Chapter 20. Mumbai

Mumbai (formerly Bombay) is a cluster of islands, of which seven comprise the city proper and four its suburbs. It is considered the financial capital of India, and it is also home to two of India's major ports. This coastal megacity occupies an area of 468 square kilometers (sq. km.), and its width is 17 km. east to west and 42 km. north to south. It has a rich a rich natural heritage, such as hills, lakes, coastal water, forests, and mangroves, alongside built areas. Because of its geographical location and its physical, economic, and social characteristics, Mumbai is vulnerable to the effect of climate variability and change, including storms, floods, and sea-level rises. Its growing population is the most important factor making it susceptible to climatic events. As a financial center, Mumbai attracts people searching for economic opportunities. This activity puts pressure on the operational efficiency of the infrastructure, civic amenities, and housing. Furthermore, this megacity is coping with traffic congestion, carbon emission from heavy vehicular circulation, solid waste issues, and the growth of illegal slum dwellings that are urgent problems exacerbating climate risks (Patankar, et al.).

For megacities, understanding the nature of their vulnerabilities is a challenge. It helps them to identify the risks and is crucial for an effective adaptation and mitigation plan. Mumbai's current population is about 21 million (Population Facts, 2014), and its per capita income is a little more than three times that of India. The United Nations estimates that Mumbai’s population will grow to about 27 million by 2030, making it the second most populated city in the world after Tokyo (Jadhav, 2014).

Vulnerabilities to Climate Risks

In July 2005, Mumbai was beset with India's heaviest rainstorm in a century. This catastrophic event killed nearly 600 people and paralyzed the city's operations from infrastructure, public health facilities, and transportation. It was one of the most devastating storms ever recorded in the country (Patil & Deepa, 2007).

Mumbai's built environment has problems directly related to its drainage system and its squatter communities. Water shortages, building collapses, and sewage disposal issues leave the city perilously exposed to severe weather events. Access to drinking water is limited, and sanitation is poor (Sherbinin, 2007).

The old section of the city has a propensity to flooding, which leads to shutting down commuter rail lines. Subsequently, the flooding occurrences contribute to sea-level rise. In a national study of India's coastal zones, according to their vulnerability, Mumbai was found very susceptible to harm.

Approximately 55 percent of Mumbai's population lives in slums are mostly located in low-lying coastal areas and along stream banks. Many of these precarious habitats are constructed with salvaged materials and are so deteriorated that they pose physical and health risks to the inhabitants. Mumbai's squatter communities are among the most densely-populated districts in the world with population as high as 94,000 people per square kilometer. (Sherbinin, 2007)

Elements of Risk in India's Cities

Several elements contribute to India's cities vulnerabilities to severe weather events:

- Slum dwellers, squatters, and migrants live in traditional and informal settlements, which are often located in the most vulnerable locations;
- Industrial and informal service sector workers, whose occupations place them at significant risk from natural hazards;
- Buildings, especially traditional and informal housing that is especially vulnerable to wind, water, and geological hazards;
- Industrial units, their in-house infrastructure, plant, machinery and raw materials;
- Lifeline public and private infrastructure, which includes roads, bridges, railways, ports, airports and other transportation systems; water, sewage and gas pipelines; drainage, flood and coastal defense systems; power and telecommunication infrastructure; and critical social infrastructure such as hospitals, schools, fire and police stations and first responder’s infrastructure; and
- Ecosystems and the natural environment, especially wetlands, estuarine and coastal ecosystems, and surface and groundwater systems.

Analyzing these elements that make a city susceptible to disaster leads to the conclusion that risk adaptation and mitigation measures must focus on particular urban populations and .infrastructure. In the case of Mumbai’s flooding in 2005, the city confronted a diverse array of constraints and challenges to efficiently respond to the disaster. Based on this experience, decentralized adaptive management strategies that engage political leaders and policy makers at all levels− from neighborhood to national−provide evidence of effectiveness to countervail the limitations and inefficacy of centralized top-down interventions (Revi, 2008).

The analysis of interventions shows that combining short-run priorities and long-run strategic actions under a universal framework can lead to a paradigm shift in current policies and management of the city. Also, private and public sector actions, urban development and planning can support the strategy and minimize climate threats (Revi, 2008) because the process of risk management is ongoing, continual improvement. As new hazards arise and the city faces new challenges and changes to the environment, these must be discussed and dealt with.

Urban Disasters: Flooding

In India, as in many developing countries, rainfall variability is central to issues of agricultural production, and, in some cases, it is at the core of the national economy. Consequently, extreme climate events impact the general economy and often affect the population in urban areas. The trends in rainfall in India have been studied since the last century such as the long-term southwest monsoon/annual rainfall trends over India as a whole by Parthasarathy et al. (1993) and trend analysis for rainfall in Delhi and Mumbai by Rana et al. (2011), among others. Over the last 50 years, studies have shown a significant decrease in in the frequency of moderate-to-heavy rainfall events over most parts of India. In some regions, however, extreme rainfall events are increasing at a rate of 100 millimeters per day (mm/day) as recorded by Goswami et al. (2006).

After the 2005 flood, economic losses and future scenarios were studied and presented by Ranger, et al. (2010). The analysis presented a harsh picture for the future of Mumbai; the authors have stressed the need to evaluate and consider uncertainties in climate projections for adaptation planning in the city. Multiple available projections need to be considered like the Global Climate Models and Regional Climate Models for example because a single scenario might not be a proper tool to obtain adequate information to apply to decision-making in adaptation planning (Rana et al., 2014).

As previously state, floods in regions of India have grown in intensity and frequency. Rain fall is has become more extreme, bringing densely populated cities like Mumbai to a standstill. Climate change has altered the frequency and intensity of these weather events in Mumbai, and 100-year floods might now happen within a decade or two and last longer. Also, during flood season, concentrated heavy showers affect the drainage system and paralyze the city's road and rail network, communications and transportation systems (Alankar, 2015).

OECD-funded research on climate change in the wake of the 2005 floods concluded that the direct economic losses totaled US$ 2bn and cause 500 fatalities (Alankar, 2015). At the same time, Mumbai's rapid urbanization has intensified threats to the urban population risks and dissuaded any adaptation effort.

Response to Climatic Impacts

The Mumbai flooding led to a focus on disaster reduction and risk mitigation as an important to the adaptation agenda. In addition, an emphasis was placed on transferring key financial infrastructure and IT-enabled services to other cities with lower risks of impact. The OECD research highlighted the weak response to climatic events by the administrators and proposed a series of activities to implement a strategy to cope efficiently with such impacts:

- Quantify immediate to medium term physical, economic, environmental and social outcomes resulting from selected weather events;
- Characterize vulnerability by examining the trends in impact indicators;
- Characterize responses in terms of costs, distributional effects and efficiency;

- Identify opportunities and means for incorporating climate risk into local and regional decision making. (Alankar, 2015).

Delayed Response and Consequences of Strategic Unpreparedness

Mumbai's official reaction to the flooding is a reflection of how unprepared its response system was, the absence of a business continuity strategy, and consequently its increased susceptibility to future climatic events. Volunteer organizations took the lead in response to initiatives while the Brihan Mumbai Metropolitan Corporation (BMC) did respond much later with a disaster management plan, which uncover the unpreparedness of the megacity's capabilities to cope with the magnitude of this event (Alankar, 2015).

As the flood water rose, the heavy rains disrupted many sectors of the city:

- Transportation system−Train movement stopped, the roads were full of water, certain roads submerged, and the airport was unable to function for two days..
- Communication system−The communication network was disrupted as telephones an cell phones went down one-by-one. Had the network been operational and the public address system effective, many people would have received guidance and not put their not put their lives in danger.
- Power supply−Due to submerged of the power stations and substations, the power supply in suburban area got suspended
- Water logging−about 22% of Mumbai's land was submerged in rain waters on 26th and 27th July, 2005
- Food and civil supplies−Commencing on the evening of 26th July, the daily consumables

could not reach to the people

- Rescue and relief measures−All efforts were made by rescue workers but the rain totals made matters very difficult to handle. Measures were taken in terms of mosquito control, water purifications. Additional physicians were employed to manage increased patient load. Water was supplied through tankers. Many NGO's were also active in rescue work (Envis Centre, 2006).

Leading Actions after the Event

The urban poor living in low-lying areas are exposed to flooding and other hazards, including inadequate storm water drainage. The city's storm water drainage (SWD) system consists of a hierarchical network, located mainly in the suburbs, which is a roadside surface drain 2,000 kilometers long and allows rain water to run away freely from the road and highway. The storm water drainage system in the city is about 70 years old and able to handle rain of 25 mm per hour at low tide. If the intensity of rainfall is more than 25 mm and the city experiences hide tides, there is a possibility of water logging (Storm water drainage, 2013).

Some city leaders recognized the urgency of the problem and took action. The Brihanmumbai Municipal Corporation (BMC) took the initiative and proposed the redevelopment of slums and villages on the coast under the Coastal Regulation Zones (CRZ) rules. However, there is no consideration of sea level rise which will affect these zones and their population. The actions of local people were the main reason the city returned to normal when the disaster management team and the corresponding authorities failed to act according to the urgency of the circumstances. Therefore, CRZ needs to recognize the significant role of local knowledge and strategies as past experiences abet in mapping the response to climate variability and change in order to learn and obtain knowledge from the local strategies and approaches to climatic events (Alankar, 2015).

Desertification and Climate Change

Desertification, the process of land degradation in land areas (Grainger et al., 2000) can be a result of climate change impacts and human activity. The understanding of such events is central to preventing desertification expansion. Desertification has detrimental economic, social and environmental consequences, increasing human survival and developments risks (Xu & Pan, 2011).

The dependency of populations on natural resources, particularly in the developing world, can be severely affected by climate change, drought, and desertification. Hence, given the intensification of extreme weather events, it becomes crucial to examine local-level adaptation plans to cope resourcefully with those effects.

Desertification and Migration

The link between climate change and international migration is problematic for many developing countries. However, research on the subject of internal population shifts suggests that is a significant factor in climate-induced migration. Climate-related desertification is causing migration in Mumbai as well as other cities like Delhi and Kolkata (DePaul, 2012). Research that investigated desertification and land degradation in India and concluded that a 105.5 megahectare area of the country, or 37 per cent of the country’s total geographic area, is undergoing these processes and of this, the area undergoing desertification is 81.4 mega hectares (Ajai et al., 2009). These conclusions affirmed that desertification reduces job opportunities, causes mass migration from rural to urban centers, and presents global food security risks. Mumbai clearly presents a good example of climate-induced mass urbanization and resulting poverty. The movement of people to Mumbai is a result of internal migration coming from the south in addition to international migration from surrounding countries. As climate change magnifies these issues, the city of Mumbai’s vulnerabilities to such impacts will be exacerbated.

Mumbai was ill-equipped for the flooding of 2005. Contributing to its susceptibility were its topography, drainage system, and low river deltas. In addition, lax building code enforcement exposed the city’s population to drowning, wall collapse, and various diseases. Those deaths were mostly among inhabitants living in slums (DePaul, 2012). These squatter communities comprise about half the Mumbai’s population, and they are characterized by poor sanitation, precarious housing infrastructure, and the lack of basic services such as potable water (Sherbinin et al., 2007). How mass urbanization under certain conditions lead to stress bundles is notorious in Mumbai. Table 20-1 lists conditions and their results:

Table 20-1 Climate-induced mass urbanization and urbanization of poverty

Condition	**Result**
Poorly designed and maintained buildings	Damage by extreme weather events.
Transportation priorities	Limits disaster preparedness
Under severe climate events	Increases pressure on resources
Impoverishment (living in slums)	Slowing of local economy
Desertification	Migration, mainly from Bangladesh

Water Scarcity	Worsening living conditions

(Adapted from DePaul, 2012).

As stated, desertification forces many migrants, particularly from Bangladesh but also locals from rural areas, to leave their homeland and seek refuge in the city. When the effects of desertification and water scarcity affect the population, their precarious socio-economic conditions make them highly vulnerable to severe weather events because it is difficult for this segment of Indian society to mobilize and change their conditions.

Built Environment

Poor living conditions and bad governance occur due to political and economic ineptitude, increasing the challenges of urban poverty. In this case, the foundation of the city's priorities is not directed towards human needs in an equitable and sustainable manner (The challenge of slums, UN Habitat, 2013).

The city build environment has problems directly related to its drainage system and its squatter communities. Water shortages, building collapses, and sewage disposal issues leave Mumbai badly exposed to severe weather. Most of the old part of the city has a propensity to flooding, which leads to shutting down it commuter rail system. Subsequently, this flooding contributes to sea-level rise and in a national study about India's coastal zones, according to their vulnerability, Mumbai was found highly susceptible to harm (Sherbinin, 2007).

Approximately, 55 per cent of Mumbai's population lives in slums and live mostly in low-lying coastal areas and along stream banks. Many such precarious habitats are in severe distress and pose physical and health risks because they are constructed with salvaged materials. Mumbai squatter communities are among the most densely-populated in the world with densities as high as 94,000 people per square kilometer. Nevertheless, accessibility to drinking water and sanitation is poor (Sherbinin, 2007).

Health and the Environment

Outbreaks of leptospirosis were reported in children living in precarious housing infrastructures after the flooding of 2000, 2001 and 2005 with an increased prevalence of eight-fold following the major flood event in July 2005 (Kovats & Akhtar, 2008). Leptospirosis is a bacterial disease caused by bacteria of the genus Leptospira. According to the Centers for Disease Control and Prevention, this disease can cause a broad range of symptoms. Without treatment, it can lead to kidney damage, meningitis (inflammation of the membrane around the brain and spinal cord), liver failure, respiratory distress, and even death (Centers for Disease Control and Prevention, 2014).

Health Impacts of Air and Water Pollution

Mumbai has severe air and water pollution according to the World Bank. About 75 percent of all sewage is unprocessed and discharged into local waterways and coastal waters. These actions cause environmental degradation and health risks to the population. Urban air pollution also affects the health of Mumbai's inhabitants as industrialization, increased vehicle use, and population growth has upped the health risks for greater numbers of residents. The World Health Organization (WHO) named Delhi as one of the top ten most polluted cities and Mumbai is next to it in air pollution levels (Shankar & Ramarao, 2002). An increased incidence of tuberculosis is an indication of air pollution health effects as in the case of Mumbai. Moreover, ambient air concentrations of suspended particulate matter (SPM), Nitrogen Oxides (NOx) and hydrocarbons have crossed the allowable limits of air pollution tolerance index, exacerbating health issues to the Mumbai's urban residents (Yedla, 2003).

Analysis of Mumbai's Climate-Disaster Resilience

Mumbai city is known for its financial and entertainment activity, but the megacity lacks the financial services, budget and subsidies, and savings and insurance to address the risks caused by severe weather impacts, climate variability and change. Moreover, Mumbai institutions are fragile in terms of resilience. If disaster led to the city's collapse, the results would be violent disorder and interruption of basic services, causing direct and indirect harm to livelihoods. As the megacity's overall climate-disaster resilience is relatively low, stakeholders need to take a step forward to sustain efforts to strengthen physical, social and institutional dimensions of resilience (Razafindrabe et al., 2009). The capacity of the megacity's infrastructure to maintain and provide services after a disaster is crucial for the health and survival of its population. Mumbai's experience with flooding makes its population aware of the consequences of such an event. Capitalizing on this awareness should help local government and civic societies to provide problem-solving strategies that build social resilience. Broader cooperation with other institutions and mainstreaming disaster risk reduction needs to be included in the megacity's development agendas as a primary objective for resilience (Razafindrabe et al., 2009).