Climate Resilient Urban Development: Vulnerability Profiles of 20 Indian Cities

Integrated Research and Action for Development

Supported By :

Rockefeller Foundation
Innovation for the Next 100 Years

Executive Summary

Climate Resilient Urban Development: Vulnerability Profiles of 20 Indian Cities

IRADe Integrated Research and Action for Development

ACCORN

Supported By
Rockefeller Foundation
Innovation for the Next 100 Years

Please use the following reference:
Parikh J, Jindal P and Sandal G. Climate Resilient Urban Developement, Vulnerability Profiles of 20 Indian Cities. COE-IRADe, 2013

C 80 Shivalik, Malviya Nagar
New Delhi 110017, INDIA
Tel: 91 (11) 2667 6180, 2667 6181, 2668 2226
Web: www.irade.org
Email : jparikh@irade.org

Foreword

Cities in the 21st century are facing enormous changes – growing populations, physical expansion, major new infrastructure investments, shifting governance parameters, and increasing citizen demand for quality services. Nowhere is this more true than in urban India, which will swell to 600 million by 2030, adding an additional 223 million new inhabitants and building 70 per cent of the infrastructure of these future cities over the same period of time. This growth challenge comes just as impacts of climate change will become ever more severe. Increasing temperatures, stronger and more frequent coastal storms, longer heat waves and droughts, more intense precipitation events and flooding will further aggravate the strains that cities face with regard to addressing poverty, inadequate services, infrastructure deficits and environmental stress. Climate change could also become a strategic economic and political concern as it starts to erode India's economic performance and affect the lives and livelihoods of millions of people. If we are to meet future challenges with effective solutions and sufficient levels of preparedness, we must today begin to make forward looking investments that build urban climate change resilience in India.

The study was supported under the Rockefeller Foundation's Asian Cities Climate Change Resilience Network (ACCCRN), a US$ 59 million effort to catalyze attention, funding, and action on building the climate change resilience of Asian cities and the most vulnerable and poor communities within them. Initially focused on ten cities in India, Vietnam, Indonesia, and Thailand, ACCCRN has enabled the development of city wide strategies and prioritization of specific investments that advance physical, social, and community resilience. Over 30 city level interventions in areas such as institutional development, land use planning, drainage and flood management, emergency response systems, ecosystem strengthening, citizens awareness building and disease surveillance have been initiated that demonstrate practical ways to build resilience of systems, sectors and communities to the effects such as rising sea-levels, unpredictable rainfall patterns and increasing temperatures. In India, projects are currently being implemented in Indore, Surat and Gorakhpur, and climate resilience planning processes are underway in additional cities. The Foundation is now investing in replicating the process in over 50 new cities across Asia, while also generating knowledge and platforms to equip national governments, multilateral donors, and the private sector to advance this agenda across hundreds more.

This important report by IRADe, analyzing vulnerability in 20 key Indian cities, will help us to better understand the specific drivers of climate vulnerability and provide an information base for future action. City level climate risk is analyzed using a framework that integrates information on physical and meteorological Hazards, analysis of Infrastructure and Urban services, Governance variables, and finally Socioeconomic and demographic indicators

(HIGS) framework. It provides a customizable approach for cities to analyze their own vulnerabilities as basis for understanding potential areas of corrective action and enables comparison across cities as well. It further identifies impacts, which are of concern across multiple cities, and are city-specific. Such a nuanced analysis will better inform national, state and local policy making on urban development and management. What is particularly valuable is that the rapid assessment methodology can spur autonomous action by enabling cities to assess their vulnerabilities using the HIGS framework, and prioritize steps to be taken in response. We hope that IRADe's work will help cities identify and channel future investments towards climate resilience, build awareness and capacity of citizens and local authorities to invest in resilience, and keep the climate resilience agenda as a visible priority.

We congratulate IRADe's researchers and the team of interns from the Centre for Environmental Planning and Technology, Ahmedabad who collaborated on this report for this important contribution and their individual work to build more resilient cities.

Ashvin Dayal
Managing Director, Asia
The Rockefeller Foundation
21st Floor UBC II Building
591 Sukhumvit 33, Wattana
Bangkok 10110- Thailand

Preface

Indian cities are potentially the most vulnerable to climate change. In cities, people and infrastructure are often concentrated within a limited geographical area. The range of risks and impacts extend far beyond physical risks posed by climate change such as sea-level rise, and extreme weather events such as storms surges, cyclones and floods, heat waves, droughts, etc.

The genesis of this project lies in a question raised at the meeting of National Action Plan for Climate Change (NAPCC) chaired by the Prime Minister, Dr. Manmohan Singh. While discussing the National Mission on Sustainable Habitat (NMSH), a question was raised: "How many cities in India are vulnerable to climate change and in what way?"

At that time IRADe was engaged in work related to the Asian Cities Climate Change Resilience Network (ACCCRN) project on a policy framework for national, state and city level climate resilience of cities. Our involvement with ACCCRN was certainly useful to us to have a good understanding of issues involved, but we could not answer this important question. At that stage, ACCCRN project had completed painstaking work, along city administrations and communities on three cities in India over three years. However, India has more than 400 cities/towns (Census 2011) and we need to reach them all in perhaps ten years of the work. Rapid vulnerability assessments of a large number of cities were needed to take timely proactive action as urbanization in India is accelerating.

One lesson we learned from the ACCCRN project done earlier was that to be climate resilient, a city has to first put itself on a sustainable path in terms of infrastructure, governance and socio-economic conditions. Unless these have their foundation in sustainability, they cannot handle a new stress such as climate change and be disaster resilient. From this, the framework of "Hazard, Infrastructure, Governance and Socio-economic conditions" (HIGS) evolved and it took us sometime to fully develop it in the context of Indian cities and data availability.

The main objective of this study was to develop a rapid assessment of vulnerability of cities by highlighting various risk exposures and vulnerability factors. Urban renewal interventions were identified in order to reduce impacts of climate change and natural hazards risk. We considered twenty Indian cities from fourteen different states. These cities were categorized in terms of population, ecosystems in which they were located such as mountain, coastal, inland and river-based cities ranging from metros, mega cities, and medium sized cities and other characteristics such as commercial, historical, tourism or pilgrimage destinations, capital city etc. The analysis shows that resilient cities were those that have sustainable infrastructure, efficient governance and informed and capable citizens. To carry out 20 case

studies has been a huge task, especially when reliable city level data in India are not available. Moreover, we find that some problems of cities were more documented than others. That does not mean that the problems not studied were less important. This study has given us the chance to see trends across cities and the problems with the approach that promote sustainable and climate resilient urbanization. However, despite the data limitations, we feel that the conclusions drawn are robust and that more detailed analysis may not change them, drastically.

We have decided, after a great deal of consideration, not using climate scenarios available for 2030, 2050 and so on. The key message was that climate change was one more significant stress and to deal with it, cities would have to be healthy and sustainable to begin with. That is, even under normal circumstances, cities need to be fully functioning first. Once that is achieved, resilience would be created, especially where the climate impact may be mild. In others, stronger and specific action, going beyond sustainability would be required, especially for coastal, river based and Himalayan cities. Now, the next step will be to reach out to the administration of each city to appraise Urban Local Bodies (ULBs) on the issues involved in their cities. The understanding of the status of the existing infrastructure and services might give the authorities an edge to insulate cities from the impact of climate change. We hope that this study will help policy makers, urban planners, city administrators, experts, academics, students and aid agencies to appreciate issues regarding climate vulnerability of the cities and help them to deal with climate change related stress and formulate adaptation strategies.

We are grateful to the ACCCRN and Rockefeller Foundation (RF) for their financial support. We hope, this work will reach a wide audience through circulation and enables cities, states and India, as well as other countries to help cities be climate resilient. We request readers of this report to give us their feedback as we take this exercise to the next level of implementation and formulation of climate adaptation strategies.

Jyoti Parikh
Executive Director
Integrated Research and Action for Development
C 80 Shivalik, Malviya Nagar
New Delhi 110017, INDIA
Tel: +91 (11) 2667 6180, 2667 6181, 2668 2226
Email : jparikh@irade.org

Acknowledgments

We thank everyone who contributed to the richness and the multi-disciplinary perspective of this report Climate Resilient Urban Development: Vulnerability Profiles of 20 Indian Cities. We are grateful to the ACCCRN and Rockefeller Foundation (RF) for their financial support. We express profound gratitude to Ms. Cristina Del Rio Rumbaitis of RF for taking a deep interest and providing valuable suggestions during the course of this work and Mr. Ashvin Dayal for his guidance.

We are grateful to Mr. M. Ramachandran, former Secretary, Ministry of Urban Development (MoUD) for reviewing this work. We are also grateful to Dr. Shailesh Nayak, Secretary, MoES, and Ms. Nivedita, Director, MoUD who helped with their valuable suggestions. We are also thankful to Dr. T Ramasami, Secretary, Department of Science and Technology Professor Amitabh Kundu, Centre for the Study of Regional Development, Jawahar Lal Nehru University (JNU), Mr. Anil Baijal, Chairperson, National Institute of Urban Affairs (NIUA), and Ms. Aude Flogny, Regional Director for South Asia, French Development Agency for the valuable information provided by them. ACCCRN partners, the Institute for Social and Environmental Transition (ISET), TARU Leading Edge Private Limited, The Energy and Resources Institute (TERI) and Gorakhpur Environmental Action Group (GEAG) have contributed through the insights they provided. We are especially grateful to Dr. Marcus Moench, Mr. G K Bhat, Mr. Anup Karanth, Ms. Usha Raghupati, Dr. Shiraz Wajih, Mr. Shashikant Chopade, Mr. Dilip Singh, Ms. Divya and others who shared their work. The authors would like to thank members of the IRADe Steering Committee for Urban Development - Chairman, Prof. S.R. Hashim, Director, ISID and the members; Mr. Aromar Revi, Director, IIHS; Mr. Ashok B. Lall, Principal, Ashok B Lall Architects; Dr. Chetan Vaidya, Director , SPA, New Delhi for guiding this work in a larger context.

Mr. A.K. Mehta, Former Join Secretary, MoUD has also contributed to this work directly by guiding previous work that IRADe did as the activity of Centre of Excellence (COE) for Climate Change and Urban Development.

Sincere gratitude and thanks is due to Dr. Kirit Parikh, Chairman, IRADe, who has given guidance and taken deep interest in the work.

Thanks are due to Mr. Rohit Magotra for copy-editing and co-ordination support for the publication. We are thankful to IRADe staff, Mr. Deepak Rai, Mr. Rakesh Ranjan, Mr. Raman K. Singh, Ms. Yogeeta Sharma, Ms. Shikha Garg, Ms. Akanksha Arora, Ms. Nidhi Nayyar and Ms. Jayeeta Bhadra for their sincere support and efforts. We also thank the summer interns from Centre of Environmental Planning and Technology, Ahmedabad.

PROJECT TEAM
Dr. Jyoti Parikh
Priyank Jindal
Geeta Sandal

Contents

Executive Summary

i.i Introduction

India is the second most populous country in the world (PRB, 2011). Its population has increased by more than 181 million during the decade 2001-2011 (Census of India, 2011). Correspondingly the urban population in India has increased from 286.1 million in 2001 to 377.2 million in 2011 (NIUA 2011). It is expected that by 2026 the urban population in India will reach 534 million (38%) (Chetan Vaidya, 2009). The rapid expansion of Indian cities, driven by increase in population and urban development has expanded the already existing gap in demands and supply of necessary infrastructure services (Mundu and Bhagat, 2008). This inefficiency of urban systems hinders their ability to adapt to climate change and affects the cities resilience to climate change. This creates a negative feedback loop where climate change resilience becomes progressively more difficult because of existing inadequacies. An increasing concentration of population, coupled with extreme events, results in high damages to assets, interruptions in business continuity, loss of lives and displacement of populations. It further enhances economic and social vulnerability of the urban system and possibly results in its collapse, as has been seen in Mumbai in 2005 and more recently in New York City.

i.ii Climate variability in India

Indian annual mean temperatures showed a significant warming trend of 0.51oC for the 100 year period 1901-2007 (Kothawale et al. 2010). Accelerated warming has been observed during 1971-2007, mainly due to intense warming in the recent decade. Mean temperature increased by about 0.2°C for the period 1971-2007, with a much steeper increase in minimum temperature than maximum temperature. Most parts of India show a warming trend, except in the north western parts of the country where a cooling trend is observed. Pockets in India with the highest rainfall are generally those receiving orographically induced rainfall caused by forced moist air ascent over mountain slopes during active monsoon situations. Western Ghats and northeast India receive such rainfall. During the Indian monsoon, Rajeevan et al (2008) showed that extreme rain events have an increasing trend between 1901 and 2005, but the trend is much stronger after 1950. Sen Roy (2009) investigated changes in extreme hourly rainfall in India, and found widespread increases in heavy precipitation events across India, mostly in the high-elevation regions of the north western Himalayas as well as along foothills of the Himalayas extending south into the Indo-Gangetic basin, and particularly during the summer monsoon season, between 1980 and

2002. Along the monsoon trough region also, more than 500 mm rainfall has been recorded within a duration of 24 hours. The sea level along the Indian coast has been rising at the rate of 1.3 mm/year and this is expected to continue. Further projections indicate that the frequency of cyclones is likely to decrease in the 2030s, with increase in cyclonic intensity (INCCA 2010). With increasing climate induced risks, Indian cities are further affected as they lack effective storm water drainage systems and face problems due to unplanned development and often encroachments due to building on natural areas and drainage systems. This increases incidences of flooding.

There have been unprecedented floods of high intensity and flash floods in many cities in the last decade, particularly in coastal cities such as Mumbai, Kolkata, Kochi, Visakhapatnam, Surat and Puri. This affects the poor the most especially those who live in slums or are located in low lying areas especially in Mumbai and Kolkata where most of the slums are located in ecologically fragile areas.

There is a need to conduct assessments of likely climate change impacts for cities to reduce the vulnerability of their services and their residents to these impacts. Therefore, many the decisions for sustainable and climate resilient development of urban areas require information on climate change risks to their systems and services.

i.iii Scope and background of the study

While developing a city level approach for the National Mission on Sustainable Habitat (NMSH) a question was raised: "How many cities in India are vulnerable to climate change and in what way?". The genesis of this study lies in this question. India has more than 400 cities in 2011 and climate informed development is needed because urbanization in India is accelerating and cities need to be sustainable and resilient. Due to diverse physiographic and meteorological conditions, cities in India are exposed to various types of natural hazards. Indian cities are facing additional risk due to climate induced extreme events such as flood, droughts, heat and cold waves. This can occur with varying intensity at varied geographical scales and degree of exposure. An increasing concentration of population coupled with extreme events, result in high damages to assets, interruptions in business continuity, opportunity losses, loss of lives, displacement of populations, which is further enhanced by economic and social vulnerability and reduced the capacity of the urban system and services to adapt to climate variability and change.

Twenty representative Indian cities from fourteen states were selected for this study based on their location and other characteristices such has population densities, geographical diversity etc. The selected cities are shown in Table i.i and Figure i.i.

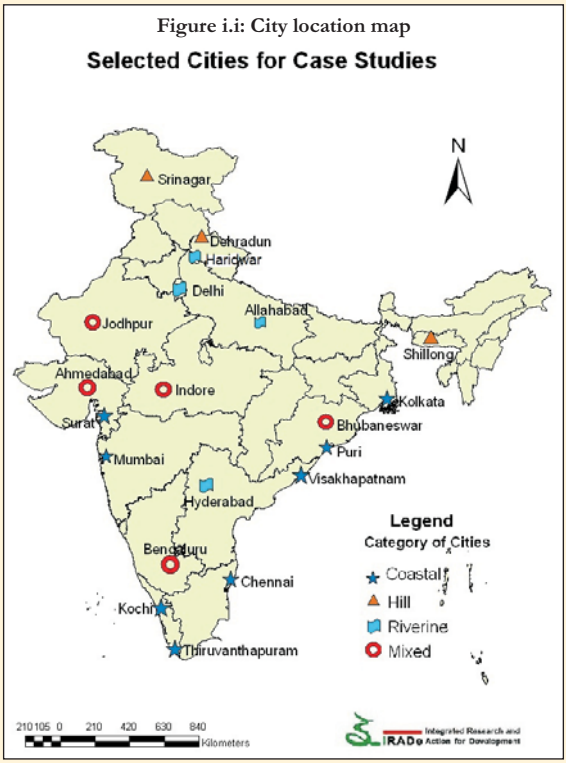
The main objective of this study was to develop vulnerability profiles of cities by highlighting exposure to various risks and hazards. Urban renewal interventions have been suggested in order to strengthen climate resilience of India's urban centres. This analysis shows that the resilient cities are those that have sustainable infrastructure, efficient governance and informed and capable citizens. This study shows trends across cities and the problems with the approach to their development. However, despite the data limitations, we feel that the conclusions drawn

Table i.i: Selected cities

S. No.	City	Population in 2011 (millions)	Ecosystem	S. No.	City	Population in 2011 (millions)	Ecosystem
1	Greater Mumbai UA	18.4	Coastal	11	Vishakhapatnam -GVMC (MC)	1.7	Coastal
2	Delhi UA	16.3	Riverine	12	Thiruvananthapuram UA	1.7	Coastal
3	Kolkata UA	14.1	Coastal	13	Srinagar UA	1.3	Hill
4	Chennai	8.7	Coastal	14	Allahabad UA	1.2	Riverine
5	Bengaluru UA	8.5	Mixed	15	Jodhpur UA	1.1	Mixed (arid)
6	Hyderabad UA	7.7	Riverine	16	Bhubaneswar UA	0.9	Mixed (arid)
7	Ahmadabad UA	6.4	Mixed (arid)	17	Dehradun UA	0.7	Hill
8	Surat UA	4.6	Coastal	18	Shillong UA	0.4	Hill
9	Indore UA	2.2	Mixed	19	Haridwar UA	0.3	Riverine
10	Kochi UA	2.1	Coastal	20	Puri Town M	0.2	Coastal

Note: UA-Urban Agglomeration, M-Municipal Corporation, GVMC-Greater Visakhapatnam Municipal CorporationSource: IRADe 2012 (Data Source: Census 2011)

Figure i.i: City location map



are robust and that more detailed data may not change them drastically.

i.iv Methodology

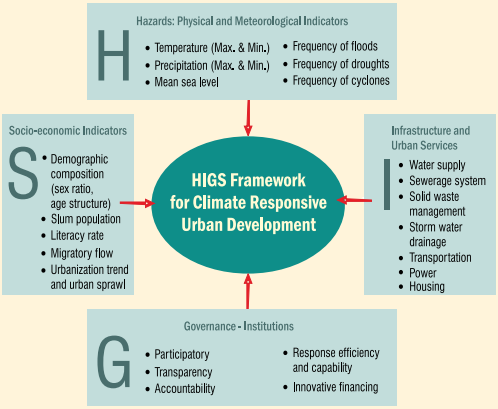
Urbanization itself is a significant factor for India, in terms of both, an opportunity to continue its accelerated economic growth, and on the other hand, a challenge to a foreseeable climate resilient future. To understand and analyze climate resilient measures for India's urban centres, a framework has been designed based on four themes 'Hazard-Infrastructure-Governance-Socio-economic characteristics (HIGS)' which are determined on the basis of cities characteristics like location, economic and geographical significance, to determine the exposure to the hazards, populations, urbanization trends, basic service level and the managing authorities. The severity of impacts from climate extremes depends not only on the extremes themselves but also on exposure and vulnerability of populations. This study uses the vulnerability definition of the IPCC (2007) as its basis, where vulnerability is "the extent to which climate change may damage or harm a system", and "depends not only on a system's sensitivity, but also on its ability to adapt to new climatic conditions". The study has also considered the IPCC (2012) definition where vulnerability is "the propensity or predisposition to be adversely affected". It aims to establish a methodology for climate vulnerability profiling of Indian cities on the basis of types of risk, exposure to elements, sensitivity and adaptive capacity.

Climate change is an additional stress that only healthy and sustainable cities can deal with. That is, even under normal circumstances, cities need to be fully functioning first. Once that is achieved, resilience would be created, especially where climate impacts may be mild. In others, stronger and specific action, going beyond sustainability would be required, especially for coastal, riverine and mountainous cities.

After a great deal of consideration, it was decided not to use climate scenarios available for the 2030, 2050. Adaptation to climate change is an essential part of the emerging strategy required to cope with and manage this pervasive threat though it not yet received the widespread recognition and public support that it so plainly merits. Therefore, this study was rooted in the observation that similar climate events can produce very different levels of socio-economic impacts, depending not only on the ecological and physiographic setting with the timing of the occurrence, but also the resources and agility of the societies to respond to climate impacts. The degree of impacts depends on how a particular natural event interacts with a specific ecosystem and characteristics of the society affected. The level of economic development; adequacy of basic services provided; demographic characteristics and structure; and socio-economic factors like livelihoods of its members and education levels generally determine how vulnerable or resilient an affected population is, along with resources available for adaptation, especially through government initiatives. The study highlights the linkages between climate change and sustainable urban development, including urban disaster mitigation programmes, improved water and sewage networks as well as ecological and environmental protection programmes.

The Hazard-Infrastructure-Governance-Socio-economic characteristics (HIGS) framework

Figure i.ii: HIGS framework for climate responsive urban development



that evolved during this project presents a holistic approach for sustainable urbanization of Indian cities. The methodology provides flexibility to converge data within these four variables – hazards and extreme events, infrastructure services, governance and socio-economic characteristics. The interplay of the four variables is of importance to understand priorities and proximate causes of increased climate risks in Indian cities. There are hydro-metrological stresses on cities and they are identified through observed trends (number of occurrences). Social and economical vulnerability have been analyzed through a study of populations, growth rate, sex ratio and literacy. Multiple risks due to inadequate basic services such as water supply, sewage network, solid waste management, storm water drainage systems, transportation, energy and housing were also examined. Governance was considered to assess the responsive strategy of cities as well as the institutional framework.

i.v Case studies

Exposure and vulnerability are dynamic that vary across temporal and spatial scales and depends upon economic, social, geographic, demographic, cultural, institutional, governance, and environmental factors. Hence to understand the vulnerability of the cities, a multi dimensional approach is required. Some of the cities in India (for example Surat Ahmedabad, Indore, Delhi and Hyderabad) have evolved along the riverside, while others were trade centres along the coast (Mumbai, Kolkata, Chennai, Vishakhapatnam and Kochi). These cities are traditionally exposed to different natural disasters like floods, cyclones droughts and landslides. Climate change has affected the intensity and frequency of these natural hazards over the last decades, whereas the large growth of population and its migration in urban areas has led to greater vulnerability of the cities.

Twenty Indian cities are selected as case studies to understand and analyze the climate vulnerability and need for resilient measures for India's urban centres. HIGS variables are considered to prepare the vulnerability profiles for each cities, these variables are 'H'=hazards, 'I'=infrastructure, 'G'= governance and 'S'=socio-economic. A template was prepared to gather information for these variables and sub variables. For example to analyzing hazards exposure, physiography/geographical setting of the city and past events of natural disasters are considered. In this study there are eight coastal cities, these cities are prone to flooding and cyclones due to proximity to the sea and low elevations. Over the past decades the frequency of tropical cyclones in the north Indian ocean has registered

significant increasing trends (20% per hundred years) during November and May which account for maximum number of intense cyclones (Singh, Alikhan & Rahman 2000).

Other than the coastal cities, there are six riverine cities, three mountainous cities and three mixed cities (mixed categorized as arid climate) .These cities are also vulnerable to serious flooding, droughts, landslides and cold waves and heat waves.

The social and economical vulnerability have been analyzed by considering variables like population, growth rate, sex ratio literacy and slum population. The multiple risks due to inadequate basic services such as water supply, sewage network, solid waste management, storm water drainage systems, transportation, energy and housing are considered for infrastructure profiling. Governance and institutional setup and initiatives are considered to assess the responsive strategy of the cities.

The study concludes with the overall picture of the cities in terms of the selected four variables. The result shows that the outcome of a high rate of urbanization has lead to the expansion of urban populations into geographic areas, which are frequently affected by extreme events and has increased vulnerability of populations and infrastructure. Besides, inadequate infrastructure has also lead to an increase in the frequency of hazards such as floods and water scarcity. Long term climate change impacts are expected to increase the vulnerability further. This section also discusses initiatives taken by the state and local level authorities.

i.vi Comparative analysis

A comparative analysis of the twenty cities gives an overview of the cities climate vulnerability and resilience capacities. The evidence from cities advance the understanding about the risks posed by climate change in urban contexts and will help to motivate and empower actions across scales to address climate change. The case studies are analyzed on the basis of the selected variables in the HIGS framework to assess the overall scenario of the cities and the impact of climate change on different socio-economic societies and ecological diverse regions. The results show that most cities are exposed to hazards like floods and drought but the intensity and frequencies of these hazards has increased over the period of time, due to inadequate infrastructure and mismanagement. A vulnerability matrix (Figure i.iii) has been prepared to analyze the cities exposure to natural hazards. The matrix entails the role of urban services and socio-economic factors in shaping the cities exposure to mishaps. Apart from their classification by location, cities are categorized on the basis of population; cities with a population of more than 4 million are in the A category, cities with populations between 1 and 4 million are in the B category and cities with a population of less than 1 million are in category C. Infrastructure depicts water supply, sewage, drainage and municipal solid waste management.

i.vi.i Findings from the case studies

The city level studies revealed that seven coastal cities may perhaps be affected by very high cyclonic wind velocities causing severe damage to tall flexible and sheeted residential and industrial structures. Five cities including Surat, Greater Mumbai and Thiruvananthpuram

are prone to cyclonic winds. The hill cities are exposed to landslides. Flooding and water scarcity is a problem faced by most cities. There have been unprecedented floods of high intensity and flash floods in many cities in the last 10 years especially in coastal cities such as Mumbai, Surat, Kolkata, Visakhapatnam, Kochi and Puri.

Several infrastructure elements were analyzed and it was found that not a single city had 100 per cent coverage of basic infrastructure facilities like water supply network, solid waste management and storm water drainage.

Cities like Allahabad, Bhubaneshwar and Mumbai receive more than 180 lpcd of water daily, while Shillong receives only 50 lpcd. Very intense rainfall leading to high runoff levels can cause soil erosion, which affects the capacity of treatment plants, due to sedimentation. It also causes damage, especially in the case of flash floods.

Surat is the only city that treats the total sewage generated, while Haridwar and Mumbai have the capacity to treat 79 and 78 per cent, of the total generated sewage respectively. Delhi and Kolkata, two of the highest sewage generating cities, have low sewage treatment capacity, in Delhi only 33 per cent of the collected sewage is treated, whereas in kolkata it is only 15 per cent. Dehradun and Bhubaneswar still do not have any sewage treatment facility. Cities like Kochi, Chennai and Visakhapatnam generate the highest per capita solid waste with 0.76 kg/day, 0.70 kg/day and 0.67 kg/day respectively.

Socio economic variables depict a high concentration of population in the cities in terms of density per house. Kolkata has the highest number of persons per household (11persons/hh), followed by Hyderabad and Chennai which have an average seven people per house. Haridwar has an average of two persons per house, while Bhubaneswar and Visakhapatnam have between two and three persons on an average in a household.

Shillong, Dehradun and Srinagar have lower population densities than coastal or riverine cities. The major natural hazards are flash floods and landslides, caused by sudden heavy rainfall, and cold waves. The inadequate drainage system and inadequate management of sewage makes it difficult for them to address climate induced risks.

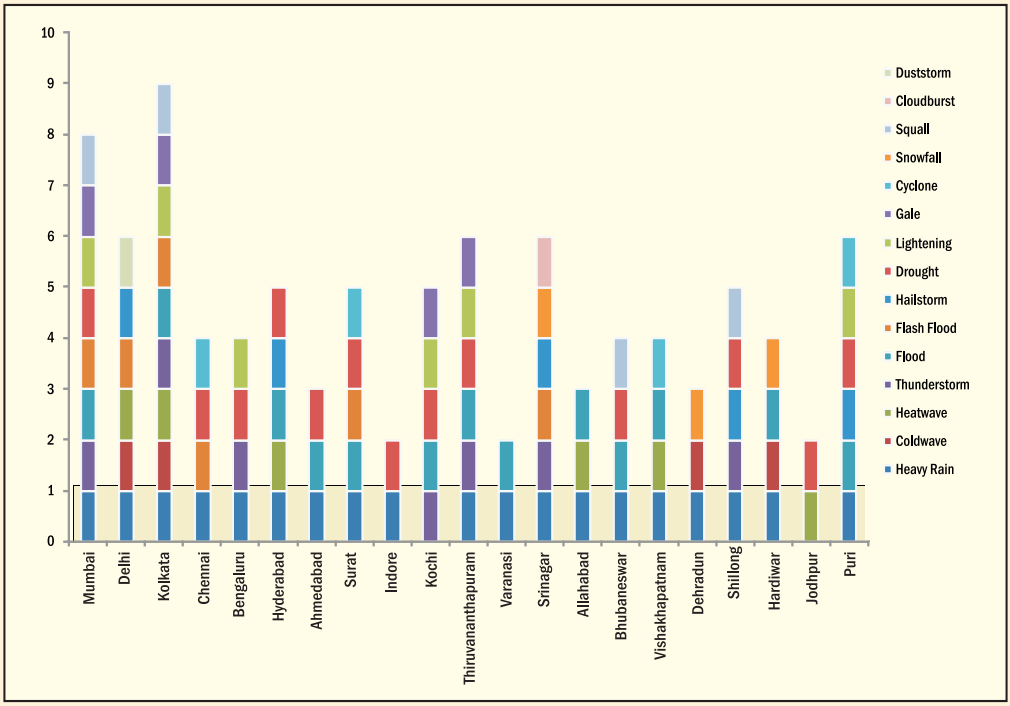
Bhubaneswar, Jodhpur and Indore - mainly suffer from drought and heat waves, as they are growing at a high rate and the expansion of concrete structures coupled with arid and semiarid conditions, are exacerbated by climate variability and increase in rainfall and temperature. Government agencies at various levels are taking steps to address the rapidly growing challenges in the urban sector in India. Initiatives at the state level such as city level development plans, water resource management, urban transport, disaster management and other risk management efforts require large investments. Local governments have taken certain initiatives as is the case of Hyderabad. The Hyderabad Metropolitan Development Authority (HMDA) has adopted Environmental Building Regulations and Guidelines (EBRGs) for energy consumption, water usage, ecology/geology on site, building materials, sewage disposal, storm water management, solid waste management, and pollution control. The Green Hyderabad Programme with plantations of 19,366 ha provides co-benefits like better run off, temperature moderation etc. These decisions reflect long term development prospects and contribute significantly to the geographical region.

Figure i.iii: Vulnerability matrix

S.No.	Classification	City Name	Hazards					Infrastructure				Population (million) base in 2011	Categorization of cities on basis of population
			Drought	Flooding	Landslides	Cyclones	Heat / cold waves	Water supply	Sewerage	Drainage	MSW		
1	Coastal	Kolkata	Y	Y		Y	Y	Y		Y	Y	141	A
2		Mumbai		Y	Y	Y				Y		184	A
3		Chennai	Y	Y		Y	Y					8.6	A
4		Surat	Y	Y		Y				Y		4.5	A
5		Visakhapatnam	Y	Y		Y	Y		Y	Y		1.7	B
6		Thiruvananthpuram		Y		Y				Y	Y	1.6	B
7		Kochi	Y	Y		Y	Y		Y	Y	Y	2.1	B
8		Puri	Y	Y		Y		Y	Y	Y	Y	0.2	C
9	Hill	Srinagar		Y	Y		Y		Y	Y	Y	1.2	B
10		Shilong		Y	Y		Y		Y	Y	Y	0.3	C
11		Dehradun		Y	Y		Y		Y	Y		0.7	C
12	Riverine	Hyderabad	Y	Y			Y	Y	Y	Y		7.7	A
13		Delhi	Y	Y			Y			Y	Y	16.3	A
14		Ahmedabad	Y	Y		Y	Y			Y		6.3	A
15		Allahabad	Y	Y			Y		Y	Y	Y	1.2	B
16		Haridwar	Y	Y	Y		Y				Y	0.3	C
17	Mixed	Bengaluru	Y	Y			Y	Y		Y		8.5	A
18		Jodhpur	Y				Y			Y	Y	1.1	B
19		Indore	Y	Y			Y			Y		2.1	B
20		Bhubaneswar	Y	Y	Y	Y	Y	Y	Y	Y	Y	0.8	C

Categorisation of cities on basis of population
> 4 million = A
1-4 million. = B.
<1 million = C

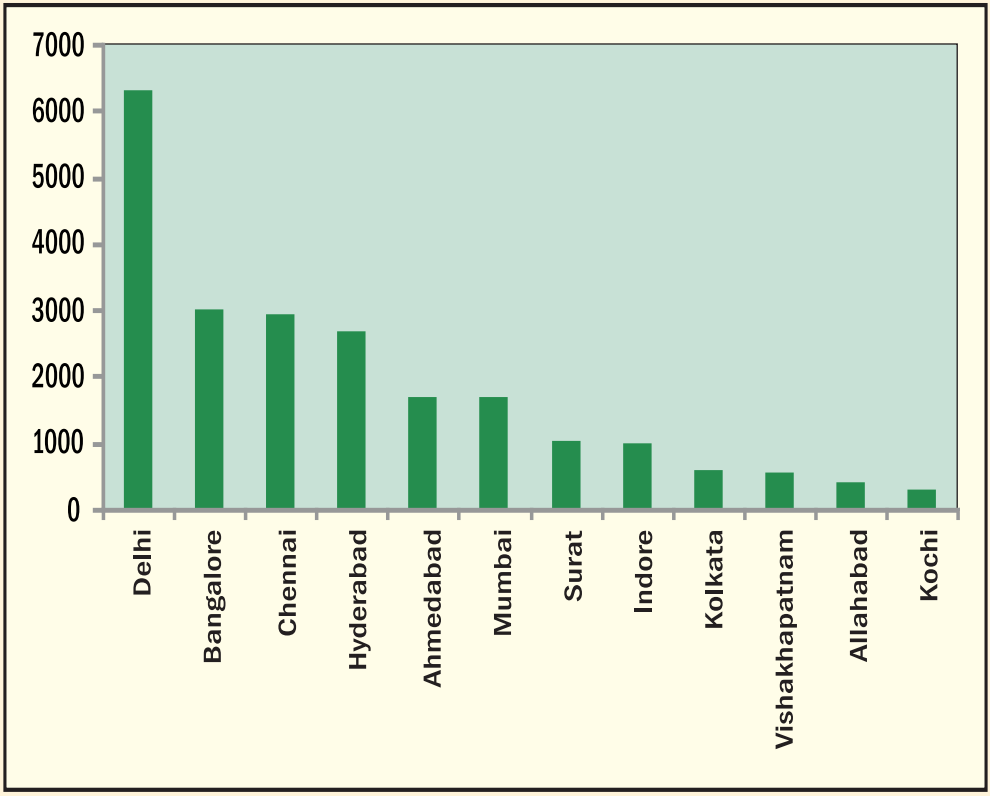
Figure i.iv: Exposure to hazards



Data: Source: BMPTC 2001, Kapur 2009, Census 2001-2011

Exposure to Hazards : Fig i.iv highlights relative exposure to hazards in twenty cities covered in the study. Most of the cities prone to multihazards, for example, cities like Shillong, Dehradun and Srinagar prone to flooding, landslides and cold waves.

Figure i.v: Registered motorised vehicles (1000s), 2009



Data: Ministry of Road, Transport and Highways

Registered motorised vehicles (1000s), 2009 : Fig.i.v highlights trend of motorised vehicles in 12 cities covered under the study. Delhi has the highest number of the registered vehicles. Traffic congestion will result in the near future, which will also add to air pollution leading to associated health hazards as well.

Key Observations

- All 20 cities covered have city development plans.
- 10 cities active in the area of disaster management, which includes Delhi and Mumbai.
- 7 cities prone to cyclones, which may cause severe damage to residential and industrial infrastructure, if such event happens in near future.
- Drought conditions prevail in most of the cities covered.
- Delhi, Surat, Chennai, Indore, Kolkata, Ahmedabad and Kochi progressive cities with respect to climate change context.
- Sewage treatment highest in Surat (100%) followed by Haridwar (79%) and Mumbai (78%). No such facility exists for Bhubaneswar and Dehradun.
- Kochi generates highest per capita solid waste (0.76 kg/day) followed by Chennai (0.70 kg/day). Dehradun and Shillong produces the least municipal solid waste.
- Kolkata has the highest population density (11 persons per household) while Haridwar has the lowest population density (2 persons per household).

i.vii Recommendations

The results of this study facilitate an understanding of likely future climate impacts while assessing the resilience of the current socio-economical system to the numerous stresses that are partly related to climate impacts and partly due to fragilities in the system itself. It also addresses the existing knowledge gap among the public regarding risks associated with climate change, and particularly the difference between climate risk and climate vulnerability. Socio-economic development interacts with natural climate variations and anthropogenic activities affecting climate and increasing disaster risks. For exposed and vulnerable communities, even non-extreme weather and climate events can have extreme impacts (IPCC SREX 2012).

The outcome of this report provides evidence that cities can use a combination of key institutions, enabling policies and financing options to allow sustainable and climate resilient urbanization of India's growing cities. There is a need to advance understanding, motivate and empower actions across scales to address climate change and facilitate adequate investments with appropriate institutional mechanisms within an enabling policy framework in order to improve resilience of India's urban areas. Some recommendations are found below.

Disaster Risk Reduction (DRR): The reduction of stressors caused by human activities will increase the resilience of habitats to the effects of climate change and variability. Through the Jawaharlal Nehru National Urban Renewal Mission (JnNURM), cities are being provided with an opportunity to respond and upgrade basic infrastructure services; however, out of twenty cities more than 14 do not have total coverage of basic services.

Rejuvenation of water bodies: Restoring lakes and urban water bodies will reduce the risk of flooding as they are the best moderators. Sixteen cities have lakes, water bodies and flood

plains. There are only three - Delhi, Surat and Trivandrum - with per capita water supply above 135 lpcd. Trivandrum has a per capita water supply above 150 lpcd, the standard bench mark for cities. Kolkata, Bengaluru, Hyderabad and Mumbai have extremely inadequate basic services.

Climate conscious development and spatial planning: Development planning that incorporates climate change and variability is essential and this should apply to institutions and governments alike. If climate change and variability are not proactively taken into account, the effectiveness of conservation plans will reduce. The use of technologies for efficiently managing resources and service quality are fast emerging and viable at city levels. The capacity of Urban Local Bodies (ULBs) to afford and use these technologies would determine their ability to deliver standardized service levels.. Prioritize a climate resilient agenda: Cities need to identify priority activities that respond to their urgent and immediate needs for adaptation to climate change since further delay could increase vulnerability or lead to increased costs at a later stage.

Sustainable urban development indicators: As this involves measuring and monitoring of service delivery, it plays a very important role in analyzing a city's capacity to cope with the climate related hazards and also gives an overview of the cities basic services status. Enhance institutional and policy coordination at the city level: It is important that activities are planned and measures undertaken are mainstreamed for maximizing benefits. There are cities that have a high degree of physical exposure to climate change and a limited capacity to respond to the challenge of adaptation, for example, hill cities like Shillong and Haridwar. Other cities, with less immediate exposure to impacts from climate change and with greater institutional and financial capacity could work jointly with more vulnerable cities to assist and enhance their technical capacities to address the challenges of adaptation.

Resource allocation: Currently, there are no specific agencies or institutions at the city level that oversee main streaming of sustainable and climate resilient measures ; managing climate change knowledge; or disseminating climate related information to the general public. There also appears to be a lack of coordination among stakeholders and local agencies. To enhance urban governance there is a need for central and state governments to be engaged in a city's climate resilience agenda for promoting sustainable development.

i.viii Climate informed urbanization and enabling policies

The issue of reducing vulnerability and better preparing for future climate hazards would need such types of analyses presented here to help develop timely and effective policies and actions. These include infrastructure projects, transport networks, land use planning initiatives, urban development master plans, which play a key role in underpinning economic development for inclusive growth. Building in timely climate change adaptation measures will greatly enhance the benefits and sustainability of many development initiatives.

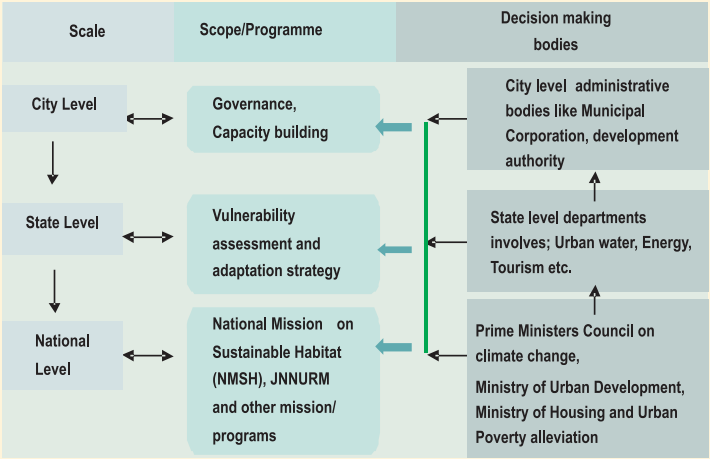
A range of development activities can help in reducing vulnerability to many climate change impacts. In some cases, however, 'development as usual' may inadvertently increase vulnerability. For instance, new roads might be weather proofed from an engineering

standpoint, even taking future climate into account, but they might trigger new human settlements in areas highly exposed to particular impacts of climate change, such as coastal zones vulnerable to sea-level rise. The risk of such maladaptation needs to be alleviated by including potential adaptation measures in development policies, plans and projects (OECD 2009).

i.viii.i Decision support systems

Decision making for climate resilient urban development, requires involvement of all the stakeholders, and therefore, the capacities of local bodies have to be strengthened. The national government needs to garner international support in terms of financial, technological and knowledge resources and other forms of support like institutional building for climate resilience. Figure i.vi below illustrates the decision support system for climate resilient urban development in India. Policies with a cross sectoral reach include building and design codes for infrastructure, regulations covering public private partnerships, use of clean technologies, capacity building and research and development. There is competition between cities within a state, for state level resources, and between states for national level resources from planned funding channels. There is an urgent need for adequate investments with the appropriate institutional mechanisms and an enabling policy framework in order to improve the resilience of urban systems to climate change. This analysis seeks to advance India's ongoing efforts on inclusive and climate responsive development for its urban centres while advancing initiatives such as the Sustainable Habitat Mission.

Figure i.vi: Decision Support System



i.viii.ii Institutional framework

There are policy making bodies and planning authorities at both the national and state level.

At the national level, there are agencies with planning and policy making functions cutting across sectoral and state boundaries. These include institutions which address urban development, environment and forests, water, transport, housing, urban poverty alleviation and disaster management.

Housing and urban development has been assigned to the state governments by the Constitution of India. Policy decisions taken at this level directly affect urban development activities and have the potential to address climate responsive urban development. The programme implementation and review revealed that competition between cities, within the state for state level resources, and between the states for national level resources from planned funding channels do exist. However, cross-sectoral policy coordination mechanisms are generally evolved and administered at the national level, where decision making on urbanization is still to be aligned with global climate initiatives.

Prime Minister's Council on Climate Change: The Prime Minister's Council on Climate Change coordinates national action for assessment, adaptation and mitigation of climate change and provides the overall guidance for actions taken by various ministries. It has architected eight national climate missions, one of them being on sustainable habitat. The National Mission on Sustainable Habitat is planned as part of one of the four core climate adaptation oriented missions (NAPCC 2007). The mission placed climate adaptation as a core objective which holds potential to facilitate climate resilient urban development for India through infrastructure, policy measures and urban design.

Planning Commission: The Planning Commission is the apex planning body in India that has been entrusted with the responsibility of the development and execution of India's five year plans. It plays an integral role in the socio-economic development while finalizing development plans of the national and state governments. The XIth Five Year Plan (2007-12) initiated several schemes, including the flagship program - Jawaharlal Nehru National Urban Renewal Mission (JnNURM) - to promote planned and sustainable urban development

Finance Commission: The main objective of the Finance Commission is to recommend the allocation of central government grants between states and began augmenting state funds to complement the resources of the local bodies. The Thirteenth Finance Commission made implementation of some its recommendations conditional for access to part of the funds recommended to the local bodies. Performance linked grants, by institutionalizing Service Level Benchmarks (SLBs), are available to 1,500 ULB's of 30 states and creates a new funding window of around 298 billion INR for India's growing urban centres.

The Ministry of Urban Development (MoUD): This ministry has the responsibility of broad policy formulation and monitoring of programmes in the areas of urban development and urban water supply and sanitation. It is the nodal ministry for carrying out the National Mission on Sustainable Habitat (NMSH) and planning and coordination of urban transport. The MoUD and the Ministry of Housing and Urban Poverty Alleviation have launched the

JnNURM, Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT) and the Rajiv Awas Yojana (RAY) programmes.

Coordinating agencies: There are coordinating bodies across various government agencies such as National Disaster Management Authority (NDMA) and National Institute of Disaster Management (NIDM). The NDMA has launched a number of missions including initiatives with the help of various institutions operating at different levels of governance. The central ministries, states and other stakeholders have been involved in the participatory and consultative process of evolving policies and guidelines.

The NIDM's main responsibility is human resource development through development and implementation of human resource plans, capacity building and training, research and policy advocacy in the field of disaster management. NIDM works in tandem with the NDMA and national, state and local governments as well as various other stakeholders. Its aim is to make a disaster resilient India by developing and promoting a culture of prevention and preparedness at all levels.

i.viii.iii Programmes/National Missions

National Action Plan on Climate Change: The National Action Plan on Climate Change (NAPCC) has eight missions in its core and additional interventions for strategic action for mitigation and adaptation and enhanced overall sustainability. The National Mission on Sustainable Habitat (NMSH) is recognised as one out of the four adaptation oriented missions (NAPCC 2008). The implementation of the NAPCC in the urban sector would be an integral part of governance activities of ULBs. The NAPCC has to be delivered effectively through suitable institutional mechanisms, including public private partnerships and civil society action. Another way for taking strategic actions for climate change adaptation by also specifying policy recommendations, that is fast becoming popular at international level is the 'Climate Change Action Plans'.

Jawaharlal Nehru National Urban Renewal Mission: This mission was launched to upgrade 65 cities for which nearly INR 100 billion have been allocated through city development plans. The climate component can be introduced by showing how climate induce risks may be reduced and city development plans can be revised. The mission is managed by the Ministry of Housing and Urban Poverty Alleviation (HUPA).

Other initiatives: The central government has initiated various measures for assisting states in the management of floods, this includes: the Rashtriya Barh Ayog in 1976 to consider the problem and based on its recommendations the flood management strategy in India was formulated and forwarded to all concerned states; the Ganga Flood Control Commission in 1972 for states in the Ganga Basin covering all the 23 river systems of Ganga; the Brahmaputra Board for the rivers Brahmaputra, Bar and their major tributaries; the National Water Policy, 2002, which has recommended preparation of basin-wise master plans for flood management and control, and for providing adequate flood cushioning in reservoir projects; a Task Force in 2004 for flood management and erosion control in Assam and its neighboring States as well as Bihar, West Bengal and Eastern Uttar Pradesh; and a state sector

scheme of the Ministry of Water Resources, "Flood Management Programme", with an outlay of INR 80 billion for providing assistance to the state governments for critical flood management and erosion control works.

i.ix Concluding Remarks

The challenge of climate change can only be met if cities are healthy and sustainable under normal circumstances. Their existing infrastructure should be adequate. An efficient and responsive governance should be in place. Their citizens should be educated, healthy and empowered who are in a position to control their destinies- at least in normal circumstances. A city that protects itself from storms, floods, droughts, heat waves, and diseases benefits its residents; their environment is better, their health is more protected, and their economic activities are less liable to damage and disruption. Such cities bounce back against natures' fury in a much shorter time as was seen in New York where despite devastation, stock market, metros, power and other infrastructure began to function in a few days. In order to have climate resilient development with positive mark on India's growing urban centres, the report is stressing to mainstream climate resilience measures in urban development programmes and policies as a priority. It is necessary to set up windows to promote and support research and development, innovation and entrepreneurship through enabling policy environment like legal and institutional landscape, financial and physical infrastructure for urban services. Thus well-targeted interventions emerging out of "HIGS" framework have multiplier effects in promoting sustainable and inclusive urban growth.

Centre of Excellence for Urban Development and Climate Change

The Ministry of Urban Development has designated IRADe as the Centre of Excellence (COE) in the area of Urban Development and Climate Change. Since 2008, the COE-IRADe is engaged in addressing the issues related to urban development and climate resilient and rendering support to national, state and local government in key areas of urban development and climate change.

The case studies and policy level recommendations for urban climate resilience were communicated to decision makers at various level and results were shared during the project with MOUD as well. The presentation on project findings, results, methodology, cities covered and future strategy for India's Urban Climate Resilience has been delivered to various forums like IPCC-SREX , European Union and others. The COE-IRADe has shared the knowledge with subcommittee on the development of sustainable habitat parameters related to urban planning and subcommittee for storm water management. These were constituted as an initiative under National Mission on Sustainable Habitat (NMSH), where IRADe is an implementation partner. IRADe has been working with the United Nations Development Programme (UNDP), India for "Review of City Disaster Management Plans" in selected Indian cities. Currently, IRADe is engaged with the Ministry of Urban Development for providing capacity building support for sustainable and resilient urban development interventions to 10 Indian cities covered under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM).

In order to strengthen capacity building initiatives in the area of climate change informed urban development, lectures on the course modules – urban planning, climate change and energy for Thirty students of Masters of Urban Planning course were conducted at School of Planning and Architecture (SPA), New Delhi. In addition, internships had been offered to twenty students of urban planning discipline from the Centre for Environment Planning and Technology (CEPT) University, Ahmadabad. The centre is now looking to stretch its arm to build the capacity of various other organizations and institutes working on Urban Climate Resilience. This includes National Institute of Urban Affairs (NIUA), various Centre of Excellence's for urban development. The ACCCRN results and lessons has been shared with the UN-Habitat, World Bank and many others to accommodate Climate resilience concerns in their upcoming investment and policy support programmes for urban development in India.

Integrated Research and Action for Development (IRADe) is set up a fully autonomous advanced research institute, which aims to do research and policy analysis, train people and be a hub of a network among various stakeholders. IRADe focuses on research and effective action through multi-disciplinary and multi-stakeholder research, which provides implementable solution for sustainable development and policy research that accounts for the effective governance of techno-economic and socio-cultural issues.

Dr. Shailesh Nayak,Secretary, Ministry of Earth Sciences

The assessment of the vulnerability, due to climate change, has emerged as a major tool towards providing site-specific hazard and risk related products to enable appropriate planning for sustainability of cities.

The assessment of 20 carefully chosen cities, depending on type and nature of hazard, population, infrastructure, governance, etc., as a case study, has clearly brought out the linkages between earth, social and human systems. It has been shown that such linkages are crucial to provide resilience to society from likely impacts of climate change. An approach to build interface and framework at local, state and national level has been suggested for effective decision making towards sustainable urban growth. This study is very important step towards future urban planning to meet challenges of climate change.

M Ramachandran, Former Secretary, Ministry of Urban Development

This study is a significant first of its kind effort in this direction, because it addresses city specific issues on a focused basis, draws attention to the immense challenges and guides us towards a workable strategy. In the large number of towns, we have been creating awareness about this issue, which is a major task and challenge.

What is important is that this study gives a 'way forward' for cities as to what should they be doing to reduce vulnerability and prepare better to face future hazards. While on the one hand, much more need to be done to improve basic infrastructure and basic service delivery in our cities, and on the other hand, today there are schemes and programmes available, which can be banked upon to use water more efficiently, reduce wastage of water, effectively handle the entire waste of the city, provide better sanitation and so on. The Service Level Benchmarking concept, if effectively applied and constantly monitored, the cities can steadily make life better for its residents.

This study can be the trendsetter for bringing about improvements in the 20 cities covered, to start with. This can be the facilitating guide to the remaining cities and towns to set the process in motion. States would do well to decide on similar studies on their vulnerability issues, say to start with, with the 468, one lakh plus population towns. At the same time, the remaining 3500 plus urban local bodies and the new category of 3894 census towns also can be brought into the scheme of things by sensitising them about this important agenda. It is a big challenge, but a challenge, which cannot be ignored or postponed because then the price we have to pay could be huge".

Dr. T Ramasami, Secretary, Department of Science and Technology

A Scientific and objective assessment of urbanization in the social context of current India's developmental paradigm with respect of climate variabilities is a need of the time. That such a rapid assessment has been made for 20 out of the 900 plus cities in India, is a laudable first measure. Since sensitivities are always local, commands cannot be Central. It does seem Dr. Jyoti Parikh and her colleagues have made a valuable effort to bring to focus the importance of the subject to the attention of the concerned people. To me, the first step, in itself amounts to half the battle won. Wish resounding success for the effort.

Prof. Amitabh Kundu, Centre for the Study of Regional Development, JNU

Analyses of the impact of climate change and determination of strategies for adaptation and resilience have generally been undertaken at global and national level. The present volume refreshingly brings these challenges and responsibilities at the doorsteps of local authorities and underlines the need also to think locally and act locally. The HIGS methodology underscores the importance of local level planning and actions based on a framework, integrating physical, environmental and socio-economic factors for Indian cities, taking into consideration their complexity and specificity.

Anil Baijal, Chairperson, National Institute of Urban Affairs

The initiative of IRADe in developing a framework integrating information on potential Hazards, status of urban Infrastructure and services, Governance issues and Socio-economic and demographic indicators – or the HIGS framework and then applying it to 20 cities of India for determining their vulnerability profiles, is indeed admirable. The study rightly points out that better functioning and well-planned cities will have greater resilience to face climate impacts. I am confident that this research work would greatly help the state governments and city administrations in focusing their efforts on the basic task of spatial planning, provision of infrastructure and effective governance tools for making their cities climate resilient. I also congratulate the Rockefeller Foundation for having engaged organizations like IRADe, ICLEI, TERI and NIUA in pursuing this important and topical research agenda

Aude Flogny, Regional Director for South Asia, French Development Agency

In the India's urban context: the report rightfully points out that the cities which are more likely to be resilient are those that have sustainable infrastructure and efficient governance. This is a very strong message to donors and a very important outcome of this report.

IRADe
Integrated Research and Action for Development
C 80 Shivalik, Malviya Nagar
New Delhi 110017, INDIA
Tel: 91 (11) 2667 6180, 2667 6181, 2668 2226
Email: info@irade.org Web: www.irade.org