neighborhoods from tidal surges, and the East and West Flood Canals. The Giant Sea Defense has been presented to the Jakarta government as a feasibility study. The Canals are the largest and most ambitious projects for Jakarta in terms of flood management, but the intricate and smaller secondary and tertiary systems are still under-managed and inadequate.

Many of the alert systems work at the community level and are largely self-organized. These are generally warnings from upstream floodgates that water is getting high that are sent via SMS text message to neighborhood heads so they can warn their communities. It is unknown how many of these small and informal networks are actually in place. It appears that they evolved out of local necessity. Many of the resources for the smaller, community-level projects and programs come from local and international NGOs. Small government agencies at the neighborhood level (RT and RW) are allocated budgets for some infrastructural interventions, but they are not consistent across the city and in many cases kelurahan-level budgets are not spent in entirety every fiscal year due in part to complicated and lengthy approval mechanisms by the provincial government, or a lack of capacity at the local level to carry out physical interventions. This is a national trend and not specific to Jakarta.

Policy Shortcomings

Formalization, publication and awareness-raising are still sorely lacking in the areas of climate change and disaster risk management in Jakarta, both inside many government agencies and in the public realm. In many ways the Jakarta government only beginning to comprehensively measure and understand the city's key vulnerabilities – as well as its strengths and resources – to become climate-resilient and to anticipate potential disasters. There is also a lack of coordination between the agencies described above, and very little enforcement of well-meaning laws to create a safer and more secure built environment. BNPB (Badan Nasional Penanggulangan Bencana) was developed as the national coordinating and monitoring agency in 2008, with an operating budget for disaster response of about IDR 4 trillion (US$

[15] Source: RTRW 2030, Biro Tata Ruang

464 million). However, more is currently needed for upgrades and implementation as reported in the National Action Plan for Disaster Risk Reduction (NAP-DRR). The table below lists items submitted for financing by various agencies for Jakarta (not exhaustive, since Jakarta is included in initiatives that also include other cities).

Target	Location	Performance Indicator	Funding Indication (in approx. USD value)			Source of Funding	Implementing Party/Coordinator
	Province		2010	2011	2012		
Improvement of the roles of the supervisory and monitoring institutions in the context of disaster risk reduction	Jakarta	Availability of a special directorate responsible for safety with an authority that can assure compliance (of the operator of facility and infrastructure) with the applicable railway regulations	$92,453	$0	$0	APBN	The Ministry of Transportation, Directorate of Safety and Technicalities of Facilities, Directorate General of Railways
CBOs and Government	Jakarta	# of IEC materials produced/ guideline for advocacy developed	$8,841	$0	$0	PHLN	ECB Indonesia (Care-CRS-Oxfam-World Vision-Save the Children-Mercy-Corps- MPBI-IMC)
—	—	Support to national and local strategy for DRR and CCA linkages	$91,202	$91,202	$91,202	PHLN	National Council for Climate Change (DNPI), National Disaster Management Agency (BNPB)
To make the command post of the Ministry of Home Affairs as the center of disaster management communication and coordination	Jakarta	Availability of data and information on disasters in regions in the Disaster Command Post of the Ministry of Home Affairs	$57,783	$0	$0	APBN	KEMDAGRI - Ministry of the Interior
ECB members-CBO's government	Jakarta	CP of ECB members compiled	$2,600	$5,201	$0	PHLN	OCHA - UN Office of the Coordination of Home Affairs
2 activities (Preparation of Program Guidelines and Planning)	Jakarta	Organization of activities for preparing program guidelines and planning which focus on the Main Program of the Ministry of Social Affairs in the National Disaster Management System namely "CCBDM" or community-based integrated disaster management aimed at increasing the capacity of the community in an integrated manner to be more prepared for anticipating future disaster through early warning system process, rapid response and social recovery	$432,715	$519,258	$623,110	APBN	The Ministry of Social Affairs
Strengthening of regulation for responding to railway accident, including accident caused by disasters	Jakarta	Availability of Ministerial Regulation concerning guideline on the audit of the safety of railway facilities and infrastructure	$46,227	$0	$0	APBN	The Ministry of Transportation, Directorate of Safety and Technicalities of Facilities, Directorate General of Railways
Strengthening of regulation for responding to railway accident, including accident caused by disasters	Jakarta	Availability of regulation concerning guidelines on investigation, examination and response to railway accidents, including those caused by disasters	$46,227	$0	$0	APBN	The Ministry of Transportation, Directorate of Safety and Technicalities of Facilities, Directorate General of Railways
Data management center, earthquake database and data sharing system	Jakarta	Th e realization of reliable national and international earthquake data service	$115,567	$57,783	$57,783	APBN	BMKG (Meteorology, Climatology and Geophysics Agency) Deputy for Geophysics
Mapping the region having high risk strong earthquake vibration	Jakarta	Th e availability of information for the need of earthquake-resistant building and other needs	$34,670	$34,670	$34,670	APBN	BMKG (Meteorology, Climatology and Geophysics Agency) Deputy for Geophysics
Improvement of earth magnet data and information service	Jakarta	Users may obtain more up to date data	$14,446	$0	$0	APBN	BMKG (Meteorology, Climatology and Geophysics Agency) Deputy for Geophysics

Sample projects for DRM and DRR activities submitted to the NAP-DRR by various agencies.[16]

Lead Agency for Disaster Risk Management

Until recently, a national ad-hoc agency (SATKORLAK) anchored in the fire department and was responsible for disaster response, but was doing very little anticipatory planning. Jakarta did not have a dedicated working group or agency. At the end of 2010, BPBD was established for the province of Jakarta. As it is a new agency, the role it will play in the development of disaster mitigation plans or funding allocation for the city's kota or kelurahan remains unclear.

[16] Source: National Action Plan for Disaster Risk Reduction, DKI Jakarta

Mainstreaming Risk Reduction

In order to mainstream risk reduction activities the Government is incorporating of those activities and projects into the long term spatial plans, the most recent of which is Jakarta's plan for 2010-2030. NGOs and other donor organizations are playing important roles currently to aid communities and community-level government actors to educated and prepare individual citizens, families and community leaders to prepare for damaging events such as floods from extreme rainfall or tidal flooding. However, these actions are piecemeal across the city and it is mostly poor communities that are targeted by these organizations.

Expenditure on Pro-Poor Programs and Climate Adaptation

The 2011 city budget for Jakarta is slightly more than USD $3 Billion. Indonesia has a countrywide poverty alleviation program (Program Nasional Pemberdayaan Masyarakat (PNPM) - Mandiri or the National Program for Community Empowerment[17]) that has had success in other urban areas, but has not adequately reached extremely poor parts of Jakarta. Many of the poverty reduction actions are disbursed throughout various services and departments.

Total Annual Budget of Departments Carrying Out Pro-Poor Services[18]	
Agency/Department	**Annual Budget 2010**
Community Empowerment	$4,757,965
Health	$198,596,454
Family Planning and Prosperity	$4,810,028
Social Services	$5,243,572

The most relevant spending on climate change adaptation related infrastructure. This is not the entire budget, but lists some larger-scale initiatives[19].

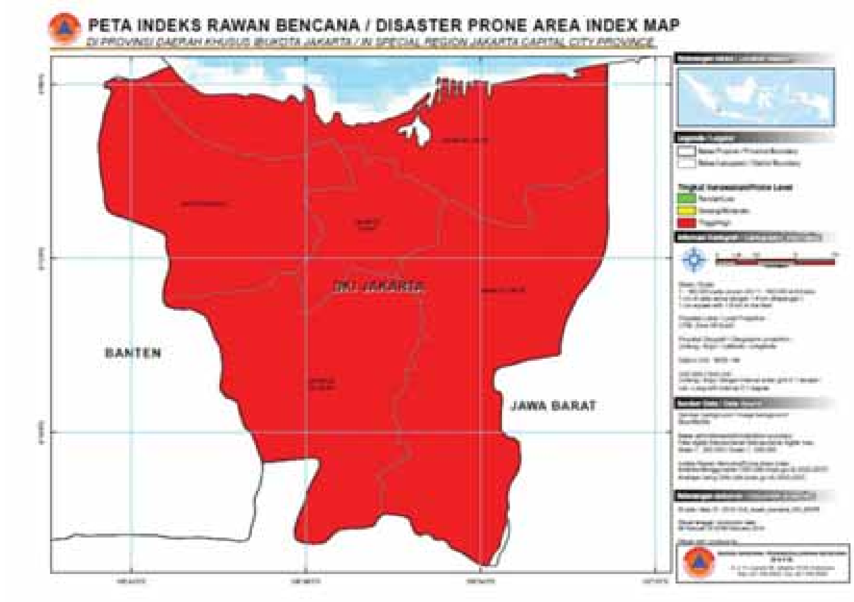
Infrastructure Investments per Year DKI	2009	2010
Flood Control		
East Flood Canal	$93,132,994	$60,350,180
Drainage and River Dredging	$10,803,427	$11,424,314
Dam, polder and catchment area development	$620,887	$40,605,985
Pollution Containment		
Open Green Space Development	$15,909,599	$77,238,296
Climate Change Adaptation		
Sea Wall	$2,235,192	$5,587,980

[17] For more information see www.pnpm-mandiri.org
[18] Source: www.jakarta.go.id
[19] Source: www.jakarta.go.id

Institutional Mapping of Disaster Risk Management Functions

Risk Assessment	Risk reduction: Technical (planning, management, maintenance)	Risk reduction: Early Warning and response	Risk reduction: Public Awareness
DNPI • Climate change technical studies • Mitigation activities coordination	BNPD • National DRR plans and policies • NAP-DRR (2010)	RT and RW • Localized early warning systems for floods via SMS and	BPLHD • Climate change related events and programs like car free day
BPBD • DRM and DRR plans, management and training	BPBD • local disaster management and response plan for Jakarta (to come).	DKI Department of Public Works (PU) • Early warning system coordination with other provinces (water management)	DNPI • Conferences and publications
BAPPENAS • Inter-agency coordination for infrastructure plans	BAPPEDA • Infrastructure and planning projects; maintenance with PU and other agencies	SATKORLAK • Emergency Response	Biro Tata Ruang • Publication of 20 year spatial plan available to public.
P2B • Risk mapping for earthquakes			

PILLAR 2 - HAZARDS ASSESSMENT



Map of Ranking of disaster-prone area by BNPB in 2008, with red being the most disaster prone. Maps beyond this level of detail do not yet exist.[20]

Past Natural Disasters

The largest floods in Jakarta's history are those that took place in 2002 and 2007. Jakarta's floods are notorious, and the resulting stalling of traffic, lost productivity and property damage is said to cost the city more than USD 400 million per year[21]. By 2002, more than a quarter of Jakarta's area was affected. The most disastrous flood to date, in February 2007, cost 57 lives, displaced more than 422,300 people, and destroyed 1,500 homes, damaging countless others. Total losses to property and infrastructure were estimated at USD 695 million[22]. However, flooding of that magnitude is relatively infrequent and is not necessarily the principal issue for Jakarta – flooding occurs regularly throughout the year, stalling traffic, damaging houses and gravely attenuating the flow of business at all levels of society. Even with just a moderate amount of rain, vehicular mobility in the city is critically impaired, often for hours.

In the NAP-DRR, parts of Jakarta are listed as vulnerable to three hazards listed in the report. However for DKI Jakarta, the analysis does not go beyond the level of the kota, so it is hard to know how the risk affects different areas of the municipalities and their diverse populations.

Natural Hazards Snapshot

	Y /N	*Date of last major event*
Earthquake	***Y***	***September 2009 and periodic***
Wind Storm	***N***	
River Flow	***Y***	***Regularly, extreme during rainy season***
Floods, Inundations and waterlogs	***Y***	***October 2010***
Tsunami	***N***	
Drought	***N***	
Volcano	***N***	
Landslide	***N***	
Storm Surge	***Y***	***January 2008 and recurring***
Extreme Temperature	***Y***	***Increasing on a yearly basis***

[20] Source: bnpb.go.id
[21] http://www.dredgingtoday.com/2010/07/23/indonesia-problems-with-flooding-in-jakarta-continues/
[22] *Why Are There Floods In Jakarta? Flood Control by the Government of the Province of Jakarta*, PT Mirah Sakethi, 2010

Table C2: Jakarta's Kota in the National Ranking of Kabupaten or Regencies at HIGH risk for various disasters.

Earthquake (out of 151 listed)	
80	West Jakarta
95	North Jakarta
122	East Jakarta
137	South Jakarta
Drought (out of 182 listed)	
8	North Jakarta
9	East Jakarta
10	Central Jakarta
11	West Jakarta
37	South Jakarta
Flood (out of 174 listed)	
2	North Jakarta
3	West Jakarta

Main Climate Hazards

The main hazards for Jakarta relate to water management and flood control. Extreme weather events cause overloading of the existing drainage system, while sea level rise coupled with land subsidence is making Jakarta increasingly vulnerable to tidal floods due to its coastal location. Jakarta has also experienced earthquakes (although minor, but as recently as 2009) and should be prepared for other unprecedented geological events and tsunamis.

Hazard	Effects	Losses
Earthquake	Until now small in scale with very little physical damage.	Until now no great material or life loss from earthquakes.
River Flow	Disruption of business, damage to property, power outage, groundwater pollution, distribution of solid waste through high and fast water flow.	Property damage, business damage, tainting of ground water, loss of life, spread of disease and refuse.
Floods, Inundations	Depending on severity can affect traffic circulation, business activity, damage to property, power outages, displacement, spread of disease.	Loss of property and businesses, spread of illness and loss of life, loss of access to clean water.
Storm Surge	Locally known as rob, extreme tidal floods from the sea have become more serious in the past few years in the coastal areas of the city. Sea water intrusion into aquifers.	Seawater intrusion into drinking water, damage to property including boats, halt of industry and mobility.
Extreme Temperature	As a result of both urbanization and loss of green space, increases in ground temperature and resulting instances of dengue.	Loss of life due to dengue, usually within very poor communities.

Areas at High Risk of Disasters and Climate Impacts

In the sea level rise scenarios that have been modeled for North Jakarta, there are a number of industrial and residential areas and ports that will be submerged in the next 100 years, given projected sea level rise and land subsidence. Most of Jakarta's remaining industries are located in the north, as are its historic and active ports, which are key for Java's fishing economy. The airport and other major roads, as well as Kota Tua, the 17th century remnants of the first Dutch settlement, will also be affected.

Figure C1: Impact of sea-level rise on North Jakarta in a business-as-usual scenario.

Other sources of Information on Potential Impacts of Disasters

- Jakarta Coastal Defense Strategy (JCDS): Recommendation and study by an international consortium to build a 60 kilometer long sea defense along the coast to prevent damage from both land subsidence and sea level rise. The consortium is funded by the city of Rotterdam and is still only at the stage of a feasibility study.[23]

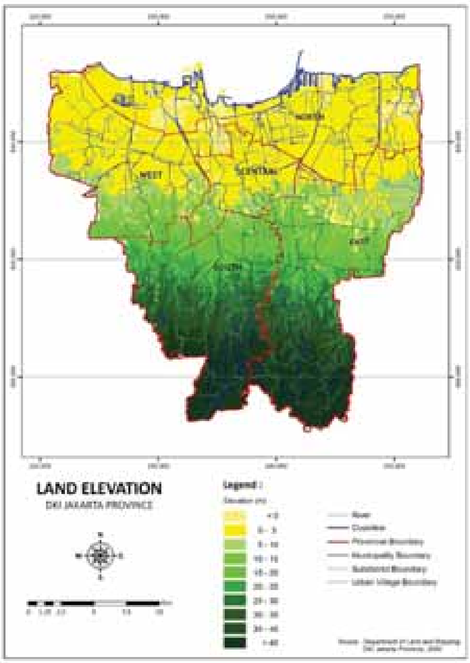
- Jakarta Urgent Flood Mitigation Plan (JUFMP): A study and dredging plan by the World Bank and DKI Jakarta, which included the "Jakarta Flood Hazard Mapping Framework" which does not include cost analysis but provides the infrastructure framework required. However, the complete financial study is available at DKI and the World Bank.[24]

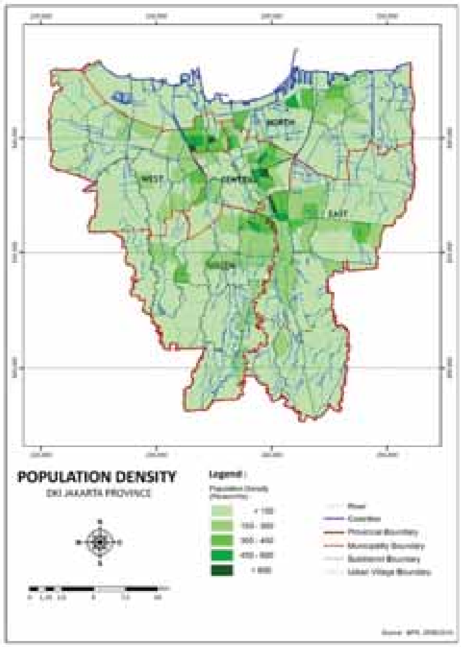
- The Jakarta Building Control and Monitoring Office (Penataan dan Pengawasan Bangunan: P2B) is developing a risk map for Jakarta within micro-zones of 150 square meters each, which analyzes buildings and soil conditions within each. This initiative relates specifically to earthquakes and building quality. The map is not yet complete.[25]

[23] http://www.beritajakarta.com/2008/en/newsview.aspx?idwil=0&id=17983
[24] http://web.worldbank.org/external/projects/main?pagePK=64283627&piPK=73230&theSitePK=40941&menuPK=228424&Projectid=P111034
[25] Source: http://www.thejakartaglobe.com/opinion/editorial-mapping-out-path-to-a-quake-ready-jakarta/432586(downloaded on April 25, 2011)

PILLAR #3 -SOCIECONOMIC ASSESSMENT

Population Exposure to Hazards





All of Jakarta is considered at high risk to disaster, since very few areas of the city are immune to recurrent floods. However, the most vulnerable areas of the city are those along the coast, since they are susceptible not only to the effects of tidal flooding from the sea, but also floods from the rivers and canals that are discharged into the Jakarta Bay. These communities in the northern areas are also experiencing the greatest land subsidence. The poorest people in Jakarta are generally those squatting on empty land along riverbanks and canals. It is estimated that they comprise about 3.5% of the urban population.

Location of the Urban Poor

The level of exposure of very poor communities in Jakarta to both climate and natural hazards is extremely high. This is due in part to the fact that many of the poorest communities have settled illegally in areas close to sources of water: along major drainage and water management areas and along the coast. This renders them vulnerable to both flooding due to increased rain, as well as extreme hydrological events and tidal anomalies and floods from the sea.

Social Assessment Snapshot

Percentage of city population below poverty line: 3.6%

Social inequality (Gini index) in 2002 (UN Habitat): .32

Unemployment (% of total labor force): 11.05%

Areal size of informal settlements as a percent of city area: Unknown

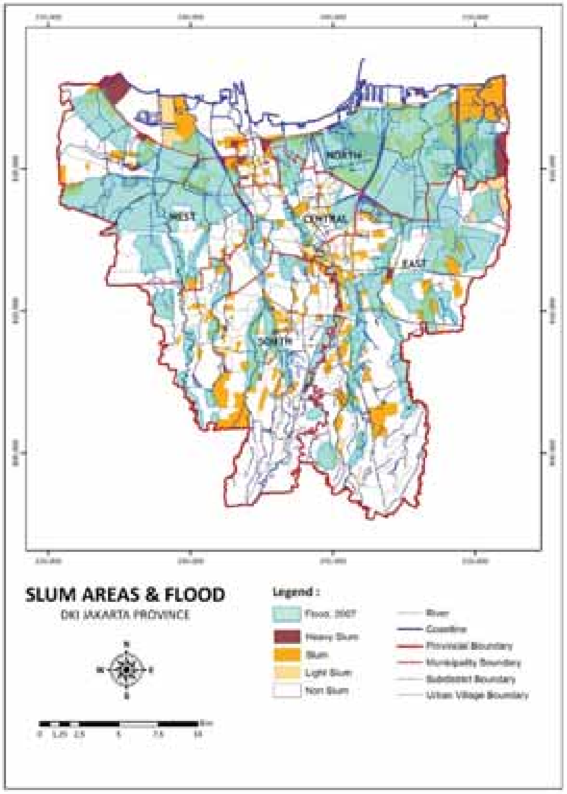
Percentage of city population living in slums: 5%

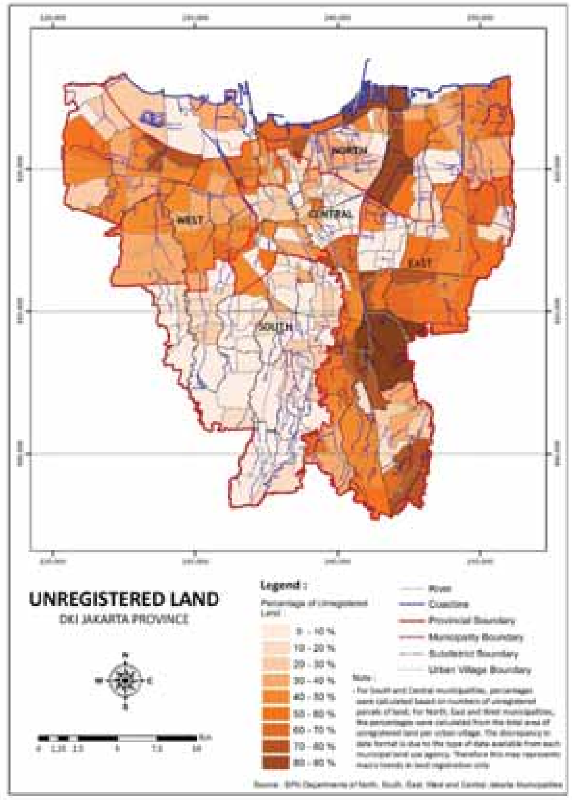
Percentage of households that exist without registered legal titles: N.A.

Percentage of children completing primary and secondary education: N.A.

Human Development Index: 77.36 in 2009

Predominant housing material: For the very poor, assorted salvaged materials, for self-builders, concrete blocks and brick.





Characteristics of Informal Settlements

The poorest communities in Jakarta live in self-constructed settlements, usually on land without formal legal title, and working in informal jobs. In some instances, illegal and undocumented land leasing and landlord-tenant contracting is practiced. Jakarta has a long history of these informal settlements. In many of these areas, some individuals and families have lived in what could be considered as 'slums' for decades, so well established social networks and cultural identities of place in Jakarta run extremely deep. While the numbers for Jakarta may be slightly lower, and remain hard to accurately measure, up to 68% of Indonesians across the country make their living through informal means.[26] In most areas of Jakarta, the residents of informal settlements work as maids, janitors, satpams (security guards), parking attendants and also run small local businesses such as food stalls and small tokos (retail kiosks). In coastal settlements, the fishermen are key to providing larger companies with supplies of fish to sell across the city.

Good Practice Examples

Jakarta has yet to develop a comprehensive plan to address extreme poverty in the city, especially in terms of involuntary relocation, housing provision and economic development of very poor communities. Indonesia has a number of poverty alleviation policies like conditional cash transfers and other mechanisms, but many of these are not designed for the issues and challenges of a megacity. Many of the very poor subsist on jobs and small businesses that are part of Jakarta's vast informal economy. Integrating climate change adaptation systems and education into regular social services and community awareness plans is new for the Jakarta government. It has really only been in 2011 that

[26] International Labor Organization, 2010

DKI Jakarta is engaging with local NGOs and other organizations and funders to develop and understand community resilience plans specifically towards climate change disaster risk management. PNPM is a 10 year government poverty reduction program funded in part by the World Bank which will be incorporating disaster risk reduction activities into their established community empowerment mechanisms and capacity building, the addition $15 million, funded over 5 years, is through a grant from the Global Facility for Disaster Reduction and Recovery, starting in 2011. However only one or two of Jakarta's kelurahan may be eligible for this program.

Constraints and Opportunities

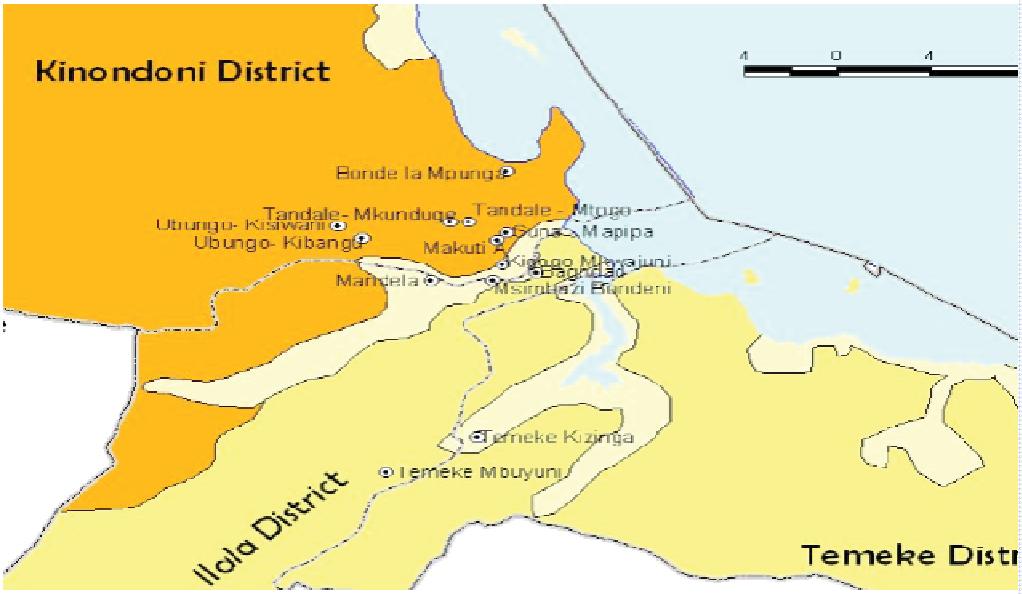
There is very little quantified, centralized information about the most vulnerable communities in Jakarta, the urban poor and informal settlements. However, the highly visible climate-vulnerable locations of these communities allows for easy identification of specific locations for interventions in spatial planning and social programming (like in North Jakarta and along many of the rivers). The creation and organization of data about the urban poor in Jakarta, and specifically about their livelihoods and economic contribution to Jakarta is key. Another asset in terms of community information dissemination and preparedness is the already fairly decentralized local government structures of the RW and RT, with budget and administrative allocation down to a very minute level in the city. With this strong system already in place it is relatively simple to scale up or replicate good community-level programs across the city.

GHG Emissions Inventory

A GHG emissions inventory for Jakarta is currently under development in partnership with BPLHD, DNPI and the NGO group Swisscontact. The report is forthcoming in 2011.

ANNEX D: URBAN RISK ASSESSMENT - DAR ES SALAAM, TANZANIA

MAP



CITY PROFILE

Dar es Salaam is located in the eastern part of the Tanzanian mainland at 6o51'S latitude and 39o18'E longitude. With an area of 1,350 km2, it occupies 0.19 percent of the Tanzanian mainland, stretching about 100 km between the Mpiji River to the North and beyond the Mzinga River in the South. The Indian Ocean borders it to the East. The beach and shoreline comprise sand dunes and tidal swamps. Coastal plains composed of limestone extend 10 km to the west of the city, 2-8 km to the north, and 5-8 km to the south. Inland, alluvial plains comprise a series of steep-sided U-shaped valleys. The upland plateau comprises the dissected Pugu Hills, 100-200 m in altitude. Dominated by limestones, sandy clays, coarse sands and mixed alluvial deposits, the soils of the Dar es Salaam region are not particularly fertile (Dongus, 2000). The City is divided into three ecological zones, namely the upland zone comprising hilly areas to the west and north of the City, the middle plateau, and the lowlands, which include Msimbazi Valley, Jangwani, Mtoni, Africana and Ununio areas.

Built Environment and Basic Service Provision

- An estimated 70 percent of Dar es Salaam's population lives in poor, unplanned settlements (World Bank, 2002). Residents are usually too poor to pay for services or infrastructure and authorities too resource-constrained to maintain these; thus, health and environmental conditions are generally extremely poor. About half the residents of Dar es Salaam's informal settlements live on an average income of US$1 per day and in constrained circumstances. Many are migrants from other parts of Tanzania in search of better opportunities.

CITY SNAPSHOT

(From Global City Indicators)

Total City Population in yr

2,497,940 (2002 census). Current estimation: Around 5 million in 2020

Population Growth (% annual)

4.39 % according to City mayor's Statistics 2006 and about 8% according to a World Bank (2002)

Land Area (Km2)

1,590.5 km² (614.1 sq mi)

Population density (per Km^2)

1,500 persons/hectare

Country's per capita GDP (US$)

Tanzania's per capita GDP was estimated at $1300 in 2007

Date of last Urban Master Plan

1979

- Access to clean water and sanitation are major problems for Dar es Salaam's poor, and contribute to widespread illness, including cholera, malaria, lymphatic filariasis, and diarrhea, particularly during flood episodes, which could be more severe or frequent in future due to climate change.

- Up to about 75 percent of the residents of Dar es Salaam's informal housing settlements are unemployed or under-employed (World Bank, 2002), with the main source of income for the latter group being through informal activities and micro-enterprise. Employment in Dar es Salaam as a whole declined from 64 percent to 42 percent between 1992 and 2000, and self-employment rose from 29 percent to 43 percent. Poverty for those in self-employment rose from 29 percent to 38 percent over the same period (ibid).

- The city's road network totals about 1,950 km in length, of which 1120 km (less than 60 percent) is paved, and is inadequate to satisfy its population density, spatial expansion and transportation needs. Dar es Salaam hosts about 52 percent of Tanzania's vehicles, and has a traffic density growth rate of over 6.3 percent per year (JICA, 1995; Kanyama et al., 2004).

- The city's planning agencies have been unable to keep pace with the rapid expansion of the city, largely fuelled by migrant growth. Most of the city's population lives in unplanned settlements – many in abject poverty – which are characterized by substandard infrastructure and lack of basic municipal and other services. These communities face transportation constraints, insecure housing, problems in accessing clean water, unhygienic sanitation provisions, and lack of awareness on hygienic sanitary practices. Climatic factors, e.g. heavy rainfall, work in conjunction with this situation to impose additional hardship and increase disease incidence.

PILLAR 1 - INSTITUTIONAL ASSESSMENT

Agencies Involved in Disaster Risk Management or Climate Change Adaptation

Dar es Salaam City is managed by the Dar es Salaam City Council and the Municipal Councils of Temeke, Kinondoni and Ilala. The three municipal authorities are under the Ministry of Regional Administration and Local Government. Each has individual sets of technical and administrative departments.

The Dar es Salaam City Council (DCC) has a coordinating role and attends to issues that cut across all the three municipalities. Its functions are:

- To coordinate the functions of the three Municipal authorities regarding infrastructure
- To prepare a coherent city-wide framework for the purpose of enhancing sustainable development
- To promote cooperation between the City Council and the three municipal or local authorities
- To deal with all matters where there is inter-dependency among the City's local authorities
- To support and facilitate the overall functioning and performance of the local authorities
- To maintain peace, provide security and emergency, fire and rescue services, ambulance and police
- To promote major functions relating to protocol and ceremonies

The Municipal Councils. The Municipal Councils are responsible for the provision of basic social services that includes primary education and partly secondary education especially where the community is involved, primary health care, waste management and cleanliness, district roads, water supply and monitor trade and development activities especially informal sector development and management, cooperatives, agriculture and livestock development, forestry, fisheries, recreational parks and urban planning.

The Tanzania Meteorological Agency (TMA) issues flood warnings for Dar es Salaam. It provides warnings and advisories on extreme rainfall and flooding based on daily weather monitoring. Cloud evolution is monitored through observations and by using satellite pictures. The evolution and pathway of tropical cyclones along the Western Indian Ocean are also monitored on a real time basis. Warnings and advisories are disseminated to the public as needed, through various stakeholders such as the mass media and the disaster management department at the Prime Minister's Office. Flood warnings and advisories are given up to a day in advance (24 hour forecast) or at seasonal timescales (up to two months in advance).

Relevant Policies and Legislation on Climate Change and Disaster Risk Management

- At National level: National Human Settlements Development policy (2000): National environmental Policy (1997), Ratification of the UN Framework Convention on Climate Change (1996).
- At local level: The Sustainable Dar es Salaam Project, and the Strategic Urban Development Plan (SUDP) started in 1992, Community Infrastructural Upgrading Programme (CIUP) started in 2001, African Urban Risk Analysis Network (AURAN) Project Phases I and II started in 2004.

Ongoing Programs and Projects Related to Disaster Risk Management or Climate Change Adaptation

Rehabilitation of storm water drainage and sewerage system: Improvements were undertaken by city authorities in the city centre. However, a new wave of investment has led to construction of new structures in former empty spaces, including the construction of multiple-use buildings that have increased demands for water supply and enlarged high capacity sewage pipes. The tonnage of solid and liquid waste generated has increased, demanding efficient solid and liquid waste management and monitoring services. On occasion, wide and deep stormwater drains are appropriated by private homeowners, fenced in as part of their property, and sealed up, which causes waste back-up problems among poorer neighbors. Laws need to be better enforced and drainage line capacity needs re-assessed. It is important that when this occurs, planners consider the fact that capacity needs are likely to change over the drainage system lifetime; the system needs to plan for changing rainfall regimes over the planning horizon e.g., up to 2050.

Property formalization in Dar es Salaam: The government is implementing a project to identify all properties in informal settlements in Dar es Salaam and at the same time issuing land/property licenses or Right of Occupancy to curb further densification of those areas and to improve security of tenure, which could be used as collateral for economic empowerment (URT 2004 in: Kyessi and Kyessi, 2007). This formalization process will be a foundation for the regularization of the slums that will ultimately allow provision of infrastructure including drainage channels for stormwater, piped water supply, refuse collection services using municipal and private vehicles, sanitation (pit and septic tank emptying services), secure tenure (loans), improving housing conditions and reducing overcrowding in unplanned settlements.

National Adaptation Programme of Action (NAPA): Tanzania is party to the UNFCCC and the Kyoto Protocol and has prepared a National Adaptation Programme of Action (NAPA, 2007). The capacity for investing in adaptation activities (protecting vulnerable populations, infrastructure, and economies) is still low due to financial constraints (NAPA, 2007). However, the NAPA will help in the integration of adaptation issues in the development process, guiding development to address urgent and immediate needs for adapting to adverse impacts of climate change. Among other objectives, the NAPA aims at improving public awareness on the impacts of climate change and on potential adaptation measures that can be adopted. In Dar es Salaam, activities have included planting trees along the beach, roadsides, near houses and in open spaces.

Management of coastal areas: Dar es Salaam is a coastal city and climate change is expected to exacerbate vulnerability of poor coastal communities through sea level rise, possibly more intense coastal storms, and increased rainfall variability. Coastal management projects involve beach conservation, including conservation of mangroves and coral reefs, as well as Marine Park protection. Poverty alleviation components, such as facilitation of seaweed farming, are also often included. Some of the city's coastal management projects are noted below. In particular, the Kinondoni Integrated Coastal Area Management Project (KICAMP) aims to formulate a comprehensive plan focused on the use of land and water resources in coastal areas. The project has banned the excavation of sands in Kunduchi-Mtongani as a way to prevent further beach erosion from occurring along the coastal area. Households are being made aware of the value of mangroves and involved in their protection, and, combined with heavy protection from KICAMP, this has led to increase in mangroves. Other civil society organizations involved in conservation, awareness raising, and environmental management included Roots and Shoots, World Vision, URASU (Uchoraji na Ramani na Sanaa Shirikishi Dhidi ya Ukimwi), and the International Organization on Migration, which helped the formation of environmental management societies in schools, markets and dispensaries. Schools had already planted trees and botanical gardens in their compounds. Msasani Bonde la Mpunga is also involved in coastal conservation measures through a partnership with WWF, Wildlife Society for Nature Conservation, the private sector (running tourist hotels and sea boats), IUCN and Tanzania Marine Park authorities.

Sustainable Coastal Communities and Ecosystems: This USAID-funded project (implemented by Rhode Island &Hawaii-Hilo universities) builds adaptive capacity and resilience among vulnerable coastal communities. The program has introduced "raft culture" techniques where seaweed is grown in deeper water where it is less vulnerable to fluctuations in temperature and salinity, which will enable beneficiaries to earn a living throughout the year.

Construction of adaptive structures in Dar es Salaam: A comprehensive beach conservation program has been designed that includes the following components: i) Sea walls have been constructed along the front of the Aga Khan Hospital to prevent further erosion of Sea View Road; ii) Sea walls and groins have been constructed along some beaches, which benefits hotels by reducing beach erosion and property damage from waves, and also helps fishing community settlements that live near the sea; iii) Land reclamation activities are taking place along coastal areas, e.g., by covering quarry pits with soil and trees and building houses on these reclaimed areas. The Kunduchi-Salasala quarry area is an example.

Other: The country has strengthened multi-lateral relations at the international level in order to enhance the ability to cope with climate change and variability for sustainable livelihoods. For example, Tanzania and the Kingdom of Norway have agreed to partner to combat adverse impacts of climate change. Under this program, Tanzanian scholars are trained on climate change issues (planning and forecasting), and, as short courses on climate change tend to be publicized through newspapers and on television, awareness is raised among the public on climate change impacts, adaptation measures and mitigation.

Leading Agencies

Currently, there isn't a leading agency coordinating the disaster risk management activities at the local level. There is a lack of coordination horizontally among departments and vertically with National policies.

Pro-Poor Services and Infrastructure Local Expenditure

Dar es Salaam's municipal agencies provide infrastructure and socio-economic services such as health, water, education, solid waste management, cooperative and community development, roads, development of natural resources, trade and agriculture and livestock sectors, and information and communication technology development. Despite efforts to improve social services for city dwellers, increased migration and unemployment have made services poor and unaffordable. Rapid urbanization in Dar es Salaam is resulting in growing numbers of the population living in un-planned, densely settled squatter areas with little or no access to social services (URT, 2004). Despite purported improvements in fiscal position and revenue collection systems, improved record-keeping and enhanced accountability, the Dar es Salaam City Council (including its Municipalities) still faces considerable challenges in spending on pro-poor services and on improving infrastructure in unplanned and underserved areas. Significant increase in revenue-generation is needed to ensure both increased service coverage and quality of services, particularly taking into account the additional resilience needed to reduce the risk posed by climate change for the city. Priorities in meeting the challenges include improving information systems (databases) and updating valuation rolls; optimizing the potential of property tax and simplifying the development levy; and developing vigilant collection strategies and more enhanced law enforcement capacity (City Council, undated Brief DSM V2: 6)

PILLAR 2 - HAZARDS ASSESSMENT

Natural Disaster History

Dar es Salaam is already highly vulnerable to climatic variability, which is expected to increase as climate continues to change. The aspect of most frequent concern to Dar es Salaam currently is heavy rainfall. In combination with poor drainage, illegal construction and other infrastructure problems, heavy rainfall results in flooding that causes major losses and disruptions. For the multitudes of the city's population living in informal settlements, poor sanitation provisions and practices contribute to an additional threat: disease. Diseases commonly occurring in these congested, unsanitary settlements during flood periods include malaria, cholera, dysentery and diarrhea. Some other factors that contribute to flooding in these settlements include flat topography, lack of storm-water drainage systems, blockage of natural drainage systems, building in hazardous areas, and unregulated housing and infrastructure development. Livelihood activities are also adversely affected by both heavy rainfall and by drought.

Hazard	Effects	Losses
floods	Drainage channels are blocked by refuse throughout the year as well as by structures that hinder the flow of wastewater, causing houses to be flooded by unhygienic, sewage-based wastewater in houses. Major effects are Water born diseases.	
DROUGHT	Diseases: malnutrition, trachoma, dysentery, cholera, and diarrhea	The drought of 2006 damaged agricultural production, necessitated electricity cuts (and thus drops in industrial production) and cut GDP growth by 1 percent (ClimateWorks Foundation et al., 2009)

Natural Hazards Snapshot

	Y /N	*Date of last major event*
Earthquake		
Wind Storm		
River Flow		
Floods, Inundations and waterlogs	***Y***	***2010***
Tsunami		
Drought	***Y***	***2006***
Volcano		
Landslide	***Y***	
Storm Surge		
Extreme Temperature	***Y***	

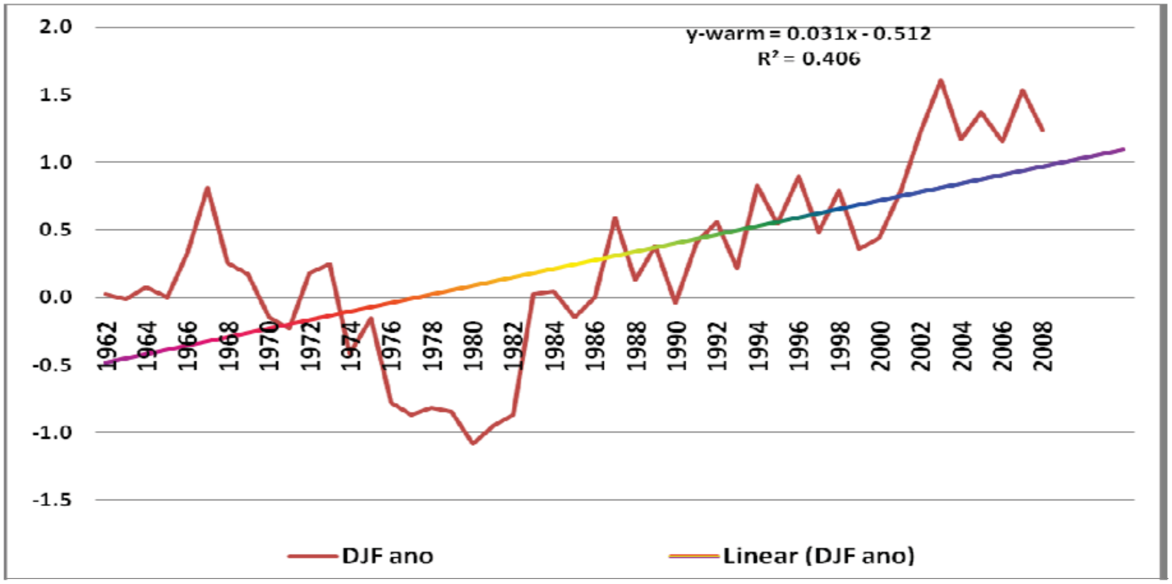
Significant Floods in Dar es Salaam (1983-2006)

Year	Months	Monthly rainfall: Long term mean (mm)	Actual (mm)	% of Long term mean
1983	May	197.8	405.6	**205**
1989	Dec.	117.8	175.6	**149**
1995	May	197.8	374.2	**189**
1997	Oct.	69.3	250.8	**361**
	Nov.	125.9	152	**121**
	Dec.	117.8	231	**196**
1998	Jan.	76.3	107.3	**141**
	Feb.	54.9	123.7	**225**
	Mar.	138.1	155.2	**112**
	April	254.2	319.9	**126**
2002	April	254.2	569.4	**224**
2006	Nov.	125.9	240.9	**191**
	Dec.	117.8	230.4	**196**

Source: Provided by Tanzania Meteorological Agency (TMA), 2010

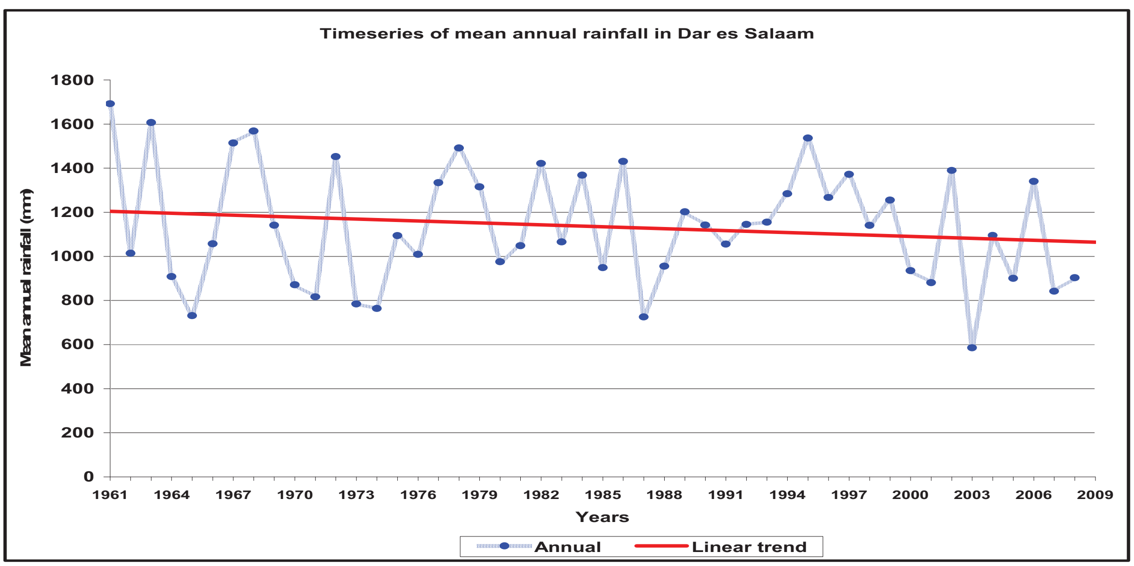
Main Climate Related Hazards

Temperature trends over the past 4-5 decades show significant increase. Temperature is projected to increase.



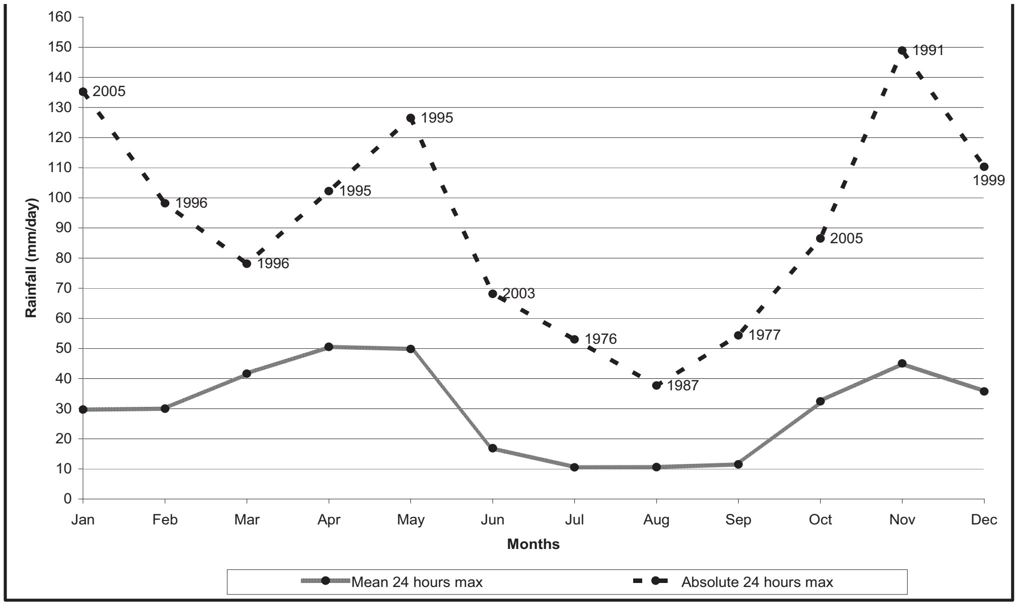
Trend of mean maximum temperature anomalies during the warmest months (December-February) at Dar es Salaam International Airport. Source: Provided by Tanzania Meteorological Agency (TMA), 2010

Mean annual rainfall has declined in Dar es Salaam over the past five decades (as recorded at the Dar es Salaam Airport station)



Source: Provided by Tanzania Meteorological Agency (TMA), 2010

Figure below shows mean and absolute 24-hour maximum rainfall for the period 1971–2009. Mean 24-hour maximum rainfall ranges from over 50 mm in April-May to 10mm for July-August. The absolute 24-hour maximum rainfall for the time period studied was recorded within the past decade.



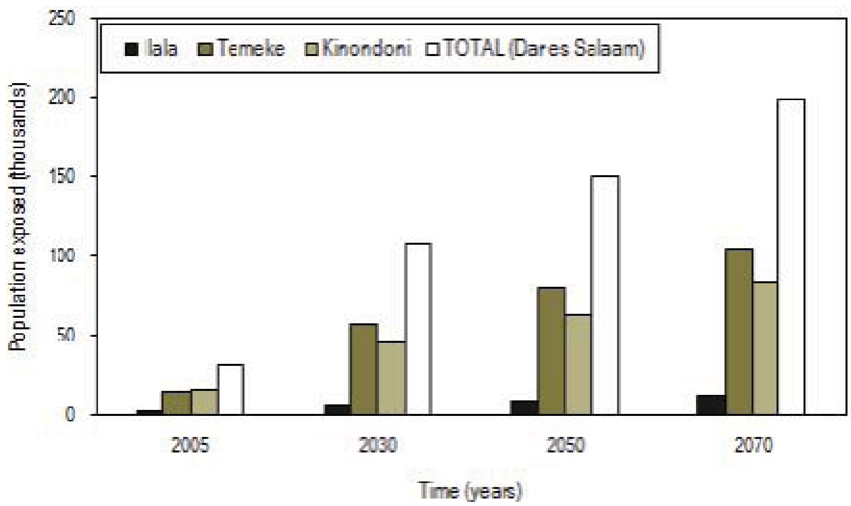
Both rainfall amount and intensity are variables of concern from the point of view of flooding in Dar es Salaam. Intensity has been increasing in last 15 years, where rainfall intensity has been well above the 38 years recorded history. This trend is expected to continue with climate change.

An important projected aspect of climate change is an increase in climatic variability, which would result in more frequent and/or severe floods and droughts in the city. Given that the city's poor are unable to cope adequately with current variability, their situation is likely to worsen in the future, unless steps are taken to ensure that urban development and poverty reduction programs specifically take into account the prospect of changing climatic conditions. Infrastructure development programs and urban planning schemes, municipal services provision, and poverty reduction programs (including safety nets and health services) need to not only better integrate disaster risk management approaches, but also to consider that the trends are changing.

GCM Projections of Future Climate

A summary of climate baseline data and severity of dry periods for March to May (MAM) and October to December (OND) are presented in the case study. Under the SRES A2 emissions scenarios, and data representing 14 of the Global Circulation Models used to simulate the 20th Century and future global climate, by mid-century, the coarser-resolution global climate models project that this site will become warmer, with more frequent heat waves and fewer frost days. They disagree on whether this site will become wetter or drier. By 2100, mean annual temperature for Tanzania is expected to increase by 1.7°C over the northern coast, including areas around Dar es Salaam (Matari et al., 2008). Rainfall intensity is expected to increase. Runoff (precipitation minus evapo-transpiration), a measure of water availability, is projected to increase. The maximum amount of rain that falls in any 5-day period (a surrogate for an extreme storm event) is expected to increase. The maximum period between rainy days is expected to increase (McSweeney et al. 2008).

Kebede and Nicholls (2010) have analyzed Dar es Salaam's vulnerability to sea level rise. They estimate that at present 8 percent of the city currently lies in a low elevation zone below the 10 m contour line, inhabited by over 143,000 people, with associated economic assets estimated (in 2005) at US$168 million.



Exposed population in Dar es Salaam in 2005, 2030, 2050 and 2070 to a 1 in 100 year flood event under the A1B mid-range SLR scenario, no adaptation. Source: Kebele and Nicholls (2010).

Magnitude, Distribution, and Probability of Potential Losses

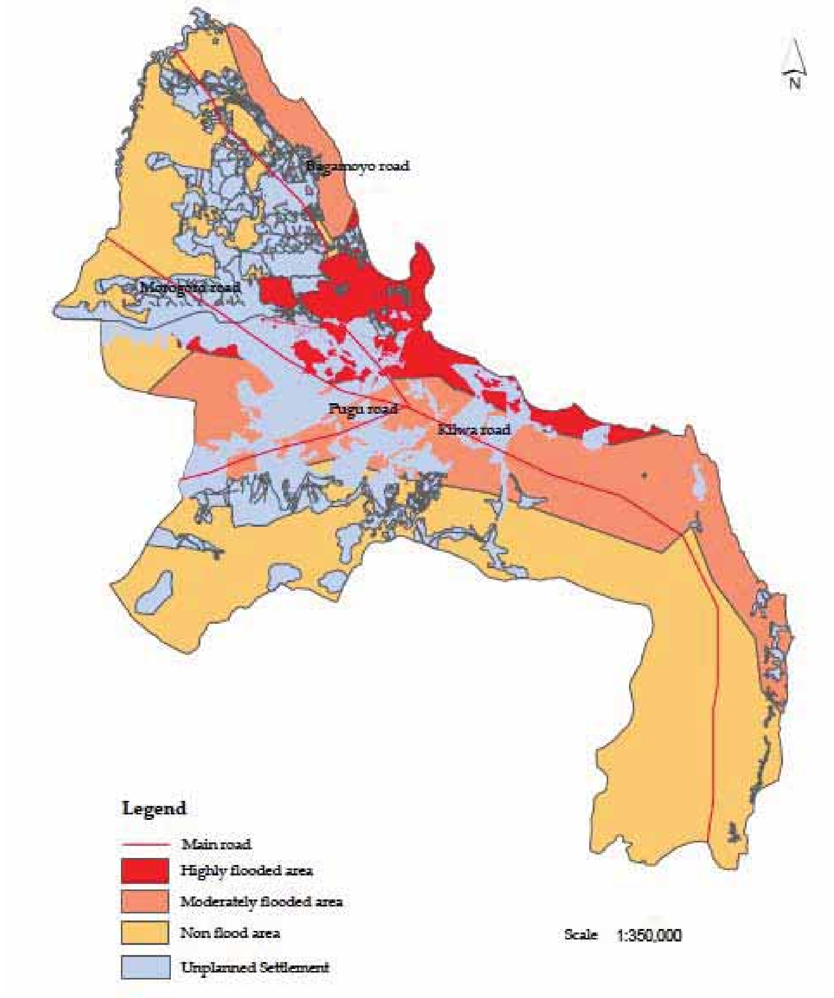
Although future rainfall patterns are uncertain, variability is likely to increase and intensification of heavy rainfall is expected. Thus flooding may become an increasingly severe issue, particularly taken together with socio-economic projections, unless adaptation measures are implemented. Increases in mean temperature, combined with fewer rainy days per year, could also prolong the length of dry seasons or intensify droughts. Recent extreme climatic events (e.g., the droughts of 2006 and 2008/2009, and the floods of 2009/2010) severely impacted sectors such as transport, energy and health, with adverse socio-economic implications. Projected changes in climate will have significant impacts on Tanzania's rain-fed agriculture and food production (Matari et al., 2008; Mwandosya et al., 1999), and could thus impact on urban agriculture in Dar es Salaam, a means of livelihood and subsistence for the city's poor. Warming will shorten the growing season and, together with reduced rainfall, reduce water availability (Paavola, 2003). Coastal degradation and salt-water intrusion are major problems for Dar es Salaam's coastal areas today, and under projected climate change and possible sea level rise, coastal ecosystems would be highly threatened (Watkiss et al., 2011), affecting the livelihoods and ecosystems services of coastal communities. Residents of coastal wetlands that have incurred saltwater intrusion (such as Suna, Mtoni Azimio, Msasani Bonde la Mpunga) informed the study team that they frequently need to repair their houses as salt-water intrusion is corroding the foundations and cement bricks are being eaten away.

PILLAR #3 -SOCIECONOMIC ASSESSMENT

Location and Exposure of the Urban Poor

An estimated 70 percent of Dar es Salaam's population lives in poor, unplanned settlements (World Bank, 2002). Life expectancy in Dar es Salaam's informal settlements is low, between 44-46 years, and infant mortality is high at about 97 deaths per 1000 live birth.

Figure D1: Flood hazard zone map overlain on urban poor settlements.



Source: Ardhi University, 2010

Residents are usually too poor to pay for services or infrastructure and authorities too resource-constrained to maintain these; thus, health and environmental conditions are generally extremely poor. Tanzania's policy towards informal settlements in Dar es Salaam has varied over past decades (discussed in World Bank, 2002). In the 1960s, slum clearance was the main approach; slum sites were cleared and buildings with high construction standards were erected on cleared sites (implemented through the National Housing Corporation). This proved unsustainable, however, and was abandoned by the end of the 60s due to high economic and social costs, and having contributed little to the net housing stock. In the 1970s and 1980s, the government's approach changed, and squatter area upgrading projects and service provision (supported by the World Bank) formed the national strategy for managing the growth of informal settlements. After World Bank funding for these projects ceased, however, the Government of Tanzania was unable to continue financing them, and subsequent years saw the growth and emergence of new unplanned settlements as well as deterioration of previously installed infrastructure, due to lack of maintenance (World Bank, 2002).

Annex E: Case Study - Dakar, Senegal[1]

Dakar, the political and economical capital of Senegal, has a metropolitan population of over 1.8 million. This sprawling urban conurbation represents less than 1% of the national territory but shelters 25% of the national population. The city is exposed to various natural hazards, the prominent being recurrent floods, coastal erosion and sea-level rise. In June 2009, a pilot study on a spatial and institutional approach of disaster risk management entitled "Preparing to manage natural hazards and climate change risks in Dakar, Senegal: a spatial and institutional approach" was carried out with support from the World Bank's Spatial and Local Development Team, the Global Facility for Disaster Reduction and Recovery (GFDRR) in collaboration with the World Bank Senegal Country Office, the Geoville Group and African Urban Management Institute. Urban hazards such as recurrent flooding and coastal erosion have been considered in the pilot study which aims at (i) proposing a new methodology for quick assessment of natural hazard risks at a metropolitan-regional scale using new tools of spatial analysis based on geographic information system (GIS) data and (ii) to apply the principles and diagnostic questionnaire of Climate Resilient Cities Primer to get a view of the institutional framework for climate change-related hazard risk management existing in the city.

Public Awareness Raising, Stakeholder Consultations, and Community Participation
Initial consultations with the municipality were undertaken to launch the study. Results arising from the study were later disseminated through workshops and public consultations to increase awareness and sensitization of local agencies and communities.

Understanding the Institutional Landscape
A Quick Institutional Assessment (based on the City Primer Approach) was undertaken based on interviews of local authorities including Préfets, city authorities (Mayors, Deputy Mayors), technicians from the cities of Dakar, Guédiawaye, Pikine, and Rufisque, urban planners, land use specialists, and financial experts. The survey analysis reviewed (i) general information on four administrative Departments of the Dakar Metropolitan Area: Dakar, Guédiawaye, Pikine, and Rufisque, (ii) governance structure related to disaster risk management, (iii) urban planning and land use regulations, and (iv) other factors such as political and economic impacts of disasters, climate change.

The survey found that the implementation framework for disaster risk management (DRM) was ambiguous and complex at the local level, even though Senegal has been actively pursuing Disaster Risk Reduction (DRR) strategies at the national and regional levels. For example, in the case of flooding the local mayor's office was often responsible for disaster response. But with most local governments lacking adequate resources and technical capacity for infrastructure investments and service delivery, complex issues such as climate variability risks remained unaddressed. Furthermore, land use planning which has the ability to influence the urban-rural form remains under the influence of the national rather than local government, rendering it a comparatively ineffective instrument.

[1] Drawn from *'Preparing To Manage Natural Hazards and Climate Change Risks In Dakar, Senegal – A Spatial and Institutional Approach'*. (2009).

Hazard impact assessment

Understanding the Historical Hazard Trend

The historical hazard impact assessment for this study was based on reviewing available information on historic disasters from different secondary sources. Based on the assessment, flooding, coastal erosion, and drought were identified as most frequent, prevalent and significant natural hazards affecting Dakar Metropolitan and surrounding areas. After reviewing available secondary data, sea-level rise was selected as the most pertinent climate change related risk for the coastal city of Dakar.

Table E1: Natural Hazards in the Dakar Metropolitan Area

Hazard Types	Characteristics	Available Information & Reference
Flooding	Recurrent and increased impacts of flooding. Causes: Increased rainfall, human factors, geological setting of the city.	Scientific research papers: Various UN-Habitat: Estimated 10,000 people and $9 million economic damage due to the next flooding Relief Web: Flood Maps of Western Africa Dartmouth Flood Observatory: Data on past floods reported in Dakar Glide Disaster Database: Past floods reported in Dakar National and local newspapers & databases: Information about past flooding disasters
Coastal Erosion	Damage from coastal erosion is a more constant risk. Cliff retreat rates up to 2 meters per annum Causes: Geotechnical properties of soil and human intervention (e.g. sand extraction)	Scientific research papers: Various UNESCO Dakar Office: Historical overview of past events National and local newspapers & databases
Drought	Major hazard at continental level; can lead to increased impacts from flooding	Scientific research papers: Various
Earthquake	Low Earthquake potential	Munich Re (Nathan Database)
Tornado	Medium probability of Tornados	Munich Re (Nathan Database)
Hail Storm	Low Hailstorm probability	Munich Re (Nathan Database)

Defining Study Area & Time Horizon

Based on available quantitative and qualitative data, local information and taking into consideration know-how of local experts, the Dakar Metropolitan Area was classified into 3 subdivisions for this study: (i) urban areas, including communes in the Department of Dakar (the city center) and four communes (Rufisque, Bargny, Diamniadio and Sébikotane) and three joint districts (Rufisque Ouest, Rufisque Nord and Rufisque Est) in the Department of Rufisque, which are in general, areas with strong urban and industrial economic activities; (ii) rural areas, including two large communes in the Department of Rufisque defined locally as Sangalkam, and Yène; and (iii) peri-urban areas, which are the areas lying in between these other types of areas, including mixed land use and relatively lower densities (Figure E1). Three points in time were considered for the land use analysis of the study (1988, 1999, and 2008).

Figure E1: Dakar Study Area

Vulnerability

In the context of this study spatial indicators of vulnerability were derived from hot spots of exposure, assuming that extreme concentrations of exposure will lead to locally increased vulnerability.

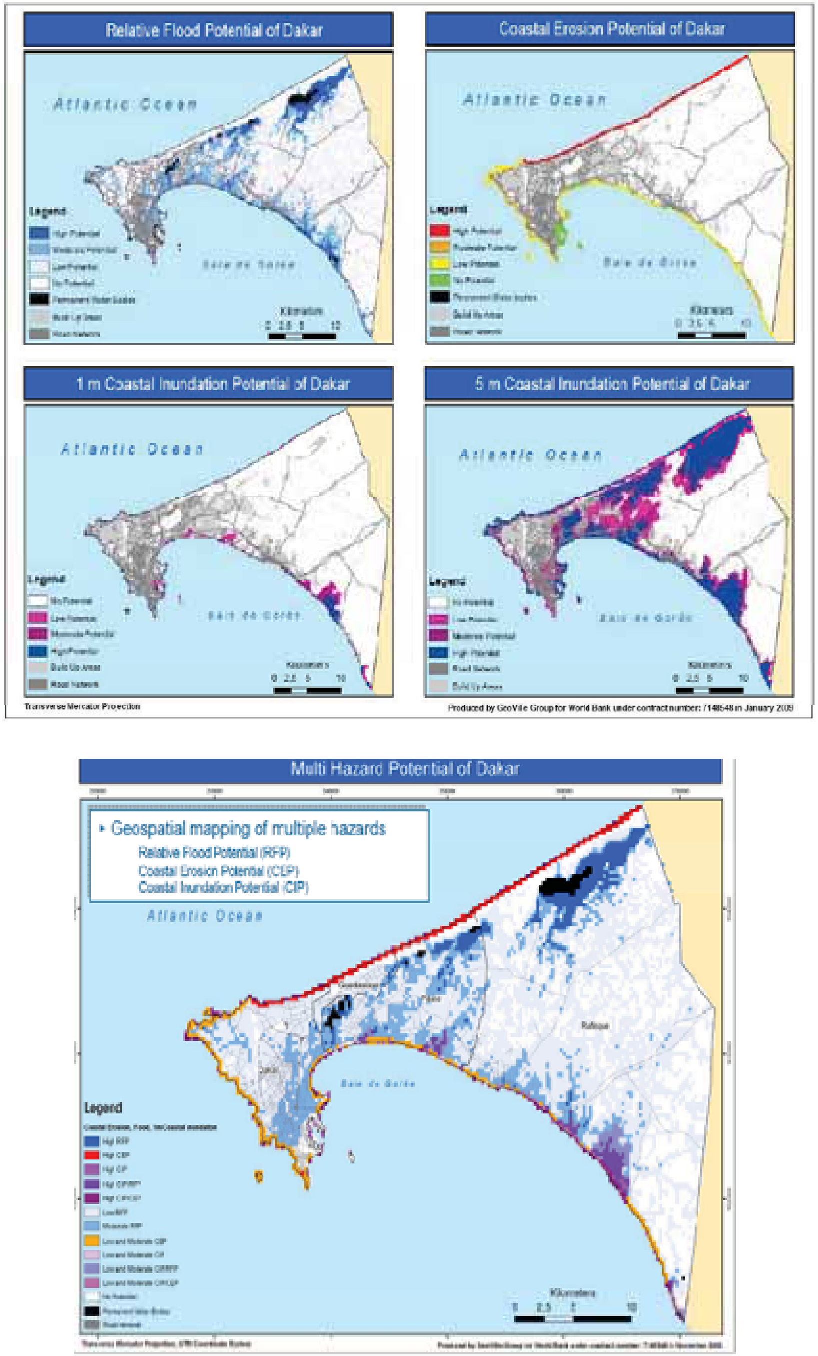
Hazard Exposure Maps

The spatial analysis combined results from hazard mapping (see maps below) with population maps, land price data, and land cover information in order to derive the exposure of different variables in different locations to the three selected natural hazards. The scale of the spatial analysis was regional/metropolitan, a level of detail that was relevant for the awareness-raising and institutional engagement purposes.

Land use and land use change

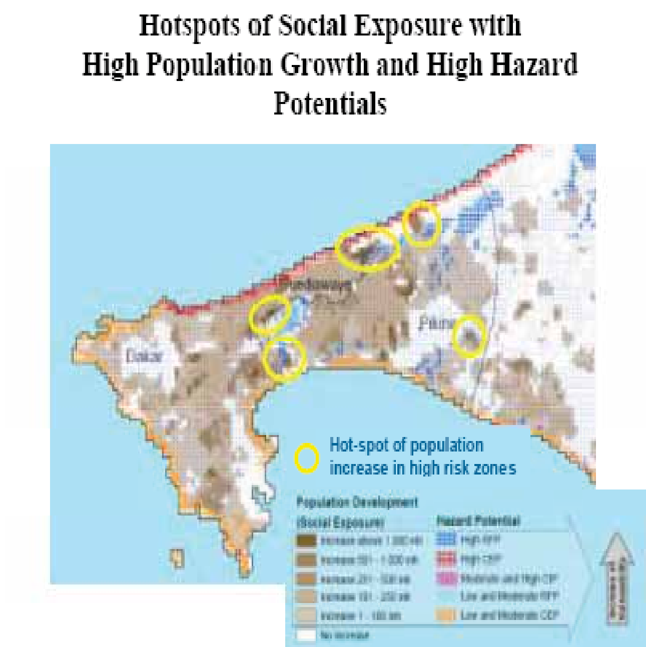
Spot 5 (2.5 m resolution) and Landsat satellite maps were used to develop base maps for 1998 and 2008 as well as to analyze land use and land use change for two periods (1988-1999, 1999-2008). Spatial analysis showed that land cover in the area under study had changed significantly in the past twenty years – the surface of urbanized areas had increased by over 25% in that period, about 1% per year. Population growth over the period between 1988 and 2008 took place to a significant extent in areas that were prone to a moderate or high hazard potential. In particular, peri-urban areas had the highest percentage of population growth in hazard prone areas.

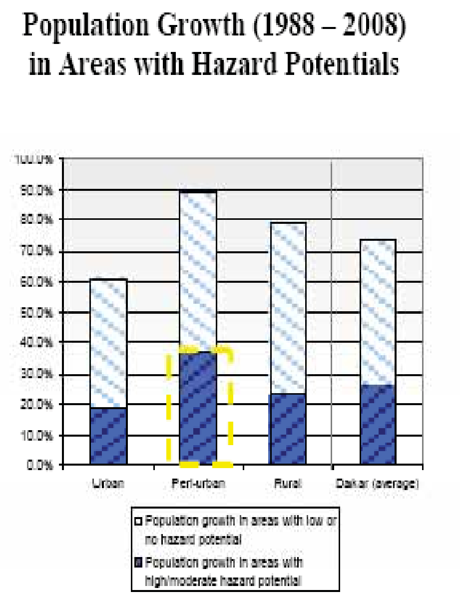
Figure E2: Single and Multiple Hazard Maps, Dakar



Identification of Hot Spots
Hazard maps were overlaid on GIS with population growth maps to identify "Hot-Spots". In communes that were defined as peri-urban, almost 40% of new population had settled in areas with significant hazard potential from inland flooding, coastal erosion, or sea level rise. This rate was twice as high that of urban (19%) and rural communes (23%) in the area under study. Peri-urban open land (non-built up) was also identified as being more exposed to risk (Figure E3).

Figure E3: Dakar Hotspots and Population Growth





Approximate loss scenario
A broad calculation of the exposure and vulnerability of economic assets in the area under study was inferred from the spatial analysis of land price values. Using this method, the study estimated that the Dakar Metropolitan Area represents a total land value of $44 billion. Out of this total value, over $2 billion or 5% is exposed to high natural hazard potential. Given the imperfect functioning of land markets in Dakar, this is only a very rough approximation to the exposure of economic assets to natural hazards.

Recommendations

1. Implement a general awareness campaign targeting local public agencies and local communities. The focus of the campaign would be on the impacts of natural hazards and climate change on day-to-day lives, with attention brought on behavior change.

2. Strengthen local institutional capacity and inter-agency coordination by identifying a viable and well-recognized institutional champion at the metropolitan level, focusing on: (a) development of early warning and quick response systems, paying attention to currently under-served peri-urban areas; and (b) improve local organization and capacity

to enforce urban zoning and regulations to reduce vulnerability to natural hazards, with special focus on currently under-served and fast-growing peri-urban areas.

3. Strengthen local land use planning and management through: (a) improvement of land property rights and enforcement with special focus on peri-urban areas; and (b) consultation around the metropolitan development plan, including identification of disaster hotspots and corridors for urban expansion and potential land acquisition plans to support urban growth corridors;

4. Strengthen resource base for local authorities, including through proposed betterment taxes that take advantage of improved land management plans and corridor development; investing in climate and disaster-proofing through retrofitting existing infrastructure and housing in hazard-prone areas; improving infrastructure planning and monitoring quality of investments.

Annex F: Case Study - Legazpi, Philippines[2]

The Legazpi case study illustrates how remote sensing and GIS can be applied for an urban risk assessment. The methodology and the case study were developed in a collaboration of the Institute to the Protection and Security of the Citizen (IPSC), Joint Research Centre (JRC) of the European Commission, and the World Bank with funding from the Global Facility for Disaster Risk and Recovery (GFDRR) and JRC. Institutional, social, ecological, and climate risk assessments were not undertaken.

Hazard impact assessment
A historical hazard impact assessment was undertaken using secondary data sources such as EM-DAT and other available information. The most devastating hazards in Legazpi are tropical cyclones (locally called typhoons), followed by floods, earthquakes and tsunamis. Flooding is a frequent consequence of heavy rainfall caused by tropical cyclones and sea level surges.

Exposure
Remote Sensing and GIS analysis were undertaken to develop built up, landuse/ landcover, building area & height assessments as discussed below.

Landuse
Available satellite images were analyzed for landuse/ land cover. For the study, analysis was restricted to an area of 1 km x 1 km. The topography for Legazpi is relatively flat and swampy, crossed by rivers and creeks. Figure F1 shows a satellite image of Legazpi. The red box identifies sample area for which the loss model was applied (taken from Ehrlich et al. 2010).

Figure F1: Legazpi Study Area

The settlements of Legazpi follow the coastline of the bay. Informal settlements are built directly on a gently sloping beach followed by flat land. A small harbor is protected by a pier. In the second row behind the harbor lies another district of poorly constructed huts and houses including a school. A small business and warehouse district extends towards the North followed again by residential areas with houses of different size, age

[2] Extracted from Ehrlich, D., Zeug, G., Small, C., Deichmann, U (forthcoming). Using High Resolution Satellite Information for Urban Risk Assessment. World Bank.

and quality. The flat and swampy area in the interior is crossed by roads, along which many residential houses were built in the recent past.

Exposure

For the quantification of building stock three types of digital information products with increasing information content were used. Figure F2a shows a pan-sharpened Quickbird satellite image at 0.6 m spatial resolution. The high resolution allows the identification and location of buildings to generate a building presence data layer which is encoded as a dot layer and shown in Figure F2b. Building footprints can be outlined generating the building footprint areas which are encoded as polygons (Figure F2c). Finally, the building footprints may have the building height as an attribute thus providing building volumes (Figure F2d). The information derived from these layers is shown in Table F1.

Figure F2: Using Pan-sharpened Quickbird imagery for Legazpi Study Area

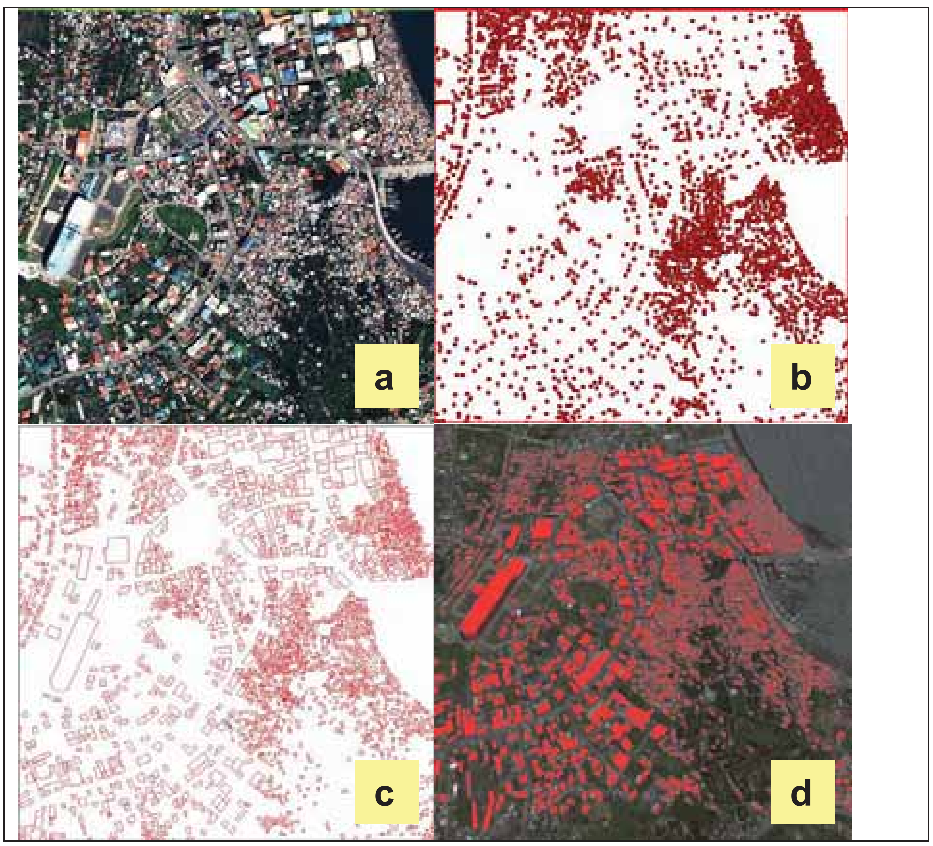


Table F1: Building Stock for Settlement Sample

Building stock	Building location (no. of buildings)	Building footprint (area measure)	Estimated building volume
	2990	254,916 m^2	1,584,067 m^3

Vulnerability

The classification presented in Table 20 provides five categories of building types used in Legazpi. The list was adapted from the global inventory of building types available from the World Housing Encyclopedia (WHT, 2009), from disaster risk work conducted in Manila, and from experience in the field.

The enumerated building stock was classified into the five building type categories (Table F2). Information gathered during the field visits informed further building classification within the area of interest. The main criteria used for labeling every single building was the building size (footprints), and the spacing of the buildings. For example, very small buildings, spaced very closely with little footprint area are deemed to be of low quality in poor neighborhoods (building type 4). Large buildings are classified as well constructed and likely to provide good resilience (building type 1 and building type 2), although in practice this would need to be confirmed on a case-by-case basis.

Table F2: Categories of building type used in Legazpi to qualify the building stock.

Building type	Definitions	Brief description of structural characteristics of building type.	On Damage
1	Reinforced concrete frame with brick in fill walls	Structures constructed with highest standards. Typically employed for large and tall buildings. Will include hazard related building codes	Sustain pressure and vibration
2	Brick traditional with reinforced concrete columns	Buildings constructed according to engineering standards. Typically on cement pillars with roof/pavements also in cement.	Sustain pressures, shakes
3	Brick traditional	Traditional building standards using local expertise and material (mortar, adobe, bricks, wood). It largely varies from geographical areas.	These buildings are typically damaged during catastrophic events
4	Assembled material (brick and corrugated iron)	Dwellings constructed with assembled material for a lack of resources, typically found in poor neighbourhoods of urban centres and settlements.	Typically very instable and vulnerable to damage
5	Timber and bamboo or assembled material	Dwellings from material that needs to be constantly fixed and repaired.	May be resilient to earthquakes but very vulnerable to floods

Figure F3: Building typology and Qualification in Legazpi

Estimating Exposed Population

Figure F4a shows the districts for which population totals are available. Two district population figures were available: one provided by the World Health Organization (WHO) and based on the National Census of 2006 and an estimate from the Municipality of Legazpi for 2008. Both statistics used the same district boundaries. The two statistics are within the range of error of population estimates. For the estimation of affected people, the statistics from WHO are more suitable since they are closer in time to the satellite image from which the building stock was derived. The downscaling procedure proceeded as follows. The first step is to compute the total population of the districts that intersect the area under study. Assuming that densities within these adjacent districts are homogeneous an area proportion between total population in districts and the area of interest yields the total population of the area of interest (Table F3).

Figure F4: Estimating Exposed Population

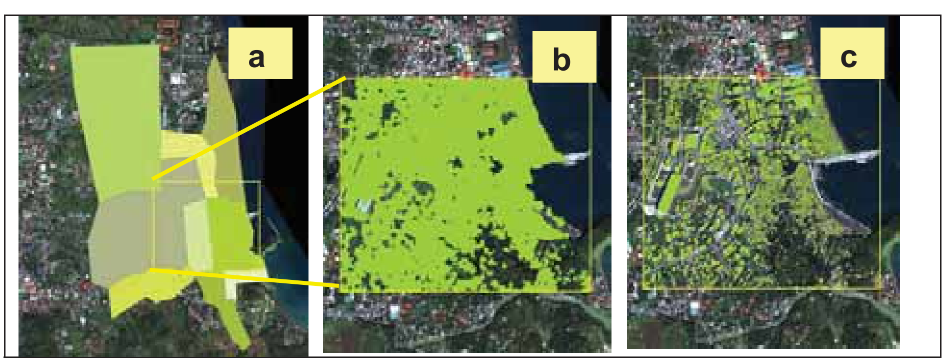


Table F3: Downscaling Population Statistics Based On Built-Up Area and Building Stock

	Area (km2)	WHO (2006)	Municipality (2008)
Districts intersecting the 1 km x 1 km study area	2.29	33,283	30,171
1 km x 1 km	1	14,534	13,175

The next step is to compute density measures. These can be derived for the built-up area as a whole (Figure F4b) or they can be related to the area taken up by buildings only (Figure F4c). Results are reported in Table F4, where the area unit of measurement is a 10 m x 10 m square. The figures suggest that over the entire built-up area (which includes roads, some open space between houses, etc.), there are slightly fewer than 2 people per 10 m grid square. If we only consider the buildings, there are approximately 6 people per 10 m square. This could be considered a measure of the average building space occupied by a household. Based on data collected from the field visits these estimates seem reasonable.

Table F4: Densities for Built-Up Area and Area of Building Footprints

	Area (km2)	Density over 10 x 10 m area
Built-up area in 1 km x 1 km	0.82	1.77
Building footprint area in 1 km x 1 km	0.25	5.81

Damage Scenarios

Two scenarios were developed, one for tsunamis and one for earthquakes. They only include direct damages, not indirect effects such as landslides triggered by an earthquake. The two scenarios were selected in consultation with local experts as potential events with a high probability of occurring in the Legazpi region. The impact scenarios are based on a building damage model structured within a geographical information system. The current models were developed using knowledge gathered from open sources, reviewed literature and field visits.

Earthquake Disaster Risk

The earthquake scenario assumes an event with an intensity of 8 on the Modified Mercalli Scale (MM). The intensity scale 8 is ranked destructive with an average ground peak acceleration of 0.25-0.30 g, where g is the speed of gravitational acceleration (9.8 meters per second squared; Smith, 2008). Because of the lack of vulnerability curves for Legazpi, the qualitative description of the MM was translated into damage percentages used in the simulation as shown in Table below:

Table F5: Empirical Fragility Curves for Earthquake Intensity

Building Type	Description	Damage Description	Damage
1	Reinforced concrete frame with brick in-fill walls	Slight	5%
2	Brick traditional with reinforced concrete columns	Slight	10%
3	Brick traditional	Considerable	30%
4	Assembled material (brick and corrugated iron)	Great	80%
5	Timber and bamboo or assembled material	Great	60%

Earthquake Losses

Applying the damage proportions in Table 2.5 to the estimates of total building stock—measured as the total area covered by building footprints in each building type category—yields estimates of total damages by type of building. The building stock value considered in this exercise is the cost of reconstruction. These estimates were made available by local construction engineers in Philippine Pesos (PHP). The values available where then converted into US Dollar (USD) per surface unit. The total value of the building stock of a given building type is the product of the footprint area times the cost per unit area. The losses are then the product of the expected damage expressed as percentage for a given building type.

Table F6: Earthquake Losses to Building Stock

Building type	Total building stock (m^2)	Value (USD/ m^2)	Total value of building stock (USD)	Damage (%)	Total damage (m^2)	Total losses (USD)
1	18328.3	435	7,972,810	5	916.4	398,640.5
2	73413.6	250	18,353,400	10	7,341.4	183,534.0
3	102151.1	110	11,236,621	30	30,645.3	3,370,986.3
4	60548.4	65	3,935,646	80	48,438.7	3,148,516.8
5	383.3	10	3,833	60	230.0	2299.8
Overall	**254824.7**		**41,502,310**		**8,7571.8**	**8,755,783.4**

Earthquake Affected Population

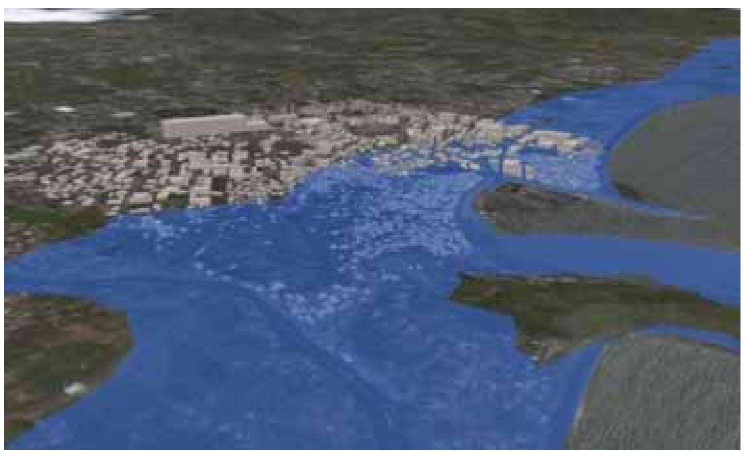
The entire population within the area under study would be affected by the earthquake. The potential fatalities can be estimated from the collapse ratio. It was hypothesized that the buildings would collapse when damage is higher than 60% for either brick or concrete buildings. In this simulation this occurs for categories 4 and 5 that account for over 60,000 square meters of buildings. That living space would account for up to 4,800 people. This is a crude and probably worst-case estimate, since the actual number of people possibly affected by collapsing buildings will be influenced, for instance, by the time of day of the event. During day time, many people will be outside, while losses may be highest during nighttime. Estimates from past events would help refine these numbers.

Tsunami Disaster Risk

The tsunami event assumes a wave height of 4m at the shoreline, impacting the coastline at right angles. The damaging effect of tsunamis depends on wave height and wave speed. The wave height is a function of local bathymetry, on land topography and shoaling—the increase in height due to bathymetric characteristics. The velocity and wave height determines the pressure exerted on buildings and therefore their destructive behavior. The tsunami wave diminishes as a function of distance, topography, and surface characteristics often referred to as surface roughness. Modeling precise wave impacts on built-up infrastructure requires in-depth modeling which was beyond this case study.

Tsunami Physical Damage
The Legazpi case study employs an inundation model developed by the UK Tsunami Initiative (NERC 2009). For modeling potentially inundated areas it is assumed that on flat coastlines the extent of the inundated zone depends more on surface roughness than on topography. The applied model calculates the inundation distance from the shoreline resulting from a certain tsunami wave height assuming also that the water flows inland with a distance that is proportional to the height of the wave at shore and to a friction factor that slows the water flow. The friction factor is measured based on "roughness coefficients" that are mainly determined by land use and land cover.

Figure F5: Simulation for inundation caused by a 4 m high tsunami



Roughness coefficients for land use categories in the Legazpi region are listed in Table below. As this exercise is limited to a study area in a central part of the town with mixed use (residential, commercial, business), the only land use considered is of the type "built-up".

Table F7: Roughness Coefficient Based On Land Use

Land Use Type	Roughness Coefficient
Mud flats, ice, open fields without crops	0.015
Built-up areas	0.035
City centre	0.100
Forests, jungles	0.070
Rivers, lakes	0.007

The inundation distance from the shore and produced by a tsunami of height H_0 is calculated as follows:

$$X_{max} = 0.06\, H_0^{4/3} / n^2$$

where n is the surface roughness coefficient as derived from Table F7 and H_0 the wave height at the shore. The simulated tsunami is based on a historic tsunami event in Luzon and Mindoro islands with a wave height of 4 m at the shoreline. This resulted in the inundation distances shown in Table F8. This distance from the shore up to which inundation may reach inland differs by land use types. In a 4m scenario, the inundation of roads, for example, could extend up to 7km from the shore due to low roughness.

Table F8: Inundation Distance from Shore

Land use type	Roughness coefficient	X_{max} [4 m scenario]
City centre	0.100	38 m
Trees and forest	0.070	78 m
Built-up areas	0.035	311 m
Open fields and roads	0.015	1.7 km
Rivers and lakes	0.007	7.8 km

The damage to the building stock is a function of the energy from wave impact and the vulnerability of the buildings expressed as fragility curves. As fragility curves for a tsunami were not available for this part of the Philippines, fragility curves reported for the July 2006 South Java tsunami were applied. This assumed that the building stock of Legazpi is similar. One factor influencing damages is the inundation height. The study distinguished three intensity levels: for an inundation height less than 1 meter, between 1 and 2 meters, and for over 2 meters (Figure F6). Apart from water depth, several other factors influence the degree of damage and could be incorporated based on empirical evidence from past events or suitable assumptions. These include flow velocity, the amount of debris and whether or not a house is shielded by other buildings. The damage observations were translated into percentage of damage for each of the three intensity zones. Assuming the 4m wave scenario, all buildings fall into one of the three inundation zones. Table below shows different building types and corresponding fragility values for the three intensities.

Table F9: Building Types and Corresponding Damage Values Per Building Type

Building types		% damage (inundation < 1 m)	% damage (inundation 1-2 m)	% damage (inundation > 2 m)
1	Reinforced concrete-frame with brick infill walls	5 %	15 %	20 %
2	Brick traditional with RC-columns	10 %	25 %	60 %
3	Brick traditional	25 %	70 %	100 %
4	Assembled material	25 %	70 %	100 %
5	Timber/bamboo	25 %	70 %	100 %

Figure F6: Inundation Height Zones 4 Meter Tsunami Wave

Tsunami Damages and Losses

The three intensity zones provide damages and losses shown in Tables F10-F12. Each zone has a different amount of exposed assets (the total building stock) and percentage of damage for the different building types. Table F10 identifies the building stock for the 1m inundation height and Table F11 and Table F12 the 1 m to 2 m and the 2 m and higher inundation heights respectively.

Table F10: Damages for the intensity determined by 1 m inundation height

Building type	Total building stock (m^2)	Value (USD/ m^2)	Total value (USD)	Damage (%)	Total damage (m^2)	Total losses (USD)
1	2126.9	435	925214.6	5	106.3	46260.7
2	9783.7	250	2445915.0	10	978.4	244591.5
3	6517.9	110	716964.6	25	1629.5	179241.2
4	6661.9	65	433024.2	25	1665. 5	108256.0
5	46.1	10	460.7	25	11.5	115.2
Overall	25136.4		4521579.0		4391. 2	578464.6

Table F11: Damages for the intensity determined by a 1 m to 2 m inundation height

Building type	Total building stock (m^2)	Value (USD/ m^2)	Total value (USD)	Damage (%)	Total damage (m^2)	Total losses (USD)
1	2126.9	435	925214.6	15	319.0	138782.2
2	16816.6	250	4204142.5	25	4204.1	1051035.6
3	12765.7	110	1404221.5	70	8936.0	982955.1
4	15867.9	65	1031412.9	70	11107.5	721989.0
5	172.0	10	1720.3	70	120.4	1204.2
Overall	47749.1		7566711.7		24687. 1	2895966.1

Table F12: Damages for the intensity determined by more than 2 m inundation height

Building type	Total building stock (m^2)	Value (USD/ m^2)	Total value (USD)	Damage (%)	Total damage (m^2)	Total losses (USD)
1	0.0	435	0	20	0	0
2	9340.7	250	2335185.0	60	5604.4	1401111.0
3	12482.4	110	1373061.8	100	12482.4	1373061.8
4	33504.0	65	2177757.4	100	33504.0	2177757.4
5	106.8	10	1067.9	100	106.8	1067.9
Overall	55433.9		5887072.1		51697.6	4952998.1

Tsunami Affected Population

The population affected is that residing in the three intensity zones. It is estimated by intersecting the inundation zones with the distribution of the population before the hazard event. The estimate shows more than 4,200 people to be affected by a 4 m tsunami wave within the 1 km x 1 km test area alone. Fatalities for such an event are not estimated for two main reasons. First, there are no good estimates for mortality during similar events that might provide guidance. Second, fatalities are often due to the debris floating in the water that would require development of a hydrodynamic impact model.

Annex G: Case Study - Sana'a, Yemen[3]

Sana'a, the capital of Yemen, is situated at an elevation of 2,200 meters above sea level. It is surrounded by mountains and is located in the western part of the country. The Sana'a Basin is spread over 3,200 sq. km. Administratively, the city is divided into ten districts. Sana'a has a population of 1.748 million (2004 Census) and has experienced the highest growth rate of any capital city in the world. Over the next 15 years, the growth rate is expected to continue at 5 to 7 percent per year. The Municipality of Sana'a is currently preparing a long-term City Development Strategy (CDS) for Sustainable Development. To help support this strategy, flood and landslide risk evaluations are being conducted. The Sana'a Probabilistic Risk Assessment study is being undertaken by the World Bank with support from GFDRR, in collaboration with the Sana'a municipality.

Table G1: Different Tasks and Key Outputs of Sana'a Study

Task	Key Output
Task 1: Historical Hazard Identification and Probabilistic Analysis	Sana'a Probabilistic Hazard Analysis Reports, Software, and Manuals, including the historical hazard review and analysis, probabilistic hazard analysis event characterization, probabilistic hazard modeling software subsystem, and data sets and maps in Geographic Information System (GIS) format with metadata files
Task 2: Inventory of Exposure and Vulnerability	Sana'a Inventory of Exposure and Vulnerability Report and Manuals, including the development and compilation of the inventory of assets, their classification and valuation
Task 3: Probabilistic Loss Modeling and Analysis and City-Level Analysis	Sana'a Probabilistic Loss Modeling and Analysis, including the validation of loss exceedance curves (LECs) and eventual adjustment to loss modeling process, risk analysis, applications of catastrophic risk modeling within the context of the Sana'a CDS and Urban Master Plan, institutional strengthening for disaster risk management (DRM), probabilistic loss modeling software subsystem, and data sets and maps in GIS format with metadata files
Task 4: Sana'a Natural Hazard Risk Map and Risk Analysis Software Development	Sana'a Integrated Storm Water Management (ISWM), including comprehensive analysis of hydrology and hydraulics, peak flow capacity in the Saylah system, feasibility study and capital investment plan for ISWMS, proposal of Flood Early Warning System (FEWS), operation and maintenance of ISWMM, printed high-quality and full-color citywide map with components of ISWMS, and data sets and maps in GIS format with metadata files

[3] Extracted from 'Probabilistic Risk Assessment Studies in Yemen' (Middle East and North Africa region, GFDRR, 2010)

Probabilistic Risk Assessment in Sana'a

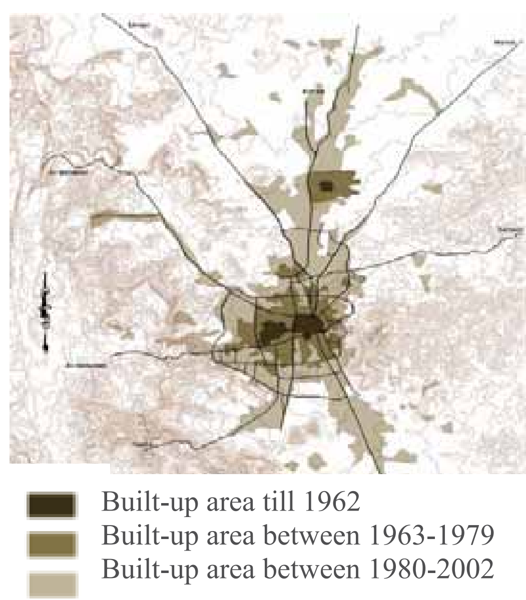
Sana'a suffers from a severe storm water drainage problem due to its geographic location. The city is located in a valley in an inter-mountainous plain that contains many wadis originating from surrounding mountains draining toward the "Great Wadi of Saylah," Due to rapid expansion of the city during the last two decades, natural wadi courses have been built-up and populated. This flood-prone residential areas and main streets are prone to flooding resulting in property damage and traffic problems during the annual rainy season. Also, all city storm water drainage systems have been developed to drain into the main Wadi Saylah causing major property damage and traffic disruptions as this wadi has been integrated into the city major transport arteries. The rapid expansion of the city and expectations of continuous urban population growth of 5-7% a year over the next 15 years, means that the city is already encroaching onto the slopes of the surrounding mountains bringing about increased vulnerability to landslides and rock falling.

Recognizing the negative and avoidable impacts of recurrent flash floods in Sana'a, the city has started building storm water drainage system, named The Saylah Project, with the objective to protect the channel of the "Great Wadi of Saylah", develop flood protection system and recharge aquifer. For the development of Integrated Storm Water Master Plan (ISWMP) for the city of Sana'a (which requires detailed hydrological information) and to assess the risk to flood and land slides hazards of the greater urban area of Sana'a, a probabilistic risk assessment was undertaken in Sana'a. The risk modeling techniques will identify losses from natural disasters and develop scenarios to incorporate urban growth estimates and build up for Sana'a 2020. The project also seeks to integrate the findings of probabilistic risk assessment into the City Development Strategy and make recommendations for the integration of the CDS and Disaster Risk Management (DRM) information for the Urban Master Plan, and for potential institutional capacity building needs with regards to disaster risk management.

Probabilistic Risk Assessment

The risk assessment for Sana'a has been carried out for an integrated manner through identifying all possible water related hazards, including how they are likely to develop in the future as a consequence of urbanization or other development activities. The hydrology and hydraulic analysis was conducted for the Sana'a basin to identify the basin and sub-basin characteristics and determine flow in each sub-basin given a rainfall amount. These analyses provided information about the probability of a hazard's occurrence and the respective loss potential. A number of different probabilistic events have been modeled to quantify the risk to buildings by their occupancy types – residential, commercial, industrial, and squatters. The results of this model are risk maps that provide information about the

Figure G1: Sana'a Urban Growth



expected flood frequencies and magnitudes (extent, depth, duration and flow velocities).

Historical Hazard Identification

Flood Hazard

The urban development of Sana'a has led to an increase in flood hazard for two reasons: (1) modifications to existing land features and (2) increased population and buildings present in flood prone areas. Modifications to land features change the runoff characteristics of watersheds, resulting in greater floods than would occur with undeveloped conditions. The primary impact of urbanization is conversion of natural ground cover to impervious surfaces, such as paved roads and building rooftops. Natural ground cover and soils provide depressional storage areas that absorb initial rainfall quantities before surface runoff occurs. Rainfall absorbed into the ground migrates slowly as subsurface flow.

Landslide Hazard

A landslide is a mass of rock, earth or debris moving down a slope. The geological conditions of Sana'a are dominated by sand and sedimentary rock, which produces unstable conditions given the presence of pores and cracks. The abundant rains during the rainy season saturate the rocks and result in landslides. Erosion also triggers these slides. Rain, wind, temperature variations, and human activities such as mining exacerbate the dangers. Finally, and probably of greatest significance, the vulnerable natural setting is being steadily invaded by development and the infrastructure that supports it.

The following data sets were collected to model historical hazard for Sana'a:

- Meteorological data
- Hydrological data
- Mapping
- Historic flood records
- Historic landslide records
- Demographic data
- Flood vulnerability
- Economic data

Exposure and Vulnerability

An inventory of exposure and vulnerability was developed for physical assets at risk. The exposure inventory benefitted from land use and land cover data from the Ikonos satellite (Table. The inventory contained buildings (residential, commercial, industrial, and public), infrastructure (transportation roads and bridges), networks (water, sewerage, power, communications) and provided the number, types, and distribution of assets as well as their valuation. The building exposure inventory of Sana'a city was developed at census tract level.

Table G2: Land Use and Land Cover Classification

S. No	Class	Class Definition
1.	Agriculture	Covered with cropland, fields with definite boundary and pattern.
2.	Airport	Includes airstrips or helipads
3.	World Heritage Site	World Heritage sites recognized by UNESCO
4.	Commercial	Multi storied commercial buildings, retailing shops etc.
5.	Dense Urban	Includes developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial complexes. Impervious surfaces account for 80 to 100 percent of the total cover.
6.	Dense Vegetation	Areas characterized by dense tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover.
7.	Industrial	Covered mainly with factories and industries manufacturing goods. Covering large spatial area on ground.
8.	Low Urban	Low density of buildings with some vegetation within the yards; vegetations are also seen along the roads, more open areas are lying in-between the houses.
9.	Open Land	Vacant or un used areas in built up or agricultural areas.
10.	Parking	Facilities for stopping vehicles for brief time
11.	Public Parks	Open spaces provided for recreational use, usually owned and maintained by a local government
12.	Residential	Includes areas covered with residential houses; may vary from apartments to single owned. Well defined pattern of house, surrounded with trees and grass cover.
13.	River	Linear water features like streams and rivers.
14.	Roads	All types of motorable roads and streets.
15.	Skyscraper	High Rise buildings (>40m), specially apartments or buildings with facilities like parkings, swimming pools etc.
16.	Sparse Vegetation	Low and scattered vegetation, thin density of forest, bushes, scrubs with low tree density.
17.	Squatters	Informal Settlements in and around Urban Areas (irregular pattern in appearance)
18.	Sub Urban	Mostly singly owned residential areas on the outskirts of the city having low population density. Impervious surfaces account for 40 to 50 percent of the total cover.
19.	Urban	Includes developed areas where medium density of people reside or work. Impervious surface account for 60 to 70 percent of total cover.
20.	Water bodies	This class consists of confined water bodies (smaller scale), lakes, reservoir and dams.

Risk Modeling Software

As part of the study, software called HazSana'a was designed and developed to perform probabilistic hazard analysis and deterministic scenario analysis based on flood and landslide hazard maps The HazSana'a software provides users with data capture tools to process probabilistic, deterministic, or user-supplied flood and landslide hazard data. This enabled the production of city risk maps which identify the most endangered areas and neighborhoods.

In addition to the identification of risk areas, the advantage of HazSana'a comprehensive risk assessments is the fact that it is possible to compare the components of risk in quantitative terms. HazSana'a can rapidly generate many sensitivity analyses in order to weight the pro and con of different approaches to risk reduction as the cost of corrective action is compared to the reduction in risk.

Figure G2: Flood Hazard Map for Sana'a

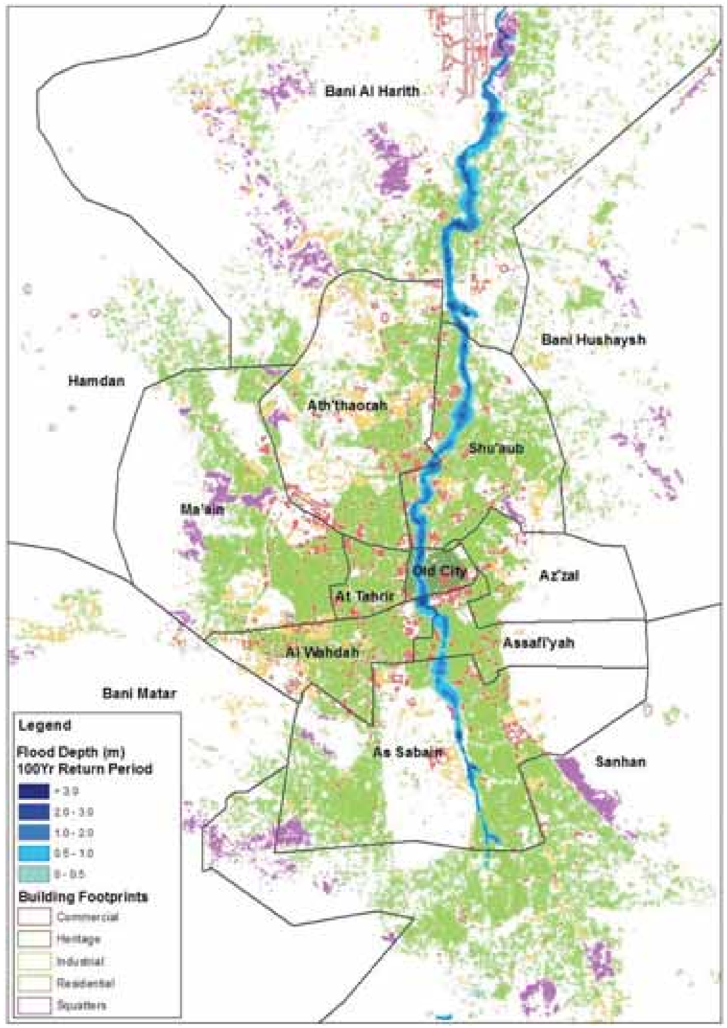
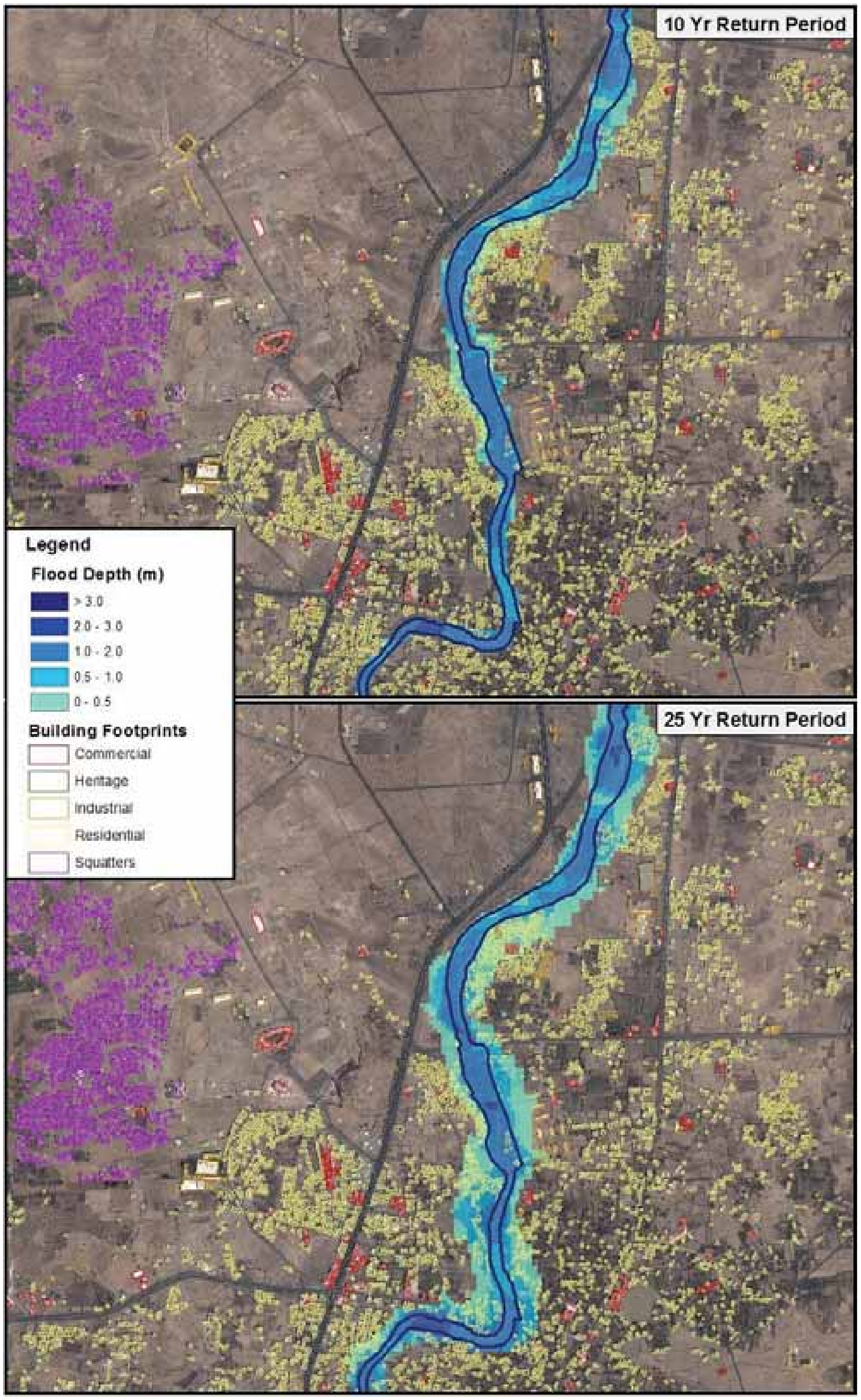


Figure G3: Flood Risk Zone for 10 and 25 Year Return Periods Over Buildings Footprints



Damage and Loss

For a flood analysis, damage is estimated in percent and is weighted by the area of inundation at a given depth for a given building footprint. Estimation of direct damage to the general building stock (percent damage to structures and their contents) is accomplished through the use of vulnerability functions. Default curves to estimate structural damage for the analyses have been selected for each *HazSana* building classes and associated content occupancy (e.g. residential, specialized-commercial, and industrial) (Figure G4). Losses corresponding to various flood return periods are listed in Table G3.

Figure G4: Sample flood vulnerability curve

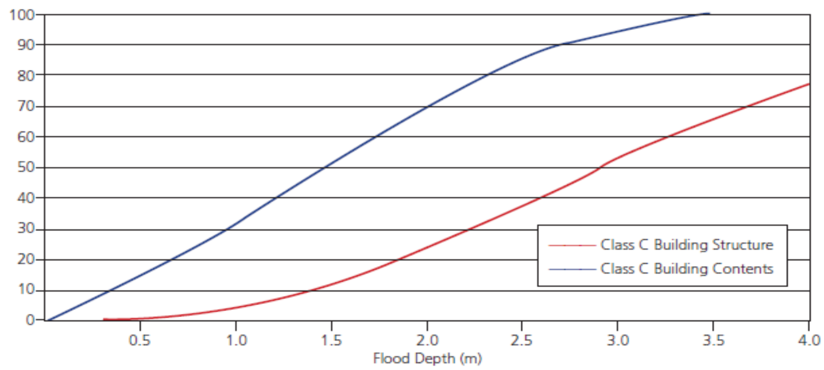


Table G3: Return Periods and Corresponding Losses for Buildings

Building Losses (Million Riyals)				
Return Period	Occupancy	Structure Loss	Content Loss	Total Loss
10	Residential	114.505	95.676	210.18
	Commercial	26.426	66.056	92.48
	Industrial	4.123	76.192	80.31
	Squatters	2.892	5.012	7.9
	Total	*147.946*	*242.936*	*390.88*
25	Residential	537.086	370.351	907.44
	Commercial	152.308	350.326	502.63
	Industrial	14.994	275.483	290.48
	Squatters	20.732	29.677	50.41
	Total	*725.119*	*1,025.84*	*1,750.96*
50	Residential	2,255.06	1,571.61	3,826.67
	Commercial	495.401	1,171.94	1,667.34
	Industrial	52.463	896.084	948.55
	Squatters	55.02	81.061	136.08
	Total	*2,857.94*	*3,720.70*	*6,578.64*
100	Residential	3,677.57	2,423.03	6,100.60
	Commercial	838.014	1,831.25	2,669.26
	Industrial	93.957	1,439.09	1,533.05
	Squatters	106.167	142.197	248.36
	Total	*4,715.71*	*5,835.56*	*10,551.27*

Annex H: Case Study - Bogota, Colombia: Using the Urban Disaster Risk Index [4]

The Republic of Colombia has seen significant seismic and volcanic activity in recent years. The capital city of Bogota is the country's largest and most populous and has the largest concentration of risks in the country[5]. It is located in a moderate seismic zone and its complex topography has also made it prone to landslides and flooding. Apart from these geographic factors, massive migration and urbanization over the years have further increased the city's vulnerability to disasters. A large portion of the city has grown in a haphazard manner and many buildings violate safety regulations. Dense informal settlements have developed on highly unstable hill-slopes and filled-in ravines making them to prone to landslides, while poor drainage and over-flowing rivers result in frequent flooding in many parts of the city.

Holistic Risk Evaluation for Bogota

Various multi-dimensional risk assessment models have been developed over the years. One such model that has been applied to evaluating risk in Bogota is the Urban Disaster Risk index (UDRi). UDRi assesses disaster risk using "hard" and "soft" variables, taking into account not only a city's physical exposure, but also indirect aggravating factors that account for the socio-economic fragility and coping capabilities of the city's population and its institutions. In the case of Bogota, UDRi has helped identify risk-prone localities and their specific social, institutional and organizational vulnerabilities which is useful for effective risk management. UDRi comprises (i) a physical risk index R_F, which is defined by the convolution of hazard parameters and the physical vulnerability of de exposed elements, (ii) an aggravating coefficient F, obtained from fragility and resilience descriptors based on indicators related to the vulnerability of the social context, and (iii) total risk R_T, is obtained from the physical risk aggravated by the impact factor in each unit of analysis, that is, a comprehensive view of risk in each zone of a metropolitan area[6].

Assessing Risk for Bogota

Total risk for the entire city of Bogota is high but this risk is not distributed evenly, reflecting the large socio-economic inequalities that exist in Colombian society. Less affluent localities of Bogota have historically suffered more damage and destruction than more affluent areas. UDRi has helped identify the comparative risk of all 19 localities to assess seismic, flood and landslide risk. An exposure characterization of the city has been drawn up to evaluate - building by building - probabilistic disaster losses, taking into account Bogota's seismic microzonation. A look

Figure H1: Descriptors of Physical Risk, Social Fragility and Lack of Resilience

F_{RF1}	Damaged area	w_{RF1}
F_{RF2}	Number of deceased	w_{RF2}
F_{RF3}	Number of injured	w_{RF3}
F_{RF4}	Rupture of water mains	w_{RF4}
F_{RF5}	Rupture of gas network	w_{RF5}
F_{RF6}	Length of fallen power lines	w_{RF6}
F_{RF7}	Affected telephone exchanges	w_{RF7}
F_{RF8}	Affected electricity substations	w_{RF8}
F_{FS1}	Slum neighborhood	w_{FS1}
F_{FS2}	Mortality rate	w_{FS2}
F_{FS3}	Delinquency rate	w_{FS3}
F_{FS4}	Social disparity index	w_{FS4}
F_{FS5}	Density of population	w_{FS5}
F_{FR1}	Hospital beds	w_{FR1}
F_{FR2}	Health human resource	w_{FR2}
F_{FR3}	Public space	w_{FR3}
F_{FR4}	Rescue manpower	w_{FR4}
F_{FR5}	Development level	w_{FR5}
F_{FR6}	Preparedness	w_{FR6}

$$R_F = \sum_{i=1}^{8} w_{RFi} \, F_{RFi}$$

Physical risk, R_F

Aggravating coefficient, F

$$F = \sum_{i=1}^{5} w_{FSi} \, F_{FSi} + \sum_{j=1}^{6} w_{FRj} \, F_{FRj}$$

[4] This case study is drawn largely from Carreno, et al (2009), and Carreno, Cardona and Barbat (2005).
[5] World Bank, 2006. Colombia - Bogota Disaster Vulnerability Reduction Project. Project Appraisal Document.
[6] For more details and data see *Indicators of Disaster Risk and Risk Management (Main Technical Report) 2005*

at the 'Socio-economic Layers' map, for instance, (Figure H2) reveals that localities such as Ciudad Bolivar and Bosa that are inhabited by poorer sections of the population are more risk prone.

Figure H2: Exposure Characterization for Bogota (building-by-building)

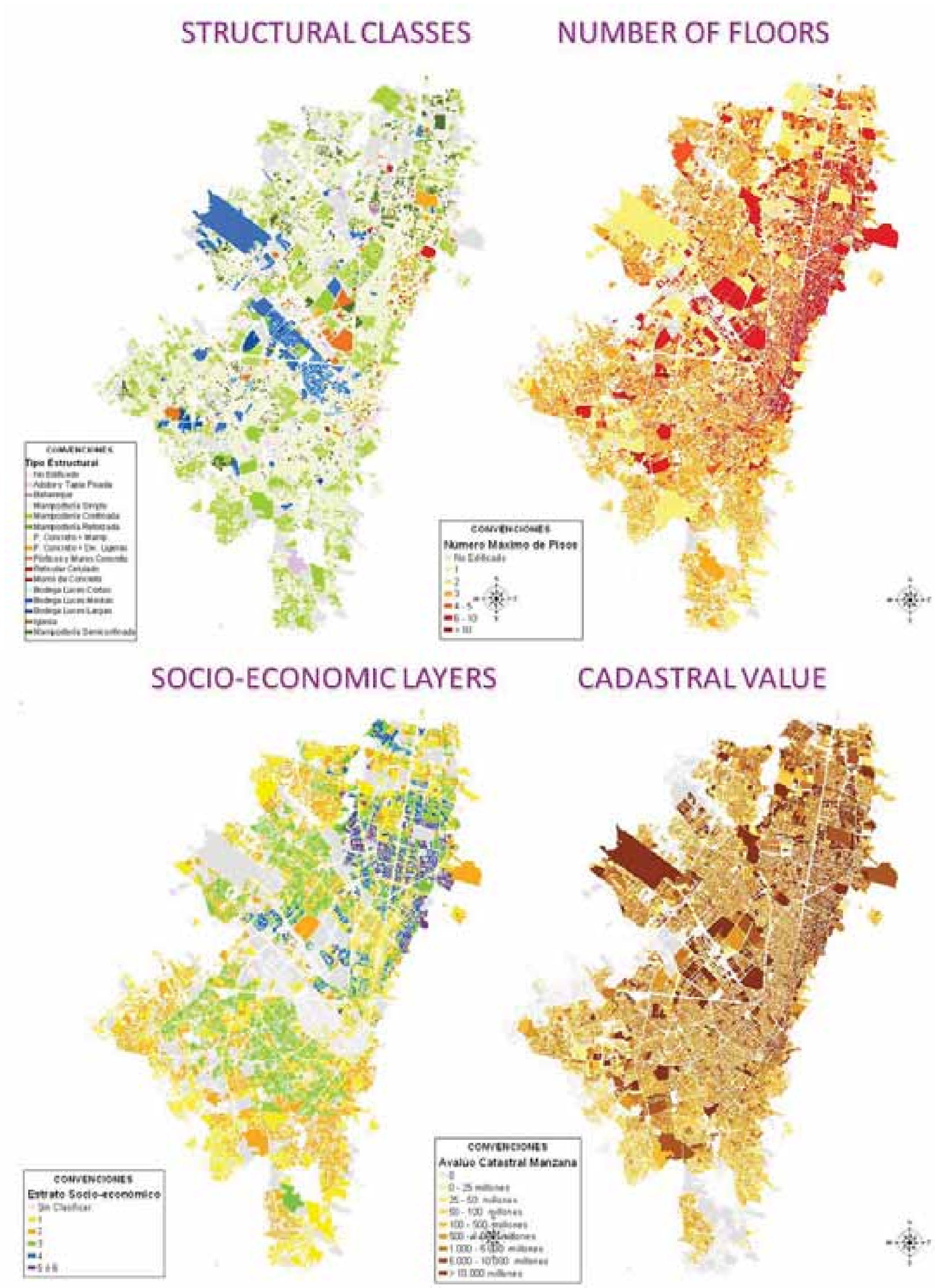
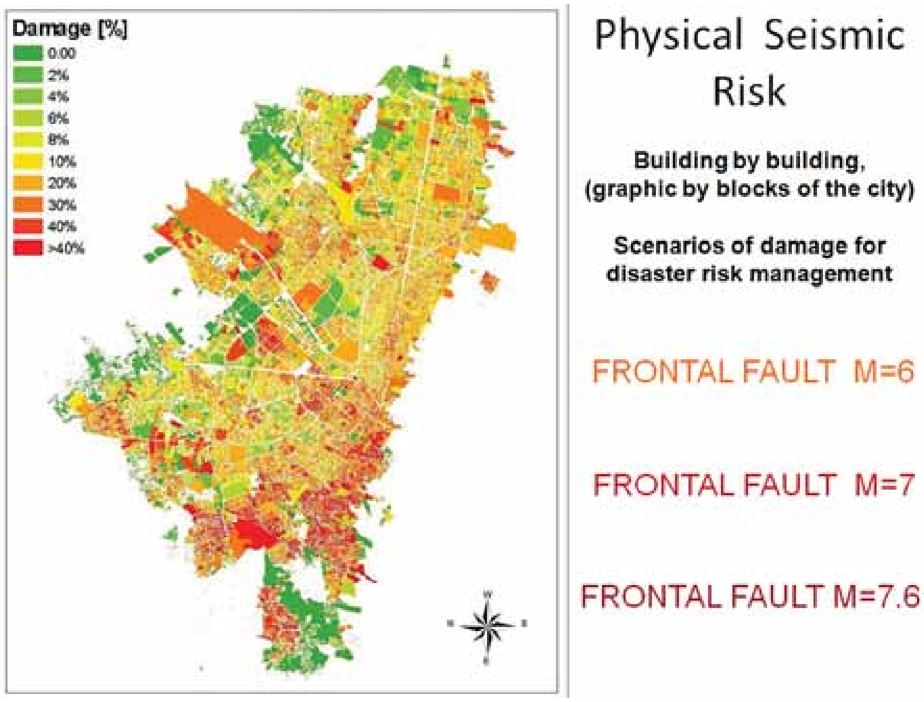


Figure H3: Physical Seismic Risk for Bogota



Exposure and Vulnerability to Multiple Hazards

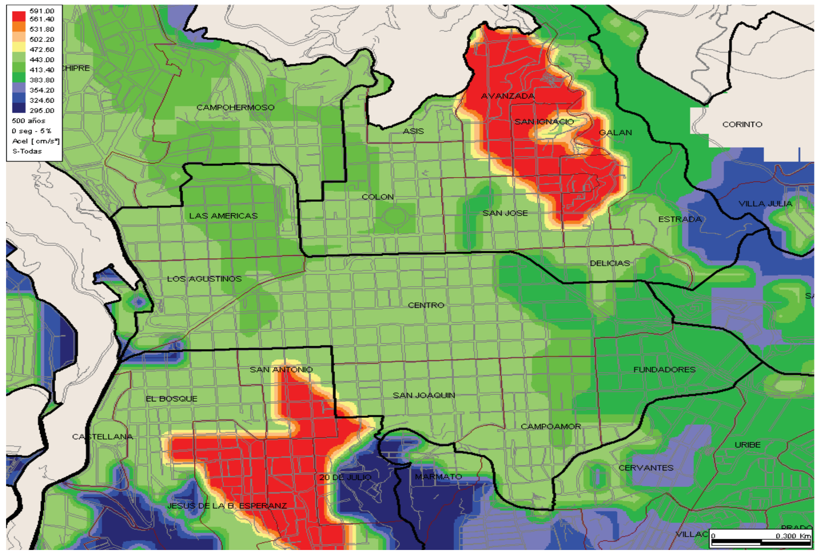
In terms of seismic risk, the locality of Candelaria has the most critical situation from the point of view of the physical (0.426) and total risk (0.694), because its aggravating factor (0.631) is significant, although it is not the highest in the city. The localities with greater impact factor are Usme, Ciudad Bolivar, San Cristobal and Bosa, whereas the lowest values are those of Barrios Unidos, Teusaquillo and Chapinero. High values of the physical risk index, in addition to Candelaria, are the localities of Usaquen (a district of middle-high socio-economic income level, located on soft soils and with mid-size buildings), Santa Fe, Suba and Teusaquillo, whereas the physical risk index is less in Ciudad Kennedy and Rafael Uribe Uribe. The greater values of total risk index appear in the localities of Candelaria, Santafe´ and Barrios Unidos and the smaller values are those of Ciudad Kennedy, Fontibon and Tunjuelito.

Other than earthquakes, landslides are a major threat to Bogota which is surrounded by mountainous terrain belonging to the Eastern 'Andean' Cordillera. During the last 30 years, Bogota has witnessed aggressive and disorganized urbanization that has pushed people to build their homes on highly unstable slopes and landfills that collapse easily, leading to heavy injuries and loss of life. The city has grown in a northerly direction along the flanks of the mountains. These areas of higher relief are composed of sedimentary rocks, which are highly fractured and covered by thick sand and gravels deposits. Natural denudation processes and mining for construction material and brick manufacturing have led to unstable ground conditions. It is estimated that between 1999 and 2003, out of the total emergency calls that the Dirección de

Prevención y Atención de Emergencias de Bogotá (DPAE) attended, 36 per cent related to landslides[7].

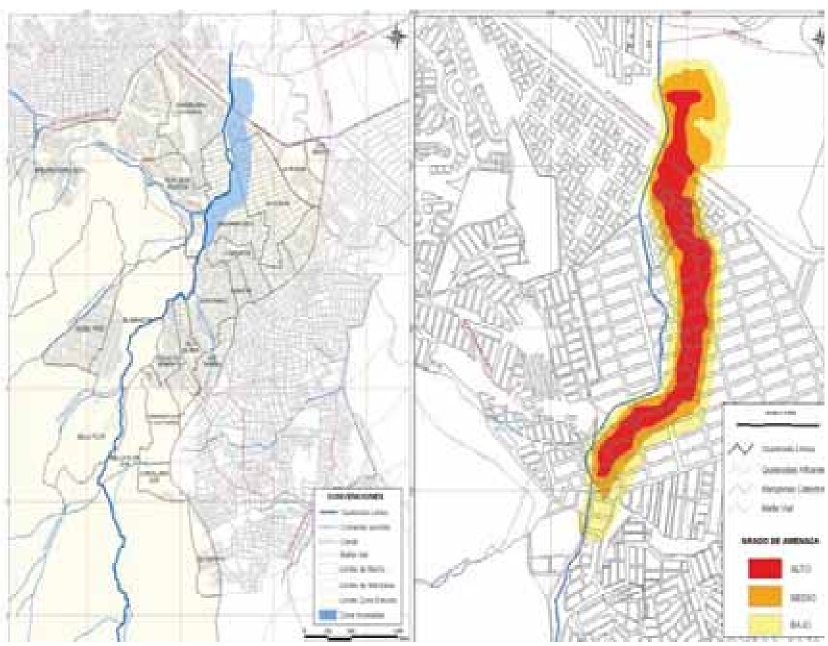
One of the most high-risk localities in Bogota is Ciudad Bolívar, located in the south-eastern mountains of Bogota. Nearly 60 per cent of the area is prone to high or mid landslide risk. People live in self-constructed shelters and building codes are not followed[8]. Poverty rates and overall social vulnerability indices are high compared with the rest of the city.

Figure H4: Physical Landslide Risk (graphic by blocks of the city)



Bogota also suffers from frequent flooding. One of the key reasons is that three major rivers - Juan Amarillo, Tunjuelito and Bogota River - flow through the city. When it rains, the river basins overflow, flooding low-lying areas. Inadequate and clogged drainage systems have aggravated the problem especially in the South and East of the city. It is estimated that almost 500,000 people live in flood hazard areas (Rogelis, 2008). One of the major flood prone areas is the Tunjuelo River Basin, located in the south of Bogotá City where 2.5 million people (or about 35% of the total population of the city) are concentrated. This 388 km^2

Figure H5: Flood Risk for Bogota



[7] Fires (37%) accounted for DPAE's largest number of emergency calls, according to '3CD City Profile Series – Current Working Document, 2006'

[8] http://emi.pdc.org/soundpractices/Bogota/SP6-resettlement-high-risk.pdf

drainage basin is characterized by a high degree of degradation due to pollution and human intervention. Most settlements here are informal and occupied by low-income families.

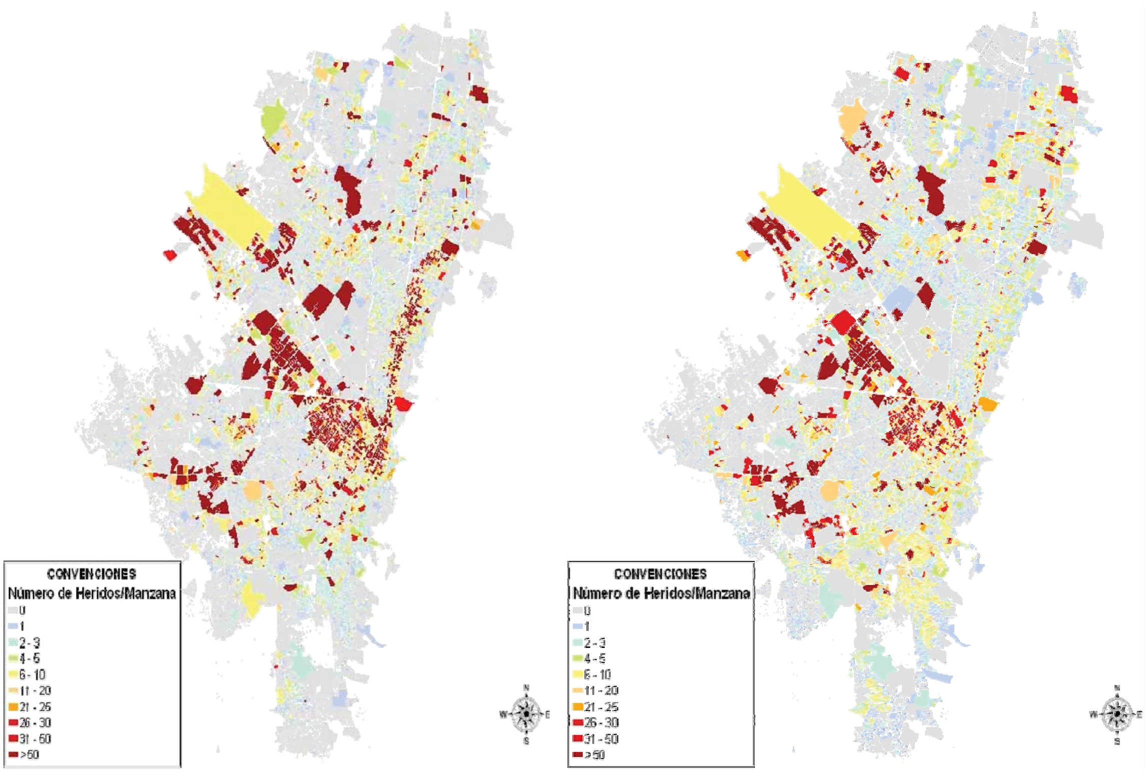
Damage and Loss

In terms of emergency preparedness, UDRi has contributed to the development of damage scenarios. Day- and night-time injuries are estimated based on occupancy and building-by-building blocks of the city. Data reveals that while all residential, commercial and industrial buildings have 90 per cent occupancy during the day, at night-time all residential buildings are fully occupied. In comparison, hospital buildings have 100 per cent occupancy at day and night time.

This has helped local authorities in Bogota to measure the potential human impact that an event can have and identify appropriate contingency and emergency plans including:

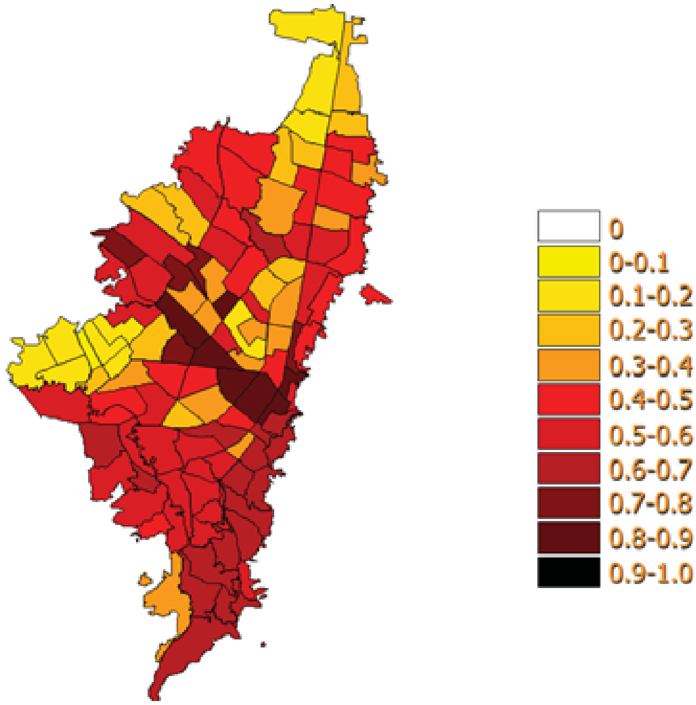
- Health services requirements
- Location of emergency units
- Security information
- Debris and construction materials
- Housing requirements
- Food requirements
- Services requirements (water, energy,etc)
- Functional vulnerability (roads, emergency routes,)

Figure H6: Injured Scenarios



Day time **Night time**

Figure H7: Total Risk Index



Comparison with other cities

Apart from Bogota, the holistic model has been applied to measure risk in three other cities: Barcelona (Spain), Manizales (Colombia), Metro Manila (The Philippines). Table H1 shows the highest value of physical risk is in Bogota while Metro Manila has the highest aggravating coefficient. Both cities are located in zones with intermediate seismic hazard, but a high aggravating factor puts Metro Manila in a worse situation.

Table H1: Comparison of Total Risk for Bogota, Barcelona, Manizales, Metro Manila

Index	Bogota	Barcelona	Manizales	Metro Manila
Physical Risk, R_F	**0.32**	0.08	0.27	0.24
Aggravating coeff, F	0.55	0.42	0.56	**0.59**
UDRi = Total Risk, R_T	0.50	0.11	0.44	0.38

An Action Plan for Risk Management in Bogota

Bogota has taken important steps in disaster risk mitigation over the last couple of decades. Under the World Bank-financed Bogotá Disaster Vulnerability Reduction Project, significant risk identification studies including hazard mapping, vulnerability assessment and risk management studies have been carried out. In fact, today Bogota has some of the world's most detailed risk and vulnerability records. Vulnerable populations have been relocated and several mitigation efforts such as structural reinforcement are underway. Risk communication systems have also been beefed up through various media, handbooks and community training. Additional efforts related to:

- **Involve local communities and the private sector in disaster reduction and mitigation**: Over the last decade, administrative authorities in Bogota have made a lot of progress in improving its risk management and emergency preparedness systems. Local and private sector involvement has, so far, been limited and should be encouraged in order to make the government disaster reduction agenda sustainable.
- **Relocation of vulnerable populations**: Since 1995, Bogota has implemented a massive resettlement program reducing the number of informal settlements. The city of Bogota's Resettlement Program for families living in high-risk zones incorporates three components: 1) relocation, 2) improving livelihood conditions, and 3) implementing environmental rehabilitation actions to avoid new occupation of the evacuated area. Over 9000 families were identified living in high-risk areas in 1997, 82% of them had been resettled as of 2008. However, a large number of families still remain vulnerable and illegal settlements in hazardous areas continue to grow.
- **Identify appropriate risk transfer mechanisms**: In Colombia, traditionally speaking, private and public assets are not insured. There is need for a national strategy that encourages risk transfer mechanisms that benefit the poor. Firstly, it is important to identify all risks in order to quantify the universe of exposure hazards in the country. With these findings, the Government can encourage States to protect vulnerable areas and handle post-disaster reconstruction by designing appropriate risk transfer and risk financing schemes such as microinsurance (Arnold, 2008).
- **Build capacity to address disaster risk**: As part of the World Bank's Natural Disaster Vulnerability Reduction Project, the Colombian government has made good inroads in decentralizing capacity for disaster risk management. However, the program still needs to reach more than half of the municipalities in the country.
- **Enforce building codes**: In 1997, the Colombian Parliament passed 'Law 400' which established seismic-resistant building standards for new construction. Since then, Colombia's building codes have been revised, but enforcement mechanisms are still weak and need to be revised. Stricter implementation and monitoring is necessary to make the built environment safer.
- **Improve emergency preparedness for 'critical events' like earthquake**: In terms of emergency response, rehabilitation and recovery, Bogota has made a lot of progress – especially when the city has to deal with frequent events such as landslides and floods. However, there is still a long way to go if the city would like to be reasonably for "critical events", such as a severe earthquake.

Annex I: Probabilistic Risk Modeling

Probabilistic risk models are built upon a sequence of modules that allow for the quantification of potential losses (in financial terms) from a given hazard. Using the combination of existing land use datasets, topographic models and improved analysis of land use from satellite imagery, current and future land use scenarios can be evaluated to more accurately define the hazard resulting from a natural event. The value of this capability is the ability to project future land use scenarios and examine the impacts of activities and policies in risk mitigation.

The hazard module defines the frequency and severity of a peril, at a specific location. This is done by analyzing the historical event frequencies and reviewing scientific studies performed on the severity and frequencies in the area of interest.

The exposure module generates an inventory of assets at risk. This inventory is created using primary data in combination with remote sensing information. When primary data are not available, secondary data sources and "proxy" approach may be used. The module aggregates the value for each type of exposures as a product of assets at risk and the average replacement cost per unit of inventory. Exposure and inventory can be developed to the extent supported by data for the physical assets at risk such as buildings (residential, commercial, industrial, and public), infrastructure (transportation roads and bridges), networks (water, sewerage, power, communications) and will detail the number, types, and distribution of assets as well as their valuation.

The vulnerability module quantifies the potential damage caused to each asset class by the intensity of a given event at a site. The development of asset classification is based on a combination of parameters including construction type (e.g. wall and roof combination), construction material, building usage, number of stories, and age. Estimation of damage is measured in terms of a *mean damage ratio* (MDR). The MDR is defined as the ratio of the repair cost divided by replacement cost of the structure. The curve that relates the MDR to the peril intensity is called a *vulnerability function*. Each asset class and building type will have different vulnerability curves for each peril.

The damage module is used to calculate losses through the damage ratio derived in the vulnerability module. The ratio is translated into dollar loss by multiplying the damage ratio by the value at risk. This is done for each asset class at each location. Losses are then aggregated as required.

The loss module builds upon the first four modules and quantifies potential losses that might arise as a result of adverse natural events. Risk metrics produced by the model provide risk managers and policy-makers with essential information necessary to manage future risks. One measure is called the Average Annual Loss (AAL) and the other is the Loss Exceedance Curve (LEC). The AAL is the expected loss per year when averaged over a very long period (e.g., 1,000 years). Computationally, AAL is the summation of products of event losses and event occurrence probabilities for all stochastic events in a loss model. The events are an exhaustive list affecting the location/region under consideration, generated by stochastic modeling. In probabilistic terms, the AAL is the mathematical expectation.

The Loss Exceedance Curve (LEC) represents the probability that a loss of any specified monetary amount will be exceeded in a given year. This is the most important catastrophe risk metric for risk managers, since it estimates the amount of funds required to meet risk management objectives (e.g., solvency criteria). The LEC can be calculated for the largest event in one year or for all (cumulative) events in one year. For risk management purposes, the latter estimate is preferred, since it includes the possibility of one or more severe events occurring over a given time frame.

Box I1: Probabilistic Flood Hazard Analysis

A probabilistic flood hazard analysis is composed of the following steps:

i. Identification, acquisition, compilation and review of relevant hydro-meteorological data
ii. Catchment rainfall analysis: rainfall intensity-frequency-duration (IFD) analysis to estimate design rainfalls for average recurrence intervals (ARI) up to 100 years; rainfall depth-area-duration analysis to estimate appropriate catchment rainfalls and spatial rainfall distribution for design studies
iii. Hydrologic (rainfall-runoff) modeling to estimate design flows at key points in each catchment
iv. Hydraulic modeling to estimate design flood levels throughout the urban agglomeration areas
v. Flood hazard mapping to show the flood extent and flood depth throughout the urban agglomeration for a range of ARI events

The catchment rainfall analysis consists of two parts:
Rainfall Depth-Area-Duration (DAD) Analysis: In any given storm event, the rainfall distribution over the basin is not uniform and varies from event to event. The purpose of this analysis is to identify the rainfall distribution that generates the largest flow in the river. In the probabilistic analysis, given an average rainfall over the basin, this distribution is used in the hydrologic model to estimate the river flow.

Rainfall Depth-Frequency-Duration (DFD) Analysis: This analysis estimates the relationship between rainfall amount (depth), duration and frequency. It provides the rainfall amount that will be used in the probabilistic analysis for the selected return periods.

Hydrologic Model (HEC-HMS): The HEC-HMS hydrologic model is exercised to determine the flow in each drainage basin given a rainfall amount.

Model Setup: Topographic maps, satellite imagery, and a digital elevation model (DEM) are used to verify the watershed delineation.

Model Calibration and Validation*:* Model calibration is the process of adjusting model parameter values until the model results match observed data based on prescribed criteria. The process is usually manual using engineering judgment to iteratively adjust hydrologic parameters and quantify the goodness of fit between the computed and observed hydrographs. Model validation is just as important as calibration because validation establishes the validity or uniqueness of the calibration parameters. The validation process is intended to ensure that the model parameters are not dependent on the calibration storms. The validation process uses data that were not included in the calibration and determines the reliability of the model for other historical events.

Floodplain Mapping: Based on the 10, 25, 50 and 100 year flow data calculated by the hydrologic model, the boundaries of the 10, 25, 50 and 100 return period flood plains can be determined in addition to flood. The corresponding flood maps will be generated. An example of an innovative presentation of flood hazard identification is two-dimensional flood modeling in an urban setting. A floodplain map is prepared by integrating model results with GIS data to produce an urban floodplain map with varying depths of flow depicted in different colors. In addition, flow paths and velocities determined from the model are shown with directional arrows across the floodplain.

Annex J: Remote Sensing as a Tool for Assessing Urban Risk

Data capture using satellite remote sensing tools has made large strides in the last few years. Remotely sensed images collected from space based satellites now provide a level of detail that is beginning to rival aerial photographs that are taken from low flying planes—a more expensive and cumbersome process especially in remote or poor regions (Ehrlich et al, 2010). The level of detail provided by these satellites is related to the size or footprint of the imagery; the larger the detail, the smaller the area that can be captured in a single image (Figure J1). With the increasing prevalence of remote sensing technologies being employed in development work, city government staff and urban practitioners stand to benefit from an improved understanding of the various applications that remotely sensed satellite can have for urban areas.

The supply of satellite images is increasing and national space programs, including an increasing number in developing countries, and commercial satellite image providers advertise earth observation products with different characteristics satisfying many application areas including disaster management (Ehrlich et al, 2010). Currently, the use of remote sensing is often associated for its application in disaster response through, for example, the International Charter on Space and Major Disasters (ICSMD). The ICSMD is a no-cost system of space data acquisition and delivery in case of natural or human-made disasters. The service is accessible 24-hours per day with an on-duty-operator, and data is delivered to civil protection agencies, emergency and rescue services once collected. Increasingly however an additional and important function of remote sensing is the capacity to detect changes associated with slow on-set climate related hazards (e.g. land motion/subsidence, heat island effect, soil moisture, water levels, air pollution). Box J1 highlights a recent case in Tunis, Tunisia where remote sensing has been used to measure land subsidence.

There is general consensus that a resolution of ideally 1m or even 0.5m is needed for detailed urban analysis. It is however worthwhile taking in to account, that even with very high resolution (VHR), important details are still lost. This underscores how several sources of data is often required to identify urban elements, and the need to consider combining remote satellite imagery with aerial images of even greater resolution (i.e., 15 cm).

Table J1: Satellite Imagery Useful for Risk and Damage Assessment

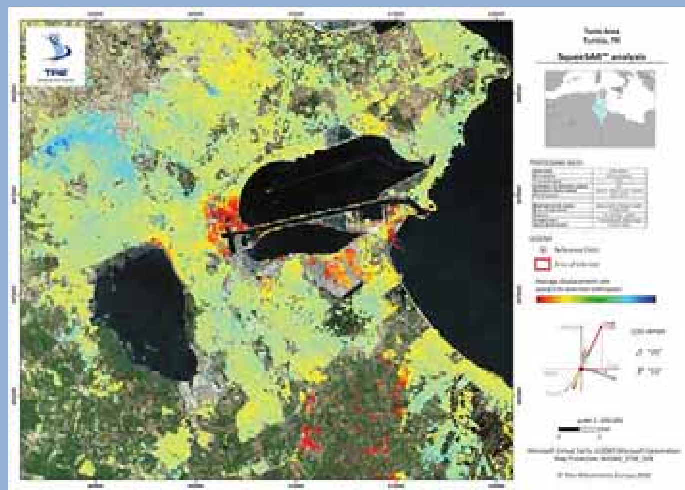
Satellite	Spatial Resolution [m]
GeoEye	0.41 1.65
WorldView-1	0.5
Quickbird	0.6 2.4
EROS-B	0.7
Ikonos	0.8 4.0
OrbView-3	1.0 4.0
KOMPSAT-2	1.0 4.0
Formosat-2	2.0 8.0
Cartosat-1	2.5
SPOT-5	2.5 10.0

Source: (Ehrlich et al, 2010)

Box J1: Land Subsidence in Tunis, Tunisia

In support of a World Bank study on coastal cities in the Middle East and North Africa, the European Space Agency (ESA) measured land subsidence in the central area Tunis. The red dots show a very high rate of subsidence of more than 5 millimeters per year.

While the on-going deformation within the city was a known fact, having it measured in an objective and incontrovertible way provides the needed entry point for city management to initiate adaptive measures that will prevent further subsidence.



Source: European Space Agency

It must be kept in mind that very high resolutions also may lead to unforeseen challenges, such as the need for extremely high computation capability in terms of algorithms or and hardware, and a balance between technological development and intended application must be found. Selected satellites with high potential for application in urban areas are presented in Table J1, and a related summary of detection capacity of satellite resolutions listed in Table J2. Within each satellite product, prices vary depending on a number of factors including the level of pre-processing (geometric and radiometric), the data provider (worldwide or regional affiliates), whether imagery is archive or new acquisitions, speed of delivery, and whether licensing applies to use by a one or multiple organizations[9].

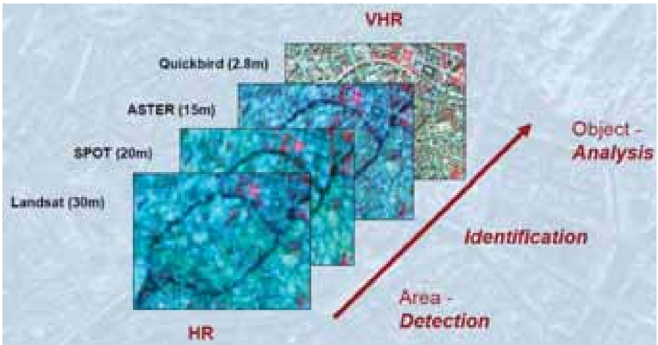
Table J2: Satellite Resolution and Detection Capacity

Spatial Resolution	Applications
0.5 – 1.5 meters	Identification, cartography of objects (cars, trees, urban materials).
1.5 - 5 meters	Distinction of buildings Identification, cartography of objects (construction)
5 - 10 meters	Location/cartography of buildings, roads, streets, agricultural lands
10 – 20 meters	Location and geometry of large infrastructure (airports, city centers, suburbs, commercial malls, industrial areas)

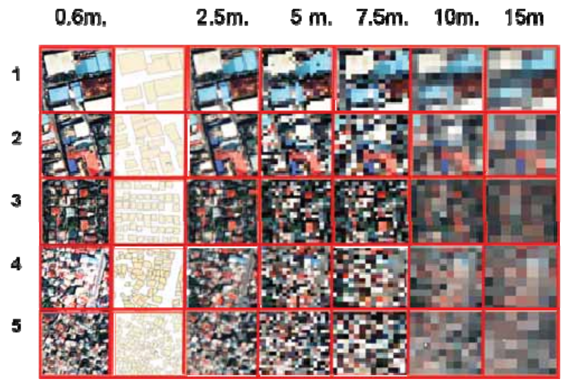
Source: Weber, C. (2008)

[9] There would likely be preferential pricing policies if cities were able to purchase remote sensing imagery in bulk. This pooling of cities could also yield cost savings for insurance provision, similar to current national level the Catastrophe Risk Deferred Drawdown Option (CAT DDO).

Figure J1: Examples of Satellite Resolution

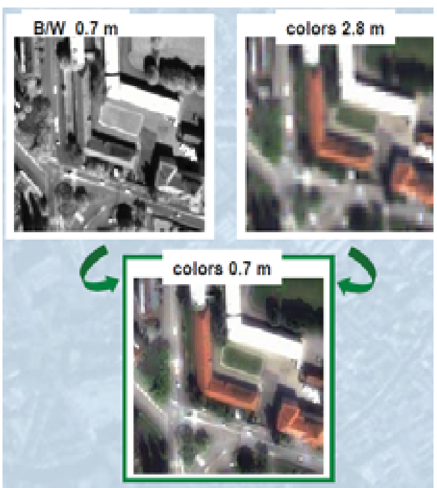


Source: Weber, C. (2008)



Source: Ehrlich, D. (2009)

Figure J2: Spectral Fusion



Source: Weber, C. (2008)

Strengthening a city government's understanding of building features is a key input to undertaking a risk assessment. A categorization of building features typically includes construction material, building footprint, roof shape and age of the structure. Such features can be determined through a combination of remote sensing and ground surveys as an important verification process (Figure J2).

Key infrastructure data can also be captured through satellite imagery including land use categorization spanning residential, commercial, industrial, transportation networks, green space, and utility systems, among others. Optical sensors, rather than radar, are typically used in determining land use given their comparatively high spatial resolution, multisprectral capacity, and ease of processing. A major limitation to the use of optical sensors, however, is their inability to produce data during night periods or in the event of cloud cover. By the very geographic location of certain cities, those for example in the equatorial regions, this necessitates the use of radar given persistent cloud coverage.

A key input to the analysis of vulnerabilities to hazards such as flooding and landslides is the generation of a Digital Elevation Models (DEM). DEMs consist of two types of digital models: Digital Terrain Models (DTM) which represent the topography of land (useful for landslide and flood risk) and Digital Surface Models (DSM) which include man made infrastructure applicable to urban areas (ISU, 2009). There are three steps to creating models of the built environment in urban areas. These include the acquisition of raw data, the generation of the model, and feature extraction of buildings through image processing. The calibration of the DEM is further enhanced through the use the Ground Control Points (GCPs) which are determined from ground-based measurements of locations with a predetermined elevation. The combination of information collected through remotely sensed imagery with a geographic information system (GIS) can provide a highly detailed neighborhood or city-wide view. GIS is a technique used to analyze data that is connected to a specific location. This can be particularly useful in improving the understanding about soils, geomorphology, vegetation, terrain slope and orientation.

<u>Remote Sensing: Satellite Descriptions, Pricing and Application for Digital Elevation Models</u>

Below is a brief description of three satellites including Geoeye-1, Ikonos, and CitySphere:

Geoeye-1: A high-resolution earth observation satellite owned by GeoEye, which was launched in September 2008. GeoEye-1 provides 41 cm (16 in) panchromatic and 1.65 m (5.4 ft) multispectral imagery in 15.2 km (9.4 mi) swaths. At the time of its launch, GeoEye-1 was the world's highest resolution commercial earth-imaging satellite. Google has exclusive online mapping use of its data. While GeoEye-1 is capable of imagery with details the size of 41 cm (16 in), that resolution will only be available to the government. Google will have access to details of 50 cm (20 in).

Ikonos: A commercial earth observation satellite, and was the first to collect publicly available high-resolution imagery at 1 and 4 meter resolution. It offers imagery in multispectral (MS) at 4m, panchromatic (PAN) at 0.8m, and 1-meter pan-sharpened.

DigitalGlobe's CitySphere: Features 60 cm or better orthorectified color imagery for 300 pre-selected cities worldwide. These GIS ready cities are available as off the shelf products and ready for immediate delivery. Each city is comprised of recent imagery, with initial imagery not older than 2006. The price of a CitySphere product depends on the size of the city and the continent. Importantly, the CitySphere licensing can be shared among a pre defined numbers of customer groups making the procurement of imaging more affordable were costs shared across government agencies or departments. Dar es Salaam, Tanzania, for example would fall into the 'Medium' size category given that the city's area is recorded at approximately 1,500 km^2.

Table J3: Pricing of Geoeye, Ikonos and CitySphere Satellite Imagery

Product		Geoeye-1 (0.5/2.0 m)[10]		Ikonos (1.0/4.0m)[11]
		USD$/ KM^2		USD$/ KM^2
Geo		25.00		20.00
GeoProfessional		35.00		33.00
GeoProfessional Precision		40.00		38.00
GeoStereo/GeoStereo Precision		Ad-hoc pricing		
Archive (Geo Product only)		12.50		10.00
Note: Prices are based on minimum order size of 49 KM^2 for Archive and 100 KM^2 for all other products				
CitySphere				
Region	Small (<1,000 KM^2)	Medium (1,001-2,000 KM^2)	Large (2,001-5,000 KM^2)	Very Large (>5,000 KM^2)

[10] Panchromatic or pan-sharpened
[11] Multispectral

US & Canada	2,750	5,000	10,500	24,250
Europe & Australasia	3,850	8,250	17,250	52,500
Rest of World	7,750	16,250	34,250	84,500

Source: Eurimage Price List

Table J4: High-Resolution Data Collection for Digital Elevation Models

Technique	Description	Considerations	Mission	Resolution		Cost
				Horizontal	Vertical	(USD/KM^2)
Stereoscopy	Uses binocular vision to produce overlapping photographs taken from different angles to produce a 3D model. Can be used to determine building height.	More cost effective than LIDAR systems, however, quality of information is weather dependent. Available on select satellite missions (IKONOS (1m), Earth Resources Observation System, EROS-B, QuickBird (0.61), System Pour l'Observation de la Terre, SPOT-5 (2.5m)). Alternative option to satellite use are airborne solutions (i.e. High Resolution Stereo Camera – Airborne (HRSC-A).	ASTER	30m	<20m	Free
			SPOT-5	30m	10m	3.3
			IKONOS	5m	<12m	Variable
Light Detection and Ranging (LIDAR)	An alternative to RADAR;	Provides very high-resolution models with	Commercial Service	0.5m	0.15m	~250

	uses ultraviolet, visible and near-infrared light waves. Usually installed on a small airplane.	better building shape characterization which allows for fine feature extraction. Drawbacks include high cost and acquisition times and degraded images due to aerosols and clouds.				
Interferometric Synthetic Aperture Radar (INSAR)	Uses two or more Synthetic Aperture Radar images and analyzes differences in the phase of returning waves.	Current spatial resolution is low for urban areas. Limitations include scattering of building geometrics, shadowing effects and resulting underestimation of building spatial distribution. Technology is developing in this area and approaching 1m resolution.	Shuttle Radar Topography Mission	90m	<16m	Free
			TanDEM-X	12m	<2m	NA

Source: International Space University (2009)

Annex K: Community Based Institutional Mapping and Other Participatory Approaches[12]

Pro-Poor Adaptation to Climate Change in Urban Centers: Case studies of Urban Poor in Mombasa in Kenya and Estelí in Nicaragua

Recently the World Bank along with the university of Manchester undertook a study to better understand what poor households, small businesses and communities are doing to cope with climate change impacts (experienced as increasingly variable and capricious weather patterns), as well as by identifying how policy and institutional systems can best build on local realities to develop pro-poor urban climate change adaptation actions, particularly relating to resilience.

Methodology

The study uses an innovative methodology, based on a framework which analyzes the assets of poor individuals, households and communities, both in terms of their vulnerability to severe weather events, as well as their sources of resilience for dealing with the negative impacts of climate change — with the range of assets grouped under a typology of: physical, financial, natural, human and social capital. The methodology has three components; most importantly an innovative new participatory climate change adaptation appraisal methodology (PCCAA) undertaken in four urban settlements in each city, an urban level rapid risk and institutional appraisal (RRIA), and finally a consultation and validation process conducted with a range of key selected stakeholders from government, civil society and local communities.

The Participatory Climate Change Asset Adaptation Appraisal (PCCAA)

Participatory Climate Change Asset Adaptation Appraisal (PCCAA) approach uses participatory methodology to identify 'bottom up' both asset vulnerability to CC, as well as asset adaptation strategies to build long-term resilience, protect assets during adverse weather and rebuild them. The objective of the PCAAA is twofold; first to understand the **asset vulnerability** of poor households, businesses and community organizations as they relate to severe weather associated with climate change, and second to identify the types of **asset adaptation strategies** implemented by the same social actors to address this issue. To undertake research, the PCCAA comprises two components that (i) identifies the links between different vulnerabilities and the poor's capital assets and (ii) explores and classifies the asset-based adaptation strategies as households, small businesses and communities exploit opportunities to develop resilience and resist, or to recover from, the negative effects of climate extremes. Following is a generic methodology used in the PCCAA:

i. Selection of researchers and local teams

First and foremost participatory research requires collaborative research partnerships with researchers (and their counterpart institutions) that have had hands-on research experience using

[12] Derived from Moser et al., 2010. "Pro Poor Adaptation to Climate Change in Urban Centers: Case Studies of Vulnerability and Resilience in Kenya and Nicaragua" http://siteresources.worldbank.org/EXTSOCIALDEVELOPMENT/Resources/244362-1232059926563/5747581-1239131985528/ESW_propoorurbanadaptationReport4947GLBweb2.pdf

PUA/PRA techniques. Constructing research teams that can undertake PUAs requires skills in judging local capacities.

ii. The fieldwork process
Once all the preparation work is completed, following the same fieldwork process already used in many such participatory studies, the actual research is undertaken over a five week period. This breaks down into the following tasks:

- Week 1: Capacity building of local researchers to train them in the conceptual framework and participatory tools and techniques used in the study
- Week 2: Study of pilot community)
- Week 3 and 4: Study of 4 further communities
- Week 5: -analysis of data and completion of preliminary research results

iii. Research techniques
Group discussions; Semi-structured interviews (on a one-to-one basis); Direct observation; Ethno-histories and biographies (on a one-to-one basis); Local stories, portraits, and case studies

iv. Locations for conducting participatory urban appraisal in communities
There are two main ways of conducting a PUA in a community (i) to carry out 'formal' focus group discussions in a local community centre or communal building and (ii) the second method is to use participatory urban appraisal tools with **'informal'** focus groups, identified on the spot while walking through the community, as well as in shops, and bars, beside football pitches or basketball courts, or outside people's houses.

v. Analysis of the research data
The research analysis can go through a number of stages: daily field notes, preliminary research findings, reworking the data and developing a final report. Apart from PCCAA, the study also relied on:

Rapid Risk and Institutional Appraisal (RRIA): provides a 'top down' review of the policy domain, in terms of the institutions tasked to deal with CC, the relevant national, regional, and municipal level policies, regulations and mandates relating to CC, as well as associated programs — and budgetary allocations.

Consultation/Validation of Results: the process of results validation depending on the level of commitment by different social actors. In Estelí an action planning exercise triangulated the results, allowing urban poor communities and public authorities to identify common problems, structure solutions, and negotiate collaboration. In Mombasa, consultation was more limited and prioritized an information sharing and capacity building event.

Findings from the Case studies

- The study found that the most significant asset of the urban poor (as they listed themselves) was housing. This highlighted a critical dimension of their vulnerability — namely weak or unclear tenure rights.

- The study found a great variety of responses to the increasing severity of local weather patterns at household, small business and community level. These included asset adaptation to build long term resilience (for example homeowners in Ziwa La Ngombe, Mombasa mobilized in order to seek assistance from donors, dug water passages in case of flooding, while small business owners constructed concrete walls to protect against flooding), asset damage limitation and protection during severe weather events (such as moving temporarily to safer places or sleeping on top of houses, and placing sandbags in the doorways of houses during floods), and asset rebuilding after such weather (for example inhabitants of 29th October, Estelí replanted trees and plants, while those living in Timbwani and Bofu, Mombasa accessed weather forecasters which informed people of the occurrence of severe weather).

Table K1: Composite matrix of perceptions of the most significant natural hazards in Mombasa and Esteli

Type of weather	Mombasa*		Estelí**	
	Ranking totals	%	Ranking totals	%
Flood/rain	166	49.8	312	69.8
Heat/sunny	105	31.4	116	25.8
Strong wind	55	16.4	20	4.4
Cold/chilly	8	2.4	-	-
Total	334	100.0	448	100.0

Sources: * Mombasa data from listing and ranking in 72 focus groups in four communities.
** Estelí data from listings and ranking in 62 focus groups in four communities.

- The rapid risk and institutional appraisal revealed that the implementation of climate change adaptation strategies at city and country level in both case studies was affected by a number of constraints. In both countries national climate change coordinating committees, with the mandate to advice on climate policy issues, were located in predominantly rural focused Ministries of Environment. In addition there was an overlap between different legal instruments, and a lack of clear mandate or effective coordination of programs within and between sector ministries as well as among the various levels of government (national, provincial, and local). Finally, the absence of concrete fiscal support was also a serious limitation to adaptation policies. Clear legal and institutional coordination and funding channels, relevant to urban areas, would make national adaptation strategies more meaningful in terms of supporting the efforts of the urban poor to build the necessary resilience to protect their assets.
- Results from institutional mapping in both cities also showed that institutions considered important by community members were not necessarily the same as those they perceived as assisting them in relation to severe weather. In Mombasa, for instance, local government representatives such as chiefs and elders were identified as important local institutions, yet did not take an active role in dealing with severe weather problems, except in Tudor.

Annex L: Global, National and Local Responses to Disasters and Climate Change

At a global level, the Hyogo Framework for Action (HFA) aims to substantially reduce disaster losses, in lives and in the social, economic and environmental assets of communities and countries by effectively integrating, in a coherent manner, disaster risk considerations into sustainable development policies, planning, programming, and financing at all levels of government. The HFA was adopted by 168 countries in 2005, and provides a technical and political agreement on the areas that needs to be addressed to reduce risk. The HFA is structured around five key priorities for action presented in Table 5 and specific tasks related to each (Box L1).

	Table L1: Hyogo Framework Priorities for Action
Priority Action 1	Ensure that disaster risk reduction is a national and local priority with a strong institutional basis for implementation.
Priority Action 2	Identify, assess and monitor disaster risks and enhance early warning.
Priority Action 3	Use knowledge, innovation and education to build a culture of safety and resilience at all levels.
Priority Action 4	Reduce the underlying risk factors.
Priority Action 5	Strengthen disaster preparedness for effective response at all levels.

Key implementing agencies for the HFA include the Global Facility for Disaster Risk and Recovery (GFDRR) and the United Nations International Strategy on Disaster Reduction (UNISDR). GFDRR provides technical and financial assistance to high-risk low- and middle-income countries to mainstream disaster reduction in national development strategies and plans to achieve the Millennium Development Goals (MDGs). UNISDR is the focal point in the UN system to promote links and synergies between, and the coordination of, disaster reduction activities in the socio-economic, humanitarian and development fields, as well as to support policy integration.

Climate change adaptation has a somewhat shorter history, emerging in the United Nations Framework Convention on Climate Change (UNFCCC) signed in 1992. However, the UNFCCC and the Kyoto protocol predominantly addressed climate change mitigation and policies and measures to reduce the emissions of greenhouse gases. It was not until quite recently that adaptation came to the forefront as a key concern within the UNFCCC. The possibilities for Least Developed Countries to develop National Adaptation Programmes of Actions (NAPAs) and the Nairobi Work Program—a 5- year (2005-2010) initiative under the UNFCCC, were important first steps towards both enhancing the understanding of adaptation and catalyzing action on adaptation. The Bali Action Plan (BAP), agreed upon at the UNFCCC Conference of Parties (COP) in Bali, provides a roadmap towards a new international climate change agreement to be concluded by 2009 as successor to the Kyoto Protocol. The BAP puts adaptation on an equal footing with mitigation. In the BAP, risk management and disaster risk reduction are identified as important elements of climate change adaptation. Further, the BAP emphasizes the importance of "building on synergies among activities and processes, as a means to support adaptation in a coherent and integrated manner."[13]

Box L1: Local/City Level Disaster Risk Reduction Tasks

Local/city governance (HFA Priority 1 related)
Task 1. Engage in multi-stakeholder dialogue to establish foundations for disaster risk reduction.
Task 2. Create or strengthen mechanisms for systematic coordination for DRR.
Task 3. Assess and develop the institutional basis for disaster risk reduction.
Task 4. Prioritize disaster risk reduction and allocate appropriate resources.

Source: *http://gfdrr.org/index.cfm*

The Global Facility for Disaster Reduction and Recovery (GFDRR) is a partnership of the International Strategy for Disaster Reduction (ISDR) system to support the implementation of the Hyogo Framework for Action (HFA) and is managed by the World Bank on behalf of the participating donor partners and other partnering stakeholders. The GFDRR provides technical and financial assistance to high-risk low- and middle-income countries to mainstream disaster reduction in national development strategies and plans to achieve the Millennium Development Goals (MDGs). The GFDRR provides financing under three tracks to meet its development objectives at the global, regional and country levels.

- **Track-I: Global and Regional Partnerships:** Enable leveraging country resources for *ex-ante* investment in prevention, mitigation and preparedness activities, particularly in low and middle-income countries.
- **Track-II: Mainstreaming Disaster Risk Reduction in Development**: Provides technical assistance to low and middle income countries to mainstream disaster risk reduction in strategic planning, particularly the Poverty Reduction Strategies (PRSs) and various sectoral development policies.
- **Track-III: Standby Recovery Financing Facility (SRFF) for Accelerated Disaster Recovery:** Supports early recovery in low-income disaster-stricken countries to bridge the gap between humanitarian assistance and medium and long term recovery and development. The SRFF includes two trust funds; a technical assistance fund to support disaster damage loss, needs assessment and planning; and a callable fund to provide speedy access to financial resources for disaster recovery.
- **South-South Cooperation:** Through grant financing up to US$500,000 the Program fosters demand-driven and results oriented South-South partnerships designed around specific needs, common interests, and shared objectives. The Program aims to strengthen

13 O'Brien, K. et al. 2008

the leadership role of developing countries in finding effective and efficient risk reduction and recovery solutions that are part of wider efforts to achieve the Millennium Development Goals. By systematically sharing experiences and lessons learned, disaster-prone countries facing similar challenges and operating under comparable financial and political constraints can arrive at more relevant and efficient solutions to daunting disaster risk and climate change problems.

UNISDR's Making Cities Resilient Campaign. The United Nations International Strategy for Disaster Reduction is the focal point in the UN System to promote links and synergies between, and the coordination of, disaster reduction activities in the socio-economic, humanitarian and development fields, as well as to support policy integration. It serves as an international information clearinghouse on disaster reduction, developing awareness campaigns and producing articles, journals, and other publications and promotional materials related to disaster reduction.

At the First World Congress on Cities and Adaptation to Climate Change ISDR launched the Making Cities Resilient: My City is Getting Ready campaign. The campaign is targeting over 1,000 local government leaders worldwide and includes a checklist of Ten Essentials for Making Cities Resilient that can be implemented by mayors and local governments. Through this campaign, ISDR and the World Bank are collaborating to streamline the use of the Urban Risk Assessment within signatory city governments.

Ten Essentials for Making Cities Resilient

1. Put in place **organization and coordination** to understand and reduce disaster risk, based on participation of citizen groups and civil society. Build local alliances. Ensure that all departments understand their role to disaster risk reduction and preparedness.

2. **Assign a budget** for disaster risk reduction and provide incentives for homeowners, low income families, communities, businesses and public sector to invest in reducing the risks they face.

3. Maintain up-to-date data on hazards and vulnerabilities, **prepare risk assessments** and use these as the basis for urban development plans and decisions. Ensure that this information and the plans for your city's resilience are readily available to the public and fully discussed with them.

4. Invest in and maintain **critical infrastructure that reduces risk**, such as flood drainage, adjusted where needed to cope with climate change.

5. Assess the **safety of all schools and health facilities** and upgrade these as necessary.

6. Apply and enforce **realistic, risk-compliant building regulations and land use planning principles**. Identify safe land for low-income citizens and develop upgrading of informal settlements, wherever feasible.

7. Ensure **education programmes and training** on disaster risk reduction are in place in schools and local communities.

8. **Protect ecosystems and natural buffers** to mitigate floods, storm surges and other hazards to which your city may be vulnerable. Adapt to climate change by building on good risk reduction practices.

9. Install **early warning systems and emergency management** capacities in your city and hold regular public preparedness drills.

10. After any disaster, ensure that the **needs of the survivors are placed at the centre of reconstruction** with support for them and their community organizations to design and help implement responses, including rebuilding homes and livelihoods.

Annex M: Tools for Climate Risk Assessment[14]

Adaptation Learning Mechanism: *UNDP*
The ALM draws from experiences on the ground, featuring tools and practical guidance to meet the needs of developing countries. Seeking to provide stakeholders with a common platform for sharing and learning, the ALM complements the wide range of adaptation knowledge networks and initiatives already underway. The ALM supports adaptation practices, the integration of climate change risks and adaptation into development policy, planning and operations, and capacity building.

Adaptation Wizard: *UK-CIP*.
The Adaptation Wizard provides a 5-step process that will help you to assess your vulnerability to current climate and future climate change, identify options to address your key climate risks, and help you to develop a climate change adaptation strategy.

Climate Change Explorer (weADAPT): *SEI.*
The Climate Change Explorer is an expanding collaboration that offers a wealth of experience, data, tools, and guidance to develop sound strategies and action on climate adaptation. weADAPT provides support for adapting to climate change by pooling expertise from a wide range of organisations that contribute to adaptation science, practice and policy. The weADAPT partners have developed tools to aid in undertaking various key steps in the climate adaptation process. These tools are designed to help people assess the situation and develop, implement and evaluate measures and strategies for adaptation.

Climate Change Portal/ADAPT: *The World Bank.*
The WB Climate Change Portal is intended to provide quick and readily accessible climate and climate-related data to policy makers and development practitioners. The site also includes a mapping visualization tool (webGIS) that displays key climate variables and climate-related data.

Climate Ready: *Massachusetts Institute of Technology (forthcoming).*
Climate-Ready is an interactive web tool designed to help local governments and communities plan for and take action to address the impacts of climate change. It helps users identify relevant adaptation activities, generates awareness of options and tradeoffs, promotes mainstreaming of adaptation, fosters learning and exchange, and promotes coordination, cooperation and collaboration across stakeholders and sectors.

CRiSTAL: *IIDS.*
The Community-based Risk Screening Tool – Adaptation and Livelihoods (CRiSTAL) is designed to help project planners and managers integrate climate change adaptation and risk reduction into community-level projects. It has been designed to assist in understanding the links

[14] *A number of actors in the fields of science, administration, and development cooperation are developing practical approaches and instruments to assist the process of mainstreaming adaptation to climate change. Please refer to a recent GTZ report on the "*International Workshop on Mainstreaming Adaptation to Climate Change*" for a full description of available adaptation tools for development practitioners as well as Tanner, Thomas and Bruce Guenther. 2007. Screening Tools Geneva Workshop Report, April 2007, in Geneva, Switzerland.

between livelihoods and climate in their project areas; assessing a project's impact on community-level adaptive capacity; and making project adjustments to improve its impact on adaptive capacity and reduce the vulnerability of communities to climate change.

SERVIR: *USAID.*
SERVIR is used by decision makers to allow for improved monitoring of air quality, extreme weather, biodiversity, and changes in land cover. SERVIR has also been used over 35 times to respond to environmental threats such as wildfires, floods, landslides, and harmful algal blooms. Special attention is given to analyzing the impacts of climate change and providing information for adaptation strategies.

Annex N: Sample Household Urban Risk Questionnaire

This questionnaire is designed to help communities gauge the impact of small-scale/local disaster and household actions to minimize risk from natural hazards and climate change.

NATURAL HAZARD INFORMATION

1. In the past ten years, have you or someone in your household experienced a natural disaster such as an earthquake, severe windstorm, flood, wildfire, or other type of natural disaster?

☐ Yes
☐ No (IF NO Skip to Question 2)

a. If ("YES"), which of these have you or someone in your household experienced and when?(Please check all that apply)

✓	Hazard	Year(s)	✓	Hazard	Year(s)
☐	Drought		☐	Wildfire	
☐	Dust Storm		☐	Household Fire	
☐	Earthquake		☐	Wind Storm	
☐	Flash Flood		☐	Winter Storm	
☐	Landslide/Debris Flow		☐	River Flood	
☐	Extreme Temperature		☐	Tsunami	
☐	Storm Surge		☐	Other:_____________	

2. How concerned are you personally about the following? (Circle the corresponding number for each hazard)

Hazard	Extremely Concerned	Very Concerned	Concerned	Somewhat Concerned	Not Concerned
Drought	1	2	3	4	5
Dust Storm	1	2	3	4	5
Earthquake	1	2	3	4	5
Flash Flood	1	2	3	4	5
Landslide/Debris Flow	1	2	3	4	5
Extreme Temperature	1	2	3	4	5
Storm Surge	1	2	3	4	5
Wildfire	1	2	3	4	5
Household Fire	1	2	3	4	5
Wind Storm	1	2	3	4	5
Winter Storm	1	2	3	4	5
River Flood	1	2	3	4	5
Tsunami	1	2	3	4	5
Other _____________	1	2	3	4	5

3. What is the frequency of the hazards that you have experienced? (e.g. 2 times per month)

Natural Disaster	**Monthly**	**Yearly**	**Cause** (i.e. Reoccurring or Manmade)
Drought			
Dust Storm			
Earthquake			
Flash Flood			
Landslide/Debris Flow			
Extreme Temperature			
Storm Surge			
Wildfire			
Household Fire			
Wind Storm			
Winter Storm			
River Flood			
Tsunami			
Other ______________			

4. What was the impact of the disasters on you/family?
   - ☐ Lost income
     - ☐ Amount ________
   - ☐ Injury/death
   - ☐ Housing damage
     - ☐ Cost of repairs _______
   - ☐ Disrupted services (ie. water/electricity)

5. Following a disaster, who assists you in recovering? Please specify (ie. community association, local government, neighbors, NGO, etc)

6. Have you ever received information about how to make your family and home safer from natural disasters?

   ☐ Yes
   ☐ No (IF NO Skip to Question 4)

   a. If "YES", how recently?

      ☐ Within the last 6 months
      ☐ Between 6 and 12 months
      ☐ Between 1 and 2 years
      ☐ Between 2 and 5 years
      ☐ 5 years or more

   b. From whom did you **last** receive information about how to make your family and home safer from natural disasters? **(Please check only one)**

   ☐ News Media
   ☐ Government Agency
   ☐ Insurance Agent or Company
   ☐ Red Cross
   ☐ Other non-profit Organization
   ☐ Not Sure

- ☐ Utility Company
- ☐ Other ________________________

7. Who would you most trust to provide you with information about how to make your family and home safer from natural disasters? **(Please check all that apply)**

- ☐ News Media
- ☐ Government Agency
- ☐ Insurance Agent or Company
- ☐ Utility Company
- ☐ Red Cross
- ☐ Other non-profit Organization
- ☐ Not Sure
- ☐ Other ________________________

8. What steps, if any, have you taken to minimize the impact of changing weather or a natural disaster?

Other Comments:

Annex O: PAGER Construction Types Used for Building Inventory Development

Construction Type	Description
Adobe Houses	This type of housing is typically built by owners and local builders from raw/processed earth. Such housing often performs poorly in earthquakes.
Wood Houses	There are many forms of wood housing: bamboo frame; plank, beam & post system; and engineered timber houses. Understandably, their quality varies depending on the level of technical inputs used.
Stone Masonry Houses	This is a very widely used housing form worldwide. The main materials used in the walls are blocks of natural stone material available, like granite, laterite, sandstone, and slate. There are stone masonry houses with and without mortars; when mortars are used, they are either mud-based or cement-based. A variety of roofing systems are adopted including tiled roof supported on wood trusses, asbestos or steel sheets on steel trusses, and reinforced concrete slab.
Brick Masonry Houses	This is another common construction type. Clay mud is used to form regular-sized masonry units. These units are sometimes burnt in a kiln, and simply sun-dried. This is also a very widely used housing form worldwide. Brick masonry houses are made with and without mortars; when mortars are used, they are either mud-based or cement-based. These units are the main materials used in the walls. Again, a variety of roofing systems are adopted including tiled roof supported on wood trusses, asbestos or steel sheets on steel trusses, and reinforced concrete slab.
Confined Masonry Houses	This type of housing has been practiced in many vernacular forms worldwide, particularly along the Alpine-Himalayan belt. These are load bearing masonry houses improved with the help of wood or concrete frame members introduced in the walls to reduce the masonry walls into smaller panels that are more capable of withstanding earthquake shaking. The masonry could be made with either stone or brick. This system is far superior to the traditional load-bearing masonry houses. A variety of roofing systems are employed with the confined masonry wall system, depending on the geographic region of construction.
Reinforced Concrete Frame Buildings	This type of housing is becoming increasing popular across the world, particularly for urban construction. It employs beams (i.e., long horizontal members), columns (i.e., slender vertical members) and slabs (i.e., plate-like flat members) to form the basic backbone for carrying the loads. Vertical walls made of masonry or other materials are used to fill in between the beam-column grids to make functional spaces. These houses are expected to be constructed based on engineering calculations. However, in a large part of the developing world, such buildings are being built with little or no engineering calculations.
Reinforced Concrete Shear Walls Buildings	This type of housing is same as the reinforced concrete frame building but provided with a select number of additional thin vertical plate-like reinforced concrete elements called structural walls, positioned in specific bays in the plan of the building. This type of construction requires a high level of engineering input like the reinforced concrete frame buildings. This type of building with structural walls shows superior seismic performance during earthquakes in comparison to that of reinforced concrete frame

	buildings without shear walls.
Precast Concrete Buildings	The building is built of individual high-quality factory-made components connected at site. Two styles of construction are adopted, namely (a) the components are of the RC frame building alone, i.e., beams, columns, structural walls, and slabs; and (b) the components consist of large-panel prefabricates of walls and slabs only, and not of beams and columns. This type of house construction is in limited use in urban areas or mass housing projects.
Buildings with Advanced Technologies	Some wood houses and reinforced concrete frame houses have been built recently using base-isolation technology. Here, the building is rested on flexible bearing pad-like devices, which absorb part of the earthquake energy transmitted from the ground to the building, thereby reducing the damage in the building. This type of construction is very expensive, but such houses perform very well during the earthquakes.
Vernacular Housing	Many housing types found today in different pockets of the world are those based on technology handed over from one generation to the next by word of mouth. What is impressive is that these construction schemes often have characteristics that address the prevalent local conditions of temperature and other natural effects (like earthquake shaking). There is much to learn from these housing practices.

Annex P: Urban Risk Assessment Template

City/ metropolitan area, country
Map

City Profile

What are the distinct characteristics of the city area and urban population? Where is the city expanding? What are the geographic characteristics of the city's location? (Including physical setting, topography (e.g. coastal area, near mountain area, on inland plains, on inland plateau, near a river), and seismic activity).

Describe predominant features of the built environment and basic service provision (Including infrastructure, water supply, energy networks, transport, waste, management, road, housing, etc). What are the priorities / main development challenges of the city?

CITY SNAPSHOT
(From Global City Indicators)

Total City Population in yr
Population Growth (% annual)
Land Area (Km2)
Population density (per Km^2)
Country's per capita GDP (US$)
% of country's pop
Total number of households
Dwelling density (per Km2)
Avg. household income (US$)
% of Country's GDP
Total Budget (US$)
Date of last Urban Master Plan

PILLAR 1 - INSTITUTIONAL ASSESSMENT

Describe briefly which agencies are involved in disaster risk management or climate change adaptation? How are they involved? What is their function? Is their role clearly reflected in their mandates, work-plans and staff job descriptions? How are the agencies or institutions active in the different fields of disaster risk management and/or climate change related to each other?

Name relevant policies and legislation available to the agencies or institutions mentioned above, or if there is any under preparation?

What are the most important ongoing programs and projects related to disaster risk management or climate change adaptation? What resources are available to support these programs? Is there a disaster response system in the city? Is it comprehensive? Is it regularly tested and updated?

Are there any shortcomings in current disaster risk management or climate change adaptation management tools/policies/programs that need to be addressed?

Is there a leading agency coordinating the disaster risk management activities of the city? Does it have sufficient financial, technical and human resources to lead the activities? Does it have a legal backing?

What is being done to mainstream risk reduction activities? (Include information on prevention and preparedness)

What are estimated levels of spending on pro-poor services and infrastructure, and where applicable, on climate mitigation and resilience (public, private)? How is this estimated?

Institutional Snapshot

Leading agency coordinating Disaster Risk Management efforts

Government staff trained in early warning, preparedness, and recovery

Disaster Risk Management budget under different agencies

Non-governmental organizations involved in Disaster Risk Management

Institutional Mapping of Disaster Risk Management Functions

Risk Assessment	Risk reduction		
	Technical (planning, management, maintenance)	*Early Warning and response*	*Public Awareness*
• Instruments • Instruments	Institutions • instruments	Institutions • instruments	Institution • instruments
• Institution • instruments • instruments	• Institution • instruments	• Institution • instruments	• Institution • instruments
• Institution • instruments • instruments	• Institution • instruments	• Institution • instruments	• Institution • instruments

Pillar 2 - Hazard impact assessment

In the past, which have been the most significant natural disasters? Include information such as total affected population (dead, wounded and those who have suffered material and economic loss), affected geographical area, estimated amount of damage and losses (assets, production and increase spending), and economic impacts (changes in GDP, exports, imports, tourism, etc).

Hazard	Effects	Losses

What are the city's main climate hazards based on historical data and/or scenarios using available climate projections?

Which specific urban areas (infrastructure and buildings) and populations at high risk of disasters and climate change impacts have been identified? (Include hazard exposure maps if available).

Is there information on the magnitude, distribution, and probability of potential losses due to each of the most relevant projected hazards? (Include information on probabilistic risk assessment methodology used if available and or vulnerability curves

Natural Hazards Snapshot

	Y /N	Date of last major event
Earthquake		
Wind Storm		
River Flow		
Floods, Inundations and waterlogs		
Tsunami		
Drought		
Volcano		
Landslide		
Storm Surge		
Extreme Temperature		

- Additional background on most relevant historical hazards, include if available picture, graphs, maps, etc.

- Additional information on most relevant projected hazards, include if available picture, graphs, maps, etc.

Pillar #3 –Socioeconomic Assessment

Which areas within the city have the highest population exposure to hazards? (Use data on land use, ecosystems, geophysical properties, socioeconomic factors, and infrastructure)

Indicate the location of urban poor settlements (Include poverty maps). What is the level of exposure of the settlements to climate and natural hazards?

What are the characteristic of slums (informal settlements or similar). Include information on geospatial, socio-economic and environmental characteristics, as well as access to basic services, tenure and social-capital?

Does the city have any good practices in addressing urban poverty? Can these be referred to as climate smart?

What are the key lessons in terms of constraints and opportunities to address urban poverty in a climate smart way for the city?

What is the urban carbon footprint of the city? What are main assumption underlying these numbers? What are the trends?

Social Assessment Snapshot

- ***Percentage of city population below poverty line***
- ***Social inequality (Gini index)***
- ***Unemployment (% of total labor force)***
- ***Areal size of informal settlements as a percent of city area***
- ***Percentage of city population living in slums***
- ***Percentage of households that exist without registered legal titles***
- ***Percentage of children completing primary and secondary education: survival rate***
- ***Human Development Index***
- ***Predominant housing material***

Annex Q: Key Definitions[15]

Adaptation

The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Comment: This definition addresses the concerns of climate change and is sourced from the secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). The broader concept of adaptation also applies to non-climatic factors such as soil erosion or surface subsidence. Adaptation can occur in autonomous fashion, for example through market changes, or as a result of intentional adaptation policies and plans. Many disaster risk reduction measures can directly contribute to better adaptation.

Capacity

The combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals.

Comment: Capacity may include infrastructure and physical means, institutions, societal coping abilities, as well as human knowledge, skills and collective attributes such as social relationships, leadership and management. Capacity also may be described as capability. Capacity assessment is a term for the process by which the capacity of a group is reviewed against desired goals, and the capacity gaps are identified for further action.

Climate change

(a) The Inter-governmental Panel on Climate Change (IPCC) defines climate change as: "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use".

(b) The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

Comment: For disaster risk reduction purposes, either of these definitions may be suitable, depending on the particular context. The UNFCCC definition is the more restricted one as it excludes climate changes attributable to natural causes. The IPCC definition can be paraphrased for popular communications as "A change in the climate that persists for decades or longer, arising from either natural causes or human activity."

[15] UNISDR Terminology on Disaster Risk Reduction (2009)
Definitions are adopted from existing definitions used in the Disaster Risk and Climate Change scientific and policy literature (UNISDR, IPCC, UNFCCC, etc). Because in some cases they differ in the literature, a comment follows selected definitions in order to better explain their use in this report.

Climate risk

Denotes the result of the interaction of physically defined hazards with the properties of the exposed systems - i.e., their sensitivity or social vulnerability. Risk can also be considered as the combination of an event, its likelihood and its consequences - i.e., risk equals the probability of climate hazard multiplied by a given system's vulnerability[16]. Climate risk management, on the other hand, implies climate-sensitive decision making in dealing with climate variability and change, and seeks to promote sustainable development by reducing vulnerabilities associated with climate risk.

Community-Driven Development (CDD)

Broadly defined, an approach that gives community groups and local governments control over planning decisions and investment resources. CDD empowers rural communities by allowing them to play a stronger role in the direct provision of basic services, and to hold government more accountable for its performance in assisting communities address their needs.

Coping capacity

The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters.

Comment: The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during crises or adverse conditions. Coping capacities contribute to the reduction of disaster risks.

Critical facilities

The primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency.

Comment: Critical facilities are elements of the infrastructure that support essential services in a society. They include such things as transport systems, air and sea ports, electricity, water and communications systems, hospitals and health clinics, and centres for fire, police and public administration services.

Disaster

A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

The Centre for Research on the Epidemiology of Disasters (CRED) defines a disaster as a "situation or event, which overwhelms local capacity, necessitating a request to national or international level for external assistance. The CRED maintains an Emergency Events Database (EM-DAT)[17], which has information on occurrence and effects of many types of disasters in the

[16] http://beta.worldbank.org/climatechange/content/adaptation-guidance-notes-key-words-and-definitions
[17] http://www.emdat.be/

world from 1900 to present. For a disaster to be entered into EM-DAT, at least one of the following criteria must be fulfilled:

- 10 or more people reported killed
- 100 people reported affected
- Declaration of a state of emergency
- Call for international assistance

Comment: Disasters are often described as a result of the combination of: the exposure to a hazard; the conditions of vulnerability that are present; and insufficient capacity or measures to reduce or cope with the potential negative consequences. Disaster impacts may include loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets, loss of services, social and economic disruption and environmental degradation.

Disaster risk

The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period.

Comment: The definition of disaster risk reflects the concept of disasters as the outcome of continuously present conditions of risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socio-economic development, disaster risks can be assessed and mapped, in broad terms at least.

Disaster risk management

The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster.

Comment: This term is an extension of the more general term "risk management" to address the specific issue of disaster risks. Disaster risk management aims to avoid, lessen or transfer the adverse effects of hazards through activities and measures for prevention, mitigation and preparedness. 'Disaster Management' implies emergency management and response, whereas Disaster Risk Management is a more holistic term implying all four phases of disaster risk reduction, preparedness, response, and post-disaster reconstruction.

Disaster risk reduction

The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events.

Comment: A comprehensive approach to reduce disaster risks is set out in the United Nations-endorsed Hyogo Framework for Action, adopted in 2005, whose expected outcome is "The substantial reduction of disaster losses, in lives and the social, economic and environmental assets of communities and countries." The International Strategy for Disaster Reduction (ISDR) system provides a vehicle for cooperation among Governments, organisations and civil society actors to assist in the implementation of the Framework. Note that while the term "disaster reduction" is sometimes used, the term "disaster risk reduction" provides a *better recognition of the ongoing nature of disaster risks and the ongoing potential to reduce these risks.*

Disaster risk reduction plan

A document prepared by an authority, sector, organization or enterprise that sets out goals & specific objectives for reducing disaster risks together with related actions to accomplish these objectives.

<u>Comment</u>: Disaster risk reduction plans should be guided by the Hyogo Framework and considered and coordinated within relevant development plans, resource allocations and programme activities. National level plans needs to be specific to each level of administrative responsibility and adapted to the different social and geographical circumstances that are present. The time frame and responsibilities for implementation and the sources of funding should be specified in the plan. Linkages to climate change adaptation plans should be made where possible.

Early warning system

The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.

<u>Comment</u>: This definition encompasses the range of factors necessary to achieve effective responses to warnings. A people-centered early warning system necessarily comprises four key elements: knowledge of the risks; monitoring, analysis and forecasting of the hazards; communication or dissemination of alerts and warnings; and local capabilities to respond to the warnings received. The expression "end-to-end warning system" is also used to emphasize that warning systems need to span all steps from hazard detection through to community response.

Exposure

People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses.

<u>Comment</u>: Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest.

Geological hazard

Geological process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

<u>Comment</u>: Geological hazards include internal earth processes, such as earthquakes, volcanic activity and emissions, and related geophysical processes such as mass movements, landslides, rockslides, surface collapses, and debris or mud flows. Hydrometeorological factors are important contributors to some of these processes. Tsunamis are difficult to categorize; although they are triggered by undersea earthquakes and other geological events, they are essentially an oceanic process that is manifested as a coastal water-related hazard.

Greenhouse gases

Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds.

<u>Comment</u>: This is the definition of the Intergovernmental Panel on Climate Change (IPCC). The main greenhouse gases (GHG) are water vapour, carbon dioxide, nitrous oxide, methane and ozone[18].

Hazard

A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

<u>Comment</u>: The hazards of concern to disaster risk reduction as stated in footnote 3 of the Hyogo Framework are "… hazards of natural origin and related environmental and technological hazards and risks." Such hazards arise from a variety of geological, meteorological, hydrological, oceanic, biological, and technological sources, sometimes acting in combination. In technical settings, hazards are described quantitatively by the likely frequency of occurrence of different intensities for different areas, as determined from historical data or scientific analysis.

Land-use planning

The process undertaken by public authorities to identify, evaluate and decide on different options for the use of land, including consideration of long term economic, social and environmental objectives and the implications for different communities and interest groups, and the subsequent formulation and promulgation of plans that describe the permitted or acceptable uses.

<u>Comment</u>: Land-use planning is an important contributor to sustainable development. It involves studies and mapping; analysis of economic, environmental and hazard data; formulation of alternative land-use decisions; and design of long-range plans for different geographical and administrative scales. Land-use planning can help to mitigate disasters and reduce risks by discouraging settlements and construction of key installations in hazard-prone areas, including consideration of service routes for transport, power, water, sewage and other critical facilities.

Natural hazard

Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

<u>Comment</u>: Natural hazards are a sub-set of all hazards. The term is used to describe actual hazard events as well as the latent hazard conditions that may give rise to future events. Natural hazard events can be characterized by their magnitude or intensity, speed of onset, duration, and area of extent. For example, earthquakes have short durations and usually affect a relatively small region, whereas droughts are slow to develop and fade away and often affect large regions. In some cases hazards may be coupled, as in the

[18] IPCC negotiations focus on six greenhouse gases: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6).

flood caused by a hurricane or the tsunami that is created by an earthquake.

Resilience

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

Comment: Resilience means the ability to "resile from" or "spring back from" a shock. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need.

Retrofitting

Reinforcement or upgrading of existing structures to become more resistant and resilient to the damaging effects of hazards.

Comment: Retrofitting requires consideration of the design and function of the structure, the stresses that the structure may be subject to from particular hazards or hazard scenarios, and the practicality and costs of different retrofitting options. Examples of retrofitting include adding bracing to stiffen walls, reinforcing pillars, adding steel ties between walls and roofs, installing shutters on windows, and improving the protection of important facilities and equipment.

Risk

The combination of the probability of an event and its negative consequences.

Comment: This definition closely follows the definition of the ISO/IEC Guide 73. The word "risk" has two distinctive connotations: in popular usage the emphasis is usually placed on the concept of chance or possibility, such as in "the risk of an accident"; whereas in technical settings the emphasis is usually placed on the consequences, in terms of "potential losses" for some particular cause, place and period. It can be noted that people do not necessarily share the same perceptions of the significance and underlying causes of different risks.

Risk assessment

A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend.

Comment: Risk assessments (and associated risk mapping) include: a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability including the physical social, health, economic and environmental dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities in respect to likely risk scenarios. This series of activities is sometimes known as a risk analysis process.

Risk management

The systematic approach and practice of managing uncertainty to minimize potential harm and loss.

<u>Comment</u>: Risk management comprises risk assessment and analysis, and the implementation of strategies and specific actions to control, reduce and transfer risks. It is widely practiced by organizations to minimise risk in investment decisions and to address operational risks such as those of business disruption, production failure, environmental damage, social impacts and damage from fire and natural hazards. Risk management is a core issue for sectors such as water supply, energy and agriculture whose production is directly affected by extremes of weather and climate.

Risk transfer

The process of formally or informally shifting the financial consequences of particular risks from one party to another whereby a household, community, enterprise or state authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party.

<u>Comment</u>: Insurance is a well-known form of risk transfer, where coverage of a risk is obtained from an insurer in exchange for ongoing premiums paid to the insurer. Risk transfer can occur informally within family and community networks where there are reciprocal expectations of mutual aid by means of gifts or credit, as well as formally where governments, insurers, multi-lateral banks and other large risk-bearing entities establish mechanisms to help cope with losses in major events.

Structural and non-structural measures

Structural measures: Any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard-resistance and resilience in structures or systems;

Non-structural measures: Any measure not involving physical construction that uses knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education.

<u>Comment</u>: Common structural measures for disaster risk reduction include dams, flood levies, ocean wave barriers, earthquake-resistant construction, and evacuation shelters. Common non-structural measures include building codes, land use planning laws and their enforcement, research and assessment, information resources, and public awareness programmes. Note that in civil and structural engineering, the term "structural" is used in a more restricted sense to mean just the load-bearing structure, with other parts such as wall cladding and interior fittings being termed non-structural.

Urban

An 'urban area' is typically defined by country statistics offices as a non-agricultural production base and a minimum population size (often 5000). There are substantial differences in practice across countries (UN Statistics Division)[19].

Comment: Urban areas include continuously built up inner city area as well as transitional or peri-urban between fully built up and predominantly agriculture use or rural areas. However there is debate on a universal definition of urban areas. In practice, countries define urban areas differently.

Vulnerability

The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

Comment: There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Examples may include poor design and construction of buildings, inadequate protection of assets, lack of public information and awareness, limited official recognition of risks and preparedness measures, and disregard for wise environmental management. Vulnerability varies significantly within a community and over time. This definition identifies vulnerability as a characteristic of the element of interest (community, system or asset) which is independent of its exposure. However, in common use the word is often used more broadly to include the element's exposure.

[19] http://unstats.un.org/unsd/demographic/sconcerns/densurb/Defintion_of%20Urban.pdf

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