

## CLIMATE CHANGE AND ITS IMPACT ON URBAN SERVICES IN INDIA: NEED FOR CLIMATE RESILIENCE

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***Abstract:** Growing urbanization is posing serious environmental concerns in India in terms of changing land use pattern, increasing carbon emissions, solid waste generation and disposal, air and water pollution and poor sanitation amenities. India is one of the major countries which witness natural and human induced disasters very frequently. Floods, droughts, cyclones, and earthquakes cause severe loss to human lives and physical resources. Resilience is proving to be a helpful way of furthering our understanding of how to improve efforts in disaster management, both in reducing the scale of impact before hand and in providing a better response afterwards. Climate resilience can be generally defined as the capacity for a socio-ecological system to: absorb stresses and maintain function in the face of external stresses imposed upon it by climate change; adapt, reorganize, and evolve into more desirable configurations that improve the sustainability of the system, leaving it better prepared for future climate change impacts. Against this view point, the present paper purports to critically examine the urban risks and climate resilience and also to assess the impact of climate change on urban services in India.*

***Keywords:** Resilience, Climate Resilience, Climate Change, Urban Services, Urbanization*

### INTRODUCTION

India is one of the major countries which witness natural and human induced disasters very frequently. Floods, droughts, cyclones, and earthquakes cause severe loss to human lives and physical resources. Communal riots, conflicts, fires, epidemics, accidents and other disasters compound the country's chronic troubles. The social and

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economic progress achieved over decades by the people, and advances in physical development, can be significantly devastated and degraded by disasters. The Government of India and State Governments through various agencies have been making efforts to meet the exigencies as arisen by natural and man-made disasters. It is, however, experienced that all these efforts and contingency plans concentrate on the post disaster situation. Thus it is imperative to prevent and mitigate the disasters, and also prepare the community and other stakeholders for disaster response, rehabilitation and reconstruction of disasters affected victims and areas. Cities may be viewed as hubs of the intensive resource demand, environmental degradation and greenhouse gas emissions. However, cities may play a critical role in promoting low carbon development through use of renewable energy, energy efficiency, green buildings and mitigating emissions from urban transport. Mainstreaming climate resilience into urban development is essential because climate risks may only be one of the several factors defining poverty level, well-being, economic growth and development in an urban environment. Strategic urban planning directly supports urban resilience as a tool for sustainable development. Urban local governments must actively coordinate and mainstream mitigation, adaption and resilience into urban planning process to prepare cities to deal with climatic risks and impacts. The Supreme Court of India has played a catalytic role for greening cities in the country. The court identified critically polluted cities and suggested an action plan to reduce the level of pollution in these cities. The immediate problems of India's cities relate to inadequate institutional arrangements for solid waste management, drainage, sewage treatment and disposal and sanitation services. Thus, it is imperative to improve the municipal services, particularly sanitation services and urban local governments adopt the integrated urban planning for climate resilience and addressing the environmental problems.

#### **OBJECTIVE OF THE STUDY**

The objective of the research paper is to examine urban risks and climate resilience and also to assess the impact of climate change on urban services in India.

## **DATABASE AND METHODOLOGY**

The paper is based on secondary data, pertinent literature, observations and discussions with municipal engineers & town planners in various conferences, workshops, training programmes, consultations etc. The practical experiences gathered during the services in various departments of state & central government have been useful in analysis of findings and suggesting policy measures..

## **CLIMATE CHANGE**

Climate change is one of the most important global environmental challenges, with implications for food production, water supply, health, energy etc. Addressing climate change requires a good scientific understanding as well as coordinated action at national and global level. IPCC has defined climate change as 'a change in the state of the climate that can be identified by changes in the mean and/or variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. Increase in the concentration of greenhouse gases in the atmosphere is considered as one of the main factors of climate change. As concentrations of greenhouse gases rise, the average surface temperature of the earth increases over time. The earth's rising temperature produces a change in weather patterns and sea levels.

According to the latest scientific assessment, the earth's climate system has demonstrably changed in both global and regional scales. Most of the warming (of 0.1°C per decade) observed over the last 50 years, is attributable to human activities. The Intergovernmental Panel on Climate Change (IPCC) projects that the global mean temperature may increase between 1.4 and 5.8 degrees Celsius by 2100. This unprecedented increase is expected to have severe impacts on the global hydrological system, eco-systems, sea level, crop production and related products (Sathaye, J. *et al.*, 2006). The impact would be particularly severe in the tropical areas, which mainly consist of developing countries, including India. The findings of

the Fourth Assessment Report of IPCC (Intergovernmental Panel on Climate Change) have highlighted the impacts of climate change and other serious implications for growth, development and social well-being in some of the most vulnerable regions. There are several dimensions of climate change that bring out the equitable aspects of this problem. The emissions of green house gases which have cumulatively resulted in the problem of human induced climate change have been produced by one set of countries while the worst impacts are going to be felt by the different set of countries and communities. Thus, Dr. Pachouri is of the view that if the earth's climate system has to be stabilized, mitigation measures will have to be undertaken with urgency. However, mitigation cannot be seen as narrow challenge and would require addressing the vary structure of economic growth as the world has come to accept over many decades (Tera Green, December 2007 - January 2008) (Chart 1) From 1900 to 2005, precipitation increased significantly in eastern parts of north and South America, northern Europe and northern and Central Asia but declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Globally, the area affected by drought has slightly increased since the 1970s. The rate of global average sea level rise has risen from 1.8 mm/yr to 3.1 mm/yr from 1961 to 1993. This has primarily been due to thermal expansion, melting glaciers, ice caps and polar ice sheets. The projected sea level rise at the end of 21<sup>st</sup> century will be an alarming 18-59 cm. Fresh water availability is projected to decrease while coastal areas, especially heavily populated mega delta regions will be at greater risk form sea flooding. Sea level rise is also expected to exacerbate inundation, storm surge, erosion and other coastal hazards threatening vital infrastructure in small island states (Tera Green, December 2007 – January 2008). Most human activities – fossil fuel combustion for power generation, transport, land use changes and industrial processes – generate emissions of green house gases. Power generation accounted for around 10 Gt CO<sub>2</sub>e or around one quarter of the total green house gases emission. Transport is the second largest source of energy related CO<sub>2</sub> emissions. (Human Development Report, 2007-2008).

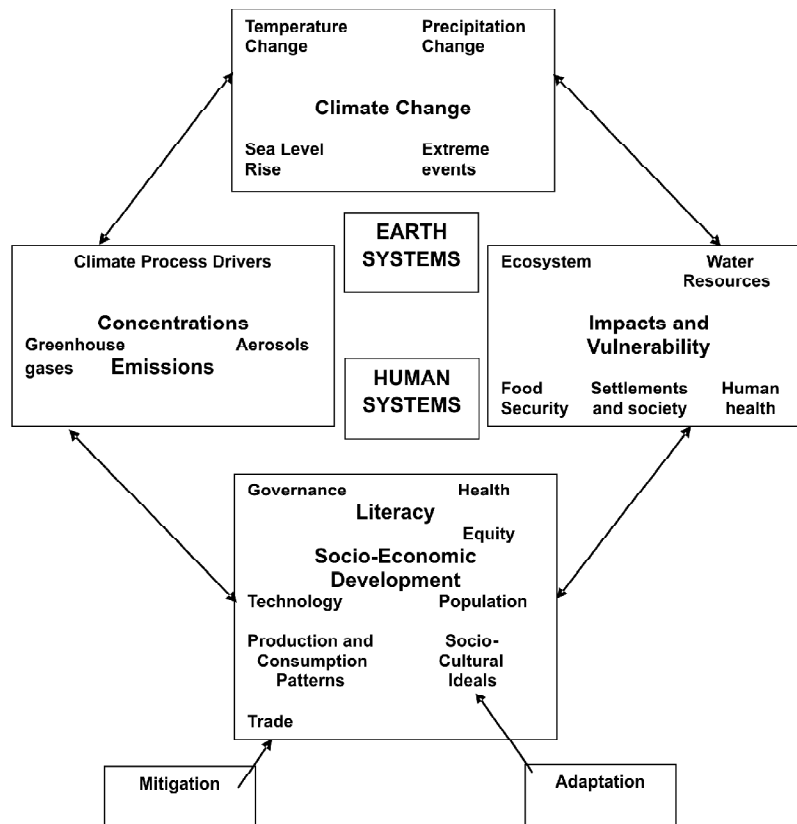


Chart 1: Climate Change & Its Implications

Source: IPCC. 2007

CO<sub>2</sub> emissions during 2005 were reported to be 1149 Mt in India. The growth during 1995-2000 was recorded 2.9 per cent while it was reported significantly high upto 3.2 per cent during 2000-2005. CO<sub>2</sub> per capita during 2005 was recorded 1.1 tonne only in India. Carbon dioxide emissions show a steady growth during 1990-2005. India's share in world's total CO<sub>2</sub> emissions was reported 4.3 per cent in 2005 however its share was recorded only 3 per cent in 1990. There has been significant increase in carbon dioxide emissions during 1990 to 2005 (92.6 per cent) in India. The per capita carbon dioxide emission has increased from 0.7 mt in 1990 to 1.1 mt in 2005. Cumulative carbon dioxide emissions since 1950 were reported to

be 28.6 billion mt in India. Non- CO<sub>2</sub> emissions have also increased significantly from 53.1 million tons in 1990 to 89.2 million tons in 2005 (Table 1). As per World Development Report, 2010, India's CO<sub>2</sub> emissions were reported to be 1146Mt while per capita CO<sub>2</sub> emission were recorded 1.18 tonnes during 2008.

**Table 1**  
**Carbon Intensity in India**

<i>Particulars</i>	<i>India</i>	<i>World</i>
Total (Mt CO <sub>2</sub> )		
1990	597	20693
2005	1149	26544
Change (Percentage)		
1990-2005	90.2	28.3
Share of World's Total		
1990	3.0	100
2005	4.33	100
Per Capita (t CO <sub>2</sub> )		
1990	0.07	4
2005	1.1	4.2
Cumulative Emissions since 1950 (Billions)	28.6	116.1
Non-CO <sub>2</sub> emissions (mt)		
1990	53.1	1861.0
2005	89.2	1978.9
Carbon Intensity of Energy		
CO <sub>2</sub> emissions per unit of energy use (kt of CO <sub>2</sub> per kt of oil equivalent)		
1990	1.87	2.39
2005	2.14	2.35

*Source:* World Development Report, 2010

Carbon emissions have been increasing in India in recent years and they are higher in urban areas. We find that average per capita carbon emissions are higher in metropolitan cities (being 1.19 tonnes per capita as compared to only 0.90 tonnes per capita in non-metropolitan cities), and the national average is 0.93 tonnes per capita (Table 2). Larger cities have more polluting activities such as power generation, industrial production and public and private

transport. However, it should be noted that municipal corporation level emissions as a percentage of city-level emissions are much higher in metropolitan areas than in non-metropolitan areas. Corporation-level emissions include those emanating from street lighting, water supply and sewage systems, transportation, building and other facilities.

**Table 2**  
**Carbon Emissions in India's Cities**

	<i>CO2 Emission Per Capita (Tonnes)</i>	<i>Corporation Level Emissions as % of City-level Emissions</i>
Jabalpur	0.30	7.80
Bhopal	0.31	8.83
Gwalior	0.37	6.09
Indore	0.41	2.28
Kanpur	0.45	3.20
Agra	0.64	10.29
Lucknow	0.64	20.77
Dehradun	0.71	7.14
Bangalore	0.82	4.14
Patna	0.83	7.10
Bhubaneshwar	0.84	1.17
Chennai	0.91	2.68
Ahmedabad	1.20	2.91
Pune	1.31	2.16
Raipur	1.32	1.85
Jaipur	1.63	4.22
Kolkata	1.83	2.15
Ranchi	1.97	0.06
Jamshedpur	2.76	NA
Average, all	0.93	5.30
Average, metros	1.19	10.39
Average, non-metros	0.90	4.72

*Source:* ICLEI-South Asia, Energy and Carbon Emissions Profiles of 54 South Asian Cities, 2009 and Sridhar *et al.* (2009).

## **IMPACT OF CLIMATE CHANGE**

Climate change is one of the most important global environmental challenges, with implications for food production, water supply, health, energy, etc. Addressing climate change requires a good scientific understanding as well as coordinated action at national and global level. India is a large developing country with nearly 700 million rural population directly depending on climate-sensitive sectors (agriculture, forests and fisheries) and natural resources (such as water, biodiversity, mangroves, coastal zones, grasslands) for their subsistence and livelihoods. Further, the adaptive capacity of dry land farmers, forest dwellers, fisher folk, and nomadic shepherds is very low (Ravindra Nath & Sathaye, 2002). Climate change is likely to impact all the natural ecosystems as well as socio-economic systems as shown by the National Communications Report of India to the UNFCCC (GoI, 2004).

Among the 32 states and Union Territories in the country, 22 are multi-disaster prone. About 40 million hectares of land in the country has been identified as flood prone and on an average 18.6 million hectare of land is flooded annually. About 57 per cent of area of the country is vulnerable to seismic activity. About 18 per cent of country's total area is drought prone, approximately 50 million people are annually affected by droughts and about 68 per cent of total sown area of the country is drought prone. India has a long coastline of 8040 km. which is exposed to tropical cyclones arising in the Bay of Bengal, the Arabian Sea and Indian Sea. The Indian Ocean is one of the six major cyclonic prone regions of the globe (Jain, 2004).

The Coromandal coastline is more cyclones prone, with 80 per cent of the total cyclones generated in this region. Risk to the existing housing stock in various states and union-territories had been estimated by Expert Group Set up by the Ministry of Urban Affairs and Employment, Government of India. About 3.9 million houses are susceptible to earthquakes of very high intensity, about 20 million houses are susceptible to damage due to winds and about 9.3 million houses are susceptible to damage due to floods. Besides



the risk of earth quakes, cyclones and floods are liable to very high damage and destruction of vulnerable houses under heavy rains (Jain, 2004).

Some 49 per cent of the total housing stock is liable to very high damage from natural hazards, while about 1 per cent of the total housing stock gets destroyed every year. It is to be noted that in earth quake, 80 per cent of the casualties are due to collapsing buildings. Brick and stone buildings without proper support are liable to collapse. Non-engineered buildings continue to be built in the areas prone to natural disasters. Unemployment, poverty backwardness, migration from rural areas and increasing price of land and construction, millions of people are occupying disaster prone areas. Thus about 6 per cent increase in disaster affected population has been reported. The changing topography due to environmental degradation has also increased the vulnerability in the country. In 1988, 11.2 per cent of total land area was flood prone, but in 1998 floods inundated 37 per cent geographical area. Three major disasters that India have experienced in the recent past are the super cyclone in Orissa (1999), earthquake in Gujarat (2001) and Tsunami (2004) in Tamil Nadu, Pondicherry, Andaman Nicobar Islands and parts of other southern states. Frequent disasters lead to erosion of development gains and restricted options threatened by hazards. Short term and long-term changes in climatic variables such as temperature and precipitation may pose hazards to urban systems. Changes in the climatic variables are likely to impact future patterns of spatial growth and development in cities and act as a stressor in addition to existing pressures. The populations most vulnerable to climate change are those living in slums and informal settlements that often lack access to basic services and infrastructure (IDS, 2007). Apart from the risk to coastal populations from sea level rise, cyclones, storm surges and other associated impacts, a high proportion of urban settlements in the low and middle-income countries are on sites that are at risk from flooding or landslides. The key primary and secondary order impacts on cities due to short-term and long-term changes in climatic variables have been summarized in Table 3.

**Table 3**  
**Impacts on Urban Systems Due to Changes in Climatic Variable**

<i>Changes in Climatic Variables</i>	<i>Primary and Secondary Impacts</i>
<p><b>Temperature Extremes</b> Rise in average temperatures of a region may lead to warm spells and heat waves</p>	<ul style="list-style-type: none"> <li>· Heat-related mortality - at high risk being the aged, those with pre-existing ailments such as cardiovascular and respiratory diseases and those with poor housing structures.</li> <li>· Increase in demand for water and impacts on air and water quality, and increased demand for cooling etc.</li> </ul>
<p><b>Heavy Precipitation Events</b> (which may or may not be associated with cyclones and storm surges)</p>	<ul style="list-style-type: none"> <li>· Deterioration of the quality of surface and groundwater</li> <li>· Mortality, injury, water-borne and food-borne diseases</li> <li>· Flooding and water-logging</li> <li>· Disruption of mobility</li> <li>· Displacement of settlements</li> <li>· Damages to industry and infrastructure (including drainage, sewerage etc.)</li> </ul>
<p><b>Sea Level Rise</b></p>	<ul style="list-style-type: none"> <li>· Land inundation</li> <li>· Salt-water intrusion into groundwater aquifers</li> <li>· Impacts on coastal agriculture and livelihoods etc.</li> <li>· Displacement of coastal settlements</li> <li>· Damage to industry and infrastructure</li> </ul>
<p>Climate change may increase the frequency and intensity of extreme events such as floods and cyclones</p>	<ul style="list-style-type: none"> <li>· Mortality and morbidity</li> <li>· Damage to infrastructure, including communication channels, power supply etc.</li> <li>· Spread of water- and food borne diseases etc.</li> </ul>

*Source: IPCC, 2007 and Prasad et al, 2009)*

An urban environment is complex primarily because of rapidly changing variables such as socio- economic and demographic indicators, land-use patterns, resource demand and utilization patterns, lifestyle changes etc. In the light of climate change, a new layer of uncertainty is added in terms of changes in precipitation, temperature and occurrence of extreme events. Due to climate change, there are more chances of occurrence of floods, river erosion,

droughts in the Himalayan region. In other regions, different water problems will require suitable strategies to address the climate change related issues (Table 4).

**Table 4**  
**Region-wise Planning Problems Due to Climate Change**

<i>Regions of India</i>	<i>Water Availability and Reliability of Outputs</i>	<i>Safety against Floods and River Erosion</i>	<i>Safety against Droughts</i>	<i>Sustainability against Sedimentation</i>	<i>Adjustments to Rise of Sea Level</i>
Himalayas	-	Very Important	Important	Very Important	
North & North West alluvial plains	Very Important	Very Important	Very Important		
Central & Eastern Plains	Important	Very Important	Important	Very Important	Very Important
Western Peninsular India	Very Important	Important	Very Important	Very Important	Very Important
Eastern Peninsular India	Important	Very Important	Important	Important	Very Important

Source: Ministry of Water Resources, GOI, 2008.

## **IMPACTS OF CLIMATE CHANGE ON URBAN SERVICES:**

### **Water Supply and Sanitation**

- Changes in precipitation patterns may lead to reductions in river flows, falling groundwater tables and, in coastal areas, saline intrusion in rivers and groundwater-all leading to a net decline in the water resources available for supply to urban areas.
- Water quality problems may also increase where there is less flow to dilute contaminants introduced from natural and human sources. The increase in water temperature can alter the rate of

operation of bio-geo-chemical processes (degrading and cleaning) and lower the dissolved oxygen concentration of water (Khatri and Vairavamorthy, 2007). This may lead to increased load on water treatment plants for bringing the water to a recommended standard before it can be released for human consumption and use in the cities.

- Water-supply abstraction and treatment plants, which are generally situated near water sources, may be affected due to disasters such as floods. In severe riverine floods with high flow velocities, pipelines, electrical switchgear and pump motors may get damaged (Satterthwaite *et al.*, 2007).
- Climate related disasters such as floods, cyclones, storm surges etc can also increase the vulnerability of sanitation infrastructure to structural damage. The main impact of climate change would be, on on-site sanitation systems such as pit latrines, is likely to be through flood damage (IPCC, 2007).
- Flooding may also cause septic tanks and sewers to overflow. Since sanitation infrastructures (or the lack of them) are the main determinant of the contamination of urban floodwater with faecal material, damage to these presents a substantial threat of enteric and other water-borne diseases.

### **Solid Waste Management**

Climate change has the potential to impact waste management services and sites (Bebb and Kersey, 2003), by:

- Damaging some on-site waste management facilities such as some gas and leachate collection systems, weighbridges etc
- Disruption of transport facilities impacting the collection of waste from source points and delivery of waste to the management site.

### **Sewerage and Storm Water Drainage**

An adverse impact on water supply is most likely to have negative effects on sewerage and drainage systems in the city. In case precipitation is very high, it can decrease the capacity of the system

making it susceptible to flooding and sewer overflow during rainfall extremes. It is important to note that the existing urban drainage system maybe designed to operate under specific weather conditions for a specific area. The age of the system can vary and, in some parts these may not be adequate to deal with future conditions of intense flooding (Berggren *et al.*, 2008).

The Ministry of Urban Development and the Ministry of Urban Employment and Poverty Alleviation constitute the nodal authorities at the national level responsible for formulating policies and guidelines, designing programmes, coordinating and monitoring activities of various central, state and urban local bodies concerning all issues of urban development in the country. A number of policies and programs, schemes and development projects are already under implementation for various urban sectors and services. These include:

- **Jawaharlal Nehru National Urban Renewal Mission (JNNURM)**, which aims at improving urban service levels in a financially sustainable manner in 63 identified cities. The JNNURM Directorate had also launched the **Peer Experience and Reflective Learning (PEARL)** to facilitate sharing of success stories and best practices (GoI, 2009). For the cities not covered under JNNURM, Government of India had launched the **Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT)**. UIDSSMT seeks to improve the urban infrastructure in towns and cities by enhancing public-private partnership in infrastructural development, and promoting planned integrated development of towns and cities.
- The Ministry of Urban Development has **Standardized Service Level Benchmark (SSLBs)** for benchmarking certain indicators for key urban services such as water supply, sewerage, solid waste management and storm-water drainage (TERI, 2009).
- Government of India announced the **National Urban Sanitation Policy (NUSP)** in November 2008 to comprehensively deal with the challenges in urban

sanitation in India's cities. The policy envisages transforming all towns and cities of India into 100 per cent sanitized, healthy, and livable spaces; and ensuring sustained public health, and improved environmental outcomes for all its citizens. The main components of the policy are awareness generation and bringing about behavior change; achieving open defecation-free cities; sanitary and safe disposal of waste; promoting proper usage and maintenance of household, community, and public sanitation facilities; extending access to sanitation facilities for poor communities and un-served settlements; and strengthening Urban Local Bodies (ULBs) to provide sanitation services by supporting need-based capacity building and training at the state level.

- The **Rajiv Awas Yojana** (RAY) was announced in 2009 and aims at providing low-cost housing for the urban poor. National Urban Housing and Habitat Policy 2007 emphasizes on in-situ development of slums and preparation of a special action plan for slum dwellers with particular reference to the socially disadvantaged groups of urban population. Recognizing that the rise of slums is rooted in the lack of proper urban planning, the RAY focuses on issues that lead to the development of slums—such as shortage of land, housing infrastructure and basic services (Mathur, 2009). If the RAY is oriented towards urban reforms, it can also be an important vehicle to mobilize the National Strategy for Inclusive Growth as well as the National Urban Housing & Habitat Policy 2007 that aims at improving the living conditions in slums and providing low-cost and alternate housing (Singh, 2010). The specific activities as envisaged under the RAY include:
  - Integrated development of notified and non-notified slums
  - Provision and/or improvement of access and provision of basic services to the urban poor. These include water supply, sewerage, drainage, solid waste management, road access,

street lighting, community toilets, market access, livelihoods centres etc.

- Liaisoning with other schemes for the urban poor, related to water and sanitation, health, education, livelihood support, infrastructure, connectivity etc.
- Development of low-cost and affordable houses along with basic infrastructure and services (for ownership, rental or both).

### **Urban Risks and Climate Resilience**

Urbanization is a global phenomenon experienced by developed as well as developing countries. There is migration from villages to towns and cities with results in growth of metropolitan cities since they provide multiple avenues, services and amenities viz. education, health care, employment, business and entertainment options etc. People also migrate for economic opportunities and urban life styles. Though urbanization brings about development in social, economic and cultural spheres of life, it sometimes disturbs the ecological systems. Rapid and unplanned growth of urban agglomerations generates a series of negative environmental effects. Today urban India presents a very pathetic scene. Cities have become a site of rotting garbage, degrading drainage system and shocking night soil removal system. India's life line is in danger. Many Indian rivers are heading towards an environmental disaster due to discharging of untreated sewage into water bodies. Besides, poor have practically no access to sanitary toilets and in many towns and cities, the majority defecate in the open. The untreated sewage being dumped into the river and water bodies leads to health hazards. Growing urbanization is posing serious environmental concerns in India in terms of changing land use pattern, increasing carbon emissions, solid waste generation and disposal, air and water pollution and poor sanitation amenities. A large segment of urban population in India resides in slums, squatters and informal settlement. These settlements are often located in low laying areas prone to direct and indirect risks due to environmental degradation including changes in the climate and lack of basic urban services.

An urban environment is complex primarily because of rapidly changing variables such as socio- economic and demographic indicators, land-use patterns, resource demand and utilization patterns, lifestyle changes etc. In the light of climate change, a new layer of uncertainty is added in terms of changes in precipitation, temperature and occurrence of extreme events. Furthermore, there are scale mismatches; in terms of the timescales over which policymakers and urban planners operate, and scales over which projected impacts of environmental decisions, degradation, climate variability and change will manifest. Also policies and developmental initiatives in cities should enable urban systems to adjust to changes as and when they happen and accordingly respond in a way that maintains their original structure and function. It is to be noted that out of 35 cities in India having population over a million, 18 are in coastal states. Major challenge for cities in the face of rapid population growth is to maintain sustainability within the social, economic and environmental dimensions. Urban systems are at risk to different kind of hazards. Several factors contribute to the urban risk profile.

Increasing urbanization, expansion of habitat into unsuitable vulnerable areas, higher population density, higher housing density, vulnerable housing and buildings construction, non engineered unsafe construction, and aging buildings and other infrastructure are some of the factors that have increased the vulnerability of hazards and disasters in urban areas. Growing urbanization is posing serious environmental concerns in India in terms of changing land use pattern, increasing carbon emissions, solid waste generation and its disposal, air and water pollution and poor sanitation amenities. Major challenge for cities in the face of rapid population growth is to maintain sustainability within the social, economic and environmental dimensions. The accelerated and uncontrolled urban growth has contributed to the ecological transformation of the cities and their immediate surroundings resulting in flash floods and water scarcity. Furthermore other factors depending on the local circumstances contribute to the urban vulnerability, hazards and risks (Singh, *et al.* 2014). Cities may be viewed as hubs of the intensive resource demand, environmental degradation and greenhouse gas



emissions. However, cities may play a critical role in promoting low carbon development through use of renewable energy, energy efficiency, green buildings and mitigating emissions from urban transport. The immediate problems of states' cities relate to inadequate institutional arrangements for solid waste management, drainage, sewage treatment and disposal and sanitation services. Thus, it is imperative to improve the municipal services, particularly sanitation services and urban local governments adopt the integrated urban planning for climate resilience and addressing the environmental problems (Singh, 2014).

Policymakers and developmental planners have increasingly become interested in understanding the concepts of resilience, vulnerability, and adaptation to enable proactive and better informed responses to urban disasters. (Dayton and Johnson , 2004). Urban Resilience" is the capacity of an urban center to absorb the shock of a sudden or unforeseen disaster provoked by an event without necessitating massive extra territorial aids and resources to maintain its urban performance quality. These shocks could be of manmade origin or of natural causes such as tsunami, flood, cyclone, earthquake, landslides, etc. The quality of urban resilience or in other words its absorbing capacity depends upon the management quality of its governance system, its resources availability, its infrastructural facilities and maneuverability, the participative dynamics of its citizens and most importantly its visions and preparedness mechanism at all levels to counteract the disasters and emergencies. In fact, an urban center is a complex entity of a total system composed of innumerable sub-systems representing different urban elements and parameters. A good number of scientific means and knowhow's such as GIS, forecasting, simulation of scenarios and magnitude of disasters' effects, etc. are available to understand, to envision and to modelise these risks and minimize their impacts on settlements. In order to encounter the disasters and improve the resilient capacity of the settlement centers, three basic strategies are needed to be developed: 1) Anticipation and envisioning of the "causes & effects chain" that constitute the total urban system of the settlement centre; 2) Improve the early warning

and preparedness capacity, infrastructural mobility and governance system; and 3) Incorporating necessary measures in the development program to rectify the planning errors (Baral, 2014).

Growing urbanization would result in an increase in dependency on urban services, economic opportunities, resources, and infrastructure. In India, while cities such as Mumbai, Bangalore, Ahmadabad, and Chennai have substantial developmental investments, medium and small towns are grappling to deal with population growth and competition for resources due to inadequate infrastructure and financial resources. (Mc Grahahanan *et al.*, 2007). A major challenge for cities facing rapid population growth is to maintain environmental sustainability. The nature of inter-linkages of services within an urban environment and consequently the highly connected nature of risks, policies relating to urban resilience and sustainability essentially need to address multiple sectors and dimensions (Nijkamp and Finco, 2000). This includes land use planning, energy management, ecosystem services, housing and transport, water supply and sanitation, health services, and waste management, inter alia.

Aggregating the findings from the extensive review of literature on climate adaptation, resilience efforts, urban risks, and development, we find (Teri, 2011):

- Resilience is multi-sectoral: Policies need to be integrated within on-going decision-making and planning processes in critical sectors;
- Resilience is an incremental process: Planning should emphasize mechanisms for on-going learning, evaluation, and adjustment of strategies based on observed impacts of climate changes
- Resilience includes not only “hard infrastructural investments” but also “soft” actions to strengthen the adaptive capacity of populations and sectors
- Resilience should be framed in line with local and regional developmental priorities, and focus on the most vulnerable sectors

- Resilience planning should involve stakeholder groups in a collaborative way. It is a multi-sectoral approach, operating at various levels of institutional set-up
- Mainstreaming resilience planning needs to be guided by policies and legislative framework or by the rules of law to help integration with development activities at each level.
- Resilience planning should be based on detailed region-specific vulnerability analysis to capture vulnerability in its varied dimensions (for example biophysical, social, and technological, etc.)

Project planning for infrastructure needs early risk audit in its formative stages of estimating investments. Hazard and vulnerability assessment need to be more focused on risk of disaster and climate change in these estimates. In local level project planning the focus on process that captures risk concerns, risk reduction to build resilience in infrastructure is lacking (Bhatt, 2014). Resilience is proving to be a helpful way of furthering our understanding of how to improve efforts in disaster management, both in reducing the scale of impact beforehand and in providing a better response afterwards (Sanderson, 2014). There is an urgent need to look for alternatives to produce greener and cleaner building materials, which consume fewer resources, produce lesser pollution and are environment friendly besides focusing on disaster resistance capability of construction materials. In India, town planning is an important entry point for mainstreaming urban resilience. Review of several planning documents is required in order to identify options and strategies towards urban resilience. These include:

- Town and country planning act and zoning regulations
- Development control rules and building bye-laws
- District planning manual of the Planning Commission
- National building codes
- Urban Development Plan Formulation and Implementation (UDPFI) guidelines
- City master plans

At the city level, budgetary challenges and lack of fiscal autonomy still exist as bulk of the finances still rest with the Central and state governments and not with city governments. The method of mainstreaming risk reduction and resilience planning is through climate risk screening. It is an approach for reducing climatic risks to developmental objectives and integrating adaptation options within developmental programmes at the national and sub-national levels (Tanner *et al.*, 2007). The steps involved in a climate risk screening include:

- Assessment of current and future impacts of climate change on developmental objectives of a project/ policy;
- Assess the ways in which the developmental project/policy already contributes towards vulnerability reduction and risk reduction Identify potential entry points to integrate climate risk management strategies into the developmental project/ policy ambit;
- Prioritization of the selected strategies based on multiple established criteria
- Conducting cost-benefit analyses of the selected strategies.

Strong urban planning can promote resilience by ensuring optimal use of space, energy and natural resources. Flexible and adaptable climate change planning processes are crucial. Engagement, education and awareness raising campaigns are a useful element within planning for development because each activity can contribute to climate change – wasting electricity, driving cars, not recycling or reusing. Decentralized and improved urban governance is important for practical implementation of resilience and sustainability strategies. Public-private partnerships are an important and effective means of leveraging stakeholder expertise and forming partnerships for greater community benefits. Municipal bodies often do not have appropriate data to address planning needs and development. Advanced mapping, visual and spatial technologies can promote effective resource allocation and resilience strategies in cities. In order to ensure disaster resilient development in cities, there is a need for *better inter—agency coordination* across ministries and departments such as urban

development , housing, water resources, environment, transport, home/internal affairs, power, communications, municipal governance amongst others at national, state and local levels along with many non- governmental organizations and civil society & organizations.

### **Way Forward**

- There is a need to prepare a comprehensive, flexible and user friendly framework for planning and policy analysis under climate variability and uncertainty scenario.
- It is imperative to establish and strengthen ground water monitoring network through construction of observation wells, sanctuary wells for coastal aquifer management and water quality monitoring.
- It is high time to review the National Water Policy with a view to ensure integrated water resource management in the context of climate change challenges in water sector.
- It is imperative to develop inter-ministerial and inter-departmental coordination for vulnerability analysis, mitigation and addressing of climate change challenges both at the state and centre level.
- Integrated Energy Policy, introduced in 2006, should be effectively enforced to promote energy efficiency in all sectors with emphasis on mass transport, renewable energy resources development and clean energy technologies.
- Promotion of cleaner technologies, strengthening of emission standards, introducing economic incentives and strengthening of monitoring and reporting system is imperative in order to control the industrial pollution.
- State specific water policies need to be prepared. Ground water legislation needs to be promulgated in all states to promote sustainable water uses and water development. Emphasis should be given to developing surface water use and taking measures for rainwater harvesting to increase water resource availability.

- It must be made mandatory to install rainwater harvesting systems in both public and private buildings, including industrial and commercial establishments. Buildings having a courtyard should allocate a prescribed proportional area for rainwater harvesting and recharging. The ULBs should make ensure such provisions before approving building plans.
- Environmental taxes can potentially be levied in a wide range of settings for effluent/emission charges for industrial pollution, and user fees for municipal solid waste, to taxes on the use of agricultural inputs such as fertilizers and pesticides and carbon taxes. The small scale industries may also be imposed taxes in accordance with polluter pays principle.
- It is imperative to develop and evaluate adaptation strategies in all the major hydro geological environments to mitigate negative impacts of climate change and variability.
- Integrating climate change adaptation considerations into policy process and decision making across a range of sectors and skills is critical in managing the impacts of climate change. There is need to develop, disseminate and implement the knowledge, tools and technologies required to effectively engaging in an integrated approach.
- A long term national programme for supporting public participation in environmental management including climate change adaptation measures aimed at educating and building capacity of all stakeholders is imperative. The most serious attention should be given to building civil society's capacity to understand the environmental issues and linkages to sector activities, to effectively engage in public participation forums; and promoting innovative and more interactive approaches to public participation that increase public ownership of environmental action.
- A comprehensive urban air quality management strategy should be formulated that includes information related to urban planning, ambient air quality, emission inventory, and air quality dispersion models.
- Water use efficiency programmes including water conservation, water recycling, piped water system, metering

and regulation of water use and rationalizing energy supply need to be adopted.

- Most environmental amenities (such as clean air and water) are being overexploited and thus, there is a need to introduce market based instruments for judicious use of such environmental amenities.
- Capacity building and institutional strengthening for environmental management including climate change adaptation measures is called for. There is need to improve the overall quality of governance, particularly at the state and local levels in order to effectively implement the environmental policies and legislations.
- There is an urgent need to reach out the poor and the marginalized groups for improving the access of water supply and sanitation services. In view of the poor state of sanitary facilities and inadequate hygiene awareness, physical infrastructure and awareness building are equally important.
- Vehicular pollution control in metropolitan cities and other cities deserve top priority. A practical strategy should be devised that reduces both emission and congestion.
- Technological intervention is required to enhance effective treatment of waste water. Strengthening of waste water and sewerage/effluent treatment plants should be undertaken on priority basis.
- Enhancing public and private investments for raising plantations for enhancing the cover and the density of forest is called for. Effectively implementation of Greening India Programme is to be ensured to increase the forest cover and vegetation. In-situ and ex-situ conservation of genetic resources, especially of threatened flora and fauna may be adopted for conserving biodiversity.
- Fostering climate resilient reforms in agriculture and water resource management is imperative to promote agricultural research and extension services for better suited agricultural crops in the context of climate risk and variability.

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