

Chapter 7

Cyclone Disaster Mitigation and Management in India: An Overview



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Abstract The Indian subcontinent is one of most affected cyclone prone region in the world. Indian coast is about 7156 long km out of which 5400 km along the mainland are highly vulnerable to cyclone and related hydro-meteorological hazards. The coastal states namely, Odhisha, Andhra Pradesh, West Bengal, and Tamil Nadu are more prone to cyclone related hazards. Tropical cyclones are associated with strong wind, heavy rainfall, flood and storm surge. They can cause devastating damage to structures and huge loss of lives. Nearly one third of the population living in the coastal region of India is at a high risk due to Cyclone related hazards. The increase in the intensity and frequency of cyclones and rise in sea level due to climate change have led to significant increase in the vulnerability of coastal region.

Learning from the past experience of super cyclone Odhisha in 1999, it has been observed that the loss of lives due to cyclone has been reduced significantly by improving initial warning systems and information dissemination, preparedness and undertaking several risk mitigations measures. But the damages to infrastructures and economic losses were very high due to past cyclones. Therefore, there is a need for integrating disaster risk reduction measures across all sectors of development. This paper presents a brief overview of cyclone disaster mitigation and management in India.

Keywords Natural hazards · Cyclones · Vulnerability · Damage · Wind · India

7.1 Introduction

Tropical Cyclones are among the most damaging natural hazards causing significant loss of life and property when they hit the coastal region worldwide. It has been observed that around 80% of natural disaster economic losses are caused due to impact of cyclones (Tamura 2009; Tamura and Cao 2012).

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India is highly prone to natural hazards such as cyclones, earthquakes, floods, drought and landslides leading to huge losses of life and property. Tropical cyclones are the most disastrous hazard in the coastal region. The east coast of India is more prone to cyclone as compared to the west coast. The ratio is approximately 4:1. It has been observed that about five to six cyclones occur in a year in the Indian coastal region, out of which two or three may be severe leading to large number of deaths, loss of property and severe damage to infrastructure.

Nearly one third of the India's population lives in coastal region and is highly vulnerable to Cyclone related hazards (NDMA 2016). Almost 250 million populaces reside within 50 km of Indian coastline (ICZMP 2010) while over 40% of our total population resides within 100 km of our coastline.

Vulnerability of the coastal population has also increased due to climate change resulting in the rise of sea level and on account of increase in the frequency and intensity of cyclones.

Developing countries are more vulnerable to cyclones than the developed countries. Hence, the problem of cyclone disaster mitigation is of national importance. As such it is not possible to prevent or control the natural hazards but the impact of hazard can be minimized by implementing mitigation measures such as, efficient early warning system, construction of safe, shelters for cyclone and houses resistant to cyclones, culverts, road links and bridges as well as the strict implementation of Coastal Zone Regulations.

7.1.1 Tropical Cyclones

Tropical cyclones, generally known as cyclones are tropical weather systems (World Meteorological Organisation (WMO) 2009) in which winds equal or exceed the minimum of 34 knot (62 kmph). In Northern Hemisphere, wind blows in counter clockwise direction whereas clockwise in the Southern Hemisphere due to the Coriolis force. The formation of a tropical cyclone depends on several conditions which include:

- A warm sea surface temperature (above 26.5 °C)
- High relative humidity in the atmosphere.
- Atmospheric instability
- Lower vertical wind shear
- Coriolis force
- An initial low-pressure disturbance

A tropical cyclone is a large funnel-shaped storm with a wide top of the order of 1000 km in diameter and narrow bottom of order of 300–500 km in diameter. The height of the storm is order is of 10–15 km. The diameter of a cyclone encompassing the region of relatively strong wind is order of 500 km. The centre part of a cyclone is called the eye. The eye normally has an average radius of about 20–30 km. The pressure is the lowest and temperature is the highest in this region. The eye is

surrounded by a ring of very strong wind extending on an average up to 30–50 km beyond the centre, known as eye wall. The strongest deep convection and often the most powerful winds can be found in the eyewall. Outer part of a cyclone is known as rain bands. These bands may be hundreds of kilometres long and a few kilometres wide. The intensity of a cyclone can be derived either by the low sea level pressure at the tropical cyclone pressure centre or the maximum sustained winds in the eyewall.

The cyclones that develop between Tropics of Cancer and Capricorn are known as Tropical Cyclones. The tropics are warm all year, averaging 25–28 °C. Cyclone is not formed at the equator because of zero **Coriolis force** which exists at the equator however, Coriolis force increases with latitude so cyclones are reported as we move away from equator. Coriolis force at 5° latitude is significant enough to create a storm. That is the reason most of the tropical cyclones are formed within the belt of 5° to 30° N and 5° to 30° S.

Hurricanes, typhoons, cyclones, and so on are different names for the same type of severe storms occurring in different geographical regions. Tropical Cyclones are known as hurricanes in the Atlantic Ocean, typhoons in the Pacific, Ocean and Willy-Willies in Australia seas and Cyclones in the North Indian Ocean. There are three hazards associated with a cyclone, which cause tremendous amount of destruction in coastal region. These are strong winds, storm surge and heavy rainfall causing flood.

7.2 Present Scenario

7.2.1 Global Trends

Cyclones were second only to earthquakes in terms of loss of lives, killing 233,000 people during 1998–2007. Storms were found to be the most damaging type of disaster, with estimated losses of US\$1300 billion over the past 20 years, which is two times the losses for either flooding or earthquakes. In terms of occurrences, 91% climate-related disasters were observed during 1998 and 2017. Within this total, floods (43.4%) and storm (28.2%) were the two most frequently occurring type of disasters as shown in Fig. 7.1 (CRED and UNISDR 2018).

During 2018, 19.4 million people were affected due to storm, out of which 17.1 million people (88% of the global total) were located in Asia. Storms have been the costliest type of disaster in terms of economic losses. The economic losses were estimated to be \$14 billion and \$16 billion in Hurricanes Florence and Michael respectively in the United States. During this period, extensive damage from multiple storms was observed in Asia, China, India, Japan, Philippine (CRED and USAID 2018). During 2019, several notable and costly tropical cyclones formed within different parts of the world. Typhoon Faxai (Japan), Hurricane Dorian (Bahamas), Typhoon Lekima (China), Cyclone Fani (India), and Tropical Storm Imelda (United States) were highly damaging disaster in terms of economic losses. It

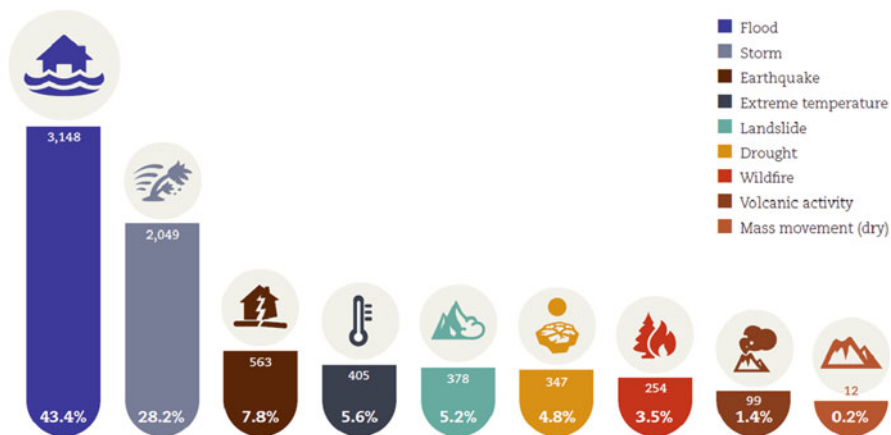


Fig. 7.1 Frequency of Disaster from 1998–2017 (CRED and UNISDR 2018)

has been estimated that the economic loss was nearly USD58 billion in these six storms (Weather, Climate and Catastrophe Insight, Annual Report 2019).

7.2.2 National Level

India is one of the most cyclone prone region of the World causing huge loss of lives and properties. The Orissa super-cyclone of 1999 was the worst cyclone of the country which killed over 10,000 people, and caused widespread damage to property and economic losses. During the period of 1980 to 1990, the average annual loss was around Rs. 200 crores (44 million US\$). The estimated loss was around Rs. 8000 crores between 1996 to 1999 (Goyal et al. 2012).

It has been observed that 308 cyclones crossed the east coast of Indian region, out of which 103 were severe during the period 1891–2006. Within this period, 48 cyclones have crossed the western coast, it was reported that among these almost 24 cyclones were categorized as being of severe intensity (NDMA 2016).

“Phailin” a very severe category of cyclone hit Odisha’s coast in 2013. It resulted in extensive damage to properties and destroyed the power as well as communication infrastructure within the State’s coastal districts. According to Rapid Damage and Needs Assessment Report (2013), the monetary loss on account of Cyclone Phailin was the order of about Rs 89,020 million (this amount was almost equivalent to 1450 million USD).

Over 13.2 million residents were affected within 171 blocks located in 18 districts over the state. Approximate 30 people lost their lives during Phailin. It was observed that the death toll reduced significantly because of timely evacuation of a large populations during Phailin in 2013 and Hudhud in 2014, however, there were significant physical and financial losses.

Cyclone Fani, hit the coastal region in 2019, the estimated total damage amounted to Rs 16,465 crores (almost equivalent to 2352 million USD) it killed about 64 people and damaged more than 3,60,000 houses in the state's coastal districts (Damage loss and need assessment Report 2019).

The year 2019 was recorded one of the most active cyclone seasons in the North Indian Ocean (NIO). During 2019, 8 cyclonic storms formed over the Indian North oceans. Out of which 5 cyclones formed over Arabian Sea against the normal of 1 per year. The frequency of cyclones was abnormally high for the Arabian Sea due to increase in temperature and other reasons.

The Super Cyclonic Storm "AMPHAN" was the first Cyclonic Storm formed over the BoB, after the Odisha super cyclone of 1999, that cause considerable damage in eastern part of the country, especially in West Bengal in May 2020. After Amphan, another severe cyclone storm, Nisarga formed over the Arabian sea, was the strongest cyclone to strike the Maharashtra coast in the month of June, 2020 since 1891.

7.3 Classification of Tropical Cyclones

The India Meteorological Department (IMD), is the nodal agency which is responsible for monitoring and forecasting of cyclones in India. Cyclones are categorized on the basis of wind speed in their circulation. However, categorization of cyclones differs in every region. In United States, Hurricane are categorized into five different classes on the basis of their wind speeds as captured over the Saffir–Simpson Hurricane Wind Scale.

The categorization of cyclones is based on maximum sustained winds associated at the surface level, it is presented within Table 7.1. These systems with low-pressure and variable intensity are usually referred to as cyclonic disturbances (Mohapatra 2015).

A table of the damage caused by tropical cyclones in the coastal region, increased storm intensity is associated with greater damage are available in Standard Operation Manual of Cyclone Warning in India published by, IMD, Delhi in 2013. The

Table 7.1 Indian system for categorization of cyclones

S. no	Classes	Highest sustained wind speed
1.	Low pressure area	Lower than 17 knots (<31 kmph)
2.	A depression	17–27 knots (31–49 kmph)
3.	Deeper depression	28–33 knots (50–61 kmph)
4.	Cyclone storm	34–47 knots (62–88 kmph)
5.	Severe cyclone storm	48–63 knots (89–118 kmph)
6.	Very severe intensity cyclone storm	64–119 knots (119–121 kmph)
7.	Super cyclone storm	120 knots and greater than 120 knots (≥222 kmph)

Source: IMD (2013)

information is based upon the prevailing scientific knowledge of tropical cyclones and expert opinions. From this table, it is possible to predict the potential damage at a particular intensity of storm, accordingly the measures can be undertaken to minimise the impact of cyclones.

7.3.1 Classification of Cyclone Prone Areas of India

The extent of damage caused by a tropical cyclone in any coastal area is determined by storm surge and wind. Among these two factors strong winds are responsible for causing the major damage. Hence it becomes significant to classify regions on the basis of cyclone-wind risk vulnerability for undertaking mitigation measures. This provides assistance in identifying locations in which lifeline systems are prone, selection of pockets for the provision of important community services, preparing insurance policies and consider those areas which require strict provisions for code.

The macro-level wind speed zones have been given for the country IS 875 (Part 3):2015. India has been divided into six zones, namely, 55, 50, 47, 44, 39 and 33 m/s on the basis of basic wind speed (V_b). From wind hazard zonation of point of view, these zones can be categorised as shown in Table 7.2.

Wind Hazard Maps have been published in Vulnerability Atlas of India which divides the area into six zones as given in Table 7.2. The Wind Hazard Map of India is given in Fig. 7.2. The cyclone affected coastal region of India come under 50 and 55 m/s zones.

Wind Hazard maps for both India and state/UT levels are available in Vulnerability Atlas of India (third edition) published by *BMTPC* in 2019. The district-wise housing vulnerability risk Tables based on wall types and roof types are also available as per 2011 Census Housing data. It is a useful tool for urban managers, town planners, Government agencies for taking necessary steps related to disaster management. It is useful in policy planning, preventive actions for housing and related infrastructures, warning system installation, land use planning, etc. thereby aiding in better cyclone management.

Table 7.2 Wind hazard zonation of country

Basic wind speed (V_b)	Risk zone
55 m/s	Very High Damage Risk Zone—A
50 m/s	Very High Damage Risk Zone—B
47 m/s	High Damage Risk Zone
44 m/s	Moderate Damage Risk Zone—A
39 m/s	Moderate Damage Risk Zone—B
33 m/s	Low Damage Risk Zone

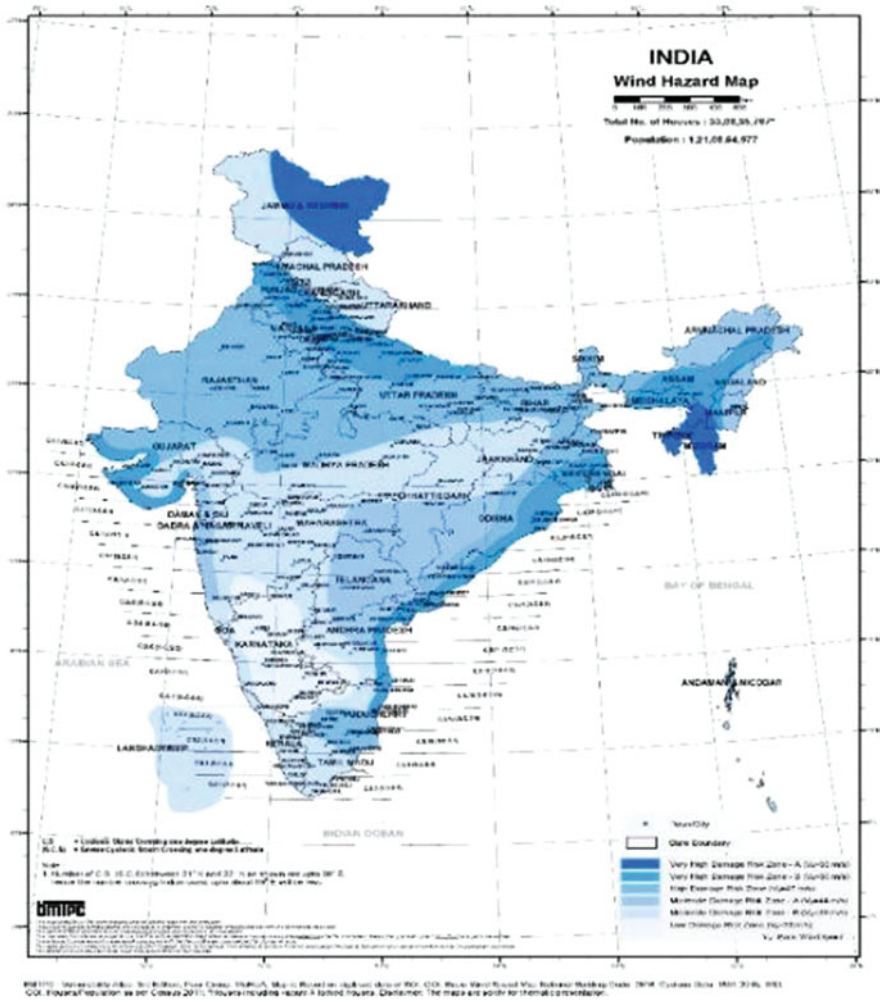


Fig. 7.2 Wind Hazard Map of India (Source: Vulnerability Atlas of India 2019)

7.3.2 Cyclone Occurrence Map of India

Cyclone occurrence map for the Indian coastal region has been developed by Building Materials and Technology Promotion Council (BMTPC). The map has been prepared based on maximum 3-min average Maximum Sustained Wind of cyclone storms that affected coastal districts of India during 1891–2008. The Vulnerability Atlas of India, 2019 (third edition) has published the cyclone occurrence map of India as shown in Fig. 7.3.

The classification of cyclone hazard prone districts by adopting hazard criteria in India was conducted in the year 2015 (Mohapatra et al. 2015). The districts are

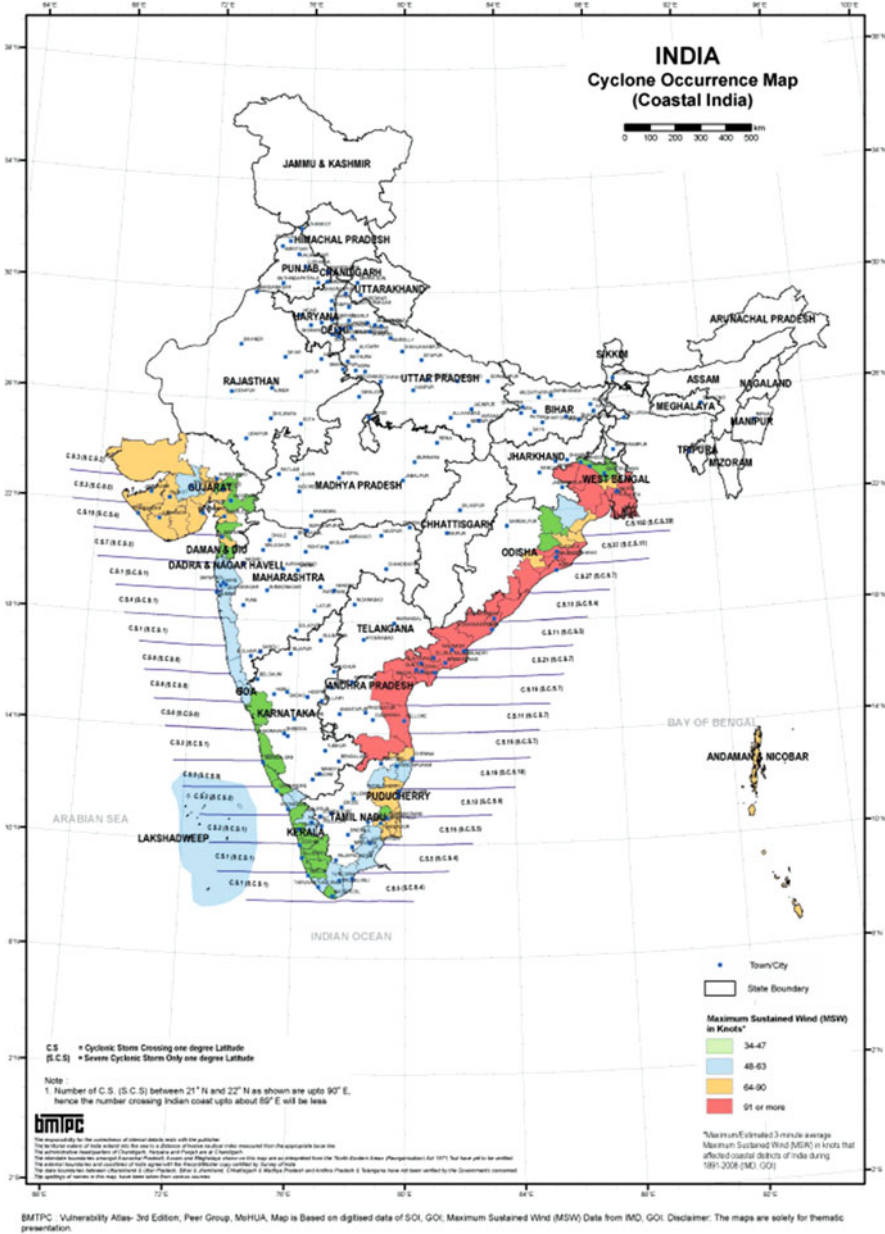


Fig. 7.3 Cyclone occurrence map (Source: Vulnerability Atlas of India 2019)

categorised as P4 (Low), P3 (Moderate), P2 (High) and P1 (Very high) based on the degree of cyclone hazard proneness. The degree of proneness was determined by undertaking the analysis of the cyclone frequency along with the intensity of the land

falling cyclones, in addition other hazards such as wind and storm surge. This classification of districts may be considered for coastal zone management and planning. Goyal and Datta (2012) presented a method for cyclone microzonation of Indian coastal areas with assistance from cyclone historical records. This procedure is very useful for those regions where measured parameters such as wind speeds are not available particularly within the coastal areas of the developing as well as the lesser developed nations.

7.4 Damage Assessment of Buildings

All buildings have been classified into three main categories in India as non-engineered (NE), semi-engineered (SE) engineered (E). Buildings, which are constructed using the conventional building materials and local construction practices are classified as non-engineered building. Buildings constructed from structural materials without proper design are classified as semi-engineered buildings. Buildings, which have been designed and constructed as per Indian standards are termed as Engineered buildings (IS 15498: 2004).

In the coastal region of India, non-engineered and semi-engineered houses are the most common residential dwelling and are a major source of casualties due to cyclones.

Study conducted by Shanmugasundaram et al. (2000) shows that failure of non-engineered houses ranged from thatch cover's complete blowing off to total lifting of the roof and the bamboo structure, several times the mud walls survive while other times there is a total breakdown of the mud walls. With regard to the semi-engineered dwellings the extent of damage ranges from breakage of the tiles and AC sheets to a total lifting-off of the roof's structure resulting inconsiderable damage to the walls. Hence, assessment of vulnerability or damage of different forms of dwellings in a coastal region is important in relation to cyclonic disaster mitigation. The damage assessment methods are classified as qualitative and quantitative methods. Qualitative damage is determined using damage scale according to Indian standard procedure (IS 15499: 2004). Guidelines for survey of housing for vulnerability assessment in cyclone prone areas is given in IS 15499:2004 (Reaffirmed 2015). Damage can be categorised as None, Marginal, Medium, Heavy and Total based on failure of houses.

It has been observed that damage to houses is mainly responsible for loss of life in the coastal region. Therefore, there should be greater emphasis on the safety of houses to minimise the damage to property and loss of life. Bureau of Indian Standards IS 15498:2004 (Reaffirmed 2015) has published guidelines for construction of houses in cyclone prone region.

There are two quantitative methods for vulnerability and damage assessment for a group of houses (1) Direct method and (2) Component-based method. In the direct method, the model is developed for the entire house. In the component-based method, the vulnerability of roof, secondary roof members, wall, etc. are computed

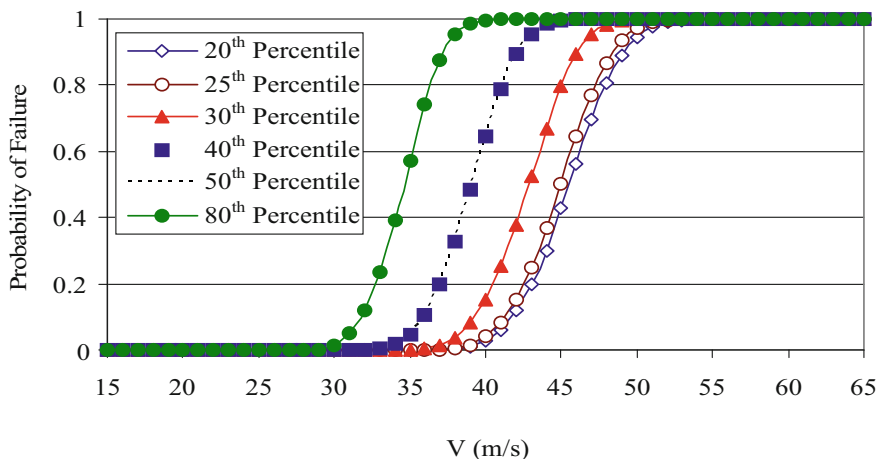


Fig. 7.4 Fragility curves for damage state III for NE:SE = 3:1 (Source: Goyal et al. 2012)

for each component. The vulnerability model of the structure is developed by combining components vulnerabilities of structure and their interactions.

A procedure has been presented by Goyal et al. (2012) for the estimation of the susceptibility of a rural house cluster to cyclones. It involved undertaking a fragility analysis analogous to varying damage states such as damage state I, state II and state III respectively of the rural houses within a cyclone susceptible region, lacking systematic data for carrying out such a statistical analysis. This method is of use in getting an initial assessment of the probability of collapse of a rural house cluster for varying states of damage and accordingly, in optimally allocating the resources for the mitigation of cyclone. Fragility curves depicting the overall failure probability for percentiles ranging from 20th–80th percentile corresponding to damage state III for NE to SE ratio of 3:1 are shown in Fig. 7.4.

A vulnerability assessment of rural houses using component-based method has been presented for the coastal region of India. Vulnerability curve for ratio of non-engineered and semi-engineered houses (n_s) equal to 3:1 is shown in Fig. 7.5 (Goyal and Datta 2014). A study was also conducted by Goyal and Datta for analysing the effect of wind directionality on vulnerability of rural houses (Goyal and Datta 2013).

7.5 Cyclone Risk: Mitigation Measures

There are structural as well as non-structural ways to reduce the impact of cyclones. Mitigation means measures taken prior to the impact of a disaster to minimise damage and injury from the storm. The structural measures imply any physical

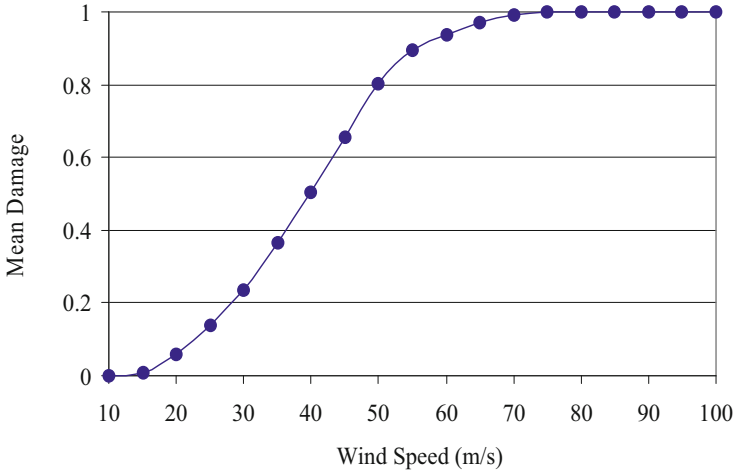


Fig. 7.5 Combined vulnerability curve for non-engineered and semi-engineered houses (Source: Goyal and Datta 2014)

form of construction to minimise the possible impacts of hazards to achieve hazard-resistance and protective the structures and infrastructure.

Structural measures consist of:

- cyclone shelter construction
- culverts, road links and bridges construction;
- drains, canals and water tanks construction,
- embankments for saline water;
- towers for communication and networks for power transmission etc.

Non-structural methods are the means to reduce cyclonic risk with the help of public awareness, training, policies, regulations, education, and vulnerability assessment of coastal regions. These measures consist of

- Early warning systems,
- Systems for communication as well as dissemination
- Coastal zones management
- Creating awareness and capacity building
- Disaster risk management

During cyclones, it is significant to ensure the provision of safe cyclone shelters for the protection of human life. It has been observed that loss of life is large due to the lack of cyclone shelters in coastal region. Many buildings, schools, places of worship, community halls, etc. have been utilized for providing shelter to population that is evacuated from the cyclone affected areas. It was found that several previously constructed cyclone shelters did not have pucca all-weather roads for access that need to be provided to affected people for shifting during emergency evacuation.

There is a need to review and improve the quality of existing road network, culvert and bridges. The coastal villages should be connected with the help of all-weather approach roads for proper coordination of relief and rescue operations and effective evacuation. The conditions of roads, bridges, and culvert should be reviewed by the concerned agencies for smooth functioning of operations related to disaster management during cyclones. Roads, bridges, culvert should be constructed for the last mile connectivity.

The network of canals and drains plays a very important role in reducing the cyclone impact through the receipt, accommodation and return back of surge waters towards the sea. Coastal canals may also be used as an alternate to road during a cyclone or flood. Further it was reported that even the surface water tanks support in lowering the effect of cyclones as well as storm surges. Construction and renovating the existing saline embankments are required to protect people, live stocks and agricultural fields from saline water inundation/storm surge. Based on failure of communication and transmission towers in past cyclone, it has been recommended that towers should be constructed based on the 100-year return period of cyclone's wind velocity.

On the basis of past experiences, it has been observed that early warning system along with community-based management have played an important role in minimising the loss of lives, and reduce economic losses.

7.5.1 Early Warning System

Early warning systems form an important part of disaster management. Past experiences have highlighted their role in managing disasters particularly with in the South Asian region. Increased lead interval along with improved accuracy in forecasting of cyclone genesis, tracking of its intensity and adverse weather would be useful in improving disaster management. A crucial short-term cyclone mitigation measure is provision of timely warning to the population as well as the officials in the area. These predictions include cyclone's arrival time, intensity and the location. It is of significance to regularly upgrade the constituents of this early warning system on the basis of latest technology for better response. Such advances have greatly enhanced the capability of EWS and as per estimates this has been instrumental in reducing the human lives loss to even below 100.

Several significant steps have been taken to modernize and upgrade the cyclone monitoring and early warning systems in India by IMD. The warning in graphics bulletins has been introduced in addition to text bulletins. However, even at present few scenarios present difficulties in forecasting of cyclones such as rapidly becoming severe or weak cyclones close to the land.

In India the early warning systems for cyclone have gradually evolved over a time period. The storm warning system was first established for the Bay of Bengal storms at Calcutta in 1865 and for the Arabian Sea storms in Mumbai by 1882. After the establishment of India Meteorological Department (IMD) in 1875, cyclone warning

started to be issued to various stakeholders (Sikka 2019). Now a days the warnings are being issued by Cyclonic warning organisation of IMD. In India, the Cyclone Warning Organization of IMD has a 3-tier system to cater to the needs of the coastal states. Cyclone Warning Division (CWD) set up at IMD Head Quarters Delhi is also functioning as Regional Specialised Meteorological Centre—Tropical Cyclones (RSMC—Tropical Cyclones), New Delhi to liaising with Central Government organisations and other government agencies. Cyclone Warning Division supervise the cyclone warning operations and provide the cyclone advisories to WMO/ESCAP Panel countries. There are three Area Cyclone Warning Centres (ACWCs) at Chennai, Mumbai and Kolkata and four Cyclone Warning Centres (CWC) at Visakhapatnam, Ahmedabad, Bhubaneswar, and Thiruvananthapuram.

The observational network for monitoring tropical cyclones should determine the correct location and intensity of cyclones. Presently, observations are collected from Surface Observatories, Upper Air Observatories, Radars and satellites monitoring and forecasting of tropical cyclones.

According to report of RSMC (2019), at presentism has 560 surface observatories. The data obtained from these stations are used on real time basis for operational forecasting. In, Upper Air Observatories, there are 62 Pilot Balloon Observatories, 43 Radiosonde/Radio wind observatories. All the 43 stations are latest of the art-GPS based observatories. The data collected all over the country are used on real time basis for tropical cyclone forecasting. There are 24 Doppler weather radars (DWRs) in weather radar network managed by IMD. IMD also utilizes the DWR installed by ISRO at Thiruvananthapuram, Cherrapunji and Sriharikota. Radars of IMD are being used for detection of rainfall, hail storm, dust storms, thunder storms and tracking of cyclonic storms. Within a phased manner IMD has planned the induction of almost 55 DWRs within the network so that the whole country including the coasts is covered under DWR. Now a days, two Indian satellites namely INSAT-3D and INSAT-3DR are used to receive and processing meteorological data. INSAT-3D and INSAT-3DR have an advanced imager with six imagery channels. The products derived from the satellite are useful for monitoring of tropical cyclones. IMD and ISRO have jointly developed a tool RAPID (Real-time Analysis of Product and Information Dissemination) for visualization, which can monitor and analyze satellite imageries and other products of INSAT 3D and 3D(R).

Four stages warning system has been introduced by IMD for tropical cyclones to issue cyclone warnings to state government and disaster managers from 1999.

- Pre-Cyclone Watch is the first stage of warning system, which is issued at least 72 h in advance. It is issued when a cyclonic disturbance in the north Indian ocean (NIO) is likely to intensify into a tropical cyclones and coastal region is likely to affect in future.
- Cyclone Alert is the second stage of warning system issued at least 48 h in advance of the expected commencement of the bad weather over the coastal areas (WMO and ESCAP 2009). It provides information regarding the storm's location, its intensity, the probable direction of movement, severity and coastal districts to be impacted by storm severity. System issues warning to fishermen,

media and the district officers. Colour code 'yellow' is used for the second stage of warning, 'cyclone Alert' and it is given by ACWC (area cyclone warning centre), CWC (cyclone warning centre) and the CWD (cyclone warning division)

- Cyclone Warning is the third stage of warning system issued at least 24 h before the commencement of the bad weather over the coastal areas at 3-h intervals (WMO and ESCAP 2009). This information also contains the expected damages and action suggested by giving the advice to media, fisherman, general public and agencies involved in disaster management. These warnings are issued by the ACWCs/CWCs/and CWD. Colour code 'orange' is used for 'Cyclone Warning'.
- Post landfall outlook is the fourth stage of warning system issued at least 12 h before cyclone landfall. At this stage, Information about time and place of landfall is more accurate and specific. The possible impact due to cyclone in interior areas are warned at this stage. Colour code 'red' is used for forth stage of warning system.

Subsequently once the cyclone weakens into a depression, a 'de-warning' message is disseminated. Warnings are shared with public via fax, telephone, SMS, email, press release, GTS (Global Telecom System), WIS (WMO Information System), radio, community radio, TV, IVRS (Interactive Voice Response system) and other print and electronic media. The weather information and forecast of important Indian cities may also be accessed by dialling this Toll-free number 1800 1801717. A central IVRS caters to major cities weather updates. Over the years several initiatives have been undertaken by IMD to improve the weather forecasting and the warning systems on the basis of recent tools and techniques. From 2009, IMD has launched SMS service for weather and alerts via AMSS at New Delhi. IMD has also made use of Digital India platform to utilize the Mobile Seva provided by the Department of Electronics and Information Technology (DeitY). For the warnings based on SMS and weather-related information to varied users the assistance has been taken from the Ministry of Communication and Information Technology. On 25th Dec, 2014 cyclone-based SMS alert service for registered users from the public was launched. The GMDSS (Global Maritime Distress and Safety System) message also is highlighted on the RSMC website (URL: www.rsmcnewdelhi.imd.gov.in) and is also transmitted via the GTS. The WIS Portal–GISC based at New Delhi is an additional system for the dissemination of cyclone warning. Warning messages may also be accessed by users from the website URL: <http://www.wis.imd.gov.in>. Since 30th March, 2016 IMD has begun issuance of the NAVTEX bulletins for the coastal regions on both the east and west Indian coasts. It supports the functioning of fisherman and lightships. Along with these networks, for rapid dissemination of warnings to public and officials against upcoming cyclones, special receivers have been installed by IMD in the susceptible coastal areas through the utilization of broadcast capacity of the INSAT satellite. This direct broadcast service of cyclone warning is issued in the local regional languages.

7.5.2 Community-Based Cyclonic Risk Management

Community based disaster risk management is important aspect to achieve sustainability for managing disaster risk. It is not possible to manage and handle disaster without active participation of vulnerable community. It is decentralized bottom-up approach involve vulnerable people in implementation of disaster management and planning. The local community is the first to respond the disaster can play an important role to deal with the impacts of disasters. Communities should be supported to understand disaster risk. The emphasis on community-based disaster management is given in the National Disaster Management Plan (NDMA 2016, 2019). Capacity of community should be enhanced through awareness, sensitization, mock drills and developing skills. During cyclone Fani, volunteers acted immediacy and supported in evacuation of people from the vulnerable area. They also supported in clearing roads, providing medical aid, food distribution and relief materials to the cyclonic victims. Therefore, the community-based approach of disaster management is strongly relevant in DRR and the climate change mitigation. It is based on managing cyclone risks, provision of early warning and preparing the community to act against a cyclone.

7.5.3 Relevant IS Codes

There are several IS codes which are referred for the planning of houses, survey of houses and construction of various type of structures, taking into account wind loads in cyclone prone region. There are also Indian Road Congress (IRC) specifications used for maintenance and guidelines for roads/culverts/bridges. These are:

- IS: 15498-2004. “Design and Construction of Buildings and Structures in Cyclone Prone Regions”.
- IS: 15499-2004. “Guidelines for Survey of Housing and Building Typology in Cyclone Prone Areas for Assessment of Vulnerability of Regions and Post Cyclone Damage Estimation”.
- IS 456: 2000(R2016). “Plain and Reinforced Concrete—Code of Practice”.
- IS 800: 2007. “General construction in steel—Code of practice”.
- IS 875(Part-3):2015. “Design Loads (other than Earthquake) for Buildings and Structures -Code of practice”.
- IS 8237: 1985. “Code of Practice for Protection of Slope for Reservoir Embankment (reaffirmed 2017)”.
- IS 12094: 2000. “Guidelines for Planning and Design of River Embankments (Levees)”.
- IS 12169: 1987. “Criteria for design of small embankment dams”.
- IS 10635: 1993. “Freeboard requirements in embankment dams—Guidelines (reaffirmed 2003)”.

- IS 11532: 1995(R2001). “Construction and maintenance of river embankments (levees)—Guidelines”.
- IRC: SP 18:1978. “Manual for highway inspection”.
- IRC: SP35:1990. “Guidelines for inspection and maintenance of bridges”.
- *IRC: SP33:1989*. “Guidelines on Supplemental Measures for. Design, Detailing and Durability of Important. Bridge Structures”.
- SP 7: 2016. “National Building Code of India 2016”.

7.5.4 National Cyclone Risk Mitigation Project (NCRMP)

The first substantial work in the area of disaster management in India was done through the constitution of the High-Powered Committee (HPC) in August, 1999, just a few months before the Orissa super cyclone in November, 1999. In the immediate aftermath of the Orissa’s Super Cyclone in 1999, the Orissa State Government set up the Orissa State’s Disaster Mitigation Authority or the OSDMA. The aim of the authority was to focus on the state residents to become more disaster resistant by systematic planning of disaster management.

Subsequent to the December 2004 tsunami, DM Act 2005 was made by the parliament to set up an institutional mechanism for proper management of disasters in the country.

The institutional framework was created at National level, State Level and District level under DM Act 2005. At the national level, National Disaster Management Authority (NDMA), at state level, State Disaster Management Authority (SDMA) and at district levels. District Disaster Management Authority (DDMA) has been were created.

After the formation of NDMA, the management of National Cyclone Risk Mitigation Project” (NCRMP) was transferred to NDMA by MHRD in September 2006. The Government of India has initiated the NCRMP to address cyclone risk in the coastal states. The overall objective of the project is to strengthen the structural and non-structural cyclone mitigation efforts to minimise the losses due to impact of cyclones in the coastal states of India. These States/UTs were classified into two categories, namely category I and category II, based on their vulnerability to such risks. In category I, the higher vulnerable coastal states of Andhra Pradesh, Gujarat, Orissa, Tamil Nadu and West Bengal were selected. In categories II, the coastal States/UTs of Maharashtra, Goa, Karnataka, Kerala, Aman& Diu, Puducherry, Lakshadweep and Andaman and Nicobar Islands were identified based on lower vulnerability to cyclones.

National Cyclone Risk Mitigation Project Phase I covers states Andhra Pradesh and Odisha, has been started from Jan. 2011. NCRMP Phase—II covers States of Gujarat, Maharashtra, Goa, Karnataka, Kerala, and West Bengal.

The phase I of National Cyclone Risk Mitigation Project (known as NCRMP-I), is a scheme sponsored by the Central government and is being funded by the World Bank in form of Adaptable Programme Grant. This scheme is being implemented in



Fig. 7.6 Approach Road in West Godavari District Bridge (Source: NDMA Annual report, 2018–19)

the states of Odisha and Andhra Pradesh from January, 2011. NDMA is the Nodal Agency at the National Level for monitoring the implementation of the project while the participating states include Odisha and Andhra Pradesh.

The major objectives of this project are the up gradation of cyclone early warning and dissemination systems (EWDS), building of the cyclone risk mitigation infrastructure for reducing the vulnerabilities of coastal communities by constructing multi-purpose cyclone shelters, bridges, roads and saline embankments and undertaking capacity building for disaster risk management.

As per the Annual report (2018–19) of NDMA various measures in form of construction of 535 cyclone shelters, 32 bridges, 1086 km of approach roads and 88.12 km of saline embankment have been finished under NCRMP Phase-I. 275 Early warning dissemination systems, 476 Alert sirens, digital mobile radio and 34 satellite terminals have been procured and installed. Under this project, three studies on the assessment of coastal hazards, risk and vulnerability, the preparation of modules for long term training as well as capacity building; and finally Post Disaster Needs Assessment (PDNA) have been conducted. Some photographs of assets created in Andhra Pradesh and Odisha under NCRMP Phase-I are given in Figs. 7.6 and 7.7.

National Cyclone Risk Mitigation Project Phase-II has been approved by Government of India in July, 2015 for a 5-year duration till March, 2020. NCRMP-II includes the Indian States of Gujarat, Goa, Kerala, Karnataka, Maharashtra and West Bengal.

For providing assistance for Implementation of Early Warning Dissemination System (EWDS), TCIL has been engaged by the states of Maharashtra, Goa, Kerala and Karnataka in the form of their partner. PWC and KPMG have been engaged by West Bengal and Gujrat as their knowledge partner (NDMA Annual report,



Fig. 7.7 Multi-purpose Cyclone Shelters in Puri District (Source: NDMA Annual report, 2018–19)

Fig. 7.8 Multipurpose cyclone shelter in West Bengal



2018–19). Photograph of multipurpose cyclone shelter constructed under NCRMP-II IN Gujrat and West Bengal are shown in Figs. 7.8 and 7.9.

Fig. 7.9 Multipurpose cyclone shelter in Gujrat



7.5.5 Role of Shelterbelts; Mangroves and Buffer Zone: Coral Reef in Cyclone Disaster Mitigation

For protection from the wrath of cyclone nature has ensured biological means in the form of mangroves and shelterbelts. It has been recognised that mangroves and shelterbelt are able to reduce the energy of storm surges and tsunami waves. They reduce the impact of tsunami waves, storm surge, and high winds resulting in fewer loss of lives and damage to property from storms and cyclones. Therefore, mangroves and shelterbelt are important measures to mitigate the impact of cyclones.

Das and Vincent (2009) have conducted a study to identify the role of mangroves in cyclone risk mitigation in 1999 Orissa Super Cyclonic Storm. It had been found that the villages, which were in the shadow of mangrove forest experienced significantly fewer death as compared to the villages with narrower or no mangrove cover.

As per report on Cyclone Hudhud, compiled by NDMA 2015, the mangroves played a significant role in protecting the coastal areas from storm surge. It has also been recommended that there is acute need to maintain more shelterbelts and mangrove in coastal region.

Coral reefs act as a buffer; protect our coastal areas from the impacts of waves, floods and storms. With the buffering action of coral reefs, the shorelines are prevented against adverse impacts of waves, floods and the storms which minimize the loss to lives and damage to property. In the absence or damage caused to such a

natural barrier, the damage caused by storms to the coastal communities may increase manifold.

The wellbeing of coral reefs is dependent on the implementation of sustainable developmental practices for the coast which guard these susceptible coral ecosystems along with the organisms which reside in these areas. Climate change presents a significant threat to coral reefs. It is evident from existing scientific evidence that anthropogenic activities have resulted in green house gas emissions which have led to the warming of Earth's atmosphere and the oceans. Climate change results in warming of oceans causing direct heat stress to coral reefs. Even indirectly it alters patterns of oceanic circulation, boosts the power of cyclones which leads to extensive destruction of coral reefs along with the associated organisms. Though the cyclone frequency is not likely to increase its intensity has been predicted to rise on a global scale which would result in occurrences of damaging cyclones with severe damage caused to coral reef ecosystems and the services which are provided by these ecosystems to populations across the globe.

The Ministry of Environment and Forest and Climate Change, Govt. of India had taken up activity under the Integrated Afforestation and Eco-development Project to form a shelterbelt along the coastline (GIDM 2020).

7.5.6 Coastal Regulation Zone

The transition area between marine and territorial zones is called as coastal zone. Owing to the continuous exploitation of the coastal regions the mangroves, fish breeding and coral reefs have been adversely impacted. This has resulted in reduction of the livelihood of 200 million villagers and other communities residing along the country's 7516 km long coastline. As such it is not possible to prevent or control natural hazards, but the losses of life and damage to property can be considerably minimised by coastal zone management. Such measures include properly protecting and restoring natural bio-shields, proper planning for finding the affected communities and building infrastructure within safer areas in coastal region, etc., Hence, it has been considered as essential to initiate a plan of action for coastal area for the purpose of overcoming the environmental problems.

The Coastal Regulation Zone (CRZ) was notified by the Ministry of Environment and Forest notification, Govt. of India in 1991 under the Environmental Protection Act, 1986 to protect and conserve the coastal environment in coastal areas of India. Coastal area has been categorised as CRZ-1, CRZ-2, CRZ-3, CRZ-4 under this notification. The Ministry of Environment, Forests, and Climate Change (MoEF&CC) was replaced the Coastal Regulation Zone (CRZ) Notification, 1991 with two Notifications namely;

1. Coastal Regulation Zone (CRZ) Notification, 2011 applicable for Mainland India to ensure livelihood security to fishing and other local community.

2. Islands Protection Zone Notification, 2011 applicable for A&N islands and Lakshadweep

A Coastal Regulation Zone Notification has been issued in 2018 on the basis of inputs received from several coastal states, the Union Territories as well as the other stake holders. The notification has been issued with a perspective to conserve as well as to protect the distinctive environment existing within the coastal and the marine areas. In addition, the focus is on provision of livelihood to coastal communities and for the promotion of sustainable development considering the risks of natural disasters and that of sea level rise on account of global warming.

The land area from High Tide Line (HTL) to 500 m on the landward side along the sea front has been declared as Coastal regulation zone as per CRZ notification 2018.

CRZ shall be applicable to the land area between HTL to 50 m or width of the creek, whichever is less on the landward side. The land area between the HTL and the Low Tide Line (LTL) is termed as “intertidal zone”.

7.5.7 Classifications of Coastal Zones

The coastal regulation zone under CRZ notification (2018) for the purpose of conserving and protecting the coastal areas are classified as under:

- **CRZ-I** These are environmentally most critical areas. The CRZ-I is further categorised into CRZ-I A consisting of the ecologically sensitive areas (ESAs) and geomorphological features (like, Mangroves, Corals and coral reefs, sand dunes, etc.) and CRZ-I B covering the area between Low Tide Line (LTL) and High Tide Line (HTL), i.e., intertidal zone.
- **CRZ-II:** Areas which are developed up to or close to the shoreline.
- **CRZ-III:** Areas that are relatively undisturbed (viz. rural areas, etc.) and do not fall under CRZ-II. The CRZ-III is further classified into CRZ-IIIA and CRZ-IIIB.

CRZ-III A–Rural areas which are densely populated with a population density of more than 2161 per km² according to 2011 Census. CRZ-III A will have a No Development Zone (NDZ) of 50 meters from the High Tide Line on the landward side as against 200 m from the High Tide Line (HTL) mentioned in the CRZ notification, 2011. CRZ-III B includes rural areas with a population density of less than 2161 per km² square according to 2011 Census.

- **CRZ- IV:** These areas are the water area. The CRZ-IV is further categorised into CRZ-IVA and CRZ-IVB. CRZ- IVA includes the water area and the sea bed area between the Low Tide Line up to 12 nautical miles on the seaward side. Areas which cover the water area and the bed area between LTL at the bank of the tidal influenced water body to the LTL on the opposite side of the bank are categorised as CRZ-IVB.

The CRZ Notification, 2018 will lead to the economic growth by enhancing the activities in the coastal regions following the conservation principles of coastal regions. It will boost tourism and environment and add value to the economy of India.

Sundarban region of West Bengal and other islands are categorised as Critical Vulnerable Coastal areas. These areas are managed with the participation of coastal communities. Nature based solution like, Mangrove plantations is one of important mitigation measure for cyclones.

The National Coastal Zone Management Authority (NCZMA) at national level and CZMAs at State level have been constituted for effectively monitoring and enforcing the notification.

7.5.8 Integrated Coastal Zone Management Project (ICZMP)

The Government of India with the assistance of World Bank has initiated the Integrated Coastal Zone Management Project to implement the various provisions of the CRZ Notification and IPZ Notification, 2011. It includes formulation of plan for Integrated Coastal Zone Management of State. The ICZMP Phase-I is being implemented by MoEF&CC in Gujarat, Odisha and West Bengal to address most of the issues relevant to impact of Climate Change in coastal areas.

7.6 Case Study: Cyclone Fani

A comprehensive report on the loss and damage along with the need assessment for Cyclone Fani which occurred in Odisha in 2019 was prepared by collaborative efforts of Odisha state Government, OSDMA, the World Bank, the agencies of United Nations along with the Asian Development Bank. Based on this report, a case study of cyclone Fani presented.

On 3rd May 2019 morning, extremely severe cyclonic storm, the Fani, a rare form of summer cyclone, reached the coast of Odisha quite close to Puri. Wind speeds of 175–180 km per h (kmph) reaching to over 205 kmph were reported during the landfall of cyclone at Satpada as per IMD. The Fani was the strongest tropical cyclone to strike Odisha, an eastern state of India since 1999 Odisha Super Cyclone. Approximately 10,000 people were killed during super cyclone of 1999, while 64 people lost their lives during the Fani. As compared to super cyclone 1999, human casualties were very low in the Fani.

7.6.1 Disaster: Effects and Impact

About 16.5 million people (about 36% of total population of Odisha) in over 18,388 villages in 14 of the 30 districts in the state were affected. The most impacted districts from Fani included Khurda, Puri, Cuttack, Kendrapara and Jagatsinghpur. During cyclone Fani the Power, telecommunication infrastructure, and road services were severely affected. About 3.62 lakh houses were damaged. Approximately 19,734 Ha of agriculture area was affected. The worst impacted sectors from Fani included power, telecom, housing, and the livelihoods in the form of agriculture, fisheries and livestock. According to the report the total damages were of the order of Rs. 16,465 crore almost 2352 million USD, while the recovery needs were estimated to be INR 29,315 crores.

7.6.2 Preparedness

Upon receiving the early warnings from IMD, Government of Odisha evacuated almost 1.55 million residents within 9177 shelters. With the help of 23 special trains as well as 18 buses over 25,000 tourists were successfully evacuated. Two days before the landfall all sorts of fishing operations were suspended. For the rescue and relief activities, 20 units of the Odisha Disaster Rapid Action Force (ODRAF), 335 units of Fire Service and 25 units of the National Disaster Response Force (NDRF) were employed into service. For 24 × 7 the block and district level emergency centres were put into action. Almost 4.5 lakh polythene sheets (temporary shelter materials) were positioned at district and sub district level. In susceptible areas the Govt's disaster response forces were brought in service. Food packets were made ready for Air force helicopters to drop to people.

Volunteers, officials, workers and other civil society organisation, NDRF, ODRAF, other agencies worked together round the clock to evacuate 1.55 million people in 24 h. It was the largest evacuation program ever done in the World.

7.6.3 Relief and Rescue Operations

A massive rescue and response operation were started immediately after the landfall. Sixty teams from NDRF, 18 units of ODRAF, 585 fire team and nearly 45,000 volunteers carried out relief operations. State Government was also supported by Eastern Naval Command of the Indian Navy undertook the rescue as well as the relief operations. Almost 10,000 packets of food were dropped from Airforce helicopters. With the help of local people, more than 6000 were opened. Major roads within Puri and Bhubaneswar were cleared and power supply was restored within 48 h.

7.6.4 *Reasons for Successful Management of FANI*

Improvements in early warning systems, forecasting capabilities, preparedness and disaster management significantly helped in mitigating the impacts of cyclone Fani.

7.6.4.1 Early Warning System (EWS)

The India meteorological department has taken several imitative to modernize and upgrade the early warning systems for cyclones and built an effective service to predict accurate timing of cyclone formation in the North Indian Ocean. Prior to formation of low-pressure area, the cyclone was monitored and predicted from 18th April onwards by IMD. Information about the formation of low-pressure area over EIO and adjoining south BoB was given on 25th April, 2019. An extremely severe cyclonic storm (ESCS) with wind speed of 175–185 kmph gusting to 205 kmph would cross around Puri on 3rd May, was continuously predicted on 30th April, 1st and 2nd May 2019. This EWS enabled the state to get prepared and steps were taken in advance to minimise the loss of lives. After issuing of warning, people followed the instruction given by the authorities. A massive evacuation drive was undertaken prior to landfall in the state of Odisha.

7.6.4.2 Cyclone Shelters

Before Odisha super cyclone 1999, state didn't have a proper plan for disaster management. Many multi-purpose cyclone shelters, and other infrastructure have been built under National Cyclone Risk Mitigation Project/other scheme. These were utilized in managing the cyclone Fani in 2019.

7.6.4.3 Proper Communication Plan

Warning and advisory through social media (face book and tweeter) was given regularly (every 6 h) during the life period of the system. Roughly [2.6 million text messages](#) were delivered to locals people before cyclone Fani hit. Press and electronic media were given daily updates by officials to update people of the approaching cyclone. People were advised not to get panicked.

Huge campaigns for awareness were organised for informing regarding the basics of cyclone by the government. This helped in the record evacuation of over 1.55 million residents within 9177 shelters.

7.6.4.4 Community Participation and Proper Co-ordination of Various Agencies

Government agencies, volunteers, local panchayats and self-help groups (SHGs) worked together in preparedness to response, evacuation, distribution of relief, and shelter management.

Community Participation is an important aspect within any disaster management strategy.

Senior Government officers were deployed at the district level to coordinate the activities of various agencies for proper management. Forces of Disaster response (ODRAF and NDRF) were pre-positioned within the districts in coastal areas. For ensuring availability of food to the community during the period of cyclone, Food supplies were pre-positioned in cyclone shelters and food packets were prepared for air force helicopters to drop to people.

7.7 Conclusion and Way Forward

India's coastal regions are highly vulnerable to the impact of cyclones and other related hazards. It is important to note that over 40% of our total population resides within 100 km of our coastline. Vulnerability of the coastal population has also increased due to climate change resulting in the rise of sea level and on account of increase in the frequency and intensity of cyclones.

In order to minimize the loss of lives and damage to houses and structures, various Structural and non-structural measures are important aspects. In the aftermath of Odisha's super Cyclone, 1999, several mitigation measures have been undertaken. As per recent trends of impact of cyclones, the number of lives lost has declined, while the goal of zero mortality is close to realization, it needs to be highlighted that the economic losses and damage to infrastructure have been on a rise. Frequency and intensity of cyclones has also increased due to climate change. Mangroves and shelterbelt are powerful tools to prevent the impact of cyclones. The coastal belt plantation drive should be promoted with the involvement of civil society and community-based organisations. The focus should be to involve community by massive awareness campaigns, training of fisherman, farmers and capacity building to prepare a resilient community. Clearly the goal of minimizing the loss of life is achieved, but we are far away from achieving the minimizing the damage to houses and infrastructures. There is urgent need to reduce the economic losses due to impact of cyclones. This can be achieved by adopting Resilient Housing, Resilient Livelihood and Resilient Infrastructure. Houses, schools, hospitals, cyclone shelter should be cyclone resistant and safe structures. Existing guidelines should be used for construction of these houses. Quality of housing can be improved through better building standards and regulations.

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