CITY RESILIENCE

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भारत 2023 INDIA

MULTI-HAZARD DISASTER RISK & RESILIENCE

VISAKHAPATNAM CITY

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Resilient India - Disaster Free India

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National Institute of Disaster Management
(Ministry of Home Affairs, Government of India)

Multi-Hazard Disaster Risk and Resilience for Visakhapatnam City

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FOREWORD

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RAJENDRA RATNOO
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Disasters are highly unpredictable and instantaneous in nature and thus demand an immediate action. India has adopted a strategic approach towards disaster management which is focused on preparedness and mitigation so the rising numbers of disasters can be brought down significantly.

A significant reduction in losses and damages due to disasters in the country has been achieved with the enactment of the Disaster Management Act, 2005 and the implementation of the National Disaster Management Policy, 2009 and National Disaster Management Plan, 2016.

A study on “Disaster Risk and Resilience in States and Union Territories – An Analytical Study” was conducted in 2019 which analyzed and measured the disaster risk and resilience level of the States/UTs of India. This report on "Multi - hazard Risk and Resilience for Visakhapatnam city" is a part of a broader study titled “Multi-hazard Disaster Risk & Resilience: Practical Learning and Step-by-Step Guide to Improve Disaster Resilience at City Levels”. This report is a propagation of the aforementioned study to the next step i.e. at the level of cities and particularly for Visakhapatnam city in Andhra Pradesh. This study has been conducted by the Indian Institute of Technology, Indore, Madhya Pradesh under the aegis of National Institute of Disaster Management, Ministry of Home Affairs, Government of India in order to improve the overall resilience level of the cities/urban local bodies towards disaster risks.

The impacts and effects of disaster are more immediate and intense at the level of the cities/urban local bodies. This study is dedicated to evaluate the risk and resilience indices for the hazards specific to the city of Visakhapatnam. Hence this study will prove to be remarkable in providing a more localized approach to the Visakhapatnam city for understanding internal disaster risks and improving their preparedness and resilience thereby making them a self-sufficient paragon to deal with disasters.

(Rajendra Ratnoo)

PREFACE

Resilient India - Disaster Free India

सत्यमेव जयते

Prof. Anil Kumar Gupta

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It's a matter of immense pleasure for me to present this study for "Multi-hazard Disaster Risk & Resilience for Vishakhapatnam city" developed in collaboration with Indian Institute of Technology, Indore as a part of the broader study on "Multi-hazard Disaster Risk & Resilience: Practical Learning and Step-by-Step Guide to Improve Disaster Resilience at City Levels". This report presents a scorecard to measure the level of disaster risks and resilience for the Vishakhapatnam city and has also been conducted as a pilot for three more cities of India viz. Guwahati, Srinagar and Jaipur representing a diverse range of geophysical characteristics. I strongly believe that this study is going to assist various line department officials in taking well-informed and precise decisions in case of the emergence of a disaster.

Climate-related extremes have more pronounced effects in cities because of the more complex urban infrastructure systems, rapid increase in urban populations and intensive economic activities. Cities are currently facing an over-burden due to the increased migration and thus are becoming sensitive and vulnerable to disasters and even unanticipated incidents like the sudden heat wave intensification in the United Kingdom in 2022. Thus, the cities specifically should be more and more focused on increasing their understanding of localized risks and developing resilience. A bottom-up approach may prove to be exceptional wherein the resilience at city levels can altogether build resilience at state and national levels.

This study is very detailed and is in the form of seven reports viz. a technical report which encompasses the development of risk and resilience scorecard for all four cities, four city-specific technical reports, a step-by-step disaster management guide to improve disaster resilience of Indian cities and a mayor's handbook. This particular report highlights the hazards and risks specific to the Vishakhapatnam city and its level of resilience in the form of preparedness and capacity building.

(Anil K Gupta)

ACKNOWLEDGEMENT

This study on "Multi-hazard Disaster Risk & Resilience: Practical Learning and Step-by-Step Guide to Improve Disaster Resilience at City Levels" has been carried out with a collaborative effort from the National Institute of Disaster Management (NIDM), New Delhi and the Indian Institute of Technology (IIT), Indore research teams.

Special thanks to the government authorities from the four cities i.e., Guwahati, Jaipur, Srinagar, and Visakhapatnam for providing valuable suggestions, feedback, and timely response for the required datasets in preparing disaster scorecards for risk and resilience of the selected cities. The project team is grateful to Major General Manoj Kumar Bindal, then Executive Director, and also to Shri Rajendra Ratnoo, IAS, present Executive Director NIDM for their constant support and encouragement in performing this study and ensuring the effective functioning of the project. A number of consultation workshops were hosted which saw participation and suggestions from regional experts, scientific community, government organizations, and National Disaster Response Force (NDRF).

The support received from Shri. B. Prasad, Shri Srinivas Rajamani, Dr. Litan Kumar Ray, Dr. Suparana Katyaini, Dr. Ramachandra Prasadand many more, for developing a consensus on the methodology and outcomes of the study, during assessment of risk and resilience for Visakhapatnam city, is highly appreciable.

The contribution of principal investigator Professor Manish Kumar Goyal and his research team comprising Dr. Vikas Poonia (Former Research Scholar, IIT Indore), Mr. Vijay Jain, Mr. Shivukumar Rakkasagi, Mr. Shivam Singh and Mr. Kuldeep Singh Rautela (Research Scholars, IIT Indore) are acknowledged for joining hands with us in completion of this study for providing a technical assessment of natural and man-made hazards in the cities through collected data and in a compilation of the report. The study was supported with continuous support of the team from NIDM comprising of Dr. Kopal Verma (also acknowledged for the special efforts in designing the report), Dr. Uzma Parveen, Ms. Fatima Binte Amin, and Mr. Michael Islary for their overall coordination with all the cities authorities and collection of the datasets. The project team extends thanks to the library and the entire publication cell of NIDM for their support and publication of this report.

(Anil K Gupta)

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LIST OF ABBREVIATIONS

BPL	Below Poverty Line
BMTPC	Building Materials and Technology Promotion Council
CAW	Crime Against Women
CDRI	Composite Disaster Risk Index
CEPI	Comprehensive Environmental Pollution Index
CGWB	Central Ground Water Board
DM	Disaster Management
DRI	Disaster Risk Index
DRR	Disaster Risk Reduction
DRS	Disaster Resilience Score
FSI	Forest Survey of India
GVMC	Greater Vishakhapatnam Municipal Corporation
IMD	India Meteorological Department
IMR	Infant Mortality Rate
MAH	Maximum Accident Hazard
MDP	Master Development Plan
MHA	Ministry of Home Affairs
MHI	Maximum Hazard Industries
MoHUA	Ministry of Housing and Urban Affairs
MoUD	Ministry of Urban Development
MMR	Maternal Mortality Rate
MPIs	Maximum Polluting Industries
MSMEs	Micro, Small and Medium Enterprises
NCRB	National Crime Records Bureau
NDRF	National Disaster Response Force
NOAA	National Oceanic and Atmospheric Administration
OGD	Open Government Data

LIST OF ABBREVIATIONS

ORGI	Office of the Registrar General & Census Commissioner, India
OSM	Open Street Map
SDGs	Sustainable Development Goals
SEZs	Special Economic Zones
SFDRR	Sendai Framework for Disaster Risk Reduction
SPI	Standardized Precipitation Index
SSI	Standardized Soil Moisture Index
ULBs	Urban Local Bodies
UNDP	United Nations Development Programme
WHH	Women Headed Household

EXECUTIVE SUMMARY

India has taken a significant step towards developing an effective Disaster Management (DM) system, such as the endorsement of the DM Act 2005, the formulation of the National Policy on DM 2009, the publication of guidelines and the implementation of plans at the District, State and National levels. Disaster Risk Reduction (DRR) refers to a policy goal or objective and the strategic & operational measures used to reduce exposure, hazard or vulnerability and improve resilience. The Sendai Framework for DRR (2015-2030) was the first key agreement of the post-2015 development agenda and provided distinct actions to defend from disaster risks. Also, the United Nations Sustainable Development Goals (SDGs) contribute in reducing disaster risks and building resilience by endorsing education for sustainable development, such as SDG 4 (ensure inclusive and equitable quality education and promote lifelong learning opportunities for all), SDG 9 (Support domestic technology development, research and innovation in developing countries) and SDG 11 (Sustainable cities and communities). The establishment of the National Disaster Response Force (NDRF) in 2006, achieved vital milestones on the journey towards the country's DRR. Urban areas act as facilitators of economic growth, as they contribute significantly to the country's economy, employment creation and productivity (GDP). The city administration in urban areas continues to lag in disaster risk reduction and have inadequate disaster management mechanisms, causing the people's substandard quality of life.

Therefore, the Government of India launched the 'Smart Cities Mission' in 2015 and selected 100 cities to accelerate financial growth and improve the living conditions of citizens through comprehensive work on social, economic, and institutional pillars of the city. Visakhapatnam city is one of the Smart Cities, which aims to leverage the city's heritage & tourism and improve citizens' quality of life with modern technology-based practices and inclusive solutions.

An increase in population and urban expansion, intensifies vulnerability to disaster events for the population of disabled, children, below the poverty line etc., during the disasters. Visakhapatnam (population 1.73 million in 2011) holds a special place in people's hearts as a Jewel on the eastern coast of India. The urban area of Visakhapatnam city was about 515.49 km^2, which is to be increased to 980 km^2 as per Master Plan 2041. It is surrounded by the hills of the eastern ghats and Bay of Bengal in the east. It is the biggest city in Andhra Pradesh and 3rd on the Eastern coast after Chennai and Kolkata. However, the development area grew with deliberate interventions in the form of sector plans to control expansion, due to land scarcity and rapid transformations. The Master Development Plan (MDP) 2041 envisions Visakhapatnam city as a worldwide metropolis and world-class city, where the population is engaged in productive work with a higher quality of life and lives in a sustainable environment. This necessitates planning and action to meet the challenge of population growth and in-migration to Visakhapatnam, by providing adequate housing, addressing the problems of small businesses, upgrading coastal and dilapidated areas of the city, providing adequate infrastructure services, conserving the natural environment, heritage etc. and blending the city with new and complex modern patterns of development. Visakhapatnam city is classified as seismic disturbance Zone-II, making it less vulnerable to earthquakes. However, the city is susceptible to natural and man-made disasters, such as Tsunami, Cyclone, Urban floods, Coastal Erosion, Heat Wave, Fire Accident etc. For example, Visakhapatnam has experienced huge impacts due to the disasters, such as the Visakhapatnam Gas leak in 2020 from LG Polymers industrial facility, causing more than 10 mortalities and injuries to several individuals. Therefore, there is an immediate requirement for assessing the city's disaster risk and resilience and accordingly, implementing the disaster management plan. In this study, hazard, vulnerability, and exposure indices for Visakhapatnam city are computed using several indicators (as per the MHA-UNDP 2019 report). The study showed that Visakhapatnam city is more prone to Flood, Coastal Erosion, Tsunami, Lightning, Industrial hazard, and Cyclone significantly, followed by Heat wave, Fire Accident, Drought, and Forest Fire.

Similarly, Visakhapatnam city is more vulnerable to disasters, in terms of Deforestation, Physical infrastructure and Disabled people, followed by unsafe buildings, Livestock, Aged People, Poverty, Women and Children. The study also revealed that the population of Visakhapatnam has a high hazard specific exposure index for natural disasters, such as Flood, Lightning, Cyclone, Coastal Erosion, Tsunami, and Industrial Hazard, that may lead to economic loss of the city. This research can be expanded to other cities in India. The risk and resilience indices will aid in evaluating disaster risk at the city level and can play an essential role in disaster resilience.

1

INTRODUCTION

In a rapidly urbanizing world, it is estimated that by 2050, two-thirds of the world's population will reside in cities and every year for the next 30 years, about 70 million people will relocate to cities (CDP, 2022). The interactions between rapid urbanization, changes in land use, vulnerability, and exposed population, will enhance the future climate change risks and associated impact on the cities (IPCC, 2022). Rapid urbanization intensifies human induced warming, climate change and extreme events like severe heat waves, heavy precipitation etc. For example, flooding will become more likely in coastal cities, due to the rise in the sea level and more frequent occurrence of extreme rainfall events (IPCC, 2021).

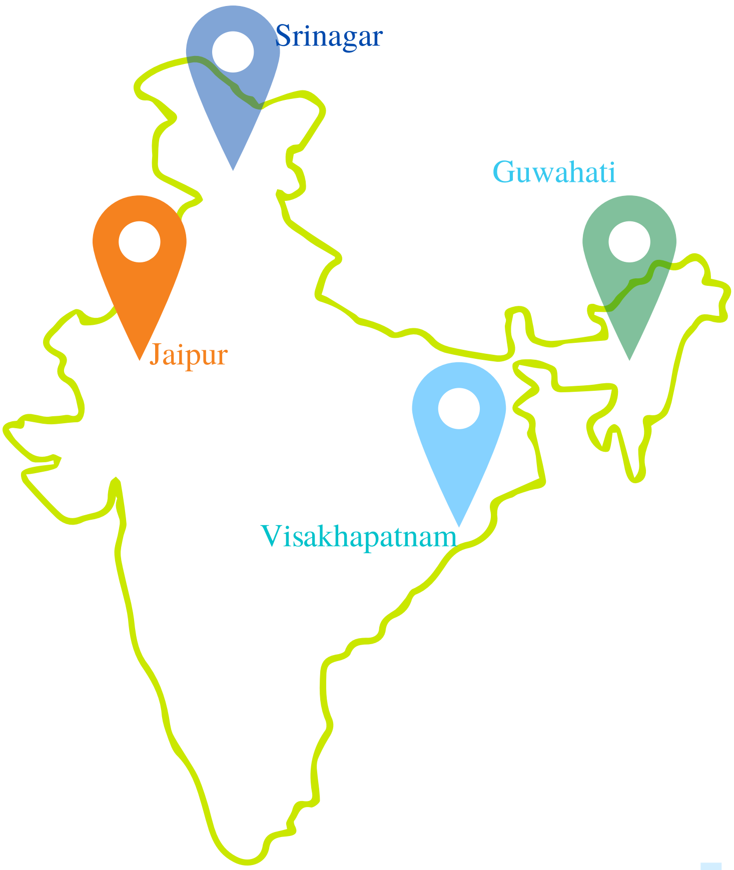


Figure 1

Selected cities for the study: Guwahati, Jaipur, Srinagar, and Visakhapatnam

An increase in population and urban expansion intensifies vulnerability to disaster events and a lack of basic amenities; the population below the poverty line is highly vulnerable during the disasters (ESCAP, 2021). Climate change is becoming more closely associated with urban issues, since it is anticipated to increase the hazards of underdeveloped infrastructure and resource-deficient urban areas (Gupta et al., 2019). The pillars of making any city robust to a changing environment are disaster risk reduction and climate change adaptation (WMO Report, 2022). The use of indigenous knowledge alongside scientific understanding in disaster risk reduction (DRR), is becoming increasingly popular to lessen community susceptibility to environmental risks (UNICEF, 2022).

The public-private involvement, strong governance and institutional framework, including disaster resilience, adaptability, environment and sustainability are crucial safety measures. The necessary step-change in urban risk management, may be realized by combining action through these technological and developmental frameworks, i.e., the Sendai Framework for Disaster Risk Reduction (SFDRR) and Sustainable Development Goals (SDGs) (consist of Goal 11 of making the cities and human settlements inclusive, safe, resilient and sustainable) (Stanton-Geddes & Vun, 2019).

The cumulative consequences of the different programmes may be seen in sophisticated early warning systems, coordinated responses to disasters and approaching disasters, dramatic reductions in disaster fatalities and a general improvement in disaster awareness at all levels such as national, state and district levels.

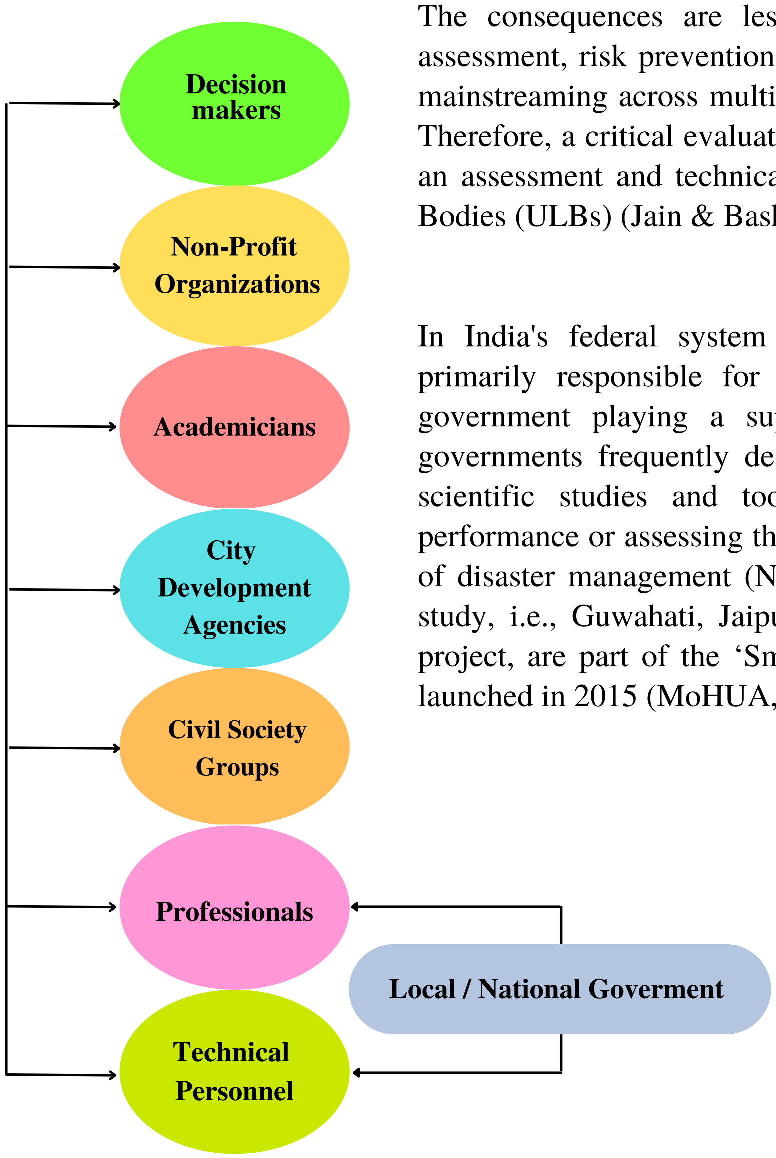


Figure 2

Technical Report's primary audience

The consequences are less noticeable in city-level disaster risk assessment, risk prevention & mitigation and disaster risk reduction mainstreaming across multiple development sectors (NDMA, 2019). Therefore, a critical evaluation of risk and resilience is required with an assessment and technical capacity development by Urban Local Bodies (ULBs) (Jain & Bashir Bazaz, 2016).

In India's federal system of governance, state governments are primarily responsible for disaster management, with the central government playing a supporting role. The regional and local governments frequently deal with disasters, but there is a lack of scientific studies and tools availability, for benchmarking the performance or assessing the progress of cities during various phases of disaster management (NDMP, 2019). The cities selected for the study, i.e., Guwahati, Jaipur, Srinagar, and Visakhapatnam in this project, are part of the 'Smart Cities Mission' of India, which was launched in 2015 (MoHUA, 2022).

The project aims to understand the perceptions & contexts for city risk & resilience and provides helpful guidance to city administration & policy makers on actions required to form resilience to disasters. The 04 Indian cities of the study exhibit a broad range of geographical variances in terms of climate, terrain, vegetation, hydrology, and habitation pattern, creating a patchwork of practically every natural hazard.

As India is yet to build a solid and robust database of hazards, vulnerabilities, risks and resilience, the 'model' theoretical framework on indicators is greatly hampered by a lack of data at the city level to monitor indicators' progress.

Thus, to make Visakhapatnam city resilient, the regional population should react to disasters with the logic of urgency and strategically reduce human, land/property and ecological loss by evolving a complete, practical, multi-disaster and technology-driven approach for Disaster Management (DM). Therefore, this is the first study of its kind at the city level on multi-hazard disaster risk & resilience, to develop a risk and resilience scorecard. This study can be extended to other cities in India, to evaluate the disaster risks and to plan for disaster resilience. This Technical Report's primary audience consists of decision-makers, professionals, and technical personnel from local to national governments, city development agencies, non-profit organizations, and civil society groups. The report is also essential to academics and interested people for further research.

2

VISAKHAPATNAM CITY PROFILE

As per the International Council for Local Environmental Initiatives (ICLEI) Report (2019), Visakhapatnam, popularly known as Vizag, is a port city, on the southeast coast of India and it is the biggest city in Andhra Pradesh, both in terms of population and economy. The city is often called "The Jewel of the East Coast" and has the oldest shipyard of the country (CDMA, 2022). The climate of Visakhapatnam is tropical savanna, with minimal variation in temperature throughout the year. The warmest month is May, with an average maximum temperature of approximately 36°C, while the coldest month is January, with an average maximum temperature of about 29°C. The peculiarities of the region and its distinctive physiography (popularly known as the dolphin nose) have a significant impact on its meteorological and climatic conditions, as well as climate-related risks. Visakhapatnam city has one of the largest municipal corporations in India with a geographical area of 515.49 km^2 with geographical coordinates of 17.68° N and 83.21° E (Figure 3).

The city has several forms of transportation, including the east coast railway, a national highway, an airport, and a seaport. Visakhapatnam Port is the country's largest port and possesses the only natural harbour on the east coast. According to the census (2011), the city has a population of about 1.73 million with a population density of 3356 persons per sq. km. The city has a literacy rate of 67.70% with a sex ratio of 978 females for every 1000 males.

The city is positioned on the international market as the financial and industrial centre due to its geographical advantage and a multitude of infrastructure facilities (ICLEI Report, 2019). Thus, Visakhapatnam is the most populous and economically significant city in Andhra Pradesh. Prior to the division of Andhra Pradesh state, Visakhapatnam was the second biggest IT destination in United Andhra Pradesh after Hyderabad, and it remains the most preferred place for IT investment as of now. During the financial year 2018-19, the city's IT sector is estimated to have grown by 30%. Major Industries in Visakhapatnam, consist of Information Technology (IT) & Information Technology Enabled Service (ITES), Metallurgy, Electronics, Agro-based, Textile, Food Processing, Automobile, Pharmaceuticals, Rubber, Gem & Jewellery, Logistics, Hospitality, Tourism, Real Estate, Construction and Warehousing. GVMC would include major enterprises, such as the Visakhapatnam Steel Plant, Bharat Heavy Plate and Vessels, and Hindustan Zinc (Eninrac Reports, 2020; ICLEI Report, 2019).

The city has been selected and ranked 8th in the list of ‘Round 1 Smart Cities’ of the 100 Smart Cities in the Ministry of Urban Development's (MoUD) ‘Smart Cities Mission’, which was launched in June 2015 (GUDCLTD, 2016; MoHUA, 2022; MyGov, 2022). In the latest Swachh Survekshan Rankings 2020, the city was ranked 9th cleanest in the country in the category of cities having a population of more than 10 lakhs (The Hindu, 2020). The city secured 2nd place in the category of ‘citizen feedback’ of the Swachh Survekshan-2022 survey (New Indian Express, 2022). Visakhapatnam city stands at 2nd in the Sustainability, 15th in Ease of Living Index, 18th rank in Economic Activity, 25th in the Quality of Life, and 47th in Citizen Perception in the year 2021 (MoHUA, 2021).

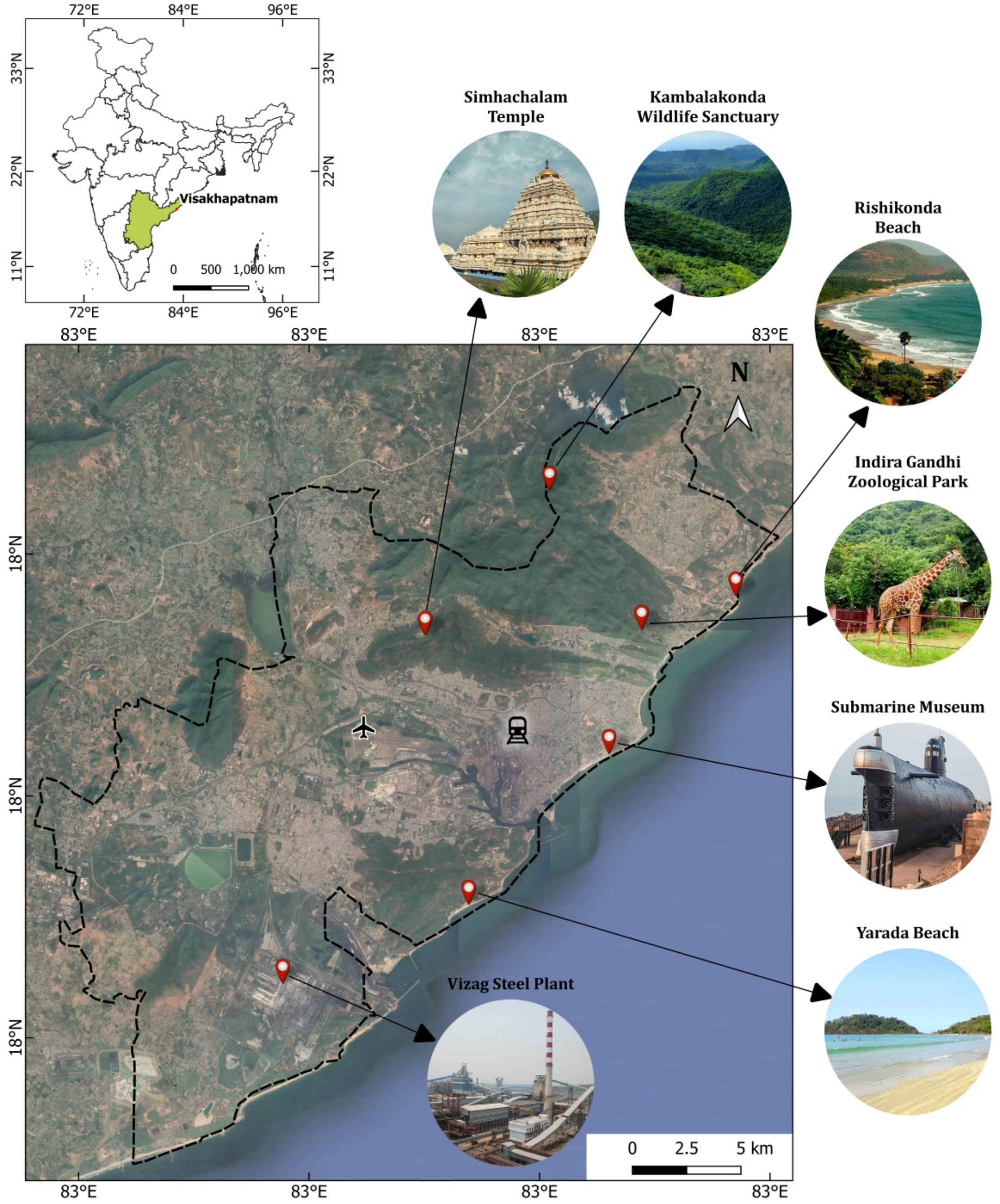


Figure 3
Location map of Vishakhapatnam city

Population

1.73 million

Population Density

3356 person per sq.km

Annual Growth Rate

2.34%

Indian Megacities Population

Rank 17

Smart Cities Mission (Round 1)

Rank 8th

3

RISK PROFILE OF THE CITY

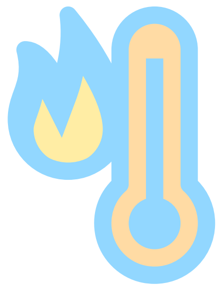
The risk profile and disasters triggered in the past in Visakhapatnam city are as follows:

As per the Building Materials and Technology Promotion Council (BMTPC) Atlas, Visakhapatnam city falls under earthquake Zone-II, up to magnitude 4.9. For instance, an earthquake measuring 5.1 and 1.8 magnitude struck on 24th August and 14th November 2021 respectively, whose tremors filled in the lowest seismic zone of the country in Visakhapatnam city (Deccan Chronicle, 2021a, 2021b).

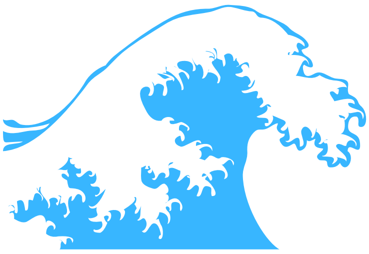
The coastal erosion severely impacts Visakhapatnam city, due to the combined impact of high tides, tsunamis, and cyclone events. As per the IPCC report, the sea level will rise by 1.77 feet in the future 100 years and it will inundate many regions of Visakhapatnam city and ports along the coastal region (The Hans India, 2021; The Hindu, 2022b; The New Indian Express, 2021; Times of India, 2021b). Presently, 5.12 km length and 2.5 km^2 of coastal area have completely been eroded.

The average rainfall of the city is 1071 mm, almost 90% of which is received in the monsoon period (i.e., June - September). The city experiences several flood events due to extreme rainfall, inefficient drainage and cyclone induced rainfall. The recent 2021 cyclone Gulab induced rainfall, broke the 30-year record of rainfall in the city and inundated several low-lying areas. Similar events were observed in 2014, 2019 and 2020. The probable average and maximum flooded area in Visakhapatnam are 50% and 60% respectively (Goyal et al., 2022; Sharma & Goyal, 2020; Goyal & Surampalli, 2018; The Economic Times, 2022; The Hindu, 2021a, 2021b).

Visakhapatnam city is characterized by moderate temperature with less variation in maximum and minimum temperature. The mean temperature of the city is 26.9°C, changing from 22.7°C in winter to 30.9°C in summer. The maximum temperature was observed in May and the minimum temperature was observed in January. A heat wave occurs during the season when the daytime temperature increases to 4-6°C above normal (Tyagi et al., 2011). Based on the research, 3 heatwave events (5 days+) occurred between 2000 to 2020, with the longest heat wave of 15 days.

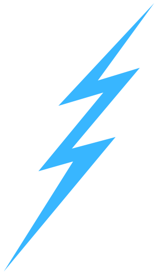


Visakhapatnam city has experienced huge impacts due to industrial hazards and fire accidents in the past. For instance, the Visakhapatnam gas leak in 2020 in the LG polymers industrial facility, caused more than 10 mortalities and several injuries. There are 18 hazardous and 148 polluting industries with an overall CEPI index of 55.40 (The Hindu, 2022a). There are several fire accidents reported in Visakhapatnam city, like a fire accident in the Visakhapatnam steel plant (The Hindu, 2021c), Hindustan Petroleum Corporation Limited (HPCL), (Times of India, 2021a), and a fire break out in the Warehouse of Ganagavaram Port (The Print, 2022).



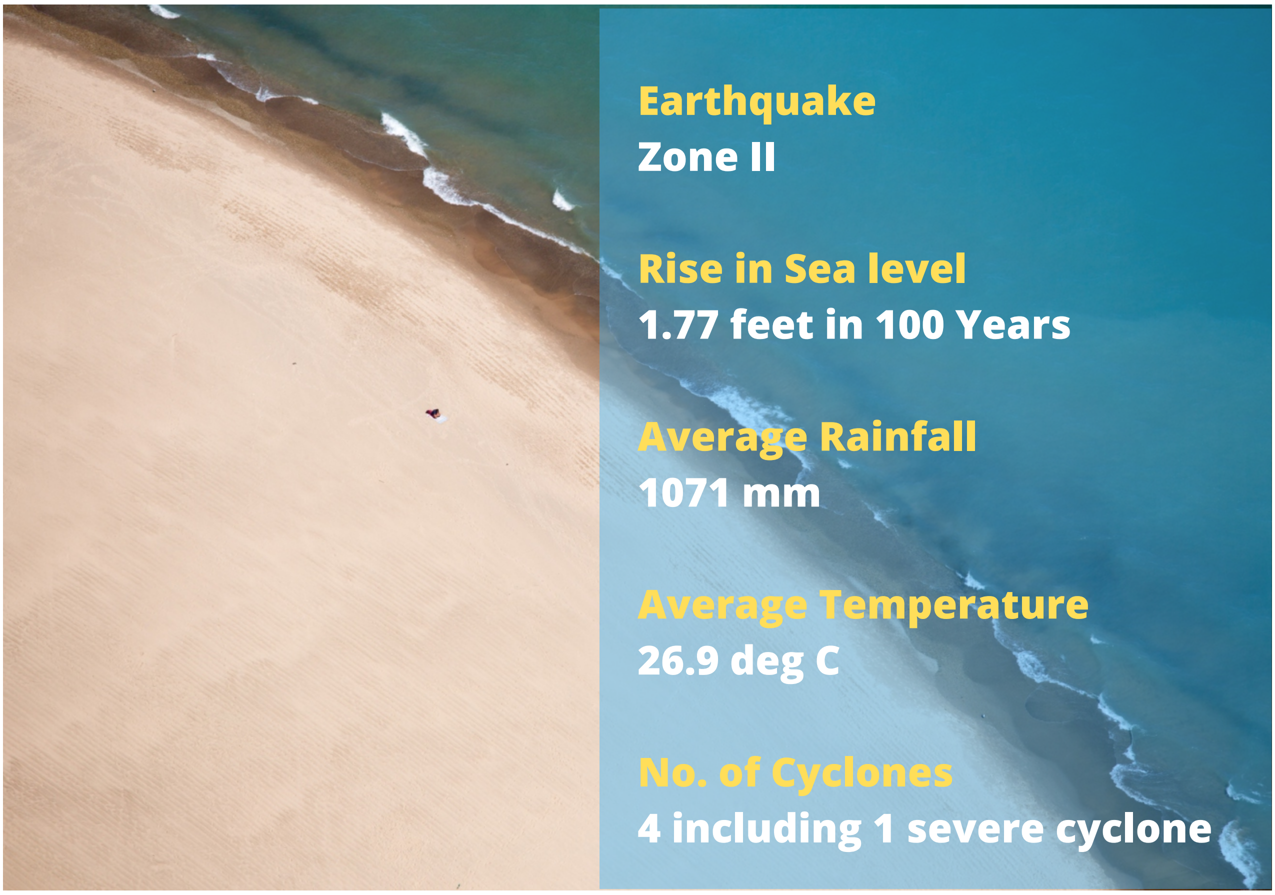
Earthquakes in the ocean bed cause tsunamis, and their high tide waves impact the coastal population significantly. Visakhapatnam city was impacted by Tsunami in 2004, with an average height of 1.78 m and it impacted about 1 million population living in the city.

Several lightning events significantly occurred in Visakhapatnam city and the mortalities associated with lightning were higher in the region, compared to other cities as per National Crime Records Bureau (NCRB) mortality data, due to natural and man-made disasters.



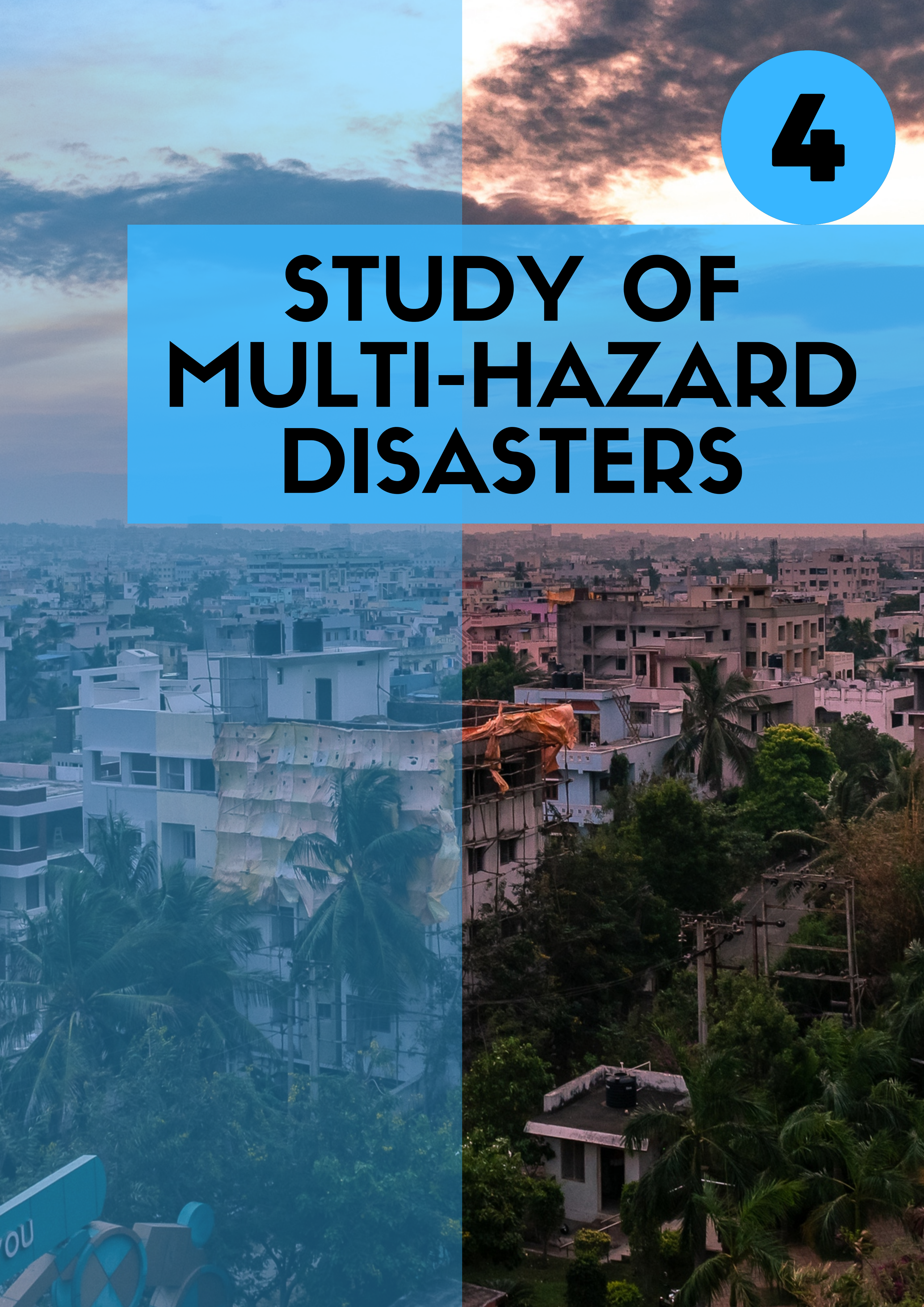
The cyclones originate and come through the Bay of Bengal, prominently impacting the eastern coast and economy of the port city of Visakhapatnam significantly. The cyclone caused a storm surge to erode the coastal region and ports, while an increase in wind speed and precipitation impacted the local population's livelihoods and the economy of the region. In the past 2000-2020 years, there were 4 cyclones reported, including one severe cyclone with a maximum storm surge (1.23 m), wind speed (126.76 kmph), and precipitation (200 mm) (IMD, 2021).

Therefore, it is essential to invest in enhancing urban resilience and undertaking risk-reducing measures for the sustainable urban development of Visakhapatnam city.



4

STUDY OF MULTI-HAZARD DISASTERS



In this study, a multi-hazard disaster risk matrix is developed by collecting primary and secondary data at the urban level, as per the Ministry of Home Affairs (MHA) and the United Nations Development Programme (UNDP) report of "Disaster Risks and Resilience in India: An Analytical Study 2019" (UNDP, 2019). The datasets are collected and generated for several parameters chosen to compute exposures, vulnerabilities, and hazard indices. Based on the importance of the parameters, weights are given to the parameters according to the Risk and Resilience matrix developed by the MHA-UNDP 2019 report (Page no.: 35) (UNDP, 2019). The methodology of the Disaster Risk Index (DRI) considered 14 indicators of hazards (12 for natural hazards and 2 for man-made hazards), 14 indicators of vulnerabilities, and 2 indicators of exposures (Refer to Table 1). The parameters and their relative weights were identified and taken from MHA-UNDP Report, 2019 (UNDP, 2019).

The Disaster Resilience Score (DRS) is computed by summing up the scores achieved by Visakhapatnam city on each of 7 indicators (based on the quantitative norms) such as i) assessment of risk, ii) prevention and mitigation of risk, iii) governance of risk, iv) preparedness, v) response, vi) relief and rehabilitation, and vii) reconstruction of a disaster. Such scores are rescaled to 100 to compute resilience, enable comparison, and thereby DRS. Based on guidelines and contents provided under the DM Act 2005 and DM Policy 2009 of the country, a set of questions are used for the performance assessment of Visakhapatnam city. As per the MHA-UNDP Report (2019), responses (received from the city's Mayor) assessment of the Questionnaire, are computed in quantitative terms. The risk and resilience scorecard methodology is explained and presented sequentially in Figure 4.

i) What constitutes risks of disasters

Risks are measured using equation (i)..(IPCC, 2014)

Where,

$$R = \{(h \times v) \times e\} \div c \qquad \text{------------- (i)}$$

R = disaster risk;
h = hazard (the possibility of an occurrence of an event which causes loss);
v = vulnerability, factors increasing the vulnerability of an area or public to the impacts of hazard;
e = exposure of vulnerable people and assets to hazards
c = capacity or resources that could decrease the risk level or the impacts of disasters.

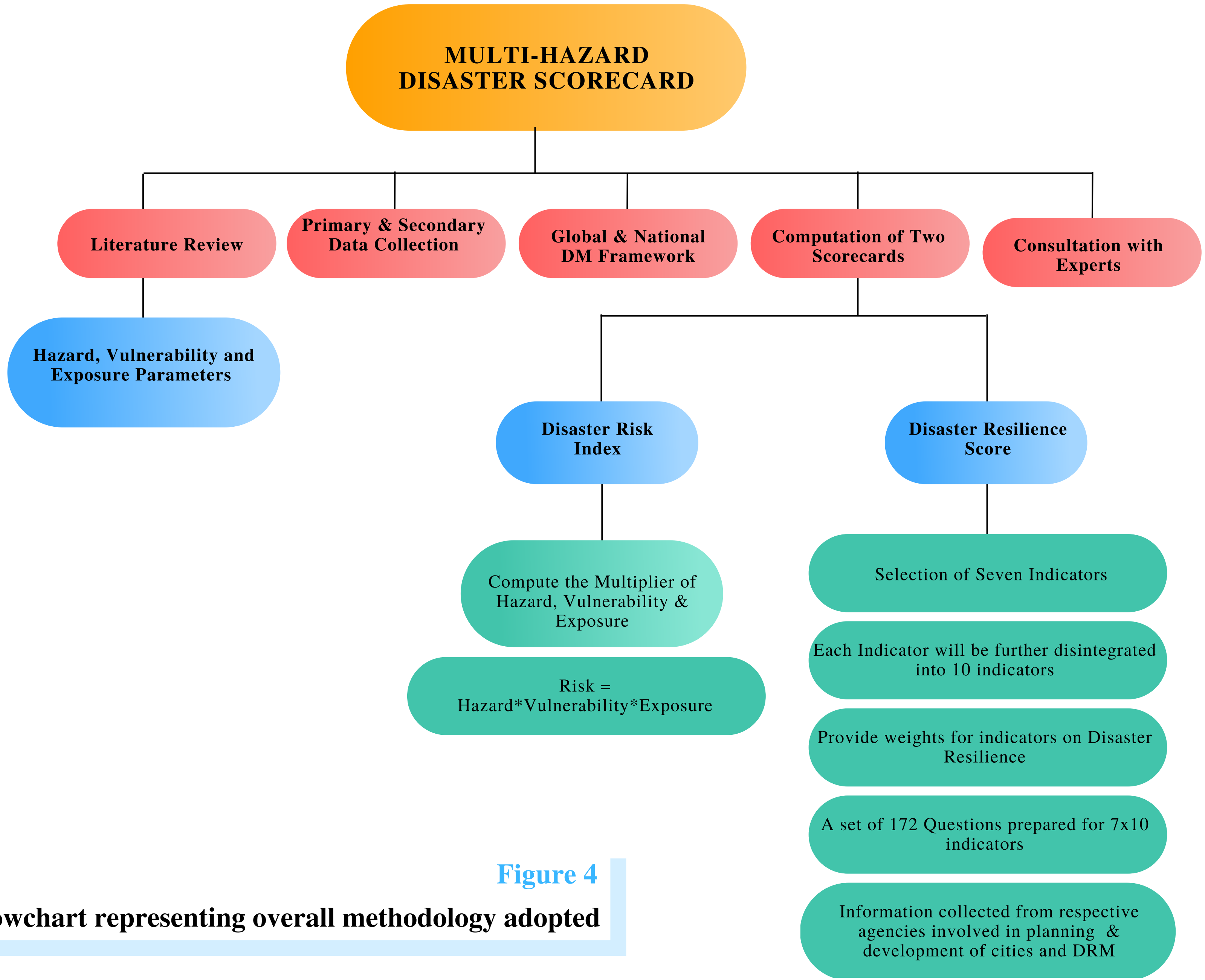


Figure 4

Flowchart representing overall methodology adopted

ii) Selection of indicators for hazard, vulnerability, and exposure

The indicators of hazards, vulnerabilities, and exposures have been chosen on their importance and the data accessibility uniformly across the city (Refer Fig 5). Although specific datasets for some indicators, like livestock, forest fire, agriculture, etc., are available at the district level, they were chosen and the best use of datasets was made based on the existing datasets.

Figure 5

Indicators selected for hazards, vulnerabilities and exposures

iii) Parameters on indicators and their weights

Each of these 14 hazards, 14 vulnerabilities, and 2 exposures indices have various parameters. These parameters (Refer Table 1) were chosen for the computation of indices on hazards, vulnerabilities, and exposures based on available datasets of the city. The weights were assigned to the parameters (Refer Table 2) following the MHA-UNDP Report, 2019 (Page numbers 33 & 34; Disaster Risks and Resilience in India- A systematic study by the MHA-UNDP 2019).

iv) For exposures, (a) population and (b) GDP are selected. The 50% of equal weights are given to both parameters.

v) Hazard-specific vulnerabilities

Each indicator of vulnerability is not related to each hazard. For instance, the susceptible buildings and infrastructure are exceptionally related to earthquakes and landslides, but not associated with a heatwave. Similarly, the susceptible forest and mangrove cover are significantly related to forest cover, but not related to industrial hazards. Thus, based on their significance, hazard-specific vulnerabilities were factored in, to measure risks in an individual instance.

vi) Comparative weights on indicators of hazards, vulnerabilities and exposures

Each hazard and vulnerability indicator will not generate an identical extent of risks. For instance, an earthquake could create a severely high risk of disasters, compared to either forest fires or landslides. Similarly, each vulnerability cannot develop in a similar quantity of damages and losses. For instance, the vulnerability of buildings and infrastructure can cause severe deaths, damages, and economic losses compared to exposed human conditions of poverty or gender bias. The datasets of past disasters have been used to develop relative weights as per MHA-UNDP Report, 2019 (Refer Table 3).

vii) Comparative weights on hazards, vulnerabilities and exposures

The risk level for the city of Visakhapatnam, which has a high population density of 3356 person per km^2 and GDP, is overestimated when hazards, vulnerabilities, and exposures are given equal weights. It was agreed that the relative weights of H (hazard), V (vulnerability) and E (exposure) should be stated in the ratio of 4:2:1 because hazards are the main factors that increase the risk of disasters (MHA-UNDP Report, 2019).

Table 1

List of hazards, parameters, and their relative weights
(as per MHA-UNDP Report, 2019, Page No: 33)

Hazards	Parameters on Hazard	Weights on parameters
Earthquake	Seismic hazard zonation: Zone-V, IV, III, and II	Zone-V: 10, Zone-IV: 6, Zone-III: 4, Zone-II: 2
Landslide	Landslide hazard zonation: Zone- IV, III, II, and I	Zone-IV: 10, Zone-III: 8, Zone-II: 4, Zone-I: 0
Avalanche	Avalanche hazard zonation: Zone- V, IV, III, II, and I	Zone-V: 10, Zone-IV: 8, Zone-III: 6, Zone-II: 4, Zone-I: 0
Drought	a) Drought-prone area, b) Number of drought years, c) Moisture index, d) Frequency of SSI (Standardized Soil Moisture Index), e) Frequency of SPI (Standardized Precipitation Index).	Equal weights
Urban Flood	a) Average annual flooding, b) Maximum annual flooding, c) Year of maximum flooding, d) Average flooded area (%), e) Maximum flooded area (%)	Equal weights
Heat Wave	a) Average Heat Index based on National Oceanic and Atmospheric Administration (NOAA) methodology b) Number of days with a heat index above 54 c) Number of a heat wave (temperature above 40°C for 5+ days) d) Longest duration of a heat wave	Equal weights
Cold Wave	When the temperature goes below 4°C in plain areas and below - 4°C in hilly areas	Equal weights

Hazards	Parameters on Hazard	Weights on parameters
Cyclone	a) Number of cyclones b) Number of severe cyclones c) Probable maximum wind speed d) Probable maximum precipitation e) Probable maximum rainfall f) Maximum Storm surge	Equal weights of 15% for (a) and (c) to (f) and 25% weights for (b)
Tsunami	a) Length of coastline b) Population living within 0.5 km of coasts c) Average height of tsunami wave	a) 25% b) 25% c) 50%
Fire	Normalized fire index of city based on average annual. a) Number of accidents by fire b) Number of deaths c) Number of injuries	Equal weights
Forest Fire	Forest fire zonation in very dense, dense and open forests a) High risk zone-very dense b) Moderate risk zone- dense c) No risk zone- open forests	Values of 10, 5 and 0 for 3 risk zones with weights of 50%, 30% and 20% on 3 types of forests
Coastal Erosion	a) Length of coastline b) Coastal length (km) under erosion c) Coastal area (sq km) under erosion	Equal weights
Industrial Hazard	a) MAH industries b) MPI industries c) CEPI index	a) 50% b) 25% c) 25%
Lightning	Normalized annual average lightning mortality in city	Mortality index scaled 0 to 10

MAH: Maximum Accident Hazard
MPIs: Maximum Polluting Industries
CEPI: Comprehensive Environmental Pollution Index

Table 2

Parameters and weights on vulnerabilities
(as per MHA-UNDP Report, 2019, Page No: 34)

Vulnerabilities	Parameters on Vulnerabilities	Weights on parameters
Unsafe Buildings	Number of buildings constructed predominantly with materials used for construction of roofs and walls and classified as Very High (VH), High (H), Moderate (M), Low (L) and Very Low (VL) risk in earthquake, landslide, flood, and cyclone	VH:10, H:8, M: 6, L:4, VL: 2
Social infrastructure	Number of educational and health institutions in the city	a) 40% weights on primary educational institutions b) 10% weights on higher educational institutions c) 25% weights on primary health institutions d) 25% weights on hospitals
Physical infrastructure	a) Length of roadways b) Length of railways c) Number of airports and seaports	Equal weights on each parameter and further equal weights on sub-parameters within each parameter
Livestock Population	Number of livestock in the city a) Bovine animals b) Other animals	a) 80% b) 20%
Vulnerable Women	a) Sex ratio b) Illiteracy (%) c) MMR d) WHH (%) e) CAW f) Dependent (%)	Equal weights
Vulnerable Children	a) Age group 0-6 and 7-18 b) Non-school going children c) Working children d) IMR	Equal weights
Aged People	a) Age group 60+ b) Age group 80+ c) Dependency Ratio	Equal weights

Hazards	Parameters on Hazard	Weights on parameters
Disabled People	Types of disability a) Visual b) Hearing c) Speech d) Physical e) Mental f) Any other	Equal weights
Net Cropped Area	a) Cropped area b) Irrigated area	a) 80% b) 20%
Industries	a) Number of MSME in city b) Number of industrial clusters c) Number of SEZ	a) 40% b) 40% c) 20%
Rural/Urban Poor	a) BPL population (rural and urban) b) Homeless population	Equal weights on both, with further equal weights on rural and urban BPL and Homeless
Deforestation	Change of forest cover (positive, negative, overall) during 2001-2015 a) Dense forests b) Open forests	Equal weights
Depletion of Mangroves	Change of mangrove cover (positive, negative, overall) during 2000-2021 a) Dense mangrove b) Open mangrove	Equal weights
Water Stress	a) Terrestrial water as captured in moisture index b) Surface water as captured in area under irrigation c) Sub-surface area as reflected in Central Ground Water Board (CWGB) data	Equal weights

MMR: Maternal Mortality Rate per 1,00,000 child births
CAW: Crime Against Women (cases registered per 1,00,000 women)
IMR: Infant Mortality Rate
MSMEs: Micro, Small and Medium Enterprises
SEZs: Special Economic Zones.
BPL: Below Poverty Line

Table 3

Comparative weights on hazards, vulnerabilities, and exposures
(as per MHA-UNDP scorecard report, 2019, Page No: 36)

HAZARDS		VULNERABILITIES		EXPOSURES	
Indicator	**Weight%**	**Indicator**	**Weight%**	**Indicator**	**Weight%**
Earthquake	15	Buildings*	15	Population	50
Landslide	7	Agriculture*	10	Economy	50
Avalanche	3	Poverty*	10		
Drought	15	Women*	8		
Urban Flood	15	Children*	8		
Heat Wave	6	Disability	6		
Cold Wave	6	Aged	6		
Cyclone	15	Livestock*	6		
Tsunami	3	Industries	6		
Fire	3	Physical Infrastructure	5		
Forest Fire*	3	Social Infrastructure *	5		
Coastal Erosion	3	Deforestation	5		
Industrial Hazard	3	Depletion of Mangrove	5		
Lightning	3	Water Stress*	5		

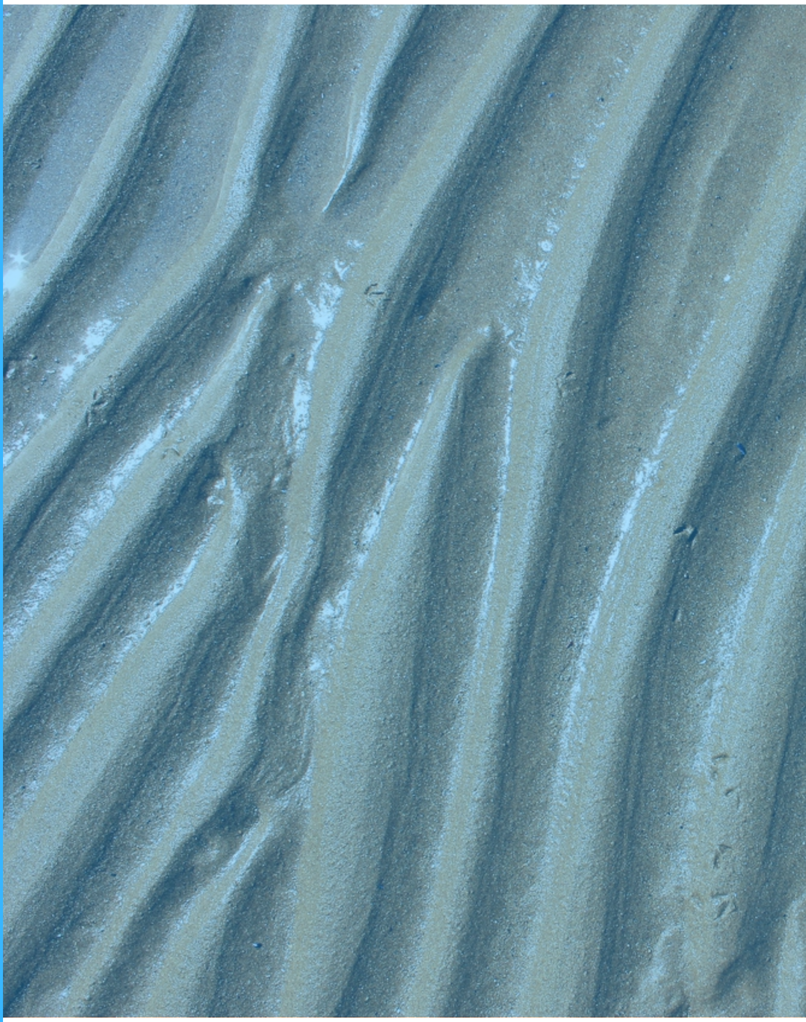
*In the absence of city-level data, the district-level data have been considered for these indicators in the entire study.

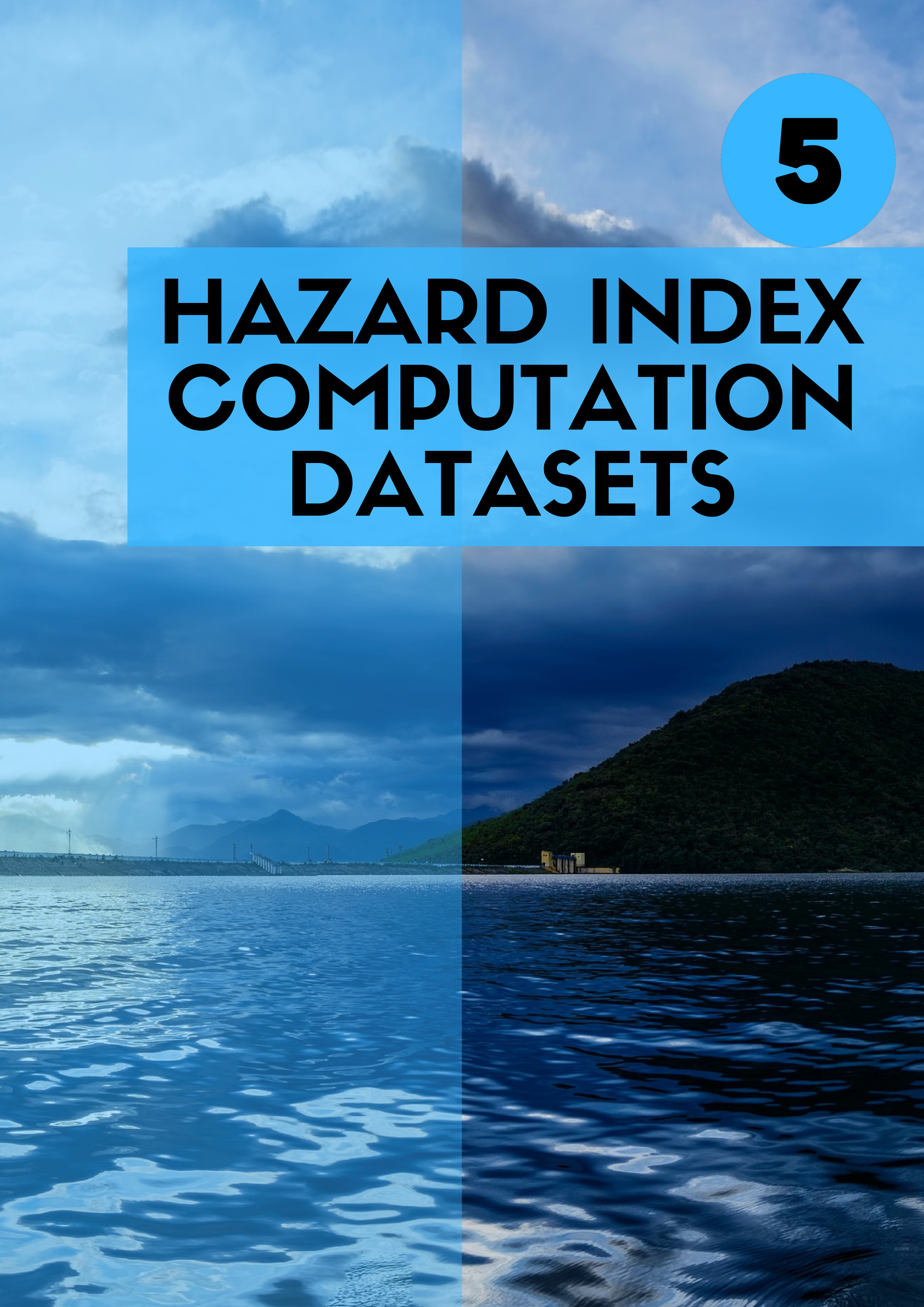
Note:

1. As per the MHA-UNDP 2019 report, the total hazard indicators in the list are 14. However, Visakhapatnam city is not prone to Landslide and Avalanche hazards, due to the geographical and topographical features of the city.

2. Likewise, all the vulnerable indicators in the list of the MHA-UNDP 2019 report are considered for Visakhapatnam city, except Depletion of Mangrove (13 vulnerable indicators are considered out of 14), as there is no mangrove in the city region.

3. The present study is carried out comparatively over Guwahati, Jaipur, Srinagar, and Visakhapatnam cities. The risk index profiling of these cities is computed comparatively for different hazards, vulnerabilities, and exposure parameters. Therefore, the various indices in this report for Visakhapatnam city are compared to the other 3 cities and should not be viewed in isolation.





5

HAZARD INDEX COMPUTATION DATASETS

1. Earthquake

The earthquake data of the city is derived from Open Government Data (OGD) Platform India (data.gov.in), as per the National Building Code 2005 (Ministry of Home Affairs). The values on a scale of 0 to 10, have been adopted for various seismic zones. Accordingly, the hazard index of the city, has been worked out: Zone-V (Very High Risk): 10, Zone-IV (High Risk): 6, Zone-III (Moderate Risk): 4, and Zone-II (Low Risk): 2, through Earthquake Hazard Zoning Atlas of India of 2016 (Table 4).

Table 4 **Earthquake hazard index**

City Area (km^2)	Area (km^2) in Earthquake Hazard Zones								Earthquake Hazard Index (Out of 10)
	ZONE II (Low Risk)		ZONE III (Moderate Risk)		ZONE IV (High Risk)		ZONE V (Very High Risk)		
	Area	%	Area	%	Area	%	Area	%	
515.49	515.49	100	0.00	0.00	0.00	0.00	0.00	0.00	2.00

Since the whole of Visakhapatnam city, lies in Zone II (for which the weight is 2), the area falling in the earthquake hazard zone is considered the city's area, i.e., 515.49 km^2. It means the whole city is susceptible to earthquake events. in a low-risk zone.

2. Landslide

As per the Landslide Hazard Zonation Atlas of India (2003), the entire landmass of India, has been classified into 4 landslide hazard zones: Zone-IV (Very High), Zone-III (High), Zone-II (Moderate to Low) and Zone-I (Unlikely). Based on this area analysis, the landslide hazard index has been worked out, based on the following values ascribed to each zone on a scale of 0 to 10: Zone-IV: 10, Zone-III: 8, Zone-II: 4, Zone-I: 0 (Table 5).

Table 5 **Landslide hazard index**

City Area (km^2)	Area (km^2) in Landslide Hazard Zones								Landslide Hazard Index (Out of 10)
	ZONE I (Unlikely)		ZONE II (Moderate Risk)		ZONE III (High Risk)		ZONE IV (Very High Risk)		
	Area	%	Area	%	Area	%	Area	%	
515.49	515.49	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Since the whole of Visakhapatnam city lies in Zone I (for which the weight is 0), the area falling in the landslide hazard zone is considered the city's area, i.e., 515.49 km². It means the city is unlikely to be susceptible to landslide events.

3. Drought

No agency has carried out any drought hazard zonation of the city. In the absence of such zonation, parameters of drought, have been captured through 5 parameters: (a) drought-prone area, (b) number of drought years, (c) moisture index, (d) frequencies of SSI (Standardized Soil Moisture Index) and (e) SPI (Standardized Precipitation Index). Equal weights of 20% have been given to each parameter (Table 6). The data sources for these parameters have been provided in the annexure section at the end of the report (Annexure 1).

Table 6 **Drought Index**

Drought Prone Area (km²)	No. of Drought Years	Moisture Index	Frequency		Normalized				Drought Index (Out of 10)
			SSI	SPI	Drought Years	Moisture Index	SSI	SPI	
0	6	-0.0743	26	29	4.62	7.31	10	6.59	**5.70**

It is observed that there were 6 drought years between 2000 to 2016. Soil moisture drought is more prominent than meteorological drought in the city. Therefore, Visakhapatnam may observe frequent increase in water scarcity and reduced drinking water sources in future.

4. Urban Flood

The urban flood index has been calculated using the BMTPC (2006) map and literature. Urban floods have been captured through 5 parameters: (a) average annual flooding, (b) maximum annual flooding, (c) year of maximum flooding, (d) average flooded area (%) and (e) maximum flooded area (%). Equal weights have been given to all the parameters (Table 7). The data sources for these parameters are provided in the annexure section at the end of the report (Annexure 1).

Table 7 **Flood Hazard Index**

City Area (km^2)	Flood Affected Area (km^2)					Flood Hazard Index (Out of 10)
	Average Annual Flooding	Maximum Annual Flooding	Year of Maximum Flooding	Average Flooded Area (%)	Maximum Flooded Area (%)	
515.49	-	-	2014	50	60	**10**

Out of the 515.49 km^2 total area of the city, the observed area of maximum flooding was 60% in 2014 during 2000-20 and the average flooded area was about 50%.

5. Heat Wave

Heat waves have been captured through 4 parameters: (a) the number of days with a heat index above 54, (b) the average number of the heat wave (temperature above 40°C for 5+ days), (c) the average longest duration of the heat wave and (d) average Heat Index (HI) based on National Oceanic and Atmospheric Administration (NOAA) methodology (Table 8). Equal weights have been given to each parameter.

Table 8 **Heat Wave Index**

Heat Waves				Heat Wave Index (Out of 10)
No of days with a Heat Index (HI) above 54 (Annual Average)	Average number of Heat Waves (5 days +)	Average longest Heat Wave (No of Days)	Average Index of Heat Waves	
4	3	15	0.63	**8.01**

There are 3 numbers of average heatwave events (5 days+) with temperatures at least 40°C or above, occurred between 2000 to 2018, in the city, every year. The number of days with HI above 54, were 4 days and the average longest heat wave was 15 days.

6. Cold Wave

Cold Wave Hazard Index has been worked out, following the Indian Meteorological Department (IMD) Weather Forecast, which defines a day as cold, when the temperature goes below 4°C in plain areas and below - 4°C in hilly areas. The percentage of days with cold wave conditions in 3 different temperature brackets in the city, has been worked out with equal weight to calculate the cold wave hazard index on a scale of 0 to 10 in other indices (Table 9).

Table 9 **Cold Wave Index**

Plain Areas (temperature <4°C)	Cold Wave Index (Out of 10)
0	**0**

There were no cold wave events observed, as the temperature less than 4°C (the sudden decrease of temperature less than the usual minimum level and the prolongation of the event for a few days) did not occur between 2000 to 2018 in the city. The cities in the hilly areas may have a high cold wave risk index compared to the plain cities like Visakhapatnam.

7. Fire

The Directorate General of National Disaster Response Force (NDRF) and Civil Defence commissioned a study on fire hazard and risk analysis in the country for revamping fire services in the States. The study did not cover fire risks in the districts or compile data on city fires. In the absence of any city-level database on fire, the National Crime Records Bureau (NCRB) State-level database has been relied upon to assess (a) the number of cases of fire accidents registered, (b) the number of deaths, and (c) number of injuries during 2001-2015 (Table 10). Data has been normalized at the city level based on population. The fire hazard index has been worked out, based on equal weights of 33.33% on these 3 parameters.

Table 10 **Fire Hazard Index**

Accidents of Fire			Fire Hazard Index (Out of 10)
Cases	Deaths	Injured	
47	50	0	**5.38**

The city had 47 cases and 50 injuries that occurred due to fire accidents between 2001 to 2015. The data sources for these parameters have been given in the annexure section at the end of the report (Annexure 1).

Gas leak in LG Polymer Plant, Visakhapatnam . 07 May 2020 (Source: The Hindu)

8. Forest Fire

The study on 'Vulnerability of India's Forests to Fire' published in 2019 by the Forest Survey of India (FSI) is the basis for data on forest fires (Table 11). The study has classified Visakhapatnam district (lack of city-level data) in terms of 3 types of a forest fires: high, moderate, and no risk. This has been supplemented with data on types of forests in the district - very dense (50%), dense (30%) and open forests (20%), as brought out in the annual India State of Forest Report 2019. The assigned weights are multiplied by the risk zone multiplier, to get the value of the hazard index.

Table 11 **Forest Fire Index**

Total Area-City (km^2)	Total Area-District (km^2)	Forest Area (km^2)						Forest Fire Index (Out of 10)
		Very Dense	Dense	Open	Total	% of Total	Risk Zonation	
515.49	11,161	11.46	2,009.95	1458.92	3479.05	31.17%	2.59	2.59

The total forest area in the Visakhapatnam district is about 3479.05 km^2. It is observed that there is a low-risk zone index (2.59) for forest fires in the district.

9. Industrial Hazard

The datasets are obtained from several sources like the Central Pollution Control Board (CPCB), the City Municipal Corporation, etc. (Table 12). The weights assigned for Maximum Hazard Industries (MHI), Maximum Polluting Industries (MPI), and Comprehensive Environmental Pollution Index (CEPI) are 50%, 25% and 25%, respectively.

Table 12 **Industrial Hazard Index**

Parameters of Industrial Hazards			Industrial Hazard Index (Out of 10)
Maximum Hazard Industries (MHI)	Maximum Polluting Industries (MPI)	Average CEPI of major Industrial Clusters	
18	148	55.40	9.57

The CEPI calculates the pollution level of air, water, and soil, due to the industrial clusters in the city. The average CEPI of major clusters is about 55.40 in Visakhapatnam city. The city shows a high score on the industrial hazard index, about 9.57, which means, there is a high risk that contributes to the trigger of the hazards, which may lead to disasters.

10. Lightning

Lightning accounts for significant mortalities during disasters in several cities in India. Although, there is a lack of scientific studies, assessing the lightning impact on the country's population. The datasets of lightning mortalities were obtained through the National Crime Records Bureau (NCRB) database at a city level. The lightning mortality index has been worked out on a scale of 0 to 10 (Table 13).

Table 13 **Lightning Hazard Index**

Accidents of Fire		Lightning Hazard Index (Out of 10)
Total Lightning Mortalities	Lightning Mortalities Average Annual	
12	0.8	10

In Visakhapatnam city, the lightning events that led to mortalities were only 12 in the past 15 years (2000-2015). It is challenging to predict the risks of lightning occurrence, as it is a natural phenomenon, but the hazard index shows that the city is experiencing a moderate rate of lightning hazard.

11. Tsunami

Parameters of Tsunamis have been captured through 3 parameters: (a) total length of coastline, (b) population living within half a kilometer of the coast, and (c) average height of tsunami wave. For this, 25% weightage has been given on parameters (a) and (b) and 50% weightage has been given on parameter (c) (Table 14).

Table 14 **Tsunami Hazard Index**

Parameters of Tsunamis			Tsunami Hazard Index (Out of 10)
Total Length of Coastline (Km)	Population living within ½ Km of Shoreline)	Average Height of Tsunami Wave (m)	
53.94	1,00,000	1.78	10

The tsunami caused a severe impact in the year 2004 across Visakhapatnam city with an average height of 1.78 meters. It caused severe impacts across 53.94 km of the coastline of Visakhapatnam city, including approximately 0.1 million population living within 0.5 km of the shoreline.

12. Coastal Erosion

Parameters of coastal erosion have been captured in 3 parameters: (a) total length of coastline, (b) coastline changes, and (c) coastal area changes, the last 2 again sub-divided into 3 parameters: erosion, accretion, and stability. Only erosion has been considered, as stability and accretion do not create risks of disasters (Table 15). An equal weightage of 33.33% has been given on all three parameters.

Table 15 **Coastal Erosion Index Computation**

Parameters of Coastal Erosion			Coastal Erosion Index (Out of 10)
Length of Coastline (km)	Coastal length under erosion (km)	Coastal area under erosion (km^2)	
53.94	5.12	2.50	10

Visakhapatnam city has a coastline of 53.94 km length. Based on the computation in QGIS through coastal erosion state maps and validation with literature, it is observed that the 5.12 km coastal length is under erosion with an area of 2.50 sq. km. Coastal erosion has been very highly observed in the region, impacting the population living across the coastline of the city and its daily port operations. It is severely impacting the city's economy.

13. Cyclone

Parameters of the cyclone have been captured through 6 parameters: (a) total number of cyclones, (b) the number of severe cyclones, (c) possible maximum wind speed, (d) possible maximum storm surge, (e) possible maximum precipitation, (f) whether located in flood zone (Table 16). An equal weightage of 15% has been given to parameter (a) and parameters (c) to (f), while 25% weightage has been given to parameter (b) for calculating the cyclone hazard index.

Table 16 **Cyclone Hazard Index Computation**

Parameters of Cyclones					Cyclone Hazard Index (Out of 10)
No. of cyclones	No. of severe cyclones	Maximum storm surge (meter)	Maximum wind speed (kmph)	Maximum precipitation (cm)	
4	1	1.23	126.76	200	9.37

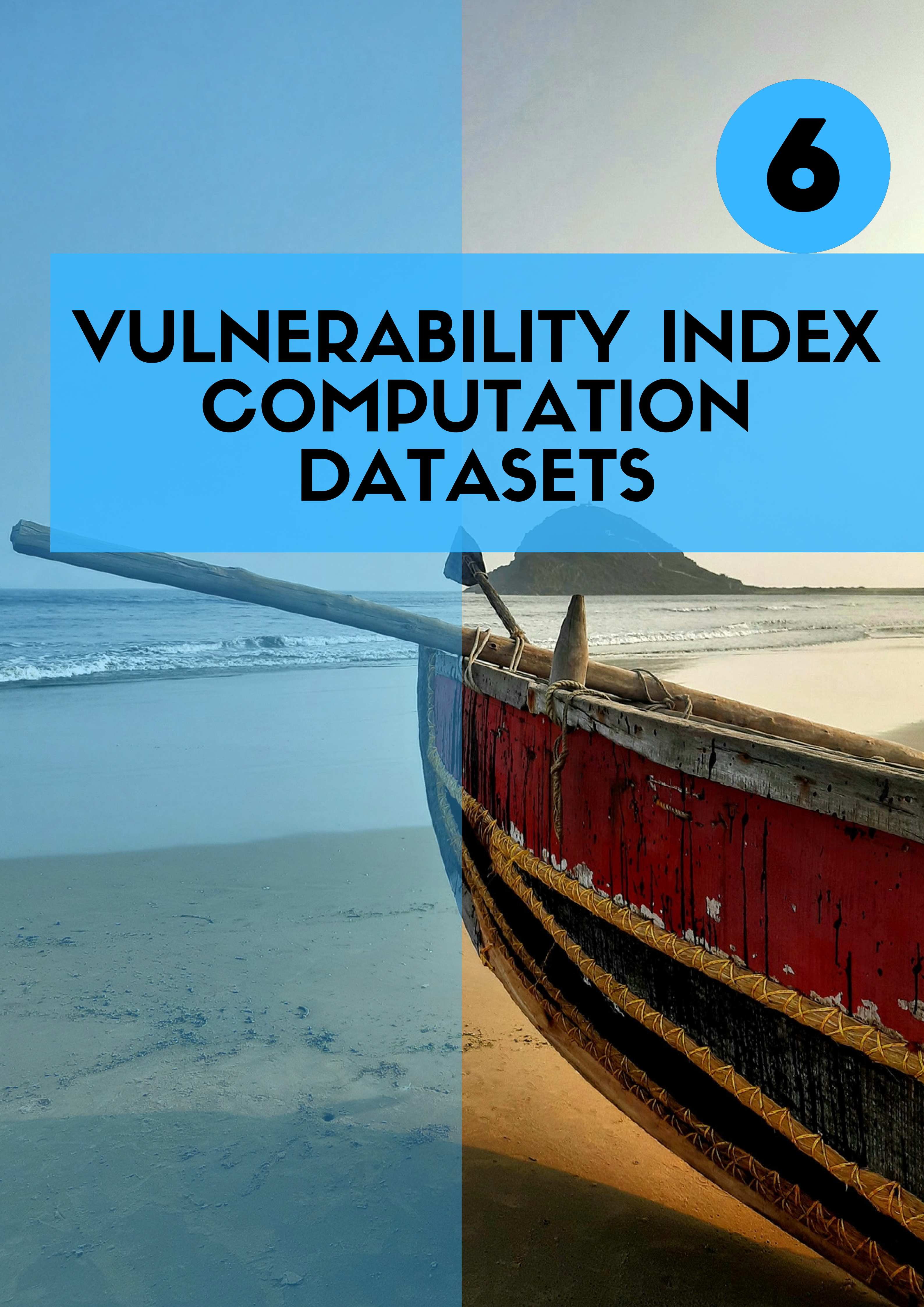
There were 4 cyclones with 1 severe cyclone observed in Visakhapatnam city between 2000 to 2020. The maximum wind speed and storm surge, due to cyclones observed with severe cyclones, were 126.76 kmph and 1.23 m respectively. Based on these parameters, the cyclone hazard index 9.37 computed for Visakhapatnam city, indicates that cyclones have a high hazard risk in the region.

Summary of Hazard Indicators

- As per the MHA-UNDP 2019 report, 13 hazard indicators relevant to Visakhapatnam city based on the geographical and topographical features of the city, have been considered.
- The methodology and weightage adopted to compute the hazard indices, are as per the MHA and the UNDP report of "Disaster Risks and Resilience in India: An Analytical Study 2019".
- The hazard indices have been computed for different hazard parameters at the city level, except for Forest Fire (for which the data was available at the district level) for Visakhapatnam city.
- Visakhapatnam city is more prone to Tsunamis, Coastal Erosion, Lightning, Cyclones, and Industrial Hazards in comparison to other hazard indicators.

6

VULNERABILITY INDEX COMPUTATION DATASETS



1. Buildings

a. Walls

The source of datasets of building walls is, 'Office of the Registrar General & Census Commissioner, India (ORGI)', used in this study (Table 17). Hazard zones are Zone V: Very High Damage Risk Zone, Zone IV: High Damage Risk Zone, Zone III: Moderate Damage Risk Zone, Zone II: Low Damage Risk Zone, and Zone I: No Risk Zone. Vulnerable buildings weights are VH= Very High (damage potential 100%); H= High (50%); M=Medium (25%); L=Low (10%); VL= Very Low (5%).

Table 17 **Vulnerability index of walls**

Grass, Thatch, Bamboo	Plastic Polythene	Mud Unburnt bricks	Wood	Stone not packed with mortar	Stone packed with mortar	GI, Metal Asbestos	Burnt Bricks	Concrete	Any other material	**Vulnerability Index of Walls (Out of 10)**
31,134	1,597	1,96,907	7,659	19,057	2,55,435	3,321	5,81,385	26,630	3,041	**7.32**

The vulnerability index of walls is about 7.32, computed based on the different building materials. It is observed that the building walls constructed with burnt bricks are more in number, compared to other building materials. Visakhapatnam is vulnerable to hazards like earthquake and urban flood, which damages the building walls. Therefore, resistant designs and specifications should be incorporated into the materials used for the construction of walls to tackle these disasters.

a. Roofs

The source of datasets of building walls is, 'Office of the Registrar General & Census Commissioner, India (ORGI)', used in this study (Table 18). Hazard zones are Zone V: Very High Damage Risk Zone, Zone IV: High Damage Risk Zone, Zone III: Moderate Damage Risk Zone, Zone II: Low Damage Risk Zone, and Zone I: No Risk Zone. Vulnerable buildings weights are VH= Very High (damage potential 100%); H= High (50%); M=Medium (25%); L=Low (10%); VL= Very Low (5%).

Table 18 **Vulnerability index of roofs**

Grass, Thatch, Bamboo	Plastic Polythene	Hand-made tiles	Machine-made tiles	Burnt Bricks	Stone Slates	GI, Metal Asbestos	Concrete	Any other material	**Vulnerability Index of Roofs (Out of 10)**
1,39,177	1,164	37,989	1,66,660	2,773	7,660	71,816	6,96,793	2,134	**6.23**

The vulnerability index of roofs is about 6.23, computed and based on the different building materials. It is observed that the building roofs constructed with concrete are more in number, compared to other building materials. Visakhapatnam city is vulnerable to hazards like Lightning, Tsunami, and Urban Flood, which impact the Building Roofs. Therefore, resistant designs and material specifications should be considered for constructing roofs to resist disasters.

2. Agriculture

The Crop Vulnerability Index has been worked out based on 2 parameters: cropped area and irrigated area (Table 19). District-wise data on the area under crops and irrigation has been collected from the Directorate of Economics and Statistics, Ministry of Agriculture, Cooperation and Farmers Welfare, GoI, through the Indiastatdistricts.com website. However, these 2 parameters have been included due to their associated impact on the urban population in the city. Considering the relative importance of crops and irrigation, 80% of weightage has been given to areas under crops and 20% to irrigated areas.

Table 19 **Crop Vulnerability Index**

Total area of district (hectare)	**Area Under Agriculture (hectare)**				**Flood Hazard Index (Out of 10)**
	Cropped Area		Irrigated Area		
	Area	%Area	Area	%Area	
11,16,100	34,350	3.08%	14,700	1.32%	**0.17**

The vulnerability index of the crop is 0.17, which is computed and based on the area of agriculture in the Visakhapatnam district. The cropped area is about 3.08% of the total area under agriculture, compared to the irrigated area. The crop vulnerability index shows that Visakhapatnam's agricultural area is less susceptible to disasters.

3. Poverty

For the poverty data, Census 2011 data on the homeless population has been adopted in this study at the district level (Table 20). The parameters BPL (Below Poverty Line) and Homeless Population have 2 sub-parameters for rural and urban areas. An equal weightage of 25% has been given to each of these 4 sub-parameters towards working out the poverty vulnerability index.

Table 20 **Poverty Vulnerability Index**

BPL Population (in Lakhs)			Homeless Population (in Lakhs)			Poverty Vulnerability Index (Out of 10)
Rural	Urban	Total	Rural	Urban	Total	
38.11	8.49	46.60	34,111	27,131	61,242	5.12

The poverty vulnerability index for Visakhapatnam district is 5.12, which means the people, who live under the poverty line in Visakhapatnam (BPL and homeless population in rural areas of the district) are more susceptible to disasters because they are more exposed to hazards and have lower coping systems against disasters.

4. Women

The gender Vulnerability Index is worked out based on 6 parameters: sex ratio (women per 1,000 men), illiteracy (%), WHH (Women Headed Household in %), MMR (Maternal Mortality Rate per 1,00,000 childbirths), CAW (Crime Against Women cases registered per 1,00,000 women) and dependent (%). District-wise data on all 6 parameters were compiled from Census 2011 (Table 21). Equal weightage has been given to each of these 6 parameters.

Table 21 **Gender Vulnerability Index**

Total Female Population	Sex Ratio	Illiteracy (%)	WHH (%)	MMR	CAW	Dependent (%)	Gender Vulnerability Index (Out of 10)
21,51,679	961	59%	17.28%	115	610	73.01%	5.42

The greater the vulnerability, the more severe the impact of hazards. The WHH is a parameter of 17.28%, an indicator of strength. The MMR per 1,00,000 childbirths in the district is about 115 and the average number of CAW is 610 cases. The dependent parameter shows 73.01%, showing non-working women in the district. The gender vulnerability index of Visakhapatnam is 5.29, which indicates women have a moderate vulnerability to disasters.

5. Children

The child vulnerability index has been worked out based on 4 parameters: age group, children not going to school, children working, and IMR (Infant Mortality Rate). District-wise data of all parameters have been compiled from Census 2011 (Table 22). Each parameter has been given an equal weightage of 25%. In contrast, 2 sub-parameters in children in the age group of 0 to 6 and 7 to 18, have been given differential weightage in a 60:40 ratio, as younger children are more vulnerable during disasters.

Table 22 **Child Vulnerability Index**

Age Group of Children (Years)						Not Going to School		Working Children		Child Vulnerability Index (Out of 10)
0-18 (Numbers)	0-6 (%)	0-6 (Numbers)	7-18 (%)	7-18 (Numbers)	IMR	(%)	Numbers	(%)	Numbers	
13,85,903	32.63	4,52,213	67.37	9,33,690	39	9.75	1,35,080	9.75	1,35,080	4.63

The index of child vulnerability has been computed, based on 3 parameters for the Visakhapatnam district: age group of children of different ages, children not attending school, and children working. The IMR in the city is 39, which is a childcare factor. The index of child vulnerability is 4.63, which indicates that children are quite susceptible to disasters. For example, the children die due to the building collapse, as they will usually be inside the building at the time of disaster and would be unaware of what to do to survive earthquakes.

6. Disability

The disability vulnerability index has been worked out based on 6 parameters: visual, hearing, speech, physical, mental, and other disabilities. The data on all these parameters have been compiled from Census 2011 (Table 23). Each parameter is given an equal weight.

Table 23 **Disability Vulnerability Index**

Total Population	Disabled		Visual		Hearing		Speech		Physical		Mental		Any other		Disability Vulnerability Index (Out of 10)
	Population	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	
17,30,000	63,130	1.47	13,082	20.72	12,078	19.13	8,166	12.94	8,525	13.50	4,054	6.42	14,002	22.18	7.23

Disasters may increase the number of disabled persons and worsen the situations of those who are already impaired. The disability vulnerable index of Visakhapatnam city is 7.23, computed based on the population with different aspects of disability. The share of the population with a disability is about 1.47% of the city's total population. Among various disabilities, other disabilities are the highest at approximately 22.18%, which means in Visakhapatnam disabled population is more susceptible to disasters.

7. Aged

The elderly vulnerability index has been worked out based on 3 parameters: the population in the 60+ age group, the population in the 80+ age group, and the dependency ratio (ratio of population in the 60+ age group over the working population in the 19-59 age group). City-wise data on all 3 parameters have been compiled from Census 2011 (Table 24). Each parameter has been given an equal weightage of 33.3%.

Table 24 **Elderly Vulnerability Index**

Total Population	60-90 Age Group		80+ Age Group		Dependency Ratio	Elderly Vulnerability Index (Out of 10)
	Number	%	Number	%		
17,30,000	2,83,748	6.61%	18,025	0.42%	22.22%	5.34

In disasters, aged people suffer disproportionately. The elderly vulnerability index of Visakhapatnam city is 5.34, computed using different age groups and dependency ratios. It is found that the age group of 60-79 is more susceptible to disasters, as it is 6.19% higher compared to the 80+ age group. The dependency ratio is about 22.22% in Visakhapatnam city, which means the ratio of the population in the 60+ age group, over the working population in the 19-59 age group.

8. Livestock

Livestock data has been compiled from Livestock Census 2012 (Table 25). The livestock vulnerability index has been worked out based on 2 parameters, (a) the number of bovine animals and (b) other animals, with an 80:20 weightage ratio between the 2 parameters.

Table 25 **Livestock Vulnerability Index**

Livestock (Numbers)			Industrial Hazard Index (Out of 10)
Bovine Animals	Other Animals	Total Animals	
811212	585798	1397010	5.40

The vulnerability index of livestock is 5.40, which is computed based on the number of different animals in Visakhapatnam. The number of bovine animals is more in total livestock compared to other animals. The index of livestock vulnerability shows that the number of livestock in Visakhapatnam, is moderately susceptible to disasters.

9. Industries

City-wise data on industries has been collected from multiple sources on 3 parameters: the number of Micro, Small, and Medium Enterprises (MSMEs), industrial clusters, and Special Economic Zones (SEZ). Data on MSMEs have been collected from the database of the Development Commissioner (MSME), while data on Industrial Clusters and SEZ in cities have been collected from several sources (Table 26). The industrial vulnerability index has been worked out, based on differential weights of 40% on MSME, 40% on Industrial Clusters, and 20% on SEZ.

Table 26 **Industries Vulnerability Index**

Industries (Numbers)			Industries Vulnerability Index (Out of 10)
MSME Industries (Numbers)	Industrial Clusters (Numbers)	Special Economic Zones (SEZ) (Numbers)	
656	2	1	3.27

The industrial vulnerability index of Visakhapatnam is 3.27, which shows that the industries are the highest vulnerable indicator in the city. It is observed that there are 656 MSME industries, 2 industrial clusters, and 1 SEZ in the city. Therefore, there is a need to formulate guidelines, norms, and regulations to ensure safety in hazardous industries and to reduce the probability of disaster events.

10. Physical Infrastructure

Data on 6 types of physical infrastructure- roadways, railways, airports, and seaports have been collected from multiple sources. Each city's total length of roadways and railways has been compiled using Open Street Map (OSM) data in QGIS software. The Airport Authority of India has collected data on the city's airports. In contrast, data on seaports has been compiled from Basic Port Statistics (Table 27). Equal weights have been given to each of the parameters, with sub-parameters within the parameters, in calculating the Physical Vulnerability Index.

Table 27 **Physical Infrastructure Vulnerability**

Road Length (km)	Railway Length (km)	Sea Port (Numbers)		Airport (Numbers)		Physical Infrastructure Vulnerability Index (Out of 10)
		Major	Minor	Int. + Dom.	Domestic	
5,393	90	1	2	1	0	7.98

The index of the physical infrastructure of Visakhapatnam is 7.98, computed using the elements of physical infrastructures, such as roads and bridges, railway lines, seaports, and airports. Road length is more than railway length, indicating that roadways are more vulnerable and typically damaged during disasters such as floods in Visakhapatnam. The factors. such as quality of construction, standards of maintenance, age of the structure, etc., make the physical infrastructure vulnerable to hazards.

11. Social Infrastructure

Social infrastructure data has been limited to health and educational institutions as these are considered critical lifeline infrastructures in any significant disaster. Data on the number of health and educational institutions have been compiled from the database of Census 2011 at the district level (Table 28). The social vulnerability index has been worked out with equal weightage on these 2 parameters.

Table 28 **Social Infrastructure Vulnerability Index**

Number of Educational Institutions							Number of Health Institutions			Social Infrastructure Vulnerability Index (Out of 10)
School Education		Higher Education				Polytechnic (Number)	Primary Healthcare			
Primary	Secondary	College	University	Engineering	Medical		Dispensaries	FW Centres	Hospitals/ Med. Schools	
138	213	30	1	13	2	2	3	3	18	1.42

Social infrastructure includes structures and other related physical facilities that provide community services in the Visakhapatnam district (lack of data at the city level). The index of the social infrastructure of Visakhapatnam is 1.42, computed using the number of educational and health institutions. These social infrastructure facilities were certainly damaged during Visakhapatnam's severe Cyclone, Tsunami, and Urban Floods. The factors like structural design, materials quality, maintenance standards, design age, etc., make social infrastructures vulnerable to hazards.

12. Deforestation

Changes in the district's forest cover (lack of data at the city level) have been captured on 2 parameters: dense forests and open forests from 2000 to 2015 (Table 29). Equal weightage has been given to both parameters while calculating the index.

Table 29 **Forest Cover Depletion Index**

Total Area of District (km²)	Changes in Forest Cover (km²)			Forest Cover Depletion Index (Out of 10)
	Dense	Open	Total	
11,161	-2.16	34.32	32.16	9.30

The depletion index of forest cover is 9.30, which is computed using the total area and change in forest cover of the Visakhapatnam district. The negative value shows the decrease in forest cover change and the positive value shows the increase in forest cover change. The depletion is an indication for quantifying the environmental vulnerability of forests in the Visakhapatnam district.

13. Water Stress

The extent of water stress in the district (lack of data at the city level) is captured through 3 parameters: surface, terrestrial and sub-surface water from the website of the Central Ground Water Board (CGWB), Ministry of Jal Shakti (Table 30). Equal weightage has been given to each parameter for calculating the water stress index. Sub-surface water has 4 sub-parameters: over-exploited, critical, sub-critical, and safe. This is distributed as follows: 50% is given to over-exploited, 30% to critical, and 20% to sub-critical components.

Table 30 **Water Stress Index**

Surface Water (km²)			Terrestrial	Subsurface Water (Number)				Water Stress Index (Out of 10)
Total Area	Non-irrigated Area	%	Moisture Index (MI)	Over Exploited	Critical	Subcritical	Safe	
11,16,100	11,01,400	0.99	-0.0743	0	0	1	42	2.31

The water stress index is 2.31, computed using Visakhapatnam's terrestrial, surface, and subsurface water. The stress on terrestrial and surface water sources has been captured in Moisture Index (MI) and areas of non-irrigated areas, as used in estimating the indices of drought hazard and agricultural vulnerability.

Summary of Vulnerability Indicators

- As per the MHA-UNDP 2019 report, 13 vulnerability indicators, relevant to Visakhapatnam city, based on the geographical and topographical features of the city have been considered.
- The methodology and weightage, adopted to compute the vulnerability indices, are as per the MHA and the UNDP report "Disaster Risks and Resilience in India: An Analytical Study 2019".
- The vulnerability indices have been computed for different vulnerability parameters at the city level except for Buildings, Agriculture, Livestock, Social infrastructure, Deforestation, Women, Children, Poverty, and Water stress (for which the data was available at the district level) for Visakhapatnam city.
- Visakhapatnam city is more vulnerable to disasters in terms of Deforestation, Physical infrastructure, and Disabled people as compared to other vulnerability indicators.

The scale of classification based on index values: The classification is based on a scale of 0 to 10 as per Table 31.

Table 31 **Scale of Classification based on index values**

Class	Range
Very High	Equal to 10
High	7 - 10
Moderate	3 - 7
Low	0 - 3
Unlikely	Equal to 0

Classification of computed hazard indicators for Visakhapatnam city based on the scale: The classes of the different hazard indicators based on the index values are presented in Table 32.

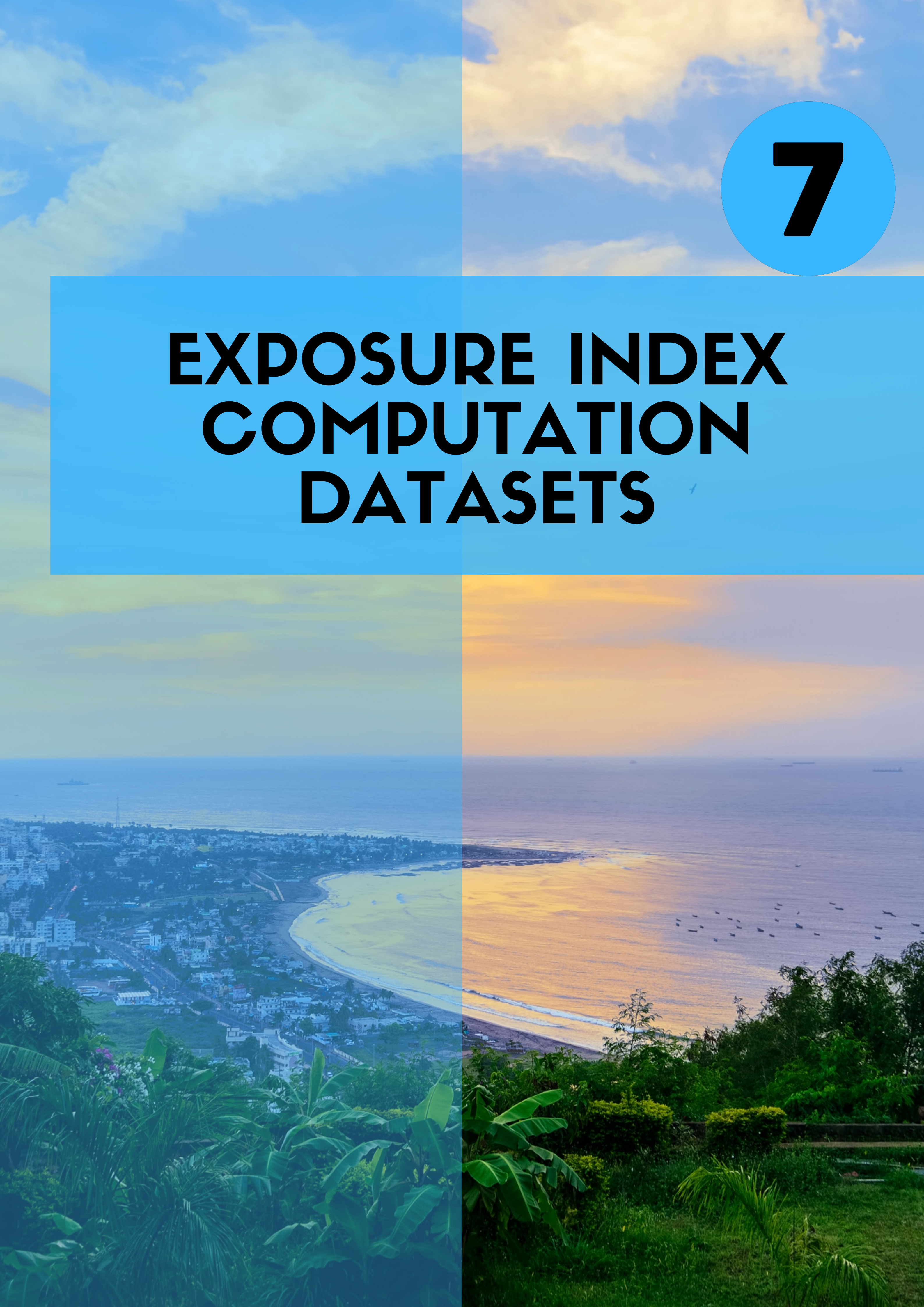
Table 32 **Classification of hazards based on the index**

HAZARDS		
Indicator	**Index**	**Class**
Earthquake	2.00	Low
Landslide	0.00	Unlikely
Drought	5.70	Modeatre
Urban Flood	10	Very High
Heat Wave	8.01	High
Cold Wave	0.00	Unlikely
Fire	5.38	Modeatre
Forest Fire	2.59	Low
Industrial Hazard	9.57	High
Lightning	10	Very High
Tsunami	10	Very High
Coastal Erosion	10	Very High
Cyclone	9.37	High

Classification of computed vulnerability indicators for Visakhapatnam city based on the scale: The classes of the different vulnerable indicators based on the index values are presented in Table 33.

Table 33 **Classification of Vulnerability based on the index**

VULNERABILITIES		
Indicator	**Weight%**	**Class**
Buildings (Walls & Roof)	**6.77**	Moderate
Agriculture	**0.17**	Low
Poverty	**5.12**	Moderate
Women	**5.29**	Moderate
Children	**4.63**	Moderate
Disability	**7.23**	High
Aged	**5.34**	Moderate
Livestock	**5.40**	Moderate
Industries	**3.27**	Moderate
Physical Infrastructure	**7.98**	High
Social Infrastructure	**1.42**	Low
Deforestation	**9.30**	High
Water Stress	**2.31**	Low



7

EXPOSURE INDEX COMPUTATION DATASETS

Data on exposures have been collected on 2 parameters in each city: exposure of population and exposure of economy, as reflected in district GDP. While data on exposure of the population is compiled from Census 2011, exposure of city GDP is derived from the newspaper article (The Times of India dated Mar 24, 2019). There have been 2 parameters considered for calculating the Exposure Index. These are (a) population density (=Population / Area in km^2), and (b) per capita GDP (=GDP (in Cr. Rs.) / Population) of a city (Table 34). Both parameters have been normalized by dividing with the maximum value and multiplying by 10 to put them on a scale of 0 to 10. Then, a simple average of these parameters was taken since equal weights were given on both.

Table 34 **Average Exposure Index**

Area (km^2)	**Exposure Parameters**				**Average Exposure Index (Out of 10)**
	Population		City GDP		
	Total	Density	Total (Rs. Cr.)	Per Capita (Rs.)	
515.49	1,730,000	3,356	43,500,000,000	25,145	**3.50**

The average exposure index is 3.50 for Visakhapatnam city, which has been computed by estimating the district's population density and per capita income and assigning equal weightage to both indicators on a scale of 10. The index shows that the population of Visakhapatnam is moderately exposed to disasters.

8

RESILIENCE SCORECARD

The Disaster Resilience Score (DRS) is based on the information collected from the cities on 7x10 indicators, through a questionnaire comprising 172 questions (as per Figure 6). The Resilience scorecard is computed discretely for Visakhapatnam city, based on the 7 parameters on the scale of 100: Risk Assessment, Risk Prevention and Mitigation, Risk Governance, Disaster Preparedness, Disaster Response, Disaster Relief & Rehabilitation, and Disaster Reconstruction, as shown in Table 35 and Figure 4.

Table 35 **Weights of Indicators on Disaster Resilience** (MHA-UNDP Report, 2019)

S.No.	Aggregate Indicators	Weights	Values for Visakhapatnam City
1	Risk Assessment	10%	**51**
2	Risk Prevention and Mitigation	20%	**61**
3	Risk Governance	20%	**77**
4	Disaster Preparedness	20%	**74**
5	Disaster Response	10%	**86**
6	Disaster Relief and Rehabilitation	15%	**74**
7	Disaster Reconstruction	5%	**66**
	Disaster Resilience Index	**70.80 on a scale of 100** (Through weighted aggregate of seven parameters)	

Based on the following values and their associated weightage, as per the MHA-UNDP Report 2019, the DRS value of 70.80 has been obtained for Visakhapatnam city on a scale of 100. Therefore, although the risk associated with Visakhapatnam city is comparatively highest with a maximum number of hazards occurring, the city is maximum resilient based on its resilience score among all the cities. Thus, city administration should enhance efforts for making the city highly resilient to natural and man-made disasters.

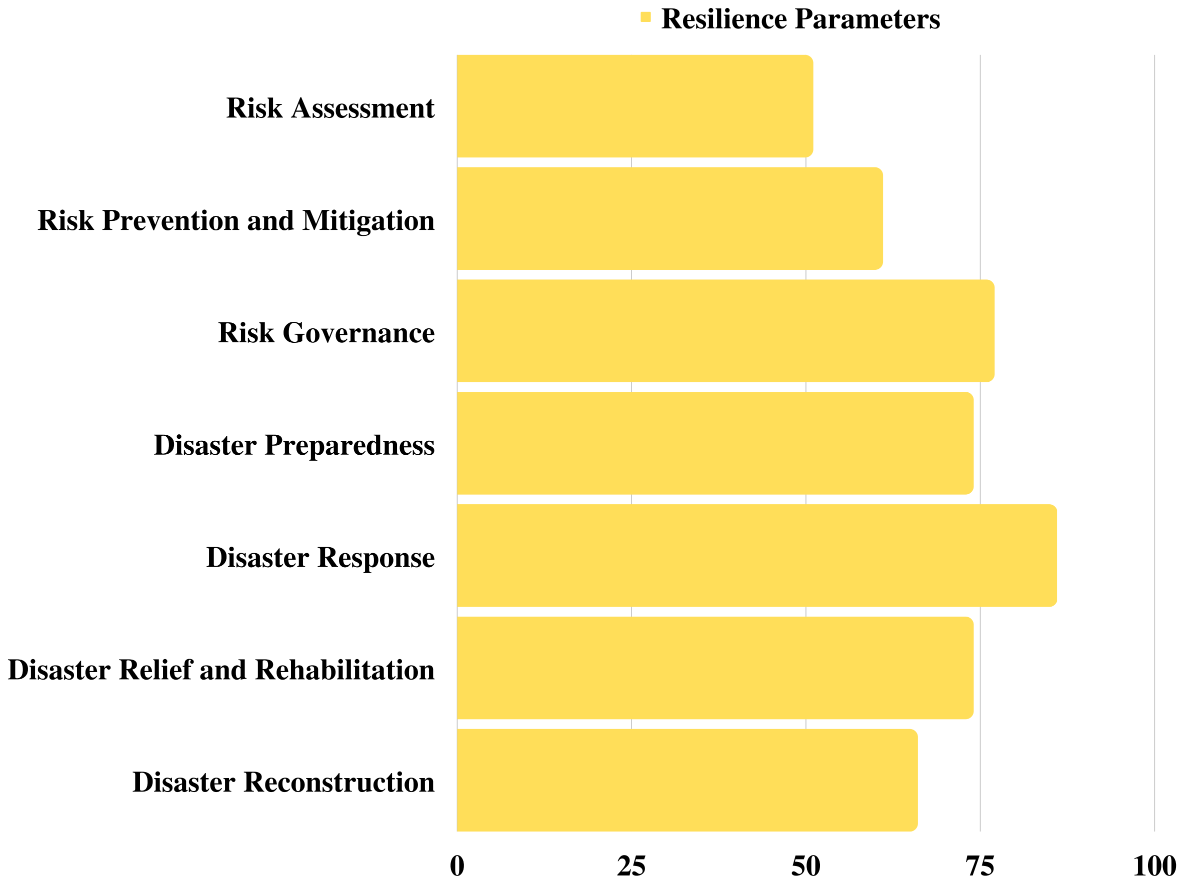


Figure 6
Disaster Resilience Scorecard for Visakhapatnam City

NDRF rescuing public from Vishakhapatnam gas leak affected areas (Source: The News Minute and Zee news)

9

CONCLUSION

The study showed that Visakhapatnam city is more prone to Floods, Coastal Erosion, Tsunamis, Lightning, Industrial hazards, and Cyclones significantly, followed by Heatwaves, Fire Accidents, Drought, and Forest fires. Similarly, Visakhapatnam city is more vulnerable to disasters, in terms of Deforestation, Physical infrastructure, and Disabled people, followed by unsafe buildings, Livestock, Aged People, Poverty, Women, and Children. The study also revealed that the population of Visakhapatnam is highly exposed to natural disasters, such as Floods, Lightning, Cyclone, Coastal Erosion, Tsunamis, and Industrial Hazards that lead to economic loss in the city.

The resilience score of the city is 70.80 on a scale of 100, making the city moderately resilient to the hazards occurring in the region, due to the municipal, government, and regional population combined efforts. Visakhapatnam city performs best in terms of Disaster Response and Risk Governance. The city is in the 1st position out of all 4 cities in terms of 5 out of 7 indicators of the disaster resilience score. The city performs relatively less for 2 indicators i.e., Risk assessment and Disaster Reconstruction. It is noteworthy to mention that Visakhapatnam city is not susceptible to Avalanche events due to its geographical and topographical features.

Visakhapatnam city has the highest risk occurrence for Coastal erosion, Tsunamis, Floods, Lightning, and Industrial Hazards among all the cities. The city has the least population density and GDP among all the cities, with 3356 persons per sq. km and Rs. 25,145 respectively. The city has been observing maximum hazards among all the cities, except avalanches, thus risks associated with all the hazards make the city highly vulnerable to disabled, unsafe buildings, aged people, people below the poverty line, women, and children population. Deforestation, physical infrastructure, and unsafe buildings are highly vulnerable to hazards in the city. Visakhapatnam city has a maximum resilient score comparatively with relatively certain low scores in Risk assessment and Disaster Reconstruction. Therefore, city administration should enhance efforts to decrease the risk associated with vulnerable populations, and infrastructure and provide improvement in policy-making significantly, for pre and post-disaster management plans for making city risk resilient to multi-hazard disasters.

10

COMPARATIVE DISASTER RISK & RESILIENCE ASSESSMENT

The present study provides Multi-hazard Disaster Risk and Resilience at the city level with a comparative analysis of Guwahati, Jaipur, Srinagar, and Visakhapatnam cities. The risk index profiling of these cities has been computed comparatively for different hazards, vulnerabilities, and exposure parameters. In the statistical assessment for calculating the Disaster Risk Index (DRI), all the hazard indicators were computed comparatively for all the cities.

All the vulnerability and exposure parameters except Buildings, Agriculture, Livestock, Social infrastructure, Deforestation, Women, Children, Poverty, and Water stress have been computed comparatively for the cities. Thus, based on this assessment, Visakhapatnam is at higher risk for Coastal erosion, Tsunamis, and Floods, while it is highly vulnerable to deforestation, physical infrastructure, and unsafe buildings based on the comparison with other cities. The resilience score of Visakhapatnam city is 70.8 on a scale of 100, making the city moderately resilient to the different hazards and risks, present in the region. For all 4 cities, hazard-specific risk indices for each of the 14 hazards have been aggregated with suitable weightage to work out the Disaster Risk Index, as shown in (Fig. 4-7 and 5-8).

The Disaster Resilience Score (DRS) is computed exclusively for each city, based on the assessment of the responses, received by the city administration for the questionnaire regarding disaster management at the city level. The DRS for all the cities has been shown in Figure 5 and responses for questionnaires are mentioned in Annexure 3. This study shows that the level of resilience to disasters in cities is comparatively low and requires considerable improvement. Most of the existing level of resilience has been developed during the past decade and a half, and it may be expected that the impacts of these initiatives will be felt in the years ahead.

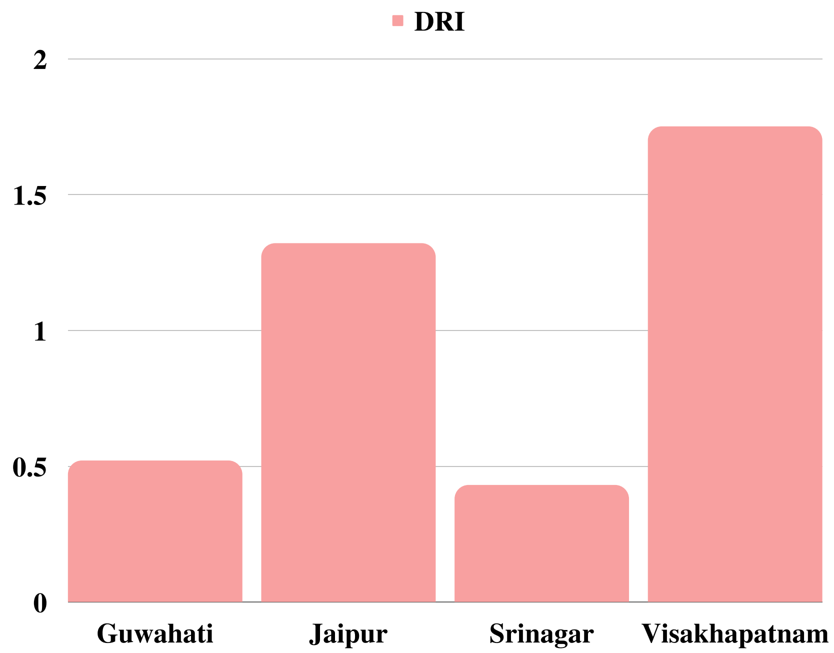


Figure 7
Composite Disaster Risk Index

Based on DRI, the order of cities at risk is
Visakhapatnam > Jaipur > Guwahati > Srinagar

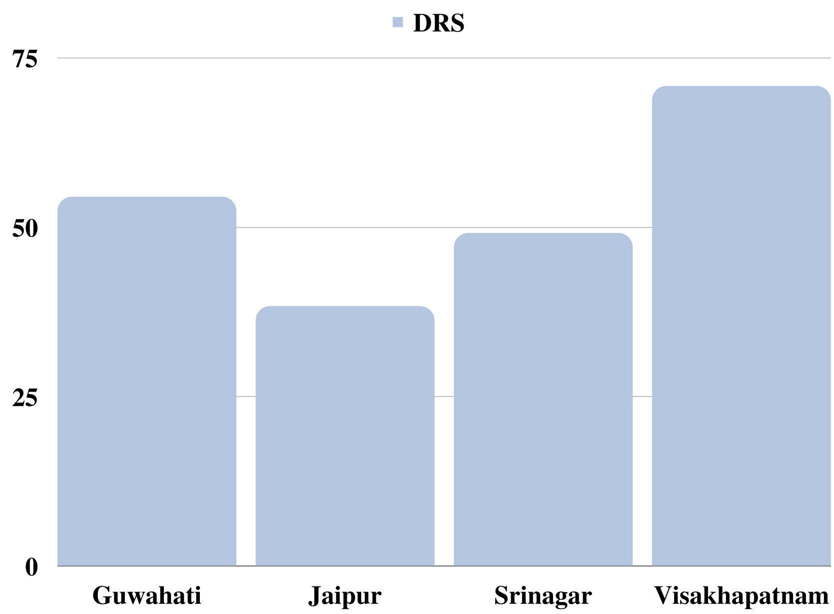
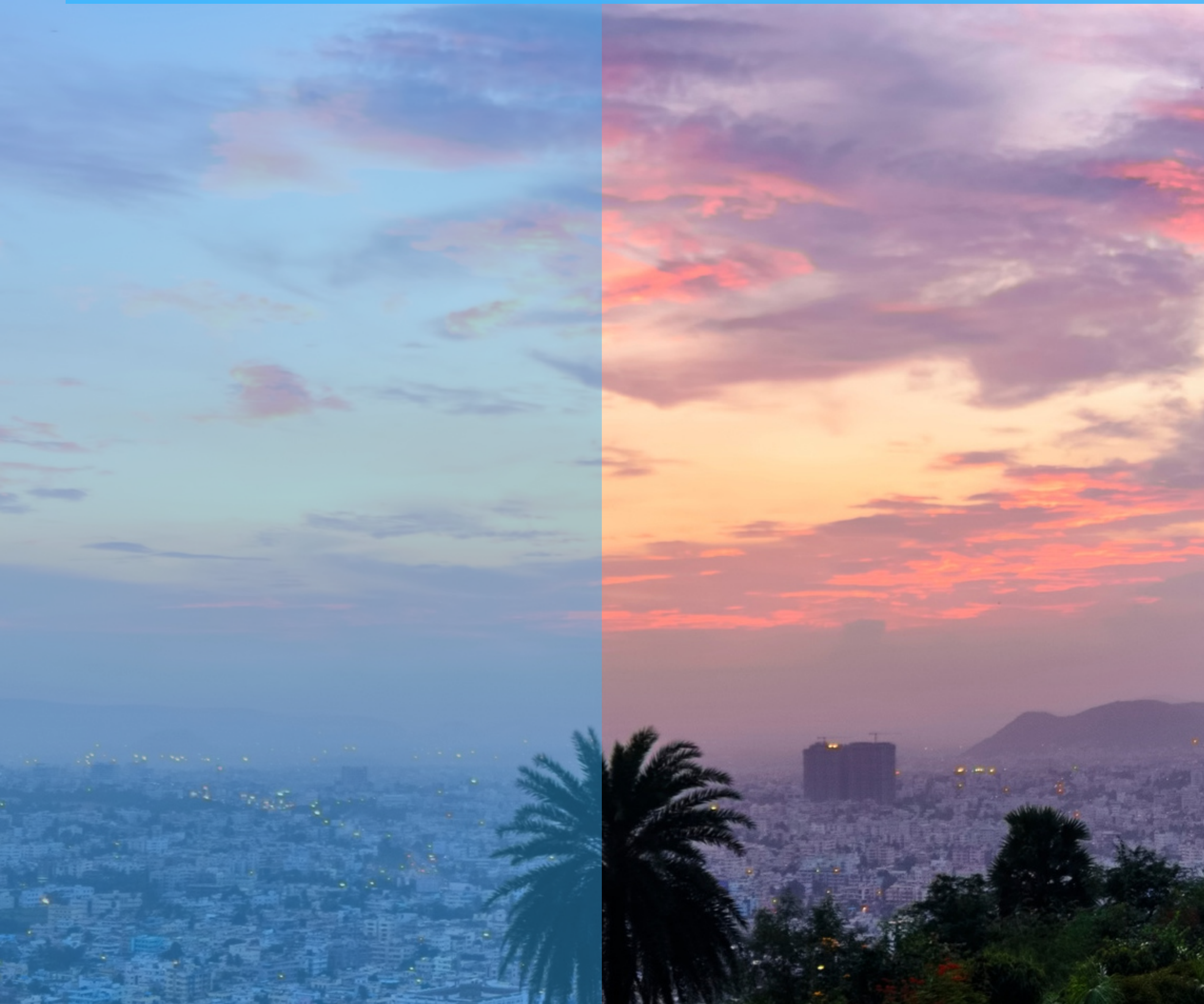


Figure 8
Disaster Resilience Index

Based on DRS, the order of cities at resilience is
Visakhapatnam > Guwahati > Srinagar > Jaipur

11

LIMITATIONS AND FUTURE SCOPE



The limitations are as follows:

- The city-level datasets for certain hazard, vulnerability, and exposure indicators are unavailable. Thus, district-level datasets are considered for 1 hazard indicator (Forest Fire) and 9 vulnerability indicators (Buildings, Agriculture, Livestock, Social infrastructure, Poverty, Women, Children, Deforestation, and Water stress) in the present studies.

- Specific hazard datasets like Landslide, Avalanche, and Coastal erosion were obtained from the national susceptible zone maps for respective hazard data in the absence of data at the city levels.

- The risk analysis of the vulnerability of buildings, is limited to significant materials, used for building walls and roofs. In contrast, other parameters such as foundation designs, structural designs, and quality & maintenance of structures have not been considered, as it is challenging to get datasets at a city scale.

The future scope can include:

- The study can be further extended at the town, municipality, and village level to improve the mitigation measures and resiliency against potential risks at a micro-scale.

- This study uses 2 scorecards (Disaster Risk and Disaster Resilience Scorecard) as per the MHA-UNDP 2019 for 4 Indian cities. However, in the future, this study can be expanded to include all Indian cities. Disaster risk and resilience scorecards at the city level will undoubtedly play an essential role in enhancing disaster resilience.

- The study can be further extended on impact assessment and representation of the impacts of disasters, by developing dashboards, interactive maps, etc., to improve community awareness and preparedness for emergencies.

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ANNEXURE 1

Sources of Hazard, Vulnerability and Exposure Datasets

Table 36: Hazard datasets and their sources

S.No.	Parameter	Value	Sources
1	Area (Sq. Km)	515.50	https://iihs.co.in/
2	Earthquake Zone (Area)	II (515.50)	https://data.gov.in/resources/list-and-zone-factors-important-cities-towns-high-risk-earthquake-zone-and-moderate-risk; https://bmtpc.org/DataFiles/CMS/file/VAI2019/MAP/eqmap/EQ_JPG/EQ_INDIA.jpg
3	Landslide Zone (Area)	I (515.50)	https://bmtpc.org/topics.aspx?mid=56&Mid1=186
4	Heat Wave	Average Heat Index: 0.63; No. of HWs: 3; Length of Longest HW: 15; No. of Days with Heat Index > 54: 4	https://zenodo.org/record/3987736#.YfJvnP5BzIV
5	Cold Wave	0	Computed using Minimum temperature (Minimum temperature is derived from Indian Meteorological Department)
6	Forest Fire (District)	11161, 11.46, 2009.95, 1458.92, 3479.05 (Total area, very dense forest area, Dense Forest area, Open Forest area, Total Forest area in sq.km)	https://www.fsi.nic.in/forest-report-2019
7	Lightning (Average)	0.80	https://ncrb.gov.in/en/accidental-deaths-suicides-in-india?field_adsi_year_value%5Bvalue%5D%5Byear%5D=2000&field_accidental_deaths_suicides_value=1&items_per_page=10
8	Industrial Hazards	18, 148, 55.40 (MAH industries, MPI industries, CEPI index)	http://www.hrdp-idrm.in/e5783/e26901/ (MAH Units) https://cpcb.nic.in/displaypdf.php?id=Q1BBL05ld0l0ZW1fMTUyX0ZpbmFsLUJvb2tfMi5wZGY= (Refer page 26-28 for CEPI Score 2009)
9	Fire	47;0; 50 (No. of cases; Injured; Died)	https://ncrb.gov.in/en/accidental-deaths-suicides-in-india?field_adsi_year_value%5Bvalue%5D%5Byear%5D=2000&field_accidental_deaths_suicides_value=1&items_per_page=10
10	Drought	0,6, 26, -0.07, 29 (Drought-prone area, number of drought years, moisture index, frequencies of SSI, and SPI)	https://www.indiastatdistricts.com/

Table 36: Hazard datasets and their sources

S.No.	Parameter	Value	Sources
11	Tsunami	Population near 0.5 Km shoreline (0.1 million), Height of Tsunami Wave (1.78m)	hhttps://vedas.sac.gov.in/vedas/downloads/atlas/Seashore/Vol-4-Full.pdf
12	Coastal Erosion	Coastline Length, (53.94) Coastal Erosion Length and Area (5.12, 2.50)	https://vedas.sac.gov.in/vedas/downloads/atlas/Seashore/Vol-4-Full.pdf , https://www.nccr.gov.in/sites/default/files/schangenew.pdf
13	Cyclone	No. of Cyclones, Severe Cyclones, (4,1) Maximum Storm Surge, Wind Speed, Precipitation (1.23m, 126.76Kmph, 200mm)	https://rsmcnewdelhi.imd.gov.in/uploads/report/61/61_245057_Cyclone%20Warning%20SOP%20Booklet%20final.pdf , https://ndma.gov.in/sites/default/files/PDF/Reports/Hudhud-lessons.pdf ; https://mausam.imd.gov.in/visakhapatnam/aboutus.php

Table 37: Vulnerability datasets and their sources

S.No.	Vulnerability	Data Parameter	Values	Sources
1	Agriculture	Total area hectares, Cropped area, Irrigated area	1116100, 34350, 14700	https://www.indiastatdistricts.com/
2	Livestock	Total Animals, Bovine Animals, Other Animals	1397010, 811212, 585798	https://dahd.nic.in/documents/statistics/livestock-census
3	Deforestation	Change in Dense Forest cover, Change in Open Forest cover (2001-2019) (in %)	-2.16, 34.32	https://www.fsi.nic.in/forest-report-2019
4	Women	Sex Ratio, Illiteracy, WHH, MMR, CAW, Dependent	961, 59%, 17.28%, 115, 610, 73.01%	https://www.core.ap.gov.in/cmdashboard/Download/Publications/Gender%20Statistics%20%202018.pdf (For WHH- Vizag district- refer page no: 188), https://cfw.ap.nic.in/pdf/Maternal%20Mortality%20Rate.pdf (FOR MMR), https://censusindia.gov.in/census.website/data/census-tables# (Sex Ratio and Illiteracy) https://ncrb.gov.in/sites/default/files/crime_in_india_table_additional_table_chapter_reports/Table%203B.1_4.pdf (CAW)
5	Children	Children population (0-6 years), (7-18 years), IMR, Non-school going children, Working children	452213, 933690, 39, 135080, 135080	https://censusindia.gov.in/census.website/data/data-visualizations/Age-Gender-Ratio_Pyramid-Chart (Common source for 0-6 and 7-18), https://censusindia.gov.in/census.website/data/census-tables# https://cfw.ap.nic.in/pdf/Infant%20Mortality%20Rate.pdf (IMR) https://censusindia.gov.in/nada/index.php/catalog/16979 (number of children attending school)
6	Aged	Age group 60+, Age group 80+, Dependency Ratio	283748, 18025, 22.22%	https://censusindia.gov.in/nada/index.php/catalog/2322/study-description
7	Disabled	Visual, Hearing, Speech, Physical, Mental Disabled and Any other Disability	13082, 12078, 8166, 8525, 4054, 14002	https://censusindia.gov.in/nada/index.php/catalog/42520

S.No.	Vulnerability	Data Parameter	Values	Sources
8	Industries	Micro, Small and Medium Enterprises (MSME), Industrial clusters, Special Economic Zones (SEZ)	656, 2, 1	http://dcmsme.gov.in/old/dips/state_wise_dips/APState%20Profile2014-15.pdf (Refer page no: 47 for MSME for Vizag city); https://www.apiic.in/industrial-clusters/ (For Industrial cluster- Vizag city); https://www.apiic.in/sezs-in-andhra-pradesh/ (For SEZ- Vizag city)
9	Depletion of mangroves	Change of mangrove cover during 2001-2020, Dense mangrove, Open mangrove	0	https://fsi.nic.in/isfr19/vol1/chapter3.pdf
10	Poverty	Rural, Urban BPL Population, Rural and Urban Homeless population (Lakhs)	38.11, 8.49, 34111, 27131	https://censusindia.gov.in/nada/index.php/catalog/7246
11	Water stress	Surface Water (%), Moisture Index, Sub-Surface Water (Over-Exploited, Critical, Sub-critical, Safe)	0.99%, -0.0743, (0,0,1,42)	http://cgwb.gov.in/gwresource.html

12. Physical Infrastructure

Length of roadways	Length of railways	No. of airports (Int+Domestic)	No. of airports (Domestic)	No. of seaports (Major)	No. of seaports (Minor)
5393	90	1	0	1	2

Source:https://www.indiastatdistricts.com/, https://gmrvisakhapatnamairport.com/ (AirPort-Visakhapatnam), Minor ports links are as follows:1. https://ports.ap.gov.in/#/gangavaram-port, 2. https://ports.ap.gov.in/#/nakkapalli-port, 3. https://ports.ap.gov.in/#/bheemunipatnam-port

13. Social Infrastructure

Primary School	Secondary School	College	University	Engineering	Medical	Polytechnique	Dispensaries/ Health Centers	FW Centers	Hospital/Medical Schools
138	213	30	1	13	2	2	3	3	18

Source: https://censusindia.gov.in/census.website/data/handbooks

14 a. Material of Roof (% of buildings as per prominent materials used for roofs)

Grass/ Thatch/ Bamboo / Wood/Mud etc.	Plastic/ Polythene	Handmade Tiles	Machine made Tiles	Burnt Brick	Stone/ Slate	G.I./Metal/ Asbestos sheets	Concrete	Any other material
3.9	0.1	1.2	2.2	0.3	1.1	7.7	83.3	0.2

Source: https://censusindia.gov.in/nada/index.php/catalog/9408

14 b. Material of Wall (% of buildings as per prominent materials used for walls)

Grass/ Thatch/ Bamboo etc.	Plastic/ Polythene	Mud/ Unburnt brick	Wood	Burnt Brick	Stone not packed with mortar	Stone packed with mortar	G.I./Metal/ Asbestos sheets	Concrete	Any other material
0.6	0.1	4	0.2	56.3	2.2	30.9	0.3	5.3	0.2

Source: https://censusindia.gov.in/nada/index.php/catalog/9408

Table 38: Exposure datasets and their sources

12. Physical Infrastructure

Population	Area in sq.km	Population Density	GDP in Cr.Rs.	Per Capita GDP	Remarks
17,30,000	515.50	3356	43,50,00,00,00 0	25,145	https://www.indiatoday.in/information/story/top-10-richest-cities-in-india-in-2020-1726702-2020-09-29 Population density = Population / Area in sq.km

ANNEXURE 2

Statistical Note on Methodology

HAZARD INDEX COMPUTATION

1. Earthquake

Earthquake Hazard Index has been calculated as the weighted average of the prescribed values of the seismic hazard zones, where the weights are the percentage of the area, falling within a particular zone. Here X2= 2, X3= 4, X4= 6, X5= 10 is the intensity of the ith hazard zone, wi's are the percentage area of the city in the ith hazard zone, i = 2, 3, 4, and 5 in equation (i).

$$I = \frac{\sum_{i=2}^{5} w_i \times X_i}{\sum w_i} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (i)$$

2. Landslide

Landslide Hazard Index has been calculated as the weighted average of the prescribed values of the landslide hazard zones, where the weightages are the percentage of the area falling within a particular zone. Here X1= 0, X2= 4, X3= 8, X4= 10 is the intensity of the ith hazard zone, wi's are the percentage of the area of the city in the ith hazard zone in equation (i).

$$I = \frac{\sum_{i=1}^{4} w_i \times X_i}{\sum w_i} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (i)$$

3. Drought

The drought Hazard Index has been calculated as the average of the normalized scores of the parameters. For X1 (drought-prone area) and X2 (drought years), moisture index, X3 frequency of SSI and X4 frequency of SPI, have been normalized by dividing by the maximum value and multiplying by 10 to put on a scale of 0 to 10 using equation (i) (MHA-UNDP Report, 2019). Then, an average of all these parameters was taken, since equal weightage had been pre-specified.

$$X_i^* = 10 \times (X_i) / (\max(X_i)) \dots\dots\dots\dots\dots\dots \quad (i)$$

$$I = \text{mean}\,(X_i^*)$$

4. Urban Flood

The urban flood index has been calculated, as the weighted average of the 3 prescribed indicators, which are the values of the percentage of flood-prone area, according to the mapping by BMTPC (2006) (BMTPC, 2011), using equation (i) and standardized by equation (ii), where w denotes the percentage of flood area in the risk zone and Y denotes the pre-specified score of the zones, as well as total number of flood-prone cities in the district, with a population greater than 1 Million and 10 Million, standardized by equation (iii), where the equal weightage had been pre-specified to every parameter.

$$X_i^* = (X_i)/10 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(i)}$$

$$X_2^* = \frac{\sum_{i=1}^{5} w_i \times Y_i}{\sum w_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(ii)}$$

$$X_3^* = 10 \times (X_3)/ (\max (X_3)) \ldots\ldots\ldots\ldots \textit{(iii)}$$

$$I = \frac{\sum_{i=1}^{3} w_i \times X_i^*}{\sum w_i}$$

5. Heat Wave

The first 3 parameters (annual average of the number of hot days, number of heat waves and length of longest heat wave), have been normalized by dividing by the maximum value and multiplying by 10, to put on a scale of 0 to 10 to equation (i). The average heat index, during the heat waves, has been normalized, according to equation (ii). Then, a simple average of all these parameters had been taken, to get the index, since equal weightage had been pre-specified.

$$X_i^* = 10 \times (X_i)/ (\max (X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(i)}$$

$$X_4^* = 10 \times (X_4\text{-}54)/ (\max (X_4)\text{-}54) \ldots\ldots\ldots\ldots\ldots\ldots \textit{(ii)}$$

$$I = \text{mean } (X_i^*)$$

6. Cold Wave

As per the India Meteorological Department (IMD, Pune) criteria, a cold wave is defined based on the actual minimum temperature of a station. Cold Wave is considered, when the minimum temperature of a station is, 4 degree Celcius or less for plains and -4°C or less for hilly regions. The cold wave index for days with cold wave events has been computed with equal weightage on a scale of 0 to 10, using equation (i). A simple average had been taken to get the index since equal weightage had been pre-specified.

$$X_i^* = 10 \times (X_i)/(\max (X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(i)}$$

$$I = \text{mean } (X_i^*)$$

7. Fire

The parameters, such as cases, deaths and injuries due to fire accidents, have been normalized by dividing with the maximum value and multiplying by 10, to put it on a scale of 0 to 10, using equation (i). Then, a simple average of all these parameters was taken, since equal weightage had been pre-specified. Since the data has been compiled at the city level, an assumption has been made that, the incidence is equally likely across all areas; hence, the areas with more population would be at a higher risk.

$$X_i^* = 10 \times (X_i) / (\max(X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \quad (i)$$

$$I = \text{mean}\,(X_i^*)$$

8. Forest Fire

We obtained a multiplier, which has been defined as the weighted average of proportions of "very dense", "dense" and "open" forest cover, in the district (area of forest category in the district divided by total forest cover in the district), where the weightage had been pre-specified. The multiplier is strictly between 0 and 1 using equation (i). Then, this multiplier is multiplied with the pre-assigned score associated with the risk category of the district, to get the hazard index.

$$X_i^* = 10 \times (X_i) / (\max(X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \quad (i)$$

$$I = \text{mean}\,(X_i^*)$$

9. Industrial Hazard

The first 2 parameters (i.e., Maximum Hazard Industries and Maximum Polluting Industries) have been normalized by dividing with the maximum value and multiplying with 10, to put on a scale of 0 to 10 using equation (i). The CEPI (Comprehensive Environmental Pollution Index) has been rescaled on a scale of 10, which is 10 for CEPI>80, 8 for CEPI>70, 60 for CEPI>60, and 4 for CEPI>50, 2 for CEPI<50. Then, a weighted average of all these parameters was taken, where the weights had been pre-specified as 50%:25%:25%.

$$X_i^* = 10 \times (X_i) / (\max(X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \quad (i)$$

$$I = \frac{\sum_{i=1}^{3} w_i \times X_i^*}{\sum w_i}$$

10. Lightning

The average annual deaths have been normalized by dividing with the maximum value and multiplying with 10, to put it on a scale of 0 to 10 using equation (i). Since the data has been compiled at the district level, an assumption has been made that, the incidence is equally likely across the city; hence the city with more population would be at a higher risk.

$$X_i^* = 10\times(X_i)/\,(\max\,(X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \; (i)$$

$$I = \text{mean}\;(X_i^*)$$

11. Tsunami

For Tsunami Hazard Index, 3 parameters have been normalized by dividing by the maximum value and multiplying by 10 to put on a scale of 0 to 10 according to formula (i). Then, a weighted average of all these parameters had been taken where the weights had been pre-specified.

$$X_i^* = 10\times(X_i)/\,(\max\,(X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \; (i)$$

$$I = \frac{\sum_{i=1}^{3} w_i \times X_i^*}{\sum w_i}$$

12. Coastal Erosion

For Coastal Erosion Hazard Index, 3 parameters have been normalized by dividing by the maximum value and multiplying by 10 to put on scale of 0 to 10. Then, a simple average of all these parameters had been taken since equal weights had been pre specified.

$$X_i^* = 10\times(X_i)/\,(\max\,(X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \; (i)$$

13. Cyclone

For calculating the Cyclone Hazard Index parameters (a), (b), (c), (d), (e), as shown in the table have been normalized by dividing by the maximum value and multiplying by 10 to get on the scale of 0 to 10 according to formula (I). For (f) an ad hoc score has been developed, which follows the following properties: (i) Score (yes) > Score (no) (ii) The mean of all scores = (0+10)/2 = 5. Out of several possible choices, the middle point has been chosen, which gives the values: Score (yes) = 5.85, Score (no) = 2.49. The score has been assigned corresponding to the responses Yes and No. Then, a weighted average of all these parameters had been taken, where the weights had been pre-specified.

$$X_i^* = 10\times(X_i)/\,(\max\,(X_i)) \ldots\ldots. \; (i)$$

$$X_6^* = \{5.85 \; if \; X_6 = yes \;\; 2.49 \; if \; X_6 = no$$

$$I = \text{mean}\;(X_i^*)$$

VULNERABILITY INDEX COMPUTATION

1. Buildings

a. Walls

In order to capture the effect, each particular hazard has, on each specific type of wall, the following coding has been used: X: {VH = 10, H = 8, M = 6, L = 4, VL = 2} and each hazard index has been categorized according to 5 risk zones. A weighted average of these, have been taken, where the weightages are the proportion of a particular wall type in all houses of the district.

b. Roofs

In order to capture the effect, each particular hazard has, on each specific type of roof, the following coding has been used: X: {VH = 10, H = 8, M = 6, L = 4, VL = 2} and each hazard index has been categorized, according to 5 risk zones. A weighted average of these have been taken, where the weightages are the proportion of a particular roof type in all houses of the district.

2. Agriculture

For agriculture, the net non-irrigated cropped area (total cropped area–irrigated area) and irrigated area, have been normalized by dividing with the district's total area and multiplying with 10, to put on a scale of 0 to 10, using equation (i). Then, a weighted average of all these parameters was taken, where the weightage had been pre-specified as 80% on the former and 20% on latter. (: Cropped area, : Irrigated area, : Total area)

$$I_a = 0.8 \times (X_c - X_i)/X_t + 0.2 \times X_i/X_t \ldots\ldots\ldots\ldots\ldots \quad (i)$$

3. Poverty

All parameters (rural and urban BPL and Homeless population) have been normalized by dividing with the maximum value and multiplying with 10, on a scale of 0 to 10 using equation (i). Then, a simple average of all these parameters was taken, since equal weightage had been pre-specified.

$$X_i^* = 10 \times (X_i) / (\max (X_i)) \ldots\ldots\ldots\ldots\ldots \quad (i)$$

$$I = \mathrm{mean}\ (X_i^*)$$

4. Women

All parameters have been normalized by dividing with the maximum value and multiplying with 10, to put them on a scale of 0 to 10, according to equation (i). Then, a simple average of all these parameters was taken, since equal weightage had been pre-specified.

$$X_i^* = 10\times(X_i - \min(X_i))/(\max(X_i) - \min(X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(i)}$$

$$I = \text{mean}\ (X_i^*)$$

5. Children

All parameters have been normalized by dividing with the maximum value and multiplying with 10, to put them on a scale of 0 to 10, according to equation (i). Then, an average of groups of these parameters was taken, since equal weightage had been pre-specified. Within each group, a weighted average of each of the parameters in the group has been taken, where the weightage had been pre-specified. This has been done twice, once with absolute numbers and once with percentages. Then, a geometric mean of both these indices was taken to obtain the final index.

$$X_1^* = 10\times(X_i - \min(X_i))/(\max(X_i) - \min(X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(i)}$$

$$I_1 = \text{mean}\ (X_i^*)$$

$$I_2 = \text{mean}\ (X_i^*)$$

$$I = \text{geo mean}\ (I_1, I_2)$$

6. Disability

All parameters have been normalized by dividing with the maximum value and multiplying with 10, to put them on a scale of 0 to 10, according to equation (i). Then, a simple average of all these parameters was taken, since equal weightage had been pre-specified. This has been done twice, once with absolute numbers and once with percentages. Then, a geometric mean of both these indices was taken to represent the final index.

$$X_1^* = 10\times(X_i - \min(X_i))/(\max(X_i) - \min(X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(i)}$$

$$I_1 = \text{mean}\ (X_i^*)$$

$$I_2 = \text{mean}\ (X_i^*)$$

$$I = \text{geomean}\ (I_1, I_2)$$

7. Aged

All parameters have been normalized by dividing with the maximum value and multiplying with 10, to put them on a scale of 0 to 10, according to equation (i). Then, a simple average of all these parameters was taken, since equal weightage had been pre-specified. This has been done twice, once using absolute numbers and once using percentages. Then, a geometric mean of both these indexes was taken to represent the final index.

$$X_1^* = 10\times(X_i - \min(X_i))/ (\max (X_i) - \min (X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (i)$$

$$I_1 = \text{mean } (X_i^*)$$

$$I_2 = \text{mean } (X_i^*)$$

$$I = \text{geo mean } (I_1, I_2)$$

8. Livestock

For livestock, the number of bovine animals and other animals, has been normalized by dividing with the total number of the district and multiplying with 10, to put it on a scale of 0 to 10, using equation (i). Then, a weighted average of all these parameters was taken, where the weightage had been pre-specified as 75% on the former and 25% on the latter.

(X_b : No. of bovine animals, X_o : No. of other animals, X_t : Total No. of animals)

$$I_a = 0.75 \times (X_b)/X_t + 0.2\times X_o/X_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (i)$$

9. Industries

The total number of industries, industrial clusters, and SEZs, has been normalized by dividing with the maximum value and multiplying with 10, to put on a scale of 0 to 10, equation (i). Then, a weighted average of all these parameters was taken, where the weightage had been pre-specified as 40%:40%:20%.

$$X_i^* = 10\times(X_i)/ (\max (X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (i)$$

$$I = \frac{\sum_{i=1}^{3} w_i \times X_i^*}{\sum w_i}$$

10. Physical Infrastructure

All parameters have been normalized by dividing with the maximum value and multiplying with 10, to put on a scale of 0 to 10, using equation (i). Then, a simple average of groups of these parameters (Road & Rail Connectivity, Sea and Air Connectivity) was taken, since equal weightage had been pre-specified using equation (ii). Within each group, a simple average of each of the parameters in the group has been taken.

$$X_i^* = 10 \times (X_i) / (\max(X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(i)}$$

$$Y_j = \text{mean}\,(X_i : X_i \in j^{th}\ \text{group}) \ldots\ldots\ldots\ldots\ldots\ldots \textit{(ii)}$$

$$I = \text{mean}\,(Y_j)$$

11. Social Infrastructure

All parameters have been normalized by dividing with the maximum value and multiplying with 10, to put on a scale of 0 to 10, using equation (i). Then, a simple average of groups of sub-groups of these parameters (Educational Institutions and Health Institutions), was taken, since equal weightage had been pre-specified using equation (ii). Within each group, a simple average of each of the sub-group of parameters has been taken. Within each sub-group, a simple average of each of the parameters, in the sub-group has been taken.

$$Y_j = \text{mean}\,(X_i : X_i \in j^{th}\ \text{subgroup}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(i)}$$

$$Z_j = \text{mean}\,(Y_i : Y_i \in j^{th}\ \text{group}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(ii)}$$

$$I = \text{mean}\,(Z_j)$$

12. Deforestation

All parameters of change (dense & open) have been normalized by dividing with the maximum value and multiplying with 10, to put it on a scale of 0 to 10, according to equation (i). Then, a simple average of all these parameters was taken, since equal weightage had been pre-specified.

$$X_1^* = 10 \times (X_i - \min(X_i)) / (\max(X_i) - \min(X_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(i)}$$

$$I = \text{mean}\,(X_i^*)$$

13. Water Stress

All parameters of change have been on a scale of 0 to 10 according to equations (i), (ii), and (iii). Then, a simple average of all these parameters was taken, since equal weightage had been pre-specified.

$$X_1^* = 10\times(\max(X_1) - X_1)/\ (\max\ (X_1)\text{-}\min\ (X_1))\ldots\ldots\ldots\ldots\ldots\ldots.\ (i)$$

$$X_2^* = (100 - X_2)/\ (100)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ (ii)$$

$$X_3^* = \left(\frac{\sum_i^3 w_i \times X_i}{\sum w_i}\right)\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ (iii)$$

$$I = \text{mean}\ (X_i^*)$$

EXPOSURE INDEX COMPUTATION

Two parameters have been considered for calculating the Exposure Index.

These are
(a) population density (=Population /Area in km^2) and
(b) per capita GDP (=GDP (in Cr. Rs.) / Population) of a city.

Both parameters have been normalized by dividing with the maximum value and multiplying by 10, to put them on a scale of 0 to 10, according to equation (i).

Then, a simple average of these parameters was taken, since equal weightage has been given on both the parameters.

$$X_i^* = 10\times(X_i)/\ (\max\ (X_i))\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ (i)$$

$$I = \text{mean}\ (X_i)$$

ANNEXURE 3

Disaster Resilience Questionnaire Responses

1. Risk Assessment (Weights 10%)

	Indicators/Questions	Aggregate Points	Points Assigned
1.1	Hazard Vulnerability Risk Assessment	10	4
1.2	Digital Risk Mapping in Public Domain	5	2
1.3	Real Time Data on Risks and Disasters	5	2
1.4	Micro Zonation of Earthquake Risks	3	0
1.5	Flood Risk Assessment	3	1
1.6	Drought Risk Assessment	5	2
1.7	Dissemination of Risk Information to People	3	2.5
1.8	Assessing Traditional and Local Knowledge	3	2.5
1.9	Assessing Patterns of Emerging Risks	3	2.5
1.10	Developing Database on Disasters	5	4
	Others	5	3

2. Risk Prevention & Mitigation (Weights 20%)

	Indicators/Questions	Aggregate Points	Points Assigned
2.1	Disaster Risk Mitigation Projects	8	6
2.2	Mainstreaming DRR in Development	3	2.5
2.3	State and Disaster Risk Mitigation Fund	3	1
2.4	Safety standards for constructions and land use	7	5
2.5	Safety audit/ retrofitting of lifeline infrastructure/ buildings	8	4
2.6	Construction of cyclone/ flood shelters	3	2
2.7	Eco System Approach for Disaster Risk reduction	3	1
2.8	Social Safety Net for Poor and Vulnerable	5	3
2.9	Mitigation of risks of heritage	2	1
2.10	Integration of climate change adaptation with DRR	3	2
	Others	5	3

3. Risk Governance (Weights 20%)

	Indicators/Questions	Aggregate Points	Points Assigned
3.1	Institutional mechanisms for risk governance	6	4
3.2	Disaster Management Policy and Plans	10	7
3.3	Disaster Management Manuals and Procedures	2	1.5
3.4	Decentralization and Devolution of Functions	2	2
3.5	Training and Capacity Development	10	8
3.6	Multi-Stakeholder Platform	2	2
3.7	Community Involvement and Participation	5	4
3.8	Enforcement and Compliance	4	3
3.9	Monitoring and Evaluation	2	2
3.10	Transparency and Accountability	2	2
	Others	5	3

4. Disaster Preparedness (Weights 20%)

	Indicators/Questions	Aggregate Points	Points Assigned
4.1	End-to-End Early Warning Systems	5	4
4.2	Emergency Operation Centers	5	4
4.3	Disaster Communication System	5	3
4.4	Emergency Medical Preparedness	5	5
4.5	Scenario Building, Simulation and Mock Drills	5	4
4.6	Contingency Plans, SOPs, Manuals	5	4
4.7	Community Based Disaster Preparedness	5	3
4.8	Awareness Generation	5	4
4.9	Resource Inventory	3	2
4.10	Media Partnership	2	1
	Others	5	3

5. Disaster Response (Weights 10%)		Indicators/Questions	Aggregate Points	Points Assigned
	5.1	State Agencies for Disaster Response	10	8
	5.2	Incident Response System	4	2
	5.3	Coordination with GOI, NDRF Armed, Forces	2	2
	5.4	Evacuation, Search and Rescue	7	6
	5.5	Emergency Medical Response	5	5
	5.6	Emergency Support Functions	5	5
	5.7	Protection of vulnerable women and children	5	5
	5.8	Disposal of dead bodies	3	3
	5.9	Disposal of Animal Carcasses	2	2
	5.10	Disposal of Debris	2	2
		Others	5	3

6. Disaster Relief & Rehabilitation (Weights 15%)		Indicators/Questions	Aggregate Points	Points Assigned
	6.1	Minimum Standard of Relief	2	1.5
	6.2	Ex-gratia Relief	1	0.5
	6.3	Relief Logistics and Supply Chain Management	7	4
	6.4	Food and Essential Supplies	7	6
	6.5	Drinking Water, Dewatering and Sanitation	7	6
	6.6	Health and Mental Health Care	7	6
	6.7	Management of Relief Camps	5	4
	6.8	Veterinary Care	3	2
	6.9	Relief Employment	3	1
	6.10	Temporary and Intermediary Shelters	3	2
		Others	5	4

7. Disaster Reconstruction (Weights 5%)

	Indicators/Questions	Aggregate Points	Points Assigned
7.1	Damage and Loss Assessment	5	3
7.2	Post Disaster Needs Assessment	5	3
7.3	Financing Reconstruction	5	2
7.4	Institutional Mechanisms for Reconstruction	5	4
7.5	Building Back Better	5	4
7.6	Reconstruction of Houses	5	3
7.7	Reconstruction of Infrastructure	5	4
7.8	Livelihood Reconstruction	5	3
7.9	Regeneration of Ecology and Environment	3	2
7.10	Learning from Reconstruction and Recovery	2	2
	Others	5	3

About the Institute

National Institute of Disaster Management (NIDM) was constituted under an Act of Parliament with a vision to play the role of a premier institute for capacity development in India and the region. The efforts in this direction that began with the formation of the National Centre for Disaster Management (NCDM) in 1995 gained impetus with its redesignation as the National Institute of Disaster Management (NIDM) for training and capacity development. Under the Disaster Management Act 2005, NIDM has been assigned nodal responsibilities for human resource development, capacity building, training, research, documentation and policy advocacy in the field of disaster management.

NIDM is proud to have a multi-disciplinary core team of professionals working in various aspects of disaster management. In its endeavour to facilitate training and capacity development, the Institute has state-of-the-art facilities like class rooms, seminar hall and video-conferencing facilities etc. The Institute has a well-stocked library exclusively on the theme of disaster management and mitigation. The Institute provides training in face-to-face, on-line and self-learning mode as well as satellite based training. In-house and off-campus face-to-face training to the officials of the state governments is provided free of charge including modest boarding and lodging facilities.

NIDM provides Capacity Building support to various National and State level agencies in the field of Disaster Management & Disaster Risk Reduction. The Institute's vision is to create a Disaster Resilient India by building the capacity at all levels for disaster prevention and preparedness.

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Resilient India - Disaster Free India

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