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Hazard Risk and Vulnerability Analysis (HRVA) of the City of Bhubaneswar (Odisha)

Final Report

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For the attention of:

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Executive Summary

The Hazard Risk and Vulnerability Analysis (HRVA) for the city of Bhubaneswar, Odisha has been carried out as part of the on-going GOI-UNDP project "Enhancing Institutional and Community Resilience to Disasters and Climate Change." It aims to reduce disaster risks in urban areas by enhancing institutional and community resilience to disasters and climate change by integrating Disaster Risk Reduction (DRR) measures in the development programs as well as to undertake mitigation activities based on scientific analysis.

This report provides findings of the hazard risk and vulnerability assessment of key natural hazards the city is exposed to, namely – Cyclonic wind, Flood, Earthquake, Heat wave, and Epidemics. Quantitative modeling techniques based on GIS were used for mapping and analysis using standard public domain models. Based on these results, recommended actions for various mitigation and adaptation measures were provided in the last section.

City Profile:

Bhubaneswar, the capital of Odisha state, is also popularly known as the "Temple City of India". It is located on the Eastern Ghats, about 40 km west of North Bay of Bengal (with an average elevation of 45 meters above mean sea level) in Khordha district. It lies on the west bank of river Kuakhai, which is a tributary of River Mahanadi that flows about 30 km southeast of Cuttack. The river Daya branches of Kathjodi and flows along the southeastern part of the city. The city has a spatial spread 135 sq. km with 67 Census wards and a population of more than 8 Lakhs. It has a population density of 6,228 person/ sq km.

City Asset:

The city has more than 197,000 households and about 75% of the buildings in the city are under residential use. The city has several commercial and industrial establishments; about 14% and 2.5% of the total buildings are under commercial and industrial use, respectively. The city has a total road network of about 1,642 km of which about 51 km is national highway passing through the city. The total length of rail network in Bhubaneswar city is about 34 km and the only international airport is located at a distance of 3 km from the city center. The city has 1,171 educational institutions and 667 health centers. The city, being a temple city, has a large number of religious places (more than 117 sites). The total estimated value for main exposure elements for Bhubaneswar city is more than INR 151,452 Crores, out of which Residential, Commercial, and Industrial exposure is about INR 91,085 Crores, INR 43,707 Crores, INR 4,353 Crores, respectively. The exposure value of essential facilities (health care centers, educational institutions, etc.), and transportation systems are estimated at about INR 4,985 Crores, and INR 7,186 Crores, respectively.

Hazard mapping and analysis:

For the past three decades, the state of Odisha and in particular, Bhubaneswar city has been experiencing unprecedented contrasting extreme weather conditions; from heat waves to cyclones; from droughts to floods. In the year 1998, the State of Odisha faced an unprecedented heat wave situation, because of which 2,042 persons lost their lives. Though extensive awareness campaigns have largely reduced the number of casualties during post 1998 period, a good number of casualties are still reported each year. It has become a menace during peak summer. The temporal analysis of daily temperature data for the past three decades shows a steady increase in city temperature. During May 2013, a maximum temperature of 47°C was recorded at Bhubaneswar. Most of the districts in Odisha, on an average, recorded 40ºC during April 2014 and, the temperature across a few districts in coastal Odisha reached 46ºC by the end of May. Very severe heat stress conditions prevailed in May / June in 2014. In fact, Bhubaneswar has become one of the hottest Indian cities in recent times.

Floods and water logging in the low-lying areas of the city have also become common due to unplanned growth of the city. The south-west monsoon contributes a considerable portion of heavy rainfall in both onset and withdrawal phases, which generally lead to flash floods in a short time. Analysis suggests that rainfall amount per event has varied from 100 mm to 520 mm and the frequency of flash floods across coastal Odisha has increased considerably from 1960 onwards. Most of the heavy rainfall events occur in July and August. The region, extending from the central part of coastal Odisha in the southeast towards Sambalpur district in the northwest, experiences higher frequency and higher intensity of heavy rainfall with less inter-annual variability. It is because low-pressure systems develop over north-west Bay of Bengal with minimum inter-annual variation and the monsoon trough extends in west northwesterly direction from the centre of the system.

During the period from September to November each year, a number of cyclonic storms originating in the Bay of Bengal overrunning the city also bring gales and heavy rains during the northeast monsoon. According to a United Nations Development Programme (UNDP) report, its wind and cyclone zone is at a "very high damage risk". During late withdrawal phase of the south-west monsoon season on Oct. 30, 1999, Bhubaneswar city received a record 43 cm of rainfall in a few hours. Again, in the year 2009, rapid formation of meso-scale disturbances due to strong low-level convergence of moist air from the Bay of Bengal in the presence of convectively unstable stratification was responsible for heavy rainfall, which led to widespread heavy rainfall events. The 1999 Odisha cyclone caused major damages to buildings and city infrastructure, and loss of human lives.

The flat coastal belts with poor drainage, high degree of siltation of the rivers, soil erosion, breaching of embankments and spilling of floodwaters over them cause severe floods in the river basin and delta areas. This problem becomes even more acute when floods coincide with high tide. The entire coastal belt in Odisha is prone to storm surges. However, Bhubaneswar city, being about 40 km from the coast, does not suffer from storm surge. The storms that produce tidal surges are usually accompanied by heavy rainfall making the coastal belt vulnerable to both floods and storm surges. A good number of people, nearly 300 persons, succumb to death due to thunderstorm lightning in the State of Odisha every year.

According to the Bureau of Indian Standards (BIS) IS:1893 (2002, 2014) on a scale ranging from I to V in order of increasing susceptibility to earthquakes, the city lies in seismic zone III, which is a moderate seismic risk zone (BMTPC, 2006). In spite of the moderate, non-damaging earthquakes observed so far in and around Bhubaneswar, it cannot be said confidently that higher intensity earthquakes are unlikely. Recently, on May 21, 2014 an earthquake of magnitude 6 on the Richter scale occurred in the Bay of Bengal, which was severely felt in different parts of Bhubaneswar city due to local soil-amplifications, though there was no report of any significant damage in the city.

Recent studies have indicated that the Mahanadi river valley is faulted and could be a potential earthquake source. Besides this, the Sumatra fault zone and tectonic plate setting along the Andaman and Nicobar Islands and Burma Micro-plate boundaries in the eastern part of the Bay of Bengal pose potential threats of tsunami for the coast of Odisha. However, the city, being about 40 km from coast, is not prone to Tsunami.

Application of hazard maps for city development and disaster management:

Hazard mapping and analyses help in identifying areas that are prone to various hazards – both in terms of intensity and in terms of probability. This also helps the City in taking appropriate site-specific short, medium, and long-term mitigation measures, which include both structural and non-structural measures. It would also help the city administration to mainstream DRR activities in the city development process.

Vulnerability Assessment:

Assessment of physical vulnerability to various hazards, and social vulnerability and environmental vulnerability in general of the city was assessed based on identified indicators and field observations. Different vulnerability functions for cyclonic winds and earthquakes were used for risk assessment, based on analysis of the building typology in the city. For social vulnerability, socio-economic indicators were considered based on secondary and field based information. The Social Vulnerability Index (SoVI) is developed for Bhubaneswar city. Poverty and gender seem to have a high influence on the social vulnerability in the city. There is a high correlation between high social vulnerable groups to low income areas, particularly slum settlements of the city. In livelihood vulnerability analysis, three types of analysis, i.e. impact of heavy rainfall, high temperature and heat wave were carried out. The city's rapid growth has converted vegetative areas, low-lying water bodies, and open spaces into built-up spaces. Built up environment has increased the rainfall run off, leading to water inundation problems in many parts of the city and during summer month increase the heat wave situation of the city due to back radiation.

Risk Assessment

The risk assessment is based on the hazard, exposure and vulnerability analysis. Risk assessment has considered five hazards (cyclone winds, earthquakes, floods, epidemics, and heat waves). However, due to non-availability of storm water drainage network data, and ward level data on epidemics, risk assessment could not be carried out for these hazards. The capacity assessment analyzed needs of the city administration and community in terms of response and preparedness. The risk analysis and capacity assessment helped in deriving the key recommendations for the city for risk mitigation and preparedness to devise short, medium, and long-term strategies for the city as well as communities at large.

Risk assessment was carried out using probabilistic method for cyclonic winds and earthquakes. For earthquakes, probable Maximum Losses[1] (PML) were estimated for the 475 years return-period hazard scenario. For cyclonic winds, PML losses were estimated for 5, 10, 25, 50, and 100 years return-period hazard scenarios. Risk matrix by hazard was developed based on estimated losses and damages attributable to each hazard.

Earthquake risk assessment: The PML for buildings were estimated based on occupancy and replacement costs for different building types. The estimated losses are to the order of INR 6,009 Crores for residential buildings, INR 3,892 Crores for commercial buildings and INR 297 Crores for industrial buildings in a 475-year return period earthquake hazard scenario. The estimated PML losses are highest for schools/college buildings (to the order of INR 346 Crores). For hospitals and places of worship, the estimated PML losses are to the order of INR 64 Crores and INR 95 Crores, respectively. In this scenario event, the estimated casualties (serious injuries including fatalities) are estimated between 1,933 – 2,075 people for the entire city.

Cyclone wind hazard risk assessment: Due to 100-years return period cyclonic wind hazard, the PML for buildings were estimated based on occupancy and replacement cost for different building types. The estimated losses are to the order of about INR 111 Crores for residential buildings, INR 56 Crores for commercial buildings and INR 6 Crores for industrial buildings, respectively. Cyclonic wind hazard losses are not significant for 5, 10, and 25 years return-period events. Average Annual Losses (AAL) losses are to the order of about INR 1.2 Crores for residential buildings, INR.0.59 Crores for commercial buildings and INR 0.06 Crores for industrial buildings, respectively.

[1] *The economic loss numbers presented in this report are structural losses and cost of land and content values are not taken in such analyses.*

Epidemic impact: For epidemic risk assessment, sufficient data at ward level was not available in the city. The State malaria statistics for the period 2007-2011 showed that Khordha district is in the group of districts with low incidence of malaria disease. However, the incidence statistics of Acute Diarrheal Disorders (ADD) show that about 2% of the city population is annually affected, which is a significant number. The recurring natural hazards, such as water logging due to flood and cyclone also act as a triggering factor for waterborne and vector borne diseases.

Climate Change impact on Health Sector: The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) concluded that climate change would have adverse impacts on human health. As the city is vulnerable to climate related hazards, this would have significant implications unless appropriate mitigation measures are adopted. The temperature variation due to climate change may have adverse effects on both morbidity and mortality (particularly on elderly people) including cardiovascular, respiratory, and heat stroke mortality as well as increase in incidence of vector borne diseases - malaria, dengue and chikungunya. The changes in the rainfall pattern would also increase the incidence of vector borne diseases.

Capacity Assessment: Capacity and needs assessment was carried out for both city administrations as well as for communities. The capacity in terms of response and relief with respect to knowledge, skill and awareness towards mitigation and adaptation measures were analyzed. The city administration has reasonably good infrastructure, knowledge, and resources for disaster management. In addition, to support and be part of the State DRR activities, the city administration is active in developing measures towards a climate risk resilient urban center. The city is part of the UNISDR global campaign of “Making Cities Resilient Campaign” and is the recipient of SASAKAWA Recognition 2011 and Role Model for Community Preparedness.

For the health-sector, there is a need to develop a long-term, comprehensive epidemic contingency plan by taking into consideration the impacts of climate change. In addition, moving forward, the city health department should develop location-specific data of epidemic hazards. This will be helpful in analyzing and promptly responding to epidemic hazards. At community-level, awareness on building codes (byelaws), land use restrictions, hazard zones etc. are needed. There should be sensitization programs on hygiene and preventive measures for minimizing epidemics particularly during post disaster situations. NGOs and community organizations need to be further encouraged to be part of community capacity building activities.

Recommended Actions:

Based on the city level risk assessment, recommended actions are suggested for DRR of the city. These include both structural and non-structural measures. Sector specific short, medium, and long-term strategies are suggested based on the assessment carried out in this study. It necessitates mainstreaming DRR in city development planning to reduce the risks and protect the population and assets of the city. This needs coordination among sectors, an integrated approach ensuring mitigation and adaptation measures that would not cause adverse impacts. The mitigation and adaptation measures need to be phased appropriately and integrated into the City's short, medium, and long-term plans.

Cyclone adaptation and mitigation measures: Among buildings, the economic losses of residential buildings are highest due to cyclonic winds. Among utility networks (Electric lines, Railway lines, Water lines, and Sewerage lines) the estimated economic losses are highest due to cyclonic winds. The following measures are needed to reduce these losses:

- Enforce building codes (byelaws) for various types (residential, commercial, and industrial) of buildings in general and residential buildings in particular, to reduce the cyclonic wind risk in the city.

- Significant damage to buildings also happens due to fallen trees/their branches from high cyclonic wind speeds. Hence, city administration should have a proper tree-pruning policy for the city.
- Evaluate tinned/asbestos roof buildings for their resistance to cyclonic wind by certified structural engineers in a phased manner. This should be followed up by appropriate retrofitting measures.
- Gradually covert the overhead lines in general, and electric power lines in particular, to underground cables. This will help in avoiding damage and loss due to cyclonic winds.

Earthquake risk mitigation measures: The estimated economic losses to residential buildings are highest followed by commercial and industrial buildings. Among schools/colleges, hospitals, and religious places, the estimated economic losses are highest for schools/colleges followed by religious places and hospitals. Since earthquake risk mitigation measures are directly related to life-safety, the city administration should take these up on priority for their strict compliance. The following are some of the measures to mitigate losses to life and property from earthquakes:

- Create regular public awareness campaigns on “Earthquake safety - Dos and Don’ts” through seminars and quizzes in schools/colleges, and through print and electronic media
- Review and enforce strict building codes (byelaws) compliance in design and construction of various types of new buildings and infrastructures.
- Evaluate old buildings from structural engineering point of view, especially starting from schools/colleges, religious places and hospitals for their structural resistance to earthquakes. This should be followed up by appropriate retrofitting measures.
- All the residential, commercial and industrial buildings should be evaluated for their structural safety in a phased manner and appropriate retrofitting measures should be taken up from building code perspectives.
- To mitigate non-structural damages, several measures can be adopted, such as:
    - Fasten shelves, cupboards etc. securely to walls,
    - Secure water heaters, LPG cylinders etc., by strapping them to the walls or bolting to the floor
    - Anchor overhead lighting fixtures and fans to the ceiling properly
    - Secure hanging objects, such as ACs, heavy glass paintings etc., as hanging objects may cause loss to life and property

Flood/Water logging mitigation measures: Taking into consideration the growth in the city, the following measures are recommended for urban flood management:

- Remove encroachment of natural drains as this helps in mitigating flood/ water logging problem of the city
- Develop and connect storm water network for the entire city including peripheral areas of the city
- Develop high resolution (preferably 0.5 m) Digital Elevation Model (DEM), which will be helpful to model and predict city flooding/water-logging accurately at sub-ward level and for planning mitigation measures.
- Periodically clean existing storm drains, which are clogged due to waste dumping and indiscriminate developmental activities
- Improve the existing solid-waste disposal system and enforce non-dumping of solid waste in drains

The service delivery of the city administration, especially the solid waste management, sewerage network and public transport system should also take into consideration population growth of the city in future.

Heat wave adaptation and mitigation measures: Though Bhubaneswar city has good cover of trees and vegetation, however, in view of the future growth of the city and predicted increase in temperature due to impact of climate change, the following measures are recommended for heat-wave adaptation and mitigation:

- City administration should develop a ward-level plan to check on vulnerable populations during heat waves, especially the elderly and poor.
- Additionally, city administration should arrange for portable water tanks in the event of heat waves.
- Create awareness among communities towards “Green buildings”[2]
- While revising building codes for residential buildings, it is also important to consider the heat wave risk in the city. The design specifications should take into account guidelines on the design of green buildings
- Building owners should be encouraged to use heat-reflecting material on roof-tops of existing buildings
- Green building designs should be adopted for government and public buildings
- Green cover should be further improved in the city in a phased manner
- Increase awareness in people to take pre-emptive measures during heat waves, for example, drinking enough water, avoiding alcohol consumption, etc. and in understanding warning symptoms of heat exhaustion and how best to keep cool.
- Training masons for constructing buildings following building codes and design specifications that cover features of green buildings

Epidemics adaptation and mitigation measures: Health is a key sector that needs priority considerations as part of DRR activities in both short and medium-term planning. These include:

- Public awareness for improving hygiene and sanitation.
- Monitoring of commercial eating places to enforce quality standards and ensuring good supply of quality drinking water
- Imparting hygiene and sanitation education in schools
- Desilting drains to avoid water logging during rainy season
- Land use planning needs to take into consideration water logging issues during and after construction and development activities
- Coordinate with the railways and PWD to regularly fumigate railway yards and trains in train yards, particularly during rainy seasons
- The drinking water supply department to the city should test water system for adequate chlorination levels and for bacterial and viral counts
- Inspection across the City to identify potential mosquito breeding grounds and take necessary steps before and during rainy season

Climate change adaptation measures

- Land use and infrastructure development plans of the city need to take into consideration the short and long- term climate change trends
- Low-lying areas of city can be best protected from water logging by developing suitable drainage system. The storm water drainage system of the city need to be

[2] *GRIHA – green building ‘design evaluation system’– A tool to design, operate, evaluate and maintain resource efficient ‘healthy’ and ‘intelligent’ building (http://www.cccindia.co/corecentre/Database/Docs/DocFiles/rating_system.pdf)*

developed taking into consideration the flood scenarios and the rainfall variation trends based on climate change scenarios.

IT and database development measures

- The city Municipality and Bhubaneswar Development Authority has some GIS data of the city. ORSAC and OSDMA are other State agencies who have/are developing GIS data for the entire Odisha state. These agencies should develop the Utility network layers (electricity network, drinking water network, storm water network, sewerage network, and communication network) in GIS platform to help various decision makers to integrate DRR activities. There should be a central database, which is accessible to various departments through defined data sharing policies
- The city needs to have a mechanism to develop disease incidence data from both government and private hospitals. This can be done through an online module in the city portal where access can be given to users (government and private hospitals) to enter tested and positively identified cases at their institutions with their spatial locations. Similar to birth and death registry, registering disease incidence for identified diseases needs to be made mandatory.
- Health contingency planning should be based on disease incidence data
- Damage assessment reports need to follow the format developed and circulated by NDMA and need to be decentralized. In the case of the City, it should be at ward level. Mobile based applications can be developed for ward officials to make online entry of damage information.

Mainstreaming integrated DRR in city development planning

- The city master plan needs to consider hazard risks from various natural hazards and integrate mitigation measures in its vision document
- City, with the support of the political representatives, needs to enforce land use zoning and building codes based on hazard and risk maps
- Implement incentives and disincentives for climate proofing – tax subsidies for houses with climate proofing and disincentives like climate risk penalties for people encroaching hazard prone areas.
- Awareness of political representatives will help regulate community encroachment in hazard prone areas
- As a medium and long-term measure, the city should build a storm water drainage system for entire city to avoid urban flash floods/water-loggings.

Risk Atlas: The outcomes of the study are presented in graphic form in a Risk Atlas and provided as a separate document. The atlas is a compilation of all the base and analytical maps generated as part of this study. The risk atlas is presented at ward level, which would help in understanding the spatial distribution of hazards, exposure and risks.

Table of Contents

List of Figures

List of Tables

Abbreviations Used

AAL	Average Annual Loss
ADD	Acute Diarrheal Disorders
AR4	Fourth Assessment Report
BDA	Bhubaneswar Development Authority
BMC	Bhubaneswar Municipal Corporation
CDMP	City Disaster Management Plan
CDMP	Community Disaster Management Plan
DRR	Disaster Risk Reduction
DM	Disaster Management
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EP	Exceedance Probability
EWS	Early warning System
GAA	Gopabandhu Academy of Administration
GIS	Geographic Information Systems
GOI	Government of India
HRVA	Hazard Risk Vulnerability Assessment
INR	Indian Rupees
IPCC	The Intergovernmental Panel on Climate Change
IRS	Incidence Response System
km	Kilometer
LEC	Loss Exceedance Curve
LISS	Linear Imaging Self-Scanner
MDR	Mean Damage Ratio
MHA	Ministry of Home Affairs
mm	Millimeter
NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NGOs	Non Government Organization
NHAI	National Highways Authority of India
NIDM	National Institute of Disaster Management
NRHM	National Rural Health Mission
ODRAF	Odisha Disaster Rapid Action Force
OSDMA	Odisha State Disaster Management Authority
PML	Probable Maximum Loss
PPP	Public- Private- Partnership
PWD	Public Works Department
RCC	Reinforced Cement Concrete
RCF	Reinforced Concrete Frame
SC/ ST	Scheduled Caste/ Scheduled Tribe
SIRD	State Institute for Rural Development

SOP	Standard Operation Procedures
UN	United Nations
UNDP	United Nations Development Programme
WHO	World Health Organization

1 Background

India has experienced exponential urban growth in the last few decades with more than 70% of its urban population residing in Class-I cities. As per 2011 Census, there are 468 Class-I cities compared to 399 such cities in 2001. Fast growth in these urban centers also leads to increased exposure of the urban population and infrastructure to natural hazards. The impact of climate change has accentuated the risk of urban centers to natural hazards, particularly, the hazards related to hydro-meteorological phenomena.

Bhubaneswar, the capital city of Odisha, has a population of about 8,40,834 with a population density of 6,228 per sq km (Census, 2011). The city is experiencing very high growth both in terms of urban built as well as population. The city is exposed to various key hazards- cyclonic winds, floods, earthquakes, heat waves, and epidemics. As per the Bureau of Indian Standards (BIS) code IS:1893 (2002) and BMTPC Atlas (2006), the city is located in the seismic zone III that is a moderate earthquake risk zone class.

In addition, to support and be part of the State Disaster Risk Reduction (DRR) activities, the city administration is active in developing measures towards a climate risk resilient urban center. The city is part of the UNISDR global campaign of “The Making Cities Resilient Campaign” and is Recipient of “SASAKAWA Recognition 2011” and Role Model for Community Preparedness.

The city has taken several proactive steps towards climate change adaption, in particular to the power, roads, and drainage infrastructure development activities. The new building byelaws are in place with design safety norms (BDA, 2008). Development plans also look into the risk zones of the city while considering any new development projects.

Bhubaneswar City has been selected as one of the eight cities in India for implementing the Climate Risk Management Project on a pilot basis under the framework of the Urban Disaster Risk Reduction project of GOI-UNDP.

The ongoing Government of India (GOI)-UNDP Disaster Risk Reduction (DRR) program aims to strengthen the capacities of government, communities and institutional structures by undertaking DRR activities at various levels and develop preparedness for recovery. Under this program, eight cities (including Bhubaneswar) prone to multi-hazards in the country were identified, and selected for detailed hazard vulnerability and risk assessment studies.

These studies will support the local administration and the community to develop risk resilience through understanding of hazards, vulnerability and risk and integrate appropriate mitigation and management practices to protect the community and its assets. The project emphasizes a participatory approach for developing the capacity of the cities in integrating Climate Change Adaptation (CCA) and DRR concerns at city level plans.

The main objective of the proposed multi-hazard risk and vulnerability analysis assignment is to assess the extent of risk and the vulnerabilities of Bhubaneswar city particularly to climate related hazards. The outcome of the exercise is expected to help identify a set of structural and non-structural steps that UNDP, City Administration and other stakeholders can take to mitigate the risks posed by various hazards. It also aims to consider the future climate change scenarios such that the development activities accommodate this understanding to reduce the impact in the medium and long- terms.

The present study provide quantified hazard, vulnerability and risk of prominent hazards prevalent in the city; development of short, medium and long term mitigation strategies for DRR in the city and develop capacity of city stakeholders in mainstreaming DRR activities in the city development activities.

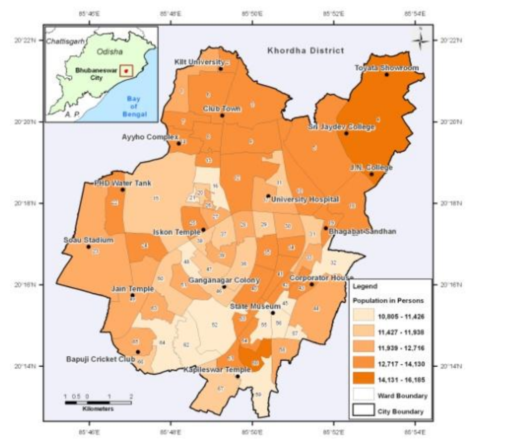
1.1 Scope of the Assignment

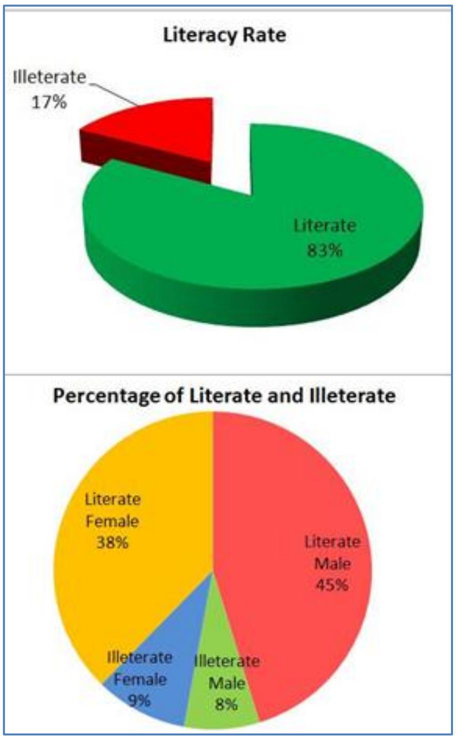
The study has various components as detailed below:

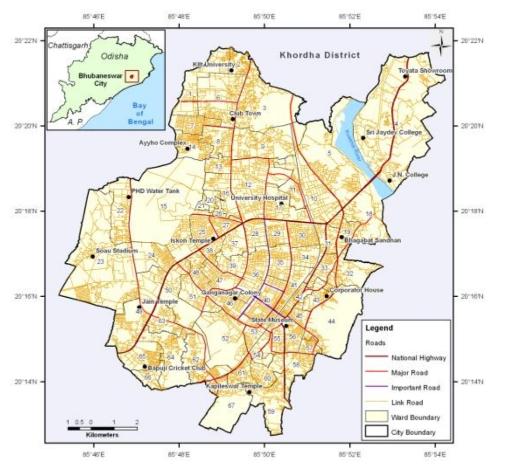
1. Component 1: Multi-Hazard Mapping and Analysis
2. Component 2: Development of Exposure Database at City level with resolution of ward level
3. Component 3: Vulnerability Assessment (Physical, Economic, Social and Environment)
4. Component 4: Risk Assessment
5. Component 5: Capacity Assessment at community, ward and city levels
6. Component 6: Recommended Actions that can be taken to mitigate multi-hazard related risks through City level Disaster Management Plan, sectoral planning and implementation of projects/initiatives at community, ward and city levels

1.2 Bhubaneswar City Profile

Bhubaneswar, the capital of Odisha, is also popularly known as the "Temple City of India".	
Area	135 sq km
Number of wards	67
Socio economic profile	
Population	840,834 (Census, 2011)
Population density	6,228 person/ sq km (Census, 2011)
Key economic activity	Industry, Tourism, Trade and Commerce
No. of households	1,97,661
Literacy rate	83%
Slum details	
Authorized slums 116	Un-Authorized slums 320
Slum Population 3.01 Lakhs	No. of slum households 80,630
Weather characteristics	
Average annual rainfall: 1,542 mm	
Mean Annual Minimum Temperature	27^0 C
Mean Annual Maximum Temperature	32^0 C
Rainy seasons	June-Oct
Mean Annual Humidity	70%
Infrastructure	
Road length	1,642 km
Railway (length)	33.8 km
Industries	1,794 (2011)
Hospitals	667 (2011)
Educational institutions	1,171 (2011)







* Source: Bhubaneswar Municipal Corporation, Census of India, http://www.odisha.gov.in/

2 Multi Hazard Mapping and Analysis

2.1 Cyclonic Wind Hazard

Tropical cyclones are large atmospheric vortices, which form over the tropical warm oceans. A severe cyclone can extend horizontally from 150 km to 1,200 km with fierce winds spiraling around a central low-pressure area. An intense cyclone carries a belt of strong winds and heavy rain clouds, which could cause destruction when the cyclone crosses the coast and makes landfall.

Hazards associated with tropical cyclones are long duration rotatory high velocity winds, which could cause massive damage not only limited to coastal regions but also to areas within about 100 km from the coast. In view of this, Bhubaneswar, one of the cities of Khordha district and located about 45 km from the coast, commonly experiences significant losses to property and infrastructure due to severe cyclonic storms. The wind speed of various categories of cyclonic disturbances provided by India Meteorological Department (IMD), are given in Table 2-1.

Table 2-1: India Meteorological Department cyclone classification by sustained wind speed

Sl. No.	Storm category (Intensity)	Abb.	Wind speed (knots)	Wind speed (kmph)
1.	Low Pressure Area	LPA	<17	<31
2.	Depression	D	17-27	31-49
3.	Deep Depression	DD	28-33	50-61
4.	Cyclonic Storm	CS	34-47	62-88
5.	Severe Cyclonic Storm	SCS	48-63	89-118
6.	Very Severe Cyclonic Storm	VSCS	64-119	119-221
7.	Super Cyclone	SC	>120	>222

The cyclone hazard assessment evaluates the frequency and severity of various cyclonic events at different recurrence intervals or return periods ranging from more frequent to rare events, based on a historical cyclonic database. The city of Bhubaneswar, due to its geographical position, has limited exposure to Very Severe Cyclonic Storms and Super cyclones. However, various storms of different intensities affected the city, especially those that made landfall in neighboring districts such as Ganjam, Puri, Jagatsinghpur and Kendrapara. The 1999 Paradip cyclone was one of the most severe cyclones that caused extensive damage to property and loss of lives in the city. Therefore, a comprehensive modeling approach was adopted for cyclone hazard assessment of Bhubaneswar city for the computation of wind speeds associated with various extreme events.

2.1.1 Cyclone Hazard in City of Bhubaneswar

The tropical cyclones originate in the Bay of Bengal and affect the coastal region of Odisha during two seasons in a year: Pre-monsoon (April-May) and Post-monsoon (October-December). In addition, intense depressions during the monsoonal periods and especially during the southwest monsoon are also affecting the Odisha coast. The peak frequency is found to be in the months of July, August and September. In the 137-year period between 1877 and 2013, 110 tropical disturbances passed within 150 km of Bhubaneswar City that include 39 cyclonic events, an average of one cyclone in 3.5 years (Table 2-2). However, a majority of the cyclones have weak effects. Exceptions to this rule are found for severe cyclonic storms of November 1973, May 1982, very severe cyclonic storms of September 1888, November 1891, October 1912, September 1936, October 1967 and October 1999 super cyclone. In the present study, historical tropical cyclones that passed the region surrounding the City of Bhubaneswar and presented in Table 2-2, were analyzed to determine the locations of high hazard incidence at ward-level.

Table 2-2: List of storm events used for the study (1877-2013)

Sl. No.	Day	Month	Year	Category/Grade
1	3	8	1878	Deep Depression
2	13	9	1878	Deep Depression
3	22	9	1879	Deep Depression
4	25	6	1880	Deep Depression
5	2	8	1881	Deep Depression
6	11	7	1882	Cyclonic Storm
7	15	7	1884	Deep Depression
8	14	7	1885	Deep Depression
9	19	9	1885	Cyclonic Storm
10	12	8	1886	Cyclonic Storm
11	13	9	1888	Very Severe Cyclonic Storm
12	18	6	1890	Deep Depression
13	1	7	1890	Deep Depression
14	10	10	1890	Deep Depression
15	1	11	1891	Very Severe Cyclonic Storm
16	7	9	1892	Cyclonic Storm
17	21	9	1893	Cyclonic Storm
18	11	7	1894	Cyclonic Storm
19	27	9	1894	Deep Depression
20	8	8	1899	Cyclonic Storm
21	27	8	1899	Deep Depression
22	11	6	1900	Cyclonic Storm
23	29	7	1900	Cyclonic Storm
24	4	10	1900	Deep Depression
25	12	7	1903	Cyclonic Storm
26	5	10	1903	Cyclonic Storm
27	1	8	1903	Deep Depression
28	7	9	1905	Deep Depression
29	30	6	1905	Cyclonic Storm
30	21	7	1906	Cyclonic Storm
31	28	8	1908	Cyclonic Storm
32	9	6	1911	Cyclonic Storm
33	28	8	1911	Deep Depression
34	1	8	1912	Cyclonic Storm
35	28	10	1912	Very Severe Cyclonic Storm
36	27	7	1912	Cyclonic Storm
37	16	7	1913	Cyclonic Storm

Sl. No.	Day	Month	Year	Category/Grade
38	13	8	1916	Deep Depression
39	5	9	1917	Deep Depression
40	1	10	1917	Deep Depression
41	28	7	1918	Deep Depression
42	1	7	1919	Deep Depression
43	24	8	1919	Deep Depression
44	20	6	1920	Deep Depression
45	21	7	1920	Deep Depression
46	15	7	1920	Depression
47	25	8	1920	Deep Depression
48	2	9	1921	Deep Depression
49	8	9	1922	Deep Depression
50	19	7	1923	Deep Depression
51	25	8	1924	Deep Depression
52	9	10	1924	Deep Depression
53	30	8	1925	Deep Depression
54	5	8	1926	Deep Depression
55	16	6	1927	Cyclonic Storm
56	11	8	1927	Deep Depression
57	1	10	1928	Cyclonic Storm
58	11	7	1929	Deep Depression
59	23	8	1929	Cyclonic Storm
60	28	6	1930	Cyclonic Storm
61	30	8	1931	Deep Depression
62	2	9	1932	Deep Depression
63	12	9	1933	Deep Depression
64	8	8	1933	Deep Depression
65	15	8	1934	Deep Depression
66	7	9	1935	Deep Depression
67	5	9	1936	Deep Depression
68	29	9	1936	Very Severe Cyclonic Storm
69	11	7	1937	Deep Depression
70	24	6	1940	Deep Depression
71	20	8	1940	Deep Depression
72	28	6	1941	Deep Depression
73	26	9	1942	Deep Depression
74	24	7	1943	Cyclonic Storm
75	9	7	1944	Deep Depression
76	18	8	1944	Cyclonic Storm
77	28	7	1944	Cyclonic Storm
78	28	9	1945	Depression
79	16	8	1946	Depression
80	11	8	1948	Cyclonic Storm
81	12	9	1949	Depression
82	23	7	1951	Cyclonic Storm

Sl. No.	Day	Month	Year	Category/Grade
83	1	9	1954	Depression
84	29	9	1955	Cyclonic Storm
85	18	8	1957	Cyclonic Storm
86	28	8	1958	Depression
87	27	6	1959	Cyclonic Storm
88	3	7	1959	Depression
89	29	6	1960	Depression
90	4	8	1964	Depression
91	16	7	1966	Depression
92	2	9	1966	Depression
93	30	7	1967	Depression
94	7	10	1967	Very Severe Cyclonic Storm
95	6	7	1973	Depression
96	3	11	1973	Severe Cyclonic Storm
97	26	9	1974	Cyclonic Storm
98	25	6	1975	Depression
99	9	9	1975	Depression
100	1	8	1976	Depression
101	30	5	1982	Severe Cyclonic Storm
102	20	8	1990	Depression
103	17	6	1992	Deep Depression
104	26	7	1992	Deep Depression
105	25	10	1999	Super Cyclonic Storm
106	12	6	2001	Depression
107	2	7	2006	Deep Depression
108	2	8	2006	Deep Depression
109	28	6	2007	Deep Depression
110	8	5	2007	Deep Depression

The data of past cyclonic disasters was collected from India Meteorological Department (IMD) reports, SAARC Meteorological Research Centre (SMRC, 1998), and from several research publications and is presented in Table 2-3. These events affected Bhubaneswar City in the last 137 years and resulted in loss of lives and property. Based on an analysis of historical data, Bhubaneswar City witnessed several storms ranging from Tropical Depressions (31 – 61 km/hr) to very strong storms (88-167 km/hr). The storm tracks of past events from 1877 to 2013 are depicted in Figure 2-1.

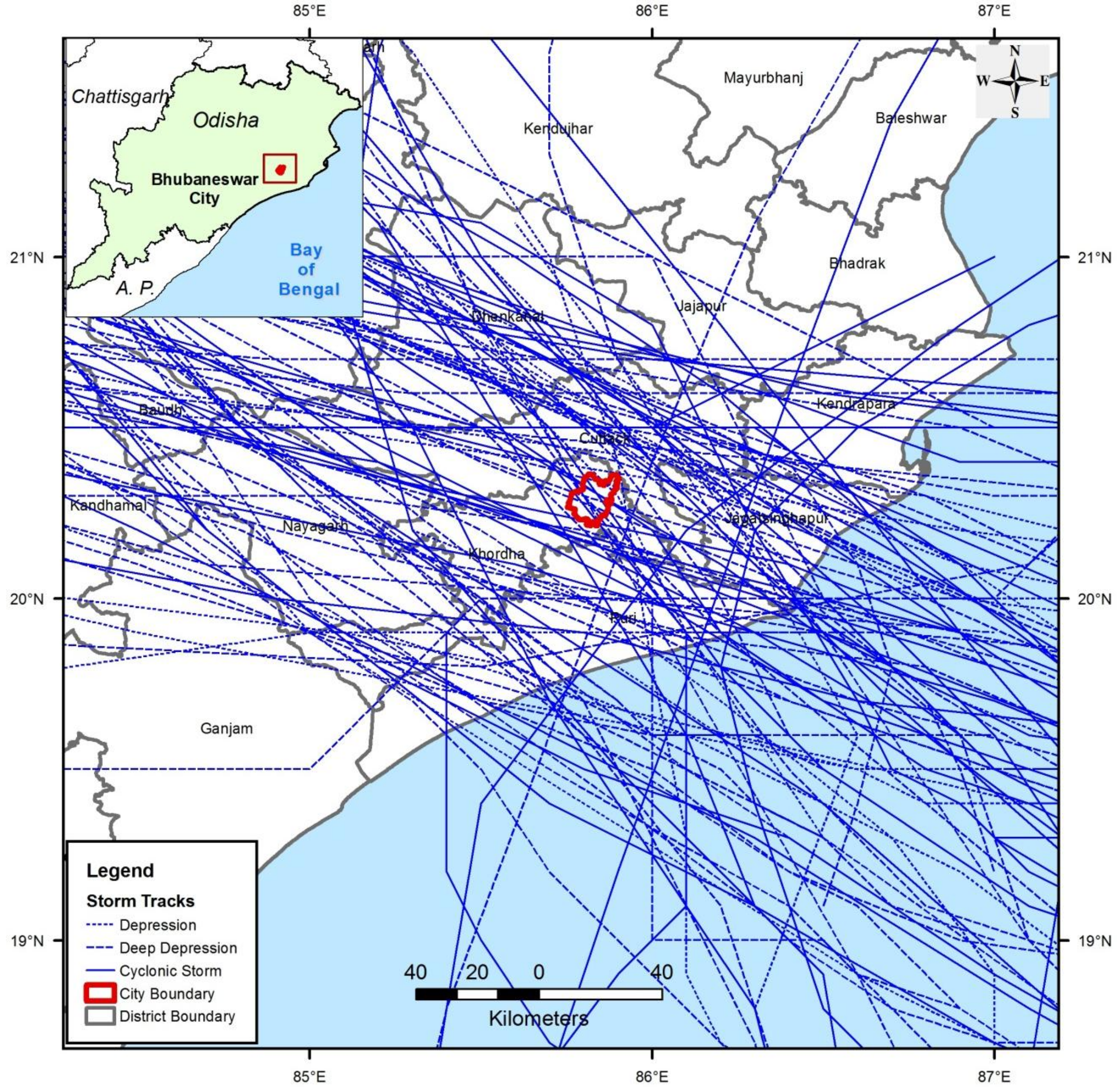


Figure 2-1: Storm tracks of past events from year 1877 – 2013 (Source: IMD and JTWC)

Table 2-3: List of notable cyclones, areas affected and lives lost (SMRC 1998 & IMD)

S No.	Date	Description of the meteorological event
1	September 7-14, 1971	Crossed South Odisha coast and adjoining North Andhra coast on September 10 and moved up to eastern Delhi. 90 People died and 8,000 Cattle heads perished. This system caused considerable damage to crops, houses, telecommunications and other property in the coastal districts of Odisha. viz., Ganjam, Puri, and Cuttack.
2	September 20-25. 1971	Crossed South Odisha coast near Gopalpur on September 22. Caused considerable damage to crops and houses due to flood and heavy rain at Vamsadhura village in Srikakulum and Koraput districts.
3	October 26-30,1971	Crossed Odisha coast near Paradip early in the morning of October 30. Maximum wind speed recorded was 150-170 kmph .Lowest Pressure recorded 966 hPa near the center of the storm. 10,000 People died and more than one million people were rendered homeless. 50,000 Cattle heads perished and 8,00,000 houses were damaged.
4	September 20-25, 1972	Crossed extreme South Odisha coast near Gopalpur on the afternoon of 22nd and weakened into a depression by the morning of the 23rd.

S No.	Date	Description of the meteorological event
		Max. wind recorded in gust was 136 kmph at Gopalpur at about 07:40 UTC on 22nd. Caused damage to crops & houses but no loss of life was reported.
5	November 3-9, 1973	Crossed Odisha coast close to and north of Paradip on the early morning of 9th. It weakened rapidly and lay as a trough over Odisha the same day. Maximum wind reported was 100 kmph at Paradip and Chandbali experienced surface winds of 100 kmph .This cyclone caused some damage to standing crops in the coastal districts of Odisha between Paradip and Chandbali.
6	September,24-28. 1981	Crossed Odisha coast near Puri on the early morning of September 26, weakened into a depression on that evening over interior Odisha, and adjoining East Madhya Pradesh. 5 Launches were lost in the Bay and many houses were damaged in Midnapur district of West Bengal and Cuttack district of Odisha.
7	May 31 to June 5th 1982	Crossed on 3rd June near Paradip, Odisha. As a result of high tides damage caused all along this coastal stretch. This cyclone caused heavy damage in the coastal districts of Puri, Cuttack and Balasore.
8	October 9-14.1984	Crossed North Odisha coast near Chandbali in the forenoon of 14^{th}. This system caused some damage in Cuttack and Balasore districts of Odisha and Midnapore district of West Bengal
9	17-21 Sept. 1985	Crossed on 20th Sept. close to Puri .For three consecutive days, due to 1.5 m sea-wave, Puri coast was inundation.
10	13-17 Oct. 1985	Crossed near Balasore on 16th Oct. High tidal crossed near Balasore on16th October. High tidal wave of about 16' to 18' was observed.
12	23-27 May 1989	Crossed 40 km northeast of Balasore. 61 persons died in Odisha and West Bengal.
13	26-27 Oct 1909	Ganjam district was severely affected. Puri and Balasore were less affected with violent winds and had lower rainfall. 22 humans and many cattle were killed. Damage ran into several lakhs of rupees. INR 15 lakhs damage was in Gopalpur alone.
14	13-18 Nov 1923	High floods occurred in the rivers in Ganjam district. Puri district was also affected. Immense destruction to communication services including railways. Considerable damage to crops. 20 humans and a few hundred cattle killed. A large number of public and private properties including irrigation works were damaged.
15	1-6 Oct 1906	Cyclonic storm crossed the coast north of Puri. Considerable damage to trees, roads, houses, even Pucca buildings in Puri.
16	15-16 Nov 1942	Less severe than the one on 16 October 1942. The cyclone was close to Odisha coast and weakened.

2.1.2 DATA AVAILABILITY AND SOURCES

The vulnerability of Bhubaneswar City due to cyclonic winds has been assessed by analyzing the past cyclone datasets. For this purpose, tropical cyclone track data for the period from 1877 to 2013 was obtained from IMD (tropical cyclone Atlas and other scientific reports and research papers from journals) and JTWC (NOAA). The other available sources like Unisys Hurricane Database (2013), SMRC (1998), and several research publications were also considered in preparing a master database of cyclonic tracks and their intensity information for Bhubaneswar City. The compiled master database of storm tracks was used for calculating the expected return period maps of cyclone wind hazard for Bhubaneswar City.

2.1.3 METHODOLOGY FOR CYCLONE HAZARD ASSESSMENT

Cyclonic wind hazard assessment identifies and demarcates areas, which are exposed to strong winds associated with tropical cyclones. It provides information on the extent and wind speed throughout cyclone prone areas for a range of wind magnitudes. The cyclone hazard assessment framework adopted for this study is depicted in Figure 2-2.

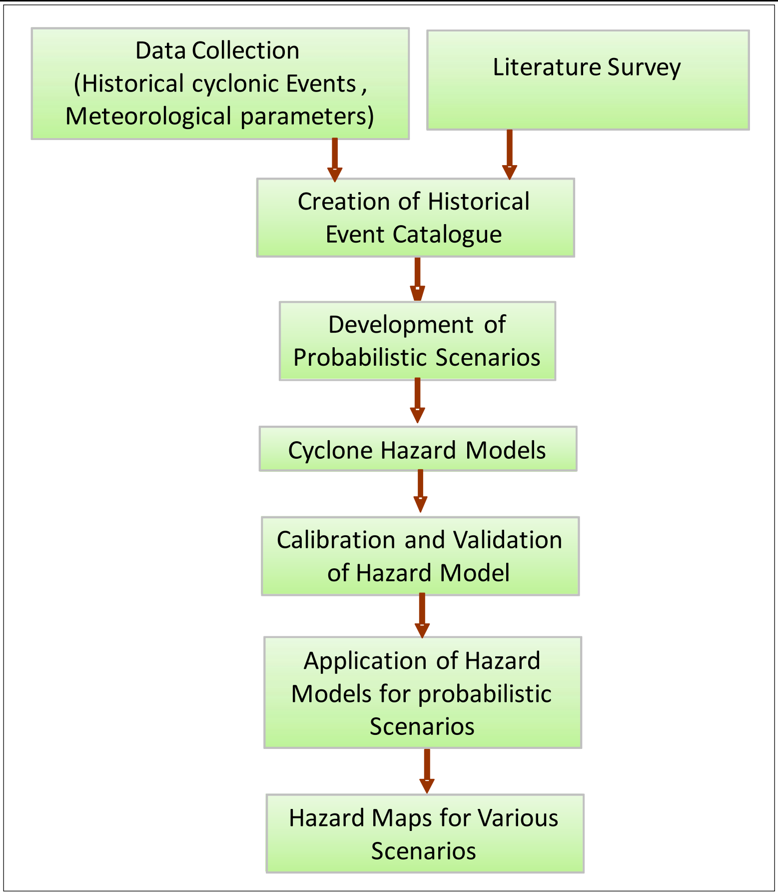


Figure 2-2: Flowchart showing approach for cyclone hazard assessment

From the generated database, frequencies, locations of landfall, and the maximum pressure deficit (ΔP) have been tabulated for each cyclone, and this input has been used to perform a suitable statistical analysis (Gumbel distribution) (Figure 2-3) to calculate maximum value of ΔP for key return periods. Climate change and other man-made changes add some degree of uncertainty beyond assessed projections of the model.

For the historical tracks, surface winds associated with a tropical cyclone have been derived from a dynamic storm model based on the formulation of Jelesnianski and Taylor (1973). Meteorological inputs used for this model include positions of the cyclone, pressure drop and radii of maximum winds at fixed intervals of time. The main component of the storm model is a trajectory model and a wind speed profile approximation scheme. The trajectory model represents a balance among pressure gradient, centrifugal, Coriolis, and surface frictional forces for a stationary storm. A variable pressure deficit, forward speed, and radius of maximum winds have been used in location specific storm model for computation of wind fields at model grid (250 m X 250 m) points. The storm strength is reduced after the cyclone crosses the coast. The above process has been repeated for each time-step along the track and the maximum wind at each location throughout the duration of the storm has been computed and retained for loss calculations. The maximum wind speed computed with the model has been calibrated/validated against observed data. Figure 2-4 explains the step-by-step approach adopted for cyclone hazard modeling. Finally, scenarios of maximum wind speed are prepared for all the key return periods (5, 10, 25, 50 100 years).

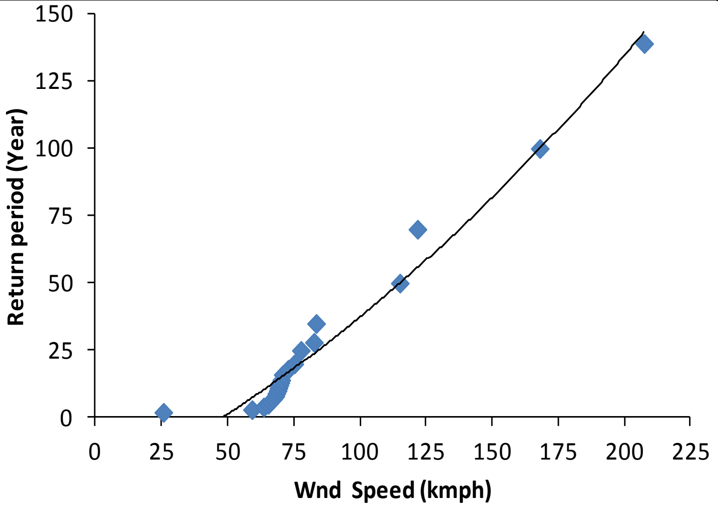


Figure 2-3: Average Wind Speed Vs Return Period based on Gumbel Distribution

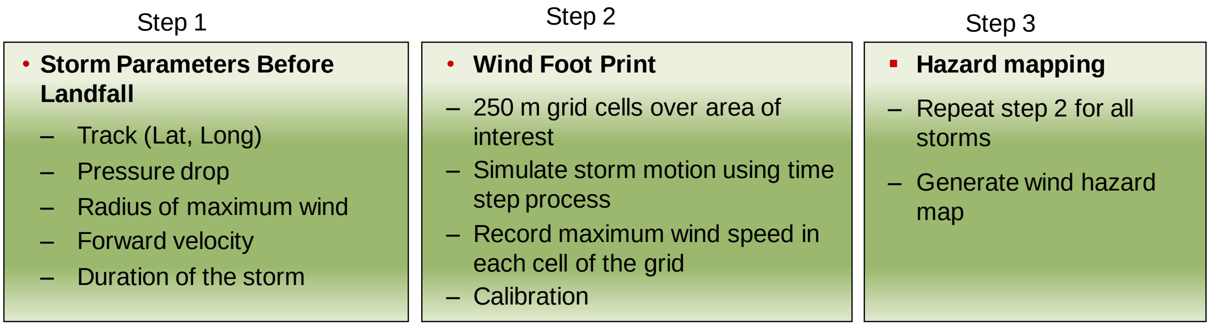


Figure 2-4 : Steps for cyclone hazard assessment

Results from this task will be used in arriving at location specific vulnerability and risk associated with cyclonic winds. Losses include physical damage due to wind. The output of the cyclone hazard analysis provides for spatial description of winds involving various GIS themes at ward level.

2.1.4 GIS Mapping and Analysis of Cyclonic Wind hazard

As mentioned above, the maximum wind speed at 250 m x 250 m grid resolution at ward level for key return periods is determined with the help of 2-D dynamical storm model. Wind hazard extent maps are prepared by integrating model results with various GIS themes to produce maps with varying wind magnitudes and are depicted in different colors. The wind hazard maps show the wind extent and wind magnitude for various return periods. The highest return period indicates the worst-case of wind hazard. Each of the wind hazard maps contain ward boundaries, city boundary, and wind extent and wind magnitudes. Ward boundaries have been labeled with ward numbers, which have been used for the study. The cyclone wind hazard maps for 5-year return period and 100-year return period are shown in Figure 2-5 and Figure 2-6, respectively. Wind hazard maps for other return periods are given in Annexure 1: Hazard Maps .

The colors designated for the specific wind speed ranges are shown in the legend of each map. The wind speeds shown with orange color indicate higher wind speed and light yellow indicates lower wind speeds. The cyclone hazard maps for different return period events are overlaid with the ward boundaries for analyzing detailed susceptibility in specific regions.

From the maps, it can be seen that for lower return periods (5 to 50 years) lower wind speed extents are limited to areas over the western wards whereas the relatively higher wind speeds cover a large extent of the eastern part of Bhubaneswar. However, in the case of 100-year return period, higher wind speeds cover a large extent of the western city and relatively lower wind speed extent is limited to the eastern side of city. As per IMD Guidelines, wind speeds associated with tropical depressions of 50-61 kmph may cause minor damage to loose and unsecured structures. Whereas, wind speeds associated with cyclonic storms (62- 87 kmph) or storms of higher categories, can cause extensive damage to thatched roofs and huts, minor damage to power and communication lines due to uprooting of large avenue trees, etc. In the higher return periods (more than 50 Years) under most severe scenario, wind magnitude and extent start increasing and cover many areas of the city.

These maps will help identify the high vulnerability zones for Bhubaneswar City. Assessment of cyclone risk and vulnerability at ward level will be useful to evolve a sustainable local level development action plan for preparedness and mitigation.

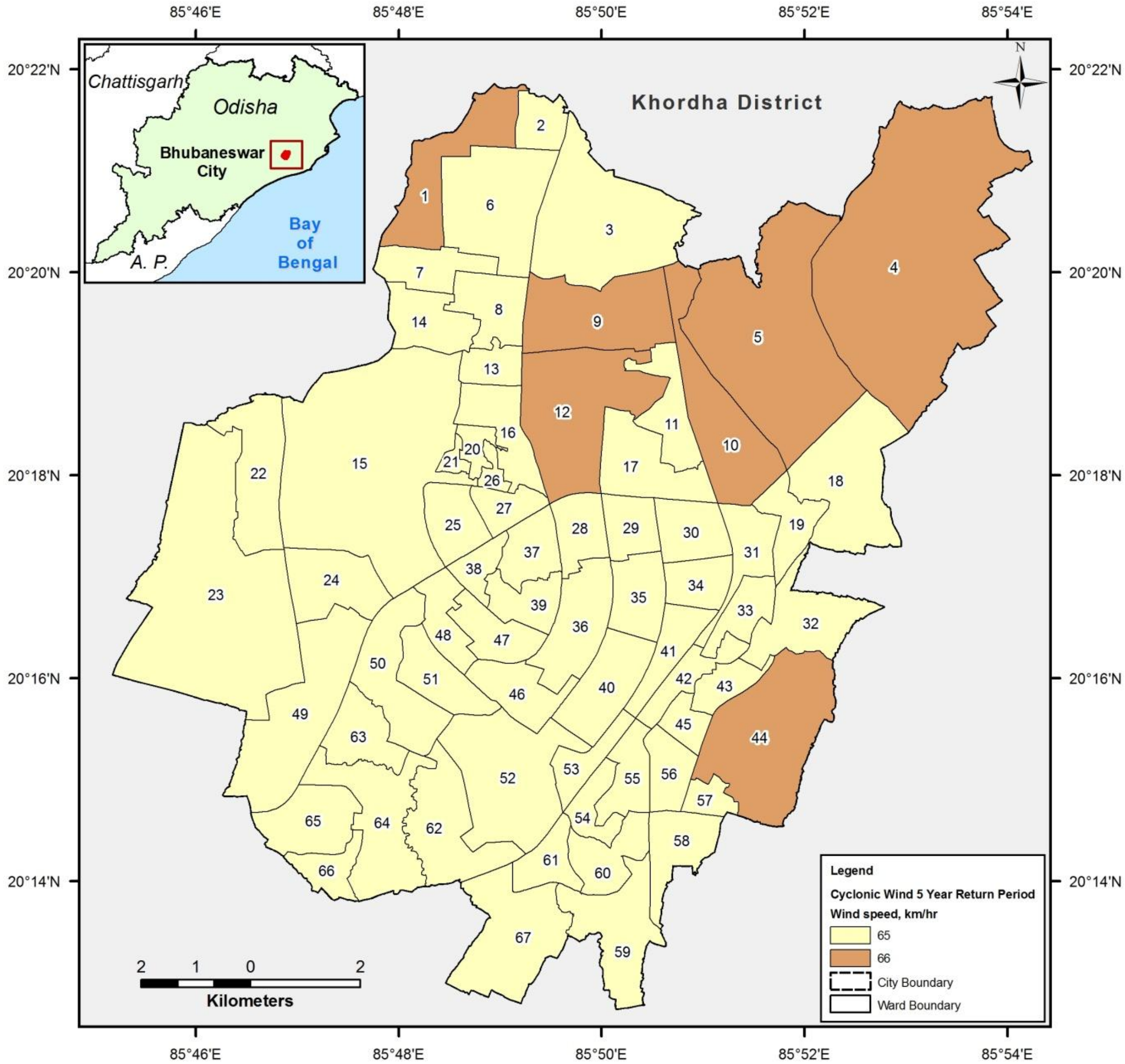


Figure 2-5: Cyclone hazard Map for 5-year return period

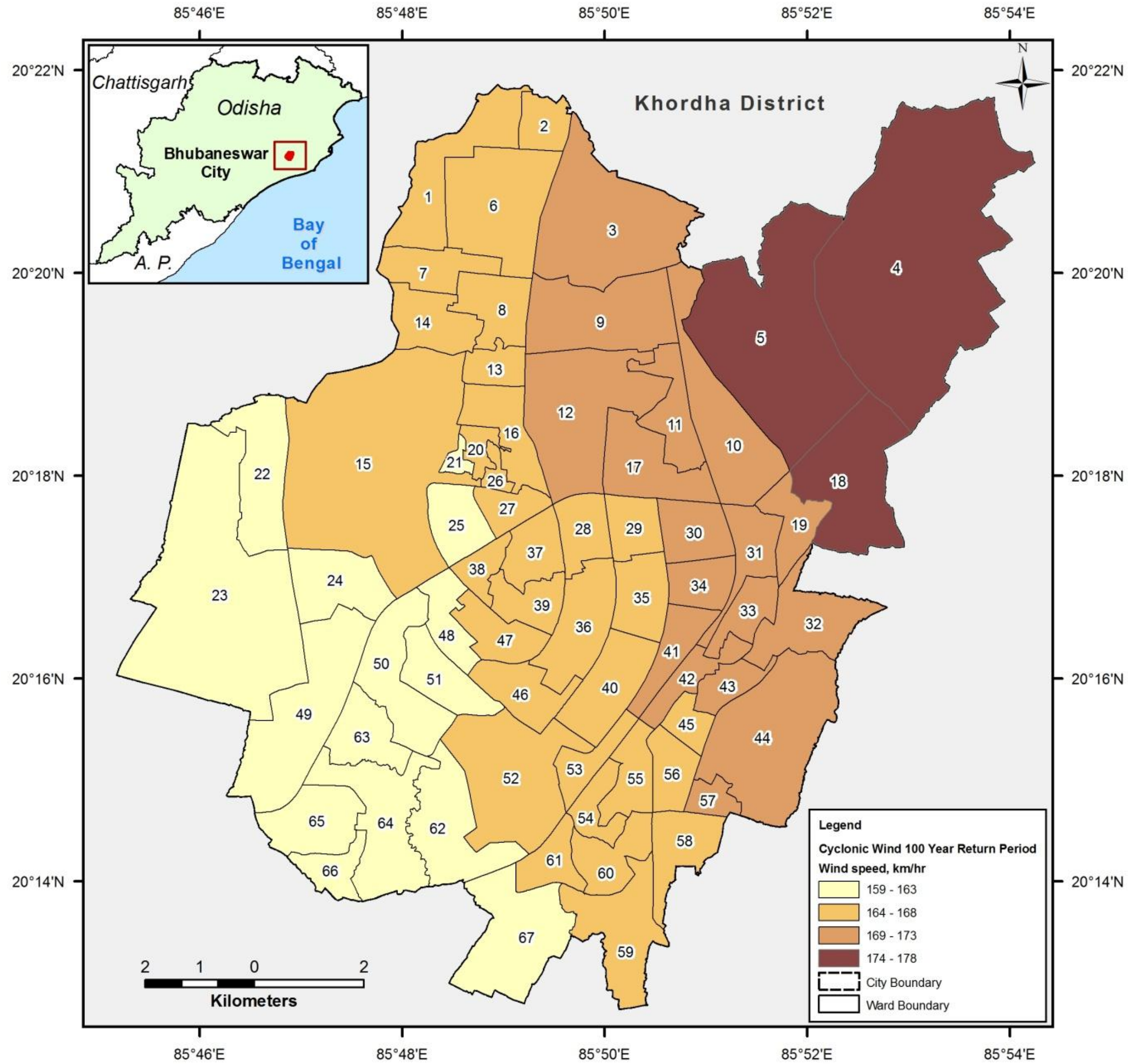


Figure 2-6: Cyclone hazard Map for 100-year return period

Analysis of cyclonic wind hazard shows average wind speed and associated extent of affected areas in various wards of the city. For analysis purpose, the five return period maps and area covered in various wards are worked out. While considering 50 and 100- year return periods, the entire city is prone to severe cyclonic storms (> 110 kmph). Ward-wise statistics are given Table 2-4.

Table 2-4: Ward-wise cyclonic wind hazard statistics

Ward No.	Average wind speed (kmph) for 5-Year Return Period	Average wind speed (kmph) for 10-Year Return Period	Average wind speed (kmph) for 25-Year Return Period	Average wind speed (kmph) for 50-Year Return Period	Average wind speed (kmph) for 100-Year Return Period
1	66	69	78	113	165
2	65	69	78	113	166
3	65	69	78	115	170
4	66	69	78	117	178
5	66	69	77	117	174
6	65	69	77	113	166
7	65	69	77	113	165
8	65	69	77	113	165
9	66	69	76	115	169
10	66	69	77	116	172
11	65	69	77	115	169
12	66	69	77	115	169
13	65	69	77	114	165
14	65	68	77	113	164
15	65	69	78	113	164
16	65	69	77	114	165
17	65	69	77	116	170
18	65	69	76	117	175
19	65	68	77	116	173
20	65	69	77	113	164
21	65	69	77	113	163
22	65	69	78	112	159
23	65	70	78	112	159
24	65	69	78	113	161
25	65	69	78	113	163
26	65	69	77	114	164
27	65	69	77	114	165
28	65	68	77	115	167
29	65	68	77	115	168
30	65	68	77	116	170
31	65	68	77	116	171
32	65	68	77	117	173
33	65	68	77	116	171
34	65	68	77	116	170
35	65	68	77	115	168
36	65	69	78	115	166
37	65	69	78	114	165
38	65	69	78	114	164
39	65	69	78	114	165
40	65	69	78	115	167
41	65	69	78	116	169
42	65	69	78	116	170

Ward No.	Average wind speed (kmph) for 5-Year Return Period	Average wind speed (kmph) for 10-Year Return Period	Average wind speed (kmph) for 25-Year Return Period	Average wind speed (kmph) for 50-Year Return Period	Average wind speed (kmph) for 100-Year Return Period
43	65	68	77	116	170
44	66	69	78	117	172
45	65	68	78	116	168
46	65	69	78	115	165
47	65	69	78	114	164
48	65	69	78	114	162
49	65	70	78	112	160
50	65	69	78	113	162
51	65	69	78	114	163
52	65	69	78	115	165
53	65	69	78	115	166
54	65	69	78	115	165
55	65	69	78	115	167
56	65	69	78	116	168
57	65	69	78	116	169
58	65	69	78	116	168
59	65	69	78	115	166
60	65	69	78	115	166
61	65	69	78	115	164
62	65	69	78	114	162
63	65	69	78	113	160
64	65	69	78	113	161
65	65	69	78	113	159
66	65	69	78	113	159
67	65	70	79	115	163

2.1.5 Application of Cyclonic Wind Hazard Maps in Disaster Management and City Planning

Cyclonic wind hazard maps have been developed at ward scale for Bhubaneswar city. Cyclonic wind affected areas have been delineated at ward level based on the return period of past events. These cyclonic wind hazard maps are developed for several purposes, such as:

- Cyclonic wind hazard maps will help the policymakers and decision makers to understand the severity of potential storms and allow them to take necessary action to ensure sustainable development by introducing necessary programs and measures.
- All the map results would be useful for the planning and design department to make decisions. These maps would provide a basis for the government for storm prediction and estimation of damage due to cyclonic winds.
- Most important sectors like education, health, housing, lifelines and transportation need special attention for storm safety. The cyclonic windstorm zones will provide fair understanding about expected performance of structures during cyclonic windstorms and necessary measures to protect the structures.
- The zones will further help the local urban government to introduce and enforce building byelaws and building codes to protect the urban infrastructure.

- These maps will also be helpful to national and international NGOs to prioritize disaster risk reduction strategies.
- The cyclonic wind hazard assessment maps will help policy makers, planners, decision makers, and related actors to better plan and implement an effective system related to storm hazard management. However, to get a clear and more detailed picture of the cyclonic wind hazard assessment in Bhubaneswar, it is recommended to integrate and utilize the networking system of storm monitoring and observations, which include the neighboring districts of Bhubaneswar.

2.2 Flood Hazard Assessment

The flood hazard assessment evaluates the frequency and severity of various flood events at different recurrence intervals or return periods ranging from more frequent to rare events, based on hydrological and physical information. Due to various flood control measures in upstream areas, overall flood risk for city of Bhubaneswar is very low. In fact, flood resilience of the city area was one of the driving factors for shifting the capital from Cuttack. Continuous heavy rainfall during the monsoon season can cause water logging in some areas of the city. A comprehensive modeling approach has been adopted for examining the riverine flood hazard for city areas.

2.2.1 Hydrology of Floods

The city of Bhubaneswar is situated on one of the anabranch of river Mahanadi in its delta area. The Mahanadi River forms the northern boundary of the city. The Mahanadi basin extends over an area of 1,41,589 km^2, which is nearly 4.3% of the total geographical area of the country and drains across Chhattisgarh, Odisha, Bihar, and Maharashtra (Figure 2-7). About 46% of the drainage area of Mahanadi lies within Odisha State. The upper basin is saucer shaped and mostly lies in Chhattisgarh state. Complete Mahanadi river basin is almost circular in shape with a diameter of about 400 km and an exit passage of about 160 km length and 60 km breadth. Mahanadi River discharges into the Bay of Bengal in Odisha forming significantly larger delta area. The annual average rainfall in the basin is about 1,500 mm. The heavy rainfall received by the basin during the monsoon months is mostly caused by the monsoon depressions. The depressions often cause heavy to very heavy rainfall along and near their tracks. These depressions originate in the Bay of Bengal, cross the eastern coast of the country, and move further inland in a west to northwesterly direction. The mean annual rainfall over the entire basin is around 1,400 mm and more than 60% of it is contributed by the southwest monsoon season.

As described above floods due to overflow from Mahanadi River is a major cause of flooding in the entire Mahanadi Delta including Cuttack. This section examines the flood hazard for the city of Bhubaneswar.

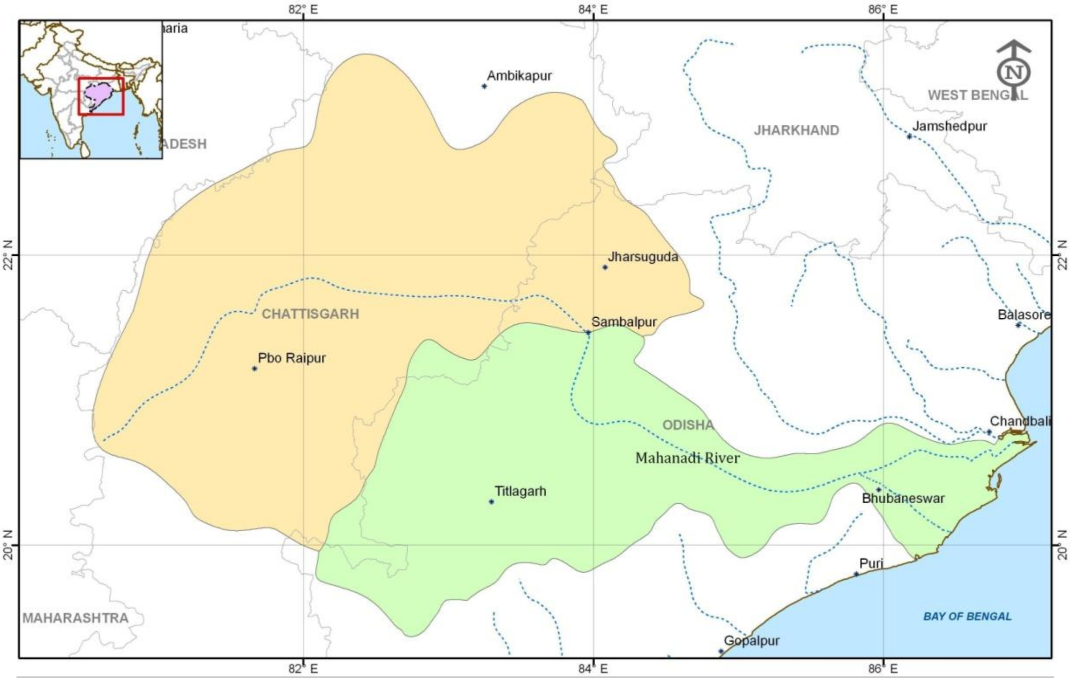


Figure 2-7: Basin Boundary Map of Mahanadi with Location of Bhubaneswar

Flood hazard assessment identifies and demarcates areas, which are exposed to floods. It provides information on the extent and depth of flooding throughout flood prone areas for a range of flood magnitudes. The flood hazard assessment framework adopted for this study is given in Figure 2-8, which comprises of the following:

- Identification, acquisition, compilation and review of all relevant hydro meteorological and biophysical data. These data includes terrain, soil, land use land cover, runoff/river discharge and flood protection measures to form the input for the model.
- Probabilistic analysis of runoff to simulate various return period events (from frequent to rare events) for flow gauge station upstream of the city.
- Hydraulic modeling to estimate flood levels throughout the flood plain areas in the city for various flows generated from key return period events
- Flood hazard mapping to show flood extent and flood depth for a range of events, which is the end result of hazard assessment.

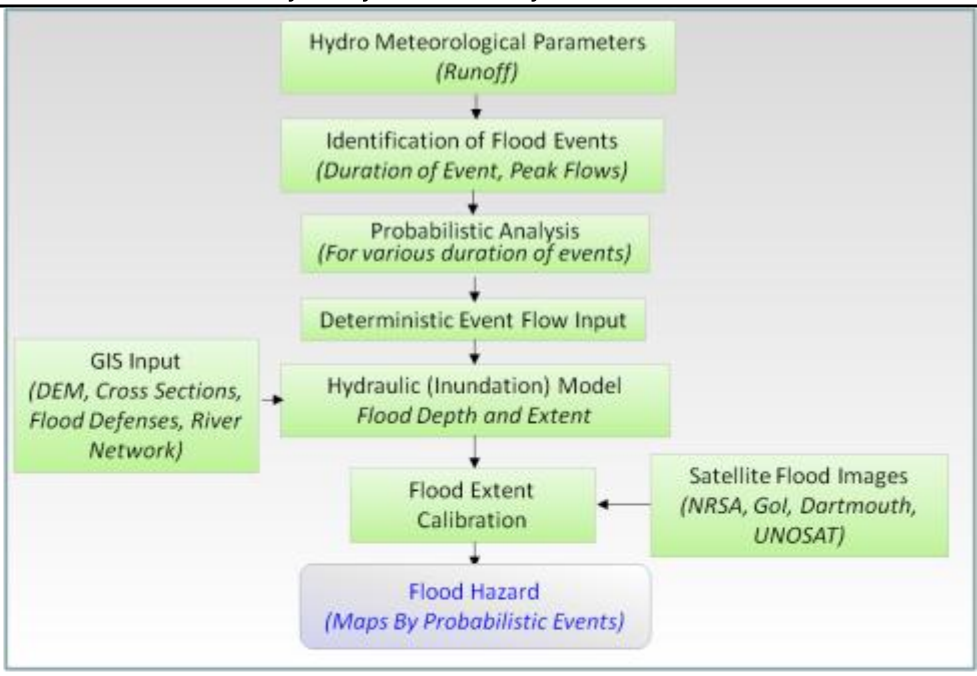


Figure 2-8: Flood hazard assessment framework

2.2.2 PROBABILISTIC SIMULATION OF RUNOFF

Probabilistic simulation is necessary due to non-availability of historical observations for long periods. Generally, historical observations are available for a relatively short period (say 20 to 50 years). Probabilistic simulation helps in generating events to capture extremes that might not have present in the available historical data sets. Probabilistic event sets have been generated using river discharge/runoff data at Tikarapara flow gauge station located upstream of the Mahanadi delta area. In the first step, daily flow data for Tikarapara flow gauge station have been collected from Central Water Commission (CWC). The annual maximum flows have been presented in Figure 2-9. The Probabilistic simulation for annual maximum flow discharge has been carried out after identifying the appropriate probability distribution. The linear moment technique (Hosking, 1990) has been used to determine the most appropriate distribution. Various L moment parameters (ratios) have been estimated using the annual maximum flows. Various flow discharges have been simulated using appropriate distribution for the long-term periods to capture extremes. The probabilistic flow discharge at key return periods (2, 5, 10, 25, 50, 100 years) have been estimated and are given in Figure 2-10. These sets of probabilistic event flows have been given as inputs to the hydraulic model for determining flood extents for each probabilistic event.

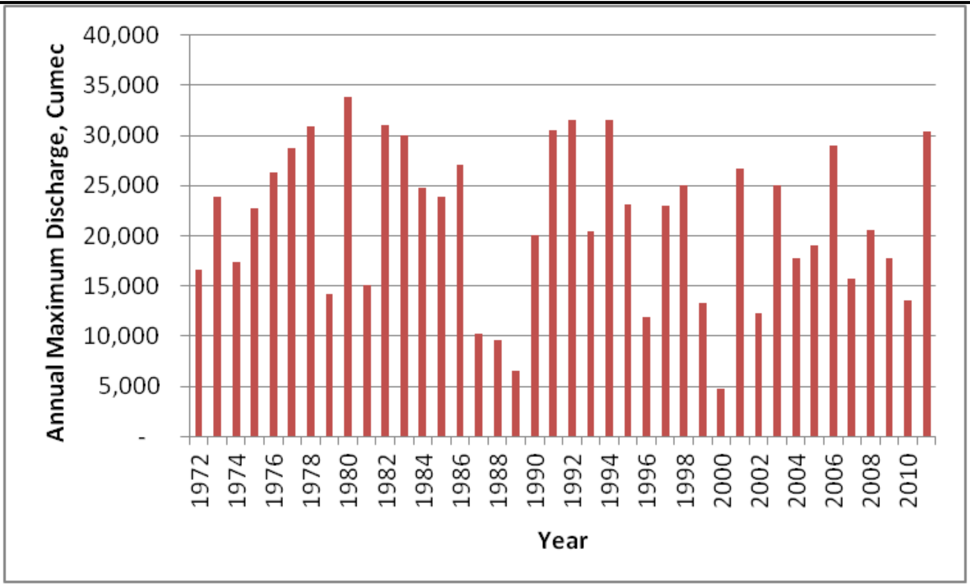


Figure 2-9: Annual Maximum Discharge for Tikarapara Flow Gauge Station

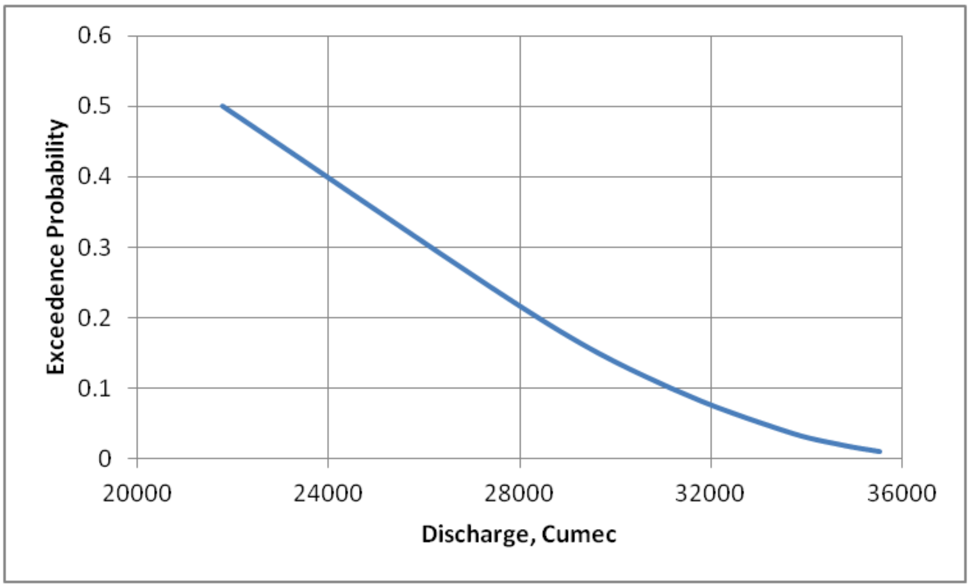


Figure 2-10: Simulated Return Period Discharges

2.2.3 Hydraulic Modeling (Inundation Model)

Flood flows estimated in the probabilistic analysis have been provided as an input to the hydraulic modeling. The hydraulic modeling calculates flood elevations along streams and rivers for flood flows of various return periods ranging from the most frequent to rare events. Flood elevations are then used to delineate the aerial extent of flooding adjacent to the streams and rivers. This technical effort serves to identify areas of flood inundation within the floodplain that are at risk and subject to flood damages.

Derivation of flood extent, flood depths and flood velocity have been determined using 1D hydraulic modeling through the river system for all return period events.1D model using HEC-RAS have been applied. In many applications of river flood modeling, a one-dimensional full hydrodynamic modeling system is used. In the riverine areas, water surface profiles for reaches have been determined using one-dimensional steady flow analysis using Hydrologic Engineering Centre's River Analysis System (HEC-RAS) software. HEC-RAS is an integrated system that contains one-dimensional hydraulic analysis components for steady and unsteady flow simulation for a full network of natural and constructed channels. The basic computational procedure is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) as also expansion and contraction losses. The momentum equation is utilized in situations where the water surface profile is rapidly varied. The situations include a mixed flow regime (USACE 2010). Basin geometric data consist of the river system connecting all segments, cross-section data, reach lengths, energy loss coefficients, and stream junction information. The river system schematic defines how the various river reaches are connected, as well as establishes the naming conventions for referencing all the other data. The connecting river reaches are important for the model to understand how the computations should proceed from one reach to the next. The river system schematic has been determined using HEC-Geo-RAS (an arc view extension for pre and post processing of RAS) in GIS environment using ESRI's Arcview. Estimated runoffs have been routed through the river system using one-dimensional hydraulic analysis to delineate flood extents and depth. Figure 2-11 shows the HEC RAS model developed for Delta area of river Mahanadi.

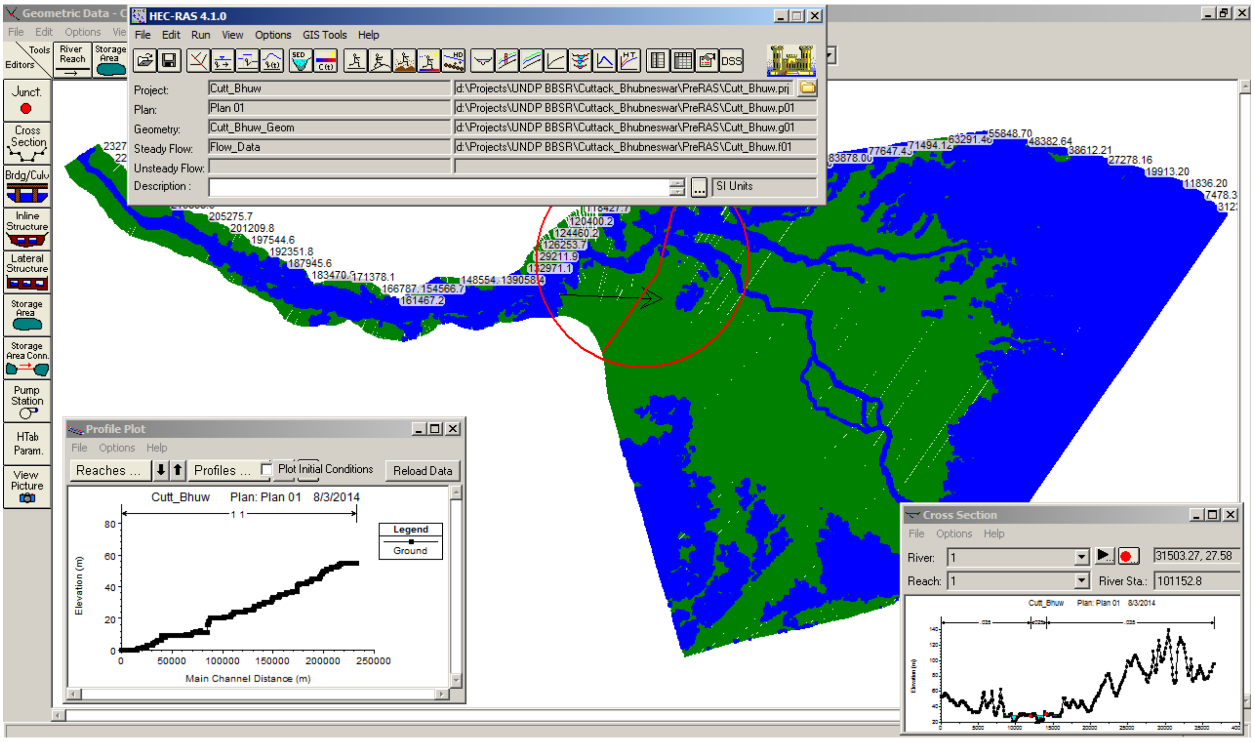


Figure 2-11: HEC RAS model for Mahanadi Delta

2.2.4 Mapping of Flood Extents

Based on the return period rainfall and corresponding flow values, the boundaries of the flood plains are determined using one-dimensional hydraulic modeling. Flood extent maps have been prepared by integrating model results with GIS data to produce a map with varying flood depths depicted in different colors. The flood hazard maps have been developed simulated flow discharges. The flood hazard maps show the flood extent and flood water depth for various return periods of 2, 5, 10, 25, 50 and 100 Years. In descriptive terms, highest return period indicates the worst case of flooding. Each of the flood hazard maps contains ward boundary, district boundary, river, flood extent and flood depths. Ward boundary has been labeled with ward number, which has been created for the study. The flood hazard map for 100-year return period is shown in Figure 2-12. The flood depths are shown in blue color ramp with dark blue indicating higher depth and light blue indicates the lower flood depths. From the maps it can be seen that the city of Bhubaneswar is least affected by riverine floods except a small portion in the south of the city in Ward Number 67.

Similar observations can be derived from the historical flood extent map of 2003 event. Flood extent map of 2006 event also showed similar trends.

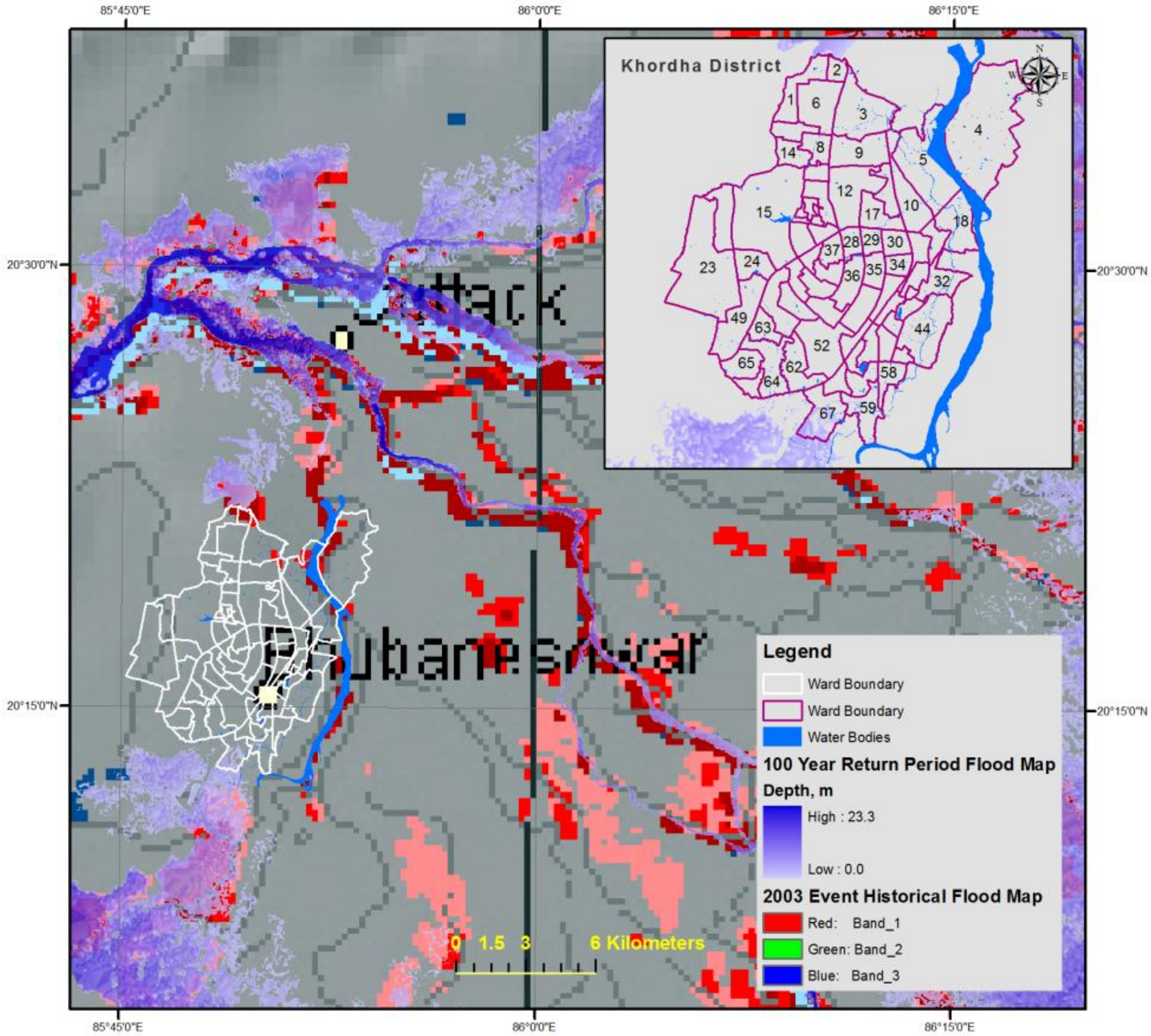


Figure 2-12: Flood Hazard Map for 100-year return period along with 2003 event flooding

2.2.5 ANALYSIS OF FLOOD HAZARD

The flood hazard maps show flood extent and flood depths. From simulated and observed flood extent maps it is evident that a majority of city areas are not prone to flood even in the most severe events.

2.2.6 LOCALIZED FLOODING/WATER LOGGING

Since the last couple of years, the city of Bhubaneswar has been experiencing localized flooding or water logging in some areas. Bhubaneswar has a system of natural drainage comprising of 10 drains. Due to rapid growth in infrastructure, encroachment, siltation, and dumping of debris, the natural carrying capacity of these drains has been reduced considerably. The reduced carrying capacity creates barriers to the natural flow of water during heavy rains.

The city has 10 major (primary) drains/nallas and several secondary and tertiary drains running along the roads. Many of the flood plains/open areas adjacent to these drains have been recently converted into residential areas – some are approved residential areas and some are encroached by city dwellers.

The wards reported to have water logging problems during the 2014 flood are shown in Figure 2-13.

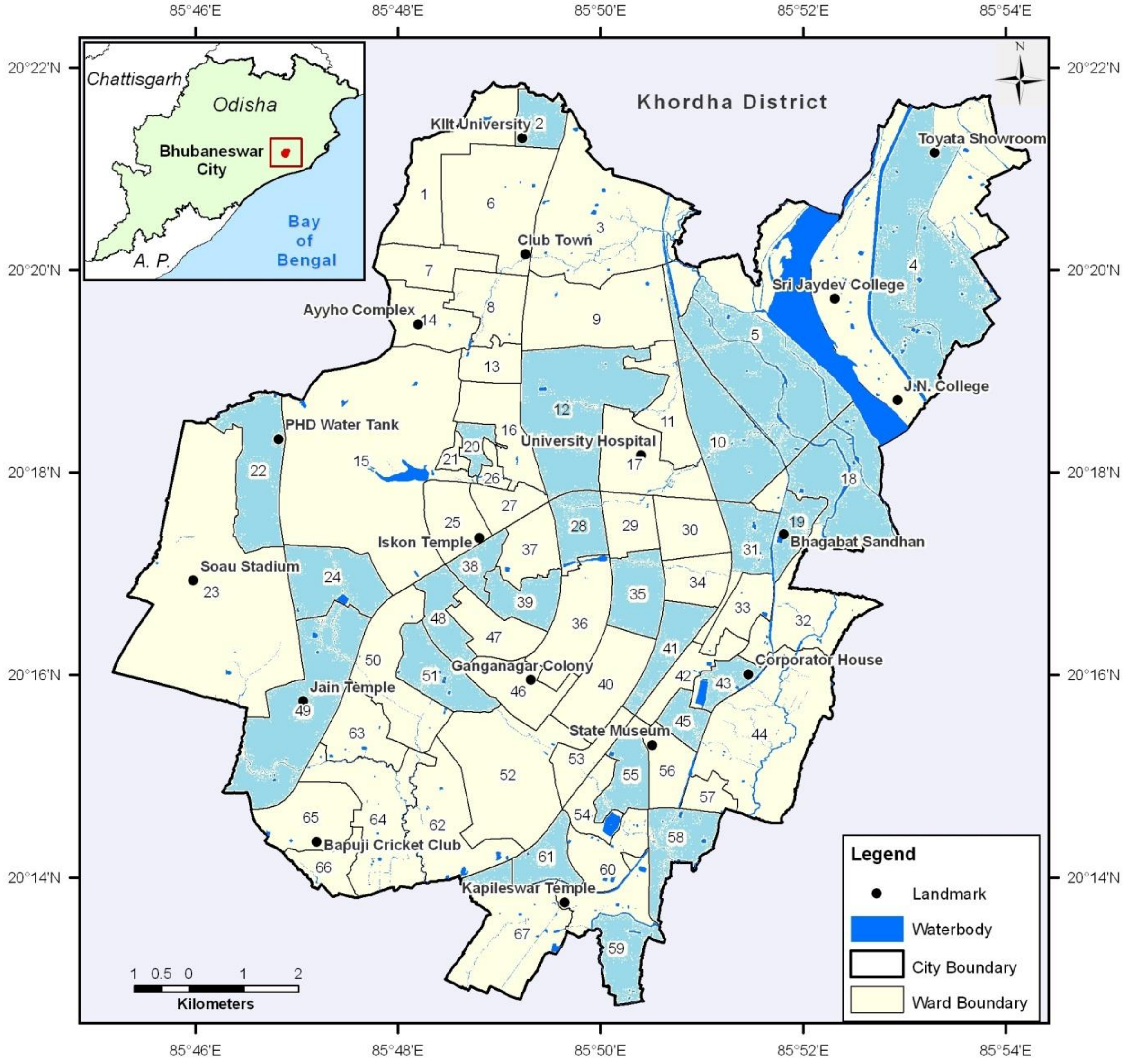


Figure 2-13: Wards reported waterlogging problems during the 2014

The areas such as Acharya Bihar, Jayadev Bihar, Chandrasekharpur, Rangamatia, Salia Sahi (Slum), GGP Colony, Dumuduma, Satya Nagar, Laxmisagar, Bamikhal, Old Town, Rasulgarh – Kalpana NH, Mancheswar, VSS Nagar, Sundarpada, Chakeisiani, Mainsikhala, Niladribihar, Sailashree Bihar, Patia, and Raghunathpur regularly experience localized flooding.

As outlined in the city development plan, a comprehensive drainage system may help in reducing the problems of localized flooding by utilizing the alignment of the existing drainage and natural drainage system. This may call upon a need for storm water management by prevention of encroachments, periodic maintenance, and land use regulations.

2.3 Earthquake Hazard

Bhubaneswar and surrounding regions lie in a Stable Continental Region (SCR) that is not seismically active. However, minor to moderate earthquakes have occurred now and then at different localities, which are not damaging in nature. In the recent past, the maximum magnitudes of these earthquakes have been reported around 4.5 to 5.3 on the Richter's scale and the maximum-recorded intensity in Bhubaneswar city so far is about VI on the MSK Intensity scale.

Seismic hazard assessment identifies and demarcates areas, which are exposed to different levels of earthquake ground motion. It provides information on the expected levels of peak ground motion that might be experienced in different parts of a city for a particular value of probability of exceedance by taking into account all the seismic sources in and around the city. Most of the seismic hazard assessment studies estimate the expected hazard at hard rock level. However, it is important to know that ground motion experienced by structures is not necessarily at hard rock level, and hence should be estimated at the surface level. Since, local soil also plays an important role in ground motion amplifications, especially when Vs30 (average shear–wave velocity up to a depth of 30 meter) values are much lower 760 meters/second. From the data analysis, it was observed that Vs30 values in Bhubaneswar city varies from about 200 m/sec to 550 m/sec. Hence, for proper estimation of seismic hazard, modeling of local soil amplification is important. The seismic hazard assessment approach for Bhubaneswar city comprises of the following:

- Seismotectonics of the study area
- Review of published probabilistic seismic hazard analyses for a key return periods and choose the hazard value(s) at hard rock level
- Model the soil-amplification on a finer grid cell of 0.1 km x 0.1 km using NEHRP (2007)/HAZUS-MH soil classification scheme
- Convolute the hazard value(s) at hard rock level with soil amplification factors, and generate earthquake hazard maps for 10% probability of exceedance (475 year return period)
- Compute the seismic hazard values at Uniform Resolution Grids (URG) at 0.1 km x 0.1 km for Bhubaneswar city
- Generate GIS based seismic hazard map at ward level

Seismic hazard mapping to show expected peak ground motion (Peak Ground Acceleration, PGA) for 10% probability of exceedance (475 year return period), which is the end result of hazard assessment.

2.3.1 SEISMOTECTONICS OF THE AREA AROUND BHUBANESWAR

In areas around Bhubaneswar, several faults have been identified in the region and some have shown evidence of movement during the Holocene epoch (SEISAT, 2000). The Brahmani Fault in the vicinity of Bonaigarh is one among them (SEISAT, 2000). The Mahanadi River also flows through a graben structure. As per Seismotectonic Atlas of India (SEISAT, 2000), several deep-seated faults are situated beneath the Mahanadi delta.

The Mahanadi and Brahmani graven, Mahanadi delta and parts of Balasore and Mayurbhanj districts come under earthquake risk zone –III (moderate damage risk zone) as per the earthquake risk zonation map prepared by Bureau of Indian Standards and published by Building Material Technology Promotion Council of India (BMTPC, 2006). As per Seismic Zoning Map of India (IS: 1893, 2002, 2014), Bhubaneswar city is located in Seismic Zone-III.

In spite of the moderate, non-damaging earthquakes observed so far in and near Bhubaneswar, it cannot be confidently said that higher intensity earthquakes are unlikely. Recently, on May 21, 2014 an earthquake of magnitude 6 occurred in the Bay of Bengal, which was severely felt in different parts of Bhubaneswar city. However, there was no report of any significant damage in the city. The following figure presents the Seismotectonic map of the areas in and around Bhubaneswar.

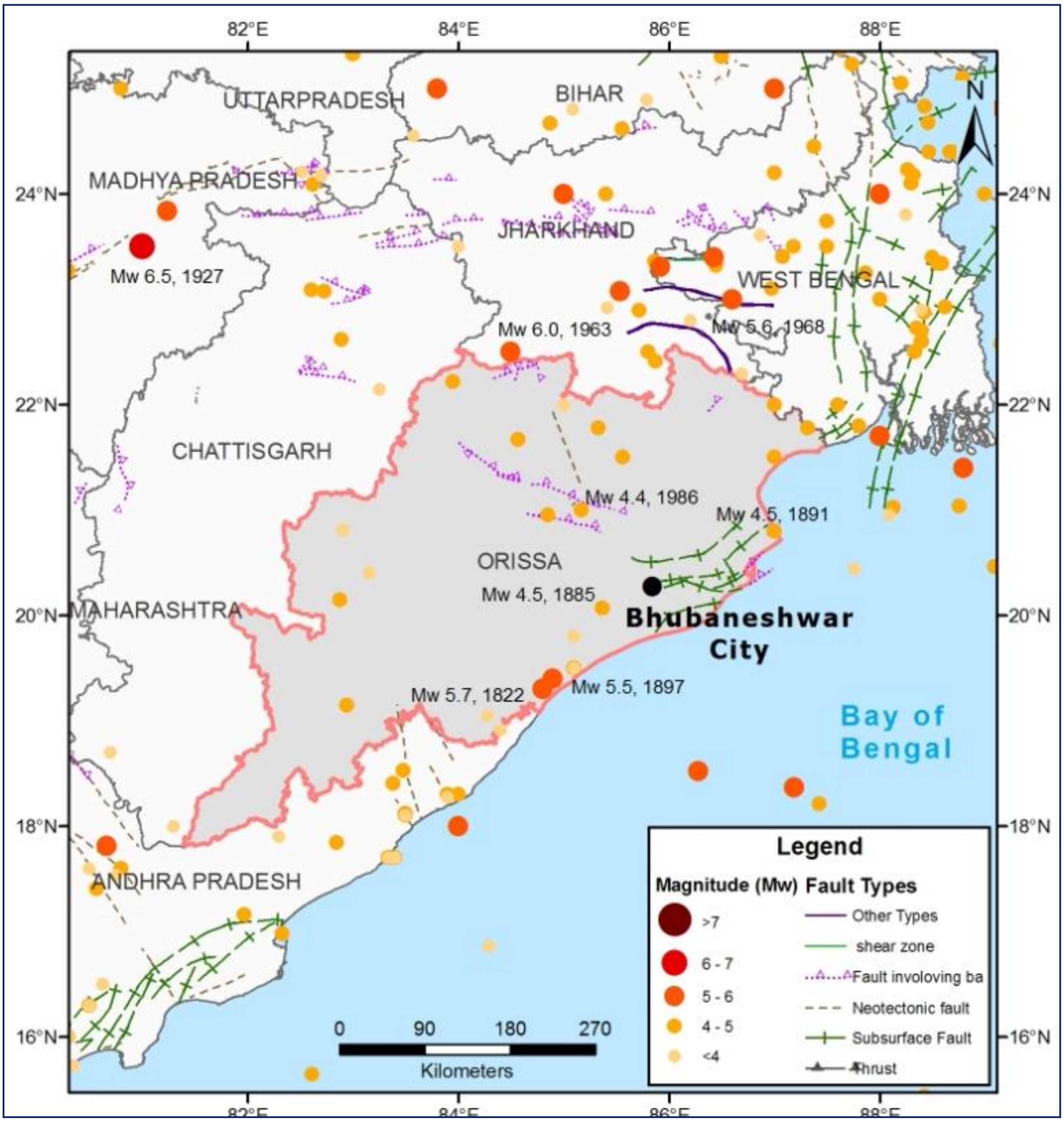


Figure 2-14: Seismotectonic map of areas around Bhubaneswar

2.3.2 SEISMIC HAZARD AT ROCK LEVEL

As per Seismic Zoning Map of India (IS: 1893, 2002, 2014; BMTPC, 2006), Bhubaneswar city lies in Seismic Zone-III, with a seismic zone factor of 0.16g, where a maximum intensity VII on MSK Intensity scale can be expected. The Global Seismic Hazard Analysis Program (GSHAP; www.seismo.ethz.ch/gshap/), provides probabilistic seismic hazard values in and near Bhubaneswar city ranging from 0.129 g to 0.13 g corresponding to 10% probability of exceedance in 50 years (475 years return period) at base rock level. This clearly indicates that PGA values are almost same for the entire city, while, in reality, different parts experience different levels of ground motion due to local soil condition effects.

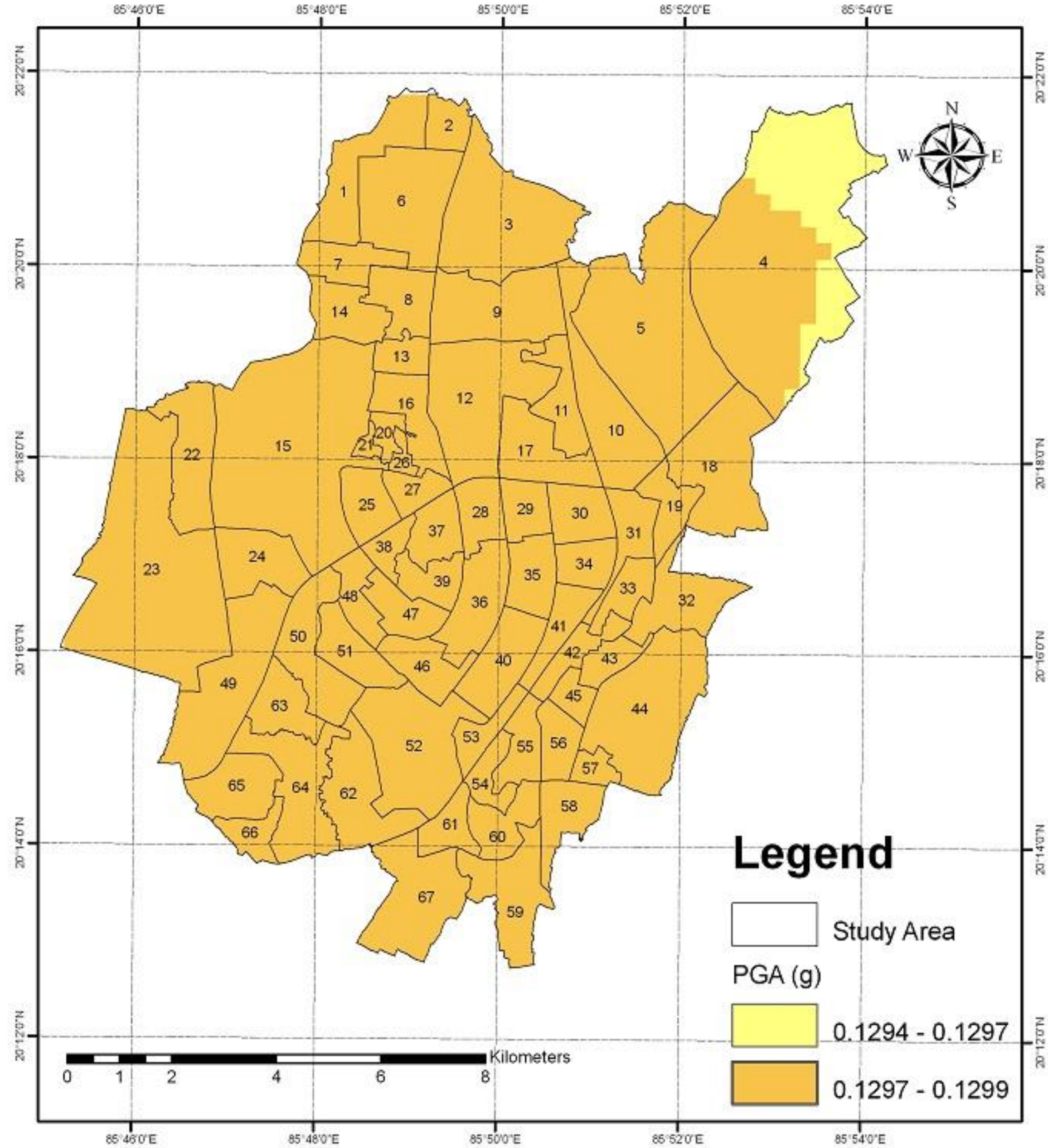


Figure 2-15: Ward level PGA map of Bhubaneswar city at hard rock-level (after GSHAP)

2.3.3 MODELING SOIL AMPLIFICATION

Local soil conditions can significantly affect earthquake ground motion of an earthquake. The soil top layers act as filters that can modify the ground motion as a function of their dynamic characteristics. Soft, weak soils tend to amplify long-period seismic motions and thus generally impart large ground displacements to structures, while very stiff soil and rock tend to de-amplify the ground motion.

For dynamic purposes, soils are classified in terms of their shear wave velocity. A majority of authors, including the European and NGA developers (for example, Schott et al., 2004; Campbell et al., 2009; Boore et al., 2011; Sandikkaya et al., 2013) have used the average shear-wave velocity in the upper 30 meters of sediments, Vs30, as the parameter for characterizing effects of sediment stiffness on ground motions. Use of this parameter is considered to be diagnostic in determining site amplification than the broad and ambiguous soil and rock categories used in earlier studies with the exception of the relation of Boore et al. (1997), who used Vs30. Therefore, the site amplifications of ground motions relative to a reference rock condition are continuous functions of Vs30 and have been used for the study area, due to the absence of Bhubaneswar-specific relationships between site classes and amplification effects, and coarse surficial geology at 1:250,000 scale. The widely used NEHRP's site amplification procedure based on shear wave velocities (Wills et al, 2000, BSSC, 2001) has been applied in this study (Table 2-5).

Table 2-5: Soil Classification Scheme based on Shear Wave Velocities

Soil Index value	NEHRP /CDMG Class	Brief Description	Shear Wave Velocity (Vs,30) m/s
1.0	AB	Very hard to firm rocks mostly metamorphic and igneous rocks	>760
1.5	BC	Firm sedimentary rocks (mid Miocene age) and weathered metamorphic	760
2	C	Sedimentary Formation Mid-Lower Pleistocene age	550-760
2.5	CD	Weak rock to gravelly soils - Deeply weathered and highly fractured bedrock	270-550
3.0	D	Holocene Alluvial soils	180-270
3.5	DE	Young alluvium / Water-saturated alluvial deposits	90-180
4.0	E	Non-engineered artificial fill, soft clays, peat and swamp deposits	<90

Using Wald et al. (2004) and Wald and Allen (BSSA, 2007) approach, gridded (0.1 km x 0.1 km) Vs30 map and corresponding soil-index map have been generated using NEHRP (Figure 2-16) classification.

The site–dependent amplification factors followed the non-linear two-dimensional soil amplification factors modified from Choi and Stewart (2005); and Walling, M, Walter Silva, and Norman Abrahamson (2008), which relate non-linear multipliers based on the level of ground motion (PGA) and averaged soil index assigned for a given location.

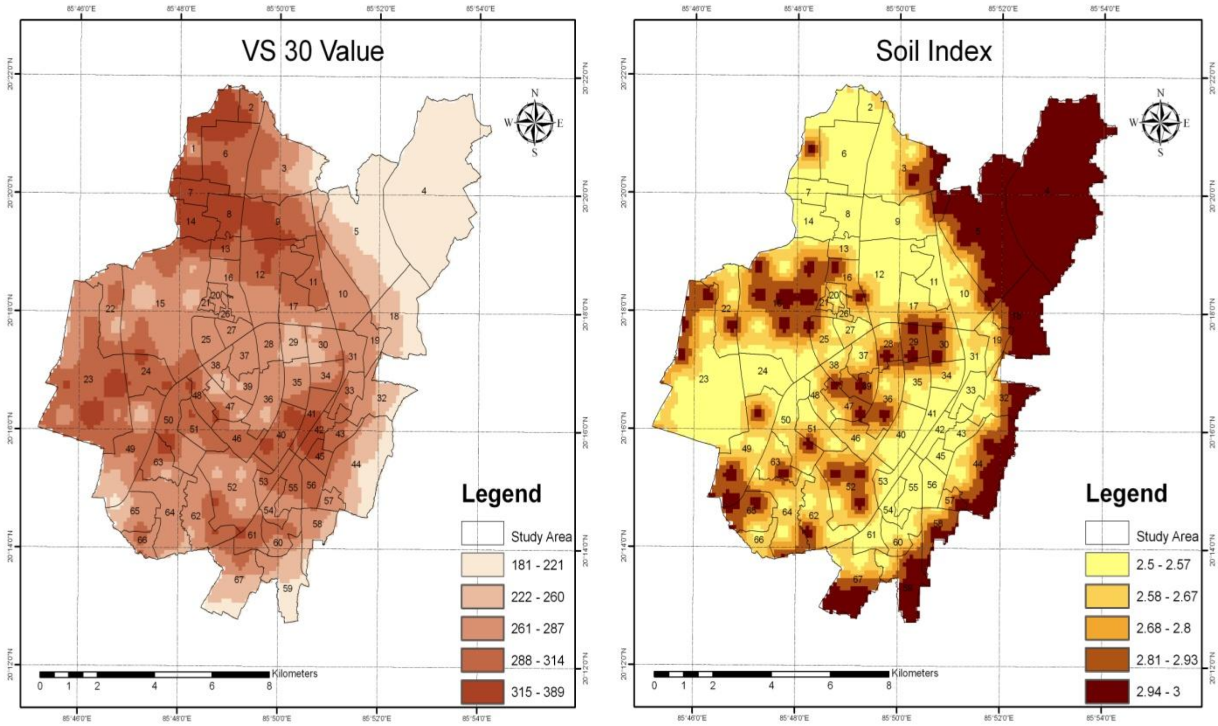


Figure 2-16: Spatial variation of (a) Vs30 values and (b) Soil-Index for Bhubaneswar city

The plot of amplification factors for different soil index classes (corresponding to respective Vs30 values) normalized by the amplification for reference BC soil Vs30=760 m/s (soil index 1.5), used in the study is shown in Figure 2-17.

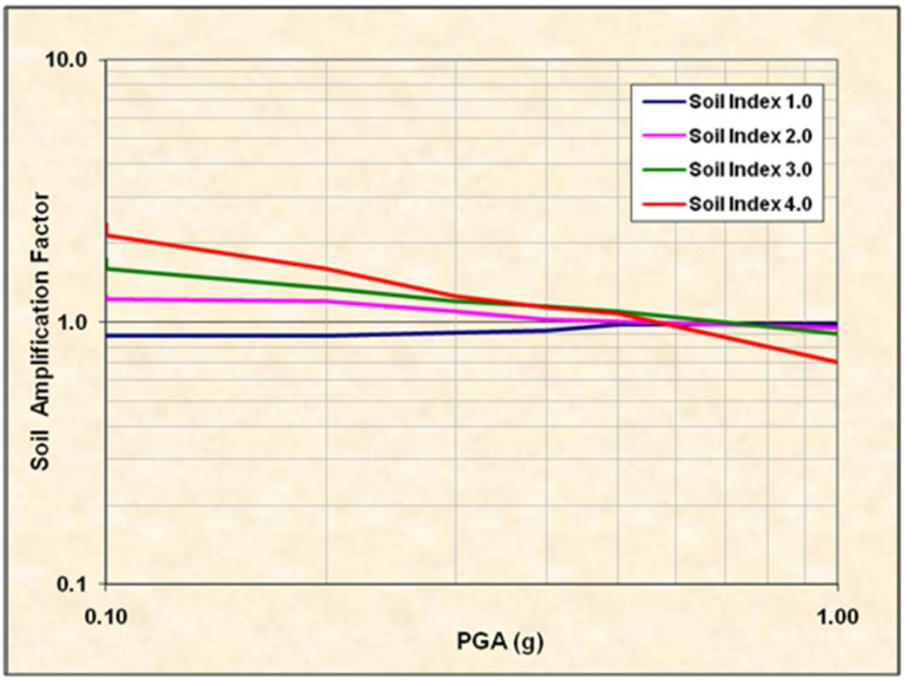


Figure 2-17: Site Amplification Factors for different Soil Index Values (=Vs30 Values)

The site amplification factors were then calculated based on the high resolution Vs30 based soil index map, and these have been multiplied with the PGA Rock values derived (as given in Figure 2-15) for the study area.

The final seismic hazard map generated at ward level contains seismic ground motion estimates at surface level, by taking into account the local soil-amplification factors in different parts of Bhubaneswar city (Figure 2-18).

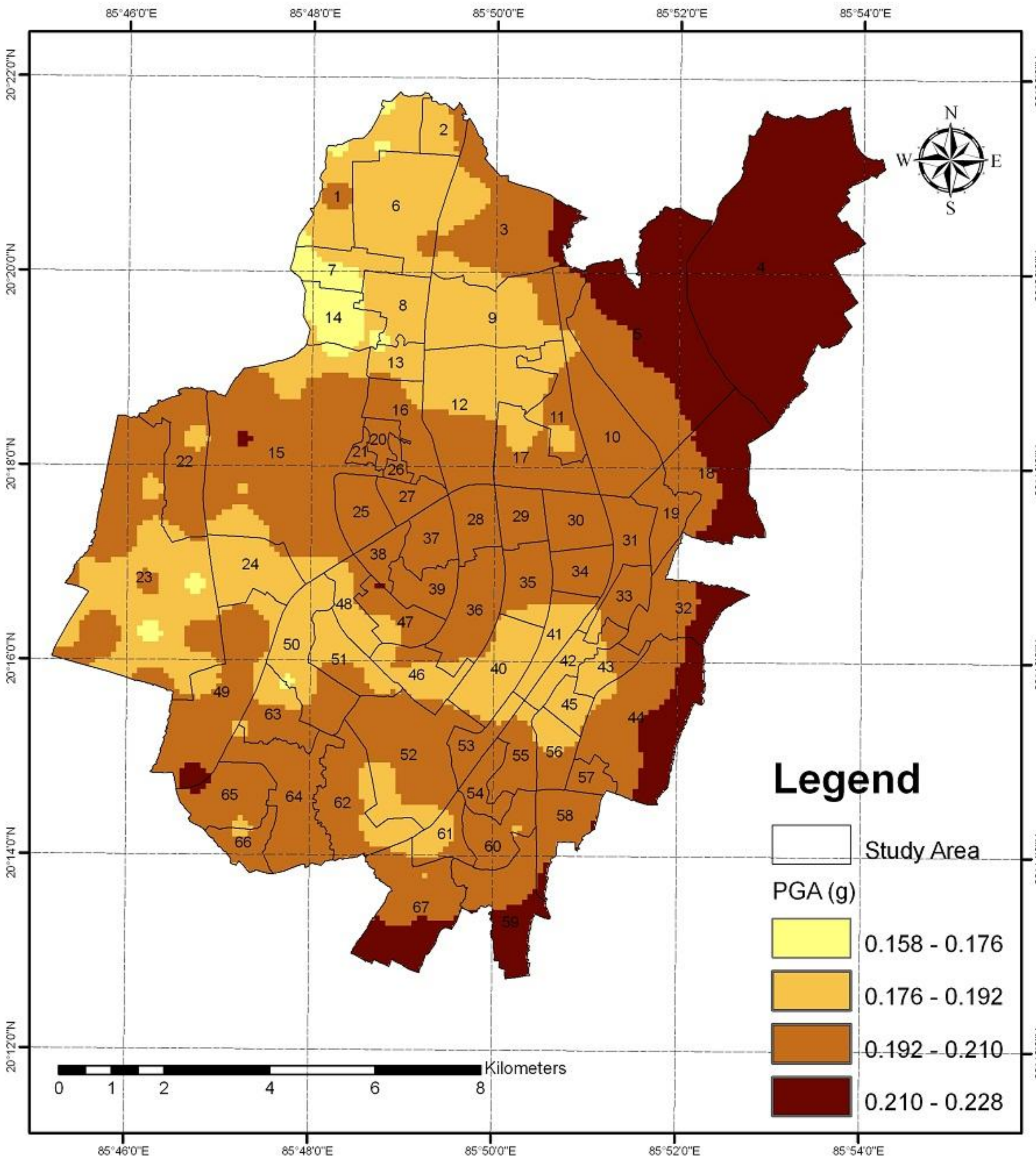


Figure 2-18: Ward level PGA based Probabilistic Seismic Hazard Map For 10% Probability in 50 Years (475-Year Return Period) for Bhubaneswar city

As discussed earlier, from Figure 2-18 it is clear that different parts of the city are expected to experience different levels of ground motion due to local soil amplification.

2.3.4 Application of Earthquake Hazard Maps in Disaster Management and City Planning

As mentioned earlier, the Seismic Zoning Map of India (BMTPC, 2006; IS: 1893, 2002, 2014) only provides a uniform seismic coefficient of 0.16, and the published probabilistic seismic hazard map presents an almost same value of about 0.13 g for the entire city. From Figure 2-16 and Figure 2-17, it is evident that local soil amplification, especially when Vs30 values are lowers than 760 m/sec, plays a significant role and must be taken into consideration in seismic design and structures. As per the ward level map, Figure 2-18, PGA based probabilistic seismic hazard analysis of Bhubaneswar city provides spatially varying values of 0.158g to 0.228g, which should be taken care of while designing new buildings as well as in taking up seismic retrofitting of old buildings.

2.4 Heat Wave Hazard

Bhubaneswar has become one of the hottest Indian cities with scorching summers in the recent time. Extremely high increase in average monthly mean maximum temperature, continuous increase in the number of hot days and rising temperature difference between Bhubaneswar and the nearby cities provide an impression of gradual emergence of the city as an urban heat island.

2.4.1 DATA SOURCE

Historical weather data was collected from the India Meteorological Department (IMD) and other available sources in order to analyze the rising trends in surface air temperature in Bhubaneswar city during the past few decades.

2.4.2 METHODOLOGY

Temporal trends in daytime maximum and nighttime minimum surface air temperatures were assessed using historical weather data.

2.4.3 ANALYSIS RESULTS

For the past three decades, the state of Odisha has been experiencing unprecedented contrasting extreme weather conditions; from heat waves to cyclones; from droughts to floods. In Bhubaneswar city of Odisha, the annual mean surface air temperature has risen during the past two centuries (Figure 2-19). However, the rate of increasing trend has sharply increased in the last few decades of the 20^{th} century, which could be attributed to global climate change due to anthropogenic forcings. Further analysis of data also suggests that the rate of increase in temperature is found to peak in May and June months of the year. In the year 1998, the State of Odisha faced an unprecedented heat wave situation, because of which 2042 persons lost their lives. Though extensive awareness campaigns have largely reduced the number of casualties during post 1998 period, still a good number of casualties are being reported each year. In the year 2009, the Odisha state experienced the worst heat wave since the one in 1998 that killed more than 2,000 people, of which 1,500 died in coastal Odisha alone. Severe heat stress conditions prevailing recurrently in Odisha in this century have put the State Government in a very difficult situation. It has become a menace during peak summer causing insurmountable human suffering. The temporal analysis of daily temperature data in Bhubaneswar for the past three decades has shown a steady increase in the city temperature over the years. In fact, Bhubaneswar has become one of the hottest Indian cities in the recent times. Extremely high rise in annual average maximum temperature, continuous increase in the number of hot days and rising temperature difference between Bhubaneswar and the nearby cities provide an impression of gradual emergence of the city as an urban heat island. During May 2013, the maximum temperature of 47^{o}C was recorded at Bhubaneswar. Subsequently, heat stress conditions prevailed in Bhubaneswar. Most of the districts in Odisha, on an average, recorded 40ºC during April 2014 and the temperature across a few districts in coastal Odisha reached 46ºC by the end of May. Very severe heat stress conditions prevailed in May / June this year. The increasing trends in observed maximum (daytime high) and minimum (nighttime low) surface temperature at Bhubaneswar are depicted in Figure 2-20 and Figure 2-21 respectively.

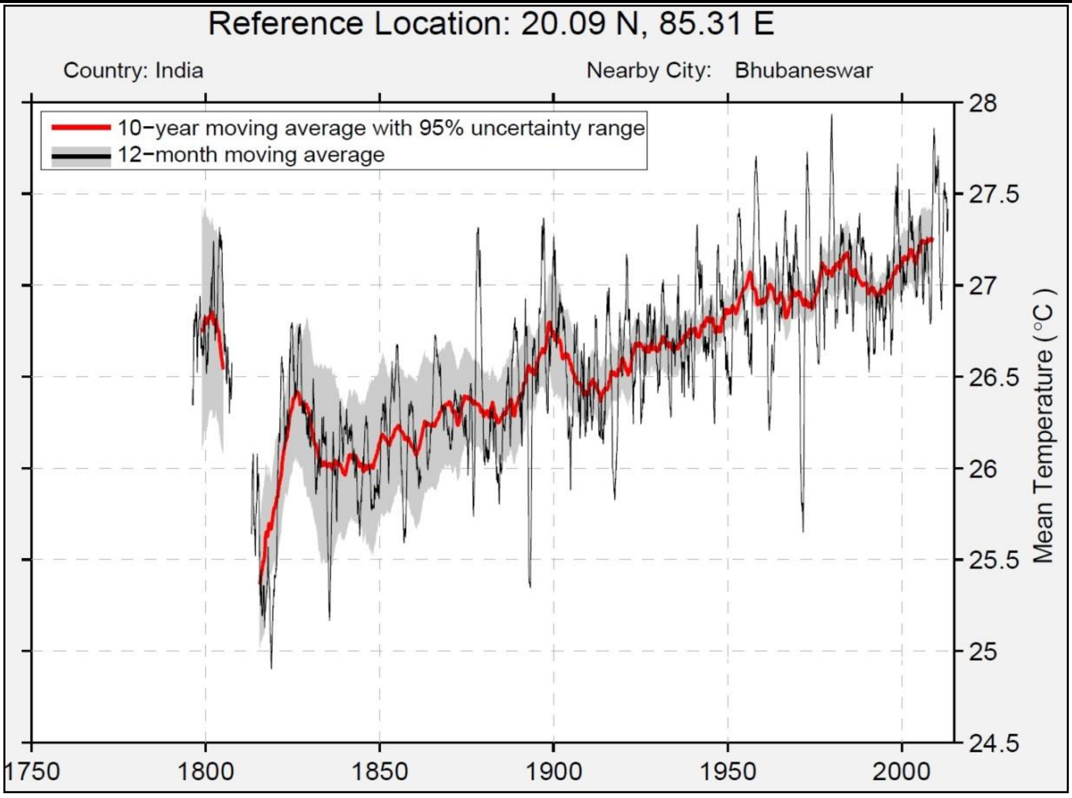


Figure 2-19: Temporal trends in observed annual mean surface air temperatures at Bhubaneswar, India

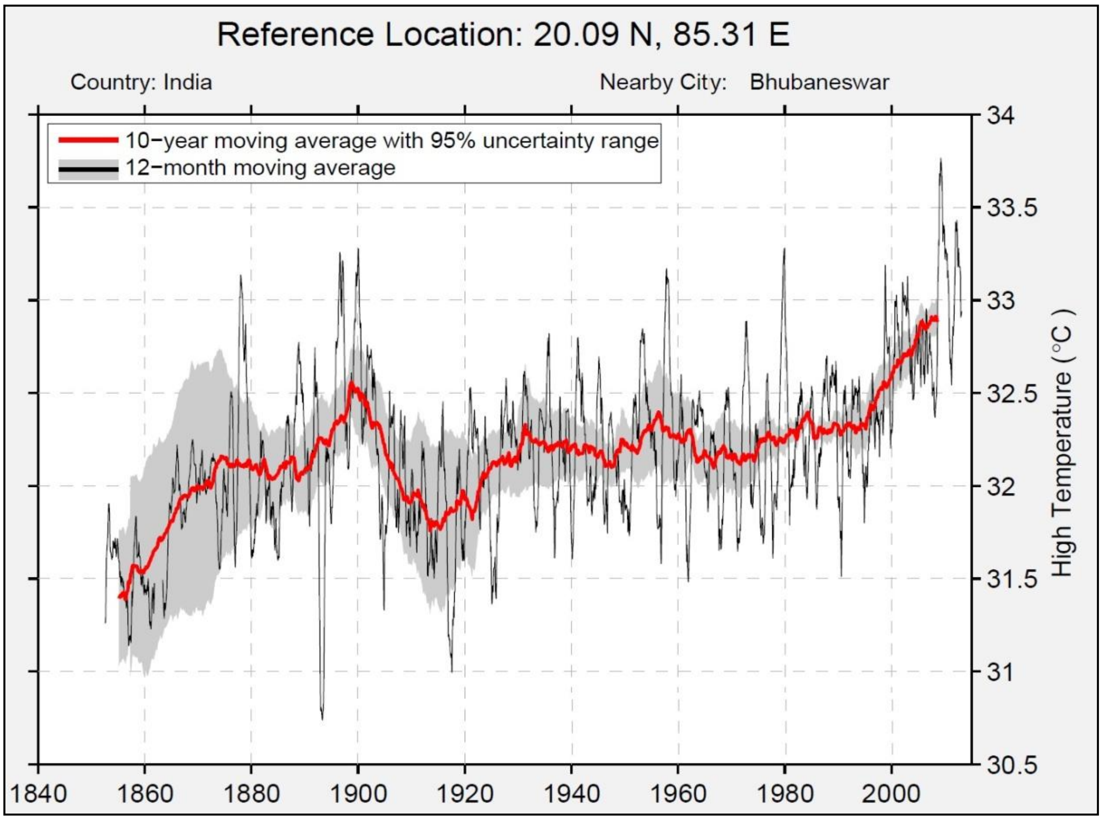


Figure 2-20: Temporal trends in observed annual mean maximum (day-time high) surface air temperature at Bhubaneswar, India

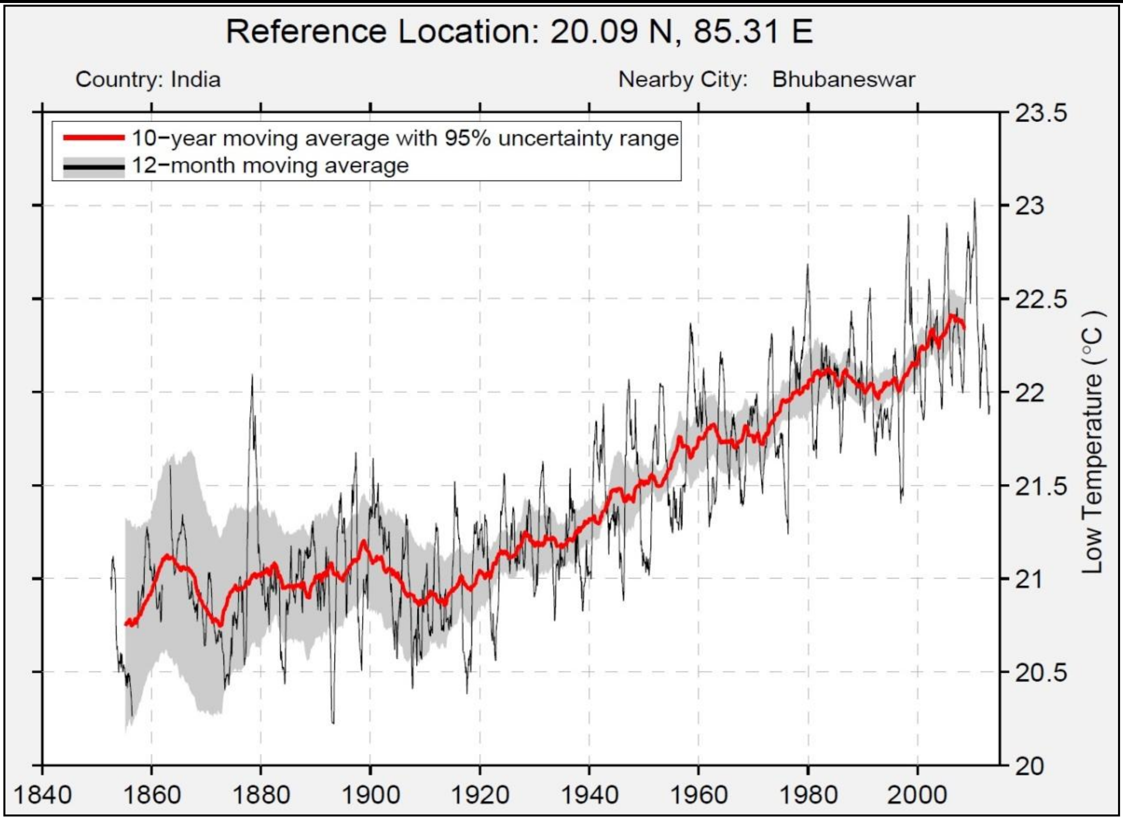


Figure 2-21: Temporal trends in observed annual mean minimum (night-time low) surface air temperature at Bhubaneswar, India

It is interesting to note from Figure 2-20 and Figure 2-21 that the rate of increase in daytime maximum temperature at Bhubaneswar is higher in comparison to the nighttime minimum temperatures meaning thereby that the diurnal temperature range at this site is increasing in recent decades. This is further illustrated in Figure 2-22 and Figure 2-23 wherein the trends in summer time maximum and minimum temperatures at Bhubaneswar are shown.

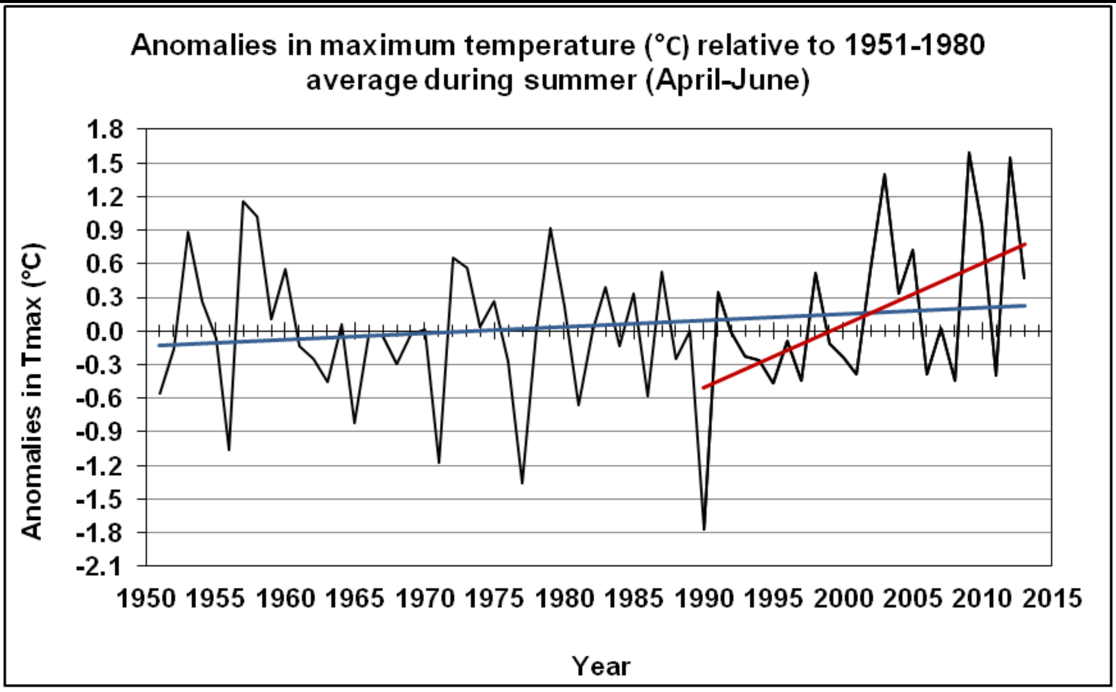


Figure 2-22: Anomalies in observed maximum (daytime high) surface air temperature during summer season (with respect to the 1951-1980 mean) at Bhubaneswar. An accelerated increasing trend is evident in recent decades

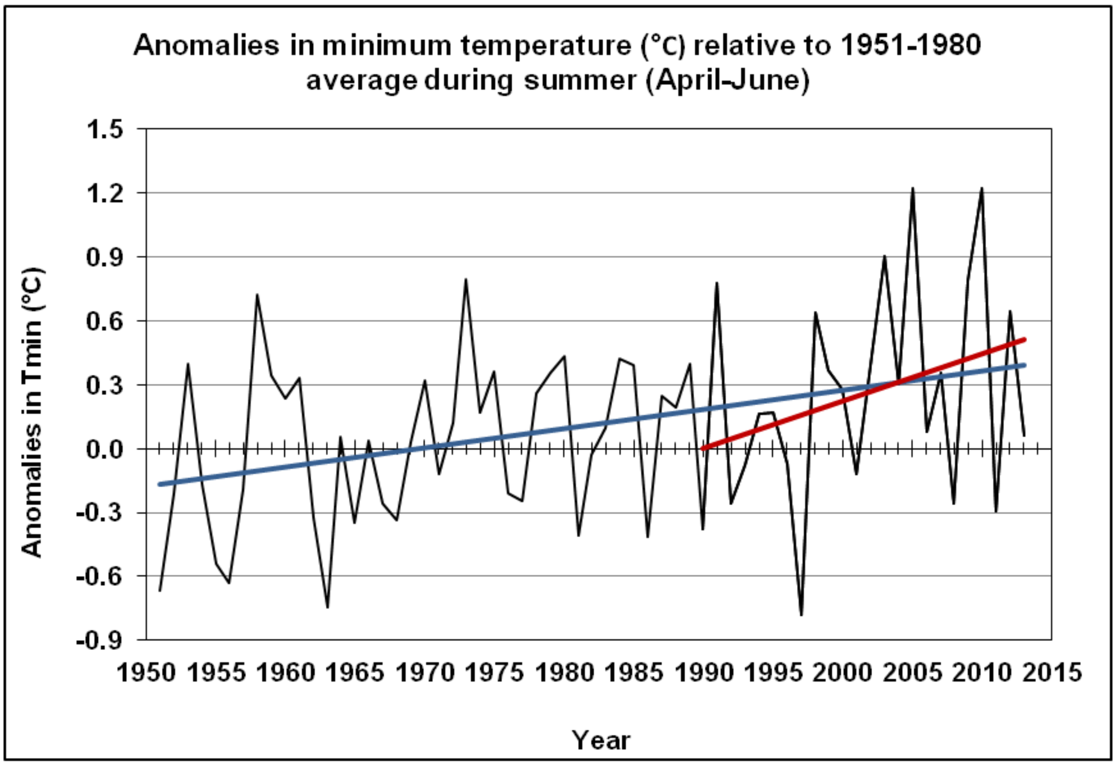


Figure 2-23: Anomalies in observed minimum (nighttime low) surface air temperature during summer season (with respect to the 1951-1980 mean) at Bhubaneswar. The increasing trend in recent decades is not pronounced as the observed maximum temperature trend

Physical considerations indicate that tropospheric warming due to observed rate of temperature rise should lead to an enhancement of moisture content of the atmosphere and is associated with an increase in heavy rainfall events. Therefore, even though an overall decrease in annual mean rainfall anomalies has been monitored at Bhubaneswar (see **Figure 2-24**), more frequent incidences of high intensity rainfall could be expected in coming years and decades. Extreme rainfall events should result in landslides, flash floods, and crop damage that would have major impacts on society, the economy, and the environment.

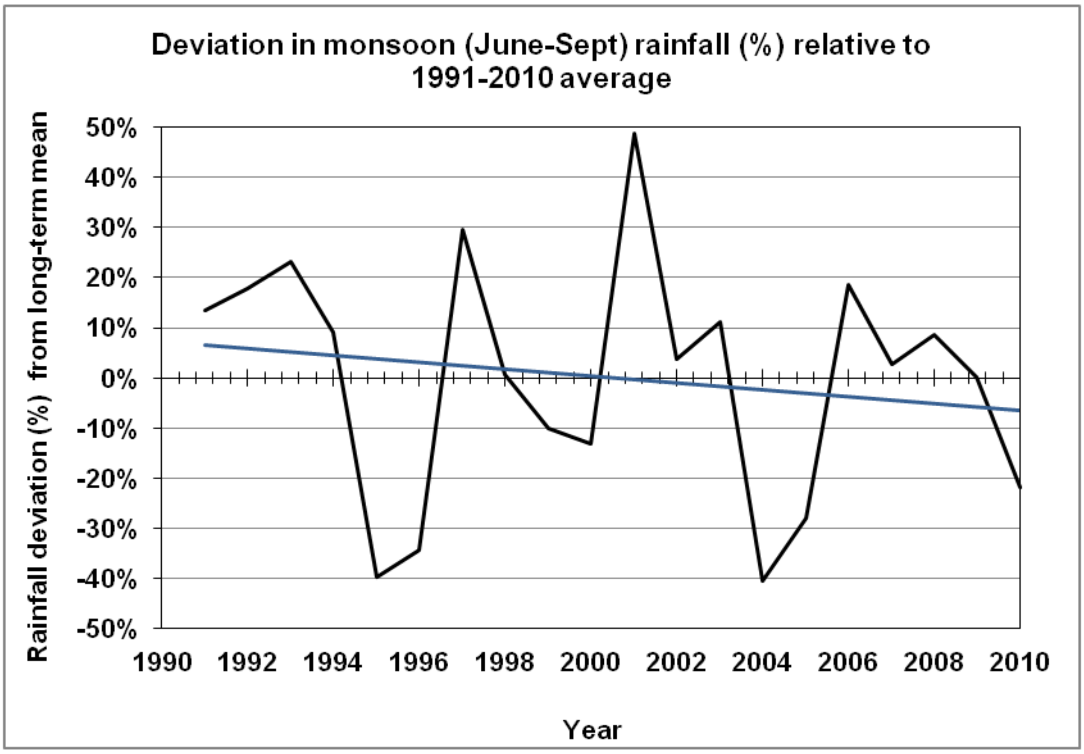


Figure 2-24: Percent deviation in observed rainfall with respect to 1991-2010 mean at Bhubaneswar during monsoon season

2.4.4 Application of Heat Wave Hazard Studies in Disaster Management and City Planning

Heat waves can affect communities by increasing summer-time peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality. These impacts include:

- Increased energy consumption;
- Elevated emissions of air pollutants and greenhouse gases;
- Compromised human health and comfort; and
- Impaired water quality

Urban heat islands increase overall electricity demand, as well as peak demand, which generally occurs on hot summer weekday afternoons, when offices and homes are running cooling systems, lights, and appliances. During extreme heat events, which are exacerbated by urban heat islands, the resulting demand for cooling can overload systems and require a utility to institute controlled rolling brownouts or blackouts to avoid power outages.

Apart from impact on energy-related emissions, elevated temperatures can directly increase the rate of ground-level ozone formation. Ground-level ozone is formed when NOx (mono-nitrogen oxides NO and NO_2) and volatile organic compounds (VOCs) react in the presence of sunlight and hot weather. If all other variables are equal, such as the level of precursor emissions in the air and wind speed and direction, more ground-level ozone will form as the environment becomes sunnier and hotter.

Increased daytime temperatures, reduced nighttime cooling, and higher air pollution levels associated with urban heat islands can affect human health by contributing to general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat strokes, and heat-related mortality. Sensitive populations, such as children, older adults, and those with existing health conditions are at particular risk from these events.

2.5 Epidemics

The demographic characteristics (mainly population density), weather conditions (mainly humidity, temperature and rainfall), and access to health infrastructure are some of the key factors that influence disease incidence/epidemic. The high variation in temperature, heavy and continuous rain, and tropical temperature can contribute to increase in the epidemic hazard in the city. Fast and unplanned growth of the city can often lead to poor drainage and overcrowding. The poorly maintained sewerage, old and poorly maintained drinking water system, etc. can trigger vector infestation and lead to outbreaks of diseases in urban system.

Several cities of Odisha have a poor mechanism for sewage treatment and sewage is let into the natural river system without any treatment. This increases the risk of water borne diseases in the state, particularly Acute Diarrheal Disorders (ADD) and Gastroenteritis. The State has also reported very high incidence of malaria cases. Taking this into consideration, the study attempts to analyze key vector borne diseases - malaria, chikungunya, and dengue, and water borne diseases - typhoid, diarrhea, jaundice and gastroenteritis based on the available historical reported cases.

2.5.1 DATA AVAILABILITY AND SOURCES

Historical disease incidence data was collected from City Capital Hospital, Integrated Disease Surveillance Project (IDSP) and from the State Malaria control unit of the National Rural Health Mission. BMC does not maintain a disease data of its own, unlike many other urban centers in the country. The city's health services are being supported by the State Health Department and for that reason data available are aggregated at district level. Some of the issues of the IDSP program include lack of adequate resources, technology issues, and non-achievement of program results even though it was launched in 2001. There is a dearth of ward level disease specific data available for the city of Bhubaneswar. There is no mechanism for private hospitals and clinics in the city to share data with the city administration. Monthly historical disease data for the last five years were available at the City Capital hospital for selected diseases.

In addition to the secondary data collected, the team also carried out a household survey in which disease incidence details of the households were collected through enumeration. Even though it was difficult for respondents to recall the disease events (including year) that occurred in the past in the family, the respondents have provided events that happened in the family in the near past. Disease data from the household sample provides a lead in understanding the incidence characteristics across the socio-economic classes in the city.

2.5.2 METHODOLOGY FOR HAZARD ASSESSMENT

The epidemic incidence data is available at district level and there is a dearth of city specific (ward level) data from the above mentioned sources. Statistical interpolation technique based on population data is used for assessing the estimated incidences at city/ward level. The service facilities at urban center may influence the health and reduce the disease incidence in cities, at the same time, overcrowding in the city and poor living condition can cause higher incidence of disease. However, both these aspects are factored in the statistical process of data.

The following steps were followed for disease hazard assessment:

1. Literature review: Literature available at the city and district levels related to various health and monitoring programs along with media articles and news were reviewed to understand the prominent diseases and outbreak histories of diseases in the city.
2. Consultation: The city/State health officers were consulted and the City hospital records were referred. Published documents of various national and state level health programs and media articles were also referred to understand what kind of diseases were reported in the city in the past
3. Disease selection: Prevalence and incidence are criteria that were considered for selection of diseases for analysis.
4. Collection of disease data: The disease data available with various government agencies were collected and compiled. The disease data is available at aggregate level for selected diseases for the last 4 years. For malaria and ADD, which are the key diseases pertaining to the city are only available at aggregate level – at district level. District level data was interpolated at city/ward level using population (incidence rate) as criteria
5. Household survey: As part of the social vulnerability analysis, a sample household survey was conducted in which questions related to disease incidence were also asked.
6. Analysis of disease data: The secondary and primary data collected were analyzed to understand the disease characteristics in terms of spatial distribution, seasonality and how it changed over the year. Based on the incidence data, a disease incidence calendar was prepared, which shows the vulnerable months for that particular disease.

2.5.3 Disease Hazard Mapping

The disease mapping for the city was carried out with the available disease data. The key objective is to understand if there is any high incidence of disease in specific months (season) of the year or if there any hotspots in the city in terms of any diseases. To develop a good analytical result of the spatial and temporal distribution of diseases it is essential to have good quality monthly ward level data, which is not available in the city. Based on the available data, the following inferences are made.

In 2010, there was an epidemic outbreak of Influenza H1N1 reported in Khordha district with 32 persons killed in the State (IDSP 2012). However, the city did not report any alarming numbers. In 2012, the Central Poultry Development Organization (CPDO) located in the heart of the city reported H5N1 positive cases in the poultry birds and the city declared a 3 km radius as surveillance zone. The Salia Sahi, the biggest slum in Odisha, falls under the alert zone and the alter zone spreads across 21 of the 67 wards in the city. One person was reported H1N1 positive in the city in 2012.

> **Disease Risk in the city**
>
> Occurrence vector borne and water high during monsoon season
>
> High incidence of disease recorded in the slum pockets of the city
>
> Malaria cases are dipping while there is an increase in waterborne diseases
>
> Warns take adequate preventive steps to avoid disease outbreak

The incidence of water borne and vector borne diseases has correlation with heavy rainfall. However, there is a high incidence of water borne diseases across the year (Figure 2-25) and also malaria incidence (Figure 2-26), even though reported cases of both these diseases are high during July and August months.

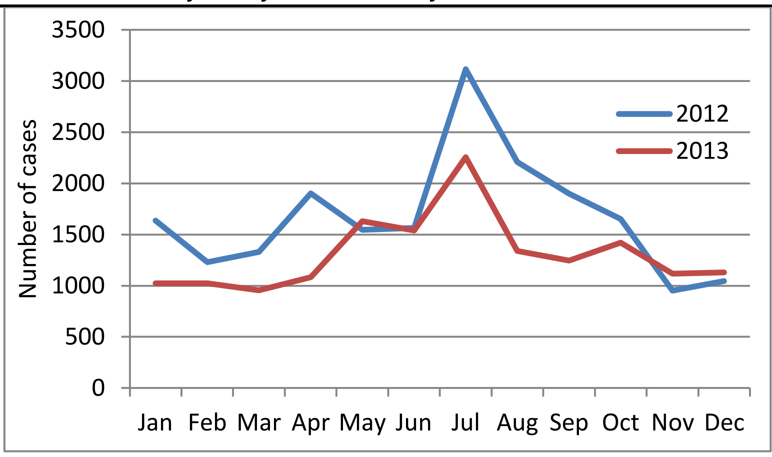


Figure 2-25: Incidence of ADD cases across the year in Bhubaneswar city (derived from district level data).

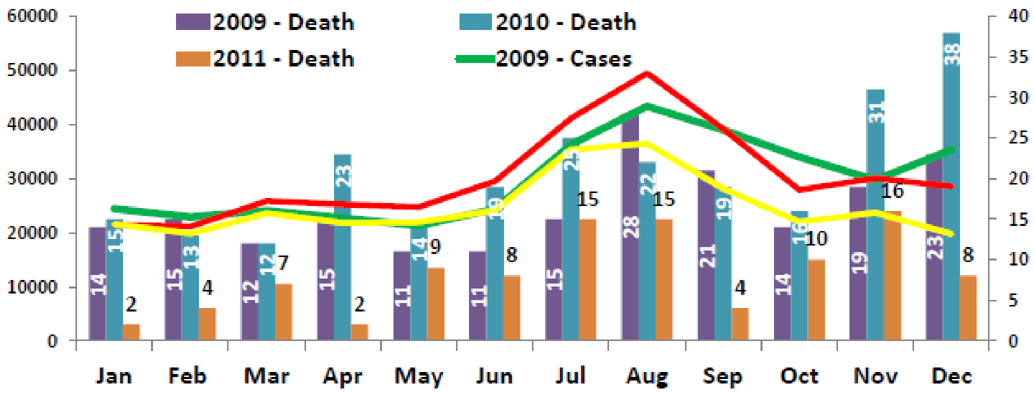


Figure 2-26: Seasonal incidence of malaria in Odisha State

Source: MM Pradhan, 2012

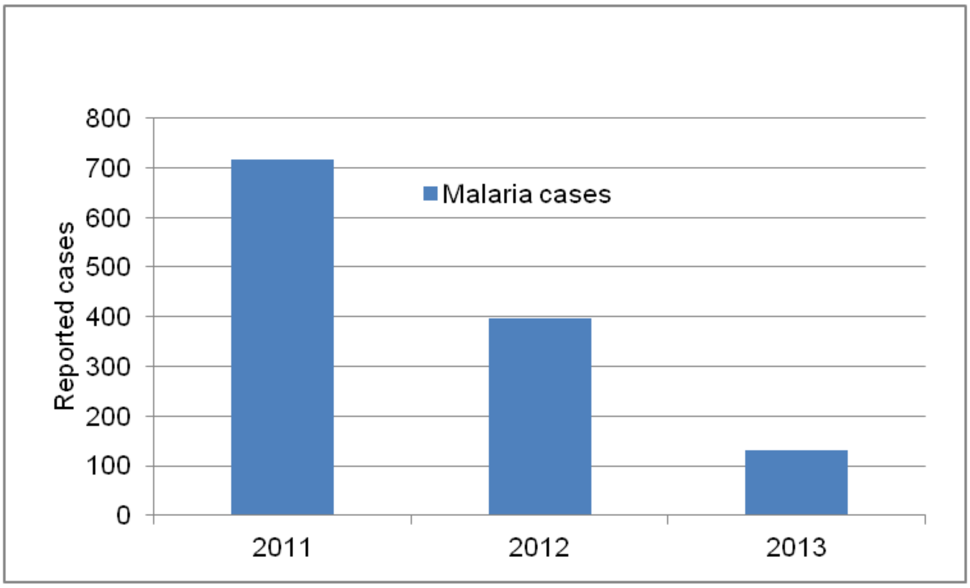


Figure 2-27: Malaria incidence trend during the last three years in Bhubaneswar city

The state level statistics on malaria show a decreasing trend.

Based on the household survey conducted, the diseases mostly reported include diarrhea (22% of reported cases), gastroenteritis (23%), malaria (31%), jaundice (23%). The household survey results also indicate that the occurrence of water borne diseases is high during the rainy season. Even though there is high incidence of malaria reported in the rainy season, there are cases reported across the year. Jaundice incidence shows a high rate of occurrence during the summer months. Gastroenteritis is common throughout the year, which is mainly to do with the unhygienic conditions, particularly in handling food. During the survey, very few dengue and no chikungunya cases were reported.

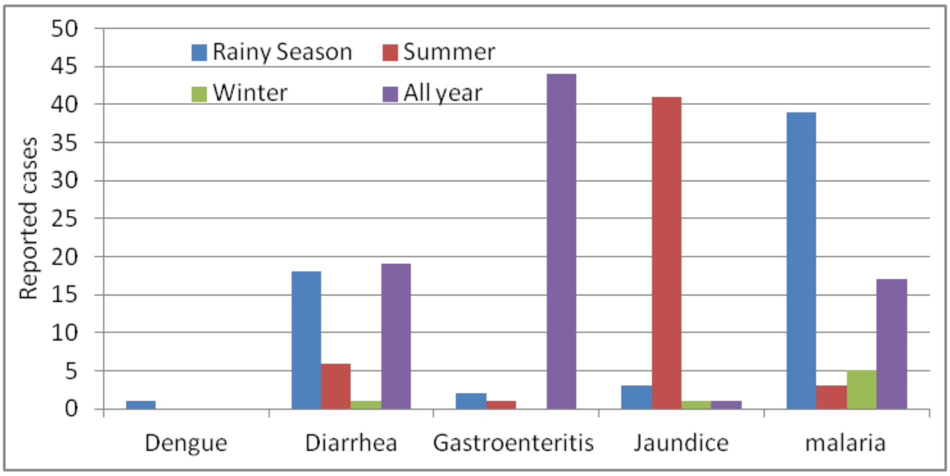


Figure 2-28: Incidence of diseases across seasons based on the sample survey, 2014Disease Susceptibility Mapping

It is interesting to note that there is no hotspot for any of the diseases in the city; rather the whole city has high incidence of water borne diseases and malaria. All the wards surveyed irrespective of income/economic classes and house types they are living in reported high incidence of both water borne diseases and malaria.

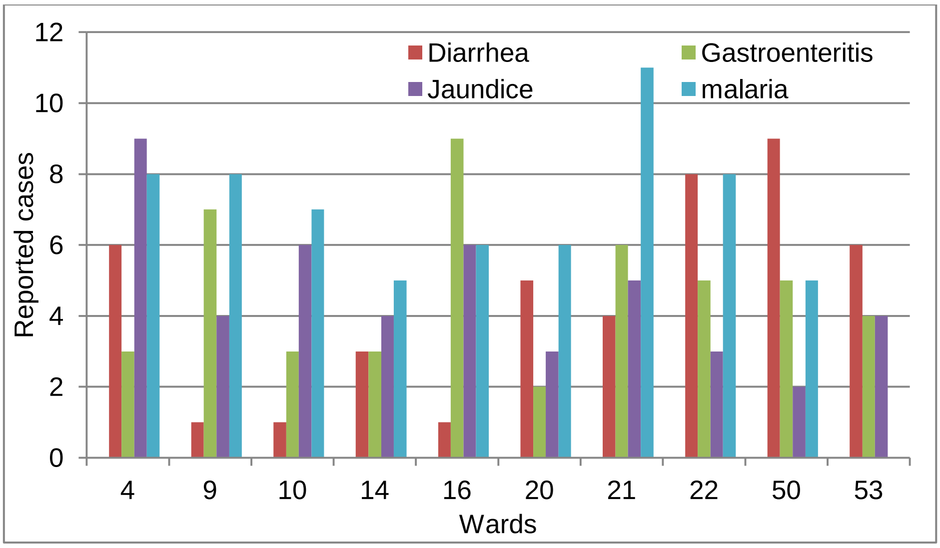


Figure 2-29: Distribution of disease cases reported across the wards of Bhubaneswar city

The city Capital hospital records document reported cases like snake bite, accidental injuries, ADD, measles and acute respiratory infections. Monthly sex-wise data is available for these diseases for the last 5 years. However, spatial distributions of the disease cases are not available for spatial analysis. There is an increase in accident injuries during the last three years and more male cases have been reported as compared to female cases.

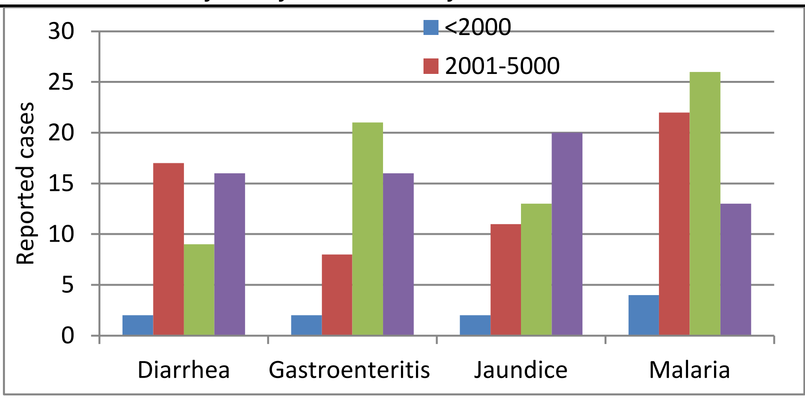


Figure 2-30: Disease incidence across income group (household survey 2014)

2.5.4 Application of Disease Susceptibility Mapping in Disaster Management and City planning

1. Understanding of disease characteristics (both incidence and prevalence) can help in predicting the risks and in appropriate mitigation planning.
2. Understanding occurrence time is important so that required prevention measures can be put in place before the events occur.
3. Correlating disease incidence with social and biophysical factors, for instance distribution of slums and reported cases, and waterlogged areas can provide insight into triggering factors that increase and spread diseases, thereby allowing them to be dealt with at the root cause level.

2.6 Climate Change and its Impact on Hazards

2.6.1 Literature review

Global warming in response to human-driven emissions, particularly of carbon dioxide (CO_2) has accelerated since 1970s and broke more countries' temperature records than ever before in the first decade of the new millennium. A new analysis from the World Meteorological Organization says average land and ocean surface temperatures from 2001 to 2010 rose above the previous decade, and were almost a half-degree Celsius above the 1961-1990 global average[3]. The decade ending in 2010 was also an unprecedented era of climate extremes as evidenced by heat waves in Europe and Russia, droughts in the Amazon Basin, Australia and East Africa, and huge storms like Tropical Cyclone 'Nargis' and Hurricane 'Katrina'. The 2012 annual global temperature across the land and ocean surface was among the 10 warmest years on record[4]. In 2013 again, the global land surface temperature was 0.77°C above the 20^{th} century average, the 11^{th} warmest August on record. Global average ocean surface temperature was higher than the 1981–2010 average value.

Experts say a decade is about the minimum length of time to study when it comes to spotting climate change. From 1971 to 2010, global temperatures rose by an average rate of 0.17°C per decade. The pace also picked up in recent decades. Average temperatures were 0.21°C warmer during the past decade (2001 to 2010) than from 1991 to 2000, which were in turn 0.14°C warmer than from 1981 to 1990. Natural cycles between atmosphere and oceans make some years cooler than others, but during the past decade, there was no major event associated with El Niño, the phenomenon characterized by unusually warm temperature in the equatorial Pacific Ocean. Much of the decade was affected by the cooling La Niña, which comes from unusually cool temperatures there, or neutral conditions.

[3] WMO, 2013: The Global climate 2001-2010: A decade of climate extremes, WMO No. 1103, 61 pp.
[4] State of the Climate report - 2012: NOAA's National Climatic Data Center, Published August 2013.

As stated under section 2.4, the state of Odisha has been experiencing unprecedented contrasting extreme weather conditions for the past three or more decades; from heat waves to cyclones; from droughts to floods. In Bhubaneswar city of Odisha, the annual mean surface air temperature has risen during the past two centuries (see Figure 2-19 above). However, the rate of increasing trend has sharply increased in the last few decades of the 20th century (Figure 2-31), which could be attributed to global climate change due to anthropogenic forcings. Figure 2-31 clearly illustrates that during the past three decades of the 20th Century, the rising trend in surface air temperature over Bhubaneswar is higher than all India and Odisha state averages thus explaining the likely contribution of global climate change to the unprecedented heat wave conditions in Bhubaneswar during hot summer months. These climatic extremes could further aggravate in future thus requiring an assessment of regional and local climate change and its impacts.

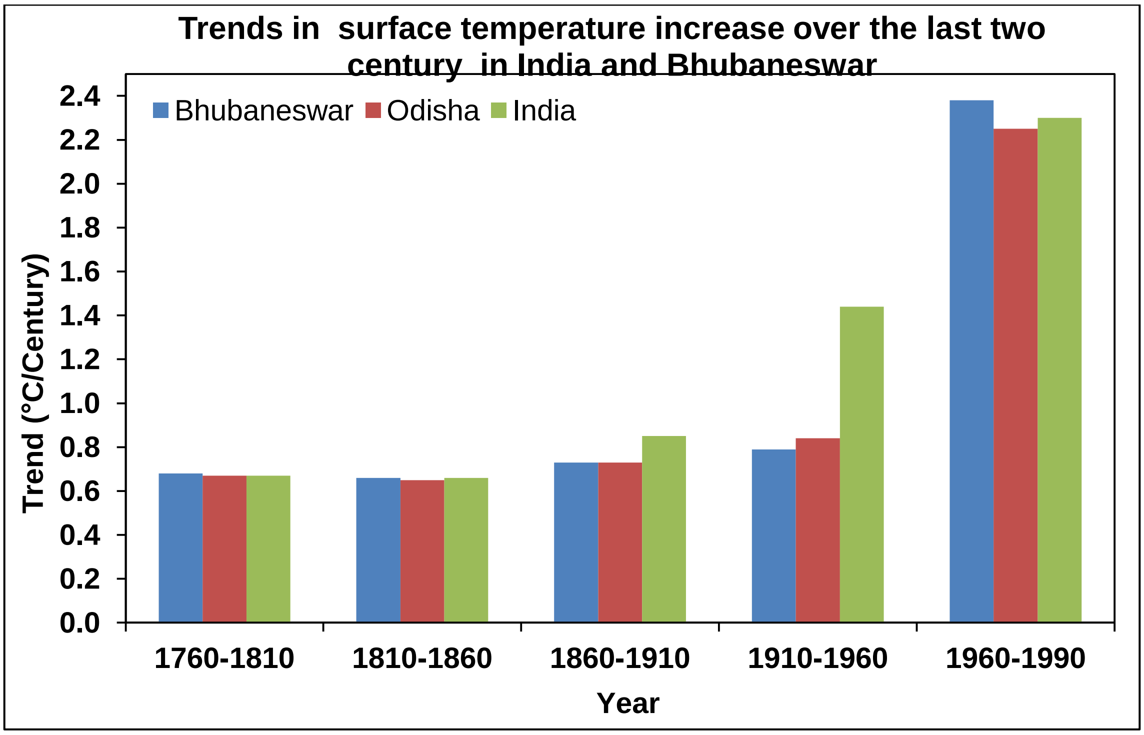


Figure 2-31: A comparison of rate of increasing trends in surface air temperature since historical times in Bhubaneswar, Odisha and India.

2.6.2 DATA SOURCE

Following data sets were used in order to execute this task:

- Historical weather data was collected from the India Meteorological Department (IMD) and other available sources.
- Projected climate data obtained from one of the state-of-the-art Global Climate Models, namely HadGEM2-ES model (UK). The reason for selection of this GCM is that this model has demonstrated reasonable degree of skill in simulating the baseline climatology over the Indian region. The emission scenario considered for development of future climate change scenarios is RCP 6.0 (Representative Concentration Pathways) emission pathways and identified as modest future emission scenario bracketing plausible future climate change without stringent mitigation policies.

2.6.3 METHODOLOGY

Two types of analysis were carried out under this task, which are detailed as under:

- Temporal trends in rainfall and surface air temperature were assessed using historical weather data.
- Spatial distribution patterns in maximum and minimum surface air temperatures and rainfall over Bhubaneswar were developed using above-mentioned HadGEM2-ES model data in GIS platform (ArcGIS 9.2). These analyses provide the likely shifts in spatial changes of temperature and rainfall during 2040s (2026-2055) and 2080s (2061-2090) with respect to baseline time period (1961-1990). The results of this, together with the trend analysis, can be used to assess the implications of climate change on various meteorological and hydro-meteorological hazards (e.g., drought, flood, and heat wave etc.).

2.6.4 ANALYSIS RESULTS

India, as a whole, has experienced its average annual surface air temperature rise by about 0.5°C during the past century as also observed across the continents and globe and thus supports its attribution to anthropogenic influences on global scale. The rise in surface temperature seems to have accelerated since 1960s and particularly so during the past decade. Past studies[5] reported that surface air temperatures over India are going up at the rate of 0.4°C per decade, with peaks during the post-monsoon and winter seasons. Summer temperatures over the State of Odisha in India are projected to increase by 2.5°C during 2040s and 3.5°C during 2080s. Winter temperatures could increase by as much as 3.0°C during 2040s and 4.5°C by 2080s. According to a more recent study, south Asian summer temperatures are projected to increase by 3°C to nearly 6°C by the end of 21st Century with the warming most pronounced in the northwestern parts of India[6]. By the time 1.5°C warming is reached, heat extremes that are unusual or virtually absent in today's climate in the region are projected to cover 15% of land areas in summer. Some regions are projected to experience unprecedented heat during more than half of the summer months.

The recent climate modeling results (CMIP5 simulations) suggest that greenhouse gases have contributed a global mean surface warming in the range of 0.5°C to 1.3°C over the period of 1951−2010, with the contributions from other anthropogenic forcings, including the cooling effect of aerosols, likely to be in the range of −0.6°C to 0.1°C. On regional scales, the confidence in model capability to simulate key climate variables remains lower than for the larger scales. However, there is high confidence that simulation of regional-scale surface temperature has significantly improved now than at the time of the AR4. The new versions of Earth System Models reproduce better some important circulation features modulating the climate anomalies. There is high confidence that the key circulation features controlling the Asian monsoon and El Niño-Southern Oscillation (ENSO) based on multi-model simulations have improved since AR4 (IPCC, 2013)[7].

A spatial distribution of rise in annual mean maximum and minimum surface air temperatures in Bhubaneswar City of Odisha, as downscaled from outputs from one of the

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[5] Lal, M. 2003: Global climate change: India's monsoon and its variability, Jr. Environmental Studies & Policy, 6, 1-34.

[6] Rajiv Kumar Chaturvedi, Jaideep Joshi, Mathangi Jayaraman, G. Bala and N. H. Ravindranath, 2012: Multi-model climate change projections for India under representative concentration pathways, Current Science, VOL. 103, NO. 7, 12 pp.

[7] IPCC, 2013: Summary for Policymakers, in: Stocker, T.F.; Qin, D.; Plattner, G.K.; Tignor, M.; Allen, S.K.; Boschung, J.; Nauels, A.; Xia, Y.; Bex, V.; Midgley, P.M. (Eds.) Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

state-of-the-art global climate model used in CMIP5 simulations (Taylor et al., 2012)[8] for the 5th scientific assessment report of IPCC under RCP 6.0 scenario, is presented here. The projected rise in maximum (day-time) and minimum (night-time) surface air temperatures in Bhubaneswar city of Odisha state at two time slices, namely, 2040s and 2080s are illustrated in Figure 2-32 and Figure 2-33 respectively. The plausible changes in annual mean and monsoon season rainfall over Bhubaneswar City of Odisha for two time slices, namely, 2040s and 2080s are depicted in Figure 2-34 and Figure 2-35 respectively. The model used here for the purpose is HadGEM2-ES model developed by Met Office Hadley Center (UK). The emission scenario RCP 6.0 used for these projections is identified as modest future scenario, bracketing plausible future climate change without stringent mitigation policies. In our previous research and analysis of model validation, this model has demonstrated reasonable degree of skill in simulating the baseline climatology over the Indian sub-continent (HadGEM2-ES is found to be the best-performing individual model in simulating the annual and seasonal Indian climatological characteristics, followed closely by a few others).

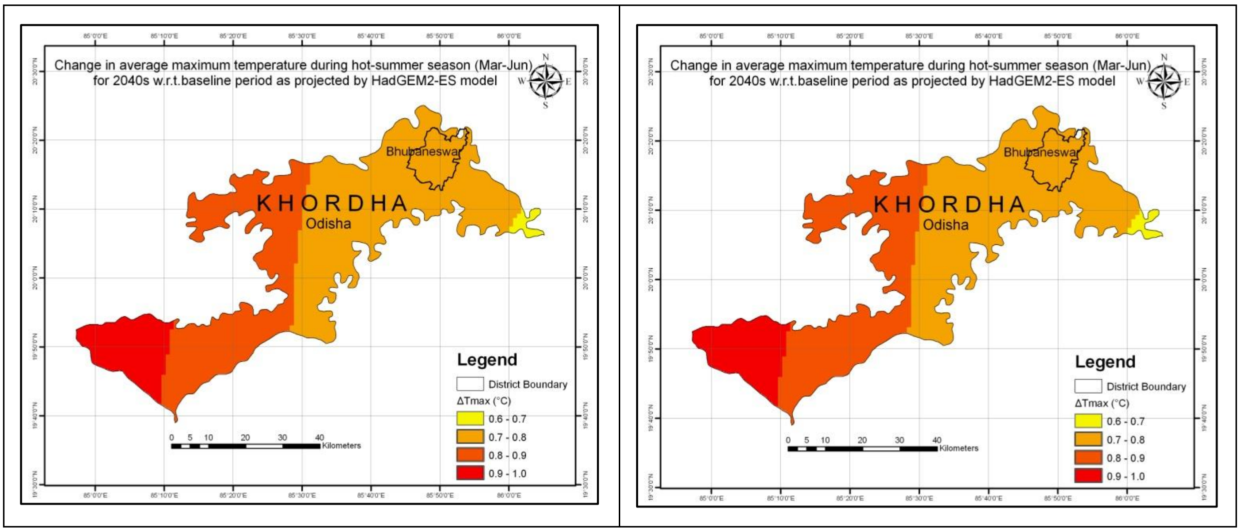


Figure 2-32: Projected rise in mean maximum and minimum surface air temperatures during hot summer months for 2040s in Khordha District of Odisha (Bhubaneswar city is marked with black boundary here)

Further, it is evident from Figure 2-32 that the mean maximum day-time surface air temperatures during hot summer months in the city of Bhubaneswar is likely to rise on an average by about 0.8°C around the middle of this century while the rise in mean night-time minimum surface air temperature during the hot summer months could exceed 1.1°C by the middle of this century. This illustration further suggests that the diurnal temperature range would reduce in future in Bhubaneswar city of Odisha State. During 2080s, the maximum day-time and minimum night-time surface air temperatures in the city of Bhubaneswar on hot summer months mean basis are expected to rise in excess of 2.1°C and 2.3°C respectively (Figure 2-33). These projections of rise in surface air temperatures in future suggest that the intensity of heat waves in the city of Bhubaneswar should become stronger with time during peak summer months and record high temperatures could be experienced here more often in future.

[8] Taylor, Karl E., Ronald J. Stouffer, Gerald A. Meehl, 2012: An Overview of CMIP5 and the Experiment Design. Bull. Amer. Meteor. Soc., 93, 485–498.

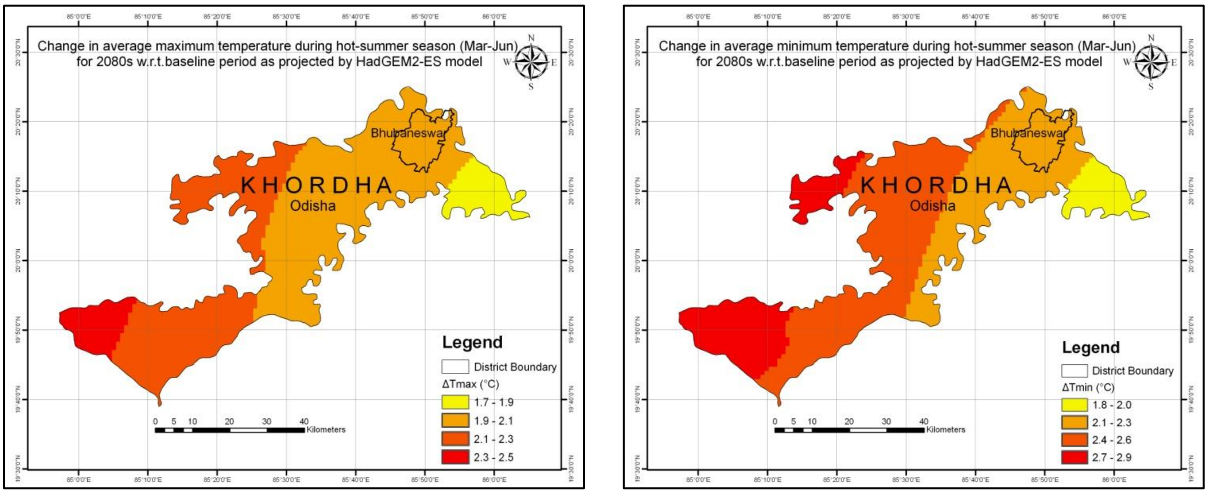


Figure 2-33: Projected rise in mean maximum and minimum surface air temperatures during hot summer months for 2080s in Khordha District of Odisha (Bhubaneswar city is marked with black boundary here)

An examination of the change in rainfall patterns as depicted in Figure 2-34 suggests that the annual mean and monsoon season rainfall is projected to increase by about 0.46 mm / day and by about 1.12 mm / day respectively (a total of about 170 mm in a year) over Bhubaneswar city by the middle of this century. Figure 2-35 reveals that the seasonal monsoon rainfall could increase by about 2.27 mm / day (a total of about 270 mm in the season) over Bhubaneswar city by the end of this century. On annual basis, the rainfall would increase over Bhubaneswar city by around 0.81 mm / day (a total of about 295 mm in a year) by the end of this century. It is evident from Figure 2-34 and Figure 2-35 that, on an average, Bhubaneswar city is likely to experience a significant increase in monsoon rainfall only in the latter part of this century.

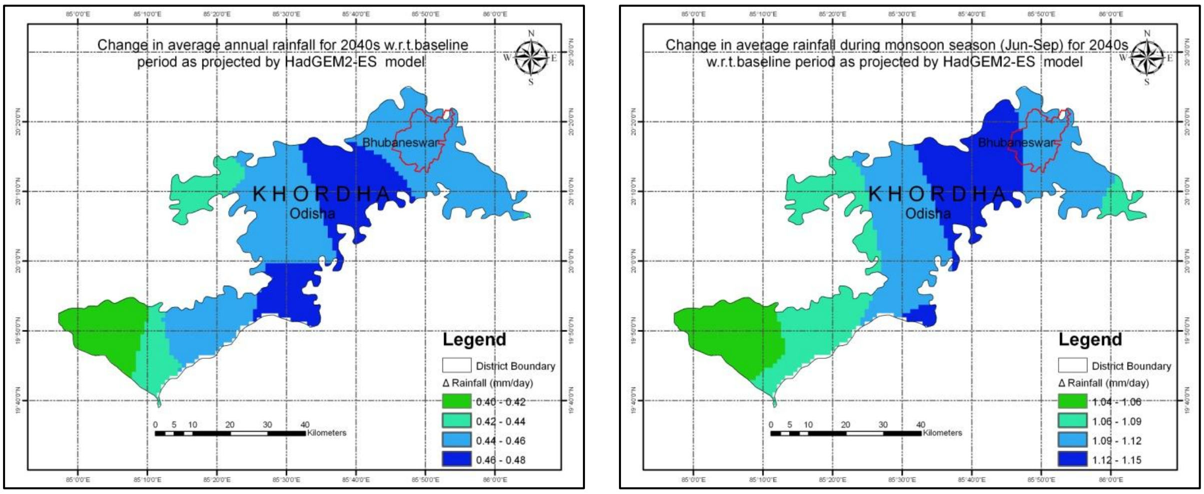


Figure 2-34: Projected change in annual and monsoon season rainfall (in mm/ day) for 2040s in Khordha District of Odisha (Bhubaneswar city is marked with red boundary here)

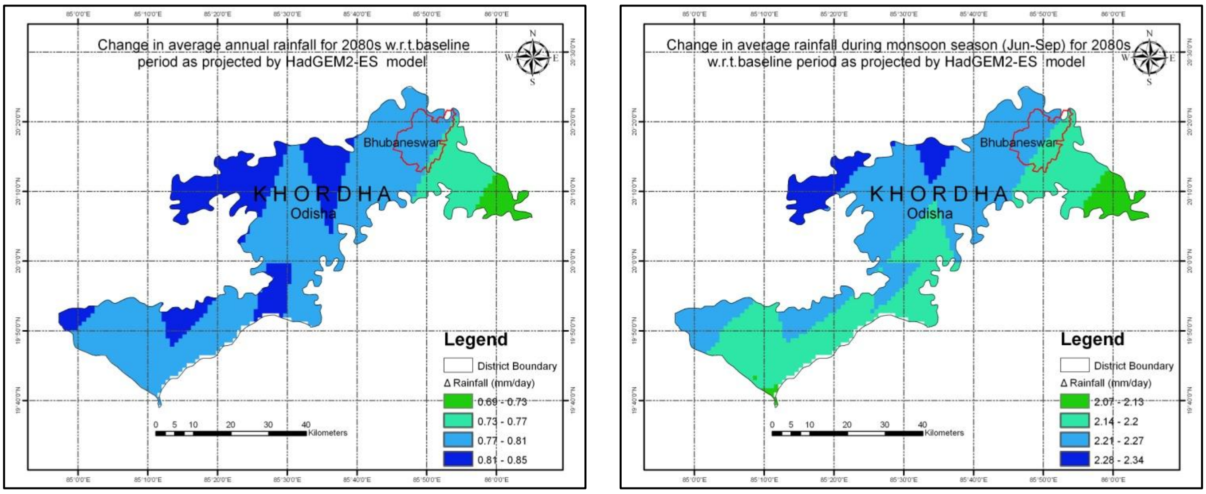


Figure 2-35: Projected change in annual and monsoon season rainfall (in mm/ day) for 2080s in Khordha District of Odisha (Bhubaneswar city is marked with red boundary here)

While an enhanced focus has been placed in recent years on short-term climate change projections (say 2040s), it must be acknowledged that there remain many uncertainties regarding future climate change on local scales. This is because the future level of global greenhouse-gas emissions is uncertain, and the available knowledge about the climate-earth ocean system is still rather inadequate for reliably forecasting the local climate change. The climate information and projections provided in this study should, therefore, be considered only as indicative, not predictive.

According to a recent World Bank Report[9], a four degrees Celsius world would bring about unprecedented heat waves, severe drought, and major floods in many regions, with serious impacts on ecosystems and associated services. In a summary for policy makers report of the Working Group 2 of the IPCC (March 2014)[10], this has been reasserted with a high degree of confidence that globally, the impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires, reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability. Impacts of such climate-related extremes include alteration of ecosystems, disruption of food production and water supply, damage to infrastructure and settlements, morbidity and mortality, and consequences for mental health and human well-being. For countries at all levels of development, these impacts are consistent with a significant lack of preparedness for current climate variability in some sectors. In such a scenario, the frequency and duration of heat waves and extremes in daily rainfall in some States of India including Bhubaneswar city is also likely to increase substantially, taking a toll on disruption to city life and human health. Agriculture too would be adversely affected by the thermal stress due to rise in temperature although part of the loss in soil evapotranspiration due to higher temperature could be compensated by increase in rainfall. Intense rainfall spells could lead to loss of top soils in farmlands and cause sedimentation concerns in river basins and deltas. A warming of the global surface temperature by 4°C could lead to an associated sea level rise of one

[9] World Bank, 2012: Turn Down the Heat: Why a 4°C Warmer World Must be Avoided, World Bank, Washington, D.C.

[10] IPCC, 2014: Summary for Policy Makers, in: Christopher B. Field (USA) et al., Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of the Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

meter or more[11]. Many cities of coastal Odisha are vulnerable to rising sea levels as is the Mahanadi delta.

2.6.5 APPLICATION OF CLIMATE CHANGE STUDIES IN CITY DEVELOPMENT

With increasing demands on resources such as water and energy, expansion of informal settlements and overall expansion of the city of Bhubaneswar is posing enormous challenges to its urban planners. In order to mainstream climate change impact in development planning tailored to the varying physical, socio-economic, and hazard contexts, it is important to understand the climate change trends and its influence on various climate related hazards in urban settlement. The climate change impacts may overwhelm the infrastructure that ensures movement of people, goods, and services; security and health to city residents, and assures livelihood opportunities and economic benefits to increasing numbers of urban migrants. It will have disproportionate impacts on poor and vulnerable urban populations. This necessitates a comprehensive vulnerability assessment for designing medium and long terms adaptation and mitigation measures for continued development in a sustainable pathway. It may be stated here that heat waves and droughts can also cause massive damage on rural (particularly peri-urban surroundings) agricultural/horticulture areas vital to providing food staples to urban population centers. Reservoirs and aquifers quickly dry up due to increased demand on water for drinking, industrial and agricultural purposes. The result can be shortages and price spikes for food and with increasing frequency, shortages of drinking water as observed with increasing severity seasonally in Bhubaneswar and throughout most of the large urban centers in India. From an agricultural standpoint, farmers could be required to plant more heat and drought-resistant crops. Agricultural practices would also need to be streamlined to higher levels of hydrological efficiency. Reservoirs should be expanded and new reservoirs and water towers should be constructed in areas facing critical water shortages. In the short term, the city of Bhubaneswar needs to conduct in-depth “sector studies” for deeper analysis on priority issues facing the city and testing small pilot activities to explore specific vulnerability needs of small areas in which they can begin making changes and monitoring the outcomes. Armed with knowledge of key vulnerabilities and existing adaptive capacities, and drawing on both international and local experience, the city needs to develop climate proof and local resilience strategies and action plans that will enable it to better prepare for the challenges of current and future climate variability. This includes a process of identifying, assessing, and prioritizing actions that will effectively build climate resilience of the city’s systems and resilience of its poorest and most vulnerable populations. These resilience strategies and action plans should be integrated with the city’s development planning processes.

Climate change is expected to lead to warmer temperatures particularly in urban environment due to heat island effect (summer day-time temperatures can reach up to 6°C hotter in Bhubaneswar city than in surrounding rural areas and between 3–4°C warmer at night), resulting in greater variability in local conditions and are likely to increase the frequency, intensity, and duration of such extreme events in unpredictable ways. Greening urban towers and structural spaces is among the most frequently mentioned strategies to address urban heat island effects. The idea is to increase the amount of natural cover within the city. This cover can be made up of grasses, bushes, trees, vines, water, rock gardens; any natural material. Covering as much surface as possible with green space will both reduce the total quantity of thermally absorbent artificial material, but the shading effect will reduce the amount of light, heat and electromagnetic radiation that reaches the concrete and asphalt that cannot be replaced by greenery. Trees are among the most effective greening

[11] IPCC, 2013: Summary for Policymakers, in: Stocker, T.F.; Qin, D.; Plattner, G.K.; Tignor, M.; Allen, S.K.; Boschung, J.; Nauels, A.; Xia, Y.; Bex, V.; Midgley, P.M. (Eds.) Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

tool within urban environments because of their coverage/footprint ratio. Trees require a very small physical area for planting, but when mature, they provide a much larger coverage area. This both absorbs solar energy for photosynthesis (improving air quality and mitigating global warming), reducing the amount of energy being trapped and held within artificial surfaces, but also casts much-needed shade on the city and its inhabitants.

Climate change projections, at current level of scientific understanding, are uncertain at least at local levels for many reasons – not the least of which being that we do not know what kind of energy and lifestyle choices will be made in the future. While climate projections cannot provide exact estimates of how much rise in maximum temperature could be expected in the following week or month or how much monsoon precipitation will fall in the city of Bhubaneswar by the middle of this century, the projections provide very useful information on the changes in trends and ranges of climate conditions here. Uncertainty in climate change projections is challenging and city planners need to explore innovative actions and "no regret" strategies that are capable of being resilient against a wide range of climate conditions, rather than relying on traditional approaches to planning and engineering that assume the future climate, including extreme events, are simply predictable reflections of historical trends.

The integration of urban systems, climate change and vulnerability to test resilience strategies would need to be based on considering both *direct* and *indirect* impacts of climate change. This would be required to develop adaptation strategies that enable the responsible agencies to confront the complexities of climate change and introduce actions that mainstream climate resilience into city planning and operations and develop strategies that support the most vulnerable groups within the city to respond effectively to climate change induced risks.

The city of Bhubaneswar needs to explore what existing capacities can enhance their ability to adapt and be more resilient to climate change. These assessments result in vital information that feeds into the resilience planning processes. They help ensure that resilience strategies, actions, and interventions will target the most vulnerable populations, address vulnerabilities of urban sectors and systems, and build on existing capacities. Climate vulnerability assessment entails:

- An understanding of projected climate scenarios and potential impacts and the limitations of the projections;
- Identification of who/what are the most vulnerable groups, areas, sectors, and urban systems and how they may be affected;
- Identification of the range of factors that systematically combine to make them vulnerable, including both direct (e.g. exposure to hazards) and indirect (e.g. regional or international food security) factors; and
- Assessment of existing capacities to adapt

3 Development of Exposure Database for Bhubaneswar City

Exposure is a critical component of any risk assessment study. Exposure constitutes population, the built environment, systems that support infrastructure and livelihood functions, or other elements present in the hazard zones that are thereby subject to potential losses. Quantifying building exposure includes the "bottom-up" approach that includes classifying the different types of buildings into different categories, estimating the number of buildings under each category, combining building counts with per unit built-up floor area, and applying costing information relevant to the conditions. In this regard, modeling vulnerability of a system to natural hazards involves establishing a relationship between the potential damageability of critical exposure elements and different levels of local hazard intensity for the hazard of interest. Thus, damage susceptibility associated with a given level of hazard is measured in terms of a Mean Damage Ratio (MDR) defined as the expected proportion of the monetary value of repair needed to bring back the facility to pre-event condition, over the replacement value of the facility, as a consequence of the hazard for various exposure elements.

In the present study, the objective of this exposure database development is to create a ward-level database of various assets. Data for various exposure elements like demography, households, public health, education, housing, amenities, transportation etc. were collected from different sources and finally exposure database was created at ward-level.

3.1 Data sources

The data used for the analysis includes:

4. Demographic and housing data of 2011 vintage from Census of India
5. Administrative boundary and major landmarks from BMC
6. Transportation and river network data from BMC
7. Building cluster data developed from LISS-4 satellite images
8. Structural information and unit replacement costs of different housing types and infrastructural elements from the field survey and literature review
9. Cultural heritage sites from internet sources

3.2 Inventory of vulnerable demographics, buildings and infrastructure

Inventory of vulnerable buildings, infrastructure, demographics and any other asset elements present in hazard zones and thereby subject to potential losses constitute critical exposure elements that are considered for risk assessment. Figure 3-1 shows the broad categories of exposure elements considered in this study.

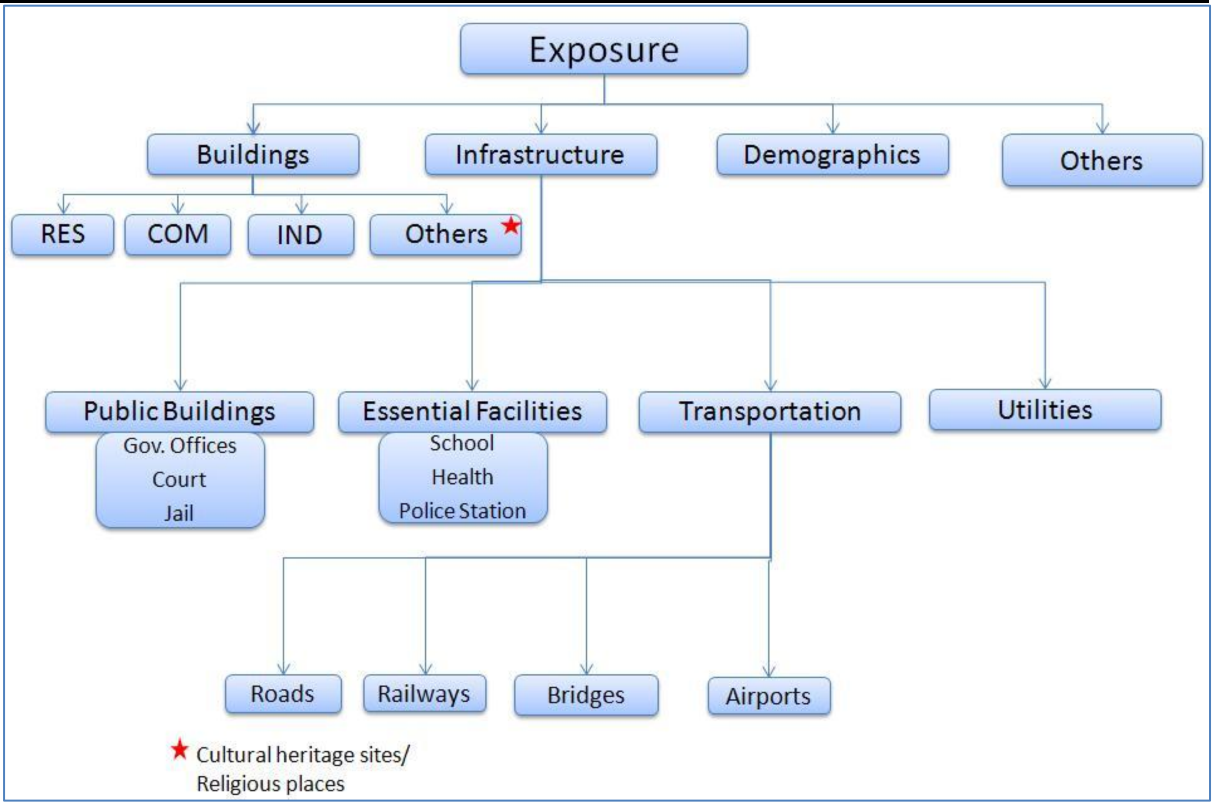


Figure 3-1: Broad categories of exposure elements considered in the study

3.3 Methodology Adopted for Exposure Database Development

The team quantified exposure using the "bottom-up" approach. This includes classifying the different types of houses and infrastructure elements into different categories, estimating their count under each category, combining building counts with per unit built-up floor area in case of buildings or other infrastructure characteristics, and applying per unit costing information relevant to the category. The output of exposure is the total monetary value by asset category. The overall process of developing the exposure database is illustrated in Figure 3-2.

One of the important aspects of exposure data development was to categorize the exposure elements into 'aggregate' or 'site specific', to analyze the impact of hazards. Aggregate data were those where area and count are summed up at a suitable administrative unit level (for instance at Municipal Ward-level), while the site-specific data were represented by geographic locations (coordinates). A general rule for categorizing data as aggregated or site specific was based on the level at which the location information is available.

The first step of developing exposure database involved collection of data from concerned agencies. In the present study, demographic data is collected from Census of India and field survey conducted by the project team, while various site-specific data is collected from BMC and other government agencies. During data processing, the tabular and GIS data collected were processed into usable format for the defined exposure elements and brought at the ward level with required attribute information associated with them. The processed data was then analyzed for data gaps and the team identified alternate data sources to fill these gaps.

After processing, these data sets are appended with other exposure data processed earlier. In the next step, the spatial location of the site-specific exposure data is validated using higher resolution satellite images/ Google Earth. For example, the spatial distribution of houses in this study was determined by using similar methods. To get an idea of construction practices (construction materials, structural types, architecture, and unit costs) for residential, commercial, industrial buildings, as well as for religious and infrastructural facilities such as roads, bridges, etc., the team undertook sample surveys. During these surveys, inputs from various government and non-government agencies are collected and existing information are validated through personal interviews, photographs, and documents.

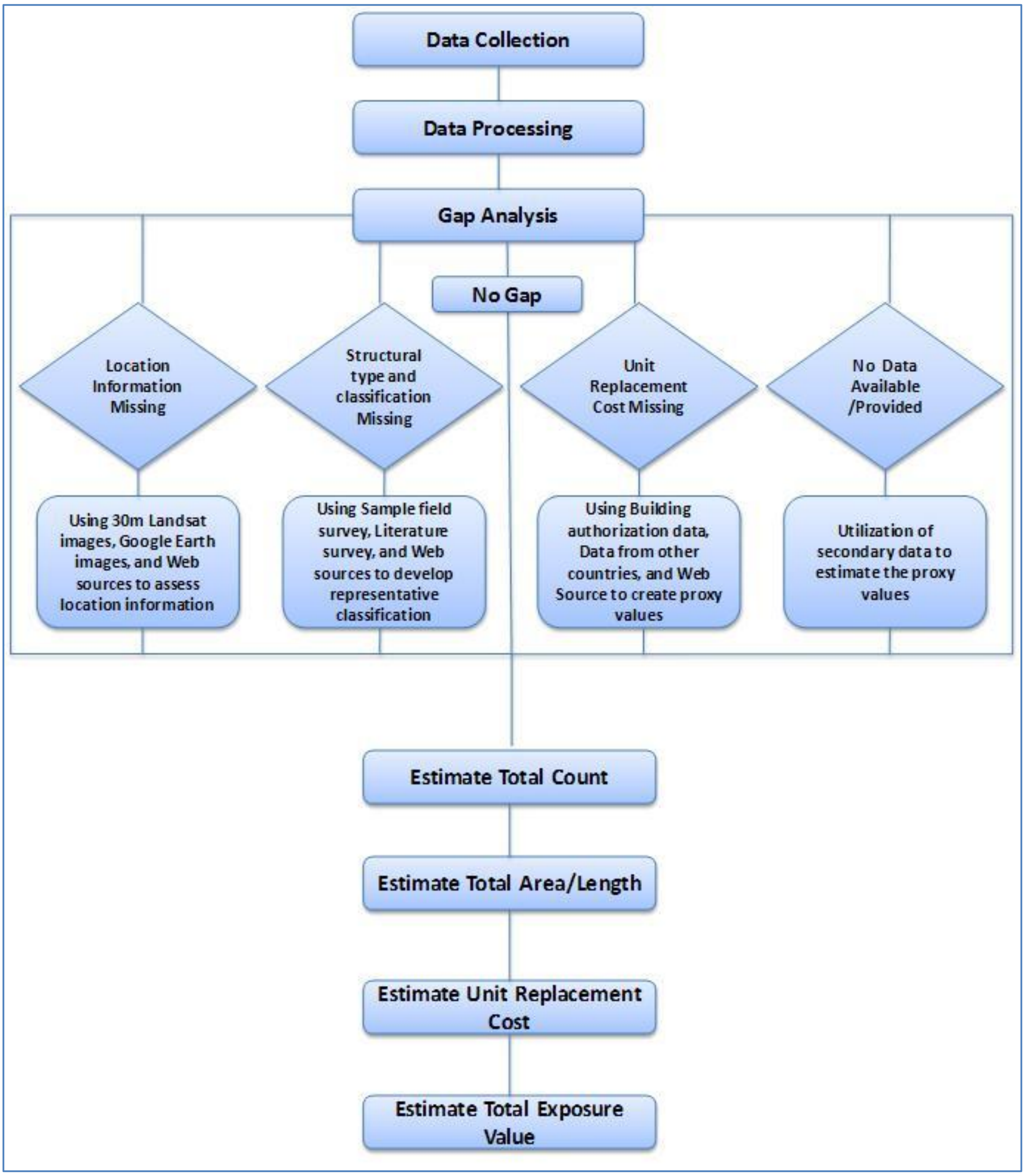


Figure 3-2: Approach to exposure development

The verified and processed data was then used as inputs to the relevant steps (count estimation, area/length estimation, unit cost estimation) from which the final total exposure value was calculated.

3.4 Analysis of Exposure Elements

3.4.1 POPULATION

The key sources of demographic data in the present study are Census of India (Census 2011) and BMC, and these data are available at municipal ward level for Bhubaneswar city. This includes population distribution by age, gender, education, and occupation. In addition, details about the other exposure elements such as access to electricity, potable water and sewerage etc. are analyzed.

As per Census 2011, the total population of the city is 840,834, which is distributed in 67 municipal wards. Out of city's total population, about 53% are male while remaining 47% are female (Figure 3-3). It is observed that Ward Number 1 has the highest percentage of male population (about 63% of ward's total population) while Ward Number 6 has higher percentage of female population (over 50% of ward's total population). The ward-wise distribution of population is presented in Table 9-1 of Annexure 2: Detailed Exposure Data of this report.

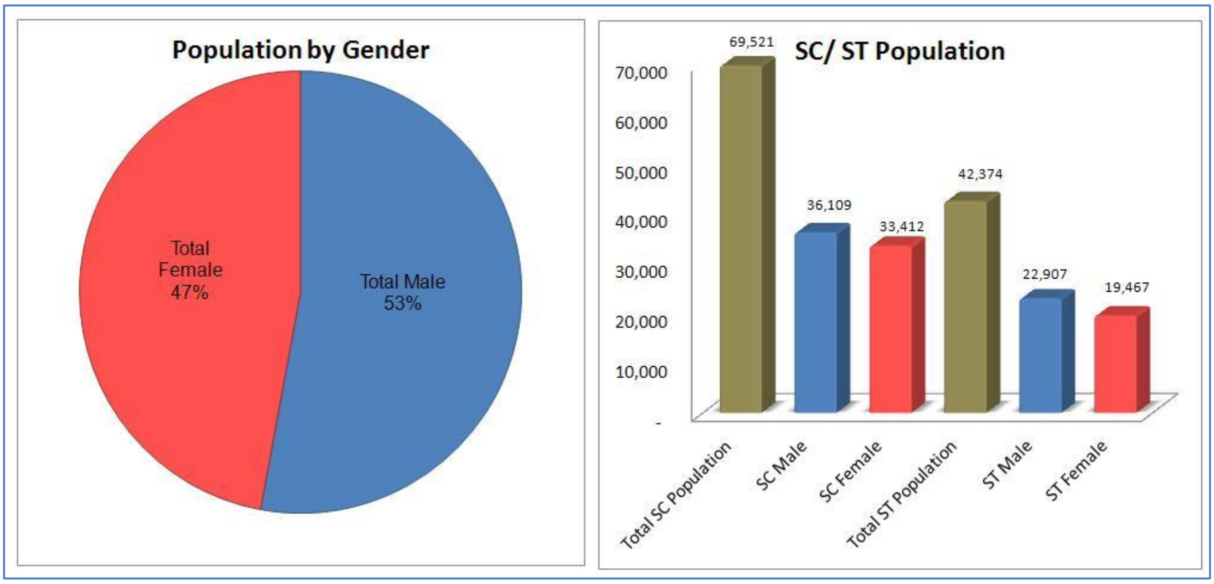


Figure 3-3: Distribution of population by gender and SC/ST (caste)

In Bhubaneswar city, about 13% of city's total population falls in Schedule Caste/ Schedule Tribe (SC/ST) category. Again, it is observed that out of the total SC/ST population of the city, about 62% falls in SC category and remaining 38% falls in ST category (Figure 3-3). The SC population of the city comprises of 52% male and 48% female while the ST population comprises of 54% male and 46% female.

The city has a higher literacy rate and about 83% of its total population is literate. Moreover, among the total literate population of the city, 55% are male and 45% are female. In terms of ward-wise distribution of literacy rates, it is observed that most of the wards have identical share of literacy rates, which is about 83% of the ward's total population. Details of ward-wise distribution of literacy rates are presented in Table 9-2 of Annexure 2: Detailed Exposure Data.

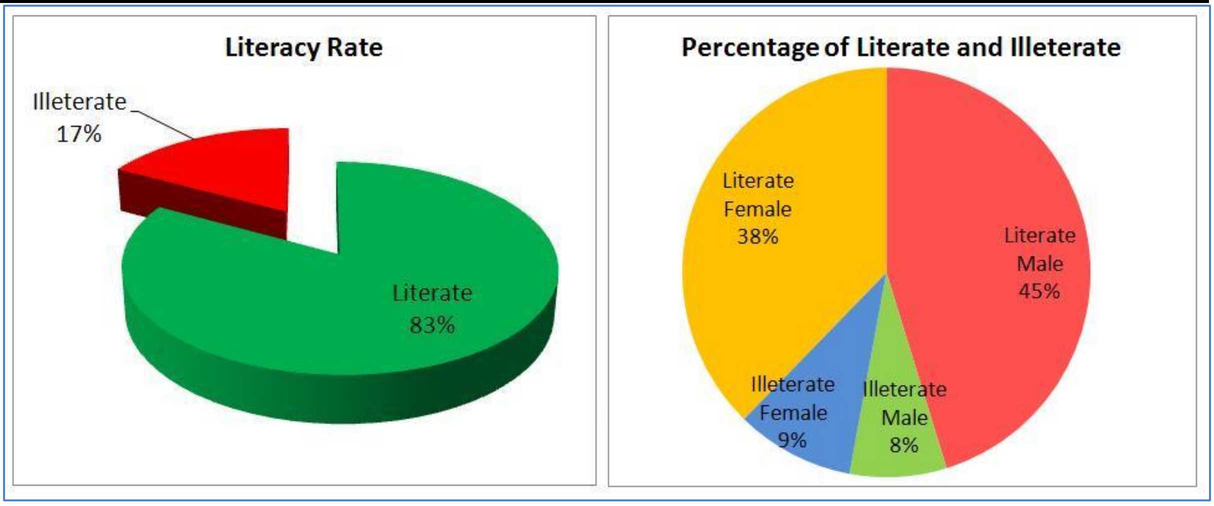


Figure 3-4: Distribution of population by literacy

The city has about 63% of non-working population residing across various wards. The non-working population comprises of about 62% female and about 38% male (Figure 3-5). It is also observed that ward number 4 has the highest number of non-working male and female population while compared to other municipal wards.

If we consider the percentage child population (<6 Years) with respect to city's total population, it is observed that Bhubaneswar city has about 9.7% (81,625 children) of child population located in it (Figure 3-5). This child population (< 6 Years) comprises of about 53% male child and 47% female child. Table 9-1 of Annexure 2: Detailed Exposure Data presents the ward-wise distribution of child population (< 6 Years).

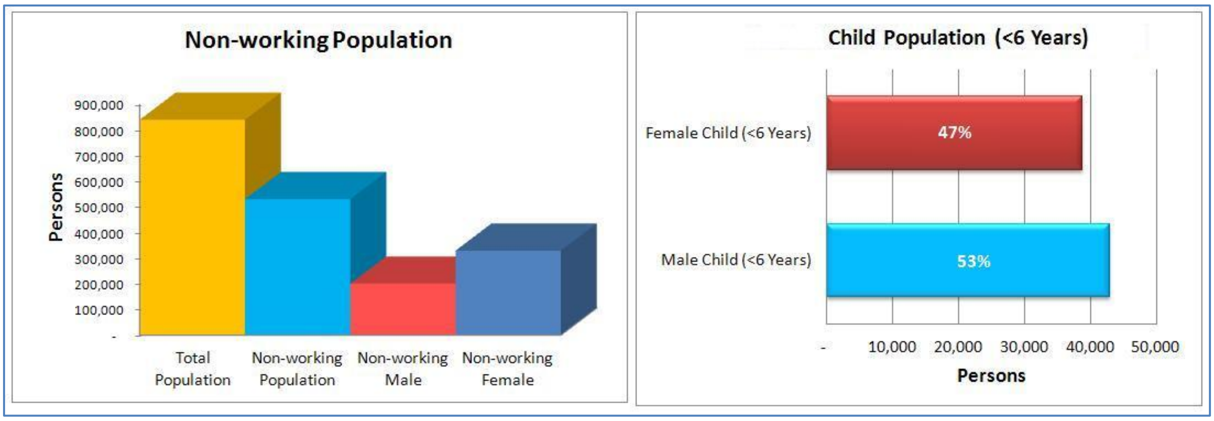


Figure 3-5: Distribution of non-working population and child population (<6 Years)

Figure 3-6 presents the density of population by municipal wards. It is observed that ward number 21 has the highest population density of more than 54,969 persons/ sq. km. whereas ward number 15 is the least densely populated (about 1,136 persons/ sq. km.) amongst all the wards.

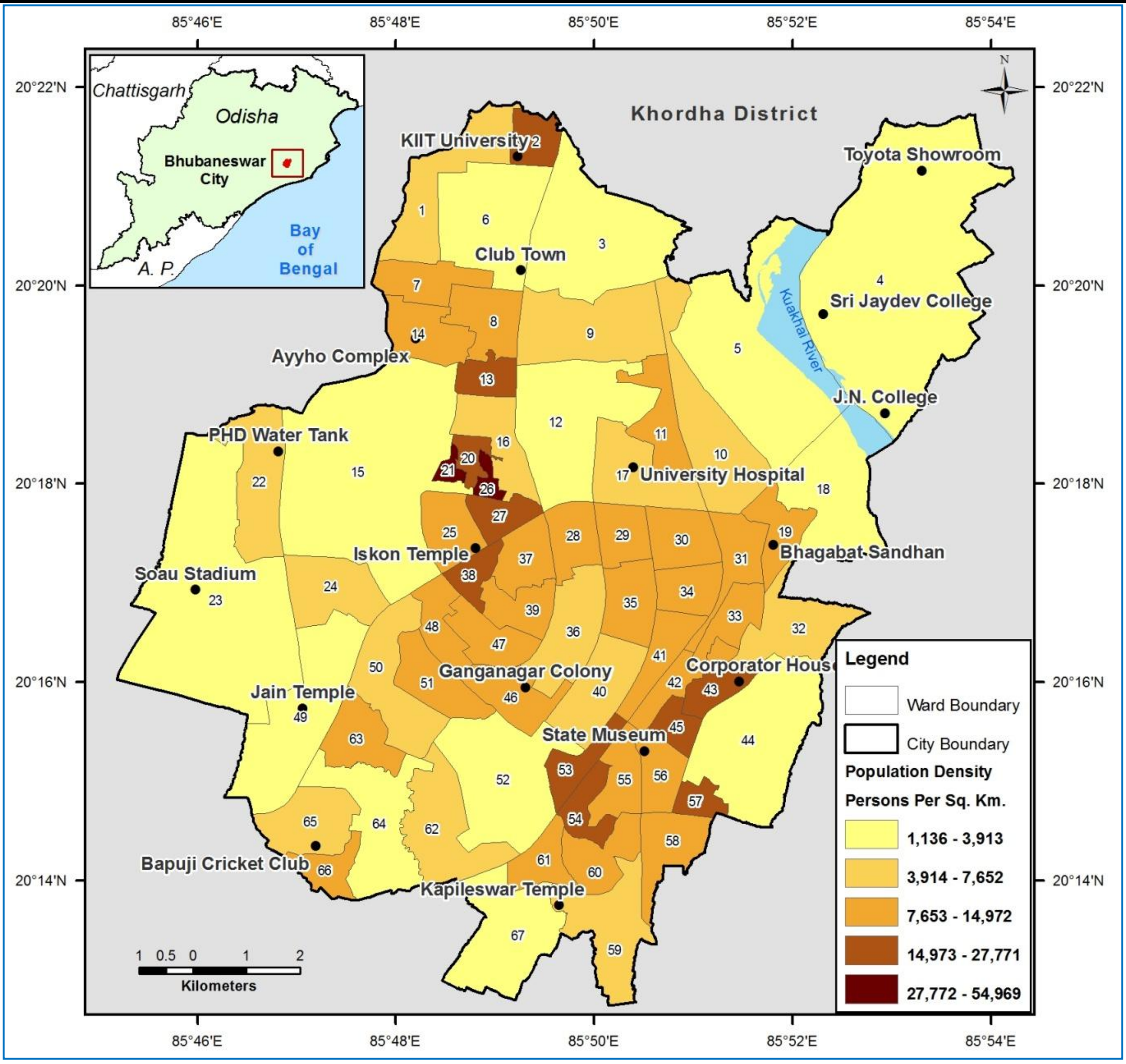


Figure 3-6: Ward-wise population density

3.4.2 HOUSING

In the present study, building classification is carried out primarily based on occupancy types and structure types. The occupancy-based classification differentiates housing into four occupancy classes viz., residential, commercial, industrial, and others. The class named as others comprises of occupancy classes such as schools and colleges, hospitals and dispensaries, government offices, places of worship etc. Structure based classification, categorizes the houses based on the construction materials used (roof and wall materials) as per Census 2011, their architecture, and height. The analysis also considered classifying houses into occupied and vacant (Figure 3-8). The different classifications represent elements that are distinctly vulnerable to the same level of hazard. The determined exposure value is used as an input to the vulnerability and risk assessment.

As mentioned above, the source of housing data is the Census of India (2011), which provides city-level data based on the usage and construction materials. Further, the data generated from the field survey conducted by the team and information gathered from local builders is used for filling the data gaps and validation of information. In this process, the city-level data is brought to the ward level using the household numbers available at ward level in the demographic data table of Census. These statistics are then correlated with the housing data received from BMC and finally ward-wise distribution of houses based on their occupancy and structural class are determined. Figure 3-7 presents the building footprints delineated from LISS IV satellite images for Bhubaneswar city. The classifications are done based on the tone, texture, shape, size, pattern, and associations between buildings as present on satellite images. For example, residential strips generally have a uniform size and spacing between structures with linear driveways and lawn areas. Commercial strips are more likely to have buildings of different sizes with non-uniform spacing between them. They are also characterized by the larger driveways and parking areas associated with them. Commercial areas are often abutted by residential, agricultural, or other contrasting uses that help in defining them. Similarly, Industrial areas are generally situated at some distance from urban centers. The ward-wise distribution of houses based on their occupancy and structure is given in

Table 9-4 of Annexure 2: Detailed Exposure Data.

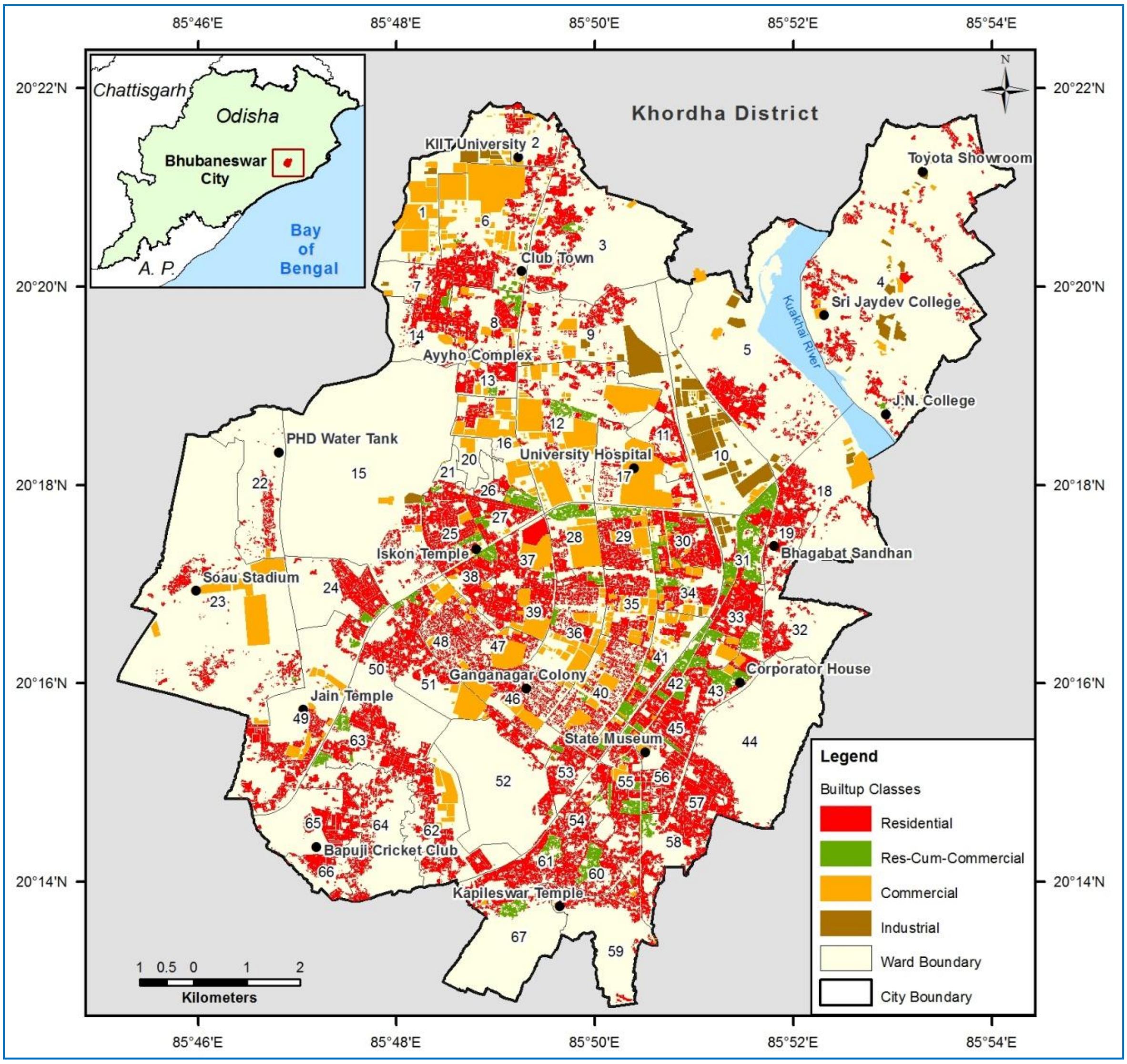
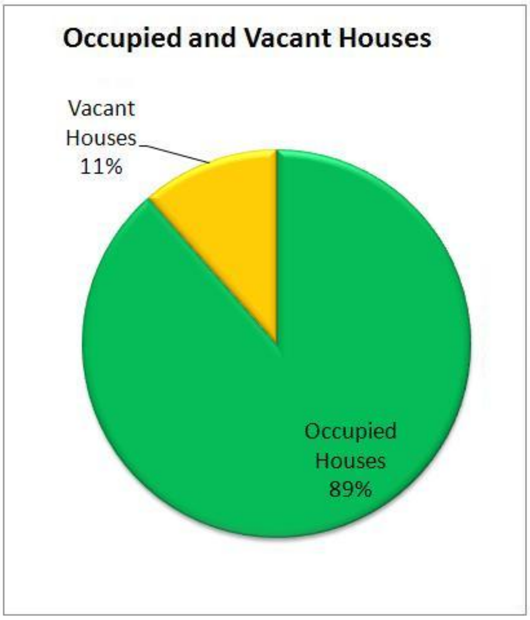


Figure 3-7: Distribution of built-up area by occupancy and major building use

It is observed that about 89% of the total houses in Bhubaneswar city are occupied and the remaining 11% are vacant (Figure 3-8). The occupancy based distribution of housing shows that about 75% of the houses are used for residential purposes, about 14% are used for commercial or residential-cum-commercial use, about 2.5% houses are used for industrial use, and remaining 8.5% houses are used for other use that include social and public uses, viz., schools, colleges, hospitals, dispensaries, place of worship etc. Figure 3-8 provides the distribution of houses based on their occupancy for Bhubaneswar city.



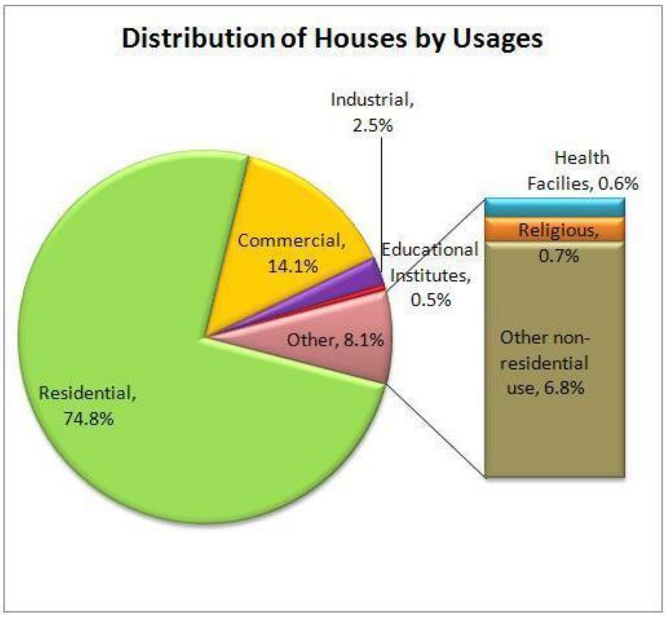


Figure 3-8: Percentage distribution of occupied and vacant house (left), Distribution of the Census houses based on usage in Bhubaneswar city (right)

3.4.2.1 *Structural Types*

From vulnerability and risks to hazard point of view, structural classification of buildings is a critical component of exposure data development. The vulnerability of houses to various hazards depends largely upon the construction materials used, structural types, and height the houses, which are categorized into different structural types based on these different characteristics. The different categorizations represent elements that are distinctly vulnerable to the same level of hazard. As the available data lacked structural details, the teams undertook a sample field survey and collated that information with data from other sources to categorize the buildings into different structural types. From structural vulnerability point of view, based on materials used for construction of walls and roofs, and building structure, the residential houses of Bhubaneswar city is classified into 90 distinct combinations that are further grouped into seven distinct structural categories (Table 3-1).

Table 3-1: Building Categories by construction materials and Structural Types

S.No.	Building Category	Structural Types (combination of major wall and roof materials)
1	Grass/ thatch/ bamboo/ wood/ plastic/ polythene etc.	Grass/ thatch/ bamboo/ wood/ plastic/ polythene etc. used in combination for wall and roof materials
2	Mud/ Unburnt Brick/ Stone without mortar	Mud/Un-burnt brick/stone without mortar as wall materials and grass/thatch/bamboo/ Plastic/ polythene/handmade tiles/ machine-made tiles etc as roof materials
3	Light Metal	G.I./metal/asbestos sheets as wall materials and grass/thatch/bamboo/ Plastic/ polythene/tiles/ G.I./metal/asbestos sheets as roof materials
4	Burnt Brick/ Stone with mortar with Temporary Roof	Burnt brick/ Stone packed with mortar as wall materials and temporary roof (tiles, wood, GI, slate, etc.)
5	Reinforced Masonry Buildings	Burnt brick walls and RCC roof
6	Reinforced Concrete Frame (RCF) with brick	Reinforced Concrete Frame buildings with brick-in-fills walls and RCC roof

S.No.	Building Category	Structural Types (combination of major wall and roof materials)
	infill	
7	Reinforced Cement Concrete (RCC)	Combination of concrete and steel to build a structure

3.4.2.2 Residential

The residential houses of Bhubaneswar city are broadly classified into four categories viz., Villas, Apartments, Row Houses and Huts based on construction materials and structures. Sample photographs of each category are provided in Figure 3-9. Though, in some cases, one category of house is often found mixed up with other categories, however, in some cases the distinct clusters can be identified. For demarcation of ward-wise residential house clusters, interpretation of LISS IV satellite image, landmark locations received from BMC and Census 2011 housing statistics are considered. The results obtained are then correlated and validated against the field survey data collected by the survey team at sample wards.

Apartment

Villa

Row Houses

Huts

Figure 3-9: Different types of residential houses in Bhubaneswar

From vulnerability and risk point of view, the residential houses are further categorized into various classes based on condition and structural parameters. In terms of residential building use, the houses of the city are classified into residence (about 98%) and residence-cum-other use (about 2%) Figure 3-10. Amongst the houses used exclusively for residential purposes, 60% are in good condition, 35% are in livable condition and about 5% are in deteriorating condition. For Residence-cum-other use, about 47% and 48% of the houses are in good and livable condition, respectively. The ward-wise distribution of the Census houses based on the condition of the houses is presented in Figure 3-10.

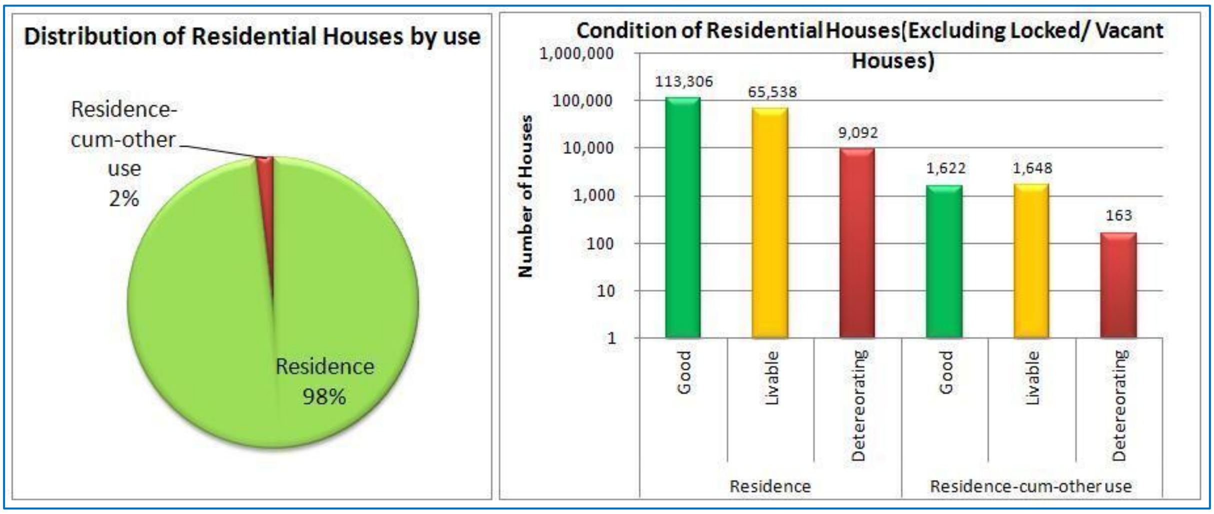


Figure 3-10: Distribution of residential houses by use (left), Condition of residential houses in Bhubaneswar city (right)

Reinforced concrete frame (RCF) with brick infill is the dominant structural class that comprises of about 72% of the residential houses (Table 3-2). Burnt brick (with mortar) with temporary roof and masonry buildings are the next dominant classes that are present for 10% and 8% residential houses, respectively (Figure 3-11). The latter two types of structures are more common in older areas and suburban areas of the city, and in isolated pockets inhabited by economically weaker sections of population. Houses made up of temporary materials like mud/ unburnt bricks/ stone without mortar are more commonly found in areas of unauthorized encroachments and slums. About 4% residential houses of Bhubaneswar are pure Reinforced Cement Concrete (RCC) buildings and majority of them are observed in planned areas of the city. Among these RCC buildings, about 77% are apartments and remaining 23% are villas. The ward-wise distribution of residential houses by structure is presented in of Annexure 2.

Table 3-2: Residential built-up area by structural types

Structural Types	**Grass, Thatch, Bamboo, Wood, Mud, Plastic, etc.**	**Mud/Unburnt Brick/Stone without mortar**	**Light Metal**	**Burnt Brick/ stone with mortar having temporary Roof (Tiles, wood, GI, slate, etc.)**	**Masonry Building**	**Reinforced concrete frame with brick infill**		**Reinforced Cement Concrete**		**Any Other**
						Villa	**Apartments**	**Villa**	**Apartments**	
Total Built-up Area (sq. km.)	0.37	3.26	0.05	6.44	5.51	35.35	12.88	0.59	2.02	0.12

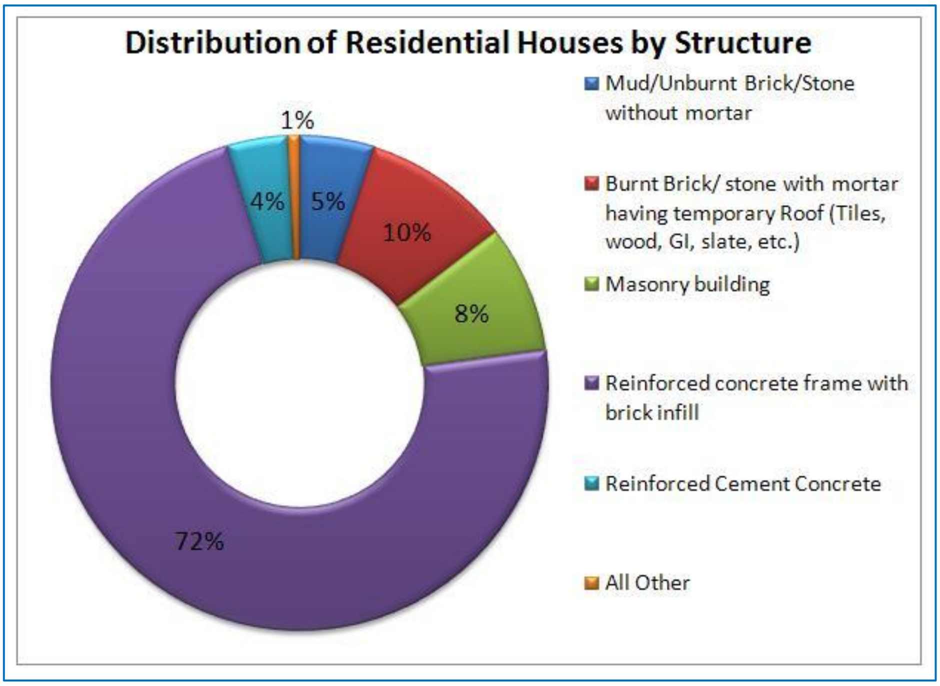


Figure 3-11: Distribution of residential houses by building construction materials and structure

3.4.2.3 Commercial

The data regarding the number and location of commercial buildings in Bhubaneswar city is collected from the Census of India 2011, BMC and other internet sources. The GIS data with detailed landmarks received from BMC is collated with the records obtained from Census of India at ward level. In the next step, based on Census records, the commercial buildings are classified into shops and offices, hotels, lodges, guest-houses, residence-cum other uses, and other non residential houses. All these categories of data are combined together to get the ward-wise aggregated number of commercial buildings in the city. Sample photographs of some of the commercial centers are provided in Figure 3-12.

It should be noted that the data on commercial buildings do not include schools and colleges, hospitals and dispensaries, places of worship, and industries.

Figure 3-12: Different types of commercial buildings/ centers in Bhubaneswar

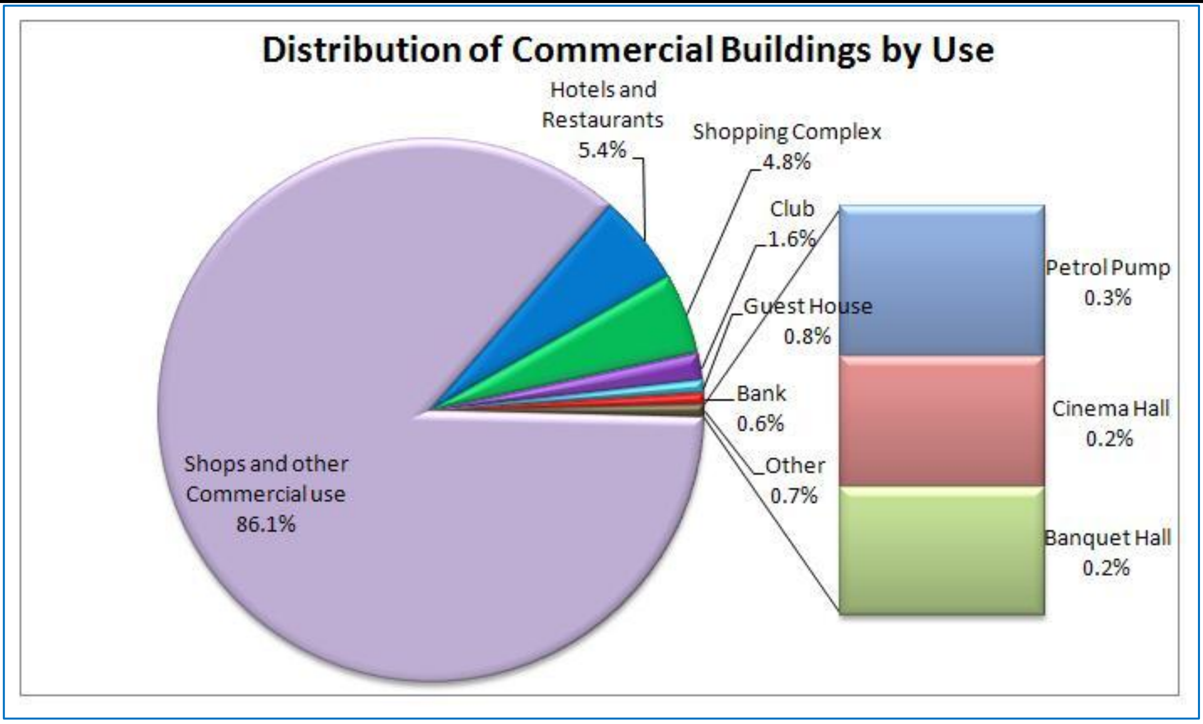


Figure 3-13: Distribution of commercial buildings by use in Bhubaneswar city

Figure 3-13 presents the distribution of various commercial establishments in Bhubaneswar city. It is observed that shops and commercial centers account for more than 86% of the total commercial buildings in the city. Hotels and restaurants, and shopping complexes are the next major commercial categories that account for about 5.4% and 4.8% of total commercial buildings, respectively. Ward number 1 has the highest percentage of commercial built-up area (about 18%), followed by ward number 12 and 23 (about 13% each) with respect to the total commercial built-up areas.

3.4.2.4 Industrial

Bhubaneswar is a largely residential city with outlying industrial areas. Mancheswar Industrial Estate and Chandaka Industrial Estate are among the major industrial sites that hold large and small-scale industries. Railway Carriage Repair Workshop (Mancheswar), Sakti Group of Industries (Mancheswar), Drugs and Chemicals IE (Chandaka) are well known industrial establishments of Bhubaneswar. The other types of industries of the city include engineering and fabricated products, engineering spare parts, corrosion protection products etc.

The data regarding the number and location of industrial buildings in Bhubaneswar city is collected from the Census of India 2011, BMC, and other internet sources. Similar to the processing of commercial buildings, the industrial buildings are also classified and aggregated ward-wise. The city has about 1.47 sq. km. of industrial built-up areas distributed largely in 21 out of 67 municipal wards. In terms of percentage distribution of industrial built-up by ward w.r.t. total industrial built-up area of the city, it is observed that ward number 10 has the highest percentage of industrial built-up area (about 46%), followed by ward number 9 (about 14%), ward number 4 (about 12%), ward number 31 (about 6%) and ward number 1 (about 6%) Figure 3-14.

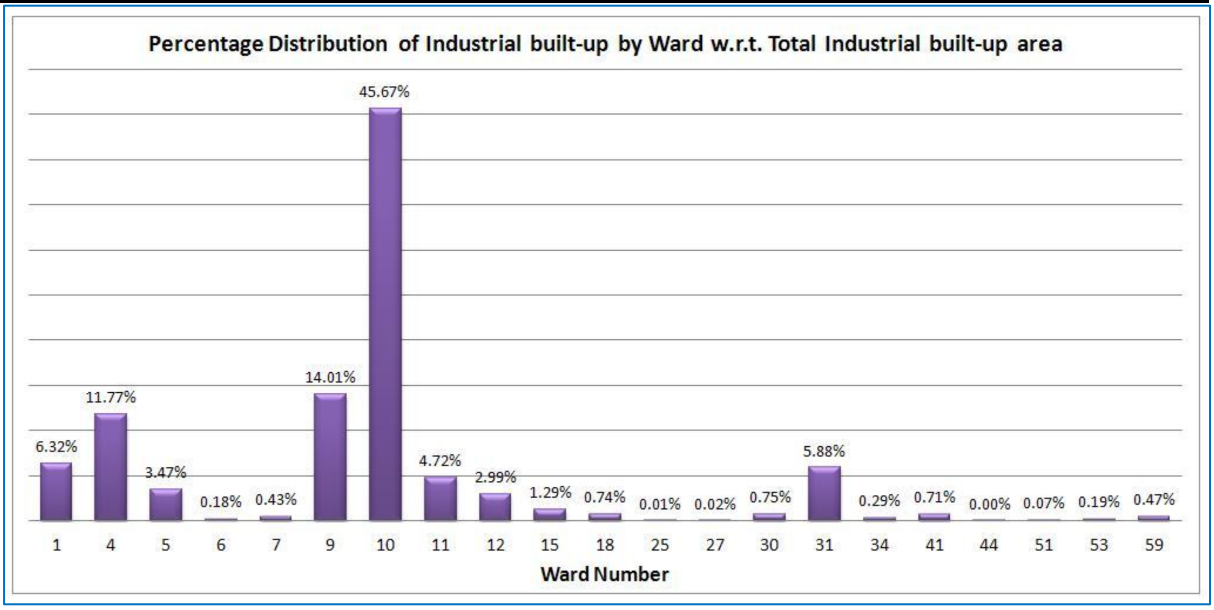


Figure 3-14: Ward-wise distribution of industrial built-up area by wards w.r.t. the total industrial area of the city

Sample photographs of some of the industries of Bhubaneswar city are presented below in Figure 3-15.

 Railway Carriage Repair Workshop	 Drug and pharmaceuticals

Figure 3-15: Different types of industries in Bhubaneswar city

3.4.3 Essential Facilities and Public Buildings

This section presents exposure data development and analysis of essential facilities (educational and health facilities) and public buildings (government offices, fire stations, police stations, religious places) in Bhubaneswar city.

3.4.3.1 Educational Facilities

Educational institutes play a critical role in mitigation and recovery operations during and after disasters as these are generally used as shelters. The data source for educational institutions for Bhubaneswar city is BMC and Census of India 2011. The landmarks data acquired from BMC is the main source of school locations distributed in various wards, while

Census data provides information about the structure of houses that are distributed ward-wise based on the household numbers available in the demographic data at ward level. As per data received from BMC, there are 346 educational institutions located in Bhubaneswar city that comprise of four main categories viz. schools, college, university and other educational institutes and cover about 3.58 sq. km. of built-up areas. It is observed that the highest number of educational institutions are located in ward number 6 (22 institutions) followed by ward number 4 and 35 (14 institutions in each ward). Figure 3-16 presents the spatial distribution of schools in Bhubaneswar city.

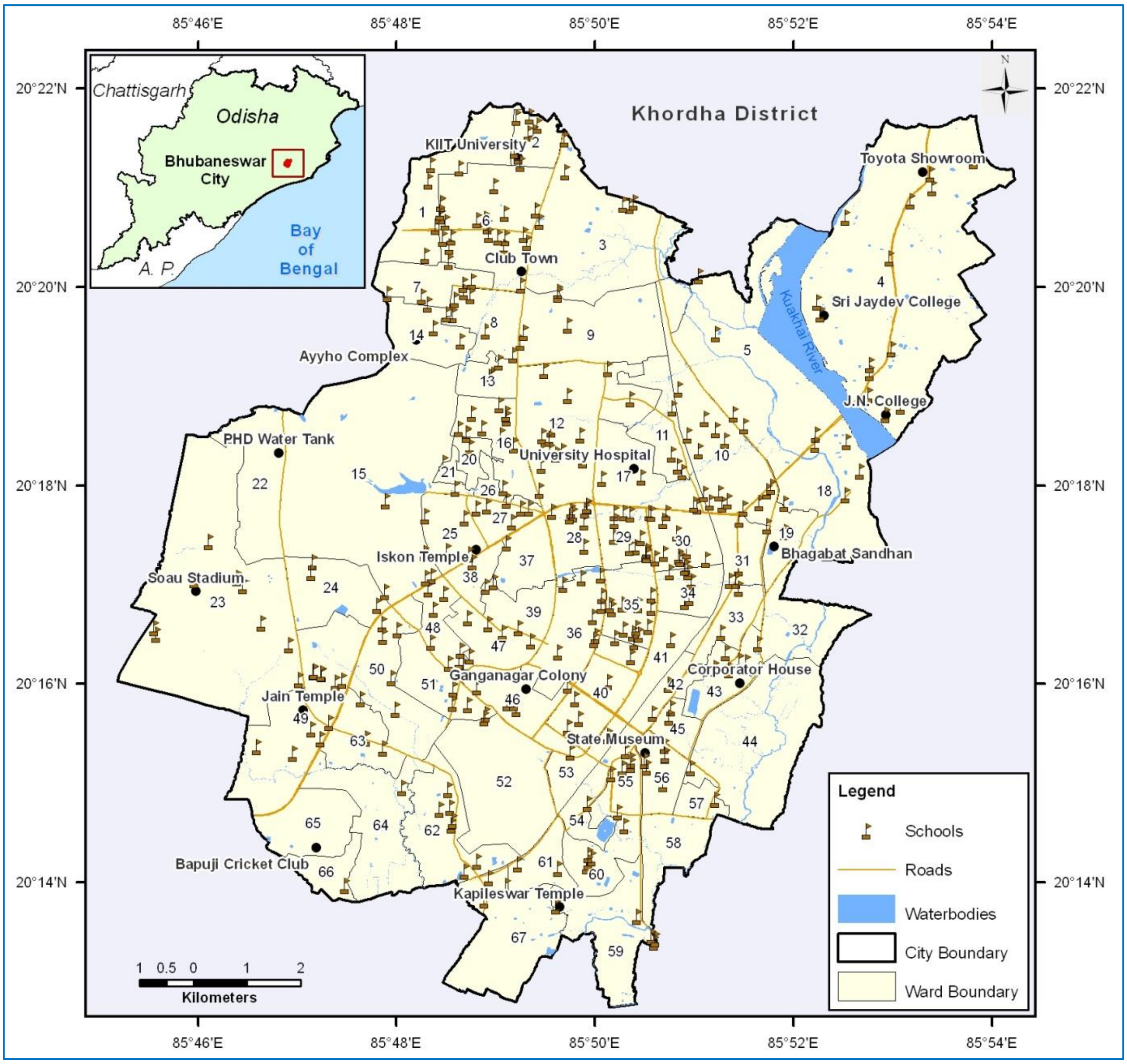


Figure 3-16: Ward-wise distribution of schools in Bhubaneswar city

3.4.3.2 Health Facilities

The health facilities play a critical role in mitigation and recovery operations during and after disasters. For Bhubaneswar city, the source of health facility data is from BMC and Census of India 2011. Data for health facilities received from the Census (2011) and BMC are correlated and collated ward-wise to estimate amount of built-up areas for each of the health centers at ward level. There are 65 major health centers located in Bhubaneswar city that comprise of hospitals, nursing homes, dispensaries, clinics and other health facilities (optical centers, blood banks etc.). It is found that hospitals and nursing homes constitute about 76%

of the health facilities of Bhubaneswar city Figure 3-17. The locations of the major hospitals are presented in Figure 3-18 below.

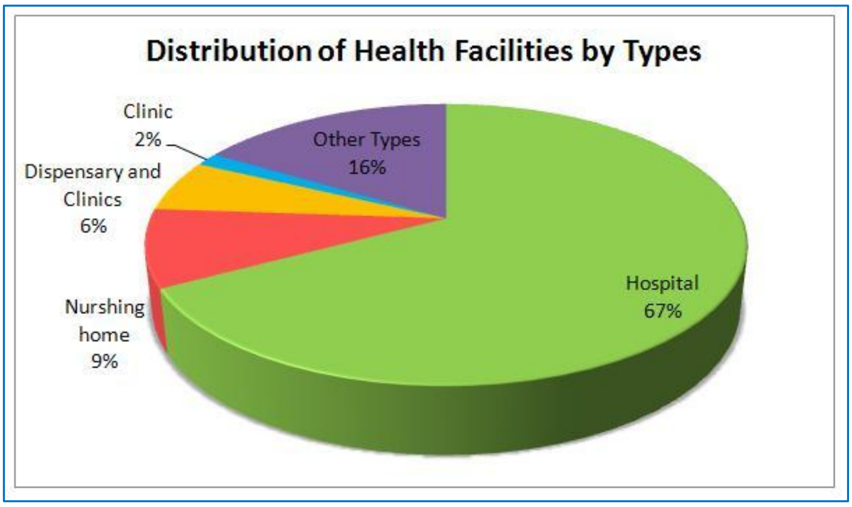


Figure 3-17: Distribution of Health Facilities in Bhubaneswar City by types of services offered

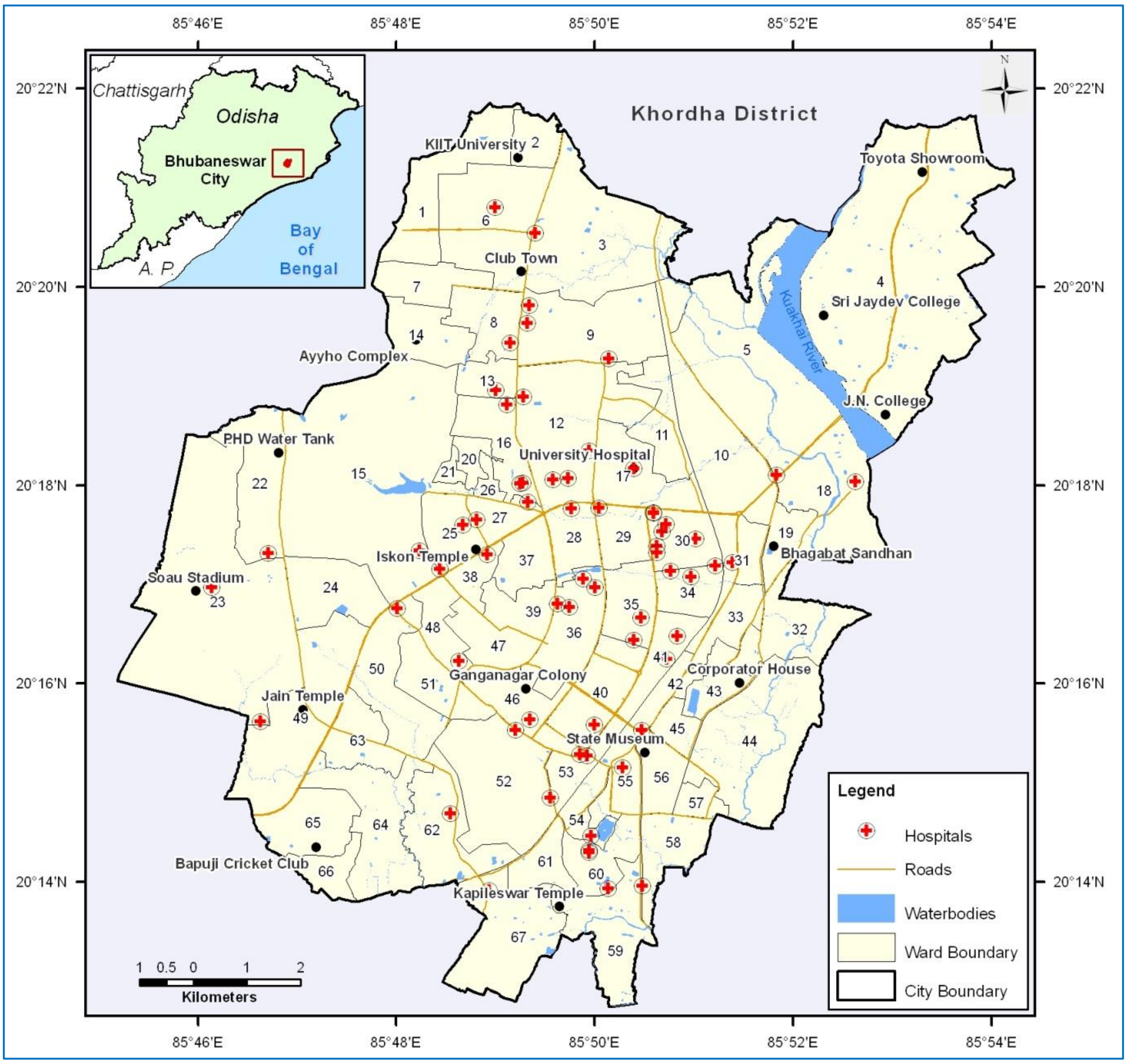


Figure 3-18: Ward-wise distribution of hospitals in Bhubaneswar city

3.4.3.3 Police Stations

The source of data for police stations in Bhubaneswar city is acquired from BMC and Police Commissionarate Bhubaneswar-Cuttack (http://bhubaneswarcuttackpolice.gov.in/). As per data received, there are 15 police stations distributed in 12 wards. The police headquarter (Commissionarate Traffic Police) office is located at Ashoknagar in ward number 40. Figure 3-19 presents the spatial distribution of police stations across the city.

Figure 3-19: Distribution of police stations in Bhubaneswar City

3.4.3.4 Fire Stations

Fire service in India is the first responder to any kind of emergency and plays a critical role in risk mitigation. The source of data for fire stations located in Bhubaneswar city is BMC and Odisha State Fire Service Department. There are six fire stations located in the city at an average distance of 2-3 kilometers between them. Figure 3-20 presents the spatial distribution of fire stations in Bhubaneswar City.

Figure 3-20: Distribution of fire stations in Bhubaneswar City

3.4.3.5 Government Offices

The source of data for main government offices in Bhubaneswar city is received from BMC. This data includes information on types of government offices and their spatial location. Bhubaneswar is a planned city and the 175 government offices are found to be located mostly at specific wards in clusters. Ward number 36, 30, 12, 10, 29, 16 constitute most of these government office clusters. Figure 3-21 presents the spatial distribution of government offices in Bhubaneswar city.

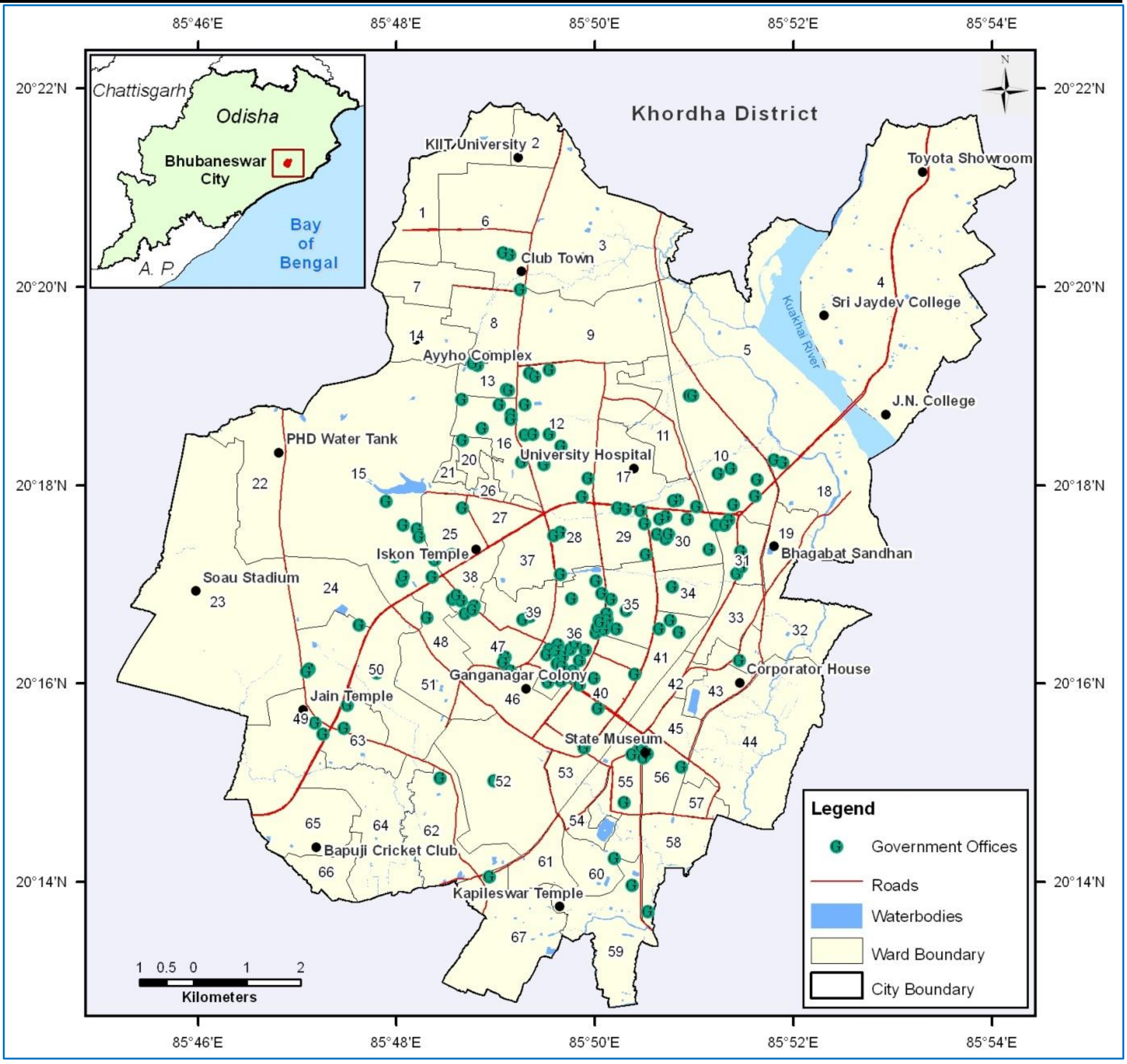


Figure 3-21: Distribution of government offices in Bhubaneswar City

3.4.3.6 Religious Places

Places of worship are important from the disaster management point of view. During times of disasters, these can be used as temporary shelters. The source of data for this analysis is received from BMC and the Census of India (2011). The BMC data is considered as the primary source that comprises of spatial locations of the 117 religious places located in Bhubaneswar city. Figure 3-22 presents the spatial distribution of religious places across various wards.

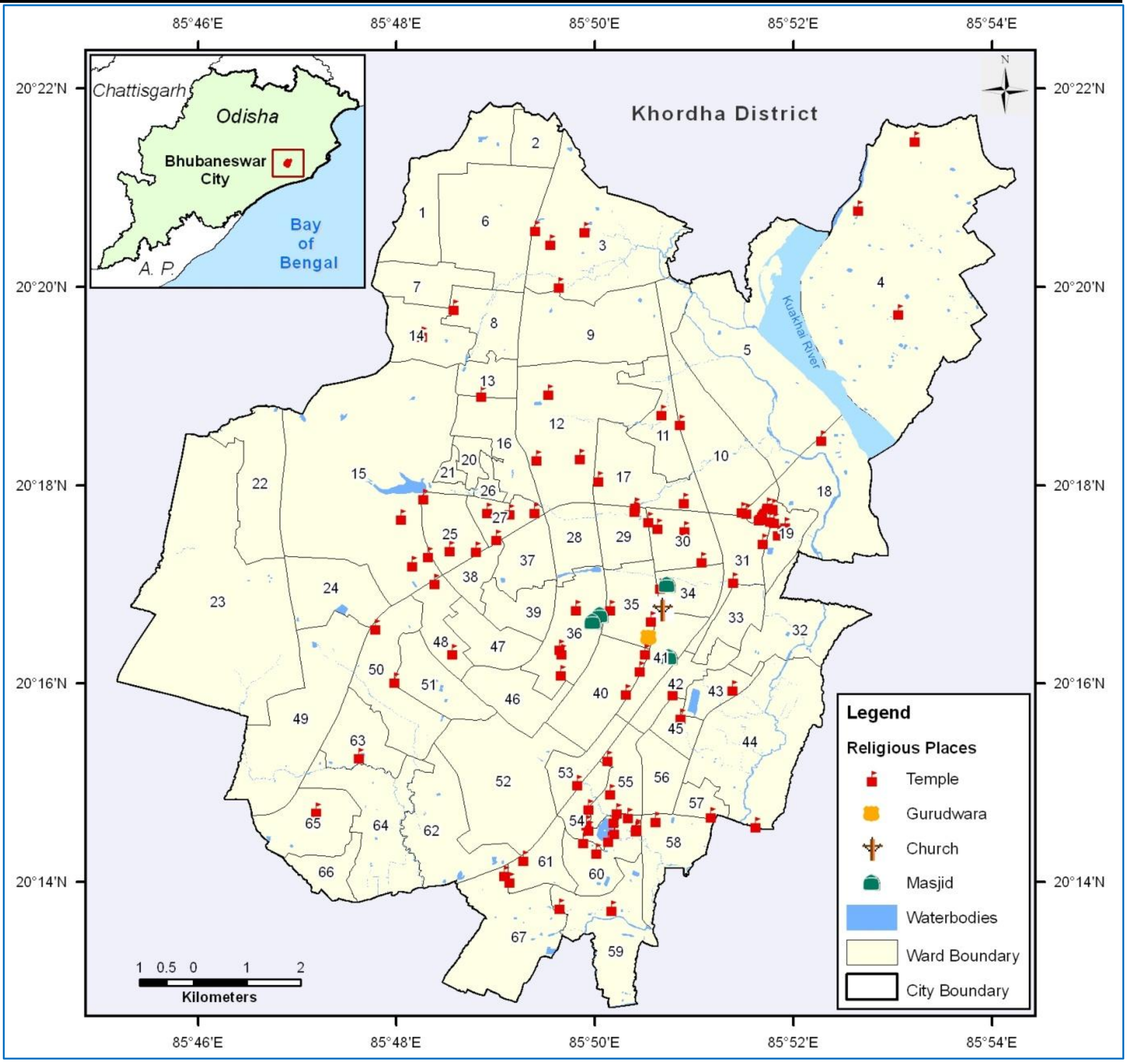


Figure 3-22: Distribution of religious places in Bhubaneswar City

3.4.3.7 Cultural Heritage Sites

Cultural heritage comprises of the sources and evidence of human history and culture regardless of origin, development and level of preservation, and the cultural assets associated with this. Because of their cultural, scientific and general human values, cultural heritage needs to be protected and preserved.

Cultural heritage conservation helps a community not only protect economically valuable physical assets, but also preserve its practices, history, and environment, and a sense of continuity and identity. Cultural property may be more at risk from the secondary effects of a disaster than from the disaster itself, therefore requiring quick action. These are invaluable, so the losses cannot be calculated in terms of monetary value but the impact of hazards on these assets will be considered during the risk assessment. The important cultural heritage sites of Bhubaneswar city is presented in Figure 3-23.

Figure 3-23: Cultural heritage sites of Bhubaneswar city

3.5 Transportation Network

During disasters, the transportation systems play an important role in rescue and recovery operations in a city. Roads, bridges, railways, and airports are considered for exposure analysis in the sections presented below.

3.5.1 Roads

The data about the road network of Bhubaneswar city is obtained from the BMC. The road data provides information regarding the various types of roads as well as their respective lengths. The available data classifies roads into four categories, namely, national highways, major roads, other important roads, and link roads. Ward-level total lengths of various categories of roads are calculated to compute the exposure value. In order to estimate the replacement cost of roads, unit costs of various road categories were determined for the city by taking inputs from the NHAI.

Bhubaneswar being a planned city has well developed road connectivity present in most parts of the city. The city has a total road length of about 1,642 km spread across various municipal wards. The road network comprises of about 51 km of national highways, 87 km of major roads, 11 km of important road and remaining 1,493 km of link roads (Figure 3-24).

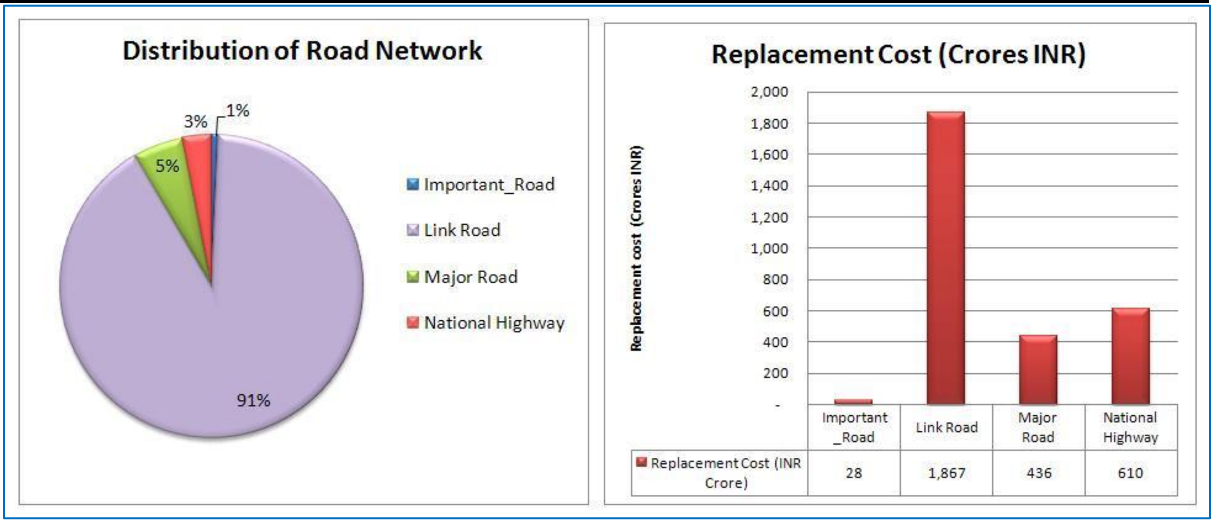


Figure 3-24: Distribution of road network (left) and replacement cost by road types (right)

The ward-wise estimated lengths of different types of roads was multiplied with the per unit replacement costs of the respective road types. Replacement costs taken in this study are INR 12 Crore per kilometer for national highways (four/ six lanes), INR 5 Crore per kilometer for major roads (four lanes), INR 2.5 Crore per kilometer for other important roads (two lanes), and INR 1.25 Crore per kilometer for link roads (Figure 3-24). Based on this, the total estimated exposure value for the road network is estimated as INR 2,941 Crore. Figure 3-25 presents the road network in Bhubaneswar city.

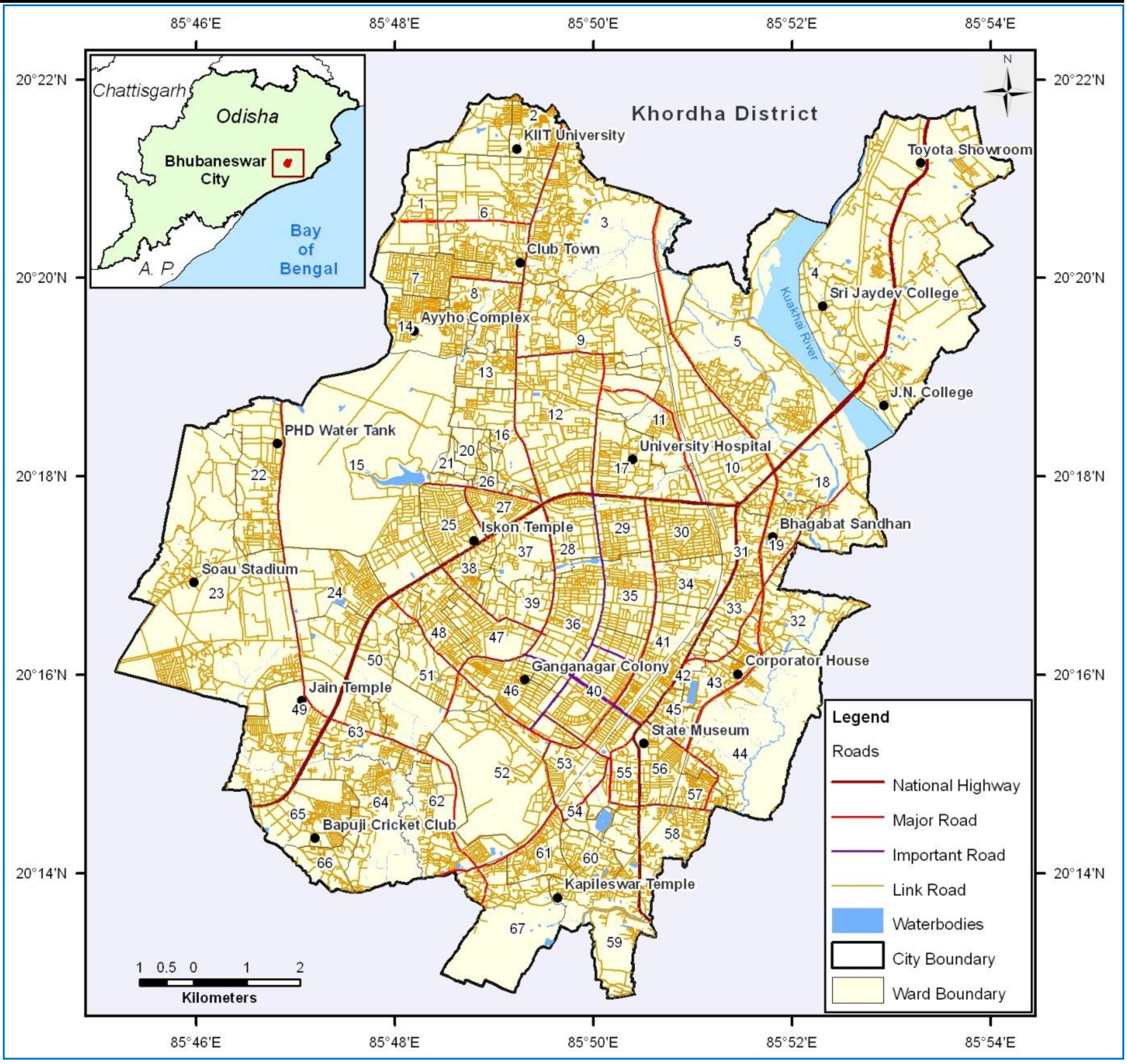


Figure 3-25: Road Network in Bhubaneswar city

3.5.2 BRIDGES AND FLYOVERS

The data on bridges and flyovers of Bhubaneswar city is acquired from the BMC and internet sources. Ward-level total lengths of bridges and flyovers are calculated to compute their exposure values. In order to estimate the replacement cost of bridges and flyovers, unit costs of various bridge-categories are determined for the city by taking inputs from the NHAI and state PWD.

The ward-wise estimated length of bridges was multiplied with per unit replacement costs of the bridges i.e. INR 19 lakh per meter. Based on this, the total estimated exposure value for bridges is estimated at INR 561.9 Crore. Similarly, the total estimated exposure value for flyovers is estimated at INR 1,822.8 Crore for the city.

Annexure 2: Detailed Exposure Data (Table 9-12) provides the ward-wise estimated lengths and exposure values for the bridges of Bhubaneswar city. Figure 3-26 shows the location of bridges and flyovers in Bhubaneswar city.

3.5.3 RAILWAYS

The data about the railway network of Bhubaneswar city is obtained from BMC. Ward level total length of the railway network are calculated to compute the exposure value. In order to estimate the replacement cost of the railway network, unit cost of the railway network is determined for the city by taking inputs from South Central Railway website.

The total length of rail network in Bhubaneswar is about 33.8 km. The ward-wise estimated length of the railway network was multiplied with per unit replacement costs of the railway network (INR 5.5 Crore for railway tracks and INR 80 Lakhs for electrification) i.e. INR 6.3 Crore per km for single line. Based on this, the total estimated exposure value for the railway network are estimated at INR 213.25 Crore.

Annex 2 (Table 9-10) provides the ward-wise estimated lengths and exposure values for the railway network of Bhubaneswar city. Figure 3-26 shows the railway network present in Bhubaneswar city.

Figure 3-26: Bridges, flyovers, railway network and airport locations in Bhubaneswar city

3.5.4 AIRPORTS

The only airport in Bhubaneswar city (Biju Patnaik International Airport) is located at a distance of about 3 km from the city center. The airport is located at 20°14'48.2" N and 85°49'06.7" E with a total land area of about 835 acres. The required information on built-up area, runway length and other infrastructure details are collected from Airport Authority of India and GIS data captured from higher resolution satellite imageries. The airport has two terminals viz. Domestic Terminal (T1) and International Terminal (T2).

In order to estimate the replacement cost of the airport, unit cost of the built up area as well as the runway are determined for the city by taking inputs from internet (http://www.aai.aero/hindi/hindimain.jsp, and Airport technology.com). The total area covered by the built up area and the runway of the airport were multiplied with their respective per unit replacement costs i.e. INR 2,400 per sq. ft. for built-up and INR 4,862 per sq. ft. for runway. Based on this, the total estimated exposure value for the airport is estimated at INR 1,647 Crore. Figure 3-26 above shows the location of the airport of the city. Table 9-11 of Annexure 2: Detailed Exposure Data provides the total area covered by the different components of airport and their exposure values

3.6 Utility Networks

Utilities are essential facilities that include electric power, waste water systems, communication systems, and systems that supply potable water. Any disruption in these services due to physical damage not only cause direct economic losses, but it also has indirect impacts in terms of disrupting livelihoods as well as slowing or disrupting post-disaster relief work.

In absence of the required utility network data from the concerned departments, the team has considered the electric power and potable water networks for risk assessment. In this approach, the above-mentioned utility networks are assumed to be spread along the road networks of the city. However, sewer network and communication network are more site specific utilities and requires detailed GIS data for risk assessment.

3.6.1 POTABLE WATER NETWORK

The sources of water supply in Bhubaneswar city include surface sources and ground water. The surface sources of water supply comprise of Daya and Kuakhai Rivers, and Spring Tanks, whereas the ground water sources are from Pumping Wells and Open Wells. As on April 2014, there are about 270 ground water sources that supply potable water to various municipal wards in the city. As a whole, the city water supply department supplies about 295.30 MLD (million liters per day), of which about 84% comes from surfaces sources and remaining 16% from groundwater sources. Out of total 67 municipal wards, 33 wards are fully covered by municipal water supply, while the remaining 34 wards are partially covered. For risk assessment purpose, the potable water network is assumed to be distributed along the city road networks.

3.6.2 ELECTRIC POWER NETWORK

The exposure data for electric power network includes electric power lines, electric sub-stations, transformers etc. In order to estimate the replacement cost of the electric power network, unit cost of the electricity line has been determined for the city by taking inputs from literature survey and costs provided by the electricity department. In case of Bhubaneswar city, in absence of details on electric power network from concerned departments, the team has assumed the electric power line to be distributed along the road network and the risk assessment was performed accordingly.

3.7 Estimation of Exposure Values

3.7.1 Estimation of Built-up Floor Area

3.7.1.1 Residential, Commercial and Industrial

The residential houses in Bhubaneswar city are classified into different structural types as mentioned in Section 3.4.2 of this report. The number of residential houses are multiplied with the average per unit built-up floor area of each structure type and approximate number of floors to estimate the total built-up floor area of residential houses for 2011.

Using a similar methodology, the total built-up floor area for commercial and industrial buildings are also estimated for the year 2011 at ward level. Annexure 2: Detailed Exposure Data gives the total estimated built-up floor areas for residential, commercial and industrial buildings.

3.7.1.2 Other types of structures

High-resolution satellite imagery, field survey, consultation with local builders, and literature survey helped in the determination of different structural types, average built up areas and unit costs of the industrial buildings, schools, health facilities and places of worship. Using a methodology similar to that explained in Section 3.3, built-up floor areas of all these categories were calculated. Annexure 2: Detailed Exposure Data gives the total estimated built-up floor areas for buildings in this category.

3.7.2 Estimation of Unit Replacement Costs

The unit replacement costs for various building and infrastructure types are collected by the field survey team and are supplemented by literature review and inputs from builders for various housing and structural types. Unit replacement costs for different structures are presented below.

Table 3-3: Unit Replacement Cost of Different Building Types

Type of Building	Average Unit Cost Per Sq Ft (in INR)
Grass/Thatch/Bamboo/Wood/Plastic etc (temporary structure)	100
Mud/ Unburnt Brick/ Stone without mortar	200
Light Metal	150
Burnt Brick/ Stone with mortar with Temporary Roof	500
Reinforced Masonry Buildings	2,000
Reinforced Concrete Frame with brick infill	2,700
Reinforced Cement Concrete	3,600

3.7.3 Calculation of Exposure Values

The ward-level estimated built-up floor areas for each housing type was multiplied with the respective per unit replacement costs. Based on this, the total estimated exposure value for the houses/buildings/infrastructures are estimated.

Table 9-8 of Annexure 2: Detailed Exposure Data gives the total exposure value of different housing/ structural types. Figure 3-27 gives the total exposure value of different housing types in INR.

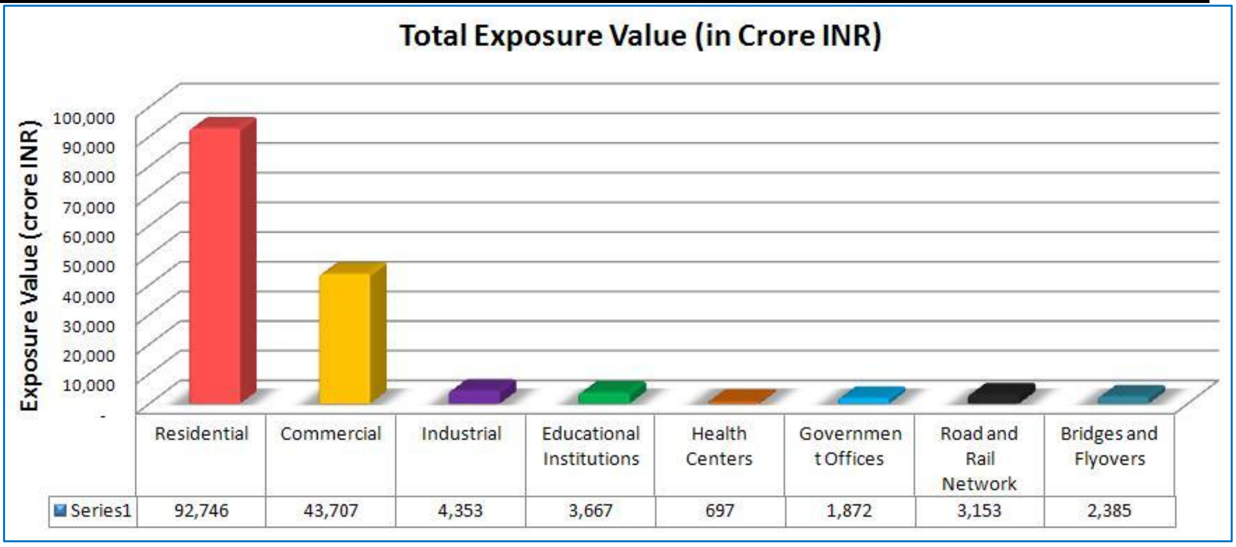


Figure 3-27: Total exposure values for different housing/ infrastructure types in Bhubaneswar city

Further, for every type of exposure element, exposure value is aggregated ward-wise. The total estimated value for main exposure elements for Bhubaneswar city is more than INR 154,227 Crores, out of which Residential exposure is about INR 92,746 Crores, Commercial is about INR 43,707 Crores and Industrial is about INR 4,353 Crores. Essential facilities (Health care, educational institutions, etc.) are estimated at about INR 6,236 Crores, and Transportation systems at about INR 7,186 Crores (Figure 3-27). Spatial distribution of exposure is very useful to decision makers from the planning perspective. Figure 3-28 to Figure 3-30 present ward-wise aggregated exposure values for residential, commercial and industrial land use.

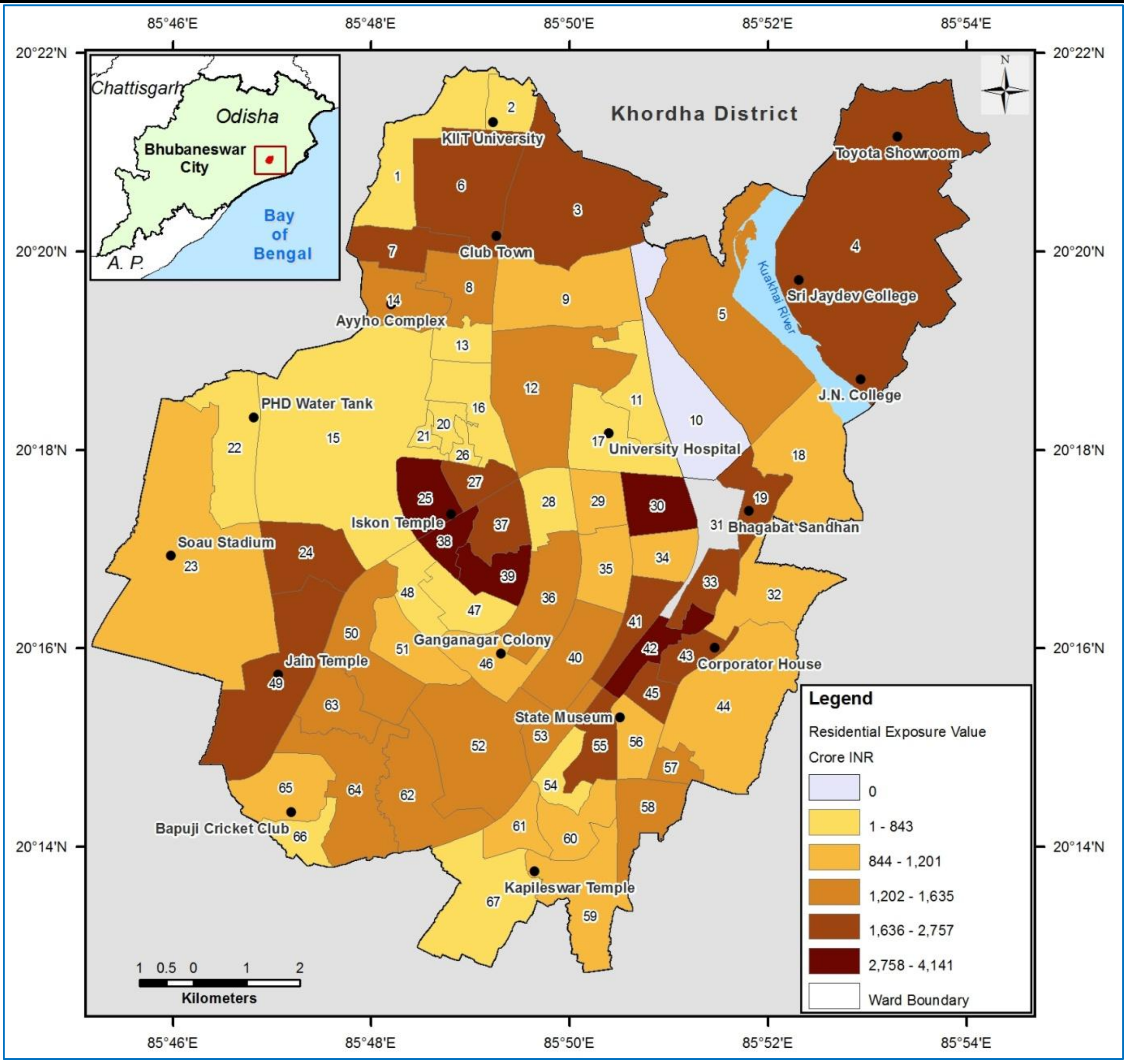


Figure 3-28: Distribution of ward-wise total residential exposure value

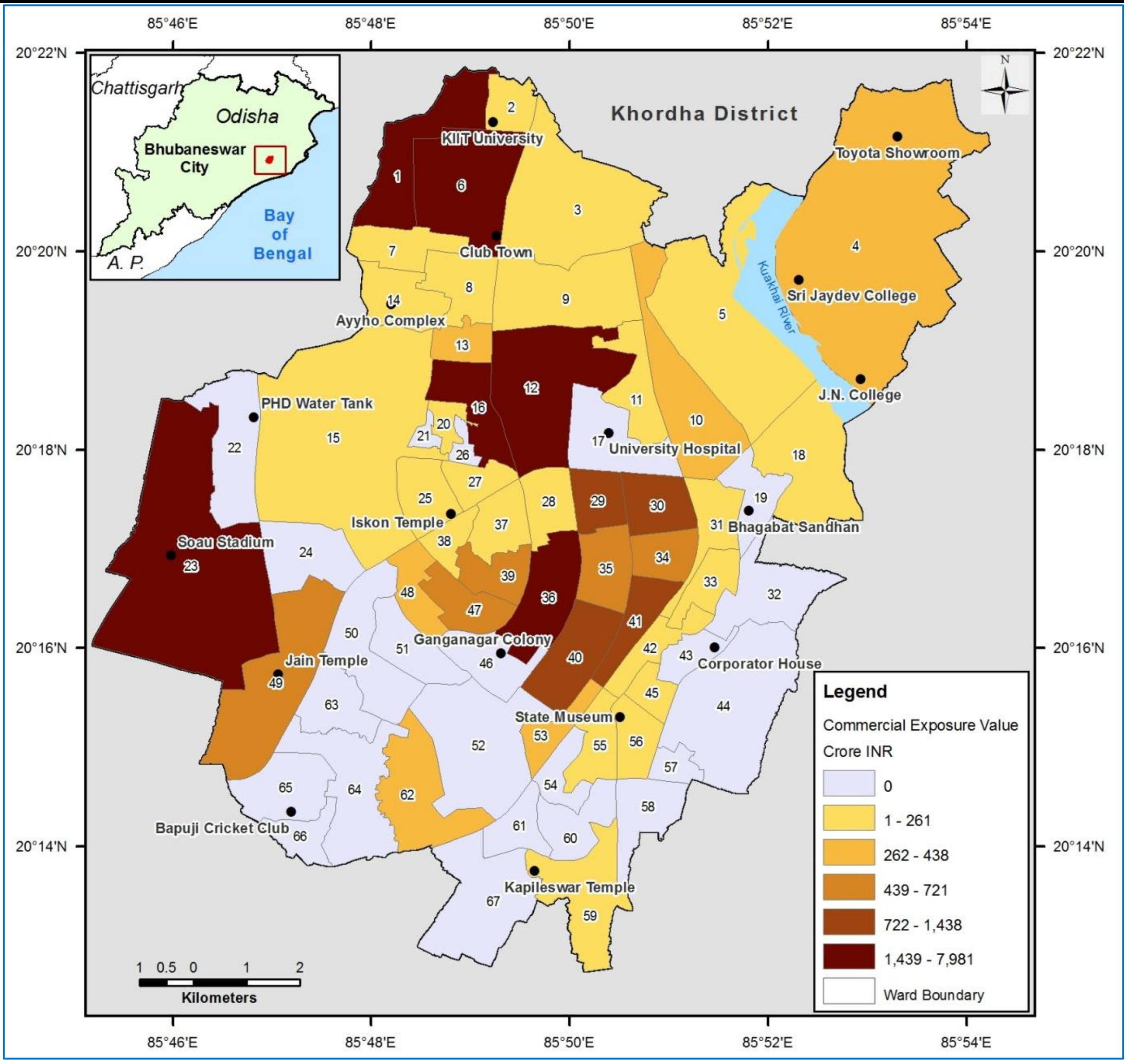


Figure 3-29: Distribution of ward-wise total commercial exposure value

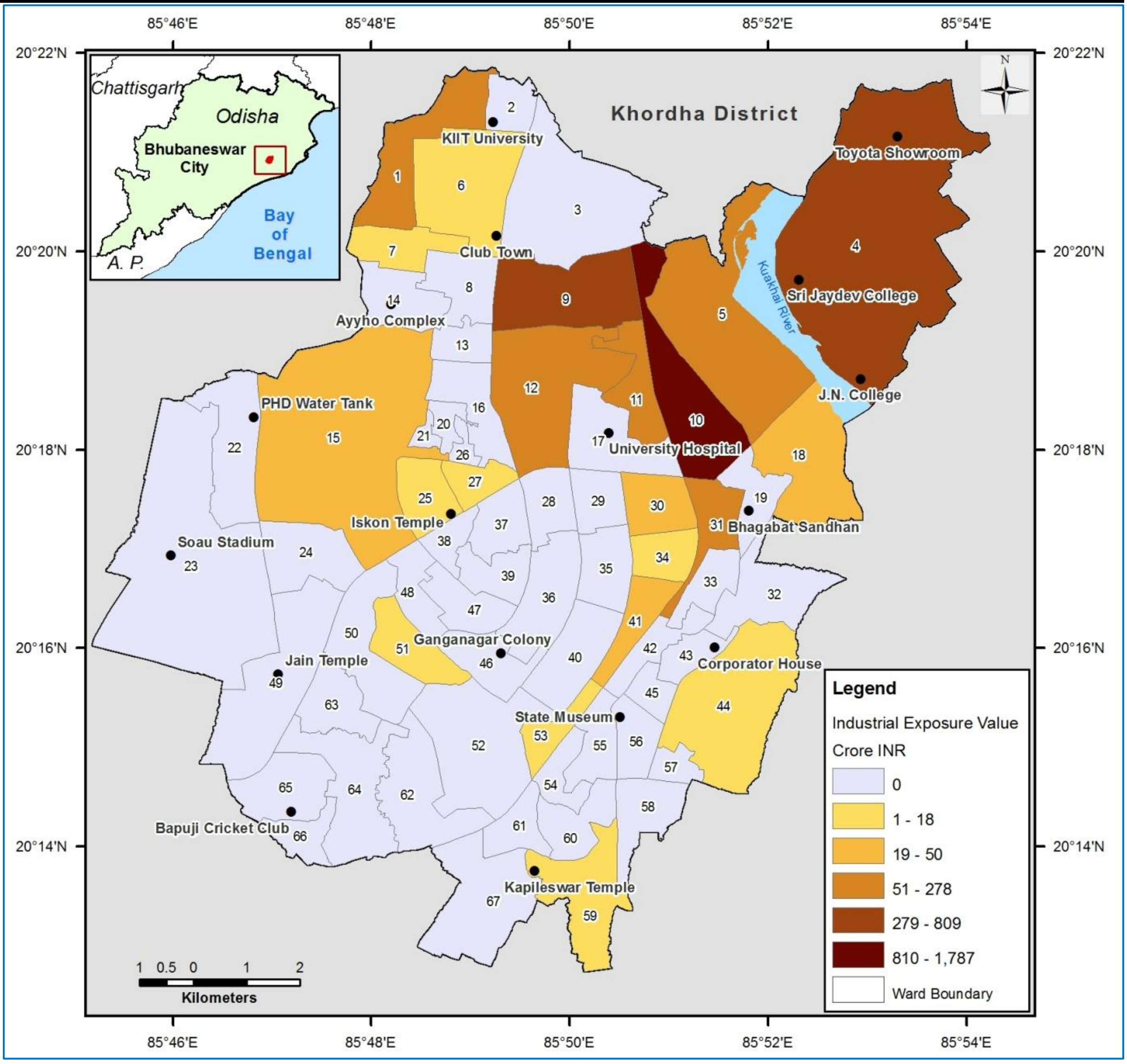


Figure 3-30: Distribution of ward-wise total industrial exposure value

4 Vulnerability Assessment

UNISDR defines vulnerability as “the characteristics and circumstances of a community, system, or asset that make it susceptible to the damaging effects of a hazard.” There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Examples may include poor design and construction of buildings, inadequate protection of assets, lack of public information and awareness, limited official recognition of risks and preparedness measures, and disregard for wise environmental management. Vulnerability varies significantly within a community and over time. This definition identifies vulnerability as a characteristic of the element of interest (community, system or asset), which is independent of its exposure. However, in common use, the word is often used more broadly to include the elements of exposure (http://www.unisdr.org/we/inform/terminology).

In other words, vulnerability is the inability to resist a hazard or to respond when a disaster has occurred. For instance, people who live on plains are more vulnerable to floods than people who live higher-ups.

In fact, vulnerability depends on several factors, such as people's age and state of health, local environmental and sanitary conditions, as well as on the quality and state of buildings and their location with respect to any hazards.

Families with low incomes often live in high-risk areas in the cities, because they cannot afford to live in safer (and more expensive) places. Similarly, a wooden house is sometimes less likely to collapse in an earthquake, but it may be more vulnerable in the event of a fire or a cyclone.

4.1 Data Sources and Availability

For physical vulnerability, field based survey of buildings was conducted and the structural details were documented. City/state specific damage assessment reports of various hazards were reviewed to understand the behavior of various structures to different types of hazards.

As previously mentioned the data that were collected and compiled lacked structural information. Therefore, the team undertook a sample field survey and has taken references from various sources to categorize the building inventory in Bhubaneswar city by structural types.

It was found that the construction practices vary within the city. The construction materials and structural types also vary within each ward among different income groups. The survey and collected published reports helped the team to map the buildings into seven building categories based on different wall and roof construction materials and building types.

For social vulnerability analysis, both primary and secondary data are used. Census data are used for all demographic and housing related data at ward level. Where latest census data is not available for instance, ward level distribution of housing types, we adopt interpolation techniques supplemented by satellite-based method for distributing house types across the wards. Primary data collection through sample survey at household level was carried out to understand the hazard impact, community needs, and community perception.

For environmental vulnerability, Land use land cover (LULC) data of different vintages was used. In addition, the data related to built-up, agricultural land, vegetation/shrubs, water bodies, and barren land was compared.

4.2 Physical Vulnerability

This section provides an assessment of the physical vulnerability by giving an understanding of the potential and performance of the built environment at different levels of intensity of hazards (i.e., flood depth, peak gust, peak ground acceleration/seismic intensity etc.). Various studies such as (US-ASCE, CAPRA, MnhPRA, HAZUS) have conducted a vulnerability assessment to analyze the specific characteristics of damage and loss assessment of each identified hazards. For the present study, the vulnerability functions are developed for hazards such as earthquake, and cyclonic wind for estimating the risks posed by different hazards.

4.3 Social Vulnerability

The city has a population of 840,834 (Census 2011) and has experienced a growth of 25% during the last decade. The density is 6,228 person/ sq km compared to the State density of 260 person/ sq km. Key socio economic variables were used for analyzing the social vulnerability.

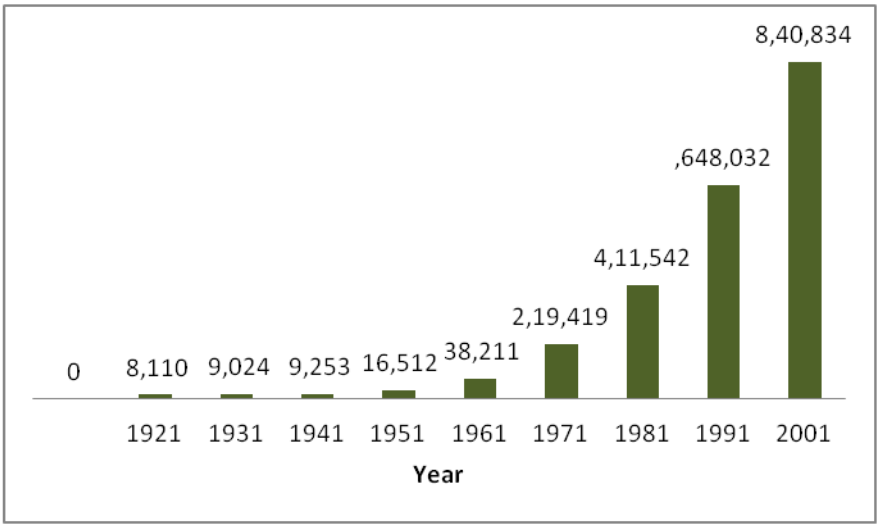


Figure 4-1: Population growth in Bhubaneswar, Odisha

Social vulnerability is a factor of the social and economic capacity of the society, which otherwise are indicators of coping capacity. Therefore, for the social vulnerability analysis, the social setting and livelihood aspects are considered.

4.3.1 SLUM POPULATION

There are 436 slums pockets spread across the city, which have a total population of 80,630 (BMC, 2013). Of the 436 slum pockets, only 116 are notified ones. The population residing in these slums is about 36% of the total population of the city. The slums are small pockets and dispersed across the city. The distribution of slum locations in the city is shown in Figure 4-3. It is interesting to note that even though the slum pockets are overcrowded in terms of plinth area, the number of people per household (3.7 persons per household) is less compared city average (4.3 persons per household).

Vulnerable population

There are about 436 slum pockets in the city with population of more than 0.8 lakhs population

Living in flood hazard prone area with poor house construction vulnerable cyclone

Most of the slums are encroachment in government land

Majority of the slum pockets, particularly in the old town area, are located in low lying areas and encroach the drains and canals of the city. The houses are mostly thatched and are of poor construction quality. These slum pockets are characterized by poor infrastructure facilities including sanitation, water, and road access.

The number of slum pockets and the population in these slum pockets are growing fast (Figure 4-2). There are various factors that drive the increase in slum population in the city.

Like other cities in the country, Bhubaneswar also has a large number of in-migration who come here in search of jobs. Another key factor that increases the urban slum population in the city is due to disasters like cyclone and flood that affect other parts of the State. Such affected people come in large numbers to the city for shelter and livelihood.

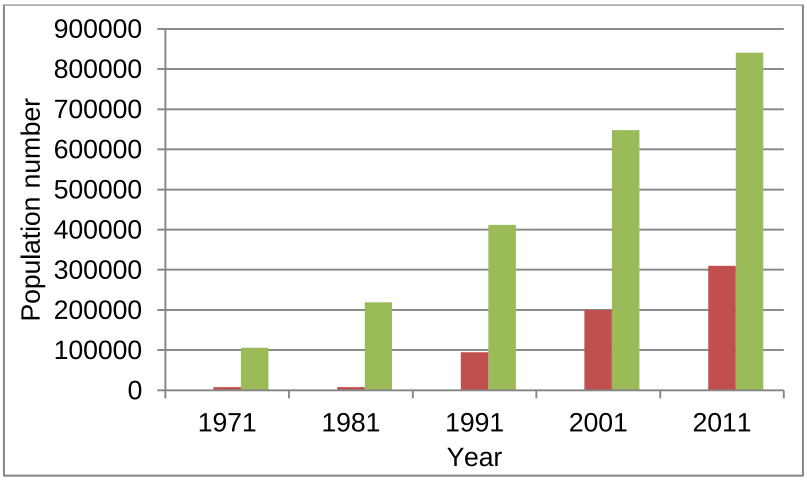


Figure 4-2: Population and slum population growth in Bhubaneswar city during the last 4 decades

Table 4-1: Growth in population and slum population in Bhubaneswar city during the last 5 decade

	Year				
	1971	**1981**	**1991**	**2001**	**2011**
City Population	105,491	219,419	411,542	648,032	840,834
Slum pockets	7	23	86	145	436
Slum household	6,000*	13,000*	21,003	30,000	80,630
Slum population	24,000*	52,000*	95,000	200,000	310,000
% of slum population to total population	23%	24%	23%	31%	37%

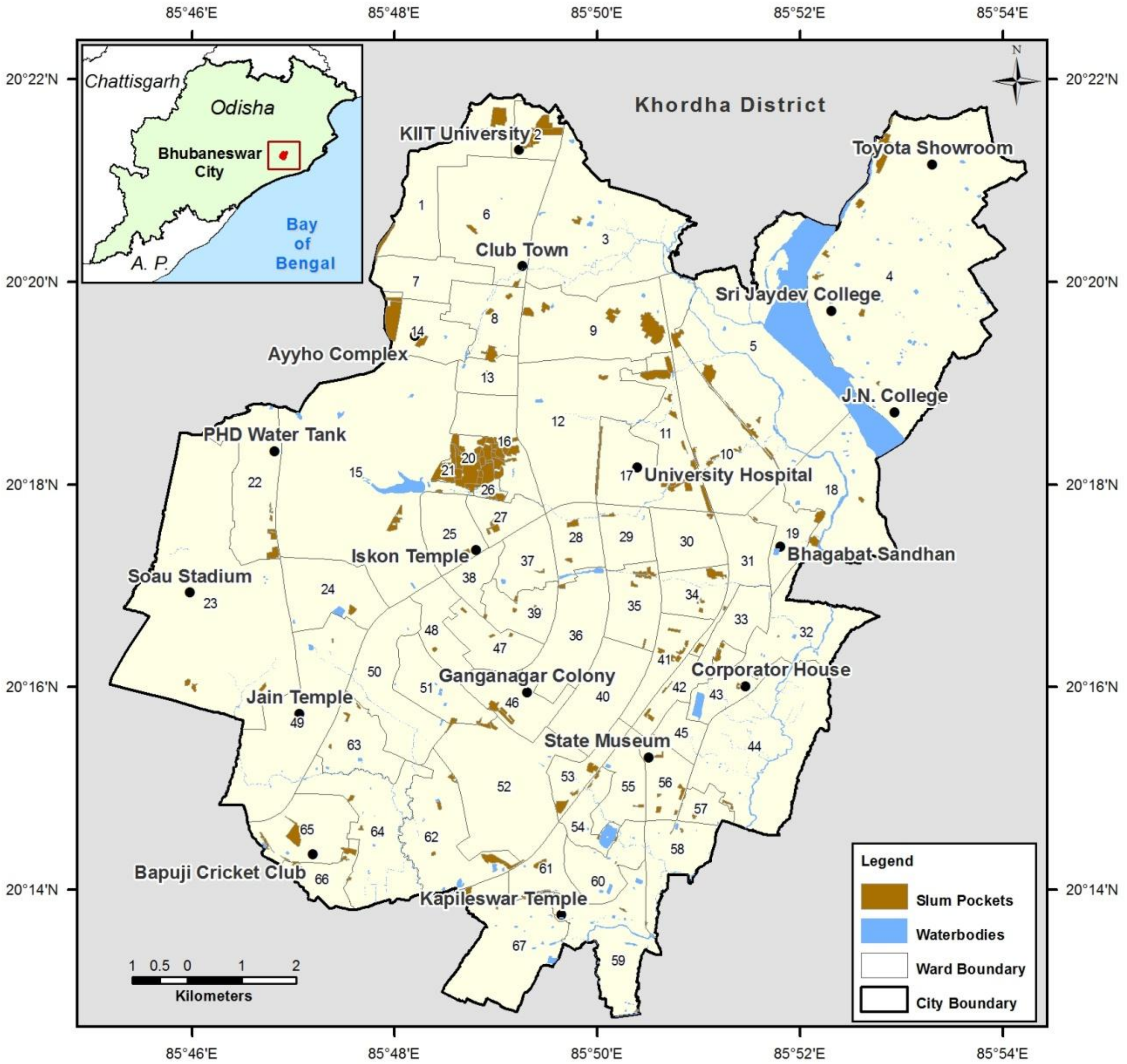


Figure 4-3: Distribution of slums in Bhubaneswar city

Based on the survey in selected slums in the city, it is observed that more than 50% of the slum population are SC and ST, with more male population indicating the migration of males mainly for work. There are some slums where residents have been staying for the last three generations. In general, about 40% only reside in their own houses with a majority of the houses (close to 80%) being of Kutcha construction. Many of the slums are reported to have high incidence of water borne and vector borne diseases. About 8% of the households are headed by single mother/divorcee/widow.

4.3.2 METHODOLOGY FOR SOCIAL AND LIVELIHOOD VULNERABILITY ASSESSMENT

Social vulnerability is partly an outcome of aspects of the social setup that influence or shape the susceptibility of various groups of society to disasters and drive their ability to respond. It is, however, crucial that social vulnerability is not considered as a function of exposure to hazards alone, but also the sensitivity and resilience of the society to prepare, respond and recover from disasters. Social vulnerability is a culmination of economic, demographic, and housing characteristics that influence a community's resilience to the hazards. The study adopted a two-pronged approach to assess the social vulnerability of the city:

(i) SoVI (Social Vulnerability Index): A scientific approach of analysis of published secondary data based on identified social indicators at ward level.

(ii) Community based survey: Analysis of primary data (sample survey) collected through household surveys in selected wards.

Identification of social indicators for social vulnerability analysis: There are several studies (Cutter et al., 2003, and S. Kumpulainen 2006) explaining the social characteristics that influence social vulnerability of a society. The socioeconomic characteristics and historical hazard events were reviewed to understand the social characteristics of urban communities. The following socio economic variables (Table 4-2) were selected for vulnerability analysis.

Table 4-2: Social indicators selected for social vulnerability analysis

Indicators	Description	Normalization
Population	More population means more people exposed to hazard	Population density (person per sq km)
Population age <6 and >60	Children and old people need support in moving out during any emergency. After an event also, this group of population takes more support in getting back to normal life	% population age <6 and > 60 to total population
Female headed household	Women and women headed households struggle more during disaster and recovery due to family responsibilities and lower incomes compared to men	% female headed households to total households
Widow, Divorce and single woman	Widow, divorce and single woman struggle more during disaster and recovery due to the social status and lower incomes compared to men	% widow, divorce and single woman to total female population
SC and ST population	SC and ST are social and economically disadvantaged group and will struggle more impact during disaster and recovery	% SC and ST to total population

Note: Most of these indicators are used by several authors elsewhere (Cutter et al, 2003, S.K 2006).

Disasters impact livelihoods of any community and depending on the hazard the impact may linger on for longer duration. Therefore, in addition to the analysis of social vulnerability, which will be a component of the risk factor of the community, it is important to analyze the disaster impact on livelihoods to make the community resilient to disaster. For this, one needs to understand the livelihood profile of the community, key livelihoods, and community behavior to adjust by choosing alternate livelihood etc. The FAO has developed a framework for livelihood assessment (FAO 2009) for responding to the impacts of disasters on the livelihoods of people. In the present situation, the analysis was carried out within this framework to assess impact of disaster on livelihood of the city dwellers.

Social Vulnerability Index (SoVI): The selected variables were analyzed to develop the social vulnerability index across the wards. This index will provide information on vulnerability distinction of the community thus allowing intervention by way of appropriate mitigation and prevention activities. SoVI would prove valuable for the city administration and state towards planning and decision-making, as it would graphically illustrate the geographic variations in social vulnerability by reflecting the uneven capacity of preparedness and response.

The following steps were followed for the SoVI analysis:

- The secondary data on the identified indicators pertaining to the same time period was collected at ward level and used as input variables to calculate the vulnerability index.
- The variables were normalized as either percentages, per capita values, or density functions
- Accuracy of the data sets was verified using descriptive statistics
- Weightage was applied to the social indicators using Analytic Hierarchy Process (AHP) method and a cumulative score derived, which is the SoVI

- The SoVI was mapped using objective classification in ward boundary map illustrating areas of very high, high, medium and low social vulnerability.

Community based survey: Household survey was conducted in selected wards using a structured pre-tested questionnaire. Ten households each from fifteen wards were surveyed for this. For the selection of wards, both the hazard history and socio economics of the wards were considered. For the selection of households, the study first analyzed the percentage of housing types in the city at ward level and similar percentage composition of were selected (Table 3-1). The house samples were selected randomly from the selected wards.

The secondary data and primary data collected was tabulated and analyzed for understanding community-specific needs and issues. The SoVI developed is used to present the social vulnerability distribution across the city and the tabulated data of the household survey was used for analyzing the vulnerability aspects related to specific hazards, event history, losses, diseases, and perception on early warning systems.

For livelihood impact assessment, data related to socio economic aspects, key occupations the community depended on for livelihood, and the nature of hazards affecting the city were considered. The FAO framework considers livelihood assets and activities, vulnerability and coping strategies, policies, institutions and processes, and livelihood outcomes. This framework is mainly for three level of assessment when a region is affected by disaster – for quick assistance, to develop short and medium term livelihood strategies, and for sectoral intervention programs for medium and long-term measures. However, in the present case our objective is to understand the sectoral impact to guide the city administrators to make short and medium term livelihood strategies to safeguard the communities. For this, we mainly focus on the first component of the framework - livelihood assets and activities. Livelihood assets are mainly of five categories: natural resources (also called ‘natural capital’), physical reproducible goods (‘physical capital’), monetary resources (‘financial capital’), manpower with different skills (‘human capital’), and social networks of various kinds (‘social capital’). In the case of the city, natural capital influences the least but this can be substituted by natural capital in the rural outskirts of the city.

4.3.3 SOCIAL VULNERABILITY DISTRIBUTION

Bhubaneswar city is among the few planned cities in the country. The social vulnerability aspect has also been highly influenced by this aspect. Being a planned city, the city has reasonably well defined land use zones and infrastructure, particularly wide roads. However, the recent trends in the economic and population growth in the city has overloaded this projected planning and affected the land use and transport infrastructure. Additionally, the lack of timely reviews of sectoral policies have led to conflicts of land use and resource use in the city. This has led to increase in social vulnerability adding to the burden of the city’s hazard exposure. The economic development of the city also has increased the built-up land area, business activities, and the traffic density of the city. This probably has given more livelihood options for the city dwellers.

The social vulnerability has a high correlation with the slum pockets of the city. Based on the SoVI, wards 20, 21, and 26, a majority of which are occupied by slum dwellers along with wards 1, 4, 22, 30, and 53 shows a high SoVI (Figure 4-4). Further wards 2, 4, 22, 20, 21, and 26 are also environmentally vulnerable wards, which frequently experience water logging and high incidence of vector and water borne diseases.

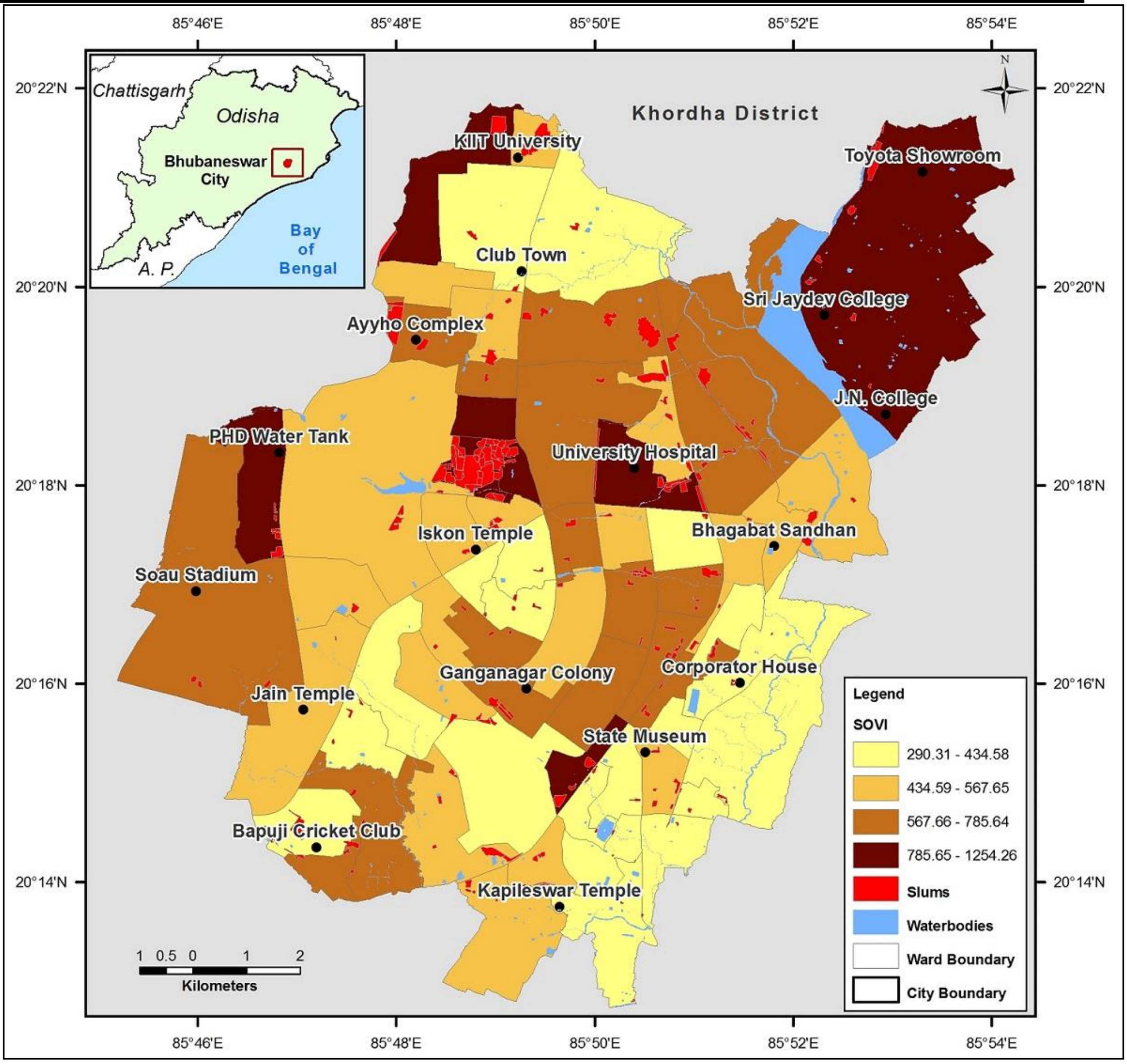


Figure 4-4: SoVI along with slum pockets of Bhubaneswar city (SOVI range is represented by different choropleth)

During the household survey, it was found that there is a higher incidence of water borne and vector borne cases even in the higher income groups. A probable reason for this would be that the poor people are not reporting the diseases.

Table 4-3: Incidence of major diseases across various income groups

Income	Diarrhea	Gastroenteritis	Jaundice	Malaria	Total
<2000	2	2	2	4	10
2001-5000	17	8	11	22	58
5001-10000	9	21	13	26	69
>10000	16	16	20	13	65
Total	44	47	46	64	202

The fast growth of the city has significantly increased the traffic density of the city. The city being part of the tourism circuit connecting Puri and Konark along with trade activities has a heavy outflow of traffic. This has increased traffic congestion particularly in certain pockets connecting the National Highways and the city roads particularly during peak hours. This has also increased the vehicular pollution and accidents in the city. The city hospital has recorded a significant increase in the accident injuries cases (Figure 4-5) in the recent years.

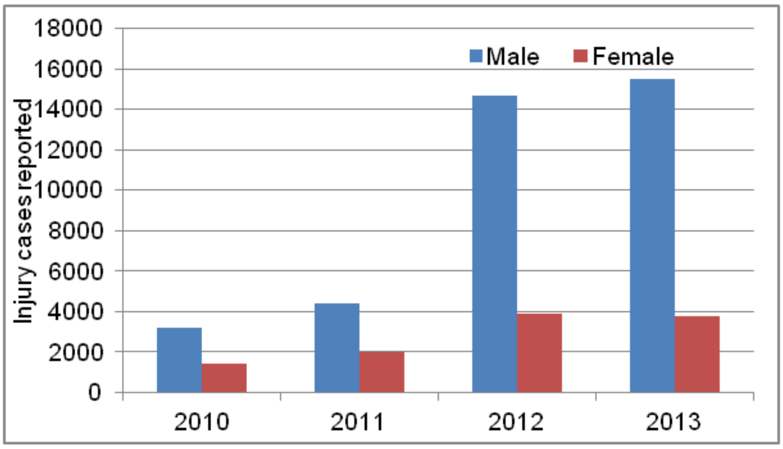


Figure 4-5: Reported accident injuries at Capital hospital, Bhubaneswar

4.3.4 Livelihood Vulnerability Analysis

The city thrives mainly on tertiary activities – industry, trade and commerce, and tourism. The city depends of its peri-urban and surrounding rural areas for the supply of vegetables and food. Even though the cost of living in the city has been increasing in recent years, it is ranked among the lowest in the country. The average per capita income of the state is INR 26,900 (as per Planning Commission statistics 2011). Over the last decade, the social sectors of the State as a whole and Bhubaneswar city in particular have registered a noticeable growth (literacy, reduction of school dropouts, fall in infant mortality rate and increase in institutional delivery rate). The poverty head count in urban areas of the State including Bhubaneswar city is 28.5% compared to 50.5% for rural Odisha. The urban poverty of the State is characterized mainly by inadequate basic service facilities and shelters including health, nutrition, water, sanitation, and housing. City level per capita figures are not available.

Based on the last 15 years daily rainfall data, on an average, the city experienced heavy rain fall for about 20 days a year and high temperatures during the summer for 10 days, which can disrupt life and livelihood. In addition to this, the heavy rainfall and floods in rural areas can affect the agriculture production and inflate the prices of food and vegetables in the city. If we consider the State per capita and 50% of the main workers of the city who are working in trade and commerce, the livelihood loss to casual workers due to 20 days of heavy rain can be to the tune of INR 33.1 Crores. Similarly, losses due to 10 days of high summer temperatures could be around INR 8.29 Crores. In the case of heat wave, only 25% of the occupational category is considered who mostly work outdoors in the unorganized business sector.

4.4 Environmental Vulnerability

The environmental vulnerability in general is highly influenced by the bio-physical set up of a region. However, in the case of cities/urban areas the social aspects dominate as the bio-physical environment of city is highly altered due to human activities. Therefore, while looking at environmental vulnerability of the city, it is essential to consider the human changes in the natural ecosystem. Some of these changes can adversely affect the city and intensify the impact of natural hazards. For instance, conversion of low-lying areas into built up areas can cause fast runoff and, unless planned well, can lead to water logging problems in the city even during normal rainfall events.

For any city, urban growth is marked by a sprawl of built up area outwards from the city center. The built up area of the city is spreading outward, which is very evident while comparing LULC of year 2000 and 2005 (Figure 4-6 and Figure 4-7).

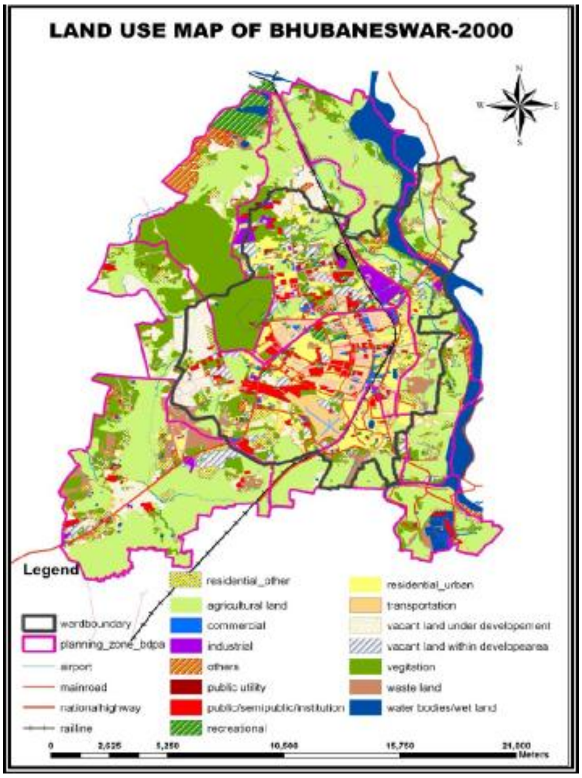


Figure 4-6: LULC 2000 of Bhubaneswar city

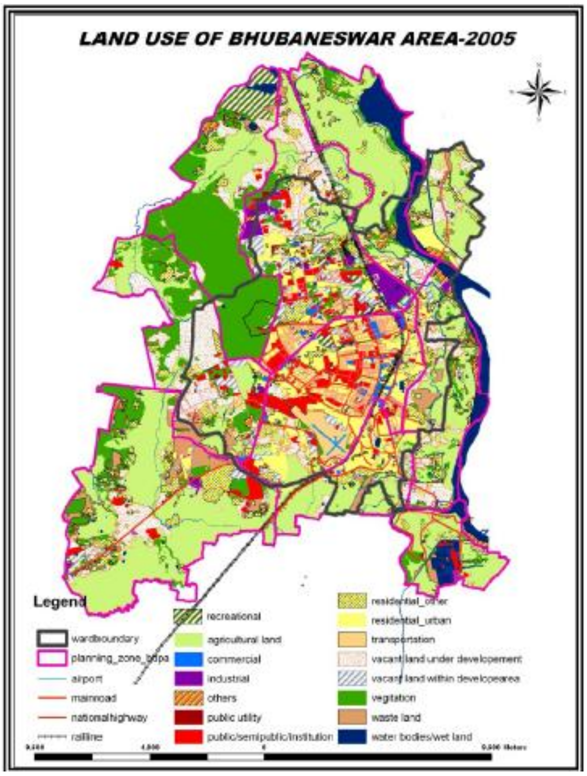


Figure 4-7: LULC 2005 of Bhubaneswar city

Source: Monalisha et al (2011)

The Figure 4-9 and Figure 4-10 shows the change in land use between 2000-2009 in the city. There is drastic change in the built-up area and green cover (agriculture areas, vegetation and shrubs) and open spaces, which are converted into built up areas. Urban sprawl analysis carried out by Monalisha et al (2011) shows that the city's built up area has increased from 1 sq km (1930) to 86 sq km (2011).

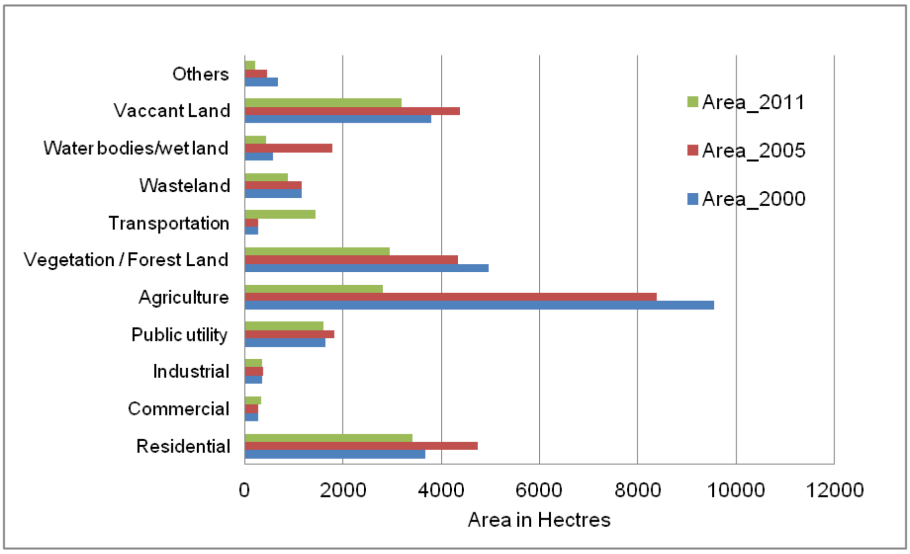


Figure 4-8: Change in LU/LC between 2005-2011 of Bhubaneswar city

The analysis of land use land cover shows that the residential area experienced maximum growth of 84%in the city between 2000-2011 (Figure 4-11), while the conversion of green area and open space is 71% and 61% respectively.

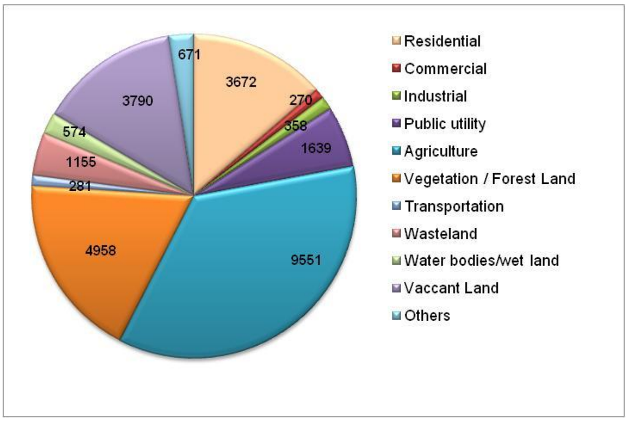


Figure 4-9 LULC composition of Bhubaneswar city (2000)

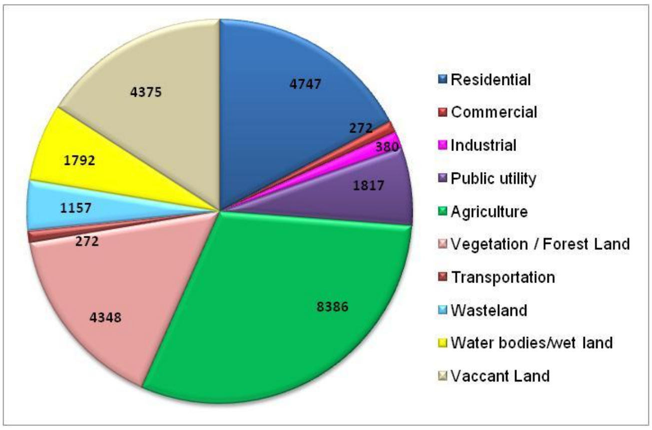


Figure 4-10 LULC composition of Bhubaneswar city (2005)

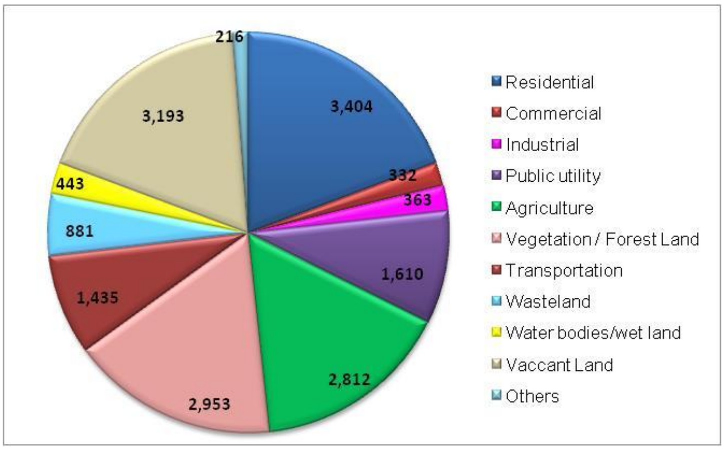


Figure 4-11: LULC composition of Bhubaneswar city (2011)

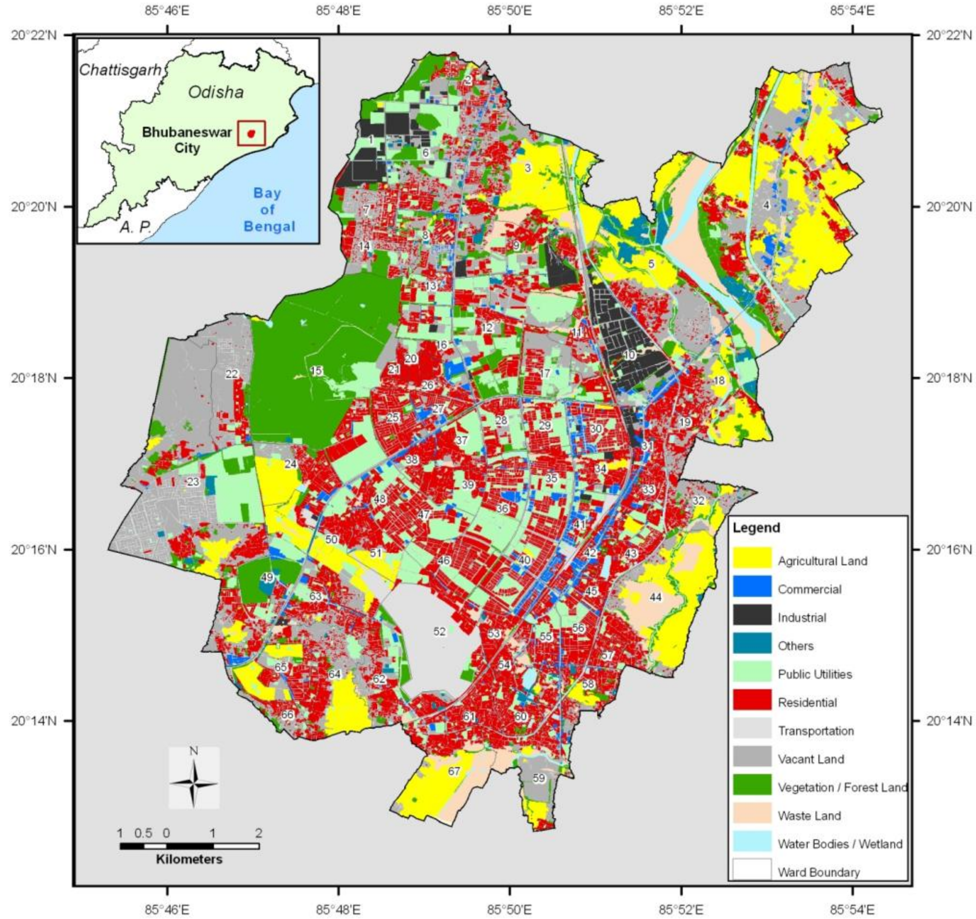


Figure 4-12: LULC map of Bhubaneswar city (2011)

The city's rapid growth has converted vegetative areas, low lying water bodies, and open spaces into built-up spaces. Built up environment has increased the rainfall run off, leading to water inundation problems in many parts of the city and during summer month increase the heat wave situation of the city due to back radiation.

5 Risk Assessment

5.1 Introduction

Risk is the uncertainty of future losses – if we perfectly know a future loss, it is simply a cost, not a risk. Risk is uncertain with regard to the causative hazard event (e.g. cyclonic wind, earthquake, etc.), and its location, date and time of occurrence, and the degree or amount of damage to assets caused by the hazard event, and what losses accrue due to the damage.

Since risks are uncertain, they must be stated probabilistically as shown in Figure 5-1, which is expressed in terms of a Loss Exceedance Curve (LEC, also sometimes termed an Exceedance Probability, or EP curve).

The abscissa of the LEC is loss, while the ordinate is the frequency or probability of loss (for most losses, probability and frequency are equivalent). Small losses occur frequently, and large losses rarely, so the curve slopes downward to the right. The probability weighted average of all possible losses is termed the Average Annual Loss, or AAL. AAL is equivalent to the average per year of all future losses. In this study, losses are presented in terms of AAL and LECs, with emphasis on some key points on the LEC, such as the "25 year loss" or the "100 year loss". By "25 year loss" we mean a loss that will occur on average about once every 25 years, given what we know about hazards, exposure etc. Such a "25 year loss" in actuality has a 1/25 = 0.04 probability of occurrence in any one year. Similarly, a "100 year loss" has probability per year (or "per annum", pa) of 1/100 = 0.001.

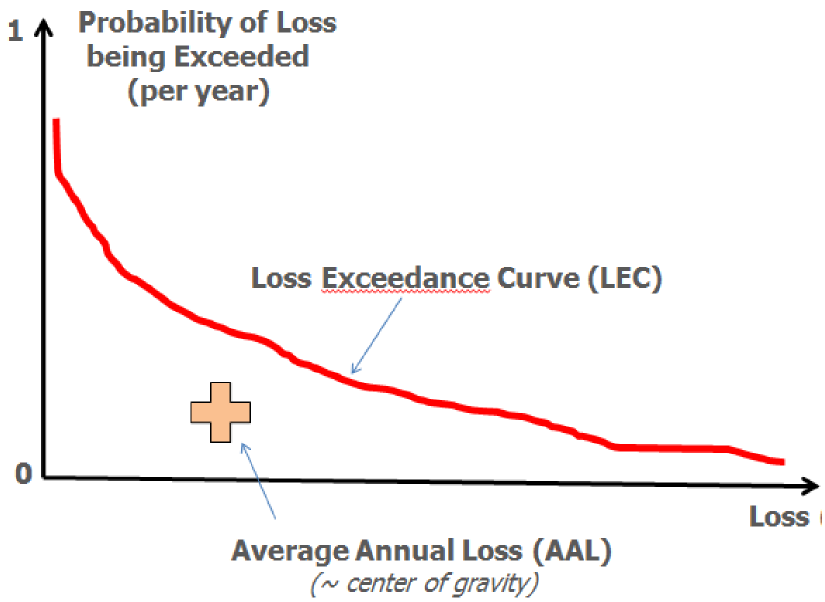


Figure 5-1: Loss Exceedance Curve

5.2 Risk Assessment Methodology

As mentioned above, risk is the uncertainty of future losses and loss is the decrease in asset value due to damage, typically quantified as the replacement or repair cost. Loss estimation is the last step in risk analysis.

Loss is a function of the damage ratio, which is derived through the damage function (vulnerability curve), translated into currency loss by multiplying the damage ratio by the value at risk.

L = MDR(j,h) * Value_At_Risk(j) Equation 1

where,

MDR(j, h) = Mean Damage Ratio for a exposure type 'j' at a specific hazard intensity 'h'

Value_At_Risk(j) = Replacement cost of the exposure type 'j'

For structures, the direct losses were computed using the MDR and structures' economic value (exposure value, discussed in the Exposure part).

As discussed in the hazard section, 5, 10, 25, 50, and 100 years return-period hazard maps are developed for cyclonic wind hazard and 475-years for earthquake hazard. Direct losses are calculated for different return period scenario events (5, 10, 25, 50, and 100 years for cyclonic winds, and 475 – years for earthquakes) and for all types of exposure at risk like residential, commercial, industrial buildings, and infrastructure. This is done for each asset class at each location where the treatment of location differs from hazard to hazard and asset class to asset class at ward level and losses are then aggregated at the city level.

L(i, j) = MDR(j,i,h) * Value_At_Risk(j) Equation 2

where:

MDR (j,i,h) = Mean Damage Ratio for exposure type 'j' at a hazard intensity 'h' for event i

Value_At_Risk(j) = Replacement cost of the exposure type 'j'

Once the losses have been computed for every return-period, two most common types of outputs are generated: Average Annual Loss (AAL) and Loss Exceedance Probability Curves (LEC).

AAL is calculated using the following equation:

AAL(j) = $\sum_{i=0}^{n} \boldsymbol{L(i,j)} * \boldsymbol{R(i)}$ Equation 3

where:

L(i,j) = Loss for event 'I' and exposure type 'j'

R(i) = Rate of occurrence of event 'i'

LEC curve is the second output that is generated. LEC is a graphical representation of the probability that a certain level of loss is exceeded in a given time period. This is expressed in terms of monetary values for different types of exposure. The probability of loss is obtained from the rate of occurrence and is calculated as shown below.

EP(i) = e power($\sum_{0}^{i} \boldsymbol{Ri}$) Equation 4

where, R is the rate of occurrence of an event

Using the LEC, losses are estimated for key return periods for all the hazards.

Next, GIS based risk maps showing AAL and losses for various key return periods are generated showing the areas likely to get affected at the ward level.

In the present context, the direct loss is the hazard-induced losses in terms of financial losses for various structures based on their valuations. The spatial distribution of the modeled risk outputs are portrayed in the form of maps showing the hazard, exposure, and risk characteristics. The temporal characteristics of the modeled risk outputs are depicted in the form of LECs.

Based on the above approach, losses are computed for all the exposure elements. As discussed in the exposure section, various exposure elements are categorized into two broad categories:

Aggregated Exposure – where the area and replacement cost of buildings representing the exposure type are summed at ward level.

Site Specific Exposure – where every asset in the exposure category is represented by a separate location (Longitude, Latitude) on the surface of the Earth with a corresponding replacement cost.

The following subsections describe how the above-described approach has been applied for these broad exposure categories.

5.2.1.1 Aggregated Exposure

Aggregated exposure at ward level has been applied for cyclonic winds and , earthquake. The losses have been estimated only on the area of the built-up cluster that is in a cyclonic wind speed grid or for certain peak ground acceleration (PGA) grid.

5.2.1.2 Site specific Exposure

Site-specific exposure features are location-type exposures, such as bridges, roads, railway lines, electric transmission lines, pipelines, etc. Since, such line type exposure elements are often spread over a long area, a single hazard value cannot be used to estimate the losses to them. Since a line type exposure element is made of a set of smaller segments, the loss is estimated at the centroid of every segment. The losses of all the segments are summed up to estimate the loss to the line exposure element. Figure 5-2 shows the segments for railways lines, Roads, Flyovers, Bridges in Bhubaneswar city at which the losses are estimated.

Figure 5-2: An example site-specific exposure (Railway lines, Roads, Flyovers, Bridges)

The generic equations for loss and AAL computation for line-type exposure elements takes the following form:

$$L(i, j, k) = \sum_{l=0}^{m} \boldsymbol{MDR(j,i,h) * Value\_At\_Risk(j,k,l)} \qquad \text{Equation 5}$$

where:

L(i, j, k) = The loss from event 'i' for exposure type 'j' and line element 'k'

MDR(j,i,h) = Mean Damage Ratio for exposure type 'j' at a hazard intensity 'h' for event i

Value_At_Risk(j,k,l) = Replacement cost of the exposure type 'j' and line element 'k' and segment 'l'

AAL, at any location, is calculated using the following equation:

$$AAL(j, k) = \sum_{i=0}^{n} \boldsymbol{L(i,j,k) * R(i)} \qquad \text{Equation 6}$$

where:

AAL(j, k) = AAL for exposure type 'j' and line element 'k'

L(i,j,k) = Loss for event 'i' and exposure type 'j' and line element 'k'

R(i) = Rate of occurrence of event 'i'

The following sections illustrate the estimated losses and discuss them. The losses are presented as tables and maps depicting the losses in different ways to make the underlying risk easier to understand.

5.3 Risk Matrix by Hazard

This section presents an estimate of the losses and damages attributable to each hazard. The findings can be used by the City administration in understanding the potential impacts of each hazard and allowing a comparison of hazards by quantifying potential impacts. The loss and damage estimates provided in this section have been developed using available data and the risk assessment methodology that includes the following steps:

- Hazard profiles which include determining the spatial extent of hazards, where possible (i.e., maps), understanding the frequency or probability of future events and their magnitude
- Characterization of exposure, which provides a summary of the inventory of assets (buildings - residential, commercial, industrial; and infrastructure), specifically their values. Exposure calculations are carried out by characterizing buildings and infrastructures and approximation of sizes of the buildings (expressed in square meters), including utilization of satellite imagery and fieldwork
- Vulnerability Assessment, which facilitates an understanding of the built environment's potential performance to different levels of hazard intensity (i.e., wind velocity, peak ground acceleration, etc.);
- Impact, loss and damage estimates, which facilitate a quick understanding of the potential impacts or consequences of hazards; and the respective economic losses for each hazard, which are calculated using factors described above.

The application of these methodologies results in an approximation of risk. These estimates can be used to understand relative risks from hazards and potential losses. However, it is important to understand that uncertainties are inherent in any loss estimation methodology, arising from approximations and simplifications that are necessary for a comprehensive analysis.

The economic losses[12] and damage results are presented here using three risk indicators:

Probable Maximum Loss (PML), which provides an estimate of losses that are likely to occur, considering existing mitigation features, due to a single hazard scenario(s) events with one or several return-period;

Loss Exceedance Curve (LEC), which plots the consequences (losses) against the probability for different scenario events with different return periods; and

Average Annualized Loss (AAL), which is the estimated long-term value of losses to assets in any single year within the study area. By annualizing estimated losses, we understand historic patterns of frequent and smaller events as well as patterns with infrequent but larger events, to provide a balanced assessment of risk. The AAL is the summation of products of event losses and event occurrence probabilities for all stochastic events in a loss model and is expressed as:

Average Annual Losses = $\sum_i P_i L_i$

The use of the annualized losses approach has two primary benefits, including: the ability to assess potential losses from all future disasters; and providing an objective means to evaluate mitigation alternatives.

[12] *The economic loss numbers presented in this report are structural losses and cost of land and content values are not taken in such analyses.*

The risk metrics (AAL, LEC and Loss Cost) can be used to identify and prioritize the parts of the city that are under risk. All the areas and exposure categories that have a high AAL or PML are automatic choices for mitigation measures. In addition, there are certain exposure elements that are critical for emergency response, such as hospitals.

5.3.1 EARTHQUAKE

As Bhubaneswar lies in a Stable Continental Region (SCR) only minor to moderate earthquakes have occurred around Bhubaneswar city, which were not very damaging in nature. In the recent past, the maximum magnitudes of these earthquakes have been reported around 4.5 to 5.3 on the Richter's scale and the maximum-recorded intensity in Bhubaneswar city so far is about VI on the MSK Intensity scale. As per Seismic Zoning Map of India (IS: 1893, 2002, 2014; BMTPC, 2006), Bhubaneswar city lies in Seismic Zone-III, with a seismic zone factor of 0.16g, where a maximum intensity VII on MSK Intensity scale can be expected. Since Vs30 values are very low (*in the range of 180-390 m/sec*) for most parts of Bhubaneswar city, the expected ground-motion is much higher due to the local soil-amplification factor. This effect of local soil-amplification was felt in a recent earthquake of magnitude 6 that occurred on May 21, 2014 in the Bay of Bengal, which was severely felt in different parts of Bhubaneswar city. A comprehensive modeling approach was adopted for earthquake hazard and risk assessment (please refer to the earthquake hazard section in earlier report).

5.3.1.1 Estimated Probable Losses, Earthquake Hazard

Table 5-1 below provides estimates of PML for general occupancy (residential, industrial, and commercial) classes due to Earthquake hazard scenario of 475-years return period. Accordingly, losses are presented at ward-level for this scenario-event (Figure 5-3, Figure 5-4, and Figure 5-5 for residential, commercial, and industrial structures, respectively). The table shows that probable maximum losses are to the order of INR 6,009 Crores for residential buildings, INR 3,892 Crores for commercial buildings and INR 297 Crores for industrial buildings.

Table 5-1: Probable Maximum Losses (PML) for the Earthquake Hazard in Bhubaneswar city

	Losses (INR Crores)		
Return Period Years	**Residential**	**Commercial**	**Industrial**
475	6,009	3,892	297

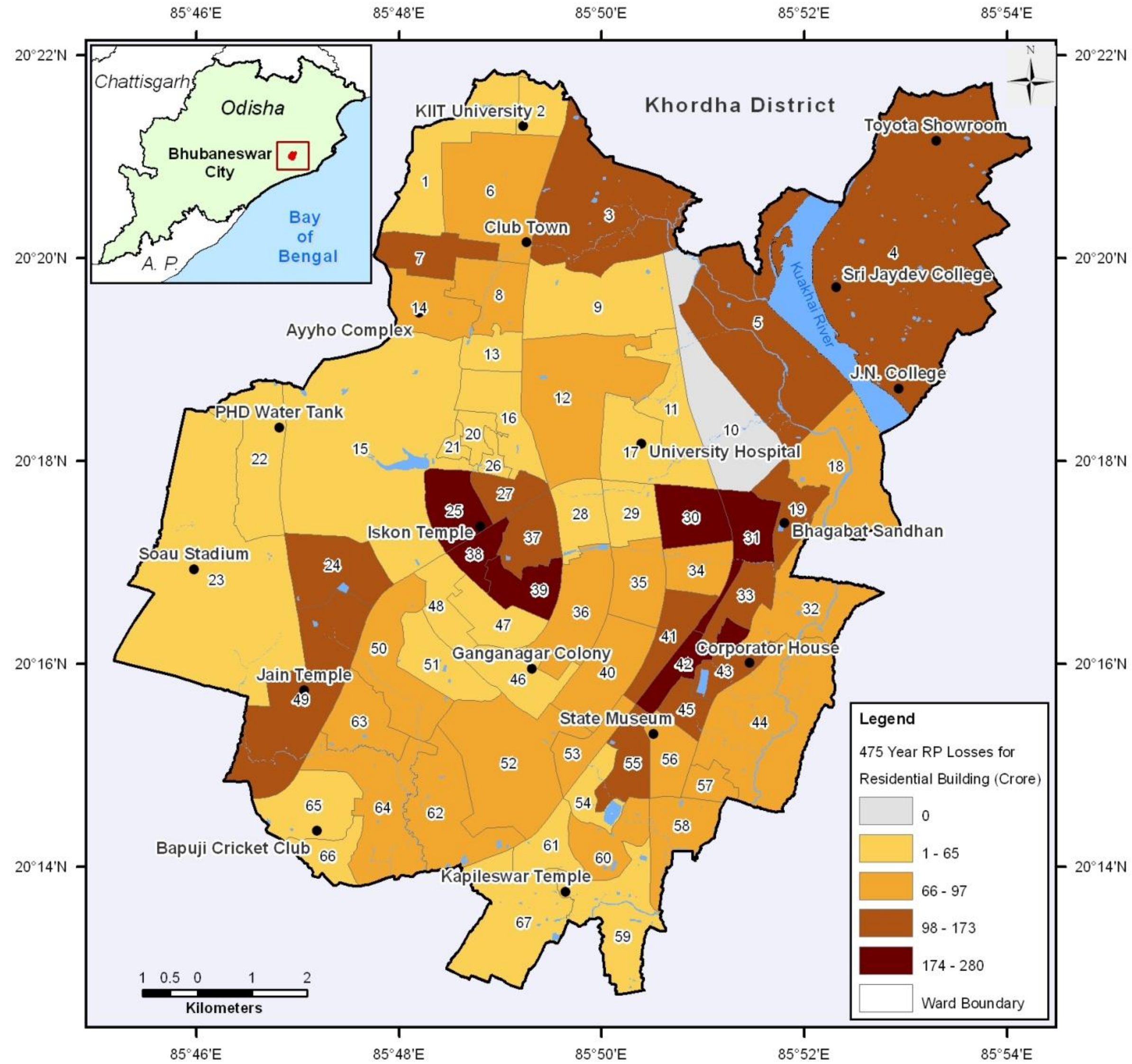


Figure 5-3: Distribution of Structural Losses (PML) corresponding to 475-years return period hazard scenario event for residential buildings in Bhubaneswar city

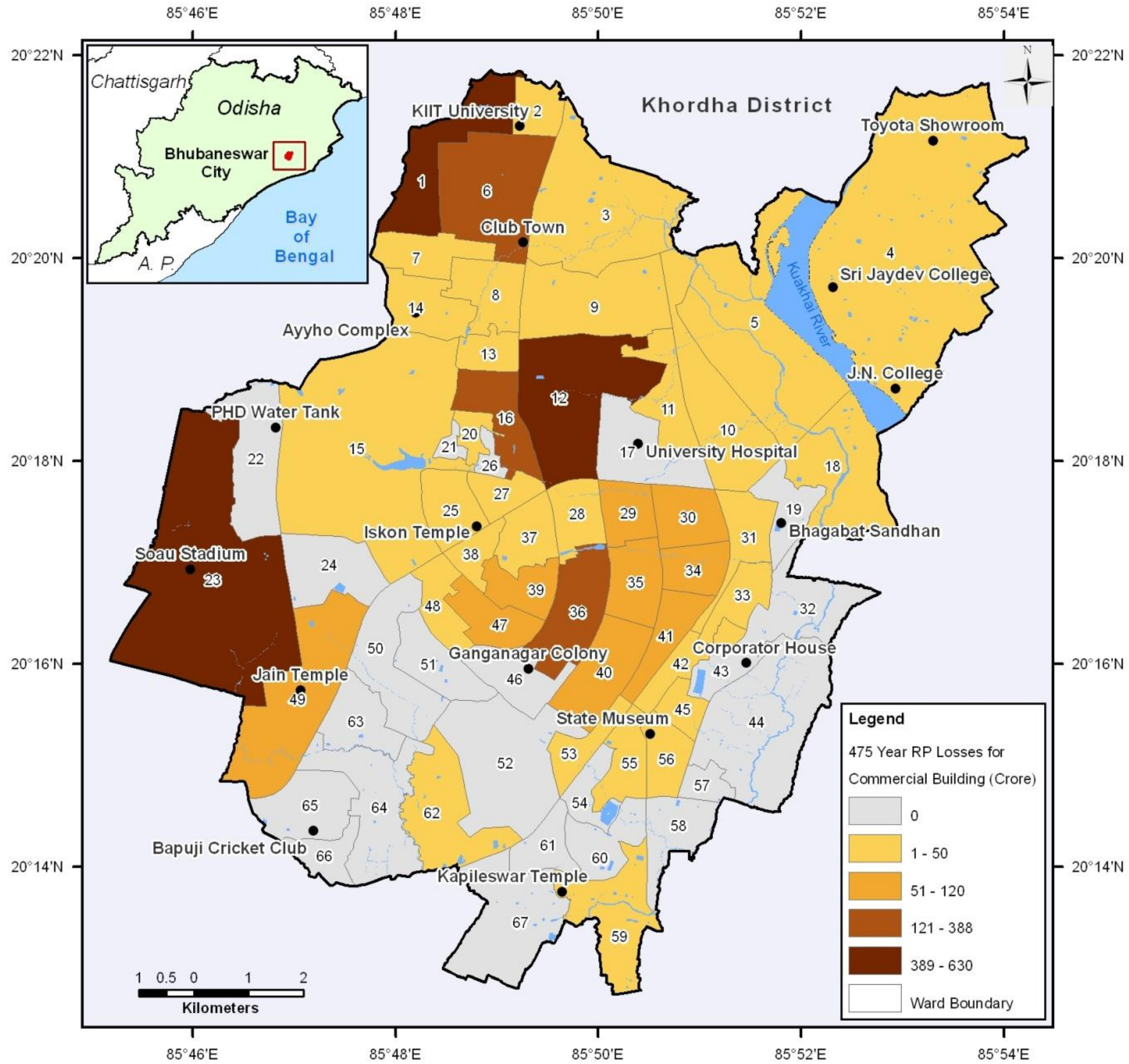


Figure 5-4: Distribution of Structural Losses (PML) corresponding to 475-years return period hazard scenario event for commercial buildings in Bhubaneswar city

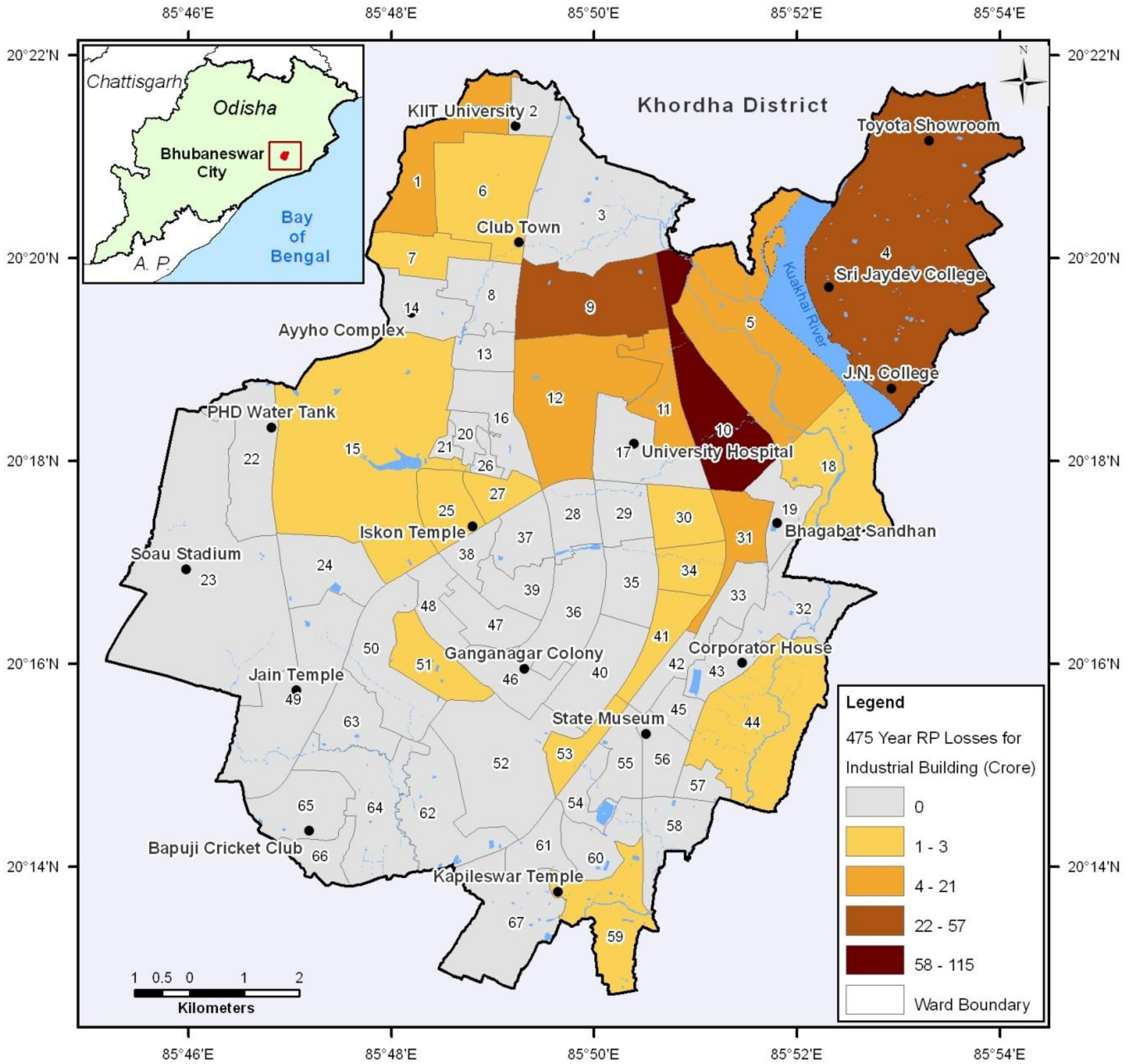


Figure 5-5: Distribution of Structural Losses (PML) corresponding to 475-years return period earthquake hazard scenario event for industrial buildings in Bhubaneswar city

5.3.1.2 Projections of Losses to Various Sectors

Table 5-2 provides estimates of projected losses to various sectors for the earthquake hazard for 475-year return-period. These sectors include transport (roads, railway lines), utility networks (electric lines, water lines, sewerage lines), and other facilities (schools, hospitals, places of worship) etc. From this table, it can be seen that maximum losses are expected in the education sector, which is to the order of 357 Crores.

Table 5-2: Estimation of projected losses to various sectors for the earthquake hazard for a 475-year return period hazard

Facility/Sectors	**No. of facilities/ length**	**Losses corresponding to 475 Year period**	
		INR Crores	**% of total exposure value**
Facilities			
Hospitals	64	61	9%
School/College	346	357	10%
Places of Worship	95	9	6%
Transport			
Road, km (National Highway)	51	Insignificant	
Road, km (Major Road)	98	Insignificant	
Road, km (Minor Road)	1,493	Insignificant	
Railway Lines, km	34	Insignificant	
Utility Networks			
Water Lines, km	936	Insignificant	
Sewerage Line, km	1,133	Insignificant	

5.3.2 CYCLONIC WIND

Cyclonic wind hazard associated loss assessment has been carried out based on the frequency and severity of various cyclonic events at different return periods ranging from more frequent to rare events. Thus, scenarios of maximum winds for key return periods (5, 10, 25, 50 and 100 years) have been developed to demonstrate the impact of cyclonic wind extent and range of wind magnitude on Bhubaneswar City using location specific dynamic storm model of resolution 250 m x 250 m.

5.3.2.1 Estimated Probable Maximum Losses for Cyclonic Wind Hazard

The estimates of losses for the Cyclonic Wind hazard are provided in Table 5-3 below, and represent the PML for general occupancy (residential, industrial, and commercial) classes. PML is estimated for five key return periods (5, 10, 25, 50, and 100 years).

From Table 5-3, it is clear that PML from cyclonic wind are insignificant for 5, 10, and 25 year return periods. Though PML is present for 50-years return period, these losses are still proportionately small. However, significant losses are expected (INR 111 Crores) for residential buildings in a 100-year return period Cyclonic Wind event for Bhubaneswar city. Figure 5-6, Figure 5-7, and Figure 5-8 present the ward-level losses to the residential, industrial, and commercials buildings.

Table 5-3: PML for the Cyclonic Wind Hazard in Bhubaneswar city

Return Period Years	**Loss (INR Crores)**		
	Residential	**Commercial**	**Industrial**
5	0.075	-	-
10	0.108	-	-
25	0.176	-	-
50	5.402	2.953	0.276
100	110.816	55.648	5.973

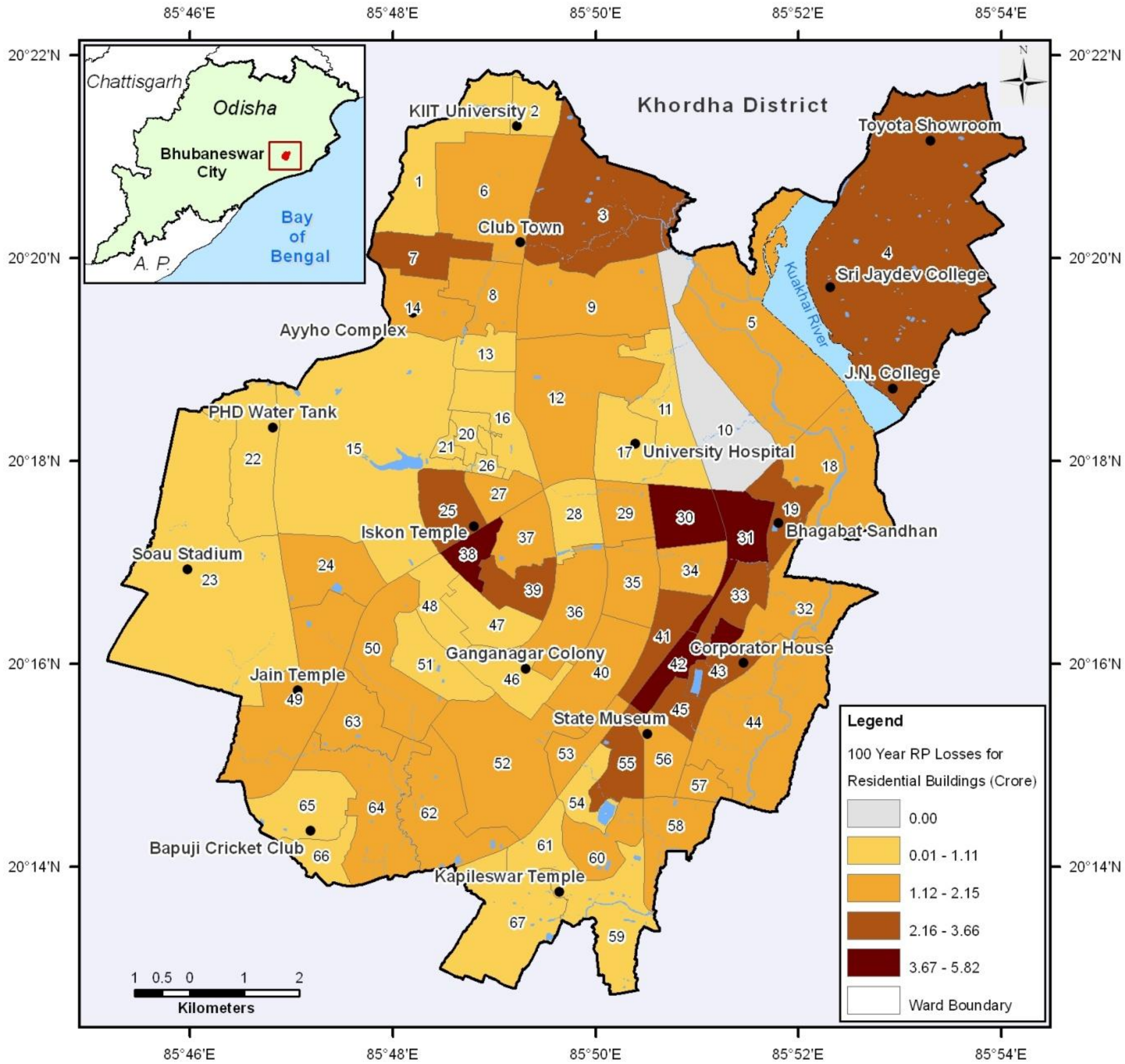


Figure 5-6: Distribution of Structural Losses (PML) corresponding to 100-years return period cyclonic wind hazard scenario event for residential buildings in Bhubaneswar city

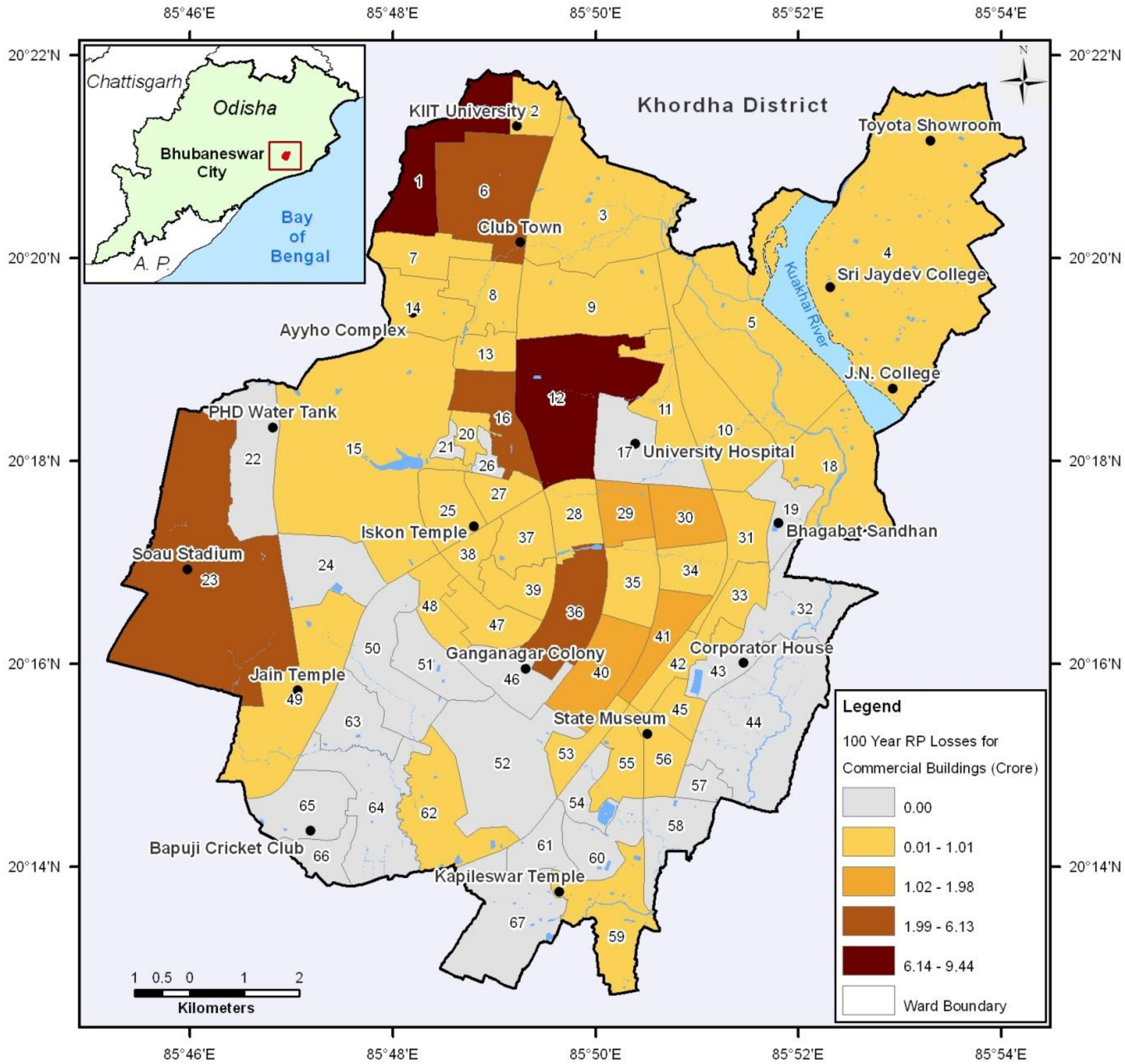


Figure 5-7: Distribution of Structural Losses (PML) corresponding to 100-years return period cyclonic wind hazard scenario event for commercial buildings in Bhubaneswar city

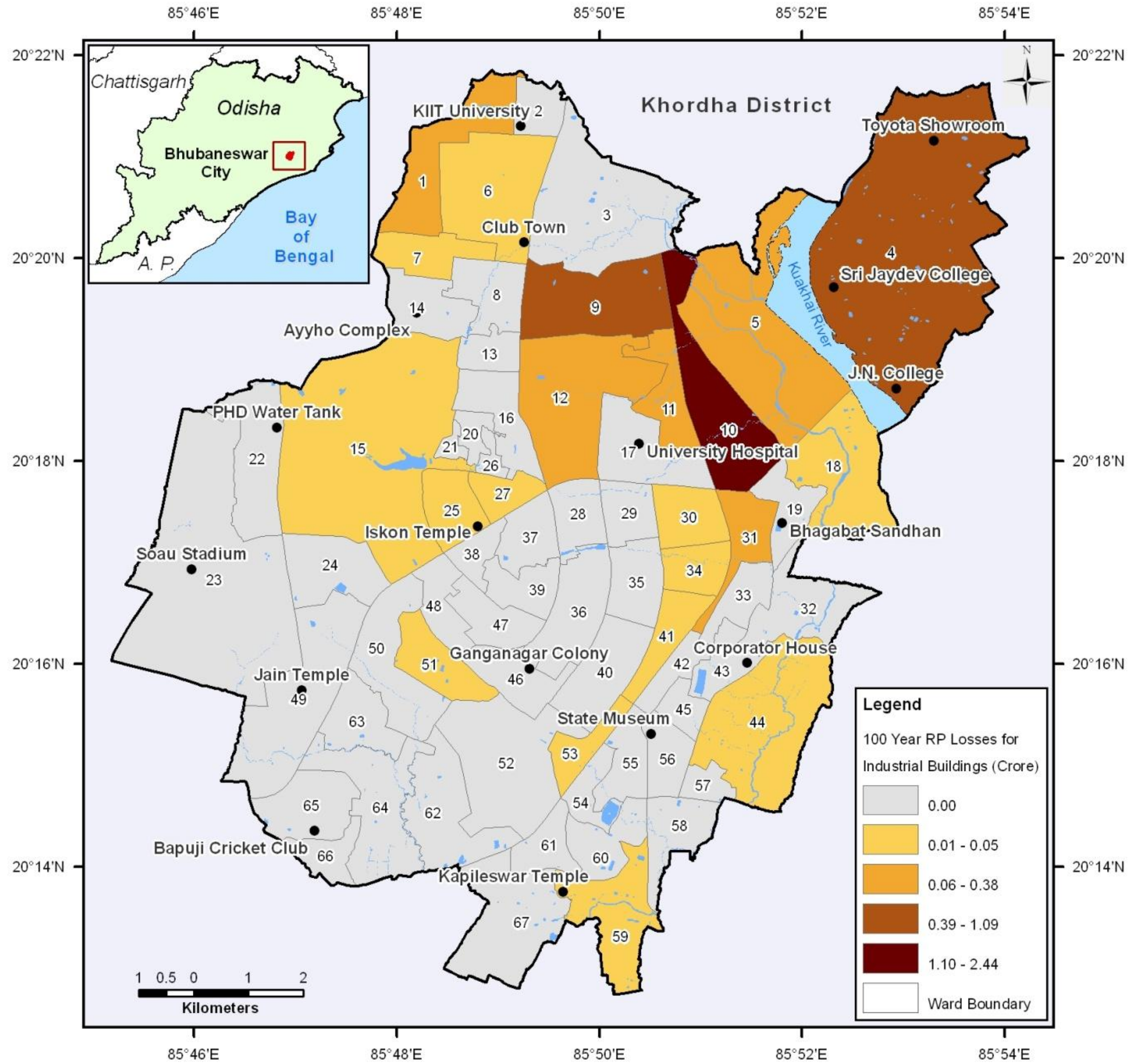
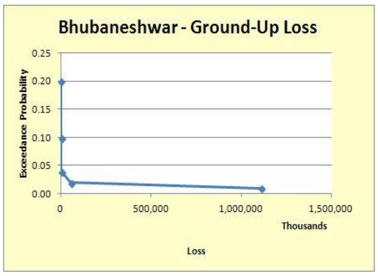


Figure 5-8: Distribution of Structural Losses (PML) corresponding to 100-years return period cyclonic wind hazard scenario event for industrial buildings in Bhubaneswar city

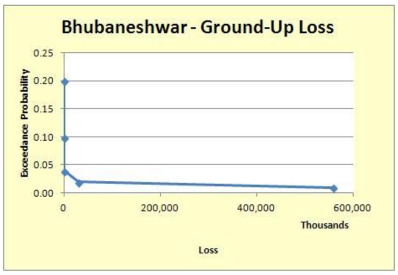
5.3.2.2 Loss Exceedance Curve and AAL

Figure 5-9 depicts the LEC and AAL for the cyclonic wind hazard in Bhubaneswar city.

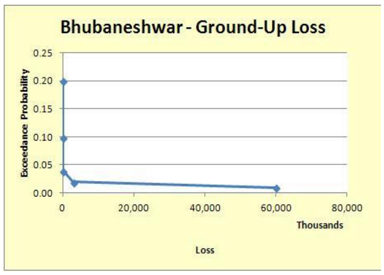
LEC, Residential



LEC, Commercial



LEC, Industrial



AAL					
Residential		**Commercial**		**Industrial**	
INR (Crore)	**% of Exposure**	**INR (Crore)**	**% of Exposure**	**INR (Crore)**	**% of Exposure**
1.180	0.0013%	0.586	0.0013%	0.062	0.0014%

Figure 5-9: LEC and AAL for Cyclonic Wind Hazard

For the cyclonic wind hazard in Bhubaneswar city, Figure 5-10, Figure 5-11, and Figure 5-12 depict the ward-level risk maps for average annual losses for residential, commercial, and industrial buildings, respectively.

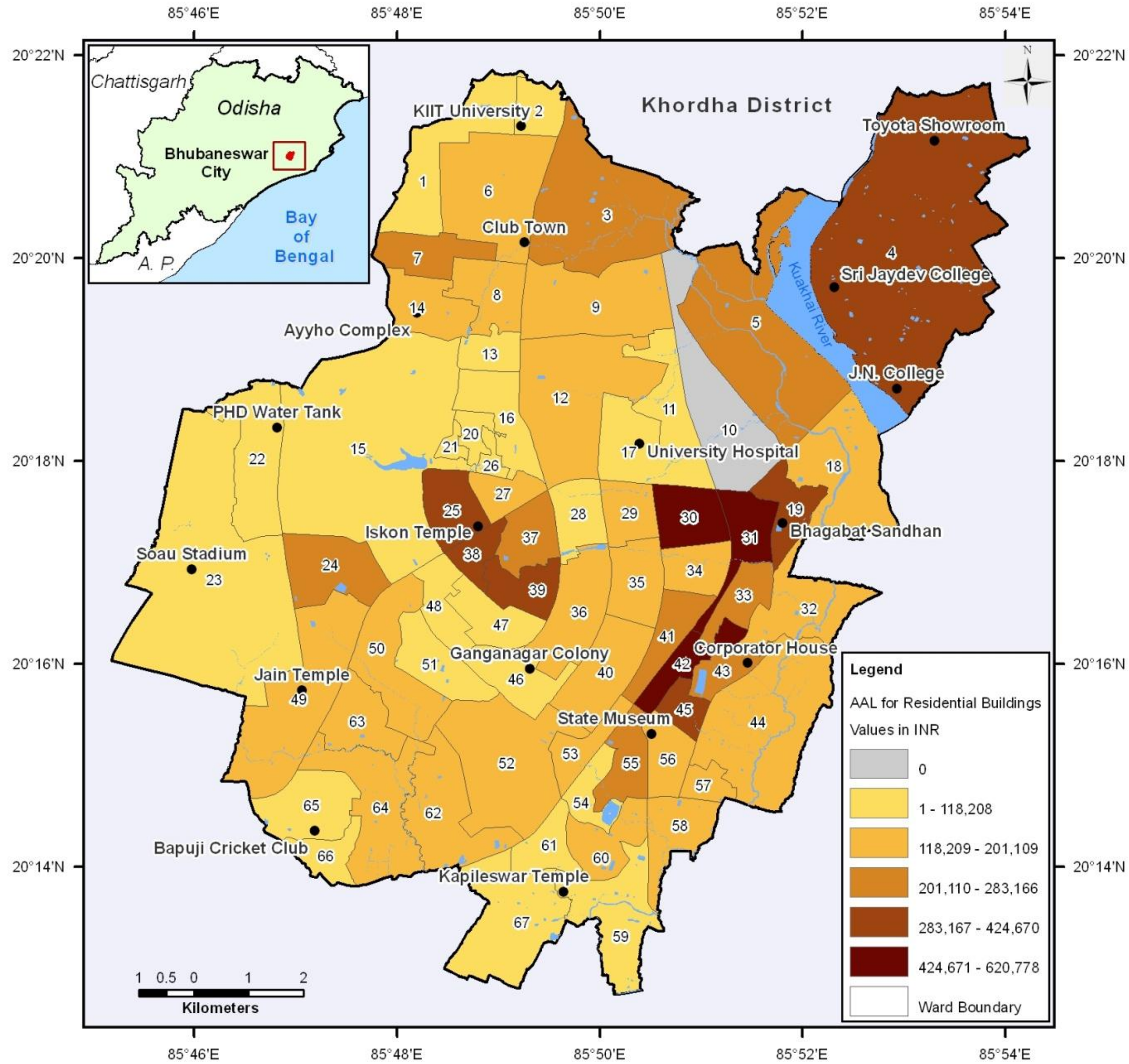


Figure 5-10: Risk Map: AAL for cyclonic wind hazard for residential buildings

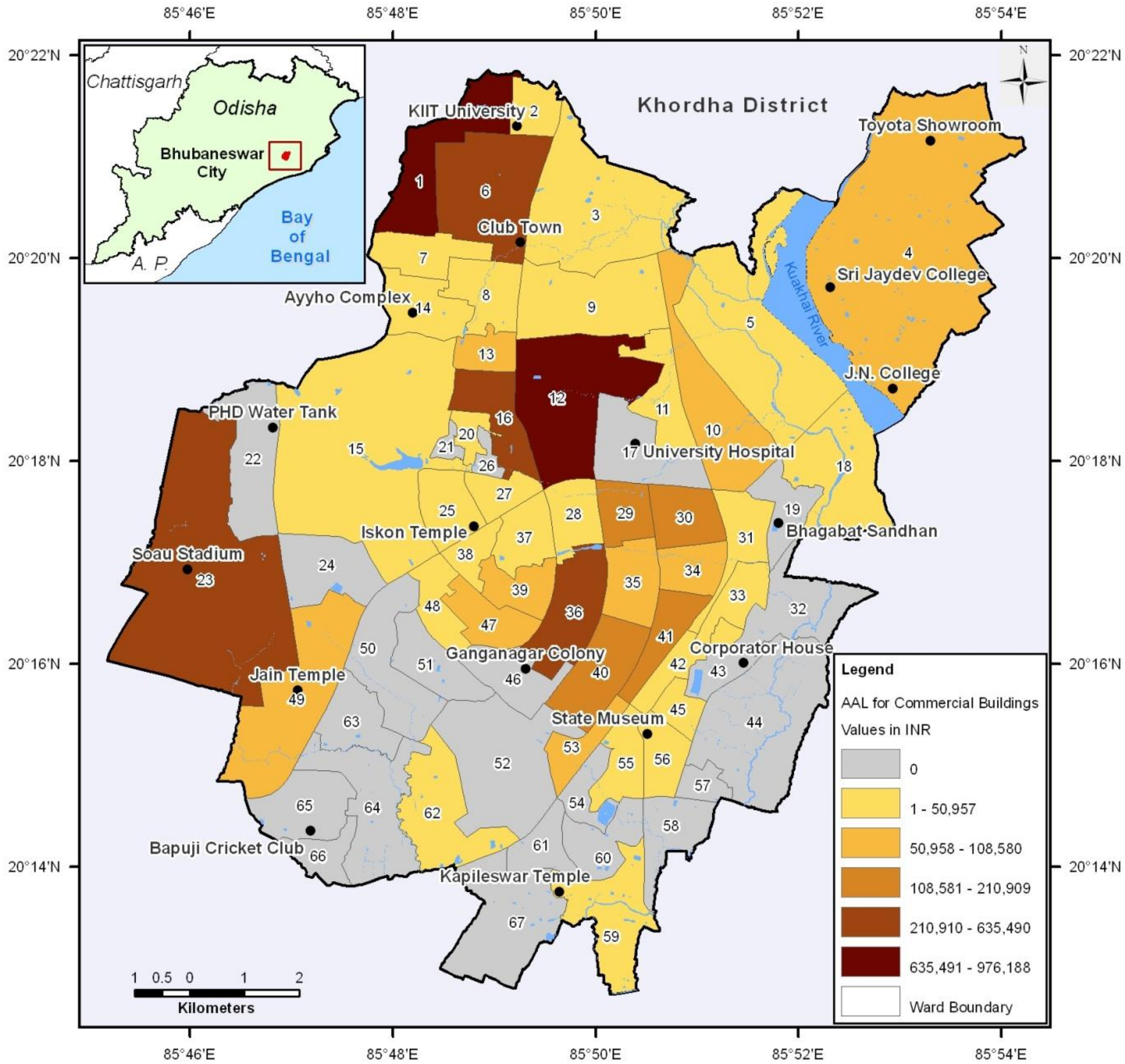


Figure 5-11: Risk Map: AAL for cyclonic wind hazard for commercial buildings

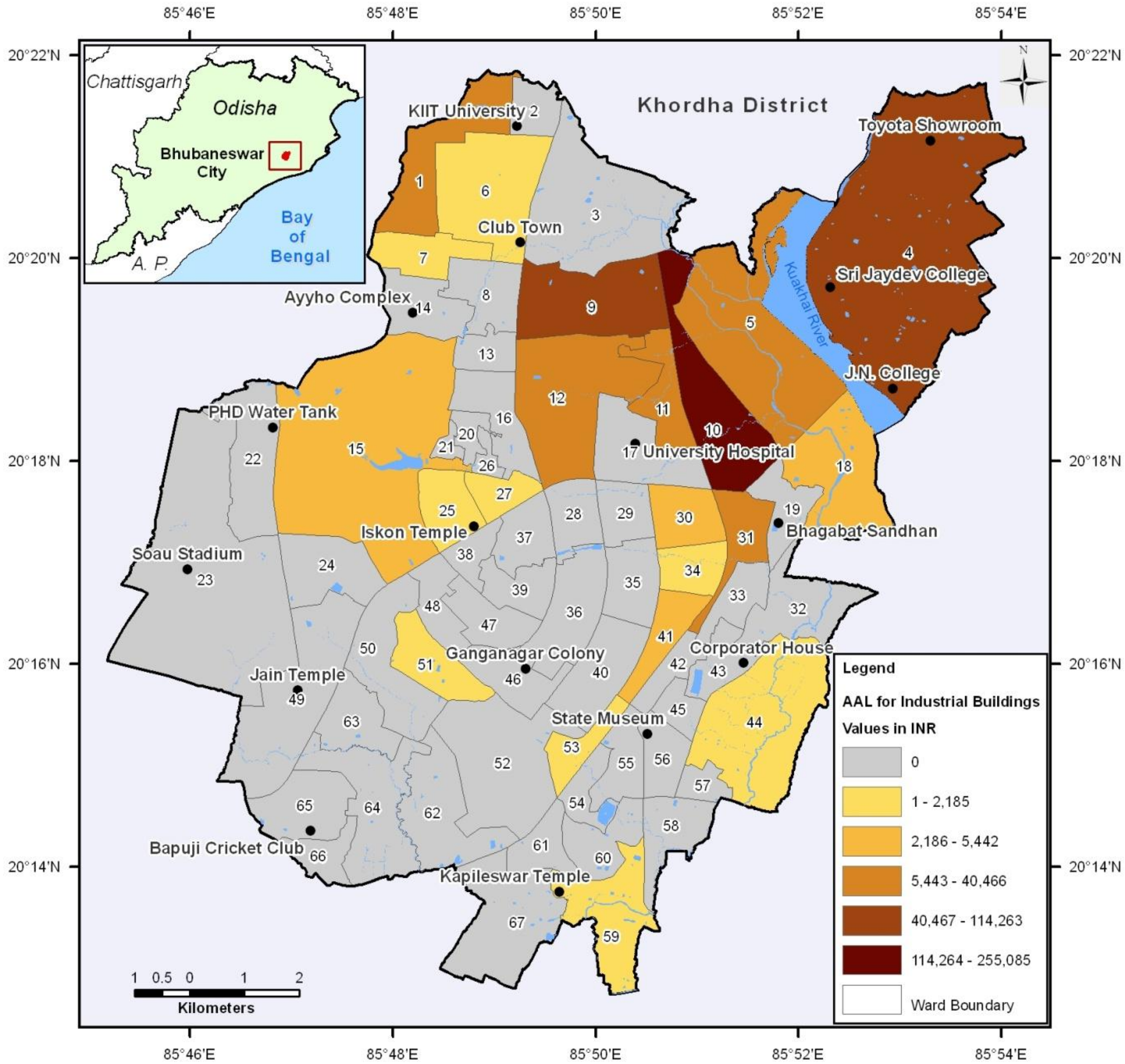


Figure 5-12: Risk Map: AAL for cyclonic wind hazard for industrial buildings

5.3.2.3 Projection of Losses to Various Sectors

Table 5-4 provides projected future losses in various sectors for 25, 50, and 100 year return periods. These sectors include transport (roads, railway lines), Utility Networks (electric lines, water lines, sewerage lines), and other essential facilities (schools, hospitals, places of worships) etc. From Table 5-4, it is clear that losses to railway lines, water lines and sewerage lines are insignificant in Bhubaneswar city, as these are not significantly affected due to cyclonic winds.

Table 5-4: Estimation of projection of losses to various sectors for the Cyclonic Wind hazard

Facility/Sectors	No. of Facilities/ Class	50 Year		100 Year	
		INR Lakh	%	INR Lakh	%
Facilities					
Hospitals	64	5.65	0.01%	91.76	0.13%
School/College	346	33.82	0.01%	513.77	0.14%
Places of Worship	95	0.71	0.01%	16.40	0.12%
Transport					
Road, km (National Highway)	51	23.79	0.04%	77.84	0.13%
Road, km (Major Road)	98	35.74	0.08%	88.31	0.19%
Road, km (Minor Road)	1493	272.43	0.15%	525.45	0.28%
Railway lines, km	34	-	-	-	-
Utility Networks					
Electric Lines, km	1429	721.93	0.15%	1,401.50	0.28%
Water lines, km	936	-	-	-	-
Sewerage lines, km	1133	-	-	-	-

5.3.3 Other Hazards

5.3.3.1 Epidemics

The State malaria statistics shows Khordha district is in the group of districts with low incidence of malaria disease (as per 2007-2011). However, the incidence statistics of Acute Diarrheal Disorders (ADD) shows that about 2% of the city population is annually affected, which is a significant number. The health impact due to waterborne diseases is also a concern of the city. Recurring natural hazards such as water logging due to flood and cyclone, and poor sewerage also act as triggering factors for waterborne and vector borne diseases in some parts of the city.

The State Public Health Department supports the city health services. Under the National Rural Health Mission (NRHM) plan fund, a budget outlay of INR 977 Crores was earmarked for the State in 2012-13 as part of the disease control program.

The Sate health sector is presently emphasizing heavily on investing in the health infrastructure like the construction of a big hospital in Bhubaneswar. The government is also encouraging a Public-Private- Partnership (PPP) model for this. The city also requires an integrate plan to minimize the health problems. The city's health sector also needs to put special emphasis on human resource development and skill improvement.

5.4 Potential Risk Based on Climate Change to Health Sector

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) concluded, among other things, that climate change is projected to increase threats to human health through the altered distribution of some infectious disease vectors, altered seasonable distribution of some allergenic pollen species, and increased heat waves (IPCC 2007). The report stated three broad categories of health impacts that are associated with climatic conditions:

1. Impacts that are directly related to weather/climate;
2. Impacts that result from environmental changes that occur in response to climatic change;
3. Impacts resulting from consequences of climate-induced economic dislocation, environmental decline, and conflict.

Table 5-5 shows the probable health implications on climate change as per IPCC and WHO.

Table 5-5: Summary of health effects of weather and climate, IPCC (2007) and WHO (2009)

Health Implication	Effects of weather and climate
Cardiovascular, Respiratory, and heat stroke mortality	Short-term increases in mortality during heat waves, particularly among elderly people
Allergic rhinitis	Weather affects the distribution, seasonality and production of aeroallergens
Respiratory cardiovascular diseases and mortality	Weather affects concentrations of harmful air pollutants; high temperatures also raise the levels of ground-level ozone. Increased forest fires affect air quality
Flooding, infectious diseases and mental health	Floods, and extreme wind cause death and injuries Flooding disrupts water supply and sanitation systems and may damage transport systems as well as public health infrastructure Flooding may cause contamination of freshwater supplies and also creates opportunities for breeding of disease carrying insects such as mosquitoes Flooding may increase post-traumatic stress disorders
Starvation, malnutrition and diarrheal diseases	Drought reduces overall water availability for sanitation Drought increases the risk of forest fires, which adversely affects the air quality Drought reduces food availability in populations that are highly dependent on household agriculture productivity and/or are economically weak
Mosquito-borne, tick-borne diseases, and rodent-borne diseases (such as malaria, dengue, tick-borne encephalitis and Lyme disease)	Higher temperatures shorten the development time of pathogens in vectors and increase the potential of transmission to humans Each vector species has specific climate conditions (temperature and humidity) necessary to be sufficiently abundant to maintain transmission
Malnutrition and under nutrition	Climate change may decrease food supplies (e.g. crop yields and fish stocks) or access to food supplies
Water-borne and food-borne diseases	Survival of disease-causing organisms is related to temperature Climate conditions affect water availability and quality Extreme rainfall can affect the transport of disease-causing organisms into the water supply

In the case of Bhubaneswar city, a few of the above observations stand true as the city experiences continuous rain for a few days during monsoon and due to cyclone events. The city experiences water logging in some parts, which is mainly caused by encroachment of natural drains and a poor drainage network. Continued water logging may also trigger both vector borne and water borne diseases. The change in rainfall patterns and temperatures due to climate change can accentuate this situation.

The climate change scenario forecasts an increase in the minimum daytime surface air temperatures, which is conducive of vector multiplication. The climate change scenario also predicts increase in the intensity of rainfall, which can increase water logging.

The disease incidence of ADD in the city shows higher reported incidence during monsoon months. Malaria epidemiological research shows that temperature and humidity are the two most important favoring factors for the vector and the parasite to propagate. The malarial parasites develop optimally in the vector at 20°-30°C. High humidity prolongs the life of the vector and transmission is extended under these conditions. In the intermediate human host, the parasite must function at 37°C or higher, since the infection induces a significant rise in core temperature during the height of the infection (Despommier et al., 2009).

There are incidences of other vector borne diseases - dengue and chikungunya, and water borne diseases - diarrhea. The increase in maximum temperature due to climate change can increase the incidence of these diseases. Rainfall and temperature were correlated to diarrhea disease incidence. The increases in rainfall and minimum temperature show favorable conditions for increase in the incidence of diarrhea.

5.5 Estimation of Affected Population and Casualties

Earthquake's most damaging impacts are in terms of structural losses and number of casualties (serious injuries including fatalities). Majority of the fatalities and injuries are caused by structural failure. As a part of the study, while estimating the probabilistic losses for 475 year return-period earthquake scenario event and their associated economic impacts, the affected population and causalities (serious injuries including fatalities) for 475 years return periods earthquake scenario event is estimated.. Table 5-6 provides the estimates of earthquake-affected population and estimates of injuries including fatalities in Bhubaneswar city.

Table 5-6: Estimated numbers of affected people and causalities (serious injuries including fatalities) for 475 years return-period earthquake hazard scenario event

Return-period (in years)	475
Affected Population	55,018
Casualty numbers	1,933 – 2,075

For Cyclonic winds, the number of injuries including fatalities are difficult to estimate, as it is a function of cyclone warning time and evacuation planning. If people are evacuated in time, causalities are unlikely. Cyclone Phailin and cyclone Hudhud are recent examples where these numbers have been reduced significantly in comparison to similar cyclonic events that occurred in the past and where corresponding number of injuries and fatalities were significantly higher.

5.6 Composite Vulnerability Analysis

Based on risks due to various hazards, Composite Vulnerability Index (CVI) for the city was developed at the ward level. The steps followed for developing the CVI are:

1. Hazard wise risk (economic losses) calculated at ward level for earthquakes and cyclonic winds,
2. Ranking wards based on risk values
3. Calculating mean value and standard deviation (after eliminating the extreme values)
4. Values below (mean minus standard deviation) are considered low, values above (mean plus standard deviation) are high and values that fall between were categorized as medium
5. The ranks of both the hazards were added and normalized to develop the CVI and were plotted in GIS at ward level.

The CVI categorizes the city into high, medium, and low vulnerability areas based on the cumulative score of all the hazards considered for the analysis. Wards with high CVI need priority interventions. Spatial analysis between location of slum pockets and the CVI shows wards with high CVI have more than 50% of the slum pockets. The composite vulnerability map of the city is shown in Figure 5-13.

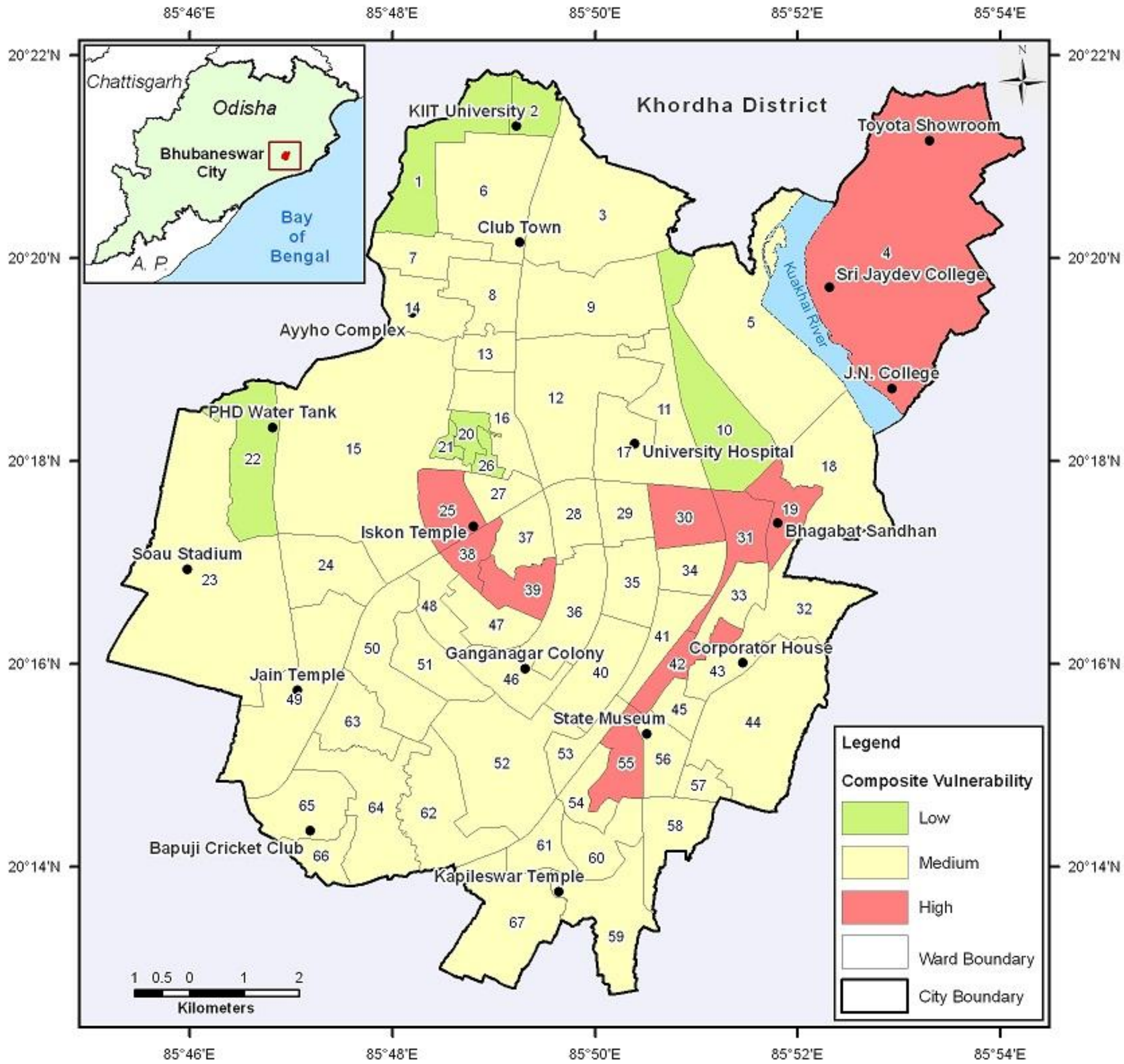


Figure 5-13: Composite vulnerability map of Bhubaneswar city

5.7 Risk Atlas

The Risk Atlas has been prepared as a separate document. It has a series of GIS maps prepared following standard cartographic rules, standard nomenclature and other basic map information. Maps are prepared for the city showing various themes including hazard, frequency, severity, vulnerability and risk.

The risk atlas includes:

1. The Introductory section describes the demography, economy in general, and the disaster profile of the city. This section also has some thematic maps and summary tables for quick reference.
2. Hazard (expressed as footprints of historical events or probabilistic maps of hazard for different hazards at different return periods).
3. Exposure/Inventory data showing distribution and valuation for various assets—(residential, commercial, industrial buildings, essential facilities, and infrastructure)
4. Social vulnerability maps by age, gender, income, religion, disabled population. These have been created based on the social impact assessment of various hazards
5. Epidemics, Heat and Climate change impacts
6. Probabilistic loss maps by hazard

7. Probabilistic loss maps by exposure asset category
8. Risk Maps: AAL and PML for Cyclonic winds and PML for earthquakes for Residential, Commercial, and Industrial buildings
9. Projection of losses to various sectors for Cyclonic winds and earthquake hazards
10. Composite Vulnerability map at ward level

6 Capacity Assessment at Community, Ward and City Levels

6.1 Methodology for Capacity Assessment

Consultative and analytical methods are adopted for assessing the capacity and needs of the community. For capacity and needs assessment, we have treated the government departments and communities separately. Even though both of them are stakeholders, the former is more a service provider while the latter is a receiving group. In terms of loss or damage, both institutions and the community get impacted.

Following are the key tasks carried out to assess capacity:

1. Review of city development plan (CDP), and other documents including notifications and legislations that contribute and influence DRR in the city
2. Review of organization structure and Standard Operation Procedures (SOP) for disaster response of the municipal corporation
3. Stakeholder discussions
4. Field investigation and household survey
5. Analysis of information gathered from the above exercises in the backdrop of the hazard exposure and vulnerability analysis and climate change scenarios.
6. Analysis of hazard, exposure, vulnerability, and climate change scenarios against the backdrop of the city's vision and development

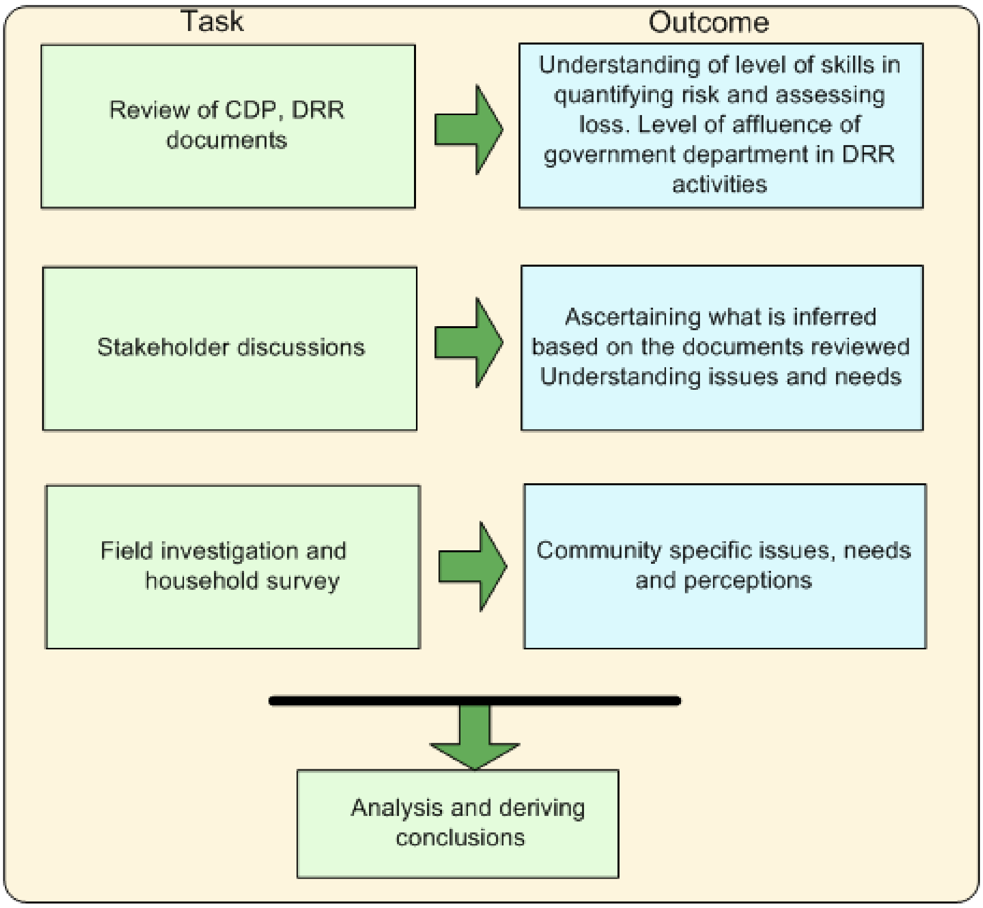


Figure 6-1: Steps involved in capacity needs assessment

6.2 Capacities of Existing Government Institutions

6.2.1 Capacity Assessment of Government Institutions

Bhubaneswar city has prepared its City Disaster Management Plan (CDMP) for the city and City Development Plan (CDP) developed in the year 2011-12. The latest CDP is of IIT Kharagpur, 2011 as part of the Bhubaneswar Development Authority master plan. The CDP is a comprehensive plan with city vision plan for development of all sectors taking into consideration the city's growth. However, the city hazard risk appears to have been overlooked in the CDP.

The State has two recognized human resource training and capacity building institutes, namely, Gopabandhu Academy of Administration (GAA) and State Institute for Rural Development (SIRD). These institutes provide training and capacity building for improving of State resources' skills. The former focuses on training and capacity building for government officials while the latter is for PRIs, Govt. Officials, Non Government Organizations, and community based organizations. In addition to this, State level organizations, Odisha State Disaster Management Authority (OSDMA), and UN organizations also provide capacity building and skill enhancement activities for government departments and communities. The Bhubaneswar city administration, non-government organizations, and communities also receive training and capacity building activities through these organizations.

Out of 10 Odisha Disaster Rapid Action Force (ODRAF) units, one is located at Bhubaneswar and another at Cuttack city, which is one of the most thickly populated cities of Odisha 30 km away from Bhubaneswar. The ODRAF provides training for disaster response like mock drills, rescue operations, etc. on a regular basis.

One of the National Disaster Response Force (NDRF) teams is located at Mundali, Cuttack and it performs various activities related to disaster risk reduction training and capacity building from time to time in different parts of the State. Key activities include liaison, reconnaissance, rehearsals and mock drills, and imparting basic and operational level training to State Response Forces (Police, Civil Defence and Home Guards). The NDRF of the State is also actively engaged in various community-based activities including:

1. Community Capacity Building Programs
2. Public Awareness Campaigns
3. Exhibitions: Posters, Pamphlets, literatures

Apart from these organizations, Civil Defence is also present in the Capital City to provide services like:

- Dissemination of warnings in the likely affected areas and evacuation of people.
- Management of shelters
- Rescue of casualties, restoration of essential services, repairs and clearance of roads by cutting off fallen trees and debris, salvage and properties etc.
- First Aid and Medical attention to the victims of road accidents, emergency sanitation, prevention of epidemic, and disposal of corpses and animal carcasses.
- Emergency feeding, sheltering and clothing of the homeless, and
- Establishment of communication network through VHF/HF sets for easy command and control.

In addition, to supporting and being part of the State Disaster Risk Reduction (DRR) activities, the city administration is active in developing measures towards a climate risk resilient urban center. The city is part of the UNISDR global campaign of "The Making Cities Resilient Campaign" and is recipient of the SASAKAWA Recognition 2011 and Role Model for Community Preparedness.

UNDP, India is very actively involved in various DRR activities in the State since the Odisha Super Cyclone of 1999. It mainly coordinates and works closely with ODSMA and supports both technical capacity building and infrastructure development for DRR.

6.2.2 Capacity Requirements of Government Institutions

The capacity requirements of government institutions need to be analyzed in the light of the nature of the hazards and their impacts on the city. It needs to evaluate whether the city, as a service provider, has adequate capacity in terms of skills and resources to support the community needs in the current and predicted future environment.

In Bhubaneswar city, major drains are being maintained by the Water Resource Department while the City Administration maintains the secondary and tertiary drains. There is a need for a coordinated effort for desilting and maintenance of these drains to avoid water logging problems in some parts of the city. Similarly, the housing permits are being issued by BDA based on the development plan prepared, while City Administration collects the housing revenue. The city plan should emphasize better coordination with Water Resource Department for water logging and with Housing and Urban development department for Building Codes for Cyclone and Earthquake hazards and their implementation in new constructions. In terms of capacity and needs of the city, the following are suggested:

1. There is a need for close coordination between City Administration and Water Resource Department for maintenance of natural drains and drainage system.
2. The building codes of the city need to be reviewed in light of the hazards in the region and, if necessary, make amendments. There should be a mechanism in the city to monitor the adherence to building codes and land use norms to improve urban resilience.
3. In terms of human resources, the city needs a dedicated workforce mainly at the field level particularly for the health sector.
4. City officials need training and capacity building to mainstream climate change impact into city development planning. The City Development Plans need to consider hazard risks and carry out Cost-Benefit-Analysis (CBA) of investments considering these.
5. The city needs epidemic contingency plans and long term plans for the health sector taking climate change impacts into consideration
6. A mechanism for enforcing registration of disease cases (with their locations) and mortality through all government and private hospitals can help in developing strategies for the health sector. There should be a mechanism for registering diseases in the city similar to birth and death registrations.
7. The city's present initiative of encouraging public private partnerships in various development sectors is favorable for improving the city's resilience.

6.3 Capacity of Social Institutions

6.3.1 Community Capacity and Awareness

Odisha State, including its city populations, has experienced some catastrophic disasters such as the "1999, Odisha Super Cyclone". The city population has experienced frequent cyclone and heavy rainfall events. For this reason, the city dwellers have reasonably good hazard coping capacity even though the economic coping capacity is low due to the economic situation.

However, the economic situation and in-migration in the city lead to development of weak building infrastructure, which are vulnerable to natural hazards. About 40% of the city populations are living in slums of which about 30-40% live in houses that are temporary structures and are vulnerable to several natural hazards.

To improve the capacity of communities, the following measures are suggested:

1. Community awareness focusing on hygiene, sanitation, causes and prevention of epidemics is required. Community organizations, Self-Help Groups (SHGs) need to be identified and trained to train the communities to work in the health sector.
2. Communities need to be sensitized on the importance of adhering to land use, building codes and hazard zones. NGOs need to be involved in the process of community sensitization.
3. Emphasis on sensitizing programs on nutrition and prevention of epidemics is important particularly in the highly vulnerable and crowded wards of the city.

7 Recommendations

Based on the city level risk assessment, recommended actions are suggested for disaster risk mitigation of the city. These include both structural and non-structural measures. Sector specific short, medium, and long-term strategies are suggested based on the assessment carried out in this study. It necessitates mainstreaming DRR in city development planning to reduce the risks and protect the population and assets of the city. This needs coordination among sectors, an integrated approach ensuring mitigation and adaptation measures that would not cause adverse impacts. The mitigation and adaptation measures need to be phased appropriately and integrated into the City's short, medium, and long-term plans.

Cyclone adaptation and mitigation measures: Among buildings, the economic losses of residential buildings are highest due to cyclonic winds. Among utility networks (Electric lines, Railway lines, Water lines, and Sewerage lines) the estimated economic losses are highest due to cyclonic winds. The following measures are needed to reduce these losses:

- Enforce building codes (byelaws) for various types (residential, commercial, and industrial) of buildings in general and residential buildings in particular, to reduce the cyclonic wind risk in the city.
- Significant damage to buildings also happens due to fallen trees/their branches from high cyclonic wind speeds. Hence, city administration should have a proper tree-pruning policy for the city.
- Evaluate tinned/asbestos roof buildings for their resistance to cyclonic wind by certified structural engineers in a phased manner. This should be followed up by appropriate retrofitting measures.
- Gradually covert the overhead lines in general, and electric power lines in particular, to underground cables. This will help in avoiding damage and loss due to cyclonic winds.

Earthquake risk mitigation measures: The estimated economic losses to residential buildings are highest followed by commercial and industrial buildings. Among schools/colleges, hospitals, and religious places, the estimated economic losses are highest for schools/colleges followed by religious places and hospitals. Since earthquake risk mitigation measures are directly related to life-safety, the city administration should take these up on priority for their strict compliance. The following are some of the measures to mitigate losses to life and property from earthquakes:

- Create regular public awareness campaigns on “Earthquake safety - Dos and Don’ts” through seminars and quizzes in schools/colleges, and through print and electronic media
- Review and enforce strict building codes (byelaws) compliance in design and construction of various types of new buildings and infrastructures.
- Evaluate old buildings from structural engineering point of view, especially starting from schools/colleges, religious places and hospitals for their structural resistance to earthquakes. This should be followed up by appropriate retrofitting measures.
- All the residential, commercial and industrial buildings should be evaluated for their structural safety in a phased manner and appropriate retrofitting measures should be taken up from building code perspectives.
- To mitigate non-structural damages, several measures can be adopted, such as:
    - Fasten shelves, cupboards etc. securely to walls,
    - Secure water heaters, LPG cylinders etc., by strapping them to the walls or bolting to the floor

- Anchor overhead lighting fixtures and fans to the ceiling properly
- Secure hanging objects, such as ACs, heavy glass paintings etc., as hanging objects may cause loss to life and property

Flood/Water logging mitigation measures: Taking into consideration the growth in the city, the following measures are recommended for urban flood management:

- Remove encroachment of natural drains as this helps in mitigating flood/ water logging problem of the city
- Develop and connect storm water network for the entire city including peripheral areas of the city
- Develop high resolution (preferably 0.5 m) Digital Elevation Model (DEM), which will be helpful to model and predict city flooding/water-logging accurately at sub-ward level and for planning mitigation measures.
- Periodically clean existing storm drains, which are clogged due to waste dumping and indiscriminate developmental activities
- Improve the existing solid-waste disposal system and enforce non-dumping of solid waste in drains

The service delivery of the city administration, especially the solid waste management, sewerage network and public transport system should also take into consideration population growth of the city in future.

Heat wave adaptation and mitigation measures: Though Bhubaneswar city has good cover of trees and vegetation, however, in view of the future growth of the city and predicted increase in temperature due to impact of climate change, the following measures are recommended for heat-wave adaptation and mitigation:

- City administration should develop a ward-level plan to check on vulnerable populations during heat waves, especially the elderly and poor.
- Additionally, city administration should arrange for portable water tanks in the event of heat waves.
- Create awareness among communities towards green buildings[13]
- While revising building codes for residential buildings, it is also important to consider the heat wave risk in the city. The design specifications should take into account guidelines on the design of green buildings
- Building owners should be encouraged to use heat-reflecting material on roof-tops of existing buildings
- Green building designs should be adopted for government and public buildings
- Green cover should be further improved in the city in a phased manner
- Increase awareness in people to take pre-emptive measures during heat waves, for example, drinking enough water, avoiding alcohol consumption, etc. and in understanding warning symptoms of heat exhaustion and how best to keep cool.
- Training masons for constructing buildings following building codes and design specifications that cover features of green buildings

Epidemics adaptation and mitigation measures: Health is a key sector that needs priority considerations as part of DRR activities both in short and medium-term planning. These include:

[13] GRIHA – green building ‘design evaluation system’– A tool to design, operate, evaluate and maintain resource efficient ‘healthy’ and ‘intelligent’ building (http://www.cccindia.co/corecentre/Database/Docs/DocFiles/rating_system.pdf)

- Public awareness for improving hygiene and sanitation.
- Monitoring of commercial eating places to enforce quality standards and ensuring good supply of quality drinking water
- Imparting hygiene and sanitation education in schools
- Desilting drains to avoid water logging during rainy season
- Land use planning needs to take into consideration water logging issues during and after construction and development activities
- Coordinate with the railways and PWD to regularly fumigate railway yards and trains in train yards, particularly during rainy seasons
- The drinking water supply department to the city should test water system for adequate chlorination levels and for bacterial and viral counts
- Inspection across the City to identify potential mosquito breeding grounds and take necessary steps before and during rainy season

Climate change adaptation measures

- Land use and infrastructure development plans of the city need to take into consideration the short and long term climate change trends
- Low-lying areas of city can be best protected from water logging by developing suitable drainage system. The storm water drainage system of the city need to be developed taking into consideration the flood scenarios and the rainfall variation trends based on climate change scenarios

IT and database development measures

- The city Municipality and Bhubaneswar Development Authority has some GIS data of the city. ORSAC, and OSDMA are other State agencies who have/are developing GIS data for the entire Odisha state. These agencies should develop the Utility network layers (electricity network, drinking water network, storm water network, sewerage network, and communication network) in GIS platform to help various decision makers to integrate DRR activities. There should be a central database, which is accessible to various departments through defined data sharing policies
- The city needs to have a mechanism to develop disease incidence data from both government and private hospitals. This can be done through an online module in the city portal where access can be given to users (government and private hospitals) to enter tested and positively identified cases at their institutions with their spatial locations. Similar to birth and death registry, registering disease incidence for identified diseases needs to be made mandatory.
- Health contingency planning should be based on disease incidence data
- Damage assessment reports need to follow the format developed and circulated by NDMA and need to be decentralized. In the case of the City, it should be at ward level. Mobile based applications can be developed for ward officials to make online entry of damage information.

Mainstreaming integrated DRR in city development planning

- The city master plan needs to consider hazard risks from various natural hazards and integrate mitigation measures in its vision document
- City, with the support of the political representatives, needs to enforce land use zoning and building codes based on hazard and risk maps
- Implement incentives and disincentives for climate proofing – tax subsidies for houses with climate proofing and disincentives like climate risk penalties for people encroaching hazard prone areas.
- Awareness of political representatives will help regulate community encroachment in hazard prone areas

- As a medium and long-term measure, the city should build a storm water drainage system for entire city to avoid urban flash floods/water-loggings.

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8 Annexure 1: Hazard Maps

Cyclone hazard maps for return periods of 10, 25 and 50 years.

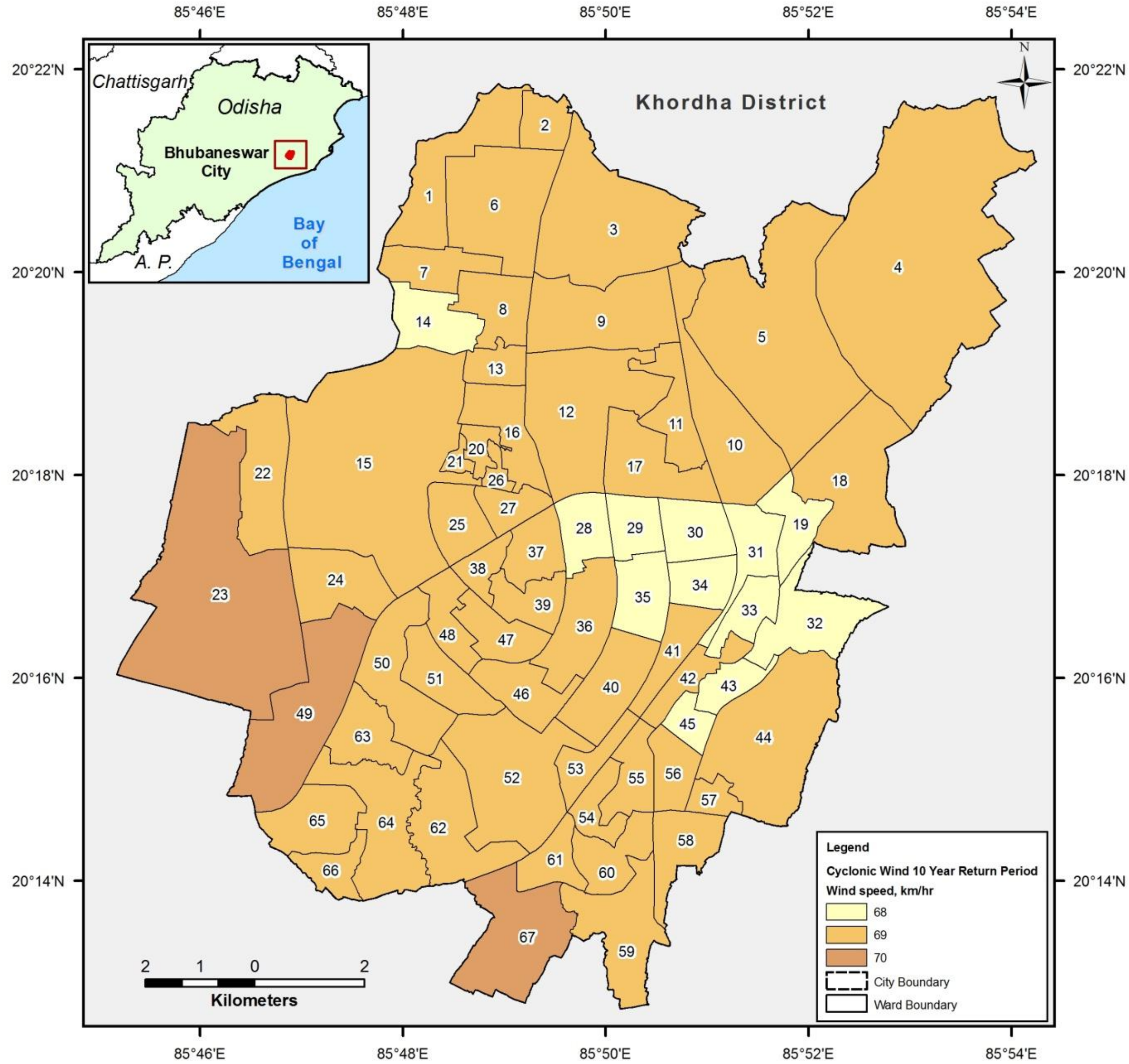

Figure 8-1: Cyclone hazard Map for 10-year return period

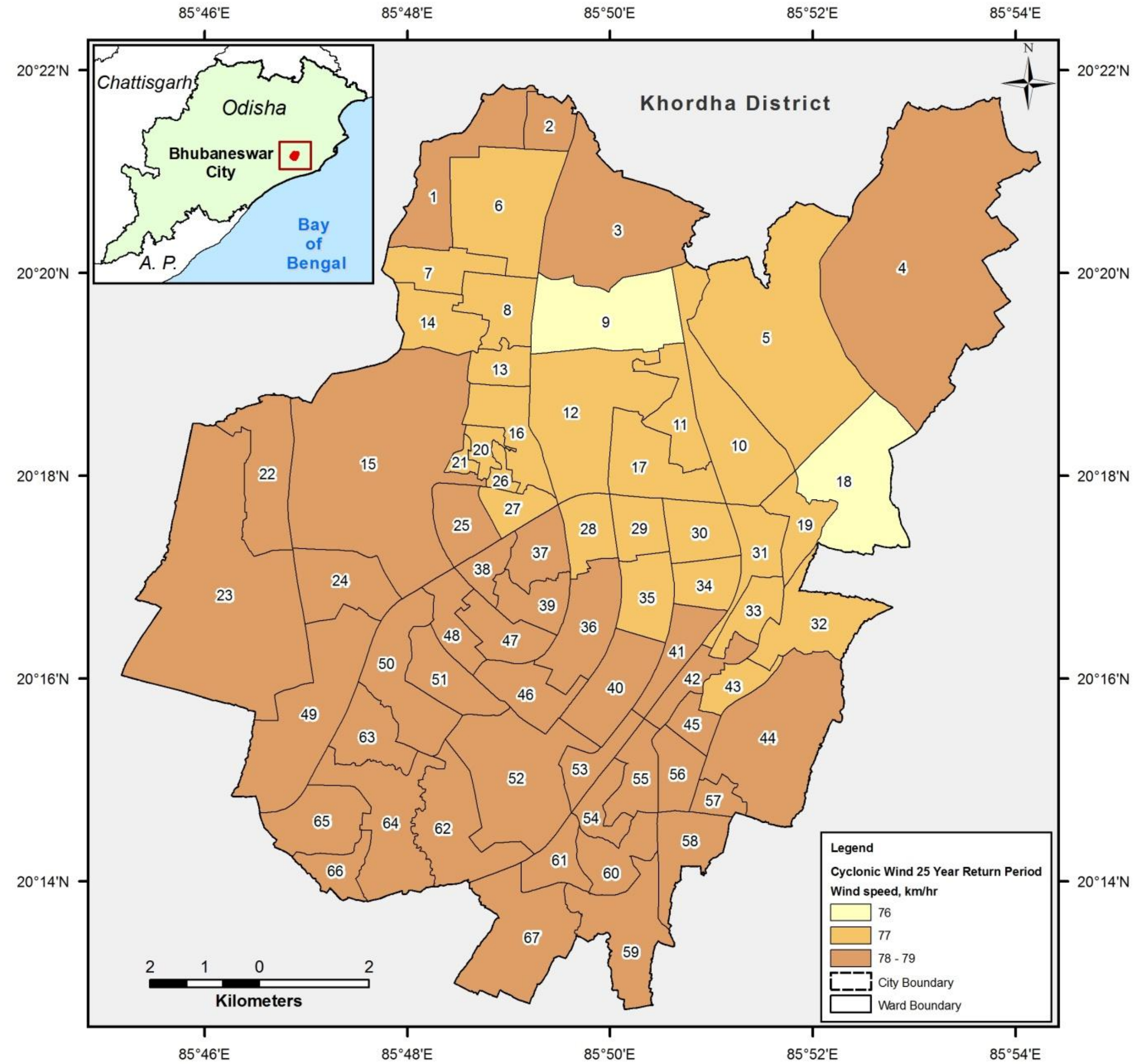

Figure 8-2: Cyclone hazard Map for 25-year return period

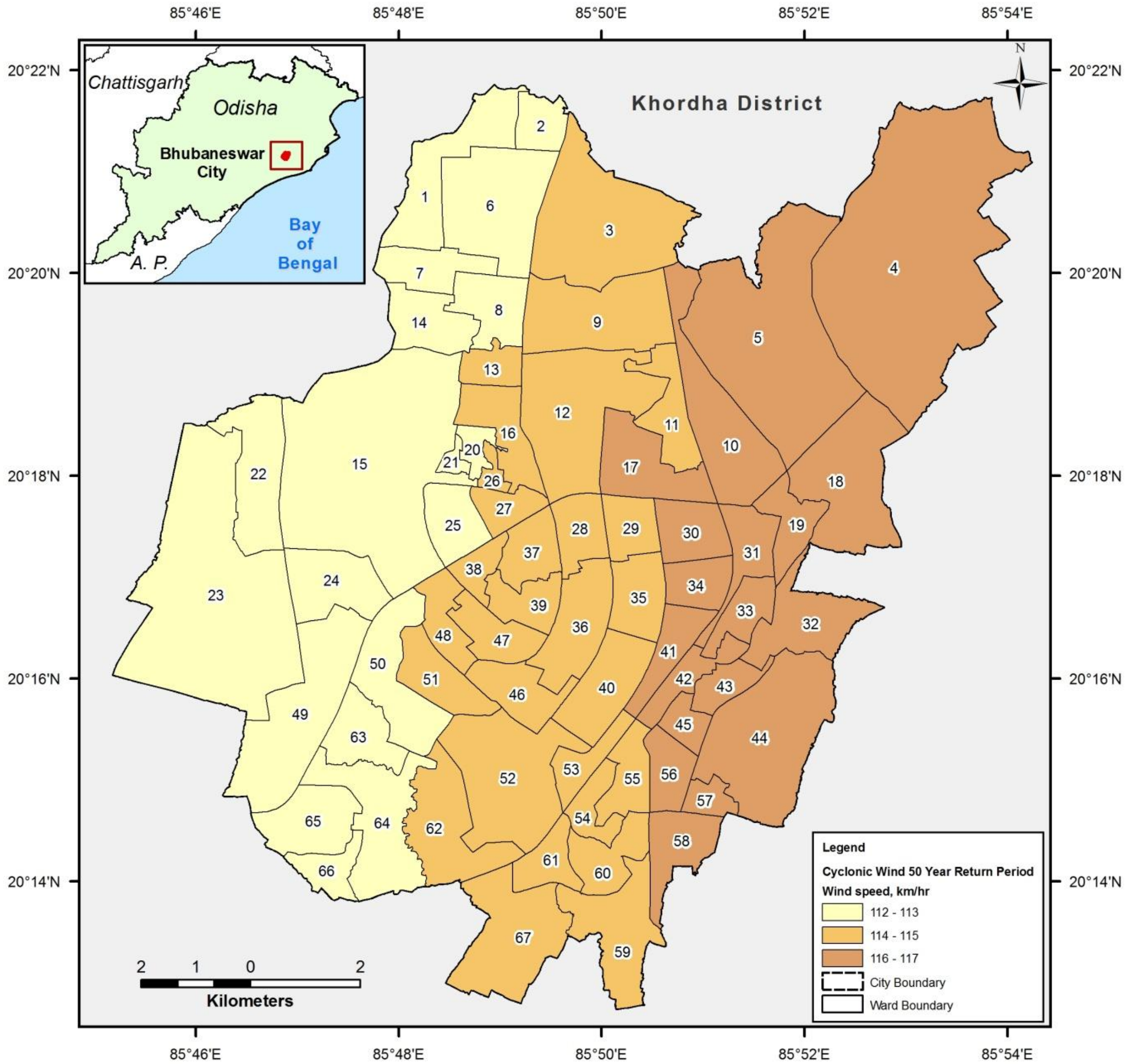

Figure 8-3: Cyclone hazard Map for 50-year return period

9 Annexure 2: Detailed Exposure Data

Table 9-1: Ward-wise distribution of population

Ward	Total Population	Total Males	Total Females	Total Number of Children (0-6 years)	Total Number of Boys (0-6 years)	Total Number of Girls (0-6 years)
1	12,378	7,745	4,633	1,202	632	570
2	13,482	7,743	5,739	1,309	688	621
3	13,110	7,004	6,106	1,273	669	604
4	16,185	8,183	8,002	1,571	826	745
5	13,637	7,318	6,319	1,324	696	628
6	13,547	6,757	6,790	1,315	691	624
7	13,698	7,188	6,510	1,330	699	631
8	13,529	7,172	6,357	1,313	690	623
9	13,932	7,302	6,630	1,353	711	642
10	13,540	7,430	6,110	1,315	691	624
11	11,834	6,235	5,599	1,149	604	545
12	13,243	7,454	5,789	1,286	676	610
13	13,287	7,002	6,285	1,290	678	612
14	13,522	7,086	6,436	1,313	690	623
15	11,528	6,319	5,209	1,119	588	531
16	11,404	6,069	5,335	1,107	582	525
17	12,238	6,334	5,904	1,188	624	564
18	13,094	6,957	6,137	1,271	668	603
19	14,071	7,505	6,566	1,366	718	648
20	11,677	6,267	5,410	1,134	596	538
21	11,320	5,930	5,390	1,099	578	521
22	13,568	7,026	6,542	1,317	692	625
23	12,240	6,206	6,034	1,188	624	564
24	13,636	7,127	6,509	1,324	696	628
25	13,508	7,068	6,440	1,311	689	622
26	12,167	6,516	5,651	1,181	621	560
27	12,039	6,293	5,746	1,168	614	554
28	12,230	6,386	5,844	1,187	624	563
29	11,518	6,115	5,403	1,118	588	530
30	12,220	6,348	5,872	1,186	623	563
31	11,633	6,328	5,305	1,130	594	536
32	11,280	5,851	5,429	1,096	576	520
33	12,453	6,754	5,699	1,209	635	574
34	13,013	6,854	6,159	1,263	664	599
35	14,130	7,436	6,694	1,372	721	651
36	11,509	6,058	5,451	1,117	587	530
37	11,679	6,079	5,600	1,134	596	538

Ward	Total Population	Total Males	Total Females	Total Number of Children (0-6 years)	Total Number of Boys (0-6 years)	Total Number of Girls (0-6 years)
38	11,916	6,118	5,798	1,157	608	549
39	12,716	6,734	5,982	1,235	649	586
40	13,179	7,069	6,110	1,279	672	607
41	13,525	7,224	6,301	1,313	690	623
42	13,272	6,951	6,321	1,288	677	611
43	13,773	7,265	6,508	1,337	703	634
44	12,091	6,549	5,542	1,174	617	557
45	11,376	6,023	5,353	1,104	580	524
46	11,804	6,128	5,676	1,146	602	544
47	11,638	6,174	5,464	1,130	594	536
48	11,369	5,855	5,514	1,104	580	524
49	12,605	6,897	5,708	1,224	643	581
50	11,795	6,379	5,416	1,145	602	543
51	12,138	6,519	5,619	1,178	619	559
52	10,805	5,668	5,137	1,049	551	498
53	13,923	7,155	6,768	1,351	710	641
54	13,318	7,032	6,286	1,292	679	613
55	11,398	5,904	5,494	1,107	582	525
56	11,228	5,853	5,375	1,090	573	517
57	11,325	6,009	5,316	1,100	578	522
58	11,998	6,282	5,716	1,165	612	553
59	11,426	5,899	5,527	1,109	583	526
60	15,459	8,045	7,414	1,501	789	712
61	13,522	6,987	6,535	1,313	690	623
62	10,979	5,736	5,243	1,066	560	506
63	12,241	6,458	5,783	1,189	625	564
64	11,236	5,740	5,496	1,090	573	517
65	12,055	6,420	5,635	1,170	615	555
66	11,707	6,024	5,683	1,136	597	539
67	11,938	6,264	5,674	1,159	609	550
Total	**840,834**	**444,806**	**396,028**	**81,629**	**42901**	**38728**

Table 9-2: Ward-wise distribution of population based on literacy rate

Ward	Total Population	Total Number of Literate Persons	Total Number of Literate Males	Total Number of Literate Females	Total Number of Illiterate Persons	Total Number of Illiterate Males	Total Number of Illiterate Females
1	12,378	10,270	5,602	4,668	2,108	946	1,162
2	13,482	11,186	6,101	5,085	2,296	1,031	1,265
3	13,110	10,877	5,933	4,944	2,233	1,003	1,230
4	16,185	13,428	7,324	6,104	2,757	1,238	1,519
5	13,637	11,314	6,171	5,143	2,323	1,043	1,280
6	13,547	11,240	6,130	5,110	2,307	1,036	1,271
7	13,698	11,365	6,199	5,166	2,333	1,048	1,285
8	13,529	11,225	6,122	5,103	2,304	1,034	1,270
9	13,932	11,559	6,305	5,254	2,373	1,066	1,307
10	13,540	11,234	6,127	5,107	2,306	1,036	1,270
11	11,834	9,818	5,355	4,463	2,016	905	1,111
12	13,243	10,987	5,993	4,994	2,256	1,013	1,243
13	13,287	11,024	6,013	5,011	2,263	1,016	1,247
14	13,522	11,219	6,119	5,100	2,303	1,034	1,269
15	11,528	9,564	5,217	4,347	1,964	882	1,082
16	11,404	9,462	5,161	4,301	1,942	872	1,070
17	12,238	10,154	5,538	4,616	2,084	936	1,148
18	13,094	10,864	5,925	4,939	2,230	1,001	1,229
19	14,071	11,674	6,367	5,307	2,397	1,076	1,321
20	11,677	9,688	5,284	4,404	1,989	893	1,096
21	11,320	9,392	5,123	4,269	1,928	866	1,062
22	13,568	11,257	6,140	5,117	2,311	1,038	1,273
23	12,240	10,155	5,539	4,616	2,085	936	1,149
24	13,636	11,313	6,171	5,142	2,323	1,043	1,280
25	13,508	11,207	6,113	5,094	2,301	1,033	1,268
26	12,167	10,095	5,506	4,589	2,072	930	1,142
27	12,039	9,988	5,448	4,540	2,051	921	1,130
28	12,230	10,147	5,534	4,613	2,083	935	1,148
29	11,518	9,556	5,212	4,344	1,962	881	1,081
30	12,220	10,139	5,530	4,609	2,081	935	1,146
31	11,633	9,652	5,264	4,388	1,981	890	1,091
32	11,280	9,359	5,104	4,255	1,921	863	1,058
33	12,453	10,332	5,635	4,697	2,121	952	1,169
34	13,013	10,796	5,889	4,907	2,217	995	1,222
35	14,130	11,723	6,394	5,329	2,407	1,081	1,326
36	11,509	9,549	5,208	4,341	1,960	880	1,080
37	11,679	9,690	5,285	4,405	1,989	893	1,096
38	11,916	9,886	5,392	4,494	2,030	912	1,118
39	12,716	10,550	5,754	4,796	2,166	973	1,193

Ward	Total Population	Total Number of Literate Persons	Total Number of Literate Males	Total Number of Literate Females	Total Number of Illiterate Persons	Total Number of Illiterate Males	Total Number of Illiterate Females
40	13,179	10,934	5,964	4,970	2,245	1,008	1,237
41	13,525	11,221	6,120	5,101	2,304	1,034	1,270
42	13,272	11,011	6,006	5,005	2,261	1,015	1,246
43	13,773	11,427	6,233	5,194	2,346	1,053	1,293
44	12,091	10,032	5,472	4,560	2,059	925	1,134
45	11,376	9,438	5,148	4,290	1,938	870	1,068
46	11,804	9,793	5,341	4,452	2,011	903	1,108
47	11,638	9,656	5,267	4,389	1,982	890	1,092
48	11,369	9,433	5,145	4,288	1,936	870	1,066
49	12,605	10,458	5,704	4,754	2,147	964	1,183
50	11,795	9,786	5,338	4,448	2,009	902	1,107
51	12,138	10,071	5,493	4,578	2,067	928	1,139
52	10,805	8,965	4,890	4,075	1,840	826	1,014
53	13,923	11,551	6,300	5,251	2,372	1,065	1,307
54	13,318	11,050	6,027	5,023	2,268	1,019	1,249
55	11,398	9,457	5,158	4,299	1,941	871	1,070
56	11,228	9,316	5,081	4,235	1,912	858	1,054
57	11,325	9,396	5,125	4,271	1,929	866	1,063
58	11,998	9,954	5,429	4,525	2,044	918	1,126
59	11,426	9,480	5,171	4,309	1,946	874	1,072
60	15,459	12,826	6,996	5,830	2,633	1,182	1,451
61	13,522	11,219	6,119	5,100	2,303	1,034	1,269
62	10,979	9,109	4,968	4,141	1,870	840	1,030
63	12,241	10,156	5,539	4,617	2,085	936	1,149
64	11,236	9,322	5,085	4,237	1,914	859	1,055
65	12,055	10,002	5,455	4,547	2,053	922	1,131
66	11,707	9,713	5,298	4,415	1,994	895	1,099
67	11,938	9,905	5,402	4,503	2,033	913	1,120
Total	**840,834**	**697,619**	**380,501**	**317,118**	**143,215**	**64,306**	**78,909**

Table 9-3: Distribution of the Census houses based on the condition of the houses

Ward	Total Residence	Total Good Residence	Total Livable Residence	Total Dilapidated Residence	Total Residence-cum-other use	Total Good Residence-cum-other use	Total Livable Residence-cum-other use	Total Dilapidated Residence-cum-other use
1	492	296	172	24	9	4	4	1
2	2,575	1,552	898	125	47	22	23	2
3	2,871	1,731	1,001	139	52	25	25	2
4	3,305	1,993	1,153	160	60	29	29	3
5	3,136	1,891	1,094	152	57	27	27	3
6	1,867	1,126	651	90	34	16	16	2
7	3,252	1,960	1,134	157	59	28	29	3
8	3,399	2,049	1,185	164	62	29	30	3
9	3,164	1,908	1,103	153	58	27	28	3
10	3,264	1,968	1,138	158	60	28	29	3
11	2,786	1,680	971	135	51	24	24	2
12	3,068	1,850	1,070	148	56	26	27	3
13	3,343	2,015	1,166	162	61	29	29	3
14	3,095	1,866	1,079	150	57	27	27	3
15	2,781	1,677	970	135	51	24	24	2
16	3,007	1,813	1,049	145	55	26	26	3
17	2,649	1,597	924	128	48	23	23	2
18	2,799	1,688	976	135	51	24	25	2
19	3,344	2,016	1,166	162	61	29	29	3
20	3,218	1,940	1,122	156	59	28	28	3
21	3,097	1,867	1,080	150	57	27	27	3
22	3,049	1,838	1,063	148	56	26	27	3
23	2,420	1,459	844	117	44	21	21	2

Ward	Total Residence	Total Good Residence	Total Livable Residence	Total Dilapidated Residence	Total Residence-cum-other use	Total Good Residence-cum-other use	Total Livable Residence-cum-other use	Total Dilapidated Residence-cum-other use
24	3,167	1,909	1,104	153	58	27	28	3
25	3,049	1,838	1,063	148	56	26	27	3
26	3,442	2,075	1,200	167	63	30	30	3
27	2,812	1,696	981	136	51	24	25	2
28	2,571	1,550	897	124	47	22	23	2
29	2,658	1,603	927	129	49	23	23	2
30	2,710	1,634	945	131	49	23	24	2
31	2,802	1,689	977	136	51	24	25	2
32	2,394	1,443	835	116	44	21	21	2
33	2,846	1,716	992	138	52	25	25	2
34	3,209	1,935	1,119	155	59	28	28	3
35	3,254	1,962	1,135	157	59	28	29	3
36	2,609	1,573	910	126	48	23	23	2
37	2,692	1,623	939	130	49	23	24	2
38	2,769	1,669	966	134	51	24	24	2
39	2,993	1,805	1,044	145	55	26	26	3
40	2,670	1,610	931	129	49	23	23	2
41	3,005	1,812	1,048	145	55	26	26	3
42	3,269	1,971	1,140	158	60	28	29	3
43	3,082	1,858	1,075	149	56	27	27	3
44	2,812	1,696	981	136	51	24	25	2
45	2,614	1,576	911	126	48	23	23	2
46	2,637	1,590	919	128	48	23	23	2
47	2,710	1,634	945	131	49	23	24	2
48	2,631	1,586	917	127	48	23	23	2

Ward	Total Residence	Total Good Residence	Total Livable Residence	Total Dilapidated Residence	Total Residence-cum-other use	Total Good Residence-cum-other use	Total Livable Residence-cum-other use	Total Dilapidated Residence-cum-other use
49	2,604	1,570	908	126	48	22	23	2
50	2,565	1,547	895	124	47	22	22	2
51	2,761	1,665	963	134	50	24	24	2
52	2,654	1,600	925	128	48	23	23	2
53	2,627	1,584	916	127	48	23	23	2
54	2,414	1,455	842	117	44	21	21	2
55	2,799	1,688	976	135	51	24	25	2
56	2,715	1,637	947	131	50	23	24	2
57	2,798	1,687	976	135	51	24	25	2
58	2,656	1,601	926	128	49	23	23	2
59	2,420	1,459	844	117	44	21	21	2
60	3,147	1,897	1,097	152	57	27	28	3
61	3,108	1,874	1,084	150	57	27	27	3
62	2,675	1,613	933	129	49	23	23	2
63	2,832	1,708	988	137	52	24	25	2
64	1,990	1,200	694	96	36	17	17	2
65	2,684	1,618	936	130	49	23	24	2
66	2,526	1,523	881	122	46	22	22	2
67	2,573	1,551	897	124	47	22	23	2
Total	**187,936**	**113,310**	**65,538**	**9089**	**3433**	**1621**	**1648**	**158**

Table 9-4: Ward-wise distribution of Census houses based on uses

Ward	Total number of census houses	Total Number of Vacant Census Houses	Total Number of Occupied Census Houses	Residential Houses	Commercial Buildings	Industrial Buildings	Schools/ Colleges etc.	Place of Worship	Hospital/Dispensary etc.	Other Non-Residential Houses
1	742	85	657	506	84	5	3	4	2	53
2	3,886	446	3,440	2,653	443	24	16	19	9	276
3	4,334	497	3,837	2,959	494	26	18	21	10	309
4	4,988	572	4,416	3,405	569	30	21	24	12	355
5	4,733	543	4,190	3,231	539	29	20	23	11	337
6	2,818	323	2,495	1,922	322	17	12	14	7	201
7	4,908	563	4,345	3,350	560	30	20	24	12	349
8	5,130	588	4,542	3,503	585	31	21	25	12	365
9	4,776	548	4,228	3,260	545	29	20	23	11	340
10	4,926	565	4,362	3,305	562	89	20	24	12	350
11	4,205	482	3,723	2,870	480	26	17	21	10	299
12	4,631	531	4,100	3,162	528	28	19	23	11	329
13	5,045	578	4,467	3,444	575	31	21	25	12	359
14	4,671	536	4,135	3,188	533	29	19	23	11	332
15	4,197	481	3,716	2,865	479	26	17	20	10	299
16	4,539	520	4,019	3,099	517	28	19	22	11	323
17	3,998	458	3,540	2,729	457	24	17	20	9	284
18	4,225	484	3,740	2,883	482	26	17	21	10	301
19	5,047	579	4,468	3,444	576	31	21	25	12	359
20	4,858	557	4,301	3,316	554	30	20	24	11	346
21	4,674	536	4,138	3,190	533	29	19	23	11	333
22	4,602	528	4,074	3,142	525	28	19	22	11	327
23	3,652	419	3,233	2,492	417	22	15	18	9	260

Ward	Total number of census houses	Total Number of Vacant Census Houses	Total Number of Occupied Census Houses	Residential Houses	Commercial Buildings	Industrial Buildings	Schools/ Colleges etc.	Place of Worship	Hospital/Dispensary etc.	Other Non-Residential Houses
24	4,780	548	4,232	3,263	546	29	20	23	11	340
25	4,602	528	4,074	3,142	525	28	19	22	11	327
26	5,195	596	4,599	3,546	593	32	21	25	12	370
27	4,245	487	3,758	2,897	484	26	18	21	10	302
28	3,880	445	3,435	2,648	443	24	16	19	9	276
29	4,012	460	3,552	2,738	458	25	17	20	9	285
30	4,090	469	3,621	2,791	467	25	17	20	10	291
31	4,229	485	3,744	2,886	483	26	17	21	10	301
32	3,613	414	3,199	2,466	413	22	15	18	8	257
33	4,295	492	3,803	2,932	490	26	18	21	10	306
34	4,843	555	4,288	3,306	552	30	20	24	11	345
35	4,911	563	4,348	3,353	560	30	20	24	12	349
36	3,938	451	3,486	2,689	449	24	16	19	9	280
37	4,062	466	3,597	2,772	464	25	17	20	10	289
38	4,179	479	3,700	2,853	477	26	17	20	10	297
39	4,517	518	3,999	3,083	515	28	19	22	11	321
40	4,030	462	3,568	2,750	460	25	17	20	9	287
41	4,536	520	4,016	3,096	517	28	19	22	11	323
42	4,934	566	4,368	3,369	562	30	20	24	12	351
43	4,651	533	4,118	3,175	531	28	19	23	11	331
44	4,245	487	3,758	2,897	484	26	18	21	10	302
45	3,945	452	3,493	2,694	450	24	16	19	9	281
46	3,979	456	3,523	2,717	455	24	16	19	9	283
47	4,090	469	3,621	2,791	467	25	17	20	10	291
48	3,971	455	3,515	2,711	454	24	16	19	9	282

Ward	Total number of census houses	Total Number of Vacant Census Houses	Total Number of Occupied Census Houses	Residential Houses	Commercial Buildings	Industrial Buildings	Schools/ Colleges etc.	Place of Worship	Hospital/Dispensary etc.	Other Non-Residential Houses
49	3,930	451	3,480	2,684	448	24	16	19	9	280
50	3,872	444	3,428	2,643	442	24	16	19	9	275
51	4,167	478	3,689	2,845	476	25	17	20	10	296
52	4,005	459	3,546	2,734	457	24	17	20	9	285
53	3,965	455	3,510	2,708	452	24	16	19	9	282
54	3,643	418	3,226	2,487	416	22	15	18	9	259
55	4,225	484	3,740	2,883	482	26	17	21	10	301
56	4,097	470	3,627	2,797	467	25	17	20	10	291
57	4,223	484	3,739	2,883	482	26	17	21	10	300
58	4,008	460	3,548	2,734	458	25	17	20	9	285
59	3,652	419	3,233	2,492	417	22	15	18	9	260
60	4,750	545	4,205	3,242	542	29	20	23	11	338
61	4,691	538	4,153	3,202	535	29	19	23	11	334
62	4,037	463	3,574	2,756	461	25	17	20	9	286
63	4,275	490	3,785	2,918	488	26	18	21	10	304
64	3,003	344	2,659	2,050	344	18	12	15	7	213
65	4,051	464	3,587	2,766	462	25	17	20	9	288
66	3,813	437	3,376	2,603	435	23	16	19	9	271
67	3,883	445	3,438	2,651	443	24	16	19	9	276
Total	**283,647**	**32,523**	**251,124**	**193,559**	**32,368**	**1,794**	**1,171**	**1,389**	**667**	**20,177**

Table 9-5: Ward-wise distribution of Census houses by building structural types

Ward	Grass, Thatch, Bamboo, Wood, Mud, Plastic, etc.	Mud/Unburnt Brick/Stone without mortar	Light Metal	Burnt Brick/ stone with mortar having temporary Roof (Tiles, wood, GI, slate, etc.)	Masonry building	RCF	RCC	OTHER
1	311.33	2,715.91	54.30	5,387.72	543.18	46,515.98	2,230.58	108.64
2	695.89	6,116.10	93.11	12,052.40	16,764.95	80,056.70	4,917.51	217.32
3	3,902.78	34,443.98	529.42	67,980.69	37,896.23	541,766.98	27,616.81	1,176.90
4	4,681.89	41,039.66	608.08	80,819.30	112,412.99	537,186.57	32,830.37	1,459.91
5	3,167.08	27,814.45	434.44	54,771.49	61,017.95	388,223.95	22,181.10	985.10
6	3,390.35	29,791.66	468.58	58,606.35	16,250.00	493,441.56	23,832.34	1,041.67
7	4,213.95	37,069.59	559.20	73,110.70	20,362.17	615,460.94	29,863.27	1,342.56
8	2,983.81	26,318.66	379.46	51,889.29	57,698.59	367,608.04	21,155.27	961.64
9	2,106.30	18,445.21	285.72	36,355.19	30,411.74	273,886.25	14,755.56	685.98
10	-	-	-	-	-	-	-	-
11	1,375.85	12,081.28	191.36	23,827.37	26,544.78	168,874.93	9,732.68	425.40
12	2,741.97	24,070.03	346.30	47,483.09	13,241.08	399,717.45	19,193.64	872.47
13	1,599.51	14,010.24	205.56	27,628.87	7,731.68	232,652.33	11,218.69	493.51
14	3,149.02	27,562.19	393.19	54,422.27	45,451.39	409,596.08	22,048.84	990.61
15	1,596.12	13,982.59	197.33	27,600.99	7,698.65	232,203.33	11,146.13	526.40
16	1,814.16	15,987.31	234.51	31,546.98	26,274.80	237,328.04	12,844.92	556.08
17	1,124.14	9,884.91	146.39	19,499.44	5,418.40	164,102.72	7,946.65	341.70
18	2,020.22	17,822.74	280.98	35,142.93	19,613.34	280,179.94	14,290.91	624.63
19	5,636.13	49,463.80	724.31	97,475.29	108,395.27	690,612.91	39,530.75	1,738.96
20	2.67	23.52	0.36	46.38	154.89	164.37	18.93	0.81
21	31.68	277.84	3.96	547.44	1,827.06	1,939.74	221.79	9.96
22	932.29	8,226.19	119.11	16,244.05	22,560.24	107,814.91	6,601.86	317.75
23	2,152.44	18,795.08	266.59	37,090.17	41,298.38	262,703.78	14,974.48	660.37

Ward	Grass, Thatch, Bamboo, Wood, Mud, Plastic, etc.	Mud/Unburnt Brick/Stone without mortar	Light Metal	Burnt Brick/ stone with mortar having temporary Roof (Tiles, wood, GI, slate, etc.)	Masonry building	RCF	RCC	OTHER
24	4,456.12	39,022.88	604.48	77,014.21	42,812.30	614,087.25	31,217.01	1,370.64
25	6,189.00	54,609.44	790.73	107,835.84	29,882.85	907,110.56	43,826.35	1,992.19
26	765.78	6,774.91	106.02	13,340.58	29,696.49	70,903.97	5,429.99	244.26
27	3,589.68	31,419.15	493.03	61,938.28	51,731.99	466,501.17	25,075.82	1,169.08
28	1,425.95	12,500.68	190.78	24,656.78	6,870.61	207,485.31	10,076.47	445.32
29	2,010.49	17,766.22	261.82	34,983.42	9,690.67	294,535.90	14,212.39	654.77
30	8,043.28	70,591.25	1,020.23	139,086.20	15,308.95	1,207,027.04	56,130.47	2,551.49
31	9,014.97	79,717.66	1,253.85	157,053.44	131,004.55	1,181,943.94	63,771.48	2,787.33
32	2,252.02	19,738.05	283.03	38,972.17	43,359.00	275,808.79	15,897.64	701.08
33	3,840.62	33,586.59	520.98	66,318.84	55,359.97	498,849.90	26,837.27	1,158.16
34	2,365.68	20,785.33	317.38	40,965.66	22,859.63	326,672.23	16,576.78	719.66
35	2,191.14	19,314.02	290.77	38,064.17	10,587.80	320,209.08	15,528.13	698.10
36	2,448.33	21,496.69	323.14	42,369.46	4,687.25	367,900.36	17,304.39	754.27
37	3,928.90	34,682.82	504.91	68,307.03	57,075.13	514,544.09	27,778.78	1,262.72
38	8,151.05	72,151.42	1,020.64	142,121.25	158,256.66	1,006,805.91	57,650.67	2,552.53
39	6,219.97	54,575.14	804.04	107,564.78	119,755.49	762,481.98	43,515.31	1,906.56
40	2,779.80	24,300.75	357.24	47,956.65	13,401.15	403,587.09	19,392.14	893.41
41	3,915.92	34,509.05	506.20	68,001.21	18,904.96	572,104.64	27,726.12	1,200.31
42	7,800.00	68,287.55	1,023.95	134,726.19	149,959.46	954,138.15	54,682.40	2,458.35
43	4,073.33	35,909.70	514.44	70,824.44	98,580.13	470,744.00	28,848.55	1,372.35
44	2,817.40	24,659.67	386.96	48,612.94	81,204.85	301,509.82	19,681.04	917.57
45	5,133.09	45,182.17	677.49	89,112.77	49,474.47	709,836.57	36,279.77	1,694.33
46	2,079.14	18,192.27	270.76	35,895.71	19,907.68	286,054.17	14,499.05	631.99
47	1,700.39	14,923.33	215.68	29,403.49	8,198.84	247,272.34	11,866.25	539.40

Ward	Grass, Thatch, Bamboo, Wood, Mud, Plastic, etc.	Mud/Unburnt Brick/Stone without mortar	Light Metal	Burnt Brick/ stone with mortar having temporary Roof (Tiles, wood, GI, slate, etc.)	Masonry building	RCF	RCC	OTHER
48	1,671.30	14,784.58	220.59	29,198.48	3,199.65	253,246.66	11,812.46	514.89
49	4,068.43	35,631.82	536.97	70,293.97	39,212.91	560,470.84	28,754.94	1,253.38
50	2,997.97	26,215.05	401.11	51,755.78	43,134.46	389,600.86	20,890.92	936.25
51	1,890.89	16,658.85	236.77	32,870.80	18,237.89	262,024.99	13,373.89	592.14
52	2,740.09	24,154.03	356.83	47,604.40	13,207.38	400,569.77	19,370.02	832.90
53	2,829.93	25,033.99	373.51	49,362.45	13,637.92	415,130.66	20,001.45	871.83
54	1,338.70	11,829.37	168.24	23,327.16	45,490.19	134,408.05	9,450.28	448.81
55	4,849.69	42,784.94	674.52	84,363.47	93,866.96	598,127.32	34,306.50	1,499.47
56	2,448.21	21,486.55	310.54	42,399.77	23,609.32	337,973.45	17,312.78	724.85
57	2,949.30	26,019.29	410.20	51,304.92	28,633.38	409,032.77	20,863.20	851.10
58	2,681.66	23,638.96	349.22	46,662.06	26,026.15	371,731.32	18,956.96	815.14
59	2,028.69	17,714.49	251.26	34,957.73	58,314.18	216,735.79	14,113.55	622.40
60	2,635.98	23,198.32	361.59	45,767.46	76,395.30	283,738.06	18,673.63	868.13
61	2,063.03	18,133.31	257.59	35,797.14	49,818.89	237,714.96	14,612.93	648.98
62	2,987.21	26,177.98	383.89	51,615.01	57,412.34	365,849.40	20,839.11	960.07
63	3,103.57	27,353.91	426.26	53,945.56	90,021.52	334,548.00	21,958.02	1,010.77
64	2,851.14	25,203.69	372.95	49,754.84	13,928.36	418,862.69	20,062.63	911.98
65	2,156.95	18,994.51	277.19	37,442.50	62,390.73	231,944.70	15,250.43	647.02
66	1,311.09	11,445.81	177.85	22,577.71	44,033.74	130,127.79	9,132.54	385.48
67	1,277.37	11,226.66	170.90	22,123.28	30,773.59	146,951.35	9,026.54	341.93
Total	**197,702.84**	**1,738,325.83**	**25,978.78**	**3,427,778.36**	**2,739,483.48**	**25,998,941.19**	**1,391,720.12**	**61,951.73**

Table 9-6: Estimated built-up floor area for different housing types (in sq. m.)

Ward	Residential	Commercial	Industrial	Schools	Hospitals	Place of Worship
1	57,868	1,647,732	93,076	24,467		
2	120,914	33,710		13,243		
3	715,314	12,371		5,011	1,779	1,600
4	811,039	90,340	173,240	41,814		1,150
5	558,596	948	51,112	6,173	10,270	
6	626,823	825,589	2,635	237,462	27,387	
7	781,982	6,029	6,283	2,605		
8	528,995	44,694		3,452	1,223	350
9	376,932	35,913	225,642	19,732	20,581	
10		77,968	672,110	628,619		700
11	243,054	53,806	69,441	17,051		350
12	507,666	1,180,753	44,006	56,068	83,177	5,700
13	295,540	89,534		244	6,847	350
14	563,614	23,216		1,393		350
15	294,952	12,162	19,023	4,153		1,050
16	326,587	741,945		52,905	72,431	
17	208,464			50,582	4,108	1,050
18	369,976	6,862	10,894	54,737	4,108	350
19	993,577			17,428		3,500
20	412	27,586		2,684		
21	4,859			661		
22	162,816				19,582	
23	377,941	1,169,395		73,091	48,098	
24	810,585			48,111		
25	1,152,237	36,343	89	2,185	17,801	5,700
26	127,262					
27	641,918	53,090	281	2,434	14,378	6,050
28	263,652	26,385		23,213	10,270	
29	374,116	216,150		85,848	1,917	350
30	1,499,759	249,218	11,967	4,240	71,221	1,400
31	1,626,547	10,087	86,594	18,729	6,847	700
32	397,012			1,064		
33	686,472	1,366		1,044		
34	431,262	117,564	4,304	37,690	9,345	4,350
35	406,883	148,869		617,564	42,814	8,350
36	457,284	788,953		9,831	47,927	4,500
37	708,084	15,017		836		
38	1,448,710	36,825		69	13,693	
39	1,096,823	137,845		1,653	10,270	
40	512,668	245,967		42,840	4,108	1,050
41	726,868	296,901	10,516	264	17,268	1,000

Ward	Residential	Commercial	Industrial	Schools	Hospitals	Place of Worship
42	1,373,076	6,769		2,262	262	350
43	710,867			392		350
44	479,790		22	836		5,000
45	937,391			1,672		350
46	377,531	2,966		6,602	46,914	
47	314,120	119,043		2,309		
48	314,649	70,040		6,742	6,847	700
49	740,223	129,197		616,921		
50	535,932			9,149	6,847	350
51	345,886		1,061	39,716		350
52	508,835			522	27,387	
53	527,242	83,005	2,735	348	1,436	350
54	226,461			207	6,847	700
55	860,473	52,415		2,264	4,108	1,750
56	446,265	7,761		9,540		
57	540,064			696		350
58	490,861				6,847	5,000
59	344,738	9,164	6,954	2,201		700
60	451,638			3,692	17,801	16,400
61	359,047			1,902		700
62	526,225	82,453		40,071	13,745	
63	532,368			1,358		350
64	531,948			16,037		
65	369,104					350
66	219,192			836		
67	221,892			609,279	13,693	350
Total	**35,581,882**	**9,023,944**	**1,491,986**	**3,586,744**	**720,183**	**80,600**

Table 9-7: Unit replacement costs of different building/ infrastructure types

Type of Building	Unit Cost Per Sq Ft (in INR)
Residential Buildings	
Grass, Thatch, Bamboo, Wood, Mud, Plastic, etc.	100
Mud/Unburnt Brick/Stone without mortar	200
Light Metal	150
Burnt Brick/ stone with mortar having temporary Roof (Tiles, wood, GI, slate, etc.)	500
Masonry building with RCC Roof	2000
Reinforced concrete frame with brick infill	2700

Type of Building	Unit Cost Per Sq Ft (in INR)
RCC	3600
Any Other	1000
Commercial Buildings	
Masonry building	2000
Reinforced concrete frame with brick infill	2700
RCC	3600
Others	
Industrial Buildings	2650-4000
Schools	950
Hospitals and Dispensaries	900
Religious Buildings	1500

Table 9-8: Ward-wise estimated exposure value for different houses by occupancy and uses (INR in Crores)

Ward	Residential	Commercial	Industrial	School	Hospital	Place of Worship
1	155.12	7,980.72	246.65	25.02		
2	306.83	163.27		13.54		
3	1,883.90	59.92		5.12	1.72	2.58
4	2,058.03	437.56	492.45	42.76		1.86
5	1,435.72	4.59	135.45	6.31	9.95	-
6	1,669.56	3,998.70	6.98	242.82	26.53	-
7	2,083.14	29.20	16.65	2.66		-
8	1,359.90	216.47		3.53	1.18	0.57
9	980.92	173.94	809.15	20.18	19.94	-
10	-	377.63	1,787.31	642.81		1.13
11	624.83	260.60	277.76	17.44		0.57
12	1,352.22	5,718.92	171.43	57.33	80.58	9.20
13	787.25	433.65		0.25	6.63	0.57
14	1,466.81	112.45		1.42		0.57
15	785.56	58.91	50.41	4.25		1.70
16	850.01	3,593.58		54.10	70.17	-
17	555.34			51.72	3.98	1.70
18	974.36	33.23	28.87	55.97	3.98	0.57
19	2,553.95			17.82		5.65
20	0.94	133.61		2.74		-
21	11.04			0.68		-

Ward	Residential	Commercial	Industrial	School	Hospital	Place of Worship
22	413.13				18.97	-
23	971.42	5,663.91		74.74	46.59	-
24	2,134.78			49.20		-
25	3,069.36	176.03	0.24	2.23	17.25	9.20
26	309.43					-
27	1,670.42	257.14	0.74	2.49	13.93	9.77
28	702.32	127.79		23.74	9.95	-
29	996.52	1,046.91		87.79	1.86	0.57
30	4,020.63	1,207.08	31.71	4.34	69.00	2.26
31	4,232.87	48.85	229.48	19.15	6.63	1.13
32	1,020.54			1.09		-
33	1,786.37	6.61		1.07		-
34	1,135.70	569.42	11.40	38.54	9.05	7.02
35	1,083.78	721.04		631.50	41.48	13.48
36	1,226.20	3,821.26		10.05	46.43	7.27
37	1,842.89	72.73		0.85		-
38	3,723.86	178.36		0.07	13.27	-
39	2,819.38	667.65		1.69	9.95	-
40	1,365.44	1,191.33		43.81	3.98	1.70
41	1,936.20	1,438.02	27.87	0.27	16.73	1.61
42	3,529.26	32.78		2.31	0.25	0.57
43	1,804.00			0.40		0.57
44	1,200.91		0.06	0.85		8.07
45	2,468.50	14.37		1.71		0.57
46	994.20			6.75	45.45	-
47	836.52	576.58		2.36		-
48	843.65	339.24		6.89	6.63	1.13
49	1,949.66	625.76		630.85		-
50	1,394.69			9.36	6.63	0.57
51	911.03		2.81	40.61		0.57
52	1,355.43			0.53	26.53	-
53	1,404.36	402.03	7.25	0.36	1.39	0.57
54	558.93			0.21	6.63	1.13
55	2,212.11	253.87		2.31	3.98	2.83
56	1,175.47	37.59		9.76		-
57	1,422.39			0.71		0.57
58	1,292.73				6.63	8.07
59	862.97	44.38	18.43	2.25		1.13
60	1,130.64			3.78	17.25	26.48
61	911.20			1.95		1.13
62	1,352.58	399.36		40.98	13.32	-

Ward	Residential	Commercial	Industrial	School	Hospital	Place of Worship
63	1,332.75			1.39		0.57
64	1,416.91			16.40		-
65	924.03					0.57
66	541.00			0.85		-
67	563.15			623.03	13.27	0.57
Total	**92745.72**	**43,707.07**	**4,353.10**	**3,667.70**	**697.68**	**136.27**

Table 9-9: Ward-wise estimated length and exposure values for different types of roads

	Lengths of different types of roads in Bhubaneswar (in km)				Estimated exposure value of different types of roads in Bhubaneswar (INR in Crores)			
Ward	Important Road	Link Road	Major Road	National Highway	Important Road	Link Road	Major Road	National Highway
1	-	25.17	1.37	-	-	31	7	-
2	-	18.54	-	-	-	23	-	-
3	-	44.39	4.27	-	-	55	21	-
4	-	80.77	-	11.06	-	101	-	133
5	-	48.90	2.78	3.35	-	61	14	40
6	-	39.62	2.25	-	-	50	11	-
7	-	30.52	0.69	-	-	38	3	-
8	-	23.78	-	-	-	30	-	-
9	-	36.92	2.92	-	-	46	15	-
10	-	31.98	1.56	3.11	-	40	8	37
11	-	15.42	1.47	-	-	19	7	-
12	0.05	49.88	4.97	1.84	0	62	25	22
13	-	12.22	-	-	-	15	-	-
14	-	27.29	-	-	-	34	-	-
15	-	36.99	0.07	1.76	-	46	0	21
16	-	16.39	0.01	-	-	20	0	-
17	0.09	25.46	2.55	3.99	0	32	13	48
18	-	22.72	1.53	0.65	-	28	8	8
19	-	16.57	0.86	-	-	21	4	-
20	-	4.90	-	-	-	6	-	-
21	-	1.38	-	-	-	2	-	-
22	-	30.14	2.69	-	-	38	13	-
23	0.00	76.45	-	-	0	96	-	-

	Lengths of different types of roads in Bhubaneswar (in km)				Estimated exposure value of different types of roads in Bhubaneswar (INR in Crores)			
Ward	Important Road	Link Road	Major Road	National Highway	Important Road	Link Road	Major Road	National Highway
24	-	21.24	1.33	1.10	-	27	7	13
25	-	24.27	0.80	1.94	-	30	4	23
26	-	4.16	-	-	-	5	-	-
27	-	15.29	2.48	2.34	-	19	12	28
28	1.21	15.19	2.38	-	3	19	12	-
29	0.02	17.13	1.95	-	0	21	10	-
30	-	26.71	0.00	-	-	33	0	-
31	-	13.98	1.13	2.54	-	17	6	30
32	-	21.13	2.25	-	-	26	11	-
33	-	12.91	1.34	2.87	-	16	7	34
34	-	13.64	0.40	-	-	17	2	-
35	-	19.78	2.89	-	-	25	14	-
36	3.42	30.22	0.08	-	9	38	0	-
37	-	9.52	-	-	-	12	-	-
38	0.01	10.41	-	-	0	13	-	-
39	-	10.11	1.05	-	-	13	5	-
40	2.70	28.73	3.70	-	7	36	19	-
41	0.22	14.32	0.47	-	1	18	2	-
42	0.09	14.38	1.00	1.57	0	18	5	19
43	-	10.58	1.73	-	-	13	9	-
44	-	15.14	0.85	-	-	19	4	-
45	-	7.61	0.77	-	-	10	4	-
46	2.37	22.54	2.44	-	6	28	12	-
47	0.04	16.77	3.24	-	0	21	16	-
48	-	17.81	2.13	-	-	22	11	-

	Lengths of different types of roads in Bhubaneswar (in km)				Estimated exposure value of different types of roads in Bhubaneswar (INR in Crores)			
Ward	Important Road	Link Road	Major Road	National Highway	Important Road	Link Road	Major Road	National Highway
49	-	37.89	2.04	-	-	47	10	-
50	-	16.92	1.09	2.69	-	21	5	32
51	-	14.70	0.71	-	-	18	4	-
52	-	25.11	3.17	-	-	31	16	-
53	0.33	11.77	0.66	-	1	15	3	-
54	-	4.75	1.78	-	-	6	9	-
55	0.49	12.06	2.47	0.00	1	15	12	0
56	0.08	16.90	1.00	1.60	0	21	5	19
57	-	11.04	0.56	-	-	14	3	-
58	-	19.13	1.27	2.21	-	24	6	26
59	-	25.48	-	-	-	32	-	-
60	-	20.15	0.38	0.02	-	25	2	0
61	-	18.07	1.54	-	-	23	8	-
62	-	32.15	2.87	-	-	40	14	-
63	-	17.36	1.43	2.51	-	22	7	30
64	-	27.38	0.26	1.67	-	34	1	20
65	-	27.23	-	2.00	-	34	-	24
66	-	10.52	-	-	-	13	-	-
67	-	14.66	1.55	-	-	18	8	-
Total	**11.12**	**1,493.24**	**87.19**	**50.82**	**27.80**	**1,866.55**	**435.93**	**609.82**

Table 9-10: Ward-wise estimated length and exposure values for railway network

Ward	Railway Network Length (In Km)	Replacement Cost (In Crores INR)
1		
2		
3	2.94	18.49
4		
5		
6		
7		
8		
9	6.51	41.01
10	0.88	5.51
11	4.31	27.13
12		
13		
14		
15		
16		
17	1.60	10.08
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30	1.96	12.33
31	1.04	6.57
32		
33		
34	2.08	13.13
35		
36		
37		
38		
39		
40		
41	1.22	7.69

Ward	Railway Network Length (In Km)	Replacement Cost (In Crores INR)
42	2.61	16.44
43		
44		
45		
46		
47		
48		
49		
50		
51		
52	2.00	12.58
53	3.27	20.58
54	0.55	3.44
55	0.41	2.6
56		
57		
58		
59		
60		
61	0.36	2.25
62	1.27	7.99
63		
64		
65		
66		
67	0.86	5.43
Total	**33.85**	**213.25**

Table 9-11: Infrastructure details and estimated exposure value for Bhubaneswar Airport

Infrastructure details	Total Area (sq. m.)	Replacement Cost (In Crore INR)
Built-up Area	35479.35	91.65
Runway Area	297,757.19	1,555.31

Table 9-12: Ward-wise estimated length and exposure values for bridges and flyovers

Ward	Ward wise estimated lengths and exposure values of Bridges and Flyovers			
	Bridge Total Length (In Meter)	**Flyover Total Length In (Meter)**	**Bridge estimated cost (In Lakhs)**	**Flyover estimated cost (In Lakhs)**
1				
2				
3	50.85		966.22	
4	490.88	42.78	9,326.65	812.88
5	704.19		13,379.60	
6	51.95		987.08	
7				
8				
9				
10				
11	22.05		418.87	
12		923.00		17,536.99
13				
14				
15		953.69		18,120.10
16				
17	2.26	1,317.33	43.01	25,029.21
18	1,070.19		20,333.58	
19	74.46		1,414.80	
20				
21				
22				
23				
24		555.64		10,557.18
25		927.44		17,621.37
26				
27		537.26		10,207.97
28				
29				
30		185.42		3,522.98
31	59.70	129.23	1,134.30	2,455.42
32	50.43		958.12	
33	27.83	290.09	528.73	5,511.75
34		161.95		3,076.97
35	23.44		445.38	
36				
37				
38		124.60		2,367.45
39				

Ward	Ward wise estimated lengths and exposure values of Bridges and Flyovers			
	Bridge Total Length (In Meter)	**Flyover Total Length In (Meter)**	**Bridge estimated cost (In Lakhs)**	**Flyover estimated cost (In Lakhs)**
40		566.72		10,767.73
41		71.72		1,362.74
42				
43	52.15		990.90	
44	2.67		50.67	
45	16.13		306.55	
46				
47				
48		105.16		1,998.07
49		42.86		814.29
50				
51				
52	26.18	307.57	497.36	5,843.74
53	9.84	754.08	186.93	14,327.59
54	42.92	246.93	815.55	4,691.63
55		282.38		5,365.21
56	62.71		1,191.56	
57				
58				
59	73.22		1,391.20	
60	28.48		541.19	
61		1,067.58		20,284.00
62				
63				
64				
65				
66				
67	15.08		286.50	
Total	**2,957.62**	**9,593.43**	**56,194.74**	**182,275.26**

10Annexure 3: Questionnaires and Forms

HVRA study of Bhubaneswar Municipal Corporation

Questionnaire for Household Profile and Social Vulnerability Analysis

Note for the Surveyors: If there are multiple options, please tick the applicable ones. In case any of the questions are not relevant to the area of the Household (HH) please write "NA". Question A and B should be filled by surveyors on their own through observation.

A. Basic details

<table>
<tr><td>A1. Form No.</td><td>A2. Ward no.</td><td>A3. Ward name:</td></tr>
<tr><td colspan="2">A4. Surveyors name</td><td>A5. Date of survey</td></tr>
<tr><td colspan="3">A6. Location details: (provide the house location details like at hill slope, or river bank, or in heavily populated area, etc)</td></tr>
</table>

B. House location and structural information

B1. Structural details

(a) Roof material: grass/hay/thatch, plastic sheet, tile, asbestos, concrete

(b) Wall material: grass/hay/thatch, plastic sheet, mud, brick, wood, concrete

(c) Floor material: mud, brick, wood, concrete

B2. House characteristics

(a) Number of rooms:
(b) Age of the house:
(c) Plinth height (provide in feet):

B3. House is located:

(a) Own land (private), (b) government allotted land, (c) public land (not allotted but occupied and living)

B4. House ownership history:

C. House hold information

C1. Name of respondent:	C2. Position in the house:
C3. Number of member males:	C4. Number of member females:
C5. No. of people age < 6 and >60:	C6. No. of differently enabled members:
C7. House ownership: (a) own, (b) rented, (c) ancestral, (d) others	C8. How long your family is living in this house: (a) <1 yr, (b) 1-5 yrs, (c) > 5 yrs
C9. Source of income for the family member (choose all that are applicable): (a) Government job, (b) domestic worker, (c) working in factory, (d) vendor, (e) casual worker, (f) agriculture, (g) fishing, (h) no job, (i) others specify:	C10. Monthly family income: (a) <2000, (b) 2001-5000, (c) 5001-10,000, (d) >10,000 C11. Number of earning members:
C12. Why did you choose this location for living: (a) Relocated by government from a hazard affected area, (b) Relocated by government as part of area development, (c) came here looking for job/livelihood, (d) since this was vacant land just constructed the house and living (d) ancestoral property, (e) others specify:	

D. Disease history

Year (provide for each year. In case there are two events in one year provide that separately)	Disease (Malaria, chinkangunea, gastritis, jaundice diarrhea)	When (after flood, during heat wave, during heavy rain, others specify)	Number of people affected in your family	Any death

E. Hazard history

Living in this house/locality have you ever affected by any natural hazards? Flood, wind, heat stroke, earthquake, others, please specify

Year (provide for each year. In case there are two events in one year provide that separately)	Hazard type (any natural hazard specify the name Flood – *Banya* Cyclone – *Batya* Heat stroke – *Anshughata* *Earthquake*	Nature of damage ((a) House completely collapsed, (b) roof destroyed, (c) assets in the house destroyed but house not damaged, (d) life loss, (e) animal life loss, (f) agriculture loss)	Damage in Rupees (Approximate damage for each item mentioned in the column 3 separately)

F. Flood and cyclone (Hazard) early warning:

F1. How you assess the natural disaster risk in the area you are living: high, medium, low, no risk

F2. Which is the worse hazard you faced living in this locality (event and year)?

F3. What precaution you have taken to prevent/reduce the risk?

F4. Are you aware of early warning systems which can help in reducing the impact of a hazard:

F5. Is there any mechanism by government/local bodies/private, on providing early warning of a hazard: Yes/No

F6. If Yes what kind of mechanism available: (a) inform through announcement (public address system) (b) radio, (c) TV, (d) new paper, (e) other specify:

F7. Did you or your community ever approached the government and explored other mechanisms for early warning or improve the existing mechanism to reduce hazard risk: Yes/No

F8. If Yes what kind:

G. Preparedness and Mitigation

G1. Did you face any difficulty (disaster risk) in living in this location:

G1. What mechanism you have devised to protect your asset and house from natural hazards?

G2. What mechanism government/city administration has devised to protect your house from natural hazards?

G3. Do you have an insurance against natural hazards?

G4. Do you have any community initiatives to protect the communities from natural hazards?

G5. According to you what need to be done to reduce the impact of natural hazard to your locality?

H. Relief and recovery

H1. Have you ever been given help with disaster relief? Yes/No

H2. If Yes, describe when, by whom and nature of help given:

H3. Was this help adequate? Yes/No

H4. If not why?

H5. How you managed to get back to life after affected by natural hazard: (a) Government support, (b) own money, (c) borrowed, (d) took loan, (e) others specify

End of Report