Risk Assessment of Indian Coastal Cities to Sea Level Rise
A Development Planning Perspective

Keywords: Risk Assessment, Sea level rise, Indian coast, Climate change, Vulnerability

Need for the research

Asian countries are epicentres for urbanization and are the most disaster-prone regions, where incidences of climate induced disasters are also high (Shaw, 2009). Due to lack of infrastructure and less preparedness to deal external exposure developing countries are more prone to disasters. Climate change is expected to increase the frequency and intensity of current hazards and the probability of extreme events, along with emergence of new hazards (e.g. sea-level rise[1]) and new vulnerabilities with differential spatial and socio-economic impacts. IPCC AR4, states global average temperatures have risen by about 0.74°C in the last 100 years and led to a sea level rise (SLR) of an estimated 17cm in the 20th century. It also predicts a rise in sea level by 1 meter in Indian sub-continent by 2100.

Based on the evaluation, India is one of the most vulnerable and risk prone countries in the world to projected climate change (International Federation of Red Cross, 2005). India has 7517 km coast-line where more than 40 million people live. A large portion of the Indian population along the coast is dependent on climate-dependent activities like marine fisheries, inland fishery, salt making etc. which could be affected. The costs of 1 meter SLR could include up to 7 million people displaced, and 5764 sqkm of land and 4200 miles of road lost (Tata, 2002). The projected SLR along India's coast would eventually have tremendous socio-economic impact on local communities and their livelihood. Mega-cities like Mumbai, Chennai, Kolkata lie along the coast which houses maximum Indian population. Several ports like Mundra, Kandla, Mumbai, Cochin, Chennai, Tuticorin, Paradip etc. would be impacted which contributes to the Indian economy. Thus SLR would ultimately degrade the resilience of the poor and vulnerable communities which make up the one quarter of the population of Indian cities[2]. Also, India has second largest Low Elevation Coastal zone population (LECZ), with about 3 percent of national land area forced to sea level rise[3]. So for better development vulnerability and risk assessment to SLR makes a strong focus. Therefore, the research would try to assess risk of Indian coastal mega-cities to SLR.

Out of the four metropolitan cities in India, three metropolitans Mumbai, Chennai and Kolkata are located on Indian coast which are growing fast and comprise large share of Indian population. The GDP contribution to the Indian economy is higher from these mega cities. Human population and density of these cities is also high. As per Census of India, 2011 the total population living in these three cities is 2,16,46,231. The physiographic, demographic, climatic and geographic profile of these cities is different which will help to carry out comparative analysis.

Objectives for the research

The study would try to understand different parameters that increase vulnerability to coastal hazard in Indian metropolitan cities. It would also assess different facets of risks and quantify the components of vulnerability. The main objective of the study will be:

- To identify the SLR impacts
  - To identify major sectors (land loss, human loss and economic losses) affected
  - To analyse different geographic land-use that could be affected
  - To identify the life-line infrastructure facilities at risk
- To analyse the economic impacts (i.e GDP at risk) due to SLR
- To understand various coping mechanisms adopted by different socio-economic groups
- To prepare strategies/measures for risk reduction
  - To prepare safeguard planning policies to make communities resilient
  - To evaluate local government's capacity or response for implementing mitigative strategies
- To emphasis outcomes of 3 coastal cities and policies for reducing coastal cities

---

[1] Nicholls, R J and J A Lowe (2006), "Climate stabilization and impacts of sea-level rise", in H J Schellnhuber, W Cramer, N Nakicenovic, T Wigley and G Yohe (editors), *Avoiding Dangerous Climate Change*, Cambridge University Press, pages 195–202.

[2] Satterthwaite, David, Saleemul Huq, Mark Pelling, Hannah Reid and Patricia Lankao Romero (2007), "Adapting to climate change in urban areas; the possibilities and constraints in low- and middle-income nations".

[3] McGranahan, G et al. (2007a), "The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones", *Environment and Urbanization* Vol 19, No 1, April, pages 17–37.

Prerak Shah, CEPT University, Ahmedabad, India ar.prerak.shah@gmail.com

Research Questions

The questions that study would try to answer are:

1. What amount of human life could be affected due to exposure to SLR?
2. Which eco-sensitive or fragile areas prevail in these cities that could be majorly affected?
3. What would be replacement cost of infrastructure loss (in economic terms); and also the cost for future adaptation strategies?
4. Which planning intervention would help to avoid, reduce or adapt to probable SLR disasters?

Methodology

The study would consider both intrinsic as well as extrinsic vulnerability indicators for risk assessment. A comprehensive local level list of indicators would be prepared to analyse actual ground scenario. Risk assessment would be carried out at a scale of 1x1 km grid to simulate the human life and economy at risk for the 3 coastal cities. Considering flood being a topographic based event, instead of analysis at administrative level, a raster based analysis at micro level (1km x 1km) grid would be carried. Sectoral economic impact and GDP contribution at risk would be carried out which would eventually help to analyse GDP at risk. Low elevation coastal zones (LECZ) would be segregated to analyse the population living in potential threat zone. Different SLR simulations would be carried out for different sea level rise to assess the risk at different scenarios. The research would compare the different simulations to analyse the changing variation in human life and economy at threat due to different SLR.

Data Needs

A detailed data inventory of Demographic, Social, Economic and Physical parameters would be colleted for analysis. The Demographic parameters would be used to analyse the growth rate and amount of population that would be at risk. Economic parameters would be used to analyse the income and expenditure pattern, Sector-wise GDP contribution and effect on GDP contribution due to SLR. Social parameters would be used to analyse the intrinsic vulnerability of the people. According to definition of intrinsic vulnerability, backward class people (SC and ST) are more vulnerable than higher class people[4]. Thus social indicators are also important. Physical parameters would be used to analyse agricultural crops and the built-up units that would be at risk due to extrinsic parameters i.e SLR. Demographic and social data would be collected from Census of India which would include Demographic details, Disability data, household data and vital statistics. LandScan[5], 2011 (ORNL) data will be collected to spatially demarcate people living in 1km x 1km grid. Per capita income and GDP contribution for economic analysis would be collected from Centre for Monitoring Indian economy. Employment and unemployment data would be collected from National Sample Survey organisation. Climatic data i.e rainfall and temperature data will be collected from Indian Meteorological station. Tide gauge data would be collected from National Institute of Oceneography, Goa. Bathymetric data and coastal slope would be derived from General Bathymetric Chart of the Oceans (GEBCO), British Oceonographic Data Center (BODC) with the help of Geographic Information Systems (GIS). Geomorphology, shoreline change and coastal topography will be derived from high resolution satellite image with the help of remote sensing and GIS techniques.

Outcomes of the research

Study would help to analyse different geographic land-uses under present use which might get affected by the inundation, which will be helpful for planners and decision-makers to devise contingency plans for combating SLR problems along the Indian coast. Impact assessment provides useful information for different sectors such as ports and infrastructure development on the coast of selected cities. It will be useful for planners and policy-makers to develop long-term adaptation measures. It would also help environmentalists and coastal zone managers to work out the plans for managing the coastline and its environment affected by SLR and natural disasters. Also land-use mechanisms and planning recommendations and strict enforcement of the Coastal Regulation Zone (CRZ) Act, monitoring of impacts would be suggested for the threat zone.

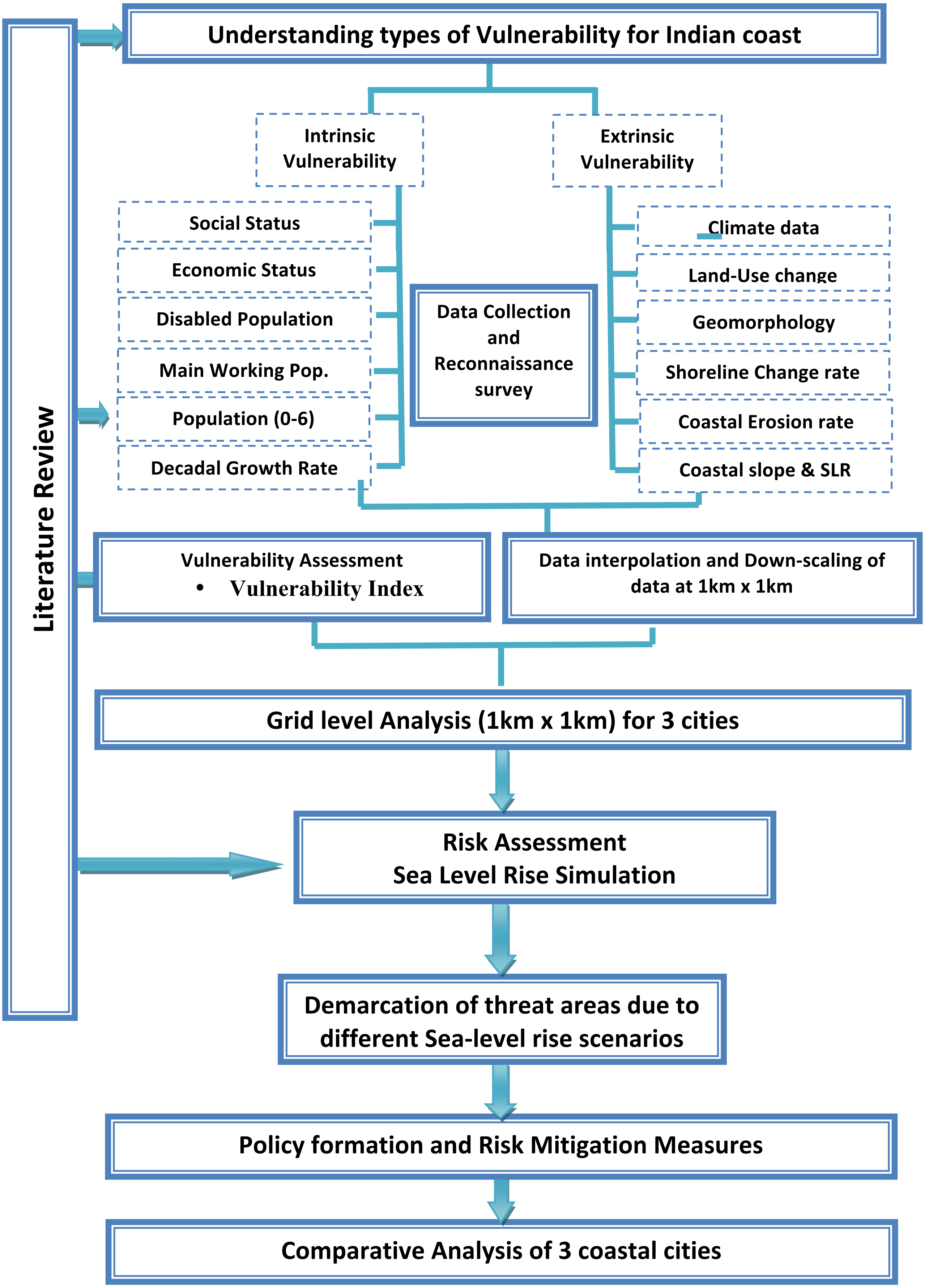
Timeframe

Study would require 2 years for SLR risk scenarios 3 coastal cities. Once a detailed methodology is developed study would try to carry out risk assessment for different cities located on Indian coast.

[4] According to Williams and Kaputska (2000), intrinsic vulnerability can be seen as "the inability of an individual to tolerate stressors over time and space". Villa and McLeod (2002) stated that an individual's vulnerability can be either intrinsic or extrinsic. Intrinsic vulnerability is related to factors internal to the system (health and resilience), whereas extrinsic vulnerability contains factors external to the system (present exposure and external hazard).

[5] LandScan data is obtained by using an innovative approach with Geographic Information System and Remote Sensing. ORNL's LandScan ™ is the community that generates data for global population distribution. At approximately 1 km resolution (30" X 30"), LandScan is the finest resolution global population distribution data available and represents an ambient population (average over 24 hours). In LandScan raster format, each pixel has a unique value which represents the population of that 1 square kilometre pixel.

Conceptual Framework



Brief Description of three cities

Mumbai

This coastal city has a total population of 1,24,78,447 as per Census of India, 2011. Mumbai is the capital of Maharashtra state. It is the most populous city of India and fourth most populous city of the world. Located on the west coast of India, the city has a deep natural harbour. It is the wealthiest city in India and has the highest GDP of any city in South, West or Central Asia. Mumbai is the commercial and entertainment capital of India, generating 5% of India's GDP, and accounting for 25% of industrial output, 70% of maritime trade in India (Mumbai port Trust &JNPT), and 70% of capital transactions to India's economy.

Mumbai city gets flooded almost every year devastating many houses, infrastructure facilities and even causing death of human life. On July 26, 2005 the floods were caused by eights heaviest ever recorded 24-hour rainfall of 994 mm.

Chennai

This coastal city has a total population of 46,81,087 as per Census of India, 2011. The city also known as Madras is the capital of Tamil Nadu state. Located on the coromandel coast of the Bay of Bengal, it is a major commercial, cultural, economic and educational centre of South India. It is the sixth most populous city of India and 31st largest urban area of the world. A major part of India's automobile industry is based in and around the city thus earning it the nickname "Detroit of India".

Kolkata

As per Census of India, 2011 the city houses 44,86,697. Kolkata is the capital of West Bengal state. Located on the east bank of the Hooghly river, it is the principal commercial, cultural, and educational centre of East India. The Port of Kolkata is India's oldest operating port. It is the third-most populous metropolitan city of India. As of 2008, its economic output as measured by gross domestic product the city ranked third among South Asian cities, behind Mumbai and Delhi.

Kolkata falls under seismic zone III, while the wind and cyclone zoning is very high due to its proximity to Bay of Bengal. May – October has a prominent cyclone season. Tidal upsurge also affects the low-lying areas with water logging and flooding problems during heavy rains. Devastating cyclone history records are traced back to 1737, 1842, 1864,1867.

****