CLIMATE CHANGE RISK: AN ADAPTATION AND MITIGATION AGENDA FOR INDIAN CITIES

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India is one of the more vulnerable and multi-hazard risk prone countries in the world (IFRC, 2005, Parasuraman & Unnikrishnan, 2000). Much of its population (72 percent) lives in about 0.6 million villages while the rest live over 5,100 urban centres (Census, 2001). They have learnt over the centuries to cope with a wide range of natural (e.g. drought, flood, cyclone, storm surge, earthquake and landslide) and human-made hazards (e.g. fire, environmental health risks, road and chemical accidents). Rapid population growth, high densities, poverty and high differentials in access to housing, public services and infrastructure have led to an increase in vulnerability over the last few decades, especially in India's urban centres.

Climate-change risk is expected to increase the frequency and intensity of current hazards, an increased probability of extreme events, spur the emergence of new hazards (e.g. sea-level rise) and vulnerabilities with differential spatial and socio-economic impacts. This is expected to further degrade the resilience and coping capacities of poor and vulnerable communities, who make up from a quarter to half of the population of most Indian cities (Satterthwaithe et. al, 2007). Climate change is therefore set to become an increasingly important strategic economic and political concern as it starts to bite into India's high growth rates and relatively low levels of internal conflict.

Vulnerability has typically contributed more to overall risk in Indian cities, than hazard exposure. It is therefore important to understand a number of transformative processes that are rapidly changing India's urban landscape, altering livelihood opportunities and income and wealth distributions. These in turn have altered the vulnerability profiles of many communities and stakeholders and their capacity to adapt to long-range risks like climate change.

This analysis provides us greater insight into an adaptation-led strategy to reduce climate change risk and increasing urban resilience in keeping with India's development and priorities challenges. This attempts shifts the emphasis away from a largely mitigation and techo-centric response that has come to dominate the climate crisis discourse emanating largely from OECD countries. This may provide a window of opportunity for countries like India to chart a more independent traverse to a more sustainable future (De Vries, Revi et.al. 2007).

India's *RUrban* Transformation (2000-2050)

India will experience one of the most dramatic settlement transitions in history over the next 40-odd years as its urban population grows from about 300 to over 700 million (Hughes, 2006). Unlike most other regions of the world, South Asia has been marked by a low level of recent urbanisation, in spite of being one of the most urbanized pre-colonial regions of the 18th century (Revi, 2002, Banga, 2005). About 30 percent of India's population lived in urban areas in 2006 (Census, 2006), but given a 1.1 billion-plus population, its urban

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population exceeds that of Japan and EU, and most other regions of the world except the United States and China (UN, 2006).

Climate change risk to India should be seen in the perspective of an ongoing three-part transition: a demographic transition that will see India's population stabilising at about 1.6 billion in the 2060s; a simultaneous *RUrban* transition, which will see an addition of almost 500 million people in an estimated 7,000 to 12,000 urban settlements over this period; and simultaneously brown (e.g., water, sanitation and environmental health); grey (e.g., air and water pollution) and green (e.g., climate change) environmental transitions (McGranahan et. al, 2007). This complex-phase space provides for multiple sub-regionally nuanced strategies to respond to the climate crisis, drawing on considerable local experience of coping with uncertainty and far-from equilibrium systems.

A central challenge of Indian urbanisation over the early 21st century, is that an almost equal number of people will live in about 0.6 million villages as in 12-15,000 towns and cities by 2050. By 2025, an estimated 70 Indian cities are expected to have a population size of over one million. In addition, three mega urban regions: Mumbai-Pune (50 million), the National Capital Region of Delhi (over 30 million) and Kolkata (20 million) will be among the largest urban concentrations in the world (Dyson & Visaria, 2004, Revi, 2006, Census, 2006).

India could by mid-century, have both the largest national urban and rural populations of the time. This will have an important bearing on global climate vulnerability and the potential for mitigation and adaptation. Hence, the future direction of Indian urbanization, is not only an important domestic concern, but will be major international opportunity to demonstrate the viability of a more sustainable development.

Urban India overtook rural India in its GDP share in the late 1990s, in spite of having a less than 30 percent share of the national population. This income skew has been accentuated by, recent rapid economic growth in the city-based services and manufacturing sectors. Urban per capita incomes are now over thrice that in rural areas (CSO, 2006, RBI, 2006). India's agriculture sector currently contributes only 18 percent of its GDP. It nevertheless, provides livelihoods to close to 60 percent of the population, and the biomass and ecosystem services that enable the 'metabolism' of most Indian cities to function. The transformation of this metabolism towards more efficient and productive use of renewable energy (e.g. via biofuels and wind) and sustainable water management, will be crucial not only to the sustainability of cities but also the creation of 21st century livelihoods, in a culture that still in touch with its peasant roots.

Climate change induced disruptions and reduction in the flow of ecosystem services and the continuing increase in Net Primary Productivity (NPP) pre-emption by human systems (Fischer-Kowalski & Haberl, 2007) could therefore force many Indian cities to adapt in the medium run by altering their extractive relationship with the countryside. Hence, *RUrbanism* or 'keeping the balance between rural and urban areas' will become increasingly important in India, as rural-urban and inter-urban resource and socio-economic conflict became sharper in the future. (Revi, et al., 2006).

This contrarian trend has been attributed to South Asia having one of the lowest current rural-urban migration rates of major regions in the world. Migration in India, has been constrained by a number of factors including a crisis in creating new urban formal sector livelihoods in an era of globalization; dismal living and working conditions of the poor in cities; high urban

poverty levels driven by high costs of living; poor improvements in rural education till the late 1990s and a slow process of social transformation (Revi, 2006).

Climate change could in unexpected ways catalyse the ongoing agrarian crisis in rural India (Sainath, 2002) into a migratory rout, driven by an increase in extreme event frequency and intensity; expansion of endemic drought to more areas in the semi-arid peninsula; drought and flooding in the super-dense Indo-Gangetic & Brahmaputra plains and coastal flooding and drought in the coastal plains (Gosain et.al, 2006, Mall et. al., 2006, Ramesh, et. al. 2005) These scenarios have only been broadly articulated, but not systematically investigated with fine-grained GIS-linked models. (Rupa Kumar et al, 2006, GSDMA/ TARU, 2005). Hence, most projections on this count can only be seen as speculative at this point of time. Nevertheless, India's medium and long-term social and political stability will require a more nuanced and geographically explicit understanding of these risks as demographic dynamics alters the political representation of southern and western India in key democratic institutions, like Parliament (De Vries, Revi et. al. 2007).

It is possible, that climate change induced drought and resource conflict may force the pace of rural-urban migration over the next few decades. Alternatively, severe stresses induced in urban areas due to a mix of water scarcity, environmental services breakdown, flooding and consequent water borne disease and malaria-like epidemics combined with a rapid rise in health expenditures could maintain the low current level of rural-urban migration. A greater mobility of the backward castes and women could in time alter the migration dynamics across demographically dominant northern and eastern India. This indicates the potential for climate change (along with other driving factors) to induce bifurcation behaviour in migration and hence urbanization trends – questions that need more investigation.

Maintaining two-ways flows of food, biomass, water, energy, livelihoods, products and services across the *RUrban* continuum will be crucial to India's 'development transition' and medium-term sustainability. Hence, climate change adaptation in both cities and their embedding countryside is an undiscovered near-term policy concern - intimately connected with livelihoods and drought, biomass and energy security. (Revi, 2006)

India, like China in the 1990s is starting to massively ramp-up infrastructure investments in the energy, water, transportation and telecommunications sector to support its growth expansion. These systems have a typical service life of 50 to 150 years. More important, they are difficult and lumpy to replace (if damaged or destroyed in extreme weather events), very challenging to relocate (if necessary for effective adaptation) and may spur significant GHG contributions (if executed using business-as-usual technologies and management methods).

The challenge for India is to step around a path of exclusive engagement with'greener and cleaner' production, systems and services a la the OECD and hence a focus only on mitigation. The real challenge is to re-examine whether India's current development trajectory and growth framework may be more appropriate to a more urbanized and industrialized and less-labour rich economy. If so, a climate policy that has a closer fit with India's initial conditions, strengths and capacities may serve both the country and the world's purposes better than a 'recycled' programme of action from a rather different context.

Urban Renewal, Disaster Management and Climate Change Mitigation

India made a late start in engaging with questions of climate change. Public engagement with this question picked up only recently in spite of early environmentalist and academic positions on these questions (Aggarwal et. al. 1999). This is largely because of country's post-Rio (1992) pre-occupation with pressing poverty, economic and social development and political challenges, at a time when climate change started slowing creeping onto the global policy agenda (IPCC, 1995).

India has undertaken four officially supported national technical assessments of Climate Change risks, impacts, adaptation and mitigation options since 1992. The first was supported by Asian Development Bank; the second the Asian Least Cost Greenhouse Abatement Study (ALCGAS) was supported by the Global Environment Facility (GEF), the third was a Climate Impact Assessment study funded by DEFRA, Govt of UK, and the fourth was the recently concluded National Communication Project supported by the GEF (Sathaye et. al, 2006). These assessments shared three common features: one, they were largely externally funded and driven; two, they were coordinated by the Ministry of Environment & Forests (MoEF), Government of India (GoI) which is far from being the politically most powerful ministry of the central government; three, they were primary focused on the 'science' of climate change closely allied to the IPCC agenda and trends of analysis and therefore were weak in engaging with the complex nature and intensity of vulnerability in India, which is probably the most critical factor in risk mitigation (Revi, 2005). A range of long-range resource, energy and sustainable development studies have also been undertaken, but have had limited impact on the GoI agenda (TERI, 1998, Planning Commission, 2002).

The official Indian position of climate change drivers and risks has been strongly tied to fixing responsibility and the onus for correction of historical emissions by the OECD countries (Parikh & Parikh, 2002). It is hence largely focused on the GHG-energy nexus and its impact on energy security; the opportunities for financial leverage from the multiple cross-post-Kyoto national flows of capital that are expected including AIJ, CDM and carbon trading modalities (in which India made a very late start) or as a fringe issue taken up by environmental NGOs and activists that had little to do with the economic 'development' agenda. (Planning Commission, 2006; Sathye, et al, 2006; Sharma, et al, 2006; Shukla, et al, 2003; Shukla, 2006; Gupta, 2005). The debate on adaptation has been weak, in spite of a moderate Indian scientific presence in the IPCC process and an Indian being the IPCC Chair since 2002.

A great missed opportunity of the last 15-years was in the inability to join-up the official climate change adaptation agenda with the rapid development of natural hazard risk assessment, management and mitigation capacity, after a series of devastating disasters in the 1990s and the early 2000s. A series of moderately successful post-disaster reconstruction and linked mitigation programmes, especially after the Orissa supercyclone (1999), the Kachchh earthquake (2001) and the Indian Ocean tsunami (2005) have dramatically altered perceptions and the institutional and technical capacity to address vulnerability reduction and risk mitigation in India. India is one of the few large countries that have a central Authority to address disaster management and similar well-developed institutions at state level (e.g., GSDMA, OSDMA).

The 2005 Indian Ocean tsunami and the devastation it wrought along India's eastern coast also brought a long simmering concern to the fore - the integrated management of India's

coastal zone balancing environmental and biodiversity conservation, livelihood and economic development and risk mitigation concerns. A series of Integrated Coastal Zone Management Plans (ICZMPs) are now in progress along with a review of the principles and norms by which the Coastal Regulation Zone (CRZ) needs to be managed. This will provide an important stepping-stone for a more evidence-based set of climate mitigation and adaptation measures for coastal India and its cities – a key driver of medium-range economic growth and development (GoI, 2006).

The other important post-2004 development is the reappearance of urban development, urban renewal and governance as a significant public policy agenda after a hiatus of over a decade. The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) was initiated in 2005 to target 60 of the largest and most important cities with a $ 10 billion challenge fund that addresses improvements in infrastructure development, urban poverty and urban governance. While this has taken off to a slow start, it is hoped that more rational urban infrastructure development with a strong pro-poor focus would help address some of the structural vulnerabilities of a number of million-plus cities and state capitals.

A large chasm exists between the official urban 'city building' development agenda and vulnerability reduction for those most at risk in these urban areas. A root cause is the ambiguity of the Indian state and its elites, in accepting the centrality of the poor and their informal settlements in the process of urban development and economic growth. Hence, the imperative of delivering entitlements of adequate services (water, sanitation, solid waste, drainage, power) and equitable access to land and housing to the bulk of city residents is still a matter of contention. This ongoing institutional and cultural failure has been documented for decades, but is now reaching a scale, along with recurrent demolitions and relocations that has led to the compounding of vulnerability of a large section of urban residents.

Breaking this impasse will be central to the next conceptual leap of political and bureaucratic attention from the state provisioning of basic services; access to livelihoods and housing to alternative mechanisms of ensuring their sustainable provisioning functioning and financing. This can be supported through multiple community, community-public, community-private or public-private partnerships. The role of risk reduction and climate change adaptation in lowering the mounting social costs of recurrent disasters will need to be situated around action in this space.

There is, however, currently no independent JNNURM sub-component that addresses either urban vulnerability or risk mitigation, and no sight of a climate change-related response. Future integration of these concerns into the JNNURM architecture will only happen if appropriate advocacy is expeditiously initiated by the climate change community. This would need to be linked to sustainable city and regional development initiatives, which provide a possible framework for the integration of climate change risk mitigation and adaptation with *RUrban* planning, land-use zonation and infrastructure development initiatives. (Revi et. al., 2005). Else, urban adaptation and mitigation could be limited to the signing of operationally meaningless MoUs between Indian and OCED cities; number of official junkets and Press releases and little impact on the most vulnerable.

An important post-1990 factor in Indian cities is the emergence of city-level political processes, community and people's movements, which have started contesting from 'below' for 'space' for the poor within many cities. This has grown partially from a greater political consciousness following the devolution of political and administrative power to Urban Local Bodies (ULBs) via a Constitutional amendment in 1993. This has also been provided fillip by

NGO and judicial activism on a range of environmental questions, ranging from local greening and urban conservation to air and water pollution. This has, unfortunately, had little impact on more proletarian concerns like environmental health, which could dramatically reduce the risk exposure of poor households who make up a large fraction (55 percent in Mumbai) of the urban population. These currently fractured forces could if adequately mobilized, provide a base for future city-wide Community Based Risk Mitigation (CBRM) efforts that are crucial to the success of climate change risk adaptation.

A parallel but often conflicting development is increasing elite concern with the quality of urban life, its security and the sustainability of various urban services. This partially in response to the greater global integration of India's ITES sector and the aspiration of others to climb into the 'world-class city' bandwagon. Here again, enlightened self interest has still not come to terms with both the challenges and opportunities that the transformation of India's cities present, outside better infrastructure, buoyant real estate and a livable city for expatriates. This is an inconvenient truth that needs to be addressed across its political economy facets to enable a concern for 'carbon neutral' lifestyles and enterprises to converge with harsh realities on the ground. This is a largely unexplored area where social innovation is in considerable a deficit.

India's Climate Change Risk Exposure

India and South Asia's climate change related risk exposure is explored in the following sections that first attempt to unbundle the first and second order risks and then define a coherent set of adaptation and mitigation measures that could converge with ongoing natural hazard risk reduction and urban renewal interventions and hence start to be implemented, without waiting for a range of global post-Kyoto negotiations to be complete.

Temperature & Precipitation Changes

While there is little scientific 'doubt' about the emergence of climate change as an important risk in the Indian sub-continent over the span of this century, there is still considerable uncertainty about precise mechanisms and impacts, especially on precipitation and sea level rise, as presented in Table (1). This is partially because of the extreme difficulty of modeling the monsoon, the regional climate and the slow iterative improvement in global climate models, as more scientific evidence and computing power become available. Since all of the current global climate models have been developed outside India, the scientific 'lag' between domestic evidence-based policy and 'educated' responses to international research is still significant, but closing (Shukla et.al. 2003)

TABLE (1): CLIMATE CHANGE PROJECTIONS FOR INDIA BASED ON AN ENSEMBLE OF FOUR GCM OUTPUTS

Year	Temperature Change (°C)			Precipitation Change (%)			Sea Level Rise (cm)
	Annual	Winter	Monsoon	Annual	Winter	Monsoon	
2020s	1.36±0.19	1.61±0.16	1.13±0.43	2.9±3.7	2.7±17.7	2.9±3.7	4 to 8
2050s	2.69±0.41	3.25±0.36	2.19±0.88	6.7±8.9	-2.9±26.3	6.7±8.9	15 to 38
2080s	3.84±0.76	4.52±0.49	3.19±1.42	11.0±12.3	5.3±34.4	11.0±12.3	46 to 59

Source: Aggarwal & Lal, 2001

In spite of the uncertainty, there is broad consensus on the envelope of first-order climate change impacts in South Asia over the 21st century:

- A general increase in both the mean minimum and mean maximum temperatures by 2 to 4^{o} C, depending on the realised atmospheric GHG concentrations. (Sharma. et.al, 2006). This would have an impact on evapo-transpiration levels and therefore agriculture, horticulture and forestry and human activities, especially in the arid, semi-arid and mountain zones.

- This could lead to a mean surface temperature rise of 3.5 to 5^{o}C by the end of the century. This in turn, would imply changes in the location and viability of some settlements (especially in the arid and semi-arid zones) and pattern of building across the sub-continent, with an increasing role for passive solar and energy efficient design as the cost of fossil energy-based cooling is expected to rise. (Planning Commission, 2006).

- This regional temperature rise, along with changes in the global climate system and the Indian Ocean monsoon system, may lead to a mean increase of 7 to 20 percent in the mean annual precipitation. A 10 to 15 percent increase in monsoon precipitation in many regions, a simultaneous precipitation decline of 5 to 25 percent in semi-arid and drought-prone central India and a sharp decline in winter rainfall in northern India is also projected (Ramesh and Yadava, 2005). This implies changes in the output of winter wheat and mustard crops in northwestern India (esp. in the Green Revolution states of Punjab & Haryana) that could, in turn, have a significant impact on national food security, regional crop mixes and resultant demand for irrigation. This is one of the most serious risks to rural India and the hope of agricultural resurgence held out in the XI Plan Approach Paper of 4 percent plus sectoral growth over 2007-2012.

- Substantial spatial differences in precipitation changes are also expected. Western and west-central India is expected to have an increase in monsoon rainfall. (Gosain, et. al. 2006, Mall et. al, 2006). This implies adaptation of sub-regional agriculture, changes in water supply arrangements and a strong policy emphasis on water conservation and efficiency in most cities, as more rain could fall in more intense spells and drought intensity could increase. This increase in monsoon rainfall, combined with a shorter wet season will imply a change in the hydrology of many river systems and therefore modification in the storage capacity and management regime of many dams and reservoirs. With large areas in peninsular India starting to provide tanker and multi-settlement piped water supply, the Planning Commission, State Planning Boards, Departments of Rural Development and PHEDs would do well to start engaging with this, before a third generation of drought envelops them.

- A decrease in the number of rainy days (by 5 to 15 days on an average) is expected over much of India, along with an increase in heavy rainfall days and frequency of heavy rainfall events in the monsoon season. (Rupa Kumar, et.al, 2006) These changes are expected to increase the vulnerability of Indian agriculture and natural resource linked livelihoods, along with that of the urban poor as they typically reside in areas that are more prone to pluvial flooding and are most vulnerable to water scarcity, as they largely depend on informal water markets.

- Extreme precipitation (similar to the extreme 2005 Mumbai, the 2005 and 2006 Gujarat flood events) is expected show a substantial increase over a large area over the west

coast and in central India. (Rupa Kumar, et.al, 2006, IITM, 1989) This will require a significant revision of urban planning practices across city and neighbourhood scales to integrate flood and climate change mitigation and adaptation measures into day-to-day urban development and service delivery activities. (Revi, 2005).

- A mean sea level rise (SLR) that could be as much as 0.8 m over the century (Aggarwal and Lal, 2001, Unnikrishnan et.al, 2006) can put a number of regions and cities at risk, especially if taken along with increased storm surge incidence. This assumes no change in the Greenland ice sheet and further Artic or Antarctic melting – which could unleash much higher levels of SLR. (Gore, 2006, IPCC, 2007)

Therefore, significant deviations from historical and experiential perception of climate, weather and hydrological trends can be expected across much of India. Most Indian communities and institutions have a history of coping with uncertainty and extreme events with great equanimity. However, the current pressure on resources, high population densities and ongoing rapid economic, technological and slower social changes imply that a mix of institutional, market and community-led mitigation and adaptation interventions will be necessary, if future losses are to be within tolerable bounds.

Within this, the poor and vulnerable who suffer the most in extreme events should be the first priority while planning for adaptation. This implies an important role for the state in light-handed regulation to ensure aggregate social costs do not go out of hand in the corporate push to maximize market growth. Further, only if all other options fail, should relocation be favoured as it usually leads to the displacement of the poor and significant defensive investments even in the private sector. (Revi, 2005)

The following sections reviews the possible impact of key climate change related natural hazards in India.

Drought

The most serious climate change risk to the Indian economy and its people is the increased intensity, frequency and geographical coverage of drought. Drought typically makes up half to two-thirds of the natural hazard risk exposure (GSDMA/TARU, 2005). Its primary impact is in rural areas where agriculture, animal husbandry, and to a lesser extent forestry (Ravindranath, et. al., 2006) and fishing are significantly impacted leading to cycles of seasonal and distress migration and increasing rural debt, which has led to a spate of farmer suicide across much of semi-arid India over the last few years (Sainath, 2002)

Drought has two typical first-order impacts on Indian cities: drinking water shortages and increases in food and biomass fuel prices that hurt the urban poor and middle classes and hence the city economy. It also has a number of important second-order impacts: increasing seasonal and distress migration from rural areas and depressed demand for urban-produced secondary goods and services because of depressed agricultural demand (GSDMA/ TARU, 2005).
Rural-urban migration has only contributed about 20 percent of India's incremental urban population growth since 1971. This trend is not expected to change dramatically in the next few decades, unless precipitated by a dramatic change in economic conditions or civil strife. However, continuing severe climate change induced drought that makes subsistence agriculture uneconomical in large parts of semi-arid central, western and southern India could

prove to be a critical factor that catalyses a sharp increase in migration. This is apparently not factored into current economic development or national security strategy.

Climate change is expected to increase the severity of drought especially in western India, where five river basins are expected to face acute to severe water shortages impacting a large number of cities in Gujarat. As a precursor to climate changes, land uses, cropping patterns and poor water resource management in the 20th century have resulted in a 50 percent reduction in the surface water discharge of the Ganga over the last 25 years and in a sharp drop in groundwater tables across the entire Indo-Gangetic plain. (Kumar et. al. 2005). The Ganga, Narmada, Krishna and Kaveri rivers are expected to experience seasonal or regular water stress impacting western, northern and eastern India (Gosain, et al, 2006). If the political and economic consequences of the Kaveri dispute and the Narmada struggle are an indication, Indian federalism could be severely challenged by these changes, with in the next decade.

Climate change is expected to increase drought in semi-arid peninsular and western India, leading to further immiserisation of the landless and small and marginal farmers, who are typically be forced to migrate more often to cities. They often form the most vulnerable groups in cities - having limited skills, education, capital and access to social networks that underpin much of economic and social mobility in urban India. They often live in illegal and unserviced settlements that are exposed to a wide range of environmental risks from flooding to fire and continual cycles of demolition and eviction by civil authorities. They are therefore, dual victims of existing natural hazards and emerging climate change - displaced from their original places of residence and occupations and multiply challenged by urban risks at their new urban places of residence.

The most serious regional impact of climate change would be changes in the river hydrology in the Indo-Gangetic plain and the Brahmaputra valley due to glacial melt and regression of the Himalayan glaciers. (Tangri, 2003). Ongoing trans-boundary conflicts between India and Pakistan; Nepal, India and Bangladesh may be compounded by a possible China-India conflict over the use of the Yarlung Tsang-po/ Brahmaputra waters as river flows decline and inter-basin transfers are increasingly suggested as solutions to challenges of urban and regional water stress. (Mall et.al, 2006; Chellaney, 2007)

Four of the ten largest mega-urban regions of the 21st century: Delhi, Dhaka, Kolkata and Karachi lie on the banks of these great rivers along with over 30 other million-plus cities. Significant changes in river hydrology and therefore in the availability of irrigation and drinking water could have a dramatic impact on the growth and development of the large number of small and medium towns and million cities that are expected to mushroom across these fertile plains, in the next three decades adding an unprecedented resource dimension to social and economic transformation of northern and eastern India.

The bulk of the water extraction from these river systems is for irrigation to provide food for a population of close to a billion people, hence, an emerging conflict is brewing between cities and rural areas from which urban water supply is drawn and city water pollution discharged. Multiple environmental struggles (e.g. around the Narmada and Tehri dams) have been fought since the 1980s, over the extraction of surface water from remote watersheds where significant numbers of relatively poor people have been displaced by exploding urban demand. (Parsuraman & Unnikrishnan, 2000). This will surely accelerate and became an increasing constraint to current resource inefficient pattern of urban development – if Delhi's

long saga with Haryana and Uttar Pradesh on drinking water transmission is an indication of the future.

As an example, the National Capital Region (NCR) of Delhi faces a severe water shortfall of 200 MGD, or over 32 percent of its production (Delhi Jal Board, 2007). Drinking water is being transported to meet the demands of this city of 15 million, from over 300 km and yet unaccounted for water losses are over 44 percent (Govt. of Delhi, 2002). Rising temperatures and therefore energy demand for cooling, increasing precipitation variability, a lower number of rainy days, the unsustainable mining of groundwater and a river system that has been polluted to death, could make the Delhi mega-urban region with a projected population of over 30 million highly unsustainable, in spite of the rapid growth in its income and wealth. These questions are far from the minds of both planners and politicians as they prepare to 'green' the city for the 2010 Commonwealth Games.

Delhi is simultaneously experiencing the 'brown', 'grey' and 'green' environmental transitions (McGranahan, 2007), in a period of less than 50 years but water availability rather than economic and social development challenges may be its undoing, as were two other great capital cities of this region: Mohammed-bin-Tuglak's (1325 to 1351) Tuglakabad, near Delhi and Akbar's (1556-1605) Fatehpur Sikri, near Agra.

River & Inland Flooding and Extreme Rainfall events

The next most important climate change risk is increased riverine and inland flooding especially in northern and eastern India and adjoining Nepal and Bangladesh. Tens of millions of people are currently affected by flood for three to six months of the year, in eastern India (Mishra, 1999). Increased precipitation and higher peak monsoon river flows due to glacial regression could exacerbate the situation for additional tens of millions. This is largely due to the high population densities across this region, combined with very high vulnerability due to a mix of poorly designed and executed flood management systems, complex land and water tenure regimes and high levels of poverty, which over the last few decades have severely degraded the coping capacity of millions of residents of eastern India. (de Vries, Revi. et.al. 2007)

Climate change is expected to increase the severity of flooding in many Indian river basins, especially of the Godavari and Mahanadi along the eastern coast. (Gosain, et al, 2006). Floods are also expected to increase in northwestern India adjoining Pakistan, and in most coastal plains in spite of existing upstream dams and 'multi-purpose' projects.

Extreme precipitation is expected show a substantial increase over a large area over the west coast and in central India. (Rupa Kumar, et al, 2006). Gujarat, one of India's most prosperous states, has experienced severe flooding for three consecutive years starting 2004, causing large economic losses in to its cities due to extreme precipitation in upstream catchments. (GSDMA/TARU, 2005)

The devastating Mumbai floods of 2005 were caused by an extreme weather event. The bulk of the city services were shutdown for the first time in recorded history for almost five days with no contact via rail, road or air with the rest of the country. Over 1,000 people lost their lives in the region and economic life in city came to a halt due to a combination of institutional failures, poor preparedness and extremely high vulnerability of the poor. (Revi, 2005).

Cyclonic Storms, Storm Surge & Coastal Flooding

The third most important climate change induced risk is that of cyclonic storms, storm surge and accompanying coastal inundation. A sea surface temperature (SST) rise of 2 to 4 ^{o}C, as expected in the Indian Ocean over the century, is expected to induce an 10 to 20 percent increase in cyclone intensity (Aggarwal and Lal, 2001). Since cyclone formation frequency in the Bay of Bengal is about five times that of the Arabian Sea (IMD, 1979, 1996, TARU, 2005), India's east coast is clearly at more risk, in spite of the fact that the north Indian Ocean basin is one of the least intense cyclone/hurricane basins in the world.

The high concentration of population especially on India and Bangladesh's eastern coast, has led to extremely high vulnerability in this region, leading to devastating loss of life and property. The 1999 Orissa supercyclone killed over 10,000 people, devastated buildings, lifeline infrastructure and economic assets across 10 coastal and 6 inland districts, which included a number of towns and cities due to a mixture of devastating storm surge, cyclonic winds and coastal flooding. (TARU/ BMTPC 2000). An 1991 cyclone killed over 139,000 people in Bangladesh, and caused a significant compression of its GDP (Benson and Clay, 2002).

Cyclone and storm surge could have a devastating impact on large urban centres including the mega cities of Mumbai and Chennai, the million cities of Vishakapatnam, Surat, Bharuch, Bhavnagar and Jamnagar apart from causing critical bottlenecks in important ports such as Kandla (GSDMA/TARU, 2005, TARU, 2005) As an example, storm surge, when accompanied by coastal flooding and cyclonic winds is the second most devastating, rapid onset hazard in Gujarat. It accounts for 12 percent of the risk to the state and a potential loss of over 11,000 lives for a probabilistic 100-year event (GSDMA/TARU, 2005). Losses could rise considerably with increased migration to the coast, drawn by huge investments in coastal infrastructure, settlements and enterprise located largely unmindful of future risk distribution.

Mean and Extreme Sea-level Rise

Historical data over the last century indicates a mean sea level rise (SLR) of less than 1 mm per year along the Indian coast. More recent observations suggest a SLR of 2.5 mm per year since the 1950s. A SLR of between 30 and 80 cm has been projected over the century along India's coast, based on multiple climate change scenarios (Aggarwal & Lal, 2001).

Two more recent studies have placed the coastal population at risk in South Asia at between 6 and 40 million. The first, World Bank-funded study (Dasgupta et.al, 2007) uses multiple scenarios ranging from 1 to 5 m of sea level rise, based on evidence of increased deglaciation rates in Greenland and Antarctica and the resultant increased probability of extreme climate scenarios. Up to 1 percent of India's urban areas could be inundated by 3 m SLR, which could climb to just fewer than 2 percent with a 5m rise. A 3 m SLR is also expected to impact above 1 percent of the population, which rises to 2.5 percent for a 5 m rise.

Bangladesh is the country in South Asia, with up to 10 percent of its area, population and urban areas being most at risk. The methodology used in this study, may be prone to inaccuracies because of the spatial databases it uses – but it provides a basis for a broad comparative analysis. The overall regional GDP compression due to direct SLR losses is estimated at 0.6 percent from 1 m, 1.6 percent for 3 m and 2.9 percent for 5 m SLR for South Asia. The relative impact on India would typically be lower, but this implies that serious

adaptation and mitigation measures will be required, especially for coastal cities and ports, which are expected to produce a relatively high share of this GDP and underpin India's growing manufacturing exports. There is, therefore, a clear case for a macro-economic analysis of risk as has been undertaken for Bangladesh (Benson and Clay, 2002) and the UK (Stern, 2007)

A second IIED-led study (McGranahan, et. al. 2007a) examined vulnerability within the Low Elevation Coastal Zone (LECZ) i.e. settlements and facilities at risk to a 10 m SLR – which is probably the outer boundary of catastrophic climate change (Diamond, 2005). Using a more robust methodology that the World Bank study, it estimated that Asian countries are highly vulnerable as they contain three-quarters of the world population residents in the LECZ and a dramatic two-third of the global LECZ urban population, with a higher concentration in cities over 5 million in size. This is driven in no small measure by explosive Chinese coastal economic and urban growth over the last two decades.

India was estimated to have the second largest population located in the LECZ of 63 million and seventh in terms of area i.e. 82,000 sq. km or about 3 percent of national geographical area at risk (McGranahan, 2007a). A 1 m SLR along the Indian coast was earlier estimated to affect about 5,700 sq. km of coastal land and put 7.1 million people at risk. (Mall et al, 2006, Aggarwal & Lal, 2001). An older economic risk assessment of 1 m rise estimated the impact on the city of Mumbai at over $ 50 billion (TERI, 1996). This was however, a first-generation estimate that could well have overestimated the potential rise (Patwardhan, 2006).

In short, irrespective of the form and method of assessment, SLR is a serious risk for a number of cities along India's coast. It is clearly in national interest to invest in more and better science to asses the possible risks to India's coasts at various levels of climate change. The costs of inaction on this count alone, could outstrip the investments by many orders of magnitude (Stern, 2007).

The most vulnerable stretches to SLR along the western Indian coast are Khambhat & Kachchh in Gujarat, Mumbai and parts of the Konkan coast and South Kerala. The deltas of the Ganga, Krishna, Godavari, Cauvery and Mahanadi on the east coast are expected to be lost, along with significant settlement areas and irrigated land and a number of urban settlements that are situated in them. (Aggarwal & Lal, 2001). The loss of these important economic and cultural regions could have a considerable impact on the states of West Bengal, Orissa, Andhra Pradesh and Tamil Nadu.

No estimates of the impact of climate change on salt-water intrusion in the coastal zone and on coastal and estuarine fisheries and therefore on fishing communities are available, but these are expected to be significant.

SLR combined with an increased frequency and intensity of tropical cyclones is expected to lead to an increase in extreme sea levels due to storm surge. (Unnikrishnan, et al, 2006). This coupled with the fact that, India's coast and especially its western seaboard and stretches along the Bay of Bengal are expected to grow dramatically in terms of population concentration, infrastructure and industrial investments and value added in the next two decades, implies a non-linear increase in coastal SLR vulnerability.

The primary driving factors for this increasing coastal vulnerability are differential population densities along the coast and in coastal deltas; a greater openness of the Indian economy to trade; a sharp upturn in energy imports where crude oil, gas and high-grade coal

are almost exclusively traded by sea and strong public investment incentives to coastal development. This ranges from a special programme for port and coastal infrastructure development, a major initiative to make Mumbai an International Financial Centre to rival Singapore and Shanghai (GoI, 2007) and massive investment in coastal energy infrastructure from LNG terminals to gas pipelines.

Environmental Health Risks

Climate change is expected to accentuate environment-related health risks, including those from water-washed diseases (e.g., diarrhoea, cholera and typhoid) due to water scarcity and malaria. Malaria is expected to expand from its currently endemic range in eastern and northeastern India to western and southern India thereby placing a large incremental population at risk (Bhattacharya et al, 2006). Given that Indian cities have become major reservoirs of vector-borne diseases such as malaria and dengue fever, it can be expected that the morbidity risks would increase. Additional research needs to be undertaken on the potential impact of water scarcity and flooding on environmental health conditions in cities and their consequent impact on morbidity, mortality and productivity.

Composite Multi-Hazard Risk Adaptation

Addressing a complex of six major risk groups: temperature and precipitation variability; drought; flooding and extreme rainfall; cyclone and storm surge; sea-level rise and linked environmental health risk is a serious public policy and adaptation management challenge for India.

An important new method that can help to address these concerns is composite risk assessment and adaptation planning. This enables a geographically explicit estimation of probabilistic hazard risk; vulnerability and the imputed composite multi-hazard economic risks. Risk prioritisation by hazard, element at risk and location can thereafter be undertaken, assisting in creating evidence based investment, regional and urban development policies and building a bridge between public agencies, communities and the private sector. (GSDMA/ TARU, 2005).

While some capacity has been built nationally and in about a quarter of Indian states to address single rapid-onset (e.g., earthquake) and long-onset (e.g., drought) risk. Nevertheless, managing a complex portfolio of hazard risks and vulnerabilities is both beyond the current mix of public institutions and the nascent private re-insurance and insurance industry.

India has no robust national estimates of composite economic risk due to natural hazards, unlike Bangladesh (Benson & Clay, 2002). A national Vulnerability Atlas (BMTPC, 1997) is being updated to assess district-level building vulnerability to cyclone, storm surge, earthquake and a broad-brush estimate of flood risk exposure. This, unfortunately, does not use probabilistic methods of risk assessment and the fragility functions used are based on a very limited analysis of loss. Further, no economic loss estimates have been derived. China, on the other hand, is moving towards probabilistic risk assessment methods in cooperation with global re-insurance industry (Shi, 2002).

The only robust state-level estimates of composite risk indicates an annual Gross State Domestic Product (GSDP) compression of about 2 percent for Gujarat, of which drought makes up 57 percent, cyclone and storm surge 12 percent and inland flooding 5 percent over a 100-year time horizon (GSDMA/TARU, 2005). This assessment breaks new ground by

unbundling risk to economic output and capital stock separately for urban and rural areas. This is one of the most detailed sub-regional risk assessments in the world that drills down to taluka (i.e. sub-district level) for eight crops, animal husbandry, fisheries, industry, services and critical infrastructure (roads and bridges, power, ports and airports). Yet, even though completed in 2005, it does not take into account increased hazard risk due to climate change, because of the low awareness of climate risk exposure in India.

A similar national and state-level estimate of GDP or GSDP compression would need to be generated as a priority based on a disaggregated district-level analysis to enable an actionable intervention set. A fundamental challenge will be the locus of such an effort. Conventional discipline and hazard-based approaches (e.g., earthquake, drought or cyclonic storms) are currently situated across a high fractured institutional environment ranging from the Ministry of Science and Technology, Environment, Agriculture and Home Affairs.

This is a sure means of ensuring that little strategic perspective and no coordinated action takes place especially because states, urban local bodies (ULBs) and communities are where the adaptation and mitigation action will take place. Given the significant national development and security implications of climate change this could be best situated in the Cabinet Secretariat of the GoI. This apex arrangement can help coordinate a large network of institutions that will need to be mobilized across India, to address climate change adaptation and mitigation.

Urban Populations & Elements at Risk

The most vulnerable populations and elements most at risk in a typical Indian city are:

- Slum, squatter and migrant populations resident in traditional and informal settlements, which are often located in the most vulnerable locations

- Industrial and informal service sector workers, whose occupations place them at significant risk to natural hazards, which is then accentuated by additional stressors such as climate change

- Buildings, especially traditional and informal housing that is especially vulnerable to wind, water and geological hazards

- Industrial units, their in-house infrastructure, plant, machinery and raw materials

- Lifeline public and private infrastructure, which includes roads, bridges, railways, ports, airports and other transportation systems; water, sewage and gas pipelines; drainage, flood and coastal defence systems; power and telecommunication infrastructure and critical social infrastructure such as hospitals, schools, fire and police station and first responder's infrastructure

- Ecosystems and the natural environment, especially wetlands, riverine, estuarine and coastal ecosystems, surface and groundwater systems

Risk adaptation and mitigation measures need to address particular populations and elements at risk within a *RUrban* landscape to be effective in responding to a heterogeneous field of constraints and opportunities. Hence, decentralised adaptive management strategies that

engage with a political, policy and implementation continuum from the neighbourhood, city, and region to national level have proved to be more effective than centralized top-down interventions. (Moffat et al., 2003) A coherent framework, within which public policy, private sector and civil society urban development and planning actions are taken, can reduce vulnerability and risk in a steady iterative manner, over a period of decades. (Revi, 2005). This, in turn, requires a new set of incentives and structures that link short-run priorities with long-run strategic actions – a major shift in the current urban management paradigm.

Urban Vulnerability to Climate Change

Indians have lived for millennia with the uncertainty of monsoon precipitation. This uncertainty has led to regular sequences of drought and famine depending on how responsive the imperial regime of the period responded (Revi, et al 2002). The last in this sequence was great (1943) Bengal famine in the last few years of British colonial rule that killed over 3 million people in both rural and urban areas.

A large (but currently indeterminate) number of people are vulnerable to climate change in India. This is therefore, a crucial emerging issue for long-range economic and social development policy. Current awareness of climate change is unfortunately extremely thin and confined to a small population of educated urban dwellers, policy makers and business leaders. As the differential impact of changes in temperature, precipitation, storm frequency and sea level rise come more apparent, climate change is set to become an important political and economic issue.

Ironically, but not surprisingly the most vulnerable urban residents are the poor, slum and squatter settlements dwellers and those who suffer from the multiple insecurities that poor governance, the lack of serious investment in the commons and a strong nexus between the political class, real estate developers and public agencies being to cities. Through a long process of loss accumulation they are multiply challenged by even small events which impact their livelihoods, income, property, assets and sometimes their lives.

This is partially because of an systematic exclusion from the formal economy of the city: basic services and entitlements and the impossibly high entry barrier into legal land and housing markets. As a result most poor people live in hazardous sites, are exposed to multiple environmental health risks via poor sanitation, water supply, little or no drainage and solid waste services, air and water pollution and the recurrent threat of being evicted. And yet they survive, add considerable economic value to the city and ‘subsidise’ the better off via their poor living and working conditions.

Till basic entitlements, services and a quality of life is ensured for the bulk of India’s urban residents and the vulnerability of the rest reduced to acceptable levels – little or no public and community-based structural mitigation actions may see the light of day. Urban mitigation activities will typically be led by enterprises and large public utilities who seek carbon-offset linked financial and economic incentives.

Indian cities, neighbourhoods and communities will therefore be primarily focused on adaptation to climate change over the near term. The primary challenges here will lie in the domains of: better and more accountable city governance, democratic decentralisation improving the functioning of public institutions and the recreation of the ‘commons’ through multiple political and institutional struggles. This is in part contrast to the adoption of multiple technologies or consumption reduction measures that form the core of many western

responses to the climate crisis (Gore, 2006). Technical, purely economic or even institutional 'fixes' will typically fail to deliver results in India, unless local democratic, political and socio-cultural processes are engaged with around the themes of equity, social transformation, local 'voice' and 'agency'. Given the 'distance' between these concerns and those of the global climate change debate, a rather different set of strategies would probably emerge in India, than are currently envisaged.

A Possible Urban Climate Change Adaptation Framework

Developing a Climate change adaptation framework for urban India will require the opening up of a dialogue on urban development and growth, vulnerability, risk unbundling, the redirection of ongoing investments and programmes and the building of new alliances. This together can help transform existing cities, to make them more inclusive and productive thereby reduce structural vulnerability. An appropriate traverse will need to be built between contemporary concerns and conflicts and inclusive urban development that enables equitable vulnerability reduction and medium-term adaptation.

A pragmatic way forward is to build upon the existing momentum of hazard risk management and mitigation efforts. This is most effectively done by mainstreaming them into urban redevelopment initiatives like the JNNRURM and mobilisation from below via NGOs, CBOs and political processes in particular cities. Given that a number of these stakeholders have little or no knowledge of climate change issues, the development of a framework linking dialogue, engagement and action would be a useful step.

This framework would need to provide a link between national, state and city-level policy; political institutional arrangements and interventions at city and neighbourhood levels. It would also serve as a platform for dialogue between government functionaries, political leaders, CBOs and NGOs who are active in trying to channelise citizen and community energy towards productive ends, and private entrepreneurs who could provide the motive power for adaptation implementation.

A sketch of a possible framework at multiple levels, involving various stakeholders and institutions is presented below.

National: India has not developed a National Adaptation Programme of Action (NAPA) to address urban climate change risk reduction. This is partially because of institutional fractures within the GoI and its status as a underline middle-income state. The primary responsibility for climate change policy currently lies with the Ministry of Environment and Forests (MoEF). The Ministry typically has weak traction with key sectoral ministries including the Ministry of Urban Development (MoUD).

To integrate a crosscutting climate change agenda into the overall planning and investment process of the GoI would imply a possible relocation of this function to the Cabinet Secretariat or the Planning Commission, with strong support from the Finance Ministry. This would require an Amendment of the Allocation of Business Rules, 1961 (GoI, 1961) and the establishment of a Climate Change Secretariat to address crosscutting and high-level policy questions. This will enable the coordination of adaptation policy and programmes across key line Ministries (e.g. Urban and Rural Development, Home Affairs, Finance, Energy, Environment & Forests) and functions (e.g. national security, disaster management, fiscal and expenditure management, and coordination) and the mobilisation of state governments and

cities to enable adaptation planning and implemented. A re-examination of the 74th Constitutional Amendment in this light may be in order.

The Ministry of Finance could play a central role in defining fiscal and financial measures to incentivise both mitigation and adaptation, based on a 'NAPA-like' rollout schedule. This could include the creation of a domestic market for carbon-credits linked via appropriate institutions to the global carbon market enabling the financing of state-led pro-poor adaptation.

The National Disaster Management Authority (NDMA) situated within the Ministry of Home Affairs, is the apex disaster management agency, even though the bulk of the implementation responsibility and action lies with state governments. It would be useful to use the climate change agenda to build a bridge between current NDMA priorities and medium and long-term climate adaptation. NDMA manages important programmes such as National Cyclone Risk Mitigation Programme (NCRMP) that have a number of climate adaptation features.

The Ministry of Environment and Forests, along with the Department of Ocean Development engage with Coastal Zone regulation, in coordination with state level ministries. This is another locus of convergence that a Cabinet Secretariat based Climate Change cell could address.

The Departments of Urban Development and Poverty Alleviation, which jointly manage the JNNURM should ideally be the fulcrum of urban climate change risk mitigation, at national level and the primary agency for urban climate policy and programme design, once appropriate capacities are built. An integration of concerns into long-range City Development Plans (CDPs), infrastructure development and poverty reduction interventions at city-level is crucial. Disaster management is one of the many elements of the JNNURM that poorly resourced at city-level. It needs to be upscaled in terms of resourcing and institutional capacity and broadened to encompass a wider climate adaptation agenda.

The creation of a National Technical Mission on Urban Climate Change adaptation to deliver time bound outcomes may be a useful way to focus energies and bring the climate crisis onto the public policy agenda. Specific tasks could include the development of a National Risk and Vulnerability Atlas that includes climate change related risks; estimates of potential losses to economic activity and capital stocks as a priority by the GoI. This will enable the identification of priority cities and sectors for intervention and thereby open appropriate windows of opportunities within the JNNURM. A new series of national building and lifeline infrastructure risk mitigation standards will be necessary, taking into account climate related risks. This can be taken forward by the NDMA, MoUD and the Bureau of Indian Standards (BIS) based on the pattern of the National Earthquake Mitigation Standards (NDMA, 2007).

A series of insurance instruments to provide short and medium term risk coverage to urban infrastructure enterprises and incentives for public-community-private partnerships to need to be put into place, similar to initiatives coming in the agricultural sector.

Apex institutions that bring together public and private sector enterprises; civil society; academic (esp. science and technology, management and social science research) institutions will need to be activated at national level to build research and action-oriented networks in and between their sectors of competence. Education, training and capacity building at school, and university for public functionaries, managers and the media will need to be launched.

State-level: Each state needs to establish a State Disaster Management Authority on the lines of the Gujarat State Disaster Management Authority (GSDMA) with appropriate changes in its objectives, powers and responsibilities to address climate change adaptation, especially in urban areas. This can build on existing flood, cyclone and surge, drought risk reduction efforts. Considerable capacity building will be required to prepare these agencies to take on these additional responsibilities and develop actionable State-level Adaptation Programmes of Action.

The State Departments of Finance and State Planning Boards will need to integrated climate change adaptation into their medium-term planning and expenditure frameworks and enable synergy between cross-sectoral adaptation and mitigation investments.

Changes in the appropriate State housing and urban development, town planning and infrastructure legislations to integrate disaster and climate change mitigation concerns into urban planning and development are necessary. Training and capacity building of state public functionaries and bureaucrats in climate change risk assessment and adaptation is an important human resource investment.

A process of catalyzing entrepreneurial activity around climate adaptation and mitigation is best led in some states by the Government, while in others a private sector lead will be most appropriate. Once, beyond a critical threshold it could well be spun-off.

City-level: Cities will be the locus of climate change adaptation and mitigation. The current legal, regulatory and governance structures and institutional culture of most cities are unprepared to address this challenge.

A development of current city-level urban governance, planning and service delivery framework and institutional arrangements will be necessary to link urban renewal and development, with short and medium-term hazard risk reduction and further to climate adaptation. Enabling public entitlements and services delivery to the poor and vulnerable to ensure that existing asymmetries and structural vulnerabilities are addressed in time are an important first step. This will involve strong interventions in real estate and housing markets and public service delivery and a supportive policy and institutional environment at state level.

This is best operationalised via a re-examination of City Development Plans (CDPs) that attempt to link a long term vision for urban development with an Action Plan for infrastructure upgradation, poverty reduction and better governance. An appropriate urban platform needs to be put in place to enable multi-stakeholder engagement with strategic risk sharing and adaptation. This will help create appropriate fiscal and financial incentives for adaptation that is linked to neighbourhood-led processes, especially in informal settlements. An outcome could be a politically mandated City Adaptation Programme of Action. This could be linked to a set of private sector and community-led adaptation programmes that focus on the primary urban GHG flux sectors i.e. transportation, building and energy systems.

Within this larger framework, a city Disaster Management Plan (DMP) and Zonal DMPs need to be developed that integrates climate change and other hazard mitigation concerns into the primary land-use and zoning instruments, City Structure and Development Plans, Zonal Development Plans (ZDPs) and appropriate building regulation and infrastructure development guidelines.

A critical support activity would be putting into the public domain a multilingual GIS-based city DMP and Zonal DMPs on the Internet. This could be linked to a public database that records property and real estate information, building permissions and public investments in infrastructure. This would then provide a framework within which neighbourhood urban renewal and planning are coordinated with risk mitigation.

A public-private-resident partnership to finance, build and retrofit housing and infrastructure to disaster-resistant standards at neighbourhood level and a public-private partnership to develop strategic flood, cyclone, storm surge and sea erosion defenses at city-level will need to be explored for each city.

Neighbourhood-Level: Each city will need to establish a network of climate change-related community-based disaster management and risk mitigation initiatives, especially for slum, squatter and informal settlements in vulnerable locations. This would provide a basis for a city-wide dialogue on the most appropriate adaptation measures and necessary mitigation interventions that involve all population groups and stakeholders. This will be a critical process to develop implementable City Adaptation Programmes of Action.

The Private sector: Given the availability of a public domain risk adaptation framework, the private sector should be encouraged to develop appropriate risk assessment, adaptation and mitigation plans for clusters of enterprises in vulnerable areas. This would enable a rebalancing of demand and supply-side initiatives, i.e., GHG emission abatement, decentralization and dematerialization of supply and service chains. Development of private enterprise-led building and infrastructure upgrading, retrofitting and technical support initiatives to enable and scale adaptation will also be important.

Civil Society Organizations (CSOs): need to take the lead in advocacy and mobilization and adaptation centered on the provision and extension of basic services and entitlements. They can also lead on the design and execution of neighbourhood pilot projects to test new methods of community-based adaptation, specifically for slum and informal settlements and vulnerable populations. NGOs can provide independent feedback and checks and balances on the functioning of public and private sector institutions working on natural hazard and climate change risk mitigation.

Key instruments that could help mitigate climate-change related risks include:

New Construction and Development: should be executed to a set of incremental land use, planning, construction and O&M standards that enable a fully-built development to meet climate change vulnerability norms and incremental improvements by poor residents in other areas cost. This will require changes in legal, regulatory, planning and design guidelines along with a recognition of the rights of residence and economic participation of all residents of the city. Considerable enterprise and institutional development inputs will be required to make this a reality. If structured imaginatively, this could well be part-funded by carbon credits.

Building Retrofitting and Strengthening: A large proportion of a typical Indian city building stock is aged, dilapidated and partially engineered and do not meet contemporary standards of building safety. Technical measures to strengthen and retrofit these buildings are well known and cost-effective (typically at 5 to 15 percent of capital investments), but have never been implemented across an Indian city, except for Bhuj after the 2001 Kachchh

earthquake. This would take considerable institutional and financial innovation and a well thought set of incentives to make possible.

Lifeline Infrastructure Development and Strengthening: Building the energy, water, waste water, transportation, telecom and IT infrastructure for city typically takes many decades. Given current growth trends, this will happen in many Indian million-cities over the next two to three decades and will need to last for a century or more. Appropriate climate change-related adaptation and mitigation measures are not integrated into the design of these systems.

Since they involve lumpy investments and require massive annual expenditures on operations and maintenance, adequate attention to risk-adjusted least life-cycle costs need to be made. Some of these services are best provided by public providers, others given possible quantum leaps in technology and distributed network development may be better managed privately. There is, therefore, a need to explore appropriate forms of regulation and management to mitigate climate risk. This is also a prime-case for carbon-offset financing.

Sequencing of these interventions should ideally be prioritised by strategic impact and vulnerability reduction potential, especially in slum and informal settlements. The priorities of the poor and the affluent could vary considerable from more affluent households. A pro-poor process of priority setting needs to be established that provides adequate 'voice' to the more vulnerable groups.

Hazard Modification: A number of pre-colonial and colonial drainage, urban surge and flood protection systems have been in operation in various parts of India. The rapid pace of urban development has often made these structures dysfunction or irrelevant. Repairing and strengthening strategic flood, storm surge and coastal defences are important city-level interventions. Detailed economic, social and environmental cost-benefit analysis will be needed to assess whether these investments are appropriate vis-à-vis relocation and other adaptation options.

Water use efficiency and conservation measures are the best strategic defense against drought on the demand side, along-with appropriate conjunctive water management practices. Enabling the conceptualization and implementation of such vulnerability reduction and hazard modification interventions will need to be explored through a series of pilot projects in different cities with varying ecological regimes.

Relocation and Rehabilitation: Relocation should emerge a policy option only after all softer adaptation options have failed. Typical measures include relocation of particular settlements, parts of a city or an entire city system depending on the expected level of risk. Changes in city economic structure to shift out of sensitive economic activities and changes in systems of governance to enable more rapid response to emerging risk, both within the public and the private domains will be necessary. A plurality of planning, market and financial instruments will be needed to adequately address local relocation and associated rehabilitation needs. It is necessary to recognize the rights of residents to compensation for the direct and indirect costs of relocation and therefore to a pro-poor rehabilitation process. Relocating a part of a city is clearly a large political decision that needs to be equitable, transparent and participative in its execution – few such precedents are available in India.

A first step in spatial adaptation would be to shift settlements out of highly vulnerable areas especially the inter-tidal zone, riverine estuarine and low lying areas. If this is inadequate,

then the relocation of a particular section of a city and finally the relocation of an entire urban system, to a new location can be considered. Relocation at this scale is unprecedented except for reservoir submergence in independent India. Hence, this would be a major economic and a political challenge, apart from being difficult to implement in an equitable manner.

Joining-up with Ongoing Hazard Risk Reduction Programmes: The most important ongoing climate change-related risk mitigation programme is the National Cyclone Risk Mitigation Programme (NCRMP) that is being implemented across India's coastal states. The Government of Orissa, Andhra Pradesh and Gujarat have made considerable progress in its implementation in rural settlements. A similar initiative needs to be developed for urban areas that combine natural hazard risk mitigation with climate change adaptation.

The 2005 Tsunami Rehabilitation programme is active in the southern coastal states of Tamil Nadu, Andhra Pradesh and Kerala. It is specifically focused on coastal zone management and the mitigation of cyclone, storm surge and sea erosion hazard risk. A climate change related agenda needs to be expeditiously introduced into this programme before it comes to a close.

A number of independent flood risk mitigation interventions have been launched by State governments and for specific cities in Maharashtra, Gujarat, Orissa, Uttar Pradesh and Bihar. A common method of addressing inland flood risk mitigation is still to be evolved. This is a crucial concern that could influence the lives of tens of millions of people. The integration of climate change adaptation measures into flood mitigation interventions will probably. First take root in Gujarat, which has suffered three seasons of extreme rainfall. This can then be adapted and scaled to other parts of the country.

Strengthening Regional and Rural-Urban Linkages: Conventional disaster management and mitigation planning has typically focused either on urban areas or villages. The increasing integration of the Indian economy has led to the strengthening of the forward-backward linkages between urban and rural settlements. The risks that cities and their embedding countryside are exposed to therefore, need to be addressed together. This can be operationalised by integrating climate change related adaptation into the regional and *RUrban* sectoral and investment planning.

This is particularly important in India where agriculture is highly sensitive to monsoon variability as 65 percent of the cropped area is rainfed. A 2 to 3.5^{o}C rise in temperature, accompanied by a 7 to 25 percent change in precipitation has been estimated to cause a loss of 9 to 25 percent of net output to farmers. This could, in turn, lead to 2 to 4 percent reduction in GDP growth. This could have significant impact on over 350 million people who are dependent on rainfed agriculture.

Over 55 million people depend on Non-Timber Forest Products (NTFPs) for their livelihoods and would be significantly impacted by climate change induced changes in the forest cover (Ravindranath, et. al, 2006). A large number of fishing communities along India's coast could experience significantly livelihood shifts due to SLR and extreme weather events.

Changes in the flows of food and biomass are especially important because Indian cities still have a metabolism dominated by substantial flows of unprocessed food and traditional bio-fuels. Similarly, drinking water and renewable bio-fuels, hydropower and possibly wind energy flows could be affected by climate changes, causing moderate to severe disruption in urban systems. Hence, instead of an exclusive focus on cities, it would be necessary to

develop regional climate change risk adaptation strategies and action plans, especially for mega-urban regions and metropolitan cities.

Institutional Capacity for Urban Climate Risk Adaptation

A fundamental challenge to Indian climate risk adaptation is the declining quality of urban governance and weak institutional capacity to manage urbanization, ensure equitable and quality public service delivery and access to housing markets via appropriate planning and regulation. Without these institutional changes, the structural vulnerability of large populations (over 6 million in Mumbai) cannot be addressed, providing a weak foundation to build climate adaptation on.

Since the mid-1990s, India has developed significant natural disaster management and risk mitigation capacity at national and state level. The National Vulnerability Atlas of India (BMTPC, 1997) was the first such attempt at identifying and mapping vulnerability at district level across the country, but risk unbundling for specific urban centres was weak. Subsequent efforts have attempted to take the process of hazard risk modeling, vulnerability assessment and composite risk assessment to finer resolution, i.e., block, taluka and settlement level (GSDMA/ TARU, 2005).

The Government of Maharashtra (GoM) developed India's first urban Disaster Management Plan (DMP) for Mumbai in the late-1990s, which identified flooding as a significant risk, pinpointed bottleneck locations in each ward, and vulnerable slums and settlements (GoM 1999; Vatsa and Joseph 2003). Nevertheless, this was hardly implemented, leading identified bottlenecks to become the primary cause of the 2005 Mumbai deluge (Revi, 2005; CAT, 2006) pointing to the need for a drastic revamp of Mumbai’s institutions to plan, design and implement effectively. The GoM has recently commissioned an advanced disaster response system to aid emergency incident management across the State.

The National Disaster Management Authority (NDMA) has been established, but the most extensive risk mitigation experience lies with State level agencies in Andhra Pradesh, Gujarat, Orissa and Tamil Nadu which have been active in disaster mitigation planning, investment and to a lesser extent community based disaster mitigation.

A number of interventions are currently being implemented in various cities to mitigate natural hazard risk, especially due to flood, sea erosion and storm surge. These are, however, responding to a contemporary perception of risk based on historical experience and records.

They have little or no capacity to engage with emergent risks induced by climate change. The ability to conceptualise and integrate these measures into existing plans and programmes will need to be developed at state and city-level, and if large in magnitude supported by the GoI.

Practically addressing the differential vulnerabilities of population groups within cities is a serious challenge in India. Improvements in access to affordable housing and land markets, lifeline infrastructure especially water, sanitation and public transportation along with more appropriate zonation regulations are important interventions with strong co-benefits for the poor today and climate change risk tomorrow, if they are planned and executed in a pro-poor manner.

One of the great risks of market-driven climate change adaptation policy is the possibility of the emergence of a slew of anti-poor interventions leading to a vicious cycle of displacement

resettlement and increasing vulnerability in many cities. A number of successful programmes have demonstrated that the cost of in-situ risk mitigation is often a fraction of relocation, typically at less than 10 percent of the capital cost of new development. This needs to be integrated into the urban planning process and legal framework.

Building a Mitigation Agenda for Indian Cities

India became a signatory to the Kyoto Protocol in 2002, which gave it some latitude in initiating mitigation activities because of its developing country status. In practice, much of the ongoing Indian efforts to mitigate Greenhouse Gas (GHG) emissions have focused on:

- Pollution control, energy conservation and efficiency
- Forest conservation and wasteland development
- Promotion of the use of renewable energy (Shukla, et. al, 2003)

When taken as a package, the impact of these measures on current and future GHG emissions is expected to be relatively small. This is primarily because India's energy intensity is growing rapidly from a very small base, which is between fifth and twentieth of energy intensity of many OECD countries. Almost half of India's households do not have access to electric power and are constrained by energy availability in meeting their basic needs and livelihoods. As this constraint is released, energy demand can be expected to grow at a faster rate than India's annual GDP growth, which currently ranges at between 6 to 8 percent. Given that the India's energy security can only be assured in the medium-run by using coal-based thermal power generation, especially when global oil and gas prices continue to be high, a domestic debate on GHG mitigation at the expense of expanding energy services will be challenging in the short run.

Hence, a series of macro policy incentives will be required to reduce the carbon intensity of India's energy system and its economy. One of these is adapting the metabolic structure of India's cities towards lower carbon and water intensity by appropriate changes in spatial structure, land use choices of mobility and building systems.

A series of debates around city sustainability and greening have opened up over the last decade. Limited progress has been made on strong interventions in real estate and housing markets and in the choice of public transportation systems that will go beyond some of these discussions. These would enable the development of compact cities, mixed land use – with limited the need for long-distance car based commutes, greater resource efficiency and recycling in buildings and services and a break with India's 20th century engagement with colonial and western-oriented planning standards.

Much of the high energy and resource intensive real estate and building boom is driven by corporations and the urban upper middle classes, who wish to participate in the replication of the 'American dream' in India. This is clearly unsustainable both in the short and medium-run. But this class of enterprises and people is growing rapidly. Hence, voluntary and public restraints on wasteful consumption and effective resource management using market-based, technological and legal instruments are also in order. It is expected that much of this mitigation agenda will be lead by the private and public sector, as they make good business sense.

Conclusions

Climate-change is expected to increase the frequency and intensity of existing hazards, an increased probability of extreme events and spur the emergence of new hazards in India – already one of the more vulnerable and multi-hazard risk prone countries in the world. The climate crisis is set to become one of the more important economic and political questions in South Asia in the coming decades, especially as it starts biting into economic growth and dislocating the lives and livelihoods of millions of people, many of whom will live in cities.

Vulnerability has typically contributed more to overall risk in Indian cities, than hazard exposure. Much of this is structural, forcing poor people to live and work in appalling conditions in informal and often illegal settlements with abysmal public services and limited access to entitlements. This combined with weak or absent governance, limited public investment in infrastructure and the commons and declining state legitimacy implies that developing and improving the incomes, productivity and quality of life of urban residents are much higher priorities than perceived 'distant' crises like climate change.

Reducing Indian urban climate change vulnerability in practical terms, will need a shift in emphasis of public policy, mobilisation and enterprise towards adaptation rather than the current OECD-led emphasis on mitigation. These need to be grounded in the institutional, socio-cultural and political realities of India and focus on the poor and most vulnerable, through a mix of policy, regulatory, fiscal and financial, institutional and mobilisational instruments.

This is probably best implemented by mainstreaming climate change risk assessment, adaptation and mitigation measures into ongoing national hazard mitigation programmes, and building a tangible set of links with urban renewal interventions that are being taken up in many of India's largest cities. This could provide an important window of opportunity that could facilitate concrete adaptation-cum-mitigation actions: greener and most resilient new construction and development; building retrofitting and strengthening, lifeline infrastructure development and strengthening; hazard modification and only when absolutely necessary relocation and rehabilitation. Joining up with ongoing hazard reduction programmes and building linkages with ongoing rural-urban linkage initiatives are practical means of crafting the traverse between contemporary urban management priorities and future concerns like climate change.

The urban infrastructure and development needs for existing and a projected 300 million new urban residents over the next couple of decades, will involve large lumpy investments and long-time horizons for repayment and redirection. Hence, far-sighted planning, design and regulation are required for Indian cities and regions to internalize climate change risks.

A multi-level climate adaptation framework is necessary that works at national, state, city and neighbourhood level and brings together the State, private and civil society sectors. The institutional and political interest to conceive and execute these sets of actions is weak or non-existent in most cities and states. This will need to be built, incentivised, and linked to existing initiatives. Bottom-up mobilization of communities will be crucial to climate adaptation that protects the interests of the poor and vulnerable. Having built a robust adaptation programme in a set of pilot cities, the important linkage between adaptation and mitigation can be explored.

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