Assessing and Managing Loss and Damage

Local-level evidence to inform global-level action in Gujarat, India

Part I



Assessing and Managing Loss and Damage

Local-level evidence to inform global-level action in Gujarat, India

Part I-A

Ex-Post Systems Analysis and Retrospective Loss and Damage Assessment

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Disclaimer

This document includes findings from the review of policies and plans at the National, State, and City level, largely based on the secondary background research conducted to arrive at the policy landscape that governs the loss and damage assessment in the cities of Ahmedabad and Surat, Gujarat, India and may require detailing as per the dedicated studies in the subsequent phases of the project.

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Abbreviations

ACCCRN	Asian Cities Climate Change Resilience Network
AMC	Ahmedabad Municipal Corporation
AMTS	Ahmedabad Municipal Transport Services
BMTPC	Building Materials and Technology Promotion Council
BPL	Below Poverty Line
BSUP	Basic Services to the Urban Poor
BRTS	Bus Rapid Transit System
CBOs	Community-Based Organisations
CRCAP	Climate Resilient City Action Plan
CRF	Calamity Relief Fund
CRS	City Resilience Strategy
DaLA	Damage and Loss Assessment
DDMP	District Disaster Management Plan
DEOC	District Emergency Operation Centre
DRMP	District Risk Management Program
DRR	Disaster Risk Reduction
EU	European Union
FGDs	Focus Group Discussions
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GRADE	Global Rapid Post-Disaster Damage Estimation
GSDMA	Gujarat State Disaster Management Authority
GSDMP	Gujarat State Disaster Management Policy
HAP	Heat Action Plan
IMD	India Meteorological Department
IPCC	Intergovernmental Panel on Climate Change
IRADe	Integrated Research and Action for Development
L&D	Loss and Damage
LST	Land Surface Temperature

MMGY	Mukhya Mantri GRUH Yojana
MRF	Material Recovery Facilities
NCCF	National Calamity Contingency Fund
NCRB	National Crime Records Bureau
NDMA	National Disaster Management Authority
NDMA	Natural Resources Defense Council
NELD	Non-Economic Loss and Damage
NFHS	National Family Health Survey
NIDM	National Institute of Disaster Management
NPDM	National Policy on Disaster Management
PDNA	Post Disaster Need Assessment
PCA	Primary Census Abstract
RAY	Rajiv Awas Yojana
RCPs	Representative Concentration Pathways
RINA	Rapid Impact & Needs Assessment
RNA	Recovery Need Assessment
SANDRP	South Asia Network on Dams, Rivers and People
SAPCC	State Action Plan on Climate Change
SDMP	State Disaster Management Plan
SPS	Sewage Pumping Station
SRC	State Relief Commissioner
UCRA	Urban Community Resilience Assessment
UHCRCE	Urban Health & Climate Resilience Centre of Excellence
UNECLAC	United Nation Economic Commission of Latin American Countries
UNDG	United Nations Development Group
VBD	Vector Borne Diseases
WDS	Water Distribution System
WB	World Bank

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Executive Summary

This report marks the first submission in a broader initiative aimed at developing a city-level methodology for assessing Loss and Damage (L&D). It examines policies and planning frameworks across National, State, and City levels, alongside historical data on extreme climate events, to assess how cities of Ahmedabad and Surat in Gujarat are managing the impacts of Loss and Damage from such events. Key climate risks addressed include extreme heat, drought, urban flooding, and sea level rise. The report aims to identify vulnerabilities- both in infrastructure and within affected communities- focusing on their exposure and associated risks. This stage of the study seeks to establish a baseline for Loss and Damage (L&D), which will guide future climate adaptation and management plans at the city level.

Acknowledging the Disaster Management framework within the Indian subcontinent, the report highlights that L&D assessment is governed by statutory frameworks (Acts, Policies, Plans, and Guidelines) at National, State, and District levels. The Ministry of Home Affairs (MHA) serves as the national authority for disaster finance, providing assistance to states during disaster relief and funding transfers. At the state level, authorities such as the State Disaster Management Authority (SDMA) and District Disaster Management Authorities (DDMA) coordinate relief operations and work closely with rescue teams. In Gujarat, city and ward-level disaster management plans have been developed for Ahmedabad and Surat; however, these plans focus more on disaster preparedness and relief rather than specific L&D assessment.

In this context, UNEP-CCC has commissioned a study, funded by DANIDA, to develop a city-level methodology for evaluating both economic and non-economic L&D. This study aims to inform the operationalization of the Loss and Damage Fund announced at COP28 by generating local-level evidence to support global L&D action, in Gujarat.

The report addresses several complex challenges inherent to this approach:

1. Data Collection on Slow-Onset Climate Risks: Collecting time-series data on gradual climate risks beyond disaster events.

2. Defining 'Irreparable' Loss and Damage: Identifying residual impacts that remain after adaptation efforts.

3. Assessing Non-Economic Losses: Characterizing prospective and retrospective non-economic losses, which are difficult to quantify.

4. Balancing Qualitative and Quantitative Methods: Determining the role of each method at different stages of the assessment.

Currently, post-disaster assessments of property and community damages occur after an extreme climatic event has been formally designated as a disaster zone, at which point relief measures are implemented. Traditionally, the Disaster and Loss Assessment (DaLA) framework, focused primarily on property and infrastructure damages, has been used. Recently, however, sub-national governments, with support from organizations like the World Bank, have adopted the Post Disaster Needs Assessment (PDNA) approach, which also includes non-economic dimensions like cultural heritage and livelihood related cascading losses at State and District levels. This approach has been used for L&D assessment due to floods in Kerala, Odisha, and Bihar State.

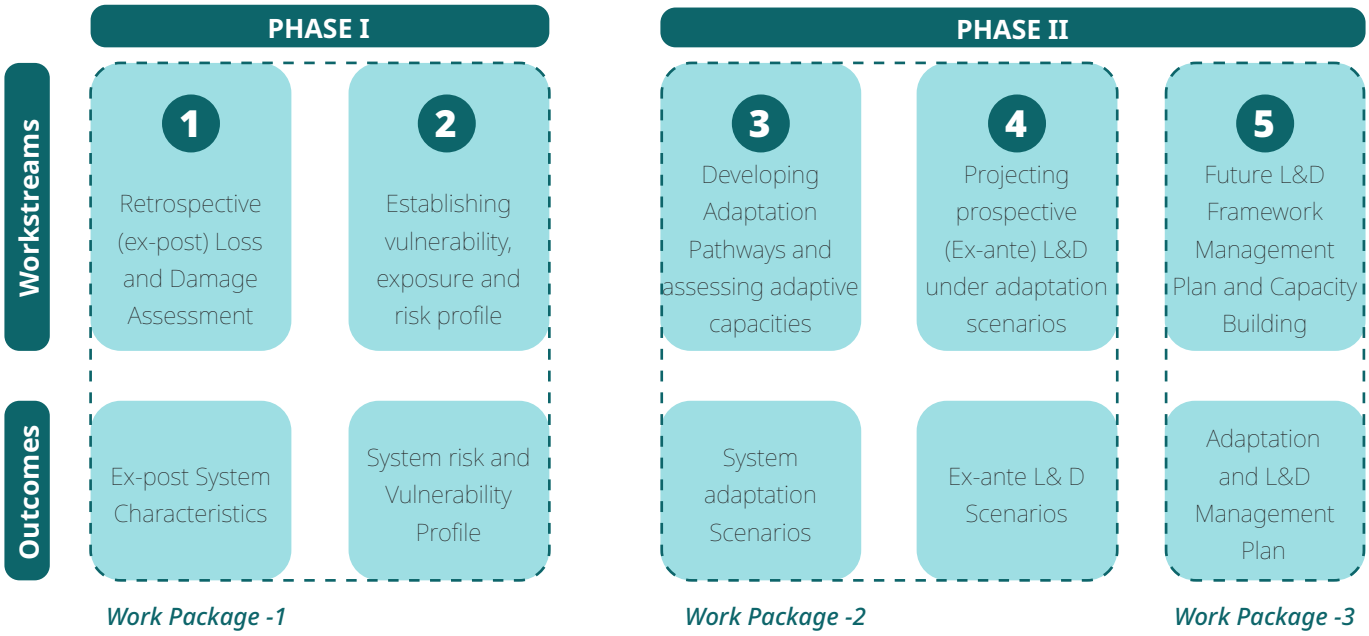
This report discusses the approaches prevalent at scales of plans i.e. National, State, and City and also looks into climate change dimensions - future climate projections and related intensity of extreme climatic events and their implications for already impacted vulnerable communities at the city level and also discussed the L&D assessment related issues. The report has been structured into four (4) chapters and each one lends a unique dimension to the complex issues highlighted earlier and the process for establishing a city level L&D assessment methodology.

Chapter 1: Introduction to Economic and Non-Economic Loss and Damage (L&D) categorizes the economic and non-economic components of L&D based on an extensive literature review, drawing on multiple sources. This categorization informs our city-specific analysis of climate-related documents, including heat resilience plans and climate-resilient city action plans. Establishing these categories provides focus for the approach, particularly given the lack of global consensus on what constitutes non-economic L&D and how to assign value to losses such as loss of life, mental stress, cultural practices, and heritage. This chapter also explains the rationale for selecting Ahmedabad and Surat as focus cities.

Chapter 2: Scope of the Work Package outlines the project's overall scope, structured according to work packages (WP) and work streams (WS) that were developed after a detailed examination of the project requirements. It emphasizes the two work streams included in Work Package 1, which are covered in this report as part of Phase 1 activities. Phase 2 activities will be addressed in a subsequent report.

- **Work Stream 1:** Retrospective (ex-post) loss and damage assessment leading to an "Ex-post System Characteristics" analysis.
- **Work Stream 2:** Developing a vulnerability, exposure, and risk profile leading to a "System Risk and Vulnerability Profile."

5 Identified work streams based on the Scope of Work



Chapter 3: Ex-Post Systems Characteristics examines global approaches to loss and damage assessment through a comparative analysis. It then summarizes relevant policies at the national, Gujarat State, Gujarat District, and city levels, highlighting key observations. For example, the National Disaster Management Act does not currently recognize heat as a climate hazard; however, there are national guidelines for managing extreme heat and drought that states and districts can reference when developing policies and plans. The chapter also outlines the existing process for L&D assessment, identifying key documents that provide guidance for sectoral departments to report sector-specific damages and discuss mechanisms for compensation to states from the national government. Some findings from the review include the following:

National Disaster Management Act (NDMA) – Mentions that the City Government must carry out relief, rehabilitation and reconstruction activities in the affected area in accordance with the State Plan and the District Plan. No real provision for Loss & Damage Assessment at the local scale.

National Policy on Disaster Management (NPDM) – Mandates reconstruction and recovery while considering the 'Build Back Better' approach. Special focus on restoring livelihoods with special attention to the needs of women-headed households, artisans, farmers and people belonging to marginalised and vulnerable sections.

Gujarat State Disaster Management Act (GSDMA) – Outlines the roles and responsibilities of local authorities and community organizations. It lays the responsibility of emergency relief on State Relief Commissioners and District Collectors and calls for the establishment of a "Disaster Management Fund" to finance actions connected to disasters.

Gujarat State Disaster Management Policy (GSDMP) - The Loss and Damage component of the Gujarat State Disaster Management Plan (GSDMP) provides a framework for assessing the impact of disasters on the state's social, economic, and environmental sectors. Mandates a Post-Disaster Needs Assessment (PDNA) which covers the following:

- **Social Sectors:** 1. Housing, 2. Health & Population, 3. Nutrition, 4. Education, 5. Cultural Heritage
- **Productive Sectors:** 1. Agriculture, 2. Irrigation, 3. Commerce & Industry, 4. Tourism, 5. Financial Sector
- **Infrastructure Sectors:** 1. Electricity, 2. Communications, 3. Community Infrastructure, 4. Transport, 5. Water, Sanitation & Hygiene
- **Cross-cutting Sectors:** 1. Governance, 2. Disaster Risk Reduction (DRR), 3. Environment & Forestry, 4. Employment & Livelihoods, 5. Social Protection, 6. Gender Equity & Social Inclusion, 7. Poverty and Human Development, 8. Macroeconomic Impact Assessment.

The chapter then conducts a comprehensive review of relevant policies, action plans, strategy documents, and academic literature on city resilience and city climate action prepared by various organizations. This review focuses on identifying how L&D components are addressed at the district and city levels, particularly for Ahmedabad and Surat. Findings are distilled into a list of relevant economic and non-economic L&D components for each city, presented in the following sections.

Classification of ELD and NELD for Surat

S. No.	Economic Loss and Damage	Non-Economic Loss and Damage
1	Slowdown of economic growth	Loss of life
2	Business and Trade	Displacement and migration
3	Food Security	Loss of mental well-being, psychological stress
4	Loss of Infrastructure	Increased health-related issues / burden on the health systems
5	Loss of property	Social cohesion
6	Loss of Livelihood	Socio-economic inequality
7	Health expenditure	Loss of ecosystem services and biodiversity
8	Damage to education infrastructure	

Classification of ELD and NELD for Ahmedabad

S. No.	Economic Loss and Damage	Non-Economic Loss and Damage
1	Trade	Loss of life
2	Loss of infrastructure	Displacement
3	Loss of property	Increased health-related issues / burden on the health systems
4	Loss of livelihoods	Heat related losses
5		Loss of community resilience
6		Socio-economic inequality
7		Loss of ecosystem services and biodiversity

The report acknowledges that city-level assessment of loss and damage (L&D) is not a common practice in India. To address this gap, it presents case studies of L&D assessments conducted at the state level using the Post-Disaster Needs Assessment (PDNA) framework, including the 2019 floods in Kerala, the 2008 Kosi floods in Bihar, and the 2019 Cyclone Fani in Odisha. These case studies highlight the challenges and critical gaps in current assessment frameworks, as well as the economic and non-economic L&D components addressed in each assessment.

The chapter further explores metrics for assessing vulnerability, providing a rationale for their inclusion based on a literature review of city-specific and broader sources. These metrics form the foundation for estimating L&D at the city level, with data sources identified from secondary information. Any gaps in data will be addressed through targeted data collection from relevant city stakeholders and departments. In the subsequent section, these metrics are organized in a format optimized for data collection, synthesis, and presentation.

The report identifies seven key data types for this purpose:


Demographic Data


Health


Community


Climate Data


Environment


Institutional


Economy

The chapter also outlines the ICLEI methodology for risk and vulnerability analysis, presenting a tabular matrix for a composite analysis of sectors in relation to climate hazards. This matrix format is shown below:

Vulnerability Variable	**Risk and Vulnerability Matrix**			
	Urban Heat Risk		**Urban Flood risk**	
	Exposure data	Fragility statement	Exposure data	Fragility statement
Socio-economic aspects	*Sectors vs Climate Hazards to assess Risk and Vulnerability*			
Water Supply				
Wastewater				
Solid Waste				
Transport				
Emergency Services				
Health				
Parks and Gardens				
Energy				
Education				
Housing				
Tourism				
Manufacturing				

Urban heat and urban flooding are particularly significant climate hazards for both Ahmedabad and Surat. In Surat, sea-level rise exacerbates flooding in creeks and adjacent settlements, so this factor is incorporated under urban flooding. Drought, as a slow-onset event, is not included in the tabular matrix due to challenges in acquiring secondary data. The chapter also lays the ground for thematic analysis based on stakeholder engagement. ***This stage of work relies heavily on secondary data collection and the stakeholder engagement will be initiated in the next stage of the work.*** A structured interview guide for government officials is presented in the annexes.

Chapter 4: System Risk and Vulnerability Profile examines the current exposure and vulnerability of Ahmedabad and Surat while establishing their climate change profiles. This is achieved through an analysis of existing data on climate hazards, Representative Concentration Pathway (RCP) scenarios, and future projections of extreme climatic events. The chapter also completes the tabular matrix introduced in Chapter 3, mapping sectoral profiles against identified climate hazards and the resultant fragility statements. (Fragility statements have not yet been developed for Surat).

A critical challenge highlighted in this chapter is the significant data gap, as most sector-specific information is scattered across various para-statal bodies, state departments, and municipal corporations, with no centralized repository for loss and damage data. To address this gap, stakeholder consultations, focus group discussions, and key informant interviews will be employed. Data collection efforts have been aligned with ICAT (Initiative for Climate Action Transparency) guidance on loss and damage, with additional focus on capturing cultural dynamics associated with non-economic L&D.

To provide deeper insights, the chapter presents detailed case studies from Ahmedabad and Surat that document community stories and their livelihood linkages to loss and damage. These narratives, originally reported by the PARI Network, have been spatially mapped to reflect climate impacts by ICLEI South Asia. The case studies highlight the vulnerabilities of economically weaker groups that have migrated to Ahmedabad and Surat due to climate factors and agricultural losses in their home states, such as Odisha and Gujarat. These stories underscore the multicultural character of the cities and include the following:

1. The Rajbhoi Tribe in Ahmedabad: Members of this Gujarat-based tribe have settled in the Vatva neighborhood of Ahmedabad. Women from the tribe are engaged in making ropes from silk textile waste collected from industries in Surat.

2. Power Loom Workers in Surat: Migrants from Odisha, displaced by climate stress and declining agricultural income, now work in Surat's power loom industry. They endure long hours for minimal wages and live in substandard housing, leaving them highly vulnerable to contagious diseases and vector-borne illnesses, especially during floods and heat waves.

The chapter also delves into climate risks and associated impacts, summarizing findings from the literature on the following components:

1. Risks from cyclones and flooding.
2. Historical impacts of extreme climatic events.
3. Current status and projected risks.
4. Impacts on transport and mobility.
5. Effects of sea-level rise and extreme heat.
6. Health risks, including communicable diseases.
7. Social cohesion erosion, leading to heightened vulnerabilities.

The chapter concludes by presenting the current status based on secondary data analysis of risks and their associated impacts. It outlines the way forward, detailing how activities not covered in this phase will transition into the next phase of the project.

Chapter 5: Annexes includes the data matrix, detailing the granularity of available data and the corresponding sources. It highlights data gaps that will inform future initiatives for data collection and stakeholder engagement. Additionally, the chapter provides a government stakeholder engagement guide, which the team intends to use during interviews with relevant government officials.

1 Introduction

Loss and damage (L&D) data in cities due to climate hazards is critical to understand vulnerabilities, exposure, and system risks. The aim is to establish a baseline of loss and damage to guide future climate adaptation and management planning. The primary objective of the project is to develop a robust framework especially tailored for cities, enabling them to accurately assess the impact of climate change induced loss and damage and devise location specific adaptation strategies. This is required as at present, the risk assessment and disaster management efforts are focussed on predominantly at the district level, state level and national level. Recognizing this challenge faced by the dense urban areas, there is a growing consensus to transition towards a city-based approach. The city level framework complements the existing district/state/national level frameworks to assess the risks and also detail out the local nuances and challenges. It also helps equip the cities with necessary data to advocate for funding support for disaster response and recovery.

The first phase of the project, presented in this report, focused on a baseline assessment of retrospective loss and damage, including an assessment of climate-related hazards and disasters that have occurred in the two selected project cities in the last 50 years and their impacts on urban systems, health & safety systems, social systems, and the economy of these cities.

Secondly, it focused on developing vulnerability, exposure, and risk profiles for the cities by assessing their current risks and weaknesses. This analysis provides insights into the potential loss and damage from anticipated disasters and establishes a baseline for evaluating future adaptation scenarios.

This report hence presents a comprehensive analysis of loss and damage assessments, focusing on urban vulnerabilities and resilience in the context of Ahmedabad and Surat. It examines the methodologies used for assessing loss and damage at both global and national levels, including India's National Disaster Management Act, 2005, and relevant state policies and disaster management plans to establish the context under which the two cities function in the space of loss and damage.



Map 1. Location of Ahmedabad and Surat in Gujarat state

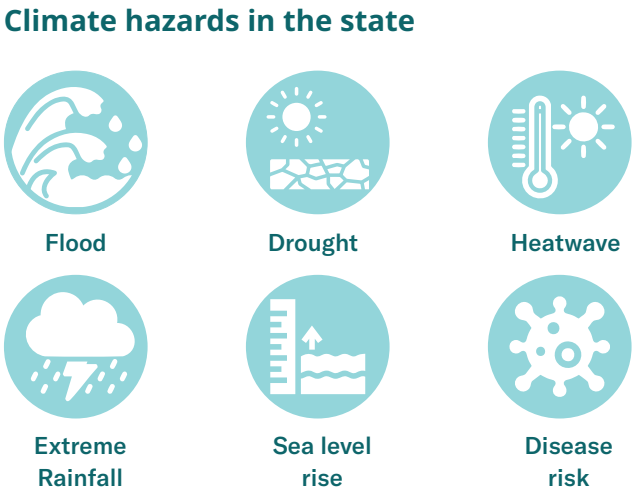


Fig 1. Climate hazards in Gujarat

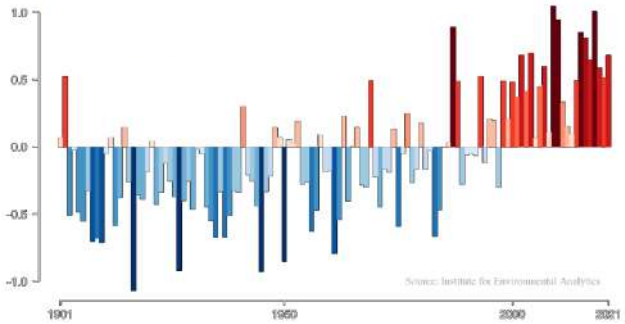
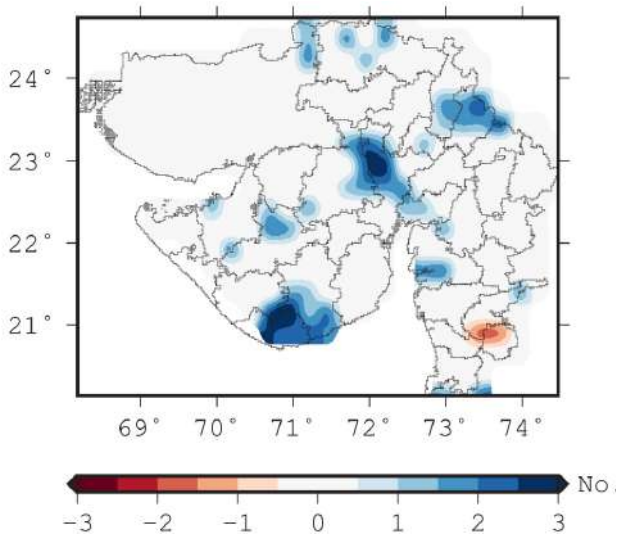


Fig 2. Temperature change in Gujarat (SAPCCHH, 2024)



Map 2. Change in number of extreme events during the period of 1951 – 2019[1]

1 Government of Gujarat. (2014). Gujarat State Action Plan on Climate Change. Climate Change Department.

1.1 Economic and Non-Economic Losses

The analysis further delves into the economic and non-economic impacts of disasters on these cities, with a particular emphasis on capturing a broad spectrum of loss and damage. Loss and damage resulting from natural disasters or climate change can be categorised into two main types: economic losses and non-economic losses.

Economic losses refer to tangible damages that can be quantified in monetary terms, including damage to infrastructure, loss of property, and decreased productivity.

Non-economic losses are distinguished by their irreversible nature, which indicates that they cannot be entirely repaired or compensated for with monetary means. Non- economic losses encompass intangible impacts, such as loss of life, displacement, psychological trauma, and loss of cultural heritage.

These losses frequently have substantial and long-term consequences for individuals, communities, and nations, far beyond the immediate aftermath of a disaster. While economic losses may be assessed and compensated for, non-economic losses present unique challenges due to their subjective and multifaceted nature.

The significance of resolving non-economic losses is a challenge due to the absence of a standardised technique for quantifying and managing these impacts. Despite their serious repercussions, non-economic losses are sometimes overlooked in disaster response and recovery efforts. By developing strategies to effectively manage and mitigate these



losses, communities can better address the holistic impacts of disasters and improve overall resilience.

Rather than focusing simply on monetary reparations for previous episodes of loss and damage, the proposed technique creates strategies for the effective management of non-economic losses. Managing non-economic losses necessitates a multifaceted strategy that covers both current demands and long-term resilience-building activities. This includes recognising vulnerabilities, taking preventive actions to lessen the likelihood and severity of future events, offering support and assistance to impacted communities, developing social and institutional resilience, and fostering community empowerment in order to cope with and recover from the intangible impacts of disasters.

By reviewing existing policies and frameworks, this report aims to identify gaps in current assessments and offer insights into city-specific vulnerability metrics and risk profiles.

Additionally, this report also presents the stakeholder engagement processes the team is planning to take in the subsequent steps of the project. The engagement plan focuses on methodologies like Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) to better understand local perspectives. Through the engagement and thematic analysis of the data collected, in the next steps of the project, the team aims to develop a contextual set of loss and damage metrics for the two cities, with evidence from the ground.

Impacts of Climate Change

Slow Onset Events



Rising Temperature



Sea level rise



Loss of Biodiversity

Extreme Weather Events



Drought



Flood



Heatwave



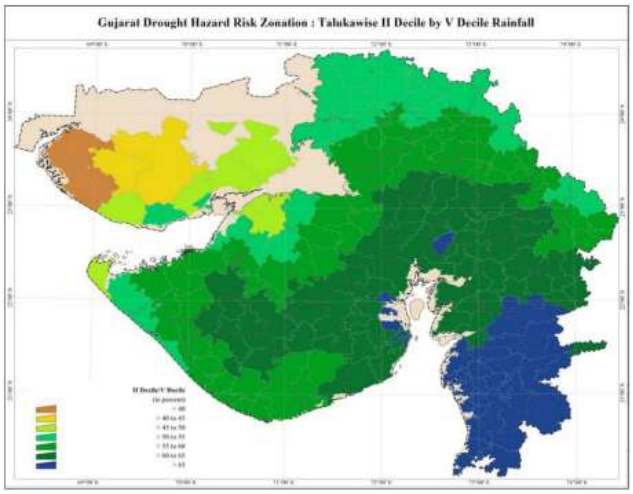
Cyclone

1.2 Rationale for city selection

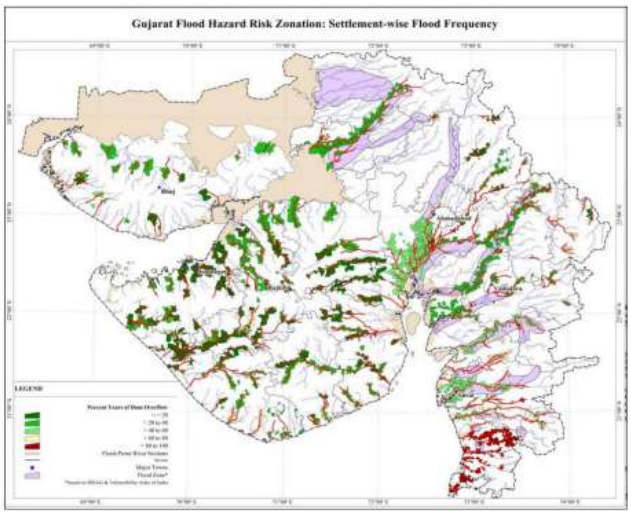
Ahmedabad and Surat, two of Gujarat's prominent cities, face distinct challenges due to climate-related risks, making them vital focus points for assessing loss and damage. Ahmedabad, the largest city in Gujarat, faces rising temperatures and recurring heat waves. In May 2024, the city recorded temperatures as high as 46.6°C, significantly above the seasonal average[1]. This issue is intensified by its semi-arid climate and rapid urbanization, which together pose significant social, health and economic concerns. Additionally, the city deals with riverine flooding and intense rainfall events, putting its infrastructure and resilience to the test[2].

In contrast, Surat, a thriving coastal city and economic centere is particularly vulnerable to sea-level rise, cyclones, and flooding. Positioned along the Tapi River and close to the Arabian Sea, Surat's geography increases its exposure to these hazards. The city has experienced severe floods, notably in 2006, which led to extensive damage[3]. Surat's climate and urban setup also heighten the risk of vector-borne diseases.

Choosing Ahmedabad and Surat for loss and damage studies spans a broad perspective on Gujarat's varied climate challenges. Each city's specific vulnerabilities provide valuable insights into the impacts of climate-induced disasters, supporting the development of city level targeted strategies for adaptation and resilience.



Map 3. Drought hazard risk zones, Gujarat (GSDMA)



Map 4. Flood hazard risk zones, Gujarat (GSDMA)

1 The Indian Express. (2024, May 23). Heatwave continues; red alert in Ahmedabad, Gandhinagar.

2 Ahmedabad Municipal Corporation. (2023). Ahmedabad Climate Resilient City Action Plan: Towards a Net Zero Future. ICLEI South Asia.

3 TARU Leading Edge. (2011). Surat City Resilience Strategy. Surat Municipal Corporation.

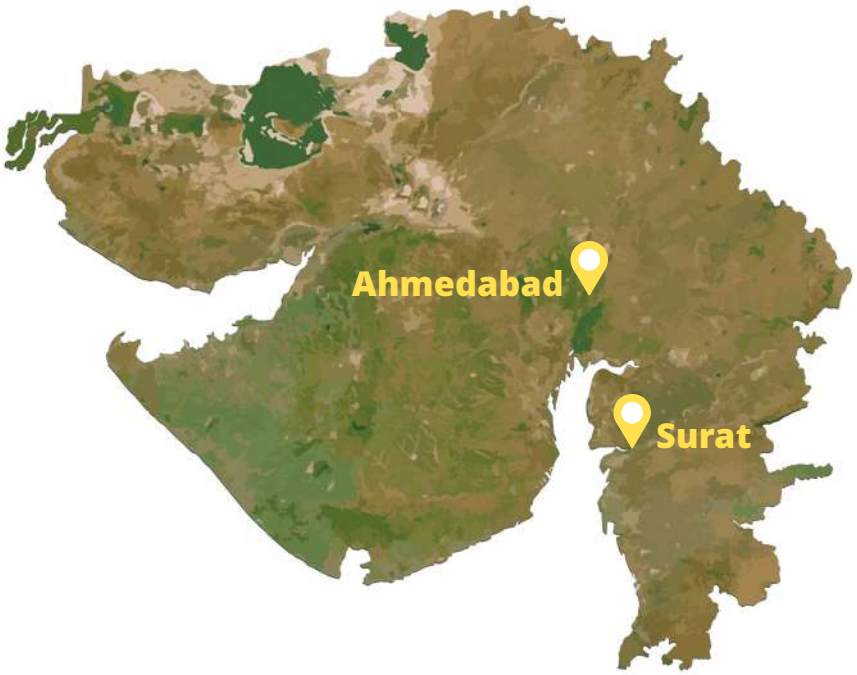
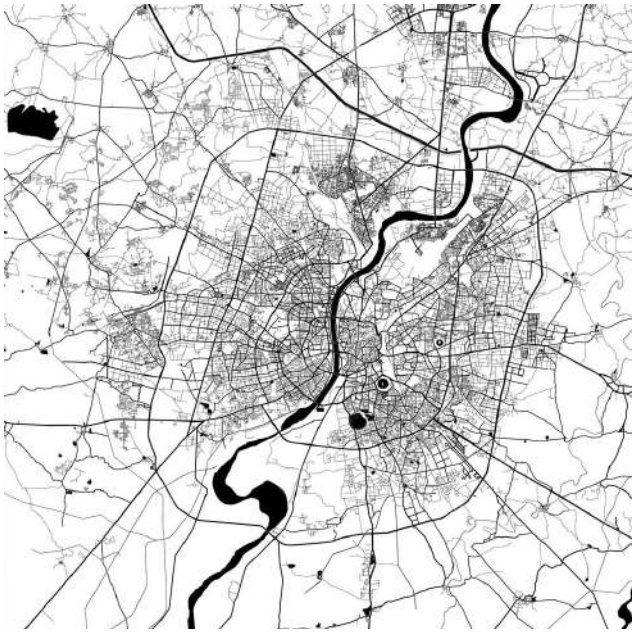


Fig 3. Location of Ahmedabad and Surat



Map 5. Ahmedabad city, Gujarat



Map 6. Surat city, Gujarat

2 Scope of Work Package

2.1 Work Streams and Phases

The scope of work focuses on systematically assessing and managing loss and damage through five key work streams, executed in two phases.

The approach aims to evaluate both past (ex-post) and potential (ex-ante) losses while developing adaptation strategies to enhance resilience.

Phase 1

Retrospective Analysis and Risk Profiling

This phase involves analyzing past loss and damage (L&D) data to understand vulnerabilities, exposure, and system risks. The objective is to establish a baseline of loss and damage to guide future climate adaptation and management planning.

Phase 2

Adaptation and Management Planning

The focus of this phase is on creating strategies and action plans to adapt to future climate risks and minimize loss and damage.

Phase 1: Retrospective Analysis and Risk Profiling

Work Package 1:

Ex-Post System Characteristics: Retrospective (ex-post) Loss and Damage Assessment

This work package assesses past climate-related loss and damage to develop a baseline and identify key metrics for monitoring.

Output 1.1: Current status of loss & damage (baseline): Conduct a comprehensive literature review to compile historical data on loss and damage, creating a baseline profile of affected sectors, populations, and assets.

Output 1.2: Identify gaps in economic and non-economic loss & damage: Engage stakeholders to gather insights on both measurable (economic) and intangible (non-economic) impacts, helping to identify current gaps in data and knowledge.

Output 1.3: Develop city-specific loss and damage metrics: Perform thematic textual analysis to create relevant metrics for loss and damage that align with the unique characteristics of the city.

Output 1.4: Establish city-specific vulnerability metrics and data sources: Conduct a valuation of economic and non-economic losses, creating vulnerability metrics for various city sectors and identifying reliable data sources.

Work Package 2:

System Risk and Vulnerability Profile: Establishing Vulnerability, Exposure, and Risk Profile

This package involves mapping the city's current vulnerability and exposure to climate risks, providing a risk profile to support future mitigation efforts.

Output 2.1: Map current vulnerability, exposure, and risks: Identify areas and communities within the city that are most vulnerable to climate hazards. Assess the degree to which people, infrastructure, and economic assets are exposed to climate risks. Conduct an assessment based on multiple factors to prioritize areas for immediate action.

Output 2.2: Project economic loss and damage for future disasters: Estimate the potential impact of future climate events based on historical data, projected climate scenarios, and vulnerability mapping. Develop a model to project the financial costs of future climate events, enabling resource allocation for preventative measures.

Phase 2: Adaptation and Management Planning

System Adaptation Scenarios: This package explores possible adaptation pathways and assesses the city's capacity for adaptation.

Work Package 3

Develop Adaptation Pathways and Assess Adaptive Capacities: Scenario development to identify feasible adaptation pathways based on city-specific vulnerabilities. Capacity evaluation for city adaptation planning, considering resources, institutional readiness, and community engagement.

Work Package 4 and 5:

Projecting prospective (ex-ante) loss and damage under adaptation scenarios: Analyze potential future loss and damage under different climate scenarios, supporting informed decision-making on adaptation investments.

Develop future L&D framework, management plans, and capacity building programs: Establish a framework for ongoing L&D assessment and management, incorporating capacity-building initiatives to strengthen community and institutional resilience.

**Work Package 1 and 2 under Phase 1 are detailed in this report.*

Phase 2 will be detailed in the subsequent report

3 Ex-post System Characteristics

3.1 Current status of Loss and Damage Assessment

3.1.1 Global Loss and Damage Assessment Methodologies

Globally, five methodologies are widely used for the assessment of damages, losses, and recovery needs caused by disaster (DLRND)[1], namely-

1. **Damage and Loss Assessment (DaLA),**
2. **Post Disaster Need Assessment (PDNA),**
3. **Recovery Need Assessment (RNA),**
4. **Global Rapid Post-Disaster Damage Estimation (GRADE), and**
5. **Rapid Impact & Needs Assessment (RINA)**

3.1.2 National Loss and Damage Assessment Methodologies

In India, two methodologies are used to assess the damages and losses of natural disasters:

1. Damage and Loss Assessment (DaLA) and
2. Post Disaster Need Assessment (PDNA)

The National Institute of Disaster Management (NIDM), Ministry of Home Affairs, Government of India has also developed the Post Disaster Needs Assessment (PDNA) Tools for India under the National Cyclone Risk Mitigation Project assisted by the World Bank. The objective of these tools is to establish a standardised mechanism based on scientific approach for conducting post disaster needs assessment for long term recovery and reconstruction. The newly developed tools are based on the existing damage assessment system in India and an internationally-accepted methodology which has been used worldwide and adopted by the United Nations Development Group (UNDG), the European Union (EU) and the World Bank (WB) which signed a joint declaration in 2008 on Post-Crisis Assessments and Recovery Planning. NIDM has completed the tools for calculating indirect loss, opportunity cost loss and its impact on the macro economy of the affected state.

1 *Global Facility for Disaster Reduction and Recovery (GFDRR). (2018). Post-Disaster Needs Assessments: Guidelines Volume (2013) & Disaster Recovery Framework Guide (2018). World Bank.*

The current tool is an improvisation on the international tool initially developed by UNECLAC (United Nation Economic Commission of Latin American Countries). It has been customised to the Indian context and procedures and has been made easy to use by the officials at the local levels. The PDNA is the most updated methodology that includes DaLA and RNA[2]. This (PDNA) methodology has been used only twice in India:

- the Kerala flood[3] and
- the FANI cyclone in Odisha[4]

During the Kerala flood, with the help of the government of Kerala, the United Nations, the World Bank, and the Asian Development Bank, a PDNA was conducted to assess the damages, losses, and need for reconstruction. The PDNA estimated the total damages to be around INR 10,557 crore and total losses to be around INR 16,163 crore[3].

With the joint effort of the Department of Economic Affairs, Ministry of Finance, Government of India, the United Nations, the World Bank, and Asian Development Bank, detailed damage, loss, and needs assessment (DLNA) was conducted in Odisha to support the recovery process after the FANI cyclone. The assessment report estimated the total damages to be worth INR 16,465 crore (USD 2,352 million) and total losses to be worth INR 7,712 crore (USD 1,102 million). The recovery needs were estimated at INR 29,315 crore (USD 4,188 million)[4].

To incur expenditure from the Calamity Relief Fund (CRF) and the National Calamity Contingency Fund (NCCF), the Government of India, through the Ministry of Home Affairs, New Delhi, has established guidelines for States to develop and submit Relief Memorandums. The existing approach, as exemplified by Kerala, involves leveraging the State Disaster Response Fund (SDRF) and the National Disaster Response Fund (NDRF) for accessing financial assistance.

2 World Bank. (2013). Damage, loss and needs assessment: Guidance notes.

3 Government of Kerala. (2018). Post Disaster Needs Assessment: Floods and Landslides – August 2018. Kerala State Disaster Management Authority

4 Government of Odisha. (2019). Cyclone Fani 2019 DLNA Report. Odisha State Disaster Management Authority.

Brief comparison of DaLa and PDNA methodology

Methodology	Year of Launch	Developed by
Damage and Loss Assessment (DaLA)[1] 	1972	UN-ECLAC (United Nations-Economic Commission for Latin America & Caribbean).
PDNA (Post Disaster Need Assessment)[2] 	2008	UNDP, EU, World Bank
PDNA (Post Disaster Need Assessment)[3] 	2019	National Institute of Disaster Management, under the Ministry of Home Affairs, Government of India

1 *ECLAC. (1972). Damage and Loss Assessment (DaLA)*

2 *UNDP (2008). Post Disaster Needs Assessment (PDNA)*

3 *NIDM (2019). Handbook: Post Disaster Needs Assessment India. Ministry of Home Affairs, GoI.*

Strength	Weaknesses	Used by (States/ Countries)
a. Includes direct and indirect losses. b. Assess disaster effects across most of the sectors of society & economy. c. Gives inputs for economic recovery and reconstruction.	a. Assess only the value of destroyed assets & change in production flows of goods and services but not overall macro-economic impact. b. No assessment of impacts at personal or household levels on income & costs of living. c. Does not include all the sectors of the economy.	Used by (States/ Countries) Managua (Earthquake), Gujarat (Earthquake), Indonesia, Thailand, India, Sri Lanka, Maldives (Indian Ocean Tsunami)
a. Detailed and globally accepted methodology. b. Covers every sector of the economy, comprehensive & systematic methodology. c. In-depth analysis of Damages, Losses, and needs of the country.	a. Limited evidence of inclusion of the Private sector. b. Exclusion of marginalised & vulnerable people. c. Accountability issue. d. There is no specific assessment procedure to cater to the needs of smaller countries.	More than 60 countries have used it.
a. A systematic and comprehensive version of PDNA methodology. b. Include the needs of India specifically. c. Provide a long- term recovery & reconstruction plan. d. Indirect losses, opportunity costs, and macro economic impacts are included.	a. Some sectors are yet to be included. b. Unavailability of data for each sector. c. Private losses are not accounted for d. Underestimation of building back better cost. e. Local government, villagers, and communities have not been given significant importance in the study.	India (Kerala Flood and Odisha FANI Cyclone)

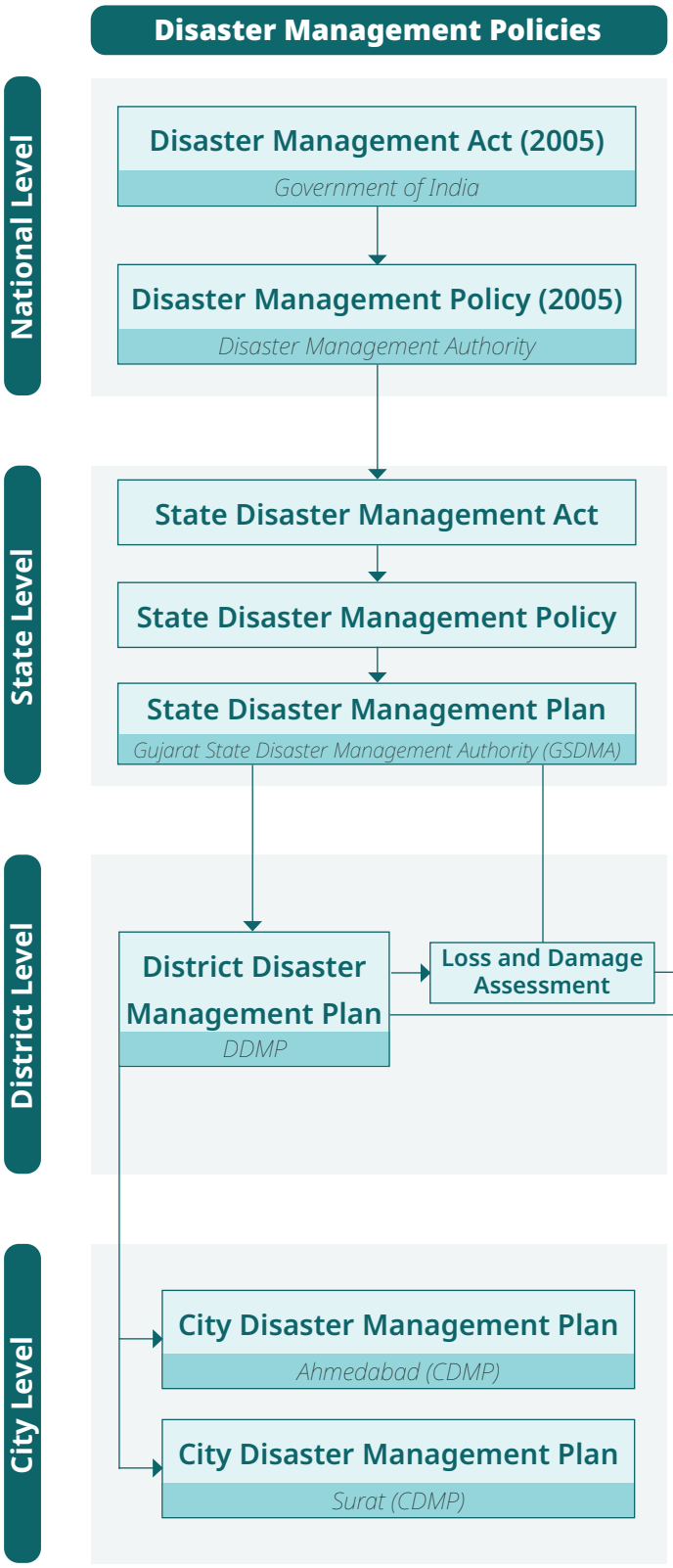
3.1.3 Loss and Damage Assessment Framework

The figure depicts a listing of the inter-relationship of statutory legislation leading to L&D assessment provision at state and district level. This highlights the multilevel framework of disaster management and climate change policies at the national level and the state, district, and city levels with reference to Gujarat, India. At the national level, key driver is the Disaster Management Act of 2005, with guidelines on flood, drought, and heatwave and an overall National Action Plan on Climate Change, NAPCC, in addition to health in the NAPCCHH.

At the state level of Gujarat, it has enacted the State Disaster Management Act, policy, and plan, with concentration put on extreme heat exposure, flood, cyclone risk management, and the State Action Plan on Climate Change (SAPCC) and health component to include SAPCCHH.

District level promotes more localized disaster preparedness through the formulation of district disaster management plans which includes focus on the assessment of loss and damage where Ahmedabad and Surat districts will be detailed in further sections in this report.

At the city level, Ahmedabad and Surat have developed specific city disaster management plan and heat action plans and larger resilience strategies in response to climate change impacts and towards sustainable urban resilience.



Guidelines/ Plans/ Initiatives	Climate Change Policies
Management of Floods 2008 *National Disaster Management Guidelines*	**National Action Plan on Climate Change** *NAPCC 2008*
Management of Drought 2010 *National Disaster Management Guidelines*	**National Action Plan on Climate Change and Human Health** *NAPCCHH 2018*
Management of Heatwave 2019 *National Disaster Management Guidelines*	
Extreme Heat Exposure and Actions for Gujarat *Gujarat Institute of Disaster Management*	**State Action Plan on Climate Change** *SAPCC*
Cyclone Risk Management *Gujarat Institute of Disaster Management*	**State Action Plan on Climate Change and Human Health** *SAPCCHH*
Surat District Disaster Management Plan *GSDMA 2024*	**Climate Change and Environment Action Plan** *Ahmedabad District CCEAP 2022*
Ahmedabad District Disaster Management Plan *GSDMA 2024*	
Heat Action Plan *Ahmedabad HAP 2016*	**Climate Resilient City Action Plan** *Ahmedabad CRCAP 2023*
Heat and Health Action Plan *Surat HHAP 2016*	**City Resilience Strategy** *Surat CRS 2017*

3.1.4 National Disaster Management Act, 2005

Under the act, the following institutions, committees, plans and policies have been set-up at national, state and district level:

- Disaster Management Authority with clearly defined powers and functions
- Advisory committee for overall coordination, hand-holding and technical assistance
- Executive committee and sub-committee
- Formulation of disaster management plans
- Guidelines for minimum standards of relief
- National Institute of Disaster Management is responsible for planning and promoting training and research in the area of disaster management, documentation and development of information base relating to disaster management policies, prevention mechanisms and mitigation measures.
- National Disaster Response Force
- Disaster Response Fund and Disaster Mitigation Fund

Core focus of National Disaster Management Plan

- Measures to be taken for the prevention of disasters, or the mitigation of their effects;
- Measures to be taken for the integration of mitigation measures in the development plans;
- Measures to be taken for preparedness and capacity building to effectively respond to any threatening disaster situations or disaster;
- Roles and responsibilities of different Ministries or Departments of the Government of India in respect of measures specified in clauses (a), (b) and (c).

Guidelines for minimum standards of relief at national level-

- The minimum requirements to be provided in the relief camps in relation to shelter, food, drinking water, medical cover and sanitation;
- The special provisions to be made for widows and orphans;
- Ex-gratia assistance on account of loss of life as also assistance on account of damage to houses and for restoration of means of livelihood;
- Similar other relief may be necessary.

Core focus of State Disaster Management Plan -

- The vulnerability of different parts of the State to different forms of disasters;
- The measures to be adopted for prevention and mitigation of disasters;
- The manner in which the mitigation measures shall be integrated with the development plans and projects;
- The capacity-building and preparedness measures to be taken;
- The roles and responsibilities of each Department of the Government of the State in relation to the measures specified in clauses (b), (c) and (d) above;
- The roles and responsibilities of different Departments of the Government of the State in responding to any threatening disaster situation or disaster.

Guidelines for minimum standard of relief by State Authority -

The State Authority shall lay down detailed guidelines for providing standards of relief to persons affected by disaster in the State, provided that such standards shall in no case be less than the minimum standards in the guidelines laid down by the National Authority in this regard.

Core focus of District Disaster Management Plan -

- The areas in the district vulnerable to different forms of disasters;
- Measures to be taken for prevention and mitigation of disaster, by the Departments of the Government at the district level and local authorities in the district;
- The capacity-building and preparedness measures required to be taken by the Departments of the Government at the district level and the local authorities in the district to respond to any threatening disaster situation or disaster;
- The response plans and procedures, in the event of a disaster.

Responsibilities of National Ministries, and State level Departments -

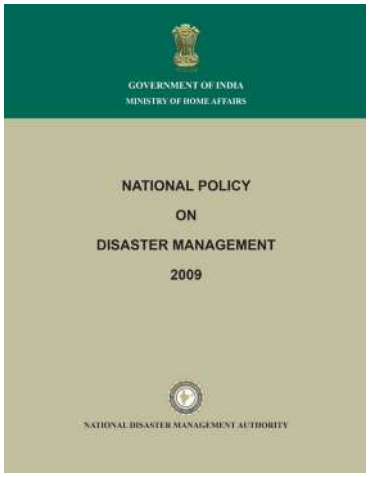
- Take measures necessary for prevention of disasters, mitigation, preparedness and capacity-building in accordance with the guidelines laid down by the Authority;
- Integrate into its development plans and projects, the measures for prevention or mitigation of disasters in accordance with the guidelines laid down by the Authority;
- Respond effectively and promptly to any threatening disaster situation or disaster in accordance with the guidelines of the Authority or the directions of the Executive Committee in this behalf;
- Review the enactments administered by it, its policies, rules and regulations, with a view to incorporate therein the provisions necessary for prevention of disasters, mitigation or preparedness;

- Allocate funds for measures for prevention of disaster, mitigation, capacity-building and preparedness;
- Provide assistance to the National Authority and State Governments for -
  - Drawing up mitigation, preparedness and response plans, capacity-building, data collection and identification and training of personnel in relation to disaster management;
  - Carrying out rescue and relief operations in the affected area;
  - Assessing the damage from any disaster; carrying out rehabilitation and reconstruction;
- Make available its resources to the National Executive Committee or a State Executive Committee for the purposes of responding promptly and effectively to any threatening disaster situation or disaster
- Local authorities: Subject to the directions of the District Authority, a local authority shall
  - Ensure that its officers and employees are trained for disaster management;
  - Ensure that resources relating to disaster management are so maintained as to be readily available for use in the event of any threatening disaster situation or disaster;
  - Ensure all construction projects under it or within its jurisdiction conform to the standards and specifications laid down for prevention of disasters and mitigation by the National Authority, State Authority and the District Authority;
  - Carry out relief, rehabilitation and reconstruction activities in the affected area in accordance with the State Plan and the District Plan.

3.1.5 National Policy on Disaster Management (NPDM), 2009

The objectives of the National Policy on Disaster Management are:

- Promoting a culture of prevention, preparedness and resilience at all levels through knowledge, innovation and education.
- Encouraging mitigation measures based on technology, traditional wisdom and environmental sustainability.
- Main-streaming disaster management into the developmental planning process.
- Establishing institutional and techno-legal frameworks to create an enabling regulatory environment and a compliance regime.
- Ensuring efficient mechanism for identification, assessment and monitoring of disaster risks.
- Developing contemporary forecasting and early warning systems backed by responsive and fail-safe communication with information technology support.
- Ensuring efficient response and relief with a caring approach towards the needs of the vulnerable sections of the society.
- Undertaking reconstruction as an opportunity to build disaster resilient structures and habitat for ensuring safer living.
- Promoting a productive and proactive partnership with the media for disaster management.



Financial Arrangements -

- Information on the National and state disaster response and mitigation funds.
- Considering that the assistance provided by the Government for rescue, relief, rehabilitation and reconstruction needs cannot compensate for massive losses on account of disasters, new financial tools such as catastrophe risk financing, risk insurance, catastrophe bonds, micro-finance and insurance etc., will be promoted with innovative fiscal incentives to cover such losses of individuals, communities and the corporate sector.

Reconstruction and Recovery Approach –

- The approach to the reconstruction process has to be comprehensive so as to convert adversity into opportunity.
- Incorporating disaster resilient features to 'build back better' will be the guiding principle.
- The appropriate choice of technology and project impact assessment needs to be carried out to establish that the projects contemplated do not create any side effects on the physical, socio-cultural or economic environment of the communities in the affected areas or in their neighbourhood.

Linking Recovery with Safe Development –

- Emphasis will be laid on plugging the gaps in the social and economic infrastructure and infirmities in the backward and forward linkages.
- Efforts will be made to support and enhance the viability of livelihood systems, education, health care facilities, care of the elderly, women and children, etc.
- Other aspects warranting attention will be roads, housing, drinking water sources, provision for sanitary facilities, availability of credit, supply of agricultural inputs, up-gradation of technologies in the on-farm and off-farm activities, storage, processing, marketing, etc.
- Livelihood restoration: State governments will have to lay emphasis on the restoration of permanent livelihood of those affected by disasters and special attention to the needs of women-headed households, artisans, farmers and people belonging to marginalised and vulnerable sections.

3.1.6 Gujarat Disaster Management Act, 2003

The Gujarat State Disaster Management Act, 2003 establishes disaster management in Gujarat, covering relief, preparedness, mitigation, recovery, and rehabilitation. Key provisions include:

Formation of Disaster Management Authority:

- GSDMA oversees state disaster response, supported by government departments, para-statal organizations, district collectors, and local authorities.

Function of State Government:

- One of the functions of the State Government is to develop plans, strategies, and guidelines for disaster management. For example, coordinating disaster preparedness, response, and recovery operations and coordination with stakeholders is the role of the GSDMA.
- Data collection, maintenance of the disaster management plan, conducting awareness campaigns, and ensuring that the required resources are available for disaster response are some of the essential functions.

Roles of Local Authorities and Community Organizations:

- After consulting with state authorities, local authorities are assigned the responsibility of creating and implementing disaster management plans.
- Disaster related activities such as readiness, capacity-building, and relief operations, are some of the functions that the Act makes provisions for the communities, businesses, and non-profit organisations to participate.

Response and Relief:

- The State Relief Commissioner and Collector have the authority to organise emergency relief efforts in the case of a disaster.
- These efforts may involve re-routing and coordinating traffic, evacuating families and communities from dangerous areas, offering first aid and shelter, and demolishing dangerous buildings and structures.

Areas at Risk of Disaster: The Act provides for the declaration of selected areas/ locations as disaster-prone areas, which enables the implementation of disaster related activities.

Violations and Related Penalties apply for spreading false information, making fraudulent aid claims, and obstructing disaster efforts.

Accounts, Audit, and Finance: The Act calls for the establishment of a "Disaster Management Fund" to finance actions connected to disasters. There are provisions for borrowing, auditing, and budget submission.

3.1.7 Gujarat State Disaster Management Policy (GSDMP) 2003

The (GSDMP), 2003 was formulated outlining the state's approach to manage and mitigate the impacts of natural and human-made disasters on overall socio-economic development of the state. The aim of the Gujarat State Disaster Management Policy is to establish systems, programs, and resources to reduce disaster risks, ensure effective response, protect lives and property, minimise economic disruption and environmental damage, and support sustainable development.

Key Principles:

- A collaborative, cross-sectoral approach involving all sectors such as agriculture, industry, and environment
- Integrating disaster management into development planning to promote sustainable growth
- Adopting a multi-hazard approach to prepare for both natural and man-made disasters
- Continuous and sustainable approach with a focus on capacity building at all levels to maintain preparedness.
- Leverage existing government machinery while encouraging effective coordination among agencies, NGOs, the private sector, and communities to ensure timely and efficient responses.
- Promote autonomy, equity, and non-discrimination in relief efforts, ensuring aid reaches all, regardless of socio-economic status.
- Legal framework underpins the policy, ensuring that institutions are empowered to act during emergencies.
- Local sensitivity, financial sustainability, risk sharing through insurance, and cost recovery mechanisms to reduce the economic burden of disasters.
- Knowledge sharing with plans to establish a dedicated research institute to support training and disseminate best practices. Disaster management education to be incorporated into school curricula, fostering a participative culture and community involvement for effective disaster mitigation and response.

Key Objectives

- GSDMP focus on assessing risks and vulnerabilities, developing prevention and mitigation strategies, and clarifying stakeholder roles for effective disaster management.
- Ensure access to resources, equipment, and funding, along with mobilizing relief, rehabilitation, and recovery efforts.
- Emphasize awareness, training, and preparedness in communities and agencies while building their capacities and establishing response systems.
- Promote coordination with national, state, and international agencies and ensure non-discriminatory relief to all affected individuals.
- Integrate risk reduction into development programs, encourages risk sharing and transfer mechanisms, and addresses gender issues by empowering women for long-term mitigation.
- Establish disaster management as a specialized discipline with a dedicated cadre.

Key Features

- The Government of Gujarat can formally declare a disaster to enable rapid response. GSDMA is the nodal agency in the overall framework for disaster management in the state.
- The Multi-Hazard Approach prepares for all potential disasters, including natural and human-made events.
- Promote disaster management education in schools and communities.
- Utilize both government funds and international aid for disaster response.

Institutional Framework

The Gujarat State Disaster Management Authority (GSDMA) serves as the nodal agency responsible for policy formulation, coordination, and monitoring of disaster management efforts.

The State Relief Commissioner (SRC) oversees disaster relief operations across multiple districts, ensuring effective coordination.

At the district level, District Collectors lead disaster management initiatives, directing efforts and mobilizing resources.

Local authorities and NGOs play a crucial role in supporting community-level disaster management activities, fostering preparedness, and assisting with response efforts on the ground.

Phases of Disaster Management

Pre-Disaster Phase (Prevention, Mitigation, and Preparedness)

- Risk assessments and vulnerability mapping.
- Development of early warning systems and emergency plans.
- Community engagement and capacity building.
- Integration of disaster management into infrastructure planning.

Impact Phase (Emergency Relief):

- Immediate search, rescue, and medical care.
- Provision of temporary shelter, food, and sanitation.
- Restoration of essential infrastructure and services.
- Security measures to prevent law and order breakdown.

Post-Disaster Phase (Reconstruction and Rehabilitation):

- Detailed damage assessments.
- Reconstruction of infrastructure and housing.
- Assistance with livelihood restoration.
- Long-term planning for sustainable development.

3.1.8 Gujarat State Disaster Management Plan (GSDMP 2020-21)


Government of Gujarat

GUJARAT STATE DISASTER MANAGEMENT
PLAN 2023-24
VOLUME 1

GSDMA

GUJARAT STATE DISASTER MANAGEMENT AUTHORITY
Block No. 11, 5th Floor, Udyog Bhavan, Gandhinagar

The plan is guided by the National Disaster Management Act, 2005, and the Gujarat State Disaster Management Act, 2003. These acts entail a transition from relief-centric activities in a reactive mode to a more proactive, integrated approach that focuses on DRR through preparedness and mitigation measures.

The GSDMP provides a high level snapshot of vulnerable population within the state and has disaggregated information based on factors such as below poverty line (BPL) population, classification of marginal workers (census, 2011), persons with disability (census, 2011), old age population (Census, 2011), population below six (6) years of age (census, 2011), old age population (census, 2011), and registered pregnancies (NFHS, 2019). The plan further discussed structural vulnerabilities along with economic and environmental vulnerabilities based on the 2011 census as the baseline. The plan addresses the capacity issues and disaster risk governance in the state.

Based on the above the GSDMP identifies agencies responsible, and their functions for reduction of disaster risk to achieve resilience based on nine (9) categories of hazards i.e. Earthquake, cyclone and wind, tsunami, floods, urban floods, nuclear and radiological disasters, chemical (Industrial) disasters, fire hazards, and biological and public health hazards. For each hazard, the approach incorporates key themes articulated in the Sendai Framework and additional ones based on a broader approach to DRR, into the planning framework. These are grouped under the following six thematic areas for DRR:

1. Understanding Risk
2. Inter-Agency Coordination
3. Investing in DRR – Structural Measures
4. Investing in DRR – Non-Structural Measures
5. Capacity Development
6. Climate Change Risk Management

The plan stresses on making all stakeholders, from government bodies to local communities, aware and prepared. Regular training, awareness campaigns, and mock drills are some of the preparatory measures outlined in the plan. Usage of technology like early warning systems and disaster mapping is recommended.

It spells out detailed procedures for immediate disaster response, relief, and long-term

recovery, including health services, search and rescue operations, and rehabilitation. It embodies the "Build Back Better" strategy for post-disaster reconstruction. The SDMP stresses on active community involvement while considering gender sensitivity and the inclusion of vulnerable groups. It encourages local disaster management committees to engage in preparedness and mitigation efforts.

The Loss and Damage component of the Gujarat State Disaster Management Plan (GSDMP) provides a framework for assessing the impact of disasters on the state's social, economic, and environmental sectors. It follows an approach to evaluating both immediate and long-term damage, enhancing recovery and resilience efforts.

On Loss and Damage the SDMP stresses upon the importance of assessing these impacts for a comprehensive response and recovery. The suggested process in the document includes:

Loss and Damage Assessment

- **Loss Assessment:** Estimating lives lost, damage to critical infrastructure, service disruption, and loss of livelihoods.
- **Damage Assessment:** Estimating physical damage to structures, roads, bridges, utilities, and agricultural land.

Data Collection and Reporting:

Effective data management is essential to understand the scale of loss and damage. The plan highlights systematic data collection during and after disasters through coordination with government agencies, local authorities, and community organisations. Key agencies like the Gujarat State Disaster Management Authority (GSDMA) and the Revenue Department play important roles. Immediate assessments are conducted during the disaster for rapid relief deployment, while detailed assessments are done post-disaster to guide long-term recovery.

Post-Disaster Needs Assessment (PDNA): PDNA is identified as a critical tool for evaluating the full impact of disasters and guiding recovery efforts. It involves:

- **Preliminary Damage Assessment:** A rapid evaluation conducted immediately after the disaster to assess the scope of losses and damage and prioritise emergency responses.
- **Detailed Assessment:** Conducted post-disaster to assess long-term impacts on housing, infrastructure, and agriculture, and to estimate financial resources for recovery and reconstruction.
- **Recovery Framework:** Based on the detailed assessment, the plan recommends rebuilding efforts with a focus on resilience, sustainability, and the "Build Back Better" principle.

The PDNA assessment covers 23 thematic areas as follows:

- **Social Sectors:** Housing, Health and Population, Nutrition, Education, Culture
- **Productive Sectors:** Agriculture, Irrigation, Commerce, Tourism and Financial Sector
- **Infrastructure Sectors:** Electricity, Communications, Community Infrastructure, Transport, Water, Sanitation & Hygiene
- **Cross-cutting Sectors:** Governance, Disaster Risk Reduction, Environment & Forestry, Employment & Livelihoods, Social Protection, Gender Equity & Social Inclusion, Poverty and Human Development, Macroeconomic Impact Assessment.

Economic Loss: This component calculates the direct and indirect costs of disasters. Direct losses include the destruction of property and infrastructure, while indirect losses involve disruptions to economic activities, livelihoods, and increased public expenditure on recovery. The SDMP prioritises vulnerable sectors, like agriculture and small businesses, to mitigate these losses.

Environmental and Social Impact: The plan also assesses the loss and damage to environmental resources such as forests, water bodies, and ecosystems, which are vital to Gujarat's economy and rural livelihoods. Social impacts include displacement, loss of cultural heritage, and psychological trauma.

Relief and Compensation Mechanisms

The SDMP outlines compensation and relief mechanisms for affected populations, ensuring timely disbursement of funds to vulnerable groups like women, children, and economically disadvantaged communities. Relief kits, financial assistance, and infrastructure rebuilding are initiated based on loss and damage assessments.

Missing components -

- *It is important to note that the GSDMP does not recognize extreme heat as a climate hazard and provides no specific guidance on addressing it.*
- *While the classification of economic and non-economic loss and damage may not be explicitly defined, the sector-based coverage is comprehensive, addressing non-economic loss and damage such as cultural heritage, environment and forestry, social protection, gender equity and social inclusion, poverty, and human development.*

3.1.9 Ahmedabad District Disaster Management Plan (DDMP)

The DDMP 2024-25 of Ahmedabad District[1] outlines strategies for preparedness, mitigation, response, and recovery. Loss of life and property due to disasters is the main focus of the plan.

Hazards such as floods, heat-waves, earthquakes, cyclones, and industrial accidents have been covered.

Key Components of the plan include the following:

Institutional Arrangements: The Ahmedabad District Disaster Management Committee (DDMC), chaired by the District Collector, is assigned the responsibility of overseeing disaster preparedness and response. DDMC functions include coordination between various government departments, NGOs, and community groups. Specific functions such as search and rescue, shelter management, health, and sanitation are assigned to different task forces.

Hazard Vulnerability and Risk Assessment: Ahmedabad's vulnerability to multiple disasters, such as earthquakes, floods, and heat waves require a detailed risk assessment for the district by DDMC, where areas like Ahmedabad city, Daskroi, Dholka, and Dhandhuka talukas have been identified as risk prone. Located in Seismic Zone III, the district is prone to earthquakes, and its proximity to the Sabarmati River increases flood risks.

Preparedness and Mitigation: The plan stresses preparedness through regular mock drills, capacity building, and public awareness programs. Structural and non-structural mitigation measures include enforcing building codes, retrofitting vulnerable structures, and improving early warning systems. Community engagement and education have been identified as key areas for disaster preparedness of residents.

Response Mechanism

The District Emergency Operation Centre (DEOC) gets activated during a disaster for coordinated response efforts. Task forces, led by government departments, enable timely rescue, relief, and rehabilitation. The plan outlines detailed procedures for evacuation, research and rescue, and provision of essential services like water, food, and medical aid.

Recovery and Rehabilitation

The post-disaster phase includes an assessment of damages, restoration of critical infrastructure, and rehabilitation. The DDMP focuses on an integrated recovery strategy that incorporates long-term measures to resilience building through the "Build Back Better" approach.

Public Awareness and Capacity Building

A key focus is creating awareness and capacity at the community level. This includes regular training for local disaster management teams, public education campaigns, and the involvement of local self-government institutions in disaster preparedness.

The DDMP for Ahmedabad, unlike the GSDMP, gives prominence to extreme heat as a hazard and lays out the detailed action points in case of an extreme heat event.

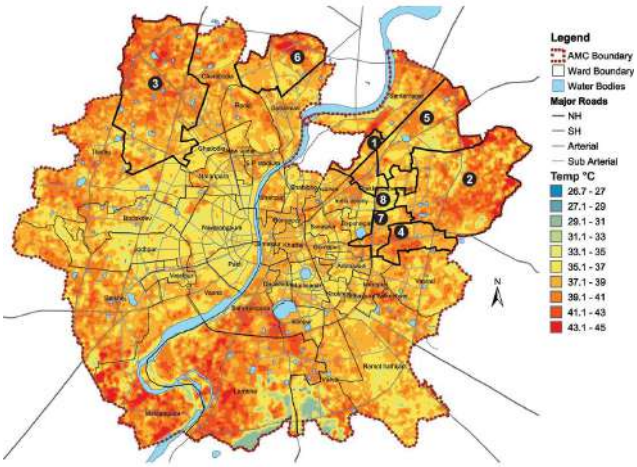
1 Ahmedabad District Administration. (2024). District Disaster Management Plan: Ahmedabad. Gujarat State Disaster Management Authority.

Heat Early Warning System (HEWS)

Temperature-based alerts for Ahmedabad and Surat districts of Gujarat based on Indian Meteorological Department's (IMD) warnings for expected heat waves in the tropical savanna climate[1].

Ahmedabad

- The district has been vulnerable to frequent heat waves in the last decade, with one in 2010 causing 1300 fatalities.
- Maximum temperature during summer months from 1951 to 2020 ranged between 29.39 and 47.41 degrees.
- The district could be most vulnerable to heat waves during April and May.
- Ahmedabad has infrastructural coping opportunities in terms of high access to drinking water in the household premises (58.62%) and ownership of fan/cooler/air conditioners (98.41%).



Map 7. The image shows a heat map with the 8 hottest areas -Kubernagar, Nikol, Gota, Odhav, Naroda, Chandkheda, Viratnagar, Saijpur Bogha in Ahmedabad[2]

Type of alert	Cutoff criteria	Cutoff temperature
Red alert	95th percentile	45
Orange alert	85th percentile	43
Yellow alert	75th percentile	41

Table 1. Temperature Thresholds (TT in Celsius) for the period of March-June (1951-2020) for Ahmedabad

Type of alert	Month			
	March	April	May	June
Red	44	46	46	42
Orange	41	44	44	41
Yellow	40	42	42	40

Table 2. Month-wise Temperature Thresholds (TT in Celsius) 1951-2020 for Ahmedabad

1 *Gujarat Institute of Disaster Management. (2023). Report on Extreme Heat Exposure and Actions for Gujarat. Retrieved from https://gidm.gujarat.gov.in/sites/default/files/Report-on-Extreme-Heat-Exposure-and-Actions-for-Gujarat-jun-2023.pdf*

2 *Ahmedabad Mirror. (2023). Heat is on. Retrieved from https://www.ahmedabadmirror.com/heat-is-on--419c/81854759.html#goog_rewarded*

3.1.10 Surat District Disaster Management Plan (DDMP) 2021[1]

The plan outlines guidelines for disaster management within Surat city, focusing on preparedness before, prompt action during, and rapid/detailed loss assessment post disasters including rescue, relief, relocation, and rehabilitation efforts. It outlines preventive measures for natural disasters and disease outbreaks. Specific roles and responsibilities are outlined for employees and officers, and training sessions enhance community awareness and participation.



There is no mention of loss and damage or its assessment within the document.

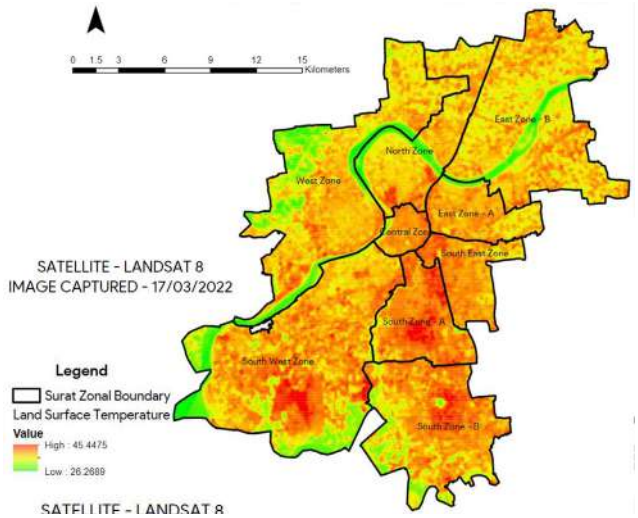
1 *Surat Municipal Corporation. (2021). District Disaster Management Plan: Surat Municipal Corporation. Gujarat State Disaster Management Authority. Retrieved from http://www.gsdma.org/uploads/Assets/ddmp2021/DDMP-Surat-MC.pdf*

Heat Early Warning System (HEWS)

Temperature-based alerts for Ahmedabad and Surat districts of Gujarat based on Indian Meteorological Department's (IMD) warnings for expected heat waves in the tropical savanna climate[1].

Surat

- Maximum temperature during summer months from 1951 to 2020 ranged between 28.79 and 44.45 degrees, with the district being most vulnerable during months of April and May.
- The district has greater proportions of households with access to drinking water in the household premise and ownership of fan/cooler/air-conditioners, compared to all districts' averages. However, the insurance coverage and governmental program utilization was lower than the state average. This demands more programmatic attention to address the effects of extreme heat events.



Map 8. Land Surface Temperature Map of Surat 2022

Type of alert	Cutoff criteria	Cutoff temperature
Red alert	95th percentile	42
Orange alert	85th percentile	40
Yellow alert	75th percentile	38

Table 3. Temperature Thresholds (TT in Celsius) for the period of March-June (1951-2020) for Surat

Type of alert	Month			
	March	April	May	June
Red	42	43	42	39
Orange	40	41	40	37
Yellow	38	40	39	37

Table 4. Temperature Thresholds (TT in Celsius) for the period of March-June (1951-2020) for Surat

1 *Gujarat Institute of Disaster Management. (2023). Report on Extreme Heat Exposure and Actions for Gujarat. Retrieved from https://gidm.gujarat.gov.in/sites/default/files/Report-on-Extreme-Heat-Exposure-and-Actions-for-Gujarat-jun-2023.pdf*

2 *Desai, V., Magotra, R., & Jha, N. (2023). Climate adaptive and gender integrated heat wave action plan of Surat City, India. Integrated Research and Action for Development (IRADe).*

3.1.11 Existing official process for estimating Loss and Damage

Assessment of losses and damages

Once a disaster is announced, the first step is to coordinate rescue and relief operations. The team on the ground, whose size and composition are determined by the magnitude of the disaster, collects damage-related data.

Once the disaster ends, the revenue department and disaster management officials at the district level verify the information and upload it to the centralised National Disaster Information Management System.

State Disaster Management Authority (SDMA) re-verifies the information and calculates the economic value based on the Norms of Assistance, a Central document which assigns values to different losses, to avail funding from the state disaster relief fund and the state government's budget.

If there is a gap in funding, they prepare a memorandum to close the gap with funding from the National Disaster Relief Fund. It is subject to approval by a central team that revisits the data.

In the case of slow-onset extreme events like drought, agencies monitor its onset by looking at precipitation and soil moisture levels. After the onset, district and panchayat level teams create seed, fodder banks and create jobs under Mahatma Gandhi National Rural Employment Guarantee Act 2005.

When state decides that the existing mechanism is unable to handle disaster management operations, international agencies like World Bank are roped in to carry out Joint Rapid Damage and Needs Assessment.

Precedent:

A **Joint Rapid Damage and Needs Assessment (JRDNA)** in collaboration with the state government, the World Bank and the Asian Development Bank, was pivotal in evaluating the impacts of the Uttarakhand floods in 2013 and the Kerala floods in 2018.

Use of robust tools

In 2018, India for the first time, used the post-disaster needs assessment tool for the Kerala floods, which had already been used across the world since 2008. In 2019, cyclone Fani in Odisha was the second disaster that used this tool. A post-disaster needs assessment has been undertaken for the Assam floods of 2022 as well.

It replaces an accepted tool called damage, loss and needs assessment, which focuses on physical infrastructure and not on social sectors. In India, the Bhuj Earthquake of 2001 and tsunami of 2004, used damage, loss and needs assessment for funding from the World Bank.

Besides analysing immediate damage, a post-disaster needs assessment, carried out along with international agencies such as World Bank, looks at macro-economic costs such as the impact of the disaster on the local economy. It has a third component that looks at improving the resilience of the region.

In 2019, India released a manual for this assessment, and as of this year, at least eight states are using it for flood management. The country plans to adopt this tool for all types of disasters over the next three years.

Precedent:

The Kerala floods 2018, cyclone Fani in Odisha in 2019 and Assam floods of 2022 used the **Post-Disaster Needs Assessment tool** for assessing the impact of the disaster and improving resilience.

Fund compensation

While the disaster is underway, only relief is provided. All compensation occurs post-disaster. Each state has a disaster relief fund, which is financed by the Union Ministry of Home Affairs, and the respective state/UT budget. The amount and the Centre-state share is decided by the Finance Commission.

State relief funds are allocated money based on a combination of capacity (as reflected through expenditure), risk exposure (area and population) and hazard and vulnerability risk index.

The Fifteenth Finance Commission (2021-26)[1] allocated a total of ₹1,60,153 crore for disaster management, with the Centre contributing ₹1,22,601 crore. This fund is disbursed annually in six instalments to state funds, addressing issues like urban floods and landslides. States may provide additional compensation to expand coverage; for example, Maharashtra has previously offered compensation for farmer suicides[2].

1 Government of Tamil Nadu. (2021). Gist of Fifteenth Finance Commission Main Report Along with Action Taken Report. Finance Department, Government of Tamil Nadu.

2 National Disaster Management Authority. (n.d.). XVth Finance Commission Recommendations for Disaster Risk Management.

3.2 Ahmedabad City

3.2.1 Economic Impacts

Trade (supply chains, transport infrastructure, debt)

Increased risk of spoilage of perishable goods and produce being sold by vendors, increasing risk of debt was noted in a study (Trahan et al., 2023).

Loss of Property

Reports indicated the collapse of 5,098 houses due to flooding in Ahmedabad city as early as 1927. A study provided evidence on formal/ public housing ameliorating the vulnerability and exposure of residents to flooding and water-logging, as compared to those living in informal settlements with lack of basic infrastructure, unhealthy surroundings (Mahadevia et al., 2018). More severe damage of household assets was noted in informal settlements, with losses incurred higher than total household income (Mahadevia et al., 2018). Additionally, 1500 vehicles were reported to be severely damaged.

Loss of Infrastructure

- *In 2022 floods, losses worth 1200 crores INR were incurred in trade, property and infrastructure*

According to reports, losses worth 1200 crores INR were incurred in trade, property and infrastructure during floods in 2022. As per Ahmedabad Chamber of Commerce and Industry, 25% of the total amount was registered by small traders without insurance cover.

Loss of livelihoods

Respondents from slum settlements reported ***2.5x higher loss of working days*** than rehabilitated residents in formal public housing, resulting in higher loss of income and education days (Mahadevia et al., 2018). Formal housing was noted to increase their savings and enable better living conditions. Flood-affected low-income populations were noted to receive insignificant help from community/ community-based organisations for economic recovery, with the government seen as the primary stakeholder for recovery (Srivastava & Shaw, 2015).

Reports suggest that parametric insurance schemes for extreme heat for self-employed women in India are gaining popularity, and have assisted women in Ahmedabad in compensating for impacts of extreme heat on livelihoods.

3.2.2 Non - economic Impacts



Loss of Life

In 2010, Ahmedabad recorded ***1,344 excess deaths, and over 2,300 people died*** in India during a 2015 heatwave (NDRC, 2016). Beyond the loss of life, extreme heat events led to economic losses, power outages, and even protests. During the 2015 heatwave, Ahmedabad reported 20 deaths (NRDC, 2016).

In 2017, heavy rain impacted 4 Talukas, including Ahmedabad, ***affecting 10,000 people***, with 20 deaths and over 950 houses damaged (GSDMA, 2021). A recent study shows Ahmedabad's higher annual attributable mortality (300 deaths) compared to other Indian cities (Bont et al., 2024).



Displacement

Large-scale displacement of poor households residing in informal self-built settlements caused by city development and infrastructure projects, and subsequent resettlement carried out at distant locations, adversely affecting access to employment, healthcare, education and other basic facilities (Patel et al., 2015). ***Records of displacement directly induced by extreme climatic events were not found.***



Heat-related loss and damage

841 heat-related emergencies, including 69 cases of heatstroke were reported in 2024, highest in the past decade.



Increased health-related issues/ burden on the health systems:

Higher frequency of health issues within three months of rainfall, higher occurrence of fatal diseases were noted in informal settlements (Mahadevia et al., 2018).



Loss of community resilience

The longest heat waves were found to be prevalent in Ahmedabad (15 days) with relatively higher annual attributable mortality (300 annual attributable deaths) as compared to other cities in India, highlighting the significant health-related effects of heat waves (Bont et al., 2024).



Socio-economic inequality

Gender disparity regarding phone ownership and access to early warning systems is particularly marked. Low income levels pose a serious limit on coping capacities to heat, and their prioritisation of income over health poses further risk to heat exposure and illness (Trahan et al., 2023).



Loss of ecosystem services and biodiversity

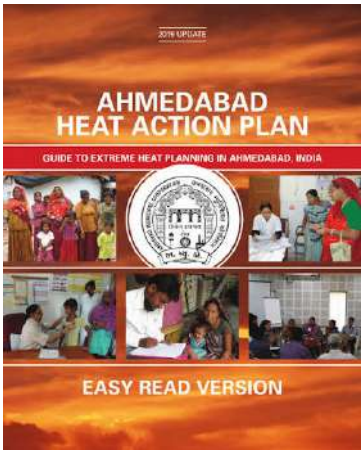
The increase in green cover has been recognized as a major requirement in reducing the effect of extreme heat and urban heat islands across the city, as currently the ***green cover is 9.41 sq km, a drop by 48% since 2011.***

3.2.3 Policy Review

Heat Action Plan (HAP) 2016

Post 2010 heat wave, the Ahmedabad Municipal Corporation (AMC) partnered with a coalition of academic, health, and environmental groups to improve the city's heat disaster response and reduce heat-related health risks. The emerging Heat Action Plan, published in 2013, developed a guide to extreme heat planning in Ahmedabad and included an early warning system for extreme heat. A 2018 study evaluated the effectiveness of the Ahmedabad HAP before and after implementation. The study found that an estimated 2,380 deaths were avoided in the post-HAP period. Subsequently, a 2019 Heat Adaptation plan was developed. Its key strategies included -

- Public awareness and outreach - to disseminate information on risks of heat waves and precautionary measures through media outlets, pamphlets, advertisements, SMS and radio services.
- Early Warning System - creation of formal communication channels to alert stakeholders about extreme temperatures forecast by Regional Meteorological Centre - Ahmedabad, Indian Meteorological Department (IMD)
- The Capacity building of healthcare professionals focused on primary medical officers, paramedical staff, and community health staff to treat and manage heat-related cases
- Cool Roof Program - mandatory, voluntary and low-income housing focused measures

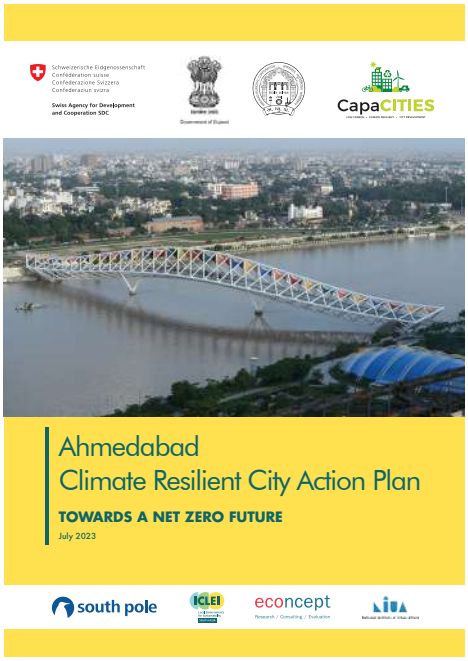


Implementation of the HAP in Ahmedabad was associated with a reduction in all-cause mortality rates during extreme heat events. The HAP serves as a guide for other cities attempting to increase resilience to extreme heat. However, aspects of heat-related health expenditure, loss and damage have not found specific mention in the action plan.

The Ahmedabad Heat Action Plan (HAP), implemented in 2013, has significantly reduced heat-related mortality. A study evaluating the HAP's effectiveness estimated ***that approximately 1,190 deaths were avoided annually in 2014 and 2015*** *compared to the baseline period of 2007–2010[1].*

1 *Hess, J. J., et. al., (2018). Building resilience to climate change: Pilot evaluation of the impact of India's first heat action plan on all-cause mortality. Journal of Environmental and Public Health.*

Ahmedabad Climate Resilient City Action Plan (2023)



The objective of the Ahmedabad Climate Resilient City Action Plan (CRCAP) is to address climate risks by promoting climate-resilient infrastructure and reducing greenhouse gas emissions. The plan envisions achieving net zero emissions by 2070, focusing on energy-efficient buildings, renewable energy, waste management, sustainable mobility, urban greening and disaster management.

The CRCAP incorporates approaches for conserving energy, utilising renewable energy, managing waste, promoting sustainable transportation, enhancing green spaces, and handling disasters. Enhancing governance, managing data, overseeing progress, developing skills, raising public awareness, and securing funds for climate initiatives are crucial for effective execution of the plan.

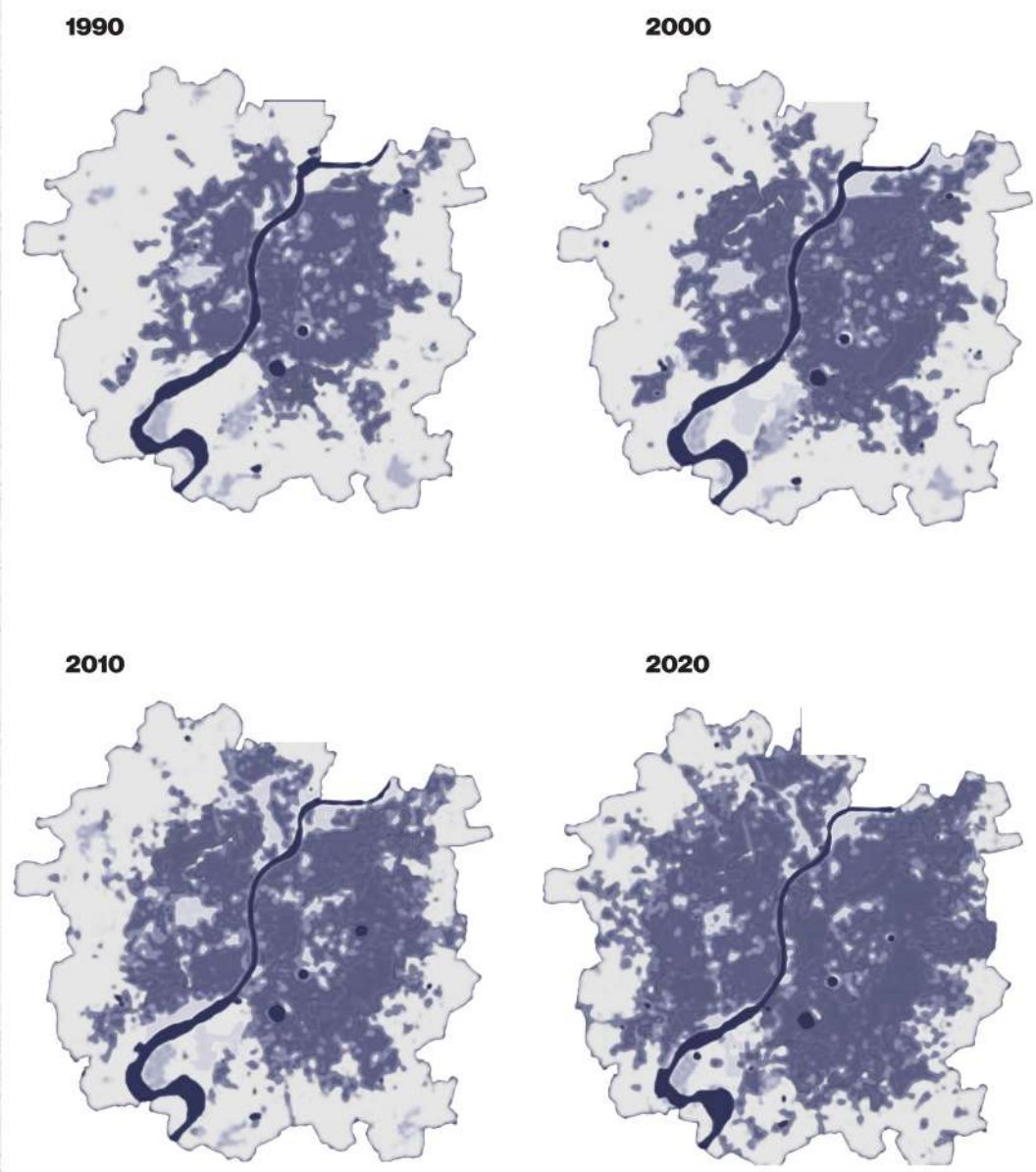
Challenges: *The actual implementation of proposed actions requires substantial financial resources, technological advancements, and capacity building. The plan acknowledges the need for over USD 85,000 billion until 2070 for financing climate action projects[1].*

The plan sets clear targets, such as achieving 100% green and energy-efficient buildings by 2050, 85% renewable energy usage in commercial and industrial sectors by 2070, and 100% circular waste management by 2030[1].

1 *Ahmedabad Municipal Corporation. (2023). Ahmedabad Climate Resilient City Action Plan: Towards a Net Zero Future. ICLEI South Asia.*

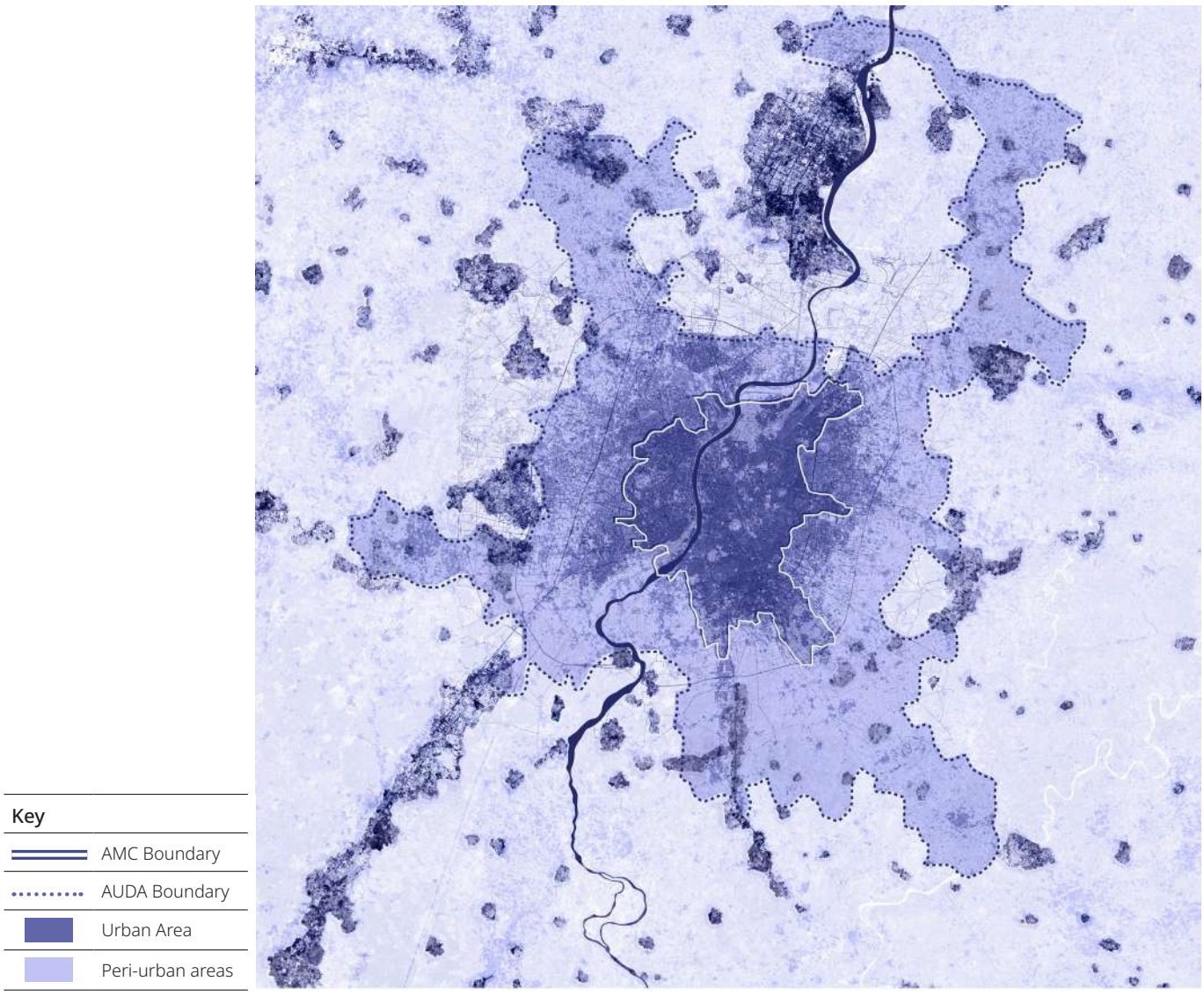
Growth and Evolution of Ahmedabad

The figures illustrate recent growth beyond the municipal limits of Ahmedabad into the areas falling under regional development authorities, such as the Ahmedabad Urban Development Authority. While these authorities use planning tools, including Town Planning Schemes, for growth management, the pace of development at times outruns their ability to provide adequate, planned services.



Map 9. Growth and evolution of Ahmedabad in last three decades

Above all, this disparity heightens vulnerability among residents, who are often burdened with self-provisioning for crucial services. These stresses are further exacerbated during extreme climatic events such as heat waves, droughts, and flooding. The visualization further maps Ahmedabad's built-up area growth over decades, showing its extension beyond municipal boundaries and highlighting it's proximity to vulnerable zones, thereby offering insights into exposure of communities and urban infrastructure to climate risks.



Map 10. Urban and peri- urban growth of Ahmedabad

3.3 Surat City

A comprehensive review was conducted to identify the aspects of loss and damage covered by published literature, relevant policies and plans at the district and city levels for Surat. The findings are given below:

3.3.1 Economic Impacts



Slowdown of Economic growth

Economic growth was recognized as an uncertainty due to sensitivity to global level changes and external shocks, increasing inflow of migrant workers required to support labour-intensive industries, outsourcing of goods and services network, shifting of production centres, international competition, etc. (Surat Resilience Strategy 2011).



Business and Trade

- *Loss of 1.51 million INR to textile weavers*
- *160 billion estimated total industrial loss (direct & indirect)*

Post 2006 floods, 145 textile-weaving businesses suffered a loss of approximately INR 1.51 million each and required an average of 49 days to return to normal (Bahinipiti et al., 2015). Labour shortage due to post-flood migration was reported to affect productivity. None of the surveyed 145 businesses were unable to access insurance due to location of businesses in risk-prone areas. However, their risk perception about potential impacts of future floods was moderate, which indicated a lack of future investment in insurance and adaptation measures. An economic loss of >210 billion INR is estimated in certain reports (SANDRP, 2007). Capital and stock losses reported from major industries including diamond, dyeing & processing, embroidery and weaving total up to 14.5 million INR. Total industrial loss (direct and indirect) is estimated at 160 billion (Thakar 2007). On average, loss in business was reported as approximately 36,000 INR across a range of establishments (Acharya et al., 2006). Recently in 2024, news reports suggest losses incurred due to flooding, with submergence of textile shops in Saroli and Kumbhariya causing losses of stock worth >30 lakh INR.

Food security

- *20 lakh people trapped without food, drinking water, milk, for four days and nights*

Certain reports have mentioned disruption in food supply during 2006 floods for days (SANDRP, 2007), approximately 30% of survey respondents not having had access to food stock or drinking water (Acharya et al., 2006). Another report mentions unfair heavier pricing by the owner of a local food store to benefit from the crisis during the 2013 floods, when the community members in Kosad Awas experienced chest-level flooding.

Loss of infrastructure

- *public infrastructure loss equivalent to 25 billion INR*
- *hospital damage incurred 0.5 - 7 million INR*

In the aftermath of 2006 floods in Surat, losses to public infrastructure including the dam, flood embankments, electricity and telephone lines totalled 25 billion INR i.e. USD 544 million (Bhat et al., 2013). Certain hospitals have reported damage from 2006 floods of 0.5 - 7 million INR (ACCCRN, 2010). According to a survey on impact of extreme weather events on livelihood, access to modes of transport and its affordability, 54% respondents reported complete loss of mobility (Mahadevia et al., 2022). While moderate access to reliable and affordable mobility was opined by communities of Morarji Vasahat, Kosad Awas and Ugat, mobility scored lowest in terms of resilience to extreme events (Rangwala & Chandra, 2018).



Loss of property

- *7821 houses damaged (2006)*
- *Loss to slum households*
- *Hotel Infrastructure: 5000 - 1.2 million INR*
- *Inundation of 6000 households (2020)*
- *955 evacuated (2024)*

In 1968, a total area of 1360 sq.km was flooded resulting in major loss and damage to life and property. Post 2006 floods, 7821 houses were damaged either structurally or completely, leaving many people stranded, having lost all savings (Thakar 2007). A financial loss of approx. 30,000 INR per household was reported on average, with very few households having insurance coverage. Areas of Rander, Jahangirpura, Mora Bhagal, Adajan and Palanpur Patia in the West Zone suffered the highest overall losses, while in the South-East zone were highly significant in terms of ratio to household earnings in predominantly slum areas (Acharya et al., 2006). Damage to hotel infrastructure ranged from 5000 INR to 1.2 million INR (ACCCRN, 2010), and approx. 1500 livestock deaths were recorded (Thakar 2007).



Loss of livelihood

- *15-30 days loss of work for 77%*
- *Among 513 households; 63% loss of income*

In 2020, heavy precipitation in catchment areas of Mithi Khadi (South-East zone) led to flooding of sewage-filled creeks, causing inundation of approx. 6000 households, evacuation of 750 people and rescue of 190 people, severely affecting areas of Limbayat and Parvat Patiya. In 2024, flooding and waterlogging damaged more than 50 houses, and the Surat Municipal Corporation rescued and evacuated 955 people to safer areas.

Loss of work productivity due to extreme events was reported to be 15-30 days for 77% of the working population, resulting in loss of income as well as labour shortage in industries (ACCCRN, 2010). Across 513 households in settlements of Morarji Vasahat, Ugat and Kosad Awas, 63% respondents reported losses in income (Rangwala & Chandra, 2018). Poor settlements suffered the maximum, requiring longer recovery periods (Surat Resilience Strategy 2011). In 6 informal settlements of Surat city, 52% respondents reported monthly productivity loss accounting for approx. 2000 INR, with an additional 48% reporting approx. 500 INR lost monthly (Desai et al., 2023).

Health expenditure

- *44% respondents report sickness*
- *highest in low income settlements*
- *Informal settlement - 50% report loss of income (1000-1999 INR)*

In a survey conducted post 2006 flooding, approximately 44% respondents reported sickness in households, and incidence was noted to be highest in the South East zone, housing most of the low-income families (Acharya et al., 2006). According to a recent study conducted in 6 informal settlements of Surat city, 50% of people reported loss of income due to heat-associated illness and leaves, with maximum loss of wages of 1000-1999 INR per month (Desai et al., 2023).

Damage to education infrastructure

- *10 educational institutions loss of 23000 - 10 million INR*

10 educational institutions surveyed in Surat reported having suffered damages of 23000 INR to 10 million INR from 2006 floods, with 1 college reporting extreme impact, 5 reporting high impact, and others with moderate impact (Acharya et al., 2006).

3.3.2 Non - Economic Impacts



Loss of life

Post the major Ukai floods in 2006, 150 human deaths were reported, with ***3 million people affected*** (Thakar 2007). Another 100 people died due to leptospirosis outbreak during the floods (SANDRP 2007).



Displacement and migration

Surat city is characterised by a high immigration rate, with "pull" factors attracting migrants from areas within Gujarat and other states (Surat CRS, 2011). According to Census 2011, ***migrants comprised approximately 26% of the 4.462 million population*** in Surat City. According to a survey, the ***main threats perceived by migrants in Surat were flooding and water-logging events*** due to heavy rains, as well as flood-induced displacement from their city homes (Santha et al., 2015).



Loss of mental well-being, psychological stress

A study conclusively found the prevalence of post-traumatic stress disorder (PTSD) among community members exposed to the floods of 2006, and highlighted the ***effects to be more common among female and middle aged victims*** (Patel et al., 2015). The symptoms of PTSD reduced in most of the victims as noted in follow-up visits, however, previous experiences of the disaster resulted in risk of longer prevalence (Patel et al., 2015).



Increased health-related issues / burden on the health systems

As per news reports, 41 cases of health issues were reported post flooding in July 2024, and many vector breeding sites were identified. According to a survey conducted across 513 households in Surat, 75% reported severe or recurrent health impacts related to extreme heat and water-logging (Rangwala & Chandra, 2018).

The first study of heat-related mortality on the urban population of Surat city was conducted in 2015, revealing an ***increase of 11% mortality at temperatures exceeding 40°C, with an 18% increase during extreme danger days of high heat index*** i.e. high temperature and humidity (Desai et al., 2015). Apart from mortality, other effects of extreme heat recognized by the study included the resulting impact on work performance and industrial economy, resulting heat disorders such as muscle cramps and co-morbidity in triggering the severity of other illnesses.



Social cohesion

Social cohesion was generally higher in long-term communities like Morarji Vasahat compared to Kosad Awas, a migrant-dominated slum relocation site (ACCCRN 2010; Rangwala & Chandra, 2018). Low social cohesion hindered resilience, as seen in Kosad Awas, where women hesitated to open windows, increasing heat-related health risks due to poor ventilation (Rangwala & Chandra, 2018). During the 2013 floods, worsening cohesion was evident when local store owners raised prices to exploit the crisis (Rangwala & Chandra, 2018). ***Stronger social bonds, formed through shared disaster experiences, enhanced resilience in areas like Morarji Vasahat and Ugat,*** both prone to flooding (Rangwala et al., 2018).



Socio-economic inequality

Differential loss and damage experienced by communities is apparent from published literature. Informal settlements with proximity to tidal creeks, low socio-economic capacity are more vulnerable to flooding events. A survey conducted across 6 informal settlements reported that the majority of households suffered from overcrowding with poor ventilation, use of heat-trapping housing materials causing higher indoor temperatures, more use of public transport or non-motorized transport, increasing duration of exposure to heat.



Loss of Ecosystem services and biodiversity

Warming temperatures increasing the likelihood of algal blooms, water quality deterioration, shrinkage of water bodies, loss of temperature-sensitive aquatic species, change in abundance and distribution of coastal and marine species are mentioned as concerns in Surat Resilience Strategy 2011. Surat aims to increase green cover throughout the city through creation of biodiversity parks and urban gardens.

3.3.3 Policy Review

Surat City Resilience Strategy (CRS) – 2011 and 2017

The plans recognize the exposure and vulnerability of Surat city to climatic events such as flooding, extreme heat and sea level rise, and the importance of preventive measures. The plans focus on addressing vulnerabilities related to climate change, rapid urbanisation, waste management, transport and mobility while laying out the next steps for building resilience at the city level. Key initiatives include-

- Establishment of early warning systems for monitoring of water yields in Tapi river, flooding risk, climate change trends
- Strengthening road connectivity, mobility and transport services, road safety through audit and traffic awareness
- Ensuring affordable housing through demand assessment, citizen awareness about housing rights, innovation in building construction and design
- Improving water availability and quality through groundwater assessment, real-time monitoring of river Tapi, water audit, preservation of tidal creeks
- Promote and support innovative business, micro, small and medium enterprises (MSMEs), women entrepreneurs
- Multi-hazard risk assessment, pollution zoning, environmental regulations



Challenges

CRS (2011): While the strategy outlined comprehensive plans, it lacked detailed frameworks for implementation and monitoring, making it challenging to assess progress and effectiveness.

CRS (2017): Despite efforts to align resilience initiatives with urban development, challenges persisted in harmonizing these plans with existing infrastructure projects and land-use policies.

In the CRS 2011 the focus was primarily on known risks like flooding, with less attention to emerging threats such as climate change-induced extreme weather events. There was limited involvement of local communities in the planning and decision-making processes, which could affect the relevance and acceptance of resilience measures.

Although the CRS 2017 strategy expanded its scope to include a broader range of risks; however, developing adaptive measures for unforeseen challenges remained complex.

Despite the explicit acknowledgement of an increase in risk and vulnerability to flooding via projected climatic trends and water yields, the plan does not cover any quantification or consideration of expected loss and damage that would be associated with such events.



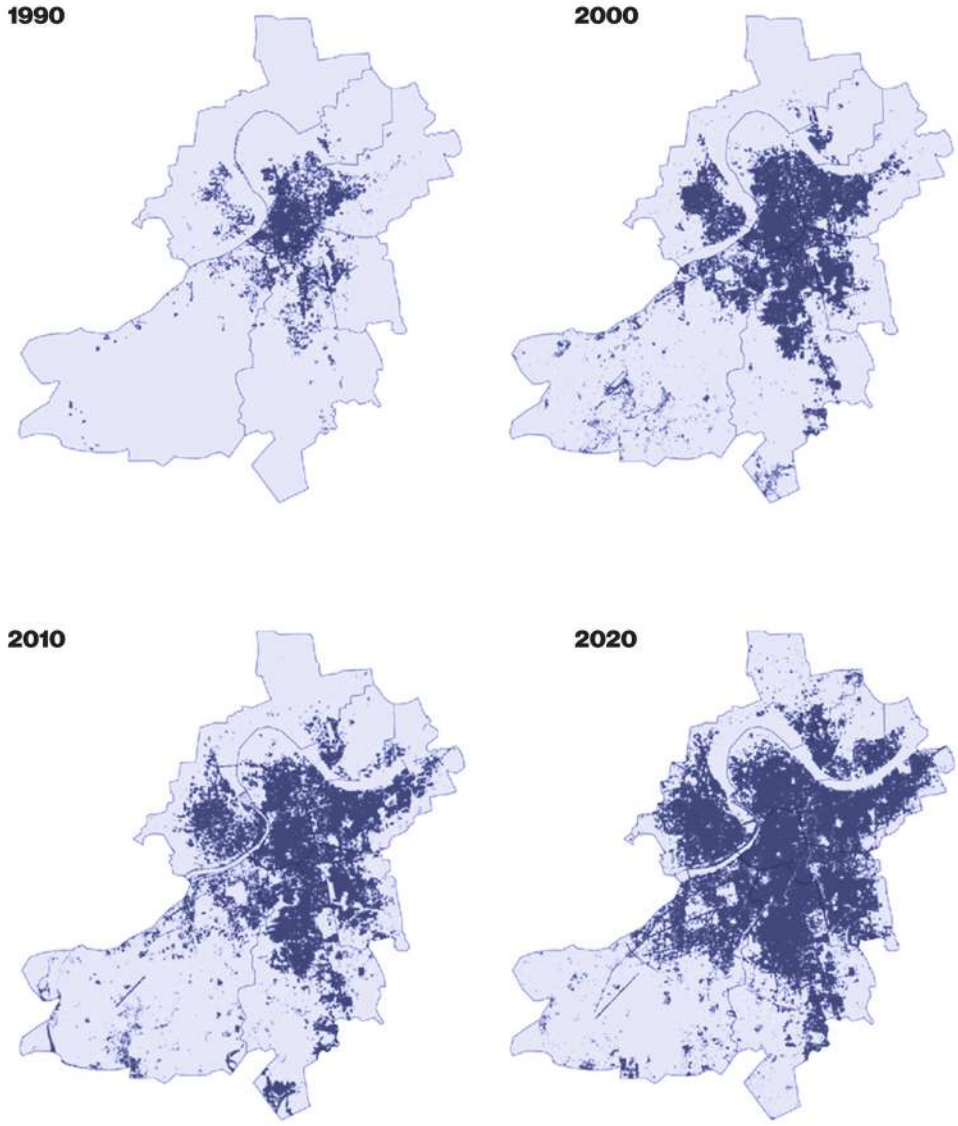
Gaps:

CRS (2011): The strategy did not fully integrate resilience measures with the city's broader urban planning and development processes, leading to potential overlaps and inefficiencies.

CRS (2017): Although improvements were made, the strategy still required more robust mechanisms for tracking the execution of resilience initiatives and evaluating their outcomes.

Growth and Evolution of Surat

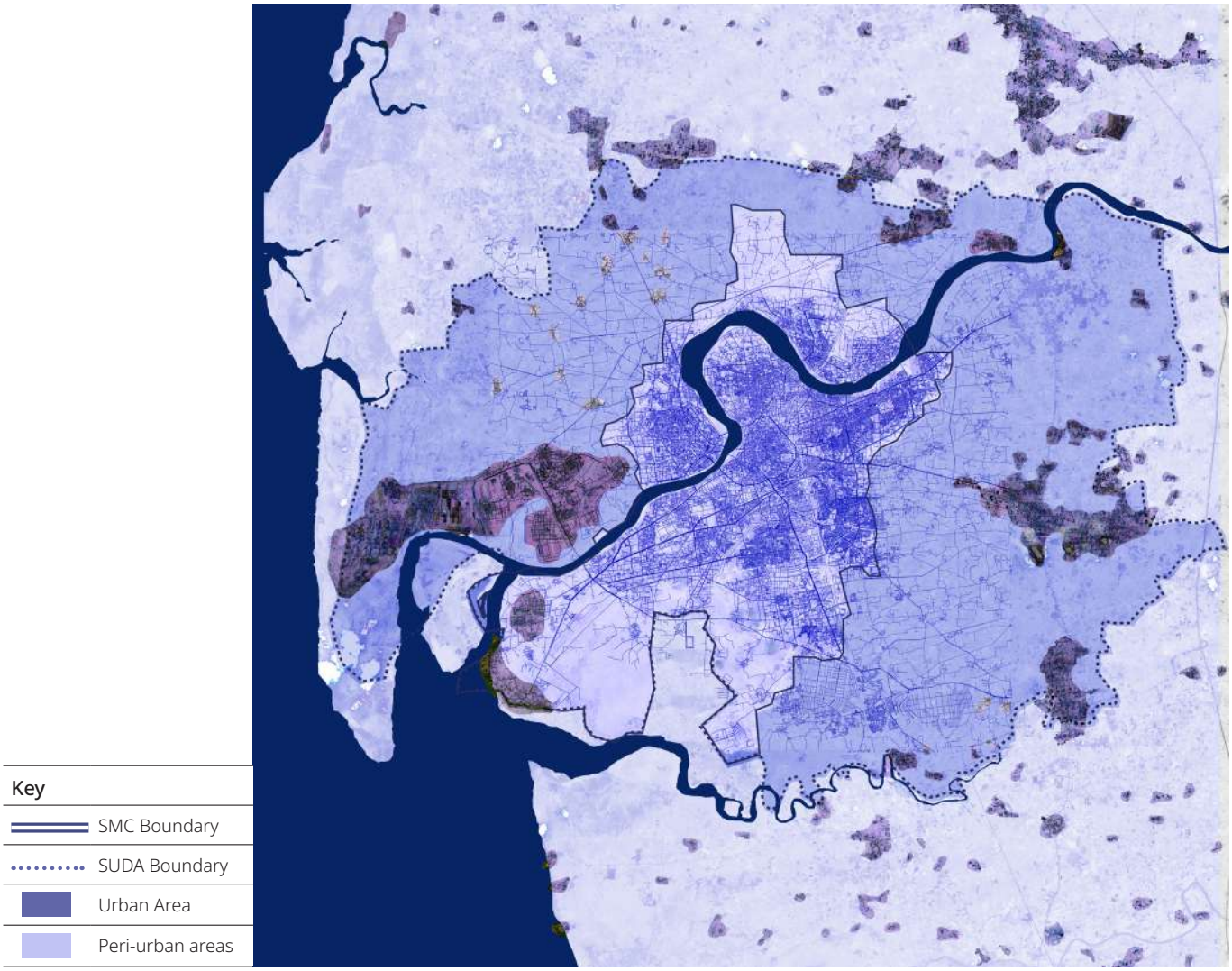
The figures shown below highlight how recent growth in built-up areas has expanded beyond municipal boundaries, extending into the jurisdictions of regional development authorities i.e. Surat Urban Development Authority (SUDA). While these authorities are tasked with managing planned growth using tools like Town Planning Schemes, the pace of development often outstrips their capacity to provide adequate planned services.



Map 11. Growth and evolution of Surat in last three decades

This mismatch results in heightened vulnerabilities for resident communities, who are frequently forced to bear the cost of self-provisioning. These challenges are further exacerbated during extreme climatic events such as heatwave, drought-like conditions, and flooding.

The figure illustrates the decades-long expansion of Surat, mapping the current built-up area (BUA) in relation to administrative boundaries. This spatial visualization reveals the extent of growth beyond the Surat Municipal Corporation (SMC) boundary and highlights the proximity of built-up areas to coastal zones and creeks. It provides critical insights into the exposure of communities and urban assets to flooding risks.



Map 12. Peri-urban areas and growth of Surat city

3.4 Gap Assessment

3.4.1 Ahmedabad

Overall Insights

GSDMA initiated the District Risk Management Program (DRMP) for disaster management within municipal corporation limits. AMC constituted the Disaster Management Cell, managed by a project officer appointed by GSDMA under DRMP. The Disaster Management Cell is responsible for preparing a 'Disaster Risk Management Program or Plan' and 'Ward Disaster Management Plan', which include information on the history of past events (including loss and damage information), intensity and impacts, emergency management strategies (for before, during and after the disaster, including safe places or infrastructure, including communication, coordination, rescue, and alternate resources etc.), safe transport during emergency, and more. The plans also include administrative and institutional frameworks for the implementation of various activities. AMC has prepared ward level disaster management plans for five wards: Bodakdev, Chandlodiya, Ghatlodia, Gota, and Thaltej.

However, this information is not available in the public domain i.e. City Disaster Management Plan and Ward Disaster Management Plans.

Ahmedabad is one of the few cities in Gujarat which has updated its HAP in view of the increasing episodes of extreme heat and has also developed a Climate Resilient City Action Plan (CRCAP) with the aim of reducing its GHG emissions. However, when vulnerable populations have to deal with co-located hazards such as extreme heat, droughts, and floods, there is attention to be paid to the residual risk and its impacts. This is where the estimation of economic damages and management of non-economic losses poses challenges not only for the affected communities but also for the administrative agencies and data on past and recurring events plays a crucial role for collective action.

Disaggregated spatial data for some of the identified categories of vulnerable populations is available in the CRCAP for Ahmedabad.

Specific Insights

Economic and non-economic impacts on health

The comparative figures on the no. of cases of vector borne diseases such as Malaria, dengue, and chikungunya sees an increase in the year 2022 which corresponds with heavy floods in the city of Ahmedabad. The neighbourhoods with high incidence of these diseases have been identified based on the no. of cases reported in the Urban Health Centres located in these neighbourhoods. However, the socio-economic status of the patients and the expenditure incurred for treatment is subject to further available data in order to draw inferences on vulnerability.

In 2022, there was a rise in vector-borne diseases in Ahmedabad, which coincided with severe flooding in the city.

***Gap:** there is no data on the socio-economic status of the patients to draw inferences and identify the vulnerable groups.*

Table 5. Situational analysis of Vector Borne Diseases (VBD) in Ahmedabad Municipal Corporation[1].

S. No.	Disease	Cases		Remarks
		2021	2022	
1	Malaria	85	278	AMC: Naroda muthia, Gomtipur, Thaltej, Sarkhej, Ghuma Urban Health Centres (UHCs) reported maximum malaria cases.
2	Dengue	61	75	AMC; 40 UHC out of 80 reported dengue cases. A maximum of 10 cases were reported from Mandaninagar (Vatva) UHC.
3	Chikungunya	124	130	Vejalpur, Ramol, Gota, Naroda, Kuber nagar, Thaltej, Sabarmati, Vatwa, Lambha, Chndalodia, Asarw a, Nava vadaj, S P Stadium, Ranip, Saijpur bogha UHCs reported maximum Chikungunya cases.

1 NCDC. (2023).National Programme on Climate Change and Human Health: Annual Report 2022-2023. Ministry of Health and Family Welfare, Government of India.

Loss of human capital

The heat related illness, vulnerabilities and fatalities have been assessed in the heat action plan; the 2010 heatwave in Ahmedabad resulting in over 1,300 deaths, underscoring the severe impact on human health, however reduction in labour availability, particularly in the sectors demanding outdoor work like construction and agriculture, are not assessed at the city level.

Slowdown of economic growth

Although it is widely acknowledged that there is a decline in labour productivity resulting from heat related illness, it's negative impacts on the city's economy and the livelihoods of its residents is not well documented.

Higher temperature and intense flooding seem to escalate costs for businesses due to supply chain disruption to business operations and delay in economic activities. Flooding is leading to crop damages, financial loss for the farmers, causing increased food prices and economic inflation.

However, there is lack of data and statistics at the city level that co-relates the data on economic slowdown due to climate-induced disasters.

Recognition of increased poverty and death

While there is sufficient data on the estimated deaths/casualties resulting from climate related disasters, including increased mortality during high temperatures and increased all-cause death rates.

There isn't sufficient data to support the socio-economic imbalance and underline the disproportionate impact on economically disadvantaged populations who are more susceptible and increases their vulnerabilities to health risks in such events. Additionally they lack adequate resources to cope during such events.

Impact on cultural heritage and tourism

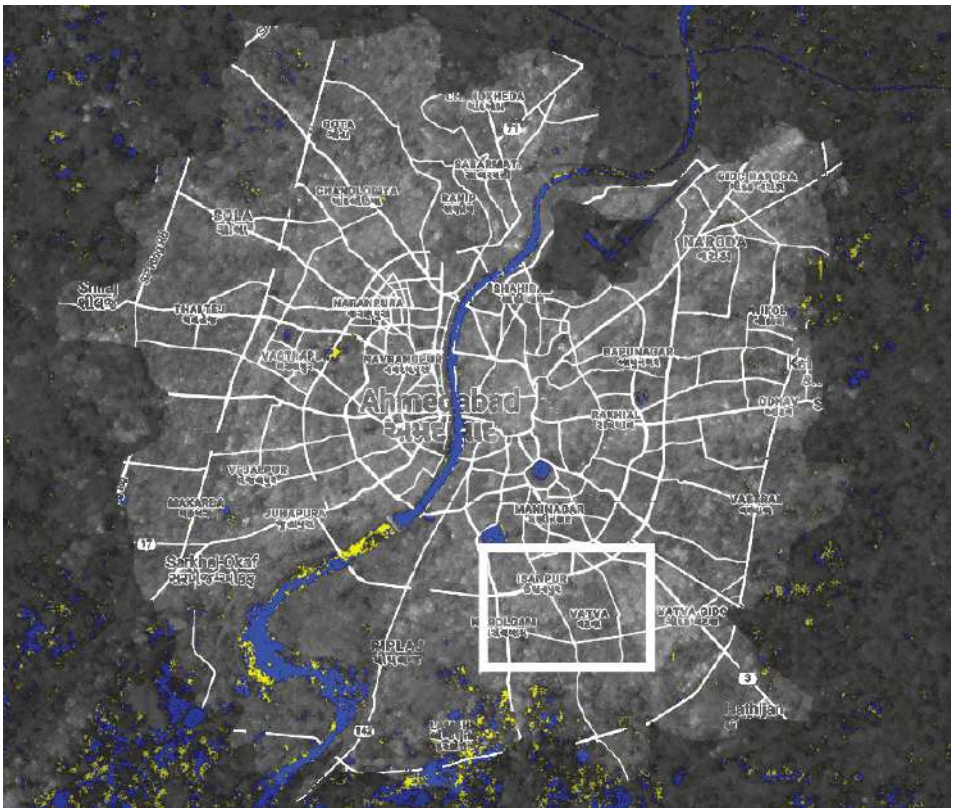
Ahmedabad, a UNESCO World Heritage City, is rich in cultural heritage and climate disaster events pose a threat to the historic buildings. There is limited study on the structural damage to buildings, deterioration and decay of materials compromising the structural and aesthetic integrity of heritage buildings and sites. Though there is limited study that highlights that air pollution, exacerbated by climate change, accelerates the natural deterioration of historic sites, diminishing their aesthetic appeal and causing socio-economic damage[1].

Additionally the 2017 floods is seen to impact the tourist footfalls, leading to a decline in visitors and revenue losses to the tourism sector. There is lack of information on the steps being taken to safeguard the cultural heritage to sustain tourism and preserving the city's historic legacy.

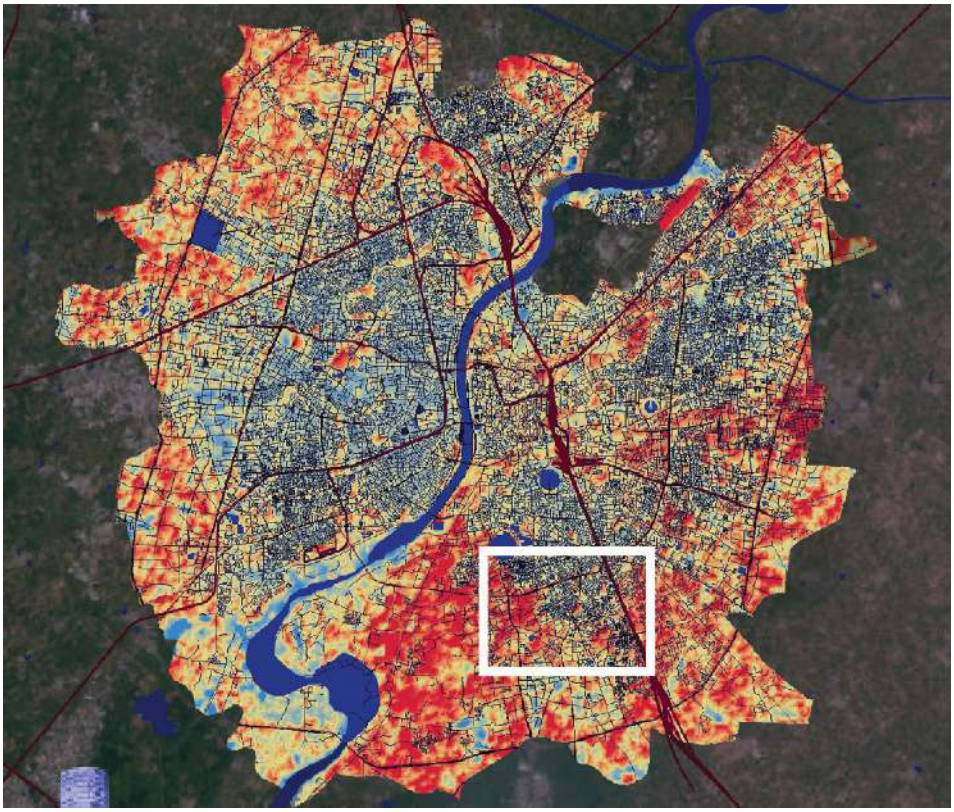
Loss and damage to infrastructure

Higher temperature and intense flooding strains the infrastructure, escalating costs for businesses, disrupting services leading to halting of business operations and delay in economic activities.

1 Arif, M., et.al., (2024). India's cultural heritage: Air quality effects amidst COVID-19 lockdown and seasonal variability. Journal of Atmospheric Chemistry, 81(5).



Map 13. Ahmedabad Food Inundation



Map 14. Ahmedabad Land surface Temperature

3.4.2 Surat

Overall Insights

The majority of research publications on risk and vulnerability in Surat were focused on flooding and inundation, with comparatively ***less locally published work on risks of sea level rise and associated land submergence.*** However, it was found that any attempt to account for loss and damage due to floods in Surat has been associated with the major flooding event of 2006, and not the consecutive years - for example, the significant albeit relatively less damaging flood of 2013, or the recurring floods year after year till 2024. The ***localised impacts of recurring flood events***, water logging and inundation, despite having found mention in certain news reports, have ***largely remained unassessed***. However, it is to be noted that this review is limited to the information available in the public domain.

Specific Insights

Economic and non-economic impacts of health: Heat-related illnesses have found recognition in available literature, but in-depth studies are lacking on the effects of increasing temperatures, humidity and ***lacks heat index on co-morbidities and health, number of medical cases attributed to heat, their associated loss and damage*** (both economic and non-economic). Heat, flood and vector-borne disease related health expenditure should be estimated across the city (both in terms of health system infrastructure as well as expenses borne by citizens) and considered as indicators in measuring success of interventions.

Loss of human capital: While human resource was recognized as an asset to business and economic production in Surat, with labour shortage directly leading to loss of business, these aspects were not found quantified in flood or heat related loss and damage assessment. The ***contribution of labour loss and shortage to overall economic loss is uncertain.***

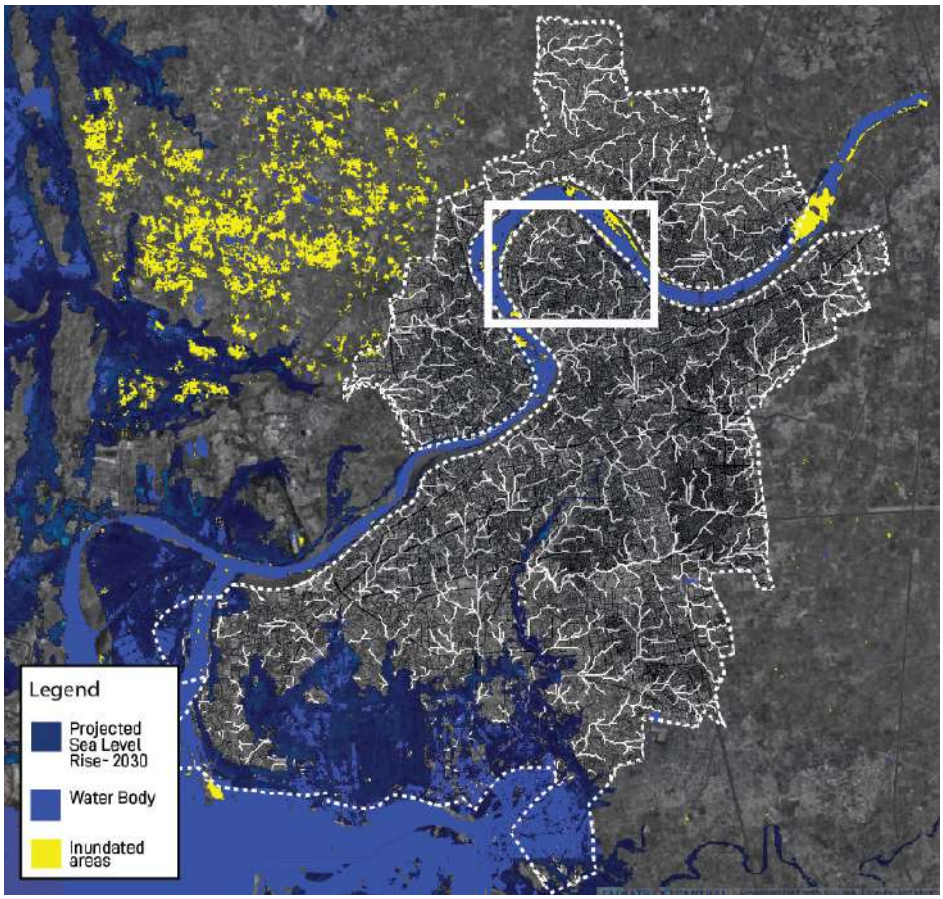
Slowdown of economic growth: Despite acknowledgement of individual level losses, loss of business stock and production, comprehensive efforts are required to assess the economic impacts of extreme events such as floods and heatwave as not one-time occurrences, but frequently recurring events.

Recognition of increased poverty and debt: As mentioned previously, low-income populations tend to be the hardest hit by extreme events and recover the slowest due to lack of insurance and limited community assistance, mainly depending on government relief. ***Changes in baselines on poverty, inequity, informal debt and loan borrowing is not assessed*** which should be measured and considered as indicators during a loss and damage assessment.

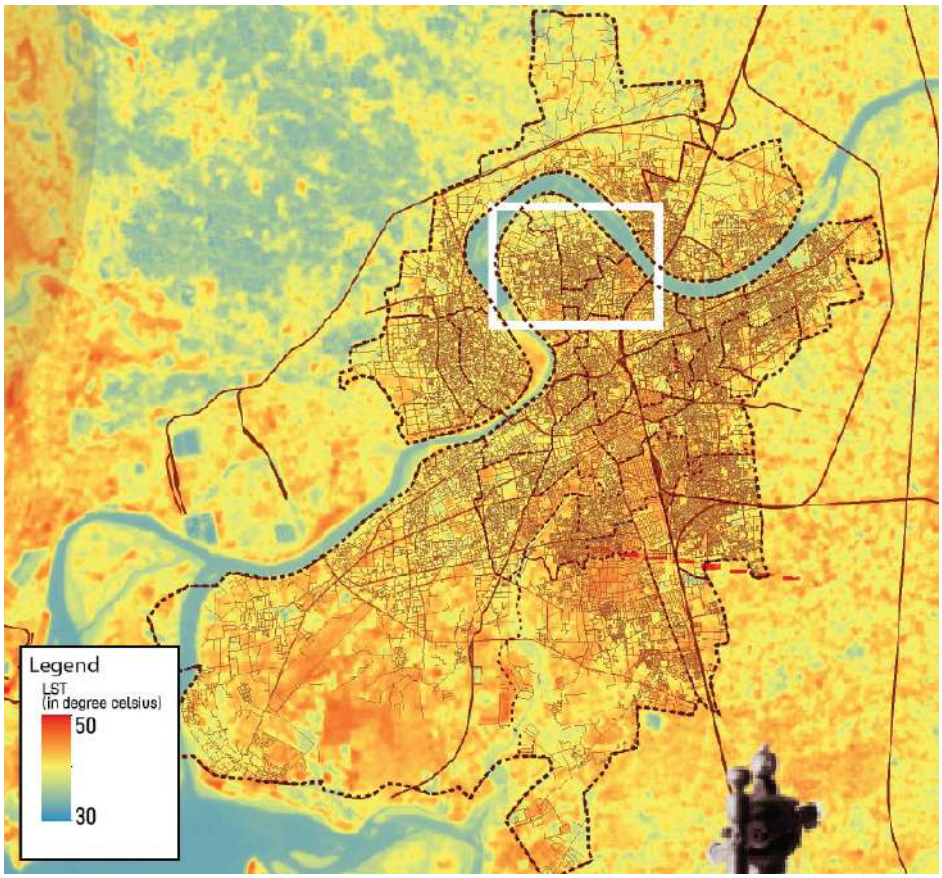
Impact on cultural heritage and tourism: Information on the economic and non-economic impacts of extreme events on architectural and cultural heritage sites, religious sites, any resulting ***impact on the tourism sector*** and religious sentiments among communities, were noted to be ***largely missing***.

Resource shortage and disruption in supply chains: Information was found to be sparse at the city level on the resulting impacts of extreme events on food and water shortage, access to essential commodities and services, economic and non-economic aspects of supply chain disruptions.

Loss and damage to infrastructure: ***No detailed city-level assessments*** were found on damages to roads, railways, bridges and public infrastructure caused by exposure to extreme events.



Map 15. Surat Food Inundation



Map 16. Surat Land surface Temperature

Source: ICLEI South Asia, 2024

3.5 Case Studies

3.5.1 Bihar Kosi Flood Needs Assessment Report (2008)

The Bihar Kosi Flood (2008) Needs Assessment Report[1] provides a comprehensive evaluation of the catastrophic flooding caused by the Kosi River's embankment breach in August 2008.

Strengths and Successes:

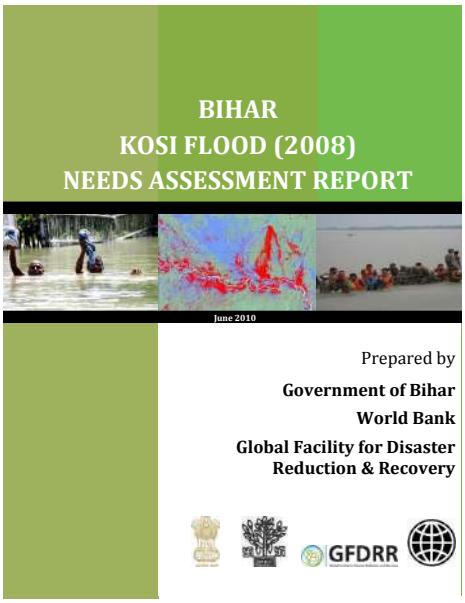
The report offers a detailed analysis of the flood's impact across various sectors, including housing, infrastructure, agriculture, health, and education.

It provides specific estimates for reconstruction and recovery, such as Rs. 9.9 billion for housing and Rs. 13.9 billion for roads and bridges. These figures are crucial for planning and allocating resources effectively.

Challenges:

- The assessment acknowledges challenges due to the lack of comprehensive data at the time, which may have affected the accuracy of damage and loss estimations.
- Some sectors typically covered in needs assessments were not included, potentially overlooking specific areas requiring attention.
- Translating the assessment's recommendations into actionable recovery plans may face obstacles such as resource constraints, bureaucratic delays, and coordination issues among stakeholders.

While the report emphasizes resilience, ensuring that reconstruction efforts are sustainable and adaptable to future climate-related challenges remains a significant concern.



This disaster affected approximately 3.3 million people in Bihar, leading to significant loss of life, displacement, and extensive damage to infrastructure and livelihoods.

Critical gaps within the framework: The report's limited scope due to data constraints, may have led to underestimations in certain sectors. Additionally, the absence of a detailed implementation framework raises questions about the practical application of the recommendations. The report's focus on immediate reconstruction needs may have overshadowed the necessity for long-term strategies addressing underlying vulnerabilities.

1 *Government of Bihar, World Bank, & Global Facility for Disaster Reduction and Recovery (GFDRR). (2010). Bihar Kosi Flood (2008) Needs Assessment Report. Retrieved from https://www.gfdrr.org/sites/default/files/publication/pda-2010-india.pdf*

3.5.2 Cyclone Fani Damage, Loss and Needs Assessment DLNA Report 2019

The Cyclone Fani Damage, Loss, and Needs Assessment (DLNA) Report of 2019[1] offers a comprehensive evaluation of the cyclone's impact on Odisha, India.

While the DLNA provides detailed estimates of damage, loss, and recovery needs across 15 sectors, including housing, infrastructure, agriculture, and social services.

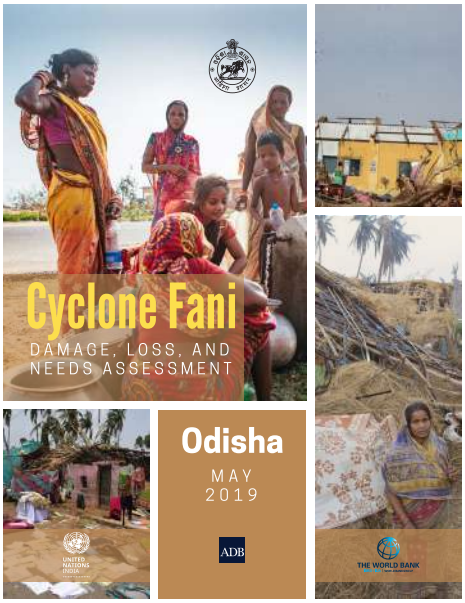
The assessment was a joint endeavour involving the Government of Odisha, the United Nations, the World Bank, and the Asian Development Bank, ensuring a multifaceted perspective.

The report offers quantitative data on the cyclone's impact, such as the estimated total damage and loss of ₹24,176 crore and recovery needs of ₹29,315 crore.

It proposes a recovery strategy centered on resilient housing, infrastructure, and livelihoods, aiming to build back better and enhance future disaster resilience.

Gaps and Challenges:

- While the report outlines recovery strategies, it lacks a detailed implementation plan with specific time lines, responsible agencies, and monitoring mechanisms.
- Securing the estimated ₹29,315 crore for recovery poses a significant challenge, requiring coordinated efforts among state, national, and international stakeholders. The report could benefit from a more in-depth analysis of community-level impacts and the inclusion of local voices in the assessment process. Ensuring that recovery efforts lead to sustainable development and enhanced resilience against future disasters remains a critical challenge.
- The assessment does not sufficiently address the specific needs of vulnerable groups, such as women, children, and marginalized communities, in the recovery process.
- There is a need for a more robust analysis of the cyclone's environmental impact and strategies for ecological restoration.



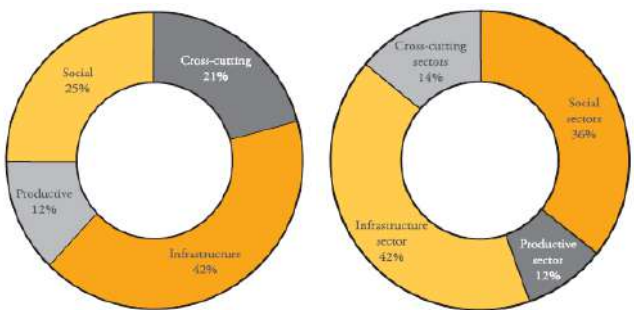


Fig 4. Share of Disaster Effects and Disaster Recovery Needs across Sectors.

1 *Government of Odisha. (2019). Cyclone Fani 2019 DLNA Report. Odisha State Disaster Management Authority. Retrieved from https://www.osdma.org/publication/cyclone-fani-2019-dlna-report/*

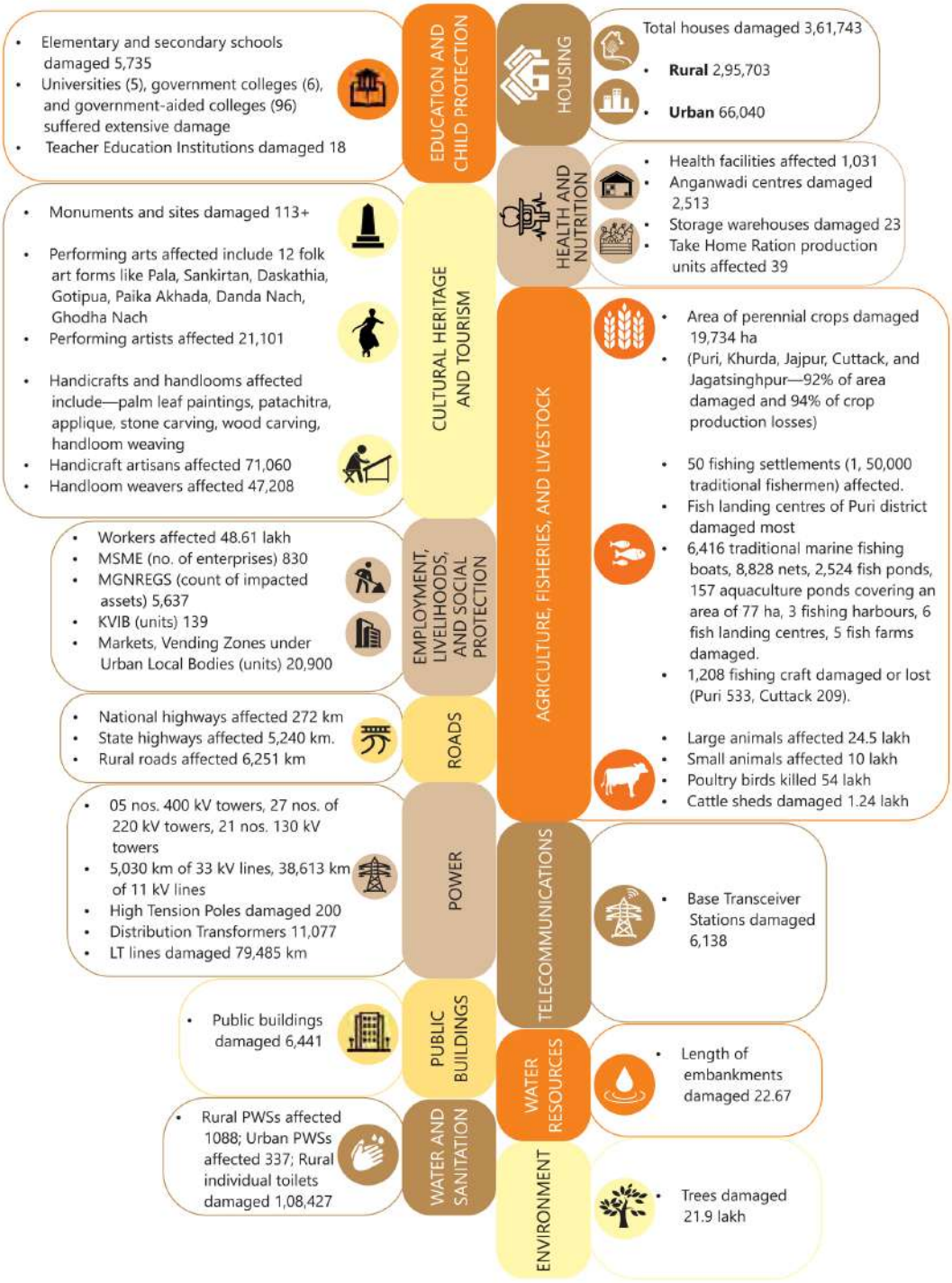


Fig 5. Assessment of Damage by Sector[1]

1 *Government of Odisha. (2019). Cyclone Fani 2019 DLNA Report. Odisha State Disaster Management Authority. Retrieved from https://www.osdma.org/publication/cyclone-fani-2019-dlna-report/*

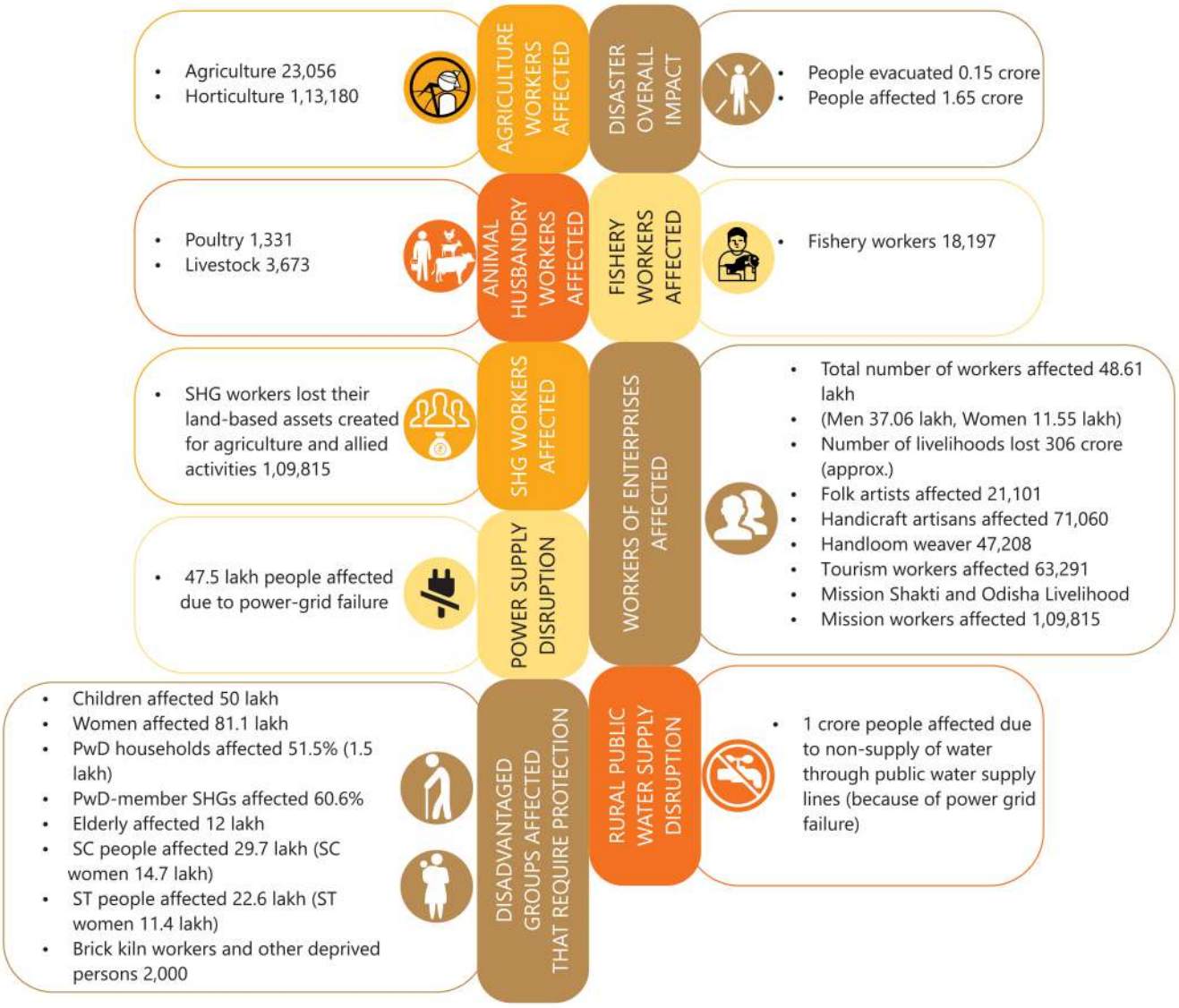


Fig 6. Sector-wise impact on humans[1]

1 *ibid.*

3.5.3 Kerala Post Disaster Needs Assessment Floods and Landslides 2018

In August 2018, Kerala experienced severe floods and landslides, resulting in 341 landslides across 10 districts. The report provides a comprehensive evaluation of the catastrophic events that struck Kerala in 2018. This assessment offers valuable insights into the disaster's impact and outlines strategies for recovery and resilience.

Translating the PDNA's[1] recommendations into actionable plans requires substantial resources and coordination, posing challenges in execution.

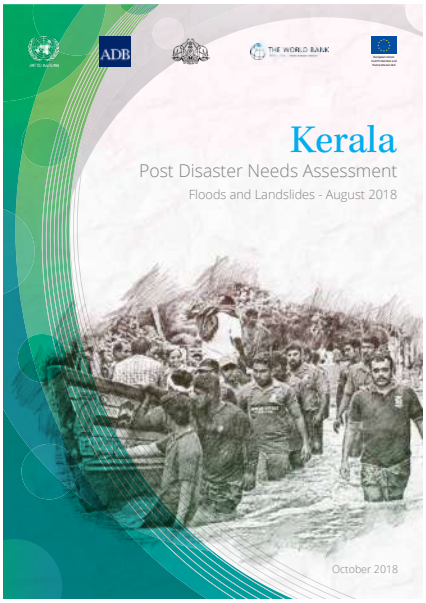
Securing the estimated USD 4.4 billion needed for recovery necessitates significant financial commitments from both national and international stakeholders.

Maintaining long-term commitment from all involved parties is essential to ensure the continuity and success of recovery initiatives.

Some stakeholders have expressed concerns regarding the time taken to complete the assessment, suggesting that delays may have affected the immediacy of the response.

While the PDNA includes community consultations, there are critiques about the depth of local community engagement in the decision-making processes.

Although environmental impacts are addressed, critics argue that the assessment could have placed a stronger emphasis on sustainable practices and ecological restoration.



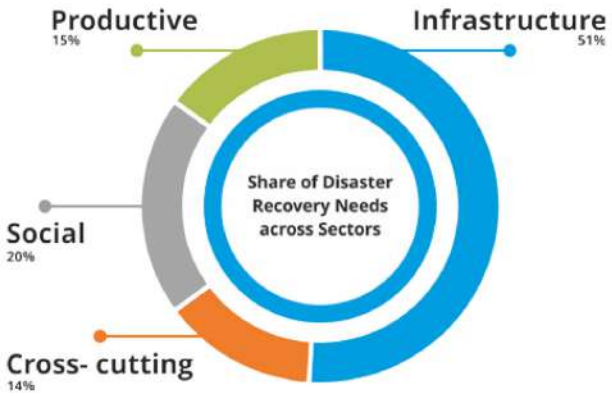


Fig 7. Share of Disaster Recovery Needs across Sectors

1 *Government of Kerala. (2018). Post Disaster Needs Assessment: Floods and Landslides. Kerala State Disaster Management Authority.*

Sector	Damage	Loss	Total Effect (D + L)		Total Recovery Needs	
	INR Crores	INR Crores	INR Crores	USD Million	INR Crores	USD Million
Social Sectors						
Housing, Land and Settlements	5,027	1,383	6,410	916	5,443	778
Health and Nutrition	499	28	527	75	600	86
Education and Child Protection	175	4	179	26	214	31
Cultural Heritage	38	37	75	11	80	11
SUB-TOTAL	**5,739**	**1,452**	**7,191**	**1,028**	**6,337**	**906**
Productive sectors						
Agriculture, Fisheries and Livestock	2,975	4,180	7,155	1,022	4,498	643
SUB-TOTAL	**2,975**	**4,180**	**7,155**	**1,022**	**4,498**	**643**
Infrastructure sectors						
Water, Sanitation and Hygiene	890	471	1,361	195	1,331	190
Transportation[a,b,c]					10,046	1,435
Power[b,c]					353	50
Irrigation[b,c]					1,483	212
Other infrastructure[b,c]					2,446	349
SUB-TOTAL	**890**	**471**	**1,361**	**195**	**15,659**	**2,236**
Cross-cutting sectors						
Environment	26	0.04	26	4	148	21
Employment and Livelihoods	881	9,477	10,358	1,480	3,896	557
Disaster Risk Reduction	17	583	599	86	110	16
Gender and Social Inclusion	0.9	0	0.9	0.13	35	5
Local Governance	28	0	28	4	32	5
SUB-TOTAL	**953**	**10,060**	**11,013**	**1,574**	**4,221**	**604**
TOTAL (A)	**10,557**	**16,163**	**26,720**	**3,819**	**30,715**	**4,389**
Integrated Water Resources Management (B)	0	0	0	0	24	3
GRAND TOTAL (A+B)					**30,739**	**4,392**
GRAND TOTAL (ROUNDED OFF)					**31,000**	**4,400**

Table 6. Sector-wise Summary of Disaster Effects (Damage and Loss) and Recovery Needs

*These disasters affected **5.4 million residents**, displaced 1.4 million individuals, and caused 433 fatalities. The state government reported that 1,259 out of 1,664 villages across 14 districts were impacted. The destruction encompassed homes, transportation infrastructure, power supplies, communication networks, and agricultural assets. A Post Disaster Needs Assessment (PDNA) led by the United Nations and the Government of Kerala estimated the total recovery needs at **USD 4.4 billion**.*

3.6 Vulnerability metrics and rationale for inclusion

Based on the literature review which includes various sources of city specific and wider areas, we have arrived at the metrics that would be foundational for estimating loss and damage at the city level. As a next step, sources of this data were identified based on secondary sources. The gaps in the data will be supplemented through a data collection process from identified city stakeholders and departments. The table below presents the identified metrics and the rationale for their inclusion. The subsequent section of the report further re-arranges these metrics based on the format most attuned to further collect, synthesise, and present this data.

Data type	Data Parameter
Demographic Data	Population
	Median Household (HH) Income
	Women
	Children
	Elderly
	Population distribution by age
	Population distribution by income level
	Literacy rate (with age group bifurcation) over the years
	Daily wage workers (trend over the years + gender bifurcation)
	Displacement rates / trends
	% of children in the workforce (pre and post high-impact disasters)

1 Gujarat Labour Commissionerate.(2023). Minimum wage rates for 46 scheduled employments. Government of Gujarat.

2 Down to Earth. (2023). Number of daily wage workers dying by suicide increased in 2022: NCRB data.

3 Yadav, S., et al., (2023). Changing pattern of suicide deaths in India. The Lancet Regional Health - Southeast Asia, 16; Down to Earth. (2023). Karnataka has highest suicide-related economic burden in country:

4 Ministry of Home Affairs, Disaster Management Division. (2024). Situation report regarding flood & heavy rainfall in the country

Rationale for Inclusion
To estimate the impacted vulnerable population, as a percentage of the total no. of people living in the city.
To estimate the adaptive capacity, in financial terms, of the households residing/ located in the city.
To identify vulnerable groups and compare them with household income, highlighting how women, as key providers of unpaid services and care, face heightened vulnerabilities. Women are often disproportionately affected by disasters, unable to escape due to caregiving responsibilities or limited mobility.
Children are the most vulnerable group since they are entirely dependent on income generators in the household. This group is also physically more vulnerable than many others.
Important to understand since this is another dependent group and highly vulnerable if coming from underprivileged sections. This group is also physically more vulnerable than many others.
Provides a comprehensive picture of the age delta of the population group to estimate the overall no. of vulnerable people within the city. At the same time, it gives a picture of the demographic dividend of the population.
Serves as an indicator of vulnerabilities based on a cross-section through income level when contrasted with age
Higher literacy enhances adaptive capacity through better wages and understanding of timely mitigation actions. Studies, including those by ILO, show that higher education and skills lead to higher earnings.
Daily wage workers face income disruptions, worsened by extreme climatic events. A gender-based lens highlights differential vulnerabilities among them. Eg -Daily wage rates in Gujarat across sectors effective from 2023[1]. As per 2022 NCRB data, India reported 1,70,924 suicides, a 4.2% rise from 2021, with the suicide rate increasing by 3.3%. Family problems (31.7%) and illness (18.4%) were the main causes, while unemployment (1.9%) and professional issues (1.2%) contributed. Daily wage earners made up the largest share, with 44,713 cases (26.4%)—41,433 men and 3,752 women. According to NCRB, 64.3% (1,09,875) of suicide victims had an annual income below ₹1 lakh, while 30.7% (52,429) earned between ₹1–5 lakh. Career and professional issues caused 371 suicides in Gujarat in 2022, with 71 cases in Ahmedabad[2]. The highest suicide rates were among men aged 18–29, 30–44, and 45–59, and women aged 18–29. Suicides among male daily wage earners surged 170.7% from 2014 to 2021, with an SDR of 34.6 for men and 13.1 for women in 2021. Unemployed individuals had high SDRs: 48.2 for men and 27.8 for women[3].
Indicates the number of households, families, or individuals impacted by extreme climatic events in the Gujarat Floods Assessment Report, 2024[4].
While this is not an internationally accepted indicator since child labour is illegal in most contexts, including in India but vulnerable households often have children in the workforce. Obtaining official data on this is possible only through KIIs and HH surveys.

Table 7. Identification of data parameters across 7 data types to assess vulnerability metrics and the rationale for their inclusion.

Seven Data types for estimating economic and non-economic loss and damage at the city level.

- *Demographic Data*
- *Climate Data*
- *Institutional*
- *Health*
- *Environment*
- *Economy*
- *Community*

Data type	Data Parameter
Climate Data	Estimated Economic Loss
	Estimated Damage by sector: housing, transport, health, water & sanitation, Education, Tourism
	Projected Climate Data
Institutional (State)	State hunger index: pre and post high-impact disasters
	Poverty levels: pre and post high-impact disasters
	Multidimensional poverty index
	Population affected by floods
Health	Child mortality rates (Over the years)

1 *Centre for Research on the Epidemiology of Disasters (CRED). (n.d.). Economic Impact Variables. EM-DAT Documentation.*

2 *Bahinipati, et.al.,(2015). Flood-induced economic loss and damage to the textile industry in Surat City, India. International Institute for Environment and Development.*

3 *NITI Aayog. (2023). National Multidimensional Poverty Index: A Progress Review*

4 *Murray, et.al., (2022). Global burden of 87 risk factors in 204 countries and territories, 1990–2020: a systematic analysis for the Global Burden of Disease Study 2020. The Lancet, 400(10352), 1223-1259.*

5 *NIUA. (2017). Children-focused vulnerability assessment and city resilience action strategy: Udaipur. Climate Smart Cities.*

Rationale for Inclusion
Relies on reconstruction costs, insured damage, and total damage. Reconstruction costs differ from total damage as they include current construction or purchase costs and additional expenses for preventive measures. Thus, reconstruction costs are typically higher than total damage[1]. Note: Birkmann and Welle (2015) note ongoing debate over L&D assessment methods, with no comprehensive approach established. Dodman and Archer[2] (2014) highlight limited knowledge on L&D estimation in urban areas of developing nations, where insurance is nascent, and most sectors are informal.
Since estimated financial requirements for repair and rehabilitation post extreme climatic events is routed based on sectors and sectoral departments, it becomes convenient to procure this data on sectoral basis.
The projected climate data considered by the Government of India (GoI) and that of the State Government to assess the future intensity of extreme climatic events helps draw out the preparedness plans for the selected scenarios.
Provide insights into food access for vulnerable groups. Comparing pre- and post-disaster data reveals the disaster's impact on basic nutrition access, highlighting broader socio-economic effects and the need for immediate relief and financial support.
Disasters have a regressive impact on the poverty alleviation measures adopted by governments. Contrasting data on pre and post disaster event estimates their negative impact on poverty levels..
India's national MPI has three equally weighted dimensions- Health, Education, and Standard of Living- represented by 12 indicators: Health (1/3): Nutrition, child/adolescent mortality, maternal health; Education (1/3): Years of schooling, school attendance; Standard of Living (1/3): Cooking fuel, sanitation, water, housing, electricity, assets, bank accounts. The MPI combines the Headcount Ratio (H) and Intensity of Poverty (A), reflecting both the share and severity of poverty. It helps assess progress toward SDG target 1.2, aiming to halve poverty in all forms. Including data on vulnerable groups- women, children, and the elderly, provides insights into population risks from climate hazards[3].
Provides an assessment of the impact of floods as a climate hazard on the population of the state whether rural or urban and the financial allocation needed to rehabilitate, if required.
Note :- The health impacts of climate extremes can be calibrated against each type of climate extremes to understand their variations. Extreme Heat: Linked to acute kidney injury, heatstroke, adverse pregnancy outcomes, poor sleep, mental health issues, and worsening cardiovascular and respiratory diseases. It also raises non-accidental and injury-related deaths and indirectly affects health by limiting work and exercise capacity. High-risk groups include older adults, pregnant women, newborns, the socially deprived, and outdoor workers[4].
This indicator is linked to internationally recognized goals for general development standards and children's rights. Similar to the infant mortality rate, the mortality rate of children aged under 5 years is a baseline indicator of how a country is progressing towards assuring children's rights - in particular, their rights to life, health care services, nutrition, water, social security and protection. Article 24 of the United Nations Convention on the Rights of the Child specifically obliges all States to take appropriate measures to reduce the child death rate. Data from a well-functioning vital registration system that covers the total population and delivers high-quality, timely data on child mortality rates at regular intervals are the gold standard for monitoring under-5 mortality[5].

Data type	Data Parameter
Health	Heat-related illnesses, number of cases during a heatwave event, health expenditure during heatwave
	Population affected by vector-borne diseases (summer, monsoon, winter)
Environment	Biodiversity and/or habitat lost post high-impact disasters
	Loss or shrinkage of water bodies
Economy	Estimated loss of work hours
	Estimated damage to businesses
	Loss of livelihoods among displaced population
	GDP rate
Community	Perceptions of trade-offs among displaced population
	Vulnerable groups
	Risk-prone zones to flood (Ahmedabad and Surat) and sea level rise (Surat)
	Heat hotspots, flood risk zones
	Prominent locations (businesses, schools, hospitals, etc.) to determine risk.

1 *Watts, et.al. (2015). Health and climate change: policy responses to protect public health. The Lancet, 386(10006), 1861-1914.*

2 *Doherty, F., & Rao, S. (2023, August 29). Extreme weather events linked to increased child marriage. PreventionWeb.*

Rationale for Inclusion
Provides an estimate on the number of people impacted by extreme heat. The data is an indirect indicator on the city's preparedness to events of extreme heat by understanding the no. of casualties, and hospitalisation due to heat stroke. When contrasted with age-wise vulnerable population data, this can provide an understanding of differential vulnerabilities and the lack of resources to combat extreme heat i.e., financial and exposure risk.
This data set provides insights on the health burden of climate change i.e. high turbidity of groundwater during the summer and presence of undesirable levels of minerals, mixing of sewage with potable water supply during floods leading to diseases such as jaundice, gastrointestinal infections, malaria etc. thereby increasing the health related expenditure, especially for the vulnerable populations.
Note: Human development has depended upon the destruction of the planet's natural environment. Yet the future for human health depends on the survival of that very same environment. Here is the paradox that faces climate negotiations[1].
This provides an estimate of the costs for the ecosystem services, such as provisioning services to communities dependent on the ecosystems for food, fuel, fodder, etc., or regulating services like water purification by wetlands or micro-climate control by green or blue areas, etc.
This estimates the costs for local authorities to source water by pumping groundwater or transporting it via pipelines, including electricity and capital expenses for pumps or pipelines.
This will provide an estimate of the loss to GDP of the city. In the community scale, it can also provide information about the loss of income, which will impact the adaptive capacity of families to respond to disaster events.
GDP influences communities' adaptive capacity. Financially stronger cities can better manage climate disasters through timely actions, while weaker finances increase community vulnerability.
This subjective information, gathered from community FGDs, reveals trade-offs vulnerable families make under financial constraints during disasters. It highlights which socio-economic sectors are most affected, such as increased early marriages or discontinuation of girls' education when families struggle to afford basic needs[2].
This is subjective information obtained from FGDs in the community to estimate the actual vulnerable population in the cities. This is important because of inter-sectionality, which results in certain members of a group being more vulnerable than others, because of allied risks. For instance, poor or uneducated women fare worse than educated women with a steady source of income who are able to tide over better in case of a disaster because of financial security.
This information can help to identify which areas in the city would be most impacted by climate disasters. Population living in these areas would be most at risk and therefore these areas should be prioritised for climate action.
This information helps identify areas most impacted by extreme temperatures or rainfall, highlighting at-risk populations and prioritizing them for climate action.
Superimposing this data on areas most at risk from extreme temperatures or rainfall helps identify vulnerable institutions and infrastructure. This allows the city to prioritize retrofitting and assess potential losses if unprotected. Damage to hospitals and schools would not only involve capital loss but also socio-economic impacts, such as disrupted education and public health, increasing financial burdens on communities.

3.7 Vulnerability matrix and data sources

ICLEI South Asia has developed a tool for producing spatial maps showing the distribution of the high priority climate risk areas across the city. The involved team then assesses which social groups are most vulnerable to the impact of these climate risks. The team and the Stakeholder Group then engage in a joint workshop to discuss the vulnerable areas and actors and conduct the vulnerability assessment.

The tool produces the following outputs:

1. Vulnerable areas in the city that are impacted by the climate risks.
2. Vulnerable people or actors in the city that are most impacted by the climate risks.
3. Adaptive capacity of the vulnerable actors - will be covered in the later reports.

The table below presents the outline for tabulating the findings about the vulnerability variables against the climate parameters such as heat and flooding to also present the exposure data to each climate hazard type. The fragility statement is based on the existing situation of the urban systems after doing the urban system analysis and superimposing the identified projected climate risks onto these to find the climate fragility statement. The VA analyses which areas in the city are most affected by the climate fragility statement, and the RA is based on the likelihood and consequence of these CFS.

Vulnerability Variable	Risk and Vulnerability Matrix			
	Urban Heat Risk		Urban Flood risk	
	Exposure data	Fragility statement	Exposure data	Fragility statement
Socio-economic	*Sectors vs Climate Hazards to assess Risk and Vulnerability*			
Water Supply				
Wastewater				
Solid Waste				
Transport				
Emergency Services				
Health				
Parks and Gardens				
Energy				
Education				
Housing				
Tourism				
Manufacturing				

Table 8. Outline for tabulating the findings about the vulnerability variables against the climate parameters

3.8 Stakeholder engagement and thematic analysis

Stakeholder engagement is integral to the project's research process. In Work Package 1, our strategy gathers community insights on climate change impacts in Ahmedabad and Surat through Focus Group Discussions, focusing on contextual risks, vulnerabilities, and specific community losses.

3.8.1 Focus Group Discussions (FGDs)

We intend to conduct four FGDs - two in each city. These discussions will be categorised as follows:

FGD 1: This session will involve a discussion with the city-level government officials, engaged in preparedness, response, and recovery phases in the cities.

FGD 2: This session will involve community-based organisations (CBOs) engaged in response and recovery initiatives.

The primary goal of the two FGDs is to collect comprehensive contextual information regarding climate-related losses faced by the communities, and how the city manages the damage and loss. We expect the CBOs to be able to dive deeper into case studies and nuanced understanding of the community, while the government officials to be able to give a more programmatic city-level gauge of how loss and damage is assessed and managed officially. Collectively, we will be able to identify aspects of loss and damage contextual to the city, their current state of management with the city officials, and potential gaps and opportunities to develop and integrate L&D assessment and management methods in the city climate plans and Disaster Risk Reduction plans.

Objectives:

- To comprehend community views on the effects of climate change.
- To gather information on specific values lost due to climate-related events.
- To identify critical community values that are at risk.
- To explore the complexities of losses incurred by communities due to climate change within the cities.

3.8.2 Stakeholder Identification and Recruitment

Stakeholder Interviews

Building on insights from the CBOs, we will conduct interviews of the members of the community, especially from the vulnerable groups. Here, we will adopt a case-study approach, engaging specific community members to obtain in-depth insights into the impacts of climate change on their livelihoods and overall quality of life.

Participants for FGD 1 will consist of officials from departments that are part of the disaster response and recovery processes, and are (or should be) part of loss and damage assessment and management at the city level. FGD 2 will consist of local CBOs experienced in the impacts of climate change on the communities living in the city. The recruitment for both FGDs will be done based on our network in the two cities, and will follow a purposive sampling method, bringing in participants with experience and knowledge on impact of climate change on the local communities.

We will conduct a stakeholder mapping exercise for Public-sector officials in departments that are involved in response and recovery for FGD 1. For FGD 2, we will map local CBOs working directly with communities in the response and recovery phases, and CBOs/research organisations with regional experience on climate change impacts on the city. For interviews, we will identify community members with direct historical impact of climate change & associated disasters. These can include community leaders of impacted communities, community volunteers who participated in response and recovery (including youth voices), and representatives of vulnerable groups within the community (women, elderly, disabled population) . We will target community members directly affected by climate change, particularly vulnerable groups such as women, the elderly, and individuals with disabilities.

These participants will be identified through our focused outreach to the selected community, through our networks of CBOs working in the cities at the community level. We will aim to bring forth 8-10 participants per FGD, and to conduct 5-10 interviews.

3.8.3 Methodology

The FGDs will commence with an introduction and an icebreaker, followed by targeted questions relevant to each group's focus. Facilitators will moderate the discussions, and data will be collected through note-taking and audio recordings, ensuring confidentiality and informed consent.

The FGDs will be focused on the following questions:

FGD 1: Public Sector Officials

- What are the key risks from climate change faced by the communities in the city?
- How do the different departments prepare, respond to, and assess the loss and damage of disasters in the city?
- What aspects of loss and damage are most pertinent in your experience?
- What are the on-ground challenges in executing the SOPs of disaster impact assessment?

The Facilitator's Guide for Stakeholder Interview and Guidelines for Key Informant Interview are attached in the Annexes.

FGD 2: CBOs

- What are the key risks from climate change faced by the communities in the city?
- Looking back 10-20 years, what losses have the community experienced?
- What has been the scale of these identified losses?
- What does the recovery from these losses look like for the community?

The interviews will be in an unstructured format, with broad questions to jump start the conversation, followed by questions building on the previous responses. This unstructured approach will help provide more space and comfort to the community members to share their experiences in their preferred narrative. We will create an interview guide to ensure all principles of the ethical interview process are met, including but not limited to informed consent, cultural sensitivity, transparency, and comfort of participants.

The stakeholder engagement process for assessing loss and damage in Ahmedabad and Surat is ensured with a well-structured approach so that to input is overlooked:

- **Stakeholder Identification:** Key individuals and groups, including government officials, local leaders, vulnerable populations, NGOs, and academics, are identified and categorized based on their roles and interests.
- **Outreach:** Personal letters, emails, and phone calls introduce project goals and the need for stakeholder input, extending an invitation to join the initiative.
- **Focus Group Discussions:** Specific groups participate in discussions focused on their experiences and perspectives regarding loss and damage, with questions tailored to their expertise.
- **Key Informant Interviews (KIIs):** Specialists offer in-depth insights through one-on-one interviews, providing detailed perspectives and expertise.

- **Community Surveys:** Quantitative and qualitative data is gathered through surveys of a representative sample in each city to understand community perceptions.
- **Stakeholder Workshops:** Early findings are shared in workshops for stakeholder feedback, utilizing interactive methods to validate data and brainstorm potential solutions.
- **Ongoing Engagement:** Stakeholders receive regular updates and are invited to provide feedback on draft reports and recommendations, ensuring they remain informed and engaged.
- **Integrating Feedback:** Stakeholder input is analyzed and incorporated into the assessment to maintain its relevance and accuracy.
- **Final Presentation:** Results are presented in accessible formats at final meetings, giving all stakeholders an overview of the outcomes and proposed action plans.
- **Post-Project Engagement:** Plans are developed for continued collaboration to monitor and implement strategies for addressing loss and damage.

This comprehensive approach ensures that diverse perspectives are included, building credibility, relevance, and a foundation for effective and collaborative action in addressing climate impacts in Ahmedabad and Surat.

The Guidelines for Key Informant Interview and the questionnaire for the interview are attached in the annexe.

3.8.4 Data Collection and Analysis

The data gathered from the FGDs & interviews will be transcribed for anonymity, and analysed thematically using coding software like NVivo. This analysis will provide critical insights into the community-specific loss and damage aspects that will inform our broader thematic analysis.

3.8.5 Stakeholder Mapping

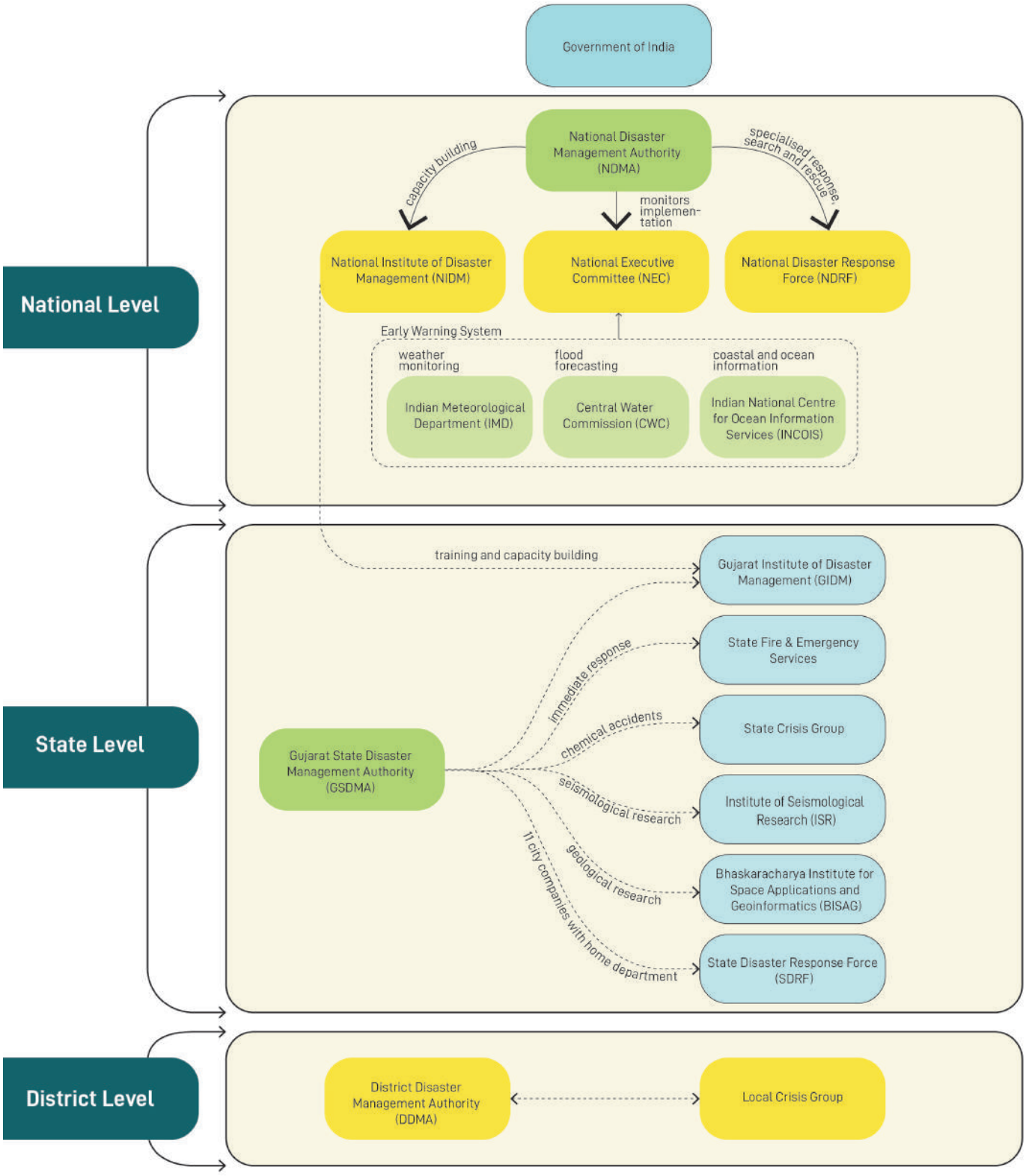


Fig 8. Multi-level Disaster Management Framework in India: Stakeholder roles and coordination

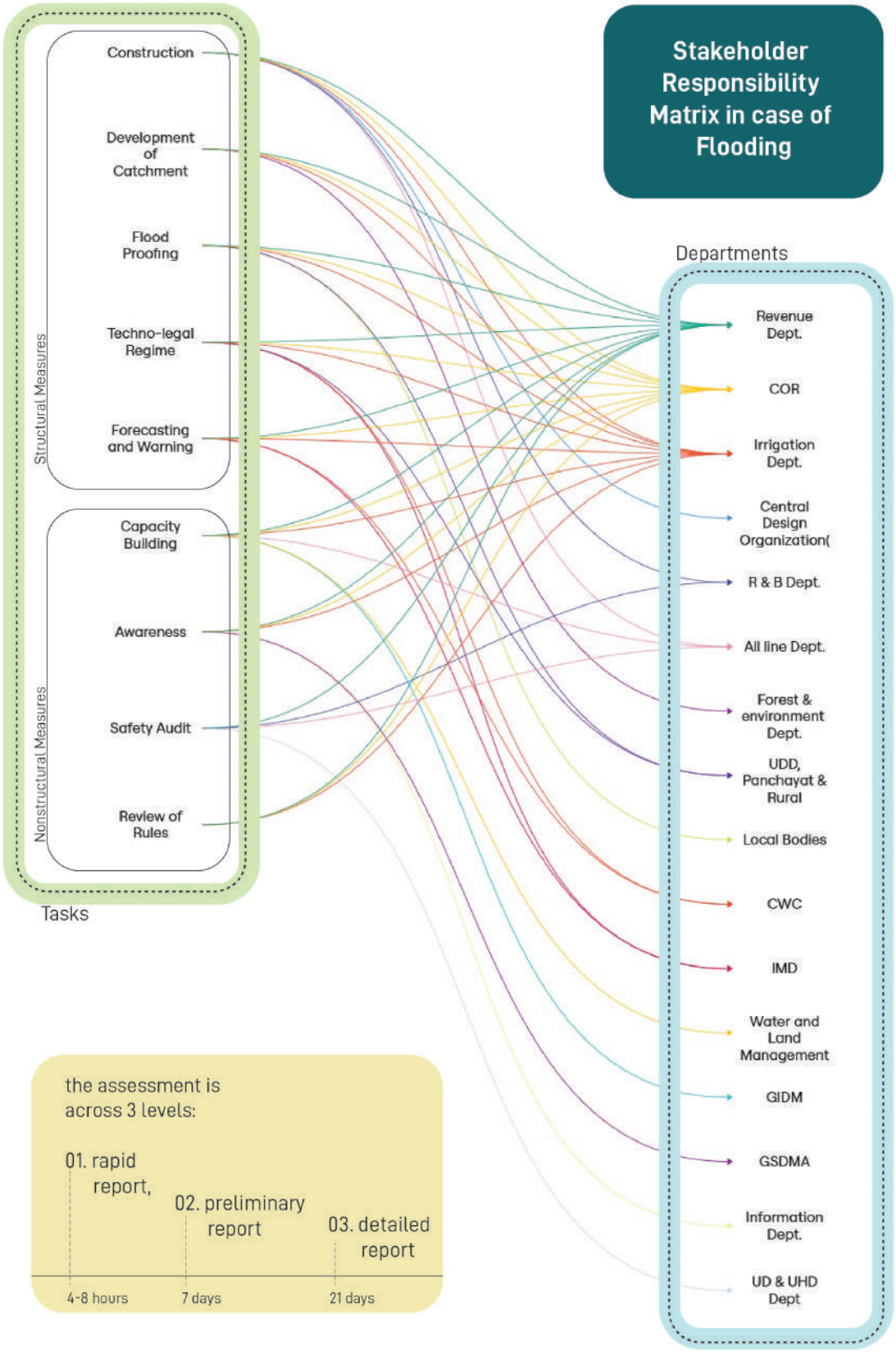


Fig 9. Stakeholder Responsibility Matrix for Flood Management: Tasks, Departments, and Assessment time frame.

4 System Risk and Vulnerability Profile

4.1 Current exposure and vulnerability of the cities

4.1.1 Ahmedabad

Ahmedabad city's risks and vulnerabilities to climate hazards have been analysed to guide climate-sensitive urban planning and resilience policies. The assessment is structured in three parts: 1) analysis of climate trends and projection scenario, 2) hazard and risk assessment, and 3) vulnerability assessment, using the 'Net Zero Climate Resilient CITIES' methodology and Shared Learning Dialogues with AMC stakeholders.

Risk assessment guided by historical weather data and future climate projections has identified Ahmedabad's vulnerability to extreme heat, urban floods, and air pollution. Risks were assessed via parameters like temperature and rainfall trends, spatial flooding analysis, and air quality data. Vulnerability assessment incorporates data from spatial analyses of vulnerable areas and urban systems. The analysis also considered impacts on vulnerable demographics and city services. High-risk areas have been identified via a map overlay technique integrating complaints, climate risks, and infrastructure gaps.

Climate projections

Historic climate and weather data from 1970 to 2020 was analysed to understand trends and patterns of change in temperature and rainfall. Climate projections for Representative Concentration Pathways (RCPs) till 2070, were derived from the State Action Plan on Climate Change (SAPCC), Gujarat 2021. This information has been substantiated with inputs from experts during stakeholder consultations in the case of Ahmedabad during the preparation of the Ahmedabad Climate Resilient City Action Plan (CRCAP). The table below presents the climate trends. These have been further analysed. Based on the trend analysis and future projections, climate scenario statements were developed.

Annual and seasonal trends of air temperature and rainfall from 1970 to 2020 were analysed based on data received from the Indian Meteorological Department (IMD), to understand the temporal change in minimum, average and maximum temperatures, and rainfall intensity. Information from the SAPCC (Gujarat 2021) from 1951 to 2019 has also been considered for trend analysis and projections. Changes in the annual number of extreme hot days and nights, and cold days and nights, and in the frequency of climate events etc., have also been analysed.

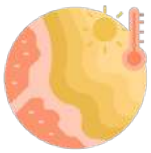
Climate Trends	Data	Source and Methodology
 Temperature	Maximum, Average and Minimum temperature has increased by 0.5 to 1°C from 1970 to 2020. The number of Hot Days has increased by 12 to 18 days and Hot Nights has increased by 18 to 24 nights. Number of Cold Days has decreased by 0 to 4 days and Cold Nights decreased by 8 to 12 nights.	Ahmedabad CRCAP analysis based on based on SAPCC (Gujarat 2021) and analysis from IMD data from 1970 - 2020
 Land Surface Temperature	LST varies from 29°C to 47°C during the day and from 26°C to 29°C at night. Maximum LST during the day increased from 45°C in 2015 to 47°C in 2021, minimum LST increased from 26°C in 2015 to 29°C in 2021. 67.9% of the total city area falls under hotspot areas, with LST more than median of 37°C, impacting 59.9% of the population in 2021.	Temporal analysis (pixel-based statistical analysis) of satellite imagery for day and night times for years 2015, 2018, and 2021 was conducted to understand the trend of LST. LST hotspots which showed consistently higher land surface temperature as compared to the median temperature (above 37°C) were identified.

Table 9. The climate trends for Ahmedabad, Gujarat.

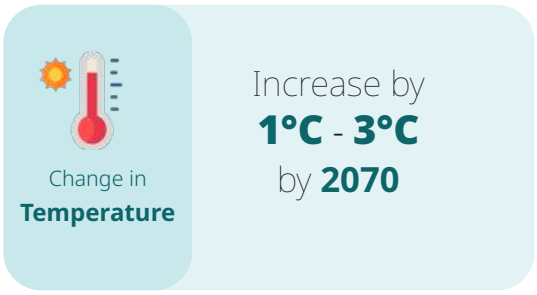
Climate Trends	Data	Source and Methodology
 Heat Index Analysis (Feels like temperature)	Ahmedabad experiences heat conditions varying from 'extreme caution' to 'extreme danger' during summer; majority days fall in the 'danger' category. Hot spot areas include 32.4% of the city area, with feels like temperatures of more than 43°C impacting 43.9% of the population. The northeast and southeast areas of the city (i.e., Sola, Sabarmati, Saraspur, Khokhra, and Vasna experience a high heat index of more than 45 °C, going up to 52 °C.	Heat index (feel like temperature) was analysed based on correlation between air temperature and humidity to establish and understand levels of thermal comfort in the city as per 'National Guidelines for Preparation of Action Plan – Prevention and Management of Heat Wave', prepared by NDMA. Areas with a heat index of more than 43°C have been considered as hotspot areas with high risks. This is the threshold temperature above which AMC issues a heatwave orange alert.
 Heat Wave Events and Trend	The number of heat wave events has increased by 4 from 1951 to 2019 and is expected to increase by 5 to 30 events by 2070 (as per RCP 2.6, RCP 4.5 and RCP 8.5 scenarios). The actual increase depends on the level of efforts made to curb greenhouse gas (GHG) emissions.	Analysed monthly heatwave warning days (including occurrences and frequency) for the last five years (monthly data provided by AMC from 2015 to 2021 summer months from April to July) and correlated with heat stroke cases and deaths for respective months
 Rainfall	Precipitation has increased by 100 mm to 200 mm between 1970 to 2021. Extreme Rainfall Event has increased by 3 to 4 events and extreme Wet Event has increased by 1 to 2 events.	Loss of community resilience Ahmedabad CRCAP analysis based on based on SAPCC (Gujarat 2021) and analysis from IMD data from 1970 - 2021.

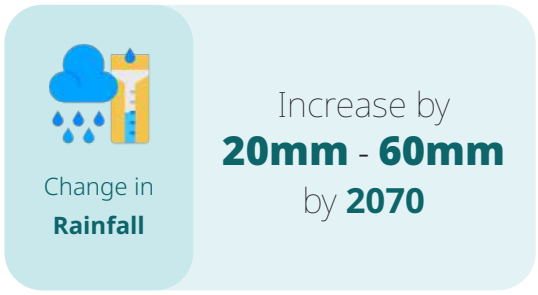
The climate trends for Ahmedabad, Gujarat.

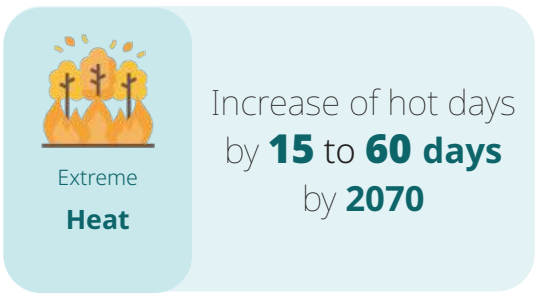
Table 10. The climate projections for Ahmedabad.

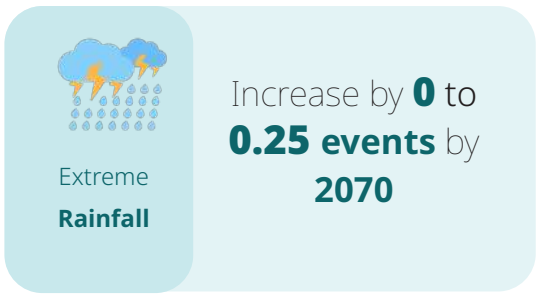
Climate Projections	Data
Change in temperature	Temperature in Ahmedabad is expected to further increase by 1°C to 3°C by 2070 (RCP 2.6, RCP 4.5, and RCP 8.5 scenarios).
Extreme heat events	Frequency of hot days is expected to increase by 15 to 60 days; frequency of hot nights is expected to increase by 30 to 110 nights by 2070 (RCP 2.6, RCP 4.5, and RCP 8.5 scenarios).
Change in rainfall	Rainfall in Ahmedabad is expected to increase by 20 mm to 60mm by 2070 (RCP 2.6, RCP 4.5, and RCP 8.5 scenarios).
Extreme rainfall events	Extreme rainfall events in Ahmedabad are expected to increase by 0 to 0.25 events by 2070 (RCP 2.6, RCP 4.5, and RCP 8.5 scenarios).

Source: Ahmedabad Municipal Corporation. (2021). Ahmedabad Climate Resilient City Action Plan (CRCAP) analysis based on State Action Plan on Climate Change (SAPCC). Climate Change Department, Government of Gujarat.









Risk and Vulnerability Profile

Vulnerability Variable		Risk and Vulnerability Matrix	
		Urban Heat Risk	
		Exposure data	Fragility statement
Socio economic aspects	Vulnerable population	72.1% of the total population in the city (5.1 million people)	Increase in extreme heat conditions causes thermal discomfort, reduced work productivity, increased heat stroke cases and heat related morbidity. Extreme heat conditions impact the economy and may severely affect vulnerable population groups. An increase in water demand and energy demand for cooling in buildings can be expected.
	Population by age	0.4 million children and 0.3 million elders	
	Population by gender	2.4 million females and 2.7 million males	
	Population requiring special needs	0.2 million people (people with difficulties in seeing, hearing, speech, movement, mental retardation, mental illness and others)	
	Population by education	1.1 million people with illiteracy	
	Population by income needs	0.7 million people live in slum localities (83.8% of the total slum population) and about 45,000 street side vendors (73.1% of the total street side vendors).	
	Population with poor workplace condition	770 workers at dump sites and material recovery facilities (MRF) are impacted due to accelerated decomposition rates and potentially hazardous conditions in open dump sites that increases the probability of landfill fires	
	Vulnerable areas and wards	Wards: Amraiwadi (39), Bapunagar (26), Viratnagar (25), Vasna (31), India Colony (22), Chandlodiya (02), Ranip (05), Thaltej (08), Gota (01), Lambha (46), Ramol-Hathijan (48). Industrial areas or estates i.e., Odhav GIDC, Vatva GIDC, Kathwada GIDC, Narol Landfill site: Gyaspur and Pirana	
Water Supply	WDS at risk	NA	Increase in ambient temperatures, especially during extreme heat events, increases water demand. Limited availability of water during summer months increases ground water extraction impacting overall water resource availability. Wards facing extreme heat conditions and drinking water supply related issues are more vulnerable.
	Vulnerable population	NA	
	Vulnerable wards	NA	

Table 11. Risk and Vulnerability matrix for Ahmedabad City

Risk and Vulnerability Matrix	
Urban Flood risk	
Exposure data	**Fragility statement**
9.5% of the total population in the city (Total 0.7 million people –0.3 million)	Increase in extreme rainfall events, coupled with limited and/or compromised storm water network capacity leads to water logging and flooding issues in the city, impacting not only urban infrastructure and property, but also livelihoods and public health. The health and livelihood of vulnerable population groups are especially impacted; urban poor are highly vulnerable due to poor living conditions and limited means.
55,000 children and 34,000 elders	
NA	
20,000 people	
0.2 million people with illiteracy	
88,000 people living in slum localities (10.5% of the total slum population) and 5,000 street side vendors (9.2% of the total street vendors).	
Inaccessible roads impacting the daily livelihood of street side vendors and slum dwellers.	
Vulnerable areas: 4.3% of the city area is impacted by urban flooding or water logging, affecting 9.5% of the population. Urban flood risk in the city is increasing with extreme rainfall events. People residing within a 250m buffer zone of 166 water-logged areas or flood points are at high risk and prone to severe health hazards. 4.3% of the city area is impacted by urban flooding or water logging, affecting 9.5% of the population.	
11.4% (28 out of 245) of the total WDS 65 are impacted due to urban flooding.	Increase in high intensity rainfall, leading to urban flooding, disrupts compromised stretches of the water distribution system, impacting public health.
0.2 million slum population (23% of total slum population) and about 14,000 vendors (22% of total vendors)	
9 wards (Danilimda (36), Amraiwadi (39), Navarangpura (18), Paldi (30), Maninagar (37), Naroda (12), S P Stadium (10), Saraspur (27), Vatva (47)	

Vulnerability Variable		Risk and Vulnerability Matrix	
		Urban Heat Risk	
		Exposure data	Fragility statement
Waste Water	SPS at risk	NA	Rising temperatures accelerate decomposition, raising fire risks in open dump sites and exposing workers to heat stress, lowering productivity.
	Vulnerable population	NA	
	Vulnerable wards	NA	
Solid Waste	Material Recovery Facility (MRF) at risk	Risk of waste burning in landfill due to high temperature	Inadequate treatment of sewage and faecal sludge is leading to unsafe disposal in natural drains. Increase in rate of decomposition with increase in temperature, impacting health of people, especially urban poor and people living in low lying areas.
	Pirana dump site at risk		
	Vulnerable population		
	Vulnerable wards		
Transport	Public Transport	117 BRTS stations (58.5% of total BRTS stations) and 2,820 AMTS stations (56.8% of total AMTS stations) are in extreme heat risk areas.	Increase in extreme heat conditions may adversely impact the health of commuters waiting at stations and using two wheelers and of pedestrians and cyclists, especially, elderly, young children and the infirm. This will increase the demand for comfortable public transport particularly at major traffic junctions, leading to an increased dependence on personal vehicles.
	Traffic Junctions	37 major traffic junctions67 with heavy traffic are in extreme heat risk areas (56.1% of the total heavy traffic junctions in the city).	
	Vulnerable People and wards	Around 40,000 to 50,000 elderly people using AMTS	
	Parks and Gardens	Increase in temperature may decrease the sparse vegetation and hence increase urban heat island effect.	During extreme heat conditions, intensity of urban heat island increases, as a result of expanding built-up areas.

Risk and Vulnerability Matrix	
Urban Flood risk	
Exposure data	**Fragility statement**
10.9% of the total SPS66 are impacted due to urban flooding.	Exacerbates the problems caused by compromised sewage networks, impacting health and groundwater and surface water quality. Operation of sewage treatment systems is also impacted.
0.3 million slum population (30.7% of total slum population) and about 16,000 vendors (25.6% of total vendors)	
11 wards (Naranpura (09), Amraiwadi (39), Thakkarbapa Nagar (23), Navarangpura (18), Paldi (30), New Vadaj (06), Maninagar (37), Vasna (31), Naroda (12), S P Stadium (10), Saraspur (27).	
2 MRFs (Khadia and Shayona), impacting 30 workers a day.	Drainage network blockages increase during periods of high rainfall. Land, surface water and groundwater are contaminated due to increased leachate flows from the open dump site.
650 workers may get impacted due to unhygienic conditions at the dump site.	
0.3 million slum population (34.2% of total slum population) and around 18,000 vendors (28.9% of total vendors)	
14 wards (Gomtipur (38), Khokhra (44), Amraiwadi (39), Thakkarbapa Nagar (23), Navrangpura (18), Bodakdev (19), Naranpura (09), Paldi (30), New Vadaj (06), Maninagar (37), Vasna (30), Naroda (12), S P Stadium (10), and Saraspur (27)), Paldi (30) and Naranpura (09) are the most vulnerable wards to solid waste cleaning issues and urban flood.	
28% of total BRTS stations (56 stations) and 8.7% of total AMTS stations (432 stations)	Extreme rainfall events are likely to worsen the road infrastructure, especially the already damaged sections. During periods of intense rainfall, waterlogged roads will further exacerbate road congestion and affect connectivity and mobility.
28.8% of the major or heavy traffic junctions (19 traffic junctions)	
8 wards (Naranpura (09), Paldi (30), Maninagar (37), Naroda (12), Navarangpura (18), S P Stadium (10), Saraspur(27), and New Vadaj (06))	
Increased runoff resulting from an increase in paved surfaces	Intense rainfall increases urban flooding and inundation, due to an increase in impermeable surfaces.

Vulnerability Variable		Risk and Vulnerability Matrix	
		Urban Heat Risk	
		Exposure data	Fragility statement
	Energy	NA	Increase in urban heat events leads to increase in electricity use due to increased cooling demand and electricity consumption for managing water requirements and pumping.
Health	Hospitals at risk Diseases	Increased heat strokes, heat stress, worsening heart disease (total 81 heat stroke cases and 7 death in 2022)	Increase in temperature may increase the number of heat stroke cases, heat stress, and heart disease related cases. Vulnerable people are at high risk with limited accessibility to healthcare services.
	vulnerable due to distant health care facilities.	0.25% of the total population in the city (18,000 people); 20% of all slum dwellers (0.2 million slum population)	
	Accessibility to health care facilities	94.1% (6.7 million) access healthcare within 1 km, 4.7% (0.3 million) within 2 km, and 1% (75,000) within 3 km. Among slum dwellers, 25% (0.2 million) access it within 1 km, 27% within 2 km, and 27% within 3 km.	
Emergency Services	Fire stations at risk	37.4% of total fire related calls (682 calls out of total 1,819 calls) received during summer season.	Rising temperatures may increase fire emergencies, posing high risks to vulnerable groups with limited access to emergency services.
	Vulnerable wards	Jamalpur area receives highest number of fire calls followed by Memnagar, Naroda, Prahladnagar, and Jasodanagar.	
Housing	Public Housing MMGY	NA	
	Public housing BSUP	NA	
	Informal settlements	NA	

Risk and Vulnerability Matrix	
Urban Flood risk	
Exposure data	**Fragility statement**
NA	Energy infrastructure damages during extreme rainfall events, may affect emergency services due to power outages. Increase in electricity demand to pump water from water logged areas.
31.3% of all hospitals (651 hospitals) Ahmedabad recorded 63,824 water and vector borne disease cases (20,734 water borne and 43,090 vector borne) during 2021. Vasna (31) registered the highest number of water and vector borne disease cases, followed by New Vadaj (06), Paldi (30), Maninagar (37), Saraspur (27) and (Figure 4.12). Amongst these, Vasna (31), Maninagar (37), and Saraspur (27) are severely impacted by flooding as well.	Increase in extreme rainfall and water logging may lead to disease outbreak, especially in congested slum areas. Limited accessibility to health care facilities increases the vulnerability of urban poor. Accessibility to emergency services is also impacted during periods of heavy rain and related flooding/inundation.
0.25% of the total population in the city (18,000 people); 20% of all slum dwellers (0.2 million slum population)	
94.1% of the total population (6.7 million) can access health care facilities within 1 km, 4.7% (0.3 million people) within 2 km, and 1% (75,000 people) within 3 km. 25% of all slum dwellers (0.2 million people) can access health care facilities within 1 km, 27% within 2 km, and 27% within 3 km.	
25% of all fire stations (5 fire stations – Bodakdev, Dudheshwar, Maninagar, Naroda, Gomtipur) 10 wards (Amraiwadi (39), Gomtipur (38), Isanpur (45), Maninagar (37), Naroda (12), New Vadaj (06), Paldi (30), Saraspur (27), Vasna (30) and Vatva (47)	Accessibility to emergency services for the vulnerable urban poor is impacted during periods of heavy rain and related flooding/inundation.
76.8% of households have been affected in the past 5 years. 78% affected HHs in the past 1 year. 0.49-0.53m mean depth of water logging. 2 mean days of water logging. 2 mean working days lost and 3 mean education days lost. 25.6% factory workers, 2.4% labourers impacted.	Based on a surveyed sample of 214 Households in 2018. 50% of households were located in public housing sites (with 38.3 per cent in MMGY housing sites and remaining 11.7 % in BSUP) and slum settlements each. Source: Mahadevia, D., Bhatia, N., Verma, P., Raj, V., & Patel, S. (2018). Affordable Housing as Flood Resilient for Low-Income Households: Case of Ahmedabad and Surat.
All households were affected in the past 5 years, with 100% impacted in the last year. Waterlogging averaged 0.64–0.79 m for 4 days. 36% of households reported structural damage, with an average cost of INR 3,982. On average, 3 workdays and 4 school days were lost. Factory workers (24%) and laborers (8%) were impacted.	
All households were affected in the past 5 years, with 100% impacted in the last year. Waterlogging averaged 0.91–1 m in depth for 6 days. 73% of households reported structural damage, incurring an average cost of INR 5,420. On average, 5 workdays and 6 school days were lost. Factory workers (52.8%) and labourers (8.3%) were notably impacted.	

The Rajbhoi Tribe in Ahmedabad

Members of this Gujarat-based tribe have settled in the Vatva neighbourhood of Ahmedabad. Women from the tribe are engaged in making ropes from silk textile waste collected from industries in Surat.

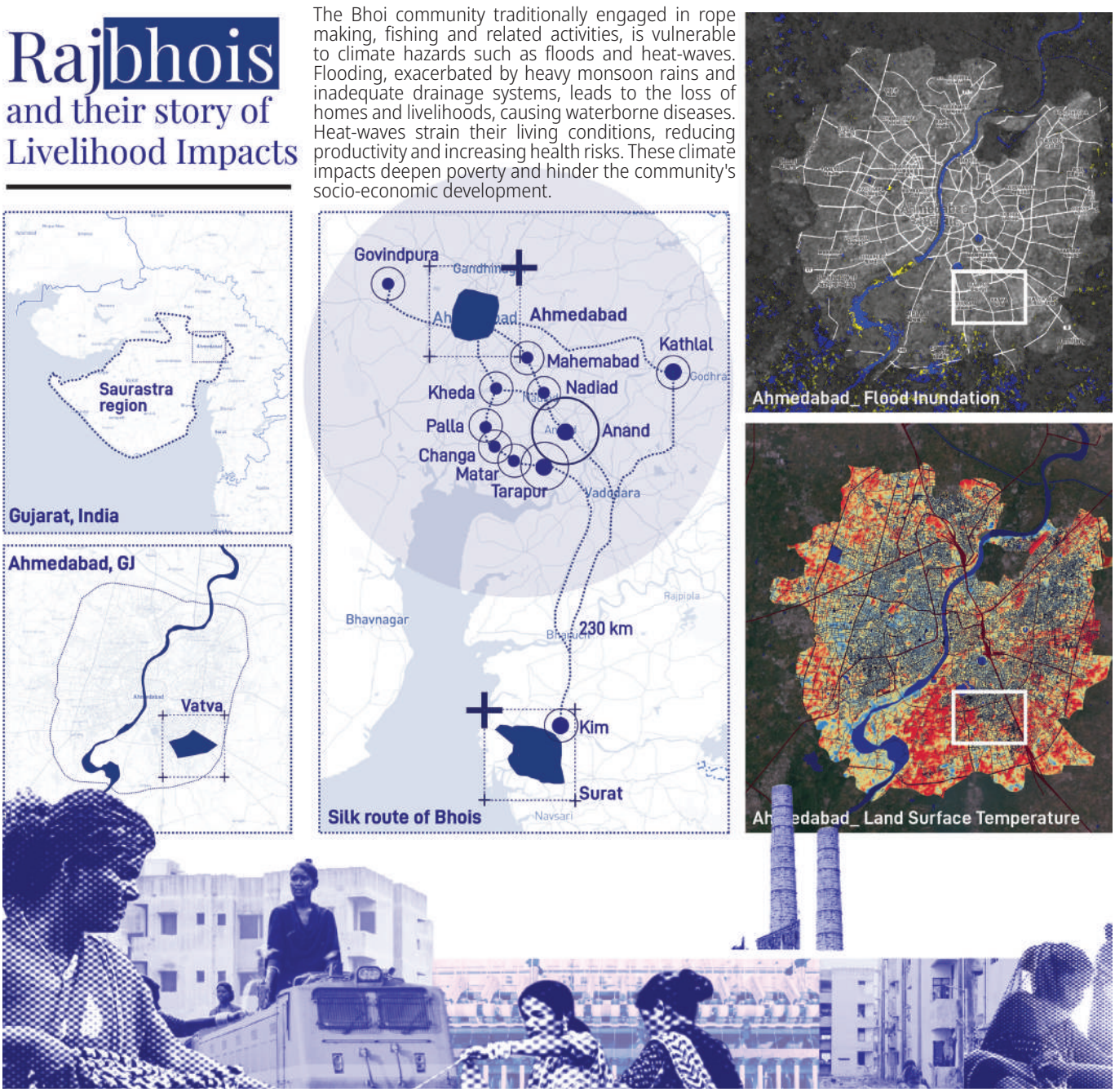
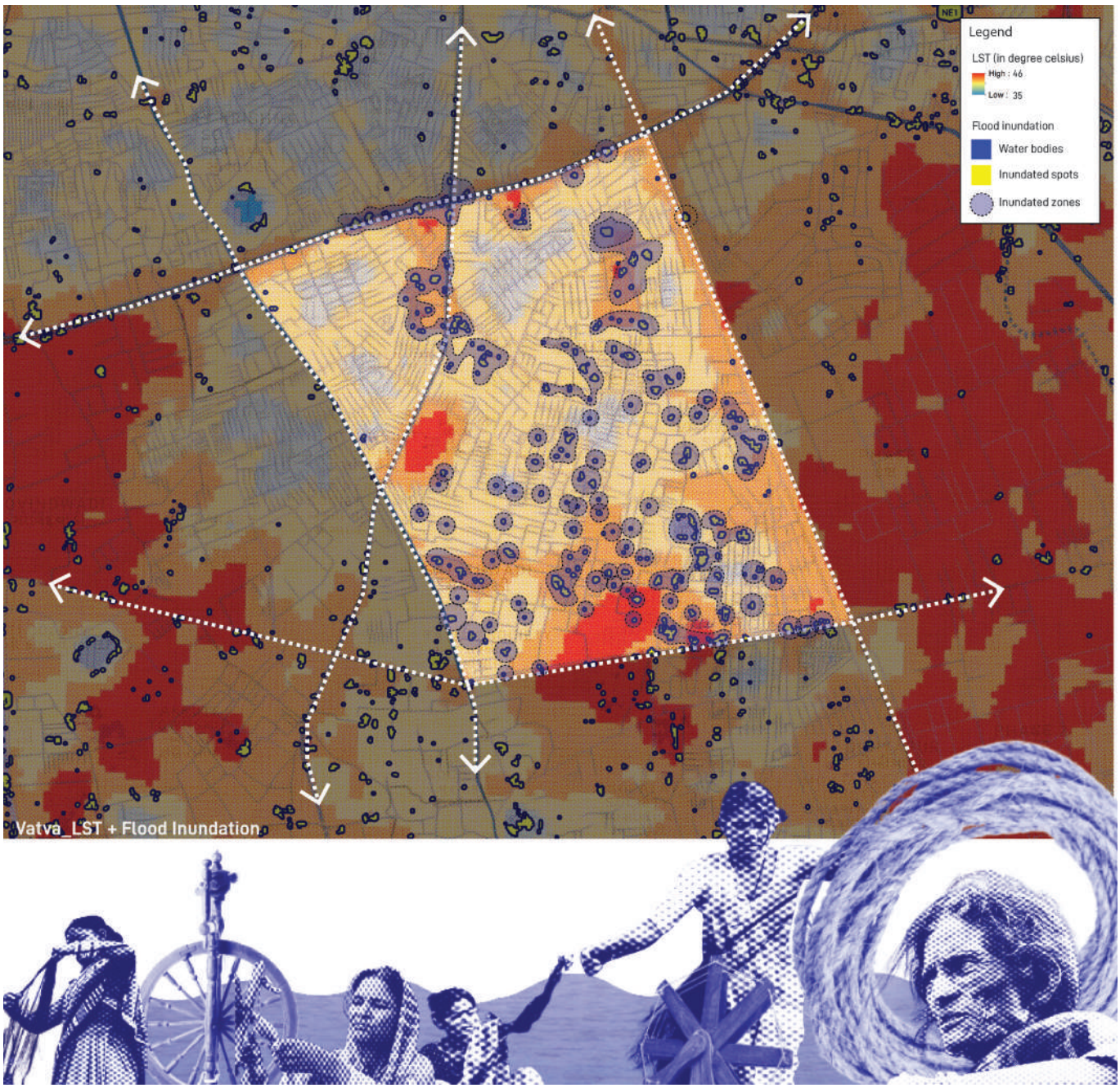


Fig 10. Community stories and their livelihood linkages to loss and damage in Ahmedabad.

The women of the Bhoi community involved in rope making face severe challenges. They work under extreme heat conditions, which not only endangers their health but also hampers productivity. Annual floods disrupt their work by breaking supply chains, making it difficult to obtain necessary materials. To sustain their livelihood, these women travel 230km to buy waste fibres from textile mills, hoping to earn a living from the ropes they produce.



Data Sources:Flood inundation- Copernicus Global Land Cover Digital Surface Model Collection 3 on Google Earth Engine
Land Surface Temperature- Landsat 8 on USGS explorer
Mapping and spatial climate assessment: ICLEI South Asia
Story and images: PARI (People's Archive of Rural India) Network

Cyclones

The India Meteorological Department (IMD), in collaboration with the Building Materials and Technology Promotion Council (BMTPC) and the Gujarat State Disaster Management Authority (GSDMA), has conducted a Cyclone Vulnerability Analysis for Gujarat. A study led by Manorama Mohapatra from IMD (2015) examined the frequency and intensity of land falling tropical cyclones, along with related hazards such as rainfall, wind, and storm surges. Based on this analysis, Ahmedabad district has been classified in the P2 category, indicating it is highly prone to cyclones—the highest risk level. Additionally, a study by BMTPC places Ahmedabad city in the fourth category, categorized as a Moderate Risk Zone – B, for wind hazards. For cyclone occurrences, the city falls in the second category, with maximum sustained wind speeds ranging between 64-90 knots.

According to GSDMA[1] Cyclone Hazard Risk Zonation for Gujarat, Ahmedabad is situated in a lower wind speed zone, with possibility of wind speeds between 122-140 km/h. As Ahmedabad is located inland and away from the coastline, it is less susceptible to frequent cyclone impacts, despite these risks[2].

Flooding

Ahmedabad faces two types of flooding: river flooding and urban flooding. River flooding occurs when there is rise in the water levels of the Sabarmati River, which flows through the centre of the city, due to heavy rainfall in its upper catchment areas. While this type of flooding is not frequent, it can cause significant disruption to the vulnerable population living in the low lying areas when it happens. On the other hand, urban flooding is more common and is caused by a combination of factors including inadequate storm water drainage, intense rainfall over short periods, and the accumulation of solid waste that clogs drains. This type of flooding leads to water logging, road cave-ins, potholes, overflow and back flow of sewers and widespread disruption in the city, particularly in low-lying areas. As Ahmedabad continues to expand rapidly, urban flooding has become a growing concern due to the strain on the city's infrastructure.

River Flooding

Sabarmati is an important river flowing through the city of Ahmedabad and has been an important source of water for its residents. Sabarmati river originates in the Aravalli ranges of Udaipur, Rajasthan and flows through Ahmedabad and flows into the Arabian Sea through the Gulf of Khambhat. The history of the city, founded in 1411, is closely tied and organised around the Sabarmati River. The river was a crucial source for domestic water use, farming and other recreational purposes. Over the years, a few dams have been built on the river, like the Dharoi dam built in 1976 to prevent flooding[3].

Ahmedabad has a history of flooding due to its location where key rivers pass through the city. In 1953, Ahmedabad witnessed the worst floods where the flood water levels rose to 20 feet in height causing large scale damage and about 10,000 lives were lost. Since then, the Ahmedabad Municipal Corporation has taken several preventive measures such as improving the city-wide drainage infrastructure and construction of flood walls and embankments in various parts of the city resulting in enhanced flood management. Despite this, the 2022 floods in Ahmedabad resulted in the loss of a dozens of lives[4].

1 GIDM (2020). Frequency of cyclones affecting Gujarat state; Role of mangroves and shelterbelt in cyclone risk mitigation.

2 ibid.

3 WIN Foundation.(n.d.). Ahmedabad water context. Urban Waters Ahmedabad.

4 Times of India. (2023). Floods in India.

Past impacts

To mitigate flooding along the Sabarmati River and stabilize its banks while also creating open spaces for public recreation, the Ahmedabad Municipal Corporation developed a riverfront on both sides of the river. Despite these efforts, the riverfront has experienced flooding on several occasions due to large volumes of water released from upstream. Significant flooding events occurred in 2006, 2011, 2015, 2017 and 2022. In 2017, continuous rainfall in the upstream regions led to the release of 1.8 lakh cusecs of water from the Dharoi Dam, which completely submerged the lower promenade of the riverfront. In some areas, the water even rose close to the upper promenade, threatening road closures. The rising water levels also led to unusual incidents, such as snakes entering factories in the nearby Behrampura area[5]. Beyond its impact on the riverfront, the rising water levels also disrupt the city's road networks and traffic flow. During the monsoon season, the Sabarmati's water level is ideally maintained at 128 feet. However, if it exceeds this level, especially during heavy rains, it can hinder the storm water drainage system as the water cannot be drained into the river and it causes back flow of the water, exacerbating flooding on the roads and causing severe traffic congestion[6].

Current status and projected risk

Ahmedabad faces increasing flood risks, driven by extreme rainfall, urbanization, and compromised drainage systems. Approximately 9.5% of the population, or 0.7 million people, are directly impacted by urban flooding, including 55,000 children, 34,000 elderly, and 20,000 people with special needs. Vulnerable communities include 88,000 slum residents (10.5% of the slum population) and 5,000 street vendors (9.2% of total vendors) dependent on public infrastructure for their livelihoods[7].

Vulnerable areas include 166 waterlogged zones identified across Ahmedabad, with residents within a 250m buffer zone at heightened risk. Notable wards affected include Maninagar (37), Paldi(30), Vatva(47), and India Colony(22). Flooding limits access to healthcare, emergency services, and daily necessities, especially for people with disabilities and the urban poor, leading to disease outbreaks. In 2021, the city recorded 63,824 water-borne and vector-borne diseases, concentrated in flood-affected areas.

Urban flooding disrupts public transport systems and road networks, further isolating vulnerable populations. For people with disabilities and low-income workers, waterlogged roads make daily commuting and access to safe spaces more difficult, increasing dependency on external support.

As extreme rainfall events increase, water-logging worsens, exacerbating congestion, mobility challenges, and public health risks. With 4.3% of the city prone to flooding, the risk to infrastructure, businesses,essential services rises.

5 Indian Express. (2017). Gujarat floods: Submerged Sabarmati Riverfront throws up snakes and many questions.

6 Times of India. (2023). Floods in Ahmedabad.

7 Ahmedabad Municipal Corporation. (2023). Ahmedabad Climate Resilient City Action Plan: Towards a Net Zero Future.

Extreme heat

Ahmedabad city, with its hot semi-arid climate, experiences extreme heat events that can result in severe health impacts. In 2010, Ahmedabad experienced a heat wave with a maximum temperature of 46.8°C, which caused a sharp rise in mortality figures with 1,344 additional all-cause deaths recorded in May 2010 alone (an increase of 43.1% over the baseline mortality rate) (Hess, et al., 2018). 51 warning days55 for extreme heat were recorded in the city in 2010. AMC realised the need to manage extreme heat events and adopted its Heat Action Plan (the first in South Asia) in 2014. From 2015 to 2022, the city experienced 44 heat wave warning days annually on average, with 2022 witnessing 56 such heat wave days. Two 'red alert' heat wave events (air temperature ›=45°C) in the month of May have been reported in 2016 and 2022. A high number of heat stroke cases were recorded in 2016 (116 cases and 21 deaths) and 2022 (81 cases and 7 deaths). A strong correlation was found between heat wave events (red alert warning days) and increase in total number of heat stroke related morbidity and mortality in Ahmedabad.

Extreme Heat Hotspots (impacted by high LST and high Feel-Like Temperature) in Ahmedabad include the following -

- Wards: Amraiwadi (39), Bapunagar (26), Viratnagar (25), Vasna (31), India Colony (22), Chandlodiya (02), Ranip (05), Thaltej (08), Gota (01), Lambha (46), Ramol-Hathijan (48).
- Industrial areas or estates: Odhav GIDC, Vatva GIDC, Kathwada GIDC, Narol
- Landfill site: Gyaspur and Pirana

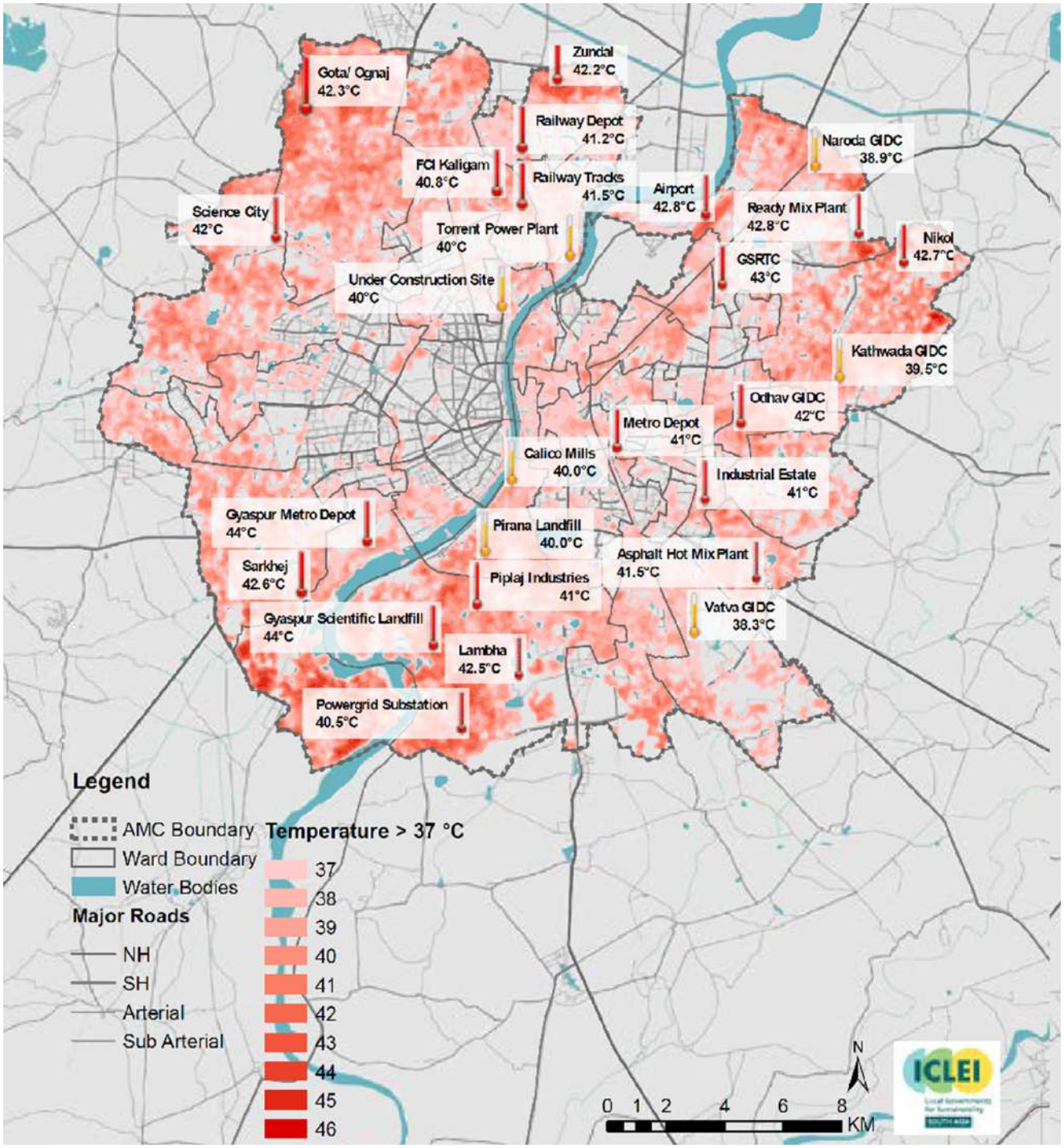
Industrial areas that are highly vulnerable to extreme heat conditions and may severely impact the health of workers. Solid waste dump sites and material recovery facilities are also highly vulnerable to extreme heat; this may impact the health of workers and worker productivity.

Extreme heat conditions may also increase water demand. Wards with constrained water supply that also experience extreme heat conditions are highly vulnerable i.e., Ranip (05), Vasna (31), Gota (01), Lambha (46), Thaltej (08) and Vatva (47)). The energy demand in buildings during such conditions may increase due to increased space cooling requirements. Power supply related infrastructure, i.e., GETCO substation and power grid substation in the south of the city, are also subject to extreme heat.

Population Vulnerable to Extreme Heat

- The elderly, children, women, differently-abled, uneducated, and poor people are more vulnerable and may be severely impacted due to extreme heat conditions.
- Elderly, children, women and people with special needs are especially vulnerable to heat related morbidity.
- Differently-abled persons face the most difficulty when trying to access emergency support, due to limited availability of disability inclusive infrastructure and limited or no consideration of special needs in disaster and/or emergency management plans, rendering them especially vulnerable to climate disasters.

Effective information and communication are critical for preventing heat illness. Uneducated people are more vulnerable due to limited access to and understanding of timely information. The urban poor remain highly sensitive to an increase in temperature due to poor living and workplace conditions along with limited access to affordable cooling options and community health centres/ government hospitals[8].



Map 17. Feel like temperature, May 2021

Impact on transport and mobility

Climate change is having a significant impact on transportation and mobility in Ahmedabad, leading to multiple challenges that need to be addressed. With a 64% rise in the vehicular population over the last decade, congestion has worsened, exacerbated by limited public transport services and poor integration between modes, such as buses and BRTS.

Insufficient public transport (0.12 buses per 1,000 people, compared to the recommended 0.6) and weak non-motorized transport infrastructure further drive reliance on private vehicles. Intense rainfall events damage road networks, causing potholes, open manholes, and water logging, which disrupt traffic and hinder mobility. Flooded roads during heavy rains lead to severe congestion and impede public transport operations.

Rising temperatures affect the health of pedestrians, cyclists, and two-wheeler users, especially the elderly and children. Long waits at poorly equipped public transport stations during heat waves increase discomfort, pushing people toward private vehicle use, which further aggravates traffic and emissions. Increased congestion and deteriorating road conditions elevate the risk of road accidents. Waterlogged roads during extreme rainfall periods further compromise safety and disrupt connectivity, affecting daily commutes and emergency services.

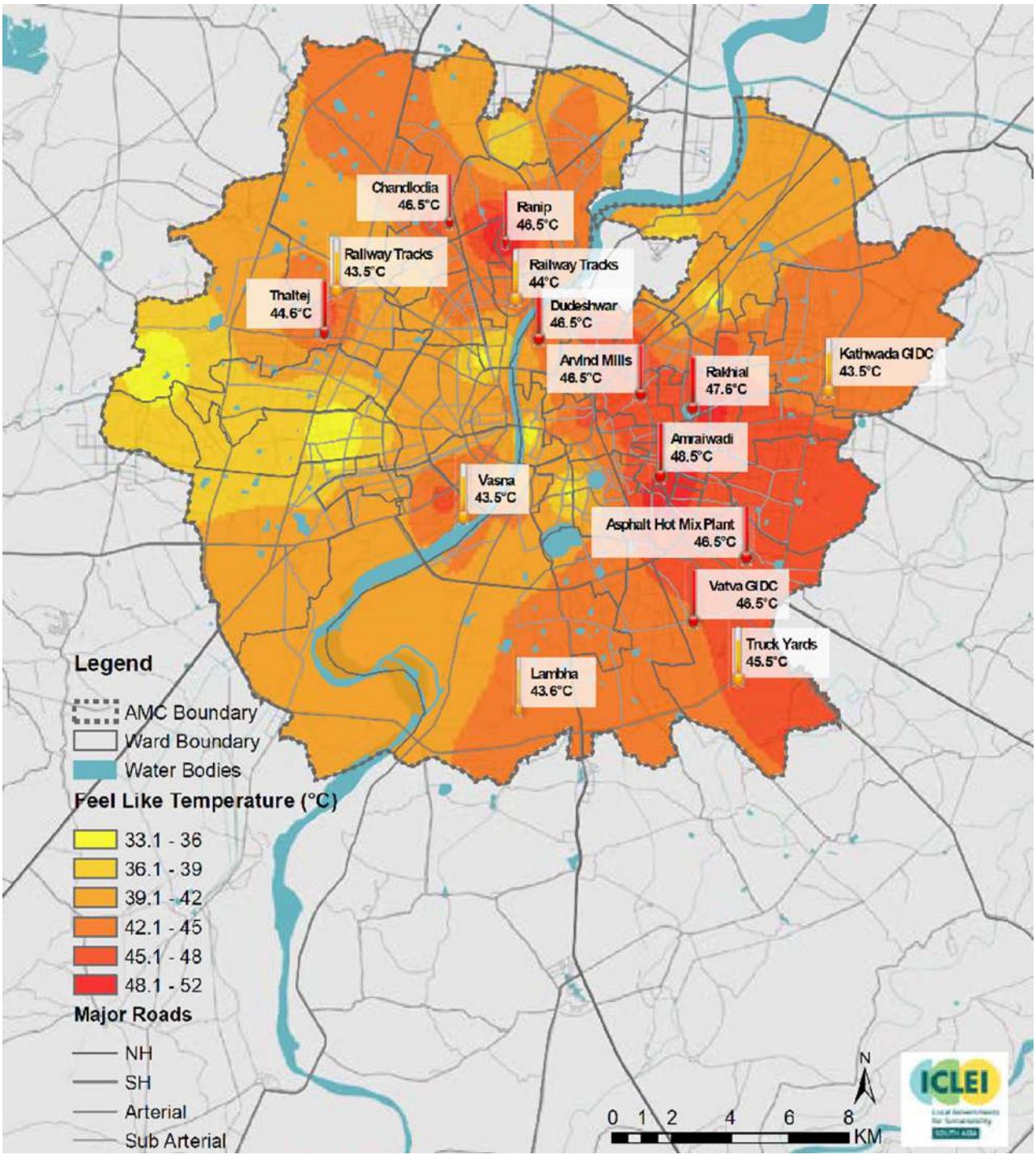
Public transport stations and major traffic junctions affected by urban flooding have been spatially analyzed. Additionally, complaints about open manholes, poor road quality, potholes, raised manhole covers, and catch pits were assessed and correlated with urban flood risk areas. Among the 48 wards, 6 received a high volume of complaints related to road infrastructure and are significantly impacted by water logging and flooding issues. Wards vulnerable to Transport Infrastructure to Urban Flood Risk comprise Naranpura (09), Paldi (30), Maninagar (37), Naroda (12), S P Stadium (10), Saraspur (27), and New Vadaj (06). Public transport stations at risk: 28% of total BRTS stations (56 stations) and 8.7% of total AMTS stations (432 stations) and major traffic junctions at risk: 28.8% of the major or heavy traffic junctions (19 traffic junctions)[8].

Disease risk

In 2021, Ahmedabad reported a total of 63,824 cases of water and vector-borne diseases, including 20,734 water-borne and 43,090 vector-borne cases. This included 20,734 water-borne cases and 43,090 vector-borne cases, with the Vasna (31) ward recording the highest incidence. Other heavily impacted wards included New Vadaj (06), Paldi (30), Maninagar (37), and Saraspur (27), which not only reported high disease rates but were also severely affected by flooding. The heavy rains during the monsoon season contributed to stagnant water in these areas, creating ideal breeding conditions for disease-carrying mosquitoes.

During 2021-22, Ahmedabad reported 2,037 air-borne disease cases, including 852 acute respiratory infections (ARI) and 1,185 tuberculosis cases. Wards like Jamalpur, Danilimda, Maninagar, Baherampura, Lambha, and Vatva exhibited moderate to high numbers, reflecting significant health risks from air pollution in densely populated areas. The combined issues of flooding, poor sanitation and air pollution have intensified the public health crisis, highlighting the need for comprehensive urban planning and public health measures to address disease transmission and enhance infrastructure resilience[8].

8 Ahmedabad Municipal Corporation. (2023). Ahmedabad Climate Resilient City Action Plan: Towards a Net Zero Future.



Map 18. Land surface temperature hotspot areas, May 2021

4.1.2 Surat

Surat city is an area of concern in case of earthquakes, cyclones, floods, sea surge and heat waves (Surat District Disaster Management Plan 2021-22). It is estimated that approx 90% of Surat's geographical area is affected by climatic hazards - flooding, coastal storms and cyclones, tidal inundation and sea level rise (Bhat et al., 2013). Certain highly populated localities such as Gopipura, Wadifalia with a population density of around 1000 persons per hectare are vulnerable to any type of extreme events.

Accordingly, climate scenario statements have been derived from the State Action Plan for Climate Change (SAPCC) 2021 for Surat. To understand the historical evidence of climate events (1951-2019), for e.g for precipitation, analysis of daily precipitation levels from IMD have been be analysed to understand its temporal and spatial distribution, extreme events, and seasonal variations. Similarly for air temperature, calculation of daily maximum, minimum, and mean temperatures, along with hot/cold days and nights, and heat waves have been analysed. To further understand the climatic events for projected scenarios (2021-2070), multi-model datasets have been used for precipitation analysis under three RCP scenarios to project future precipitation patterns, extreme events, and wet/dry spells. Similarly for air temperature, analysis of future temperature variations, including mean, maximum, minimum, and extreme events have been carried out.

Climate Projections of Surat based on three RCP scenarios

Climate Projections	Data
Change in temperature	Temperature in Surat is expected to further increase by 1°C to 3°C by 2070 (RCP 2.6, RCP 4.5, and RCP 8.5 scenarios).
	Frequency of hot days is expected to increase by 20 to 60 days; frequency of hot nights is expected to increase by 30 to 110 nights by 2070 (RCP 2.6, RCP 4.5, and RCP 8.5 scenarios).
	Frequency of cold days is expected to decrease by 22 to 36 days; frequency of cold nights is expected to decrease by 22 to 36 nights by 2070 (RCP 2.6, RCP 4.5, and RCP 8.5 scenarios).
Extreme heat events	Heatwave events in Surat are expected to increase by 5 to 30 days by 2070 (RCP 2.6, RCP 4.5, and RCP 8.5 scenarios).
Change in rainfall	Rainfall in Surat is expected to increase by 20 mm to 60mm by 2070 (RCP 2.6, RCP 4.5, and RCP 8.5 scenarios).
Extreme rainfall events	Extreme rainfall events in Surat are expected to increase by 0 to 0.5 events by 2070 (RCP 2.6, RCP 4.5, and RCP 8.5 scenarios).

Table 12. Climate projections for Surat, Gujarat

Climate trends of Surat

Climate Trends	Data	Source and Methodology
 Temperature	Annual average temperatures range from 26.5°C to 27.5°C. Daily highs reach 34–35°C, averages 28–29°C, and lows 21–23°C. Surat has experienced rising temperatures: maximums up by 0.2–1.4°C, averages increasing by 0.6°C, and minimums increasing by 0.9–1°C. Hot days increased by 0–6, hot nights by 12–18, and cold days by 8–12, cold nights decreased by 4–8.	Heat wave action plan based on article published in international journal of environmental sciences and SAPCC Gujarat 2021
 Land Surface Temperature	Intense heat waves in March 2022, with temperatures in heat hotspots ranging from 36°C to 45°C. On March 30, 2021, all zones in the city recorded LSTs exceeding 40.9°C, and some areas even reached temperatures above 43°C. Similar high temperatures were observed on March 17, 2022, particularly in South Zone A and Southwest Zone. Notably, all zones in Surat experienced LSTs that were at least 80% of the highest recorded temperatures on both dates, highlighting the widespread impact of the heat waves.	From 'Climate Adaptive and Gender Integrated Heat Wave Action Plan of Surat City, 2022'. Remote sensing using land surface temperature (LST) images procured from Landsat 8. LANDSAT images have been taken from 30 March 2021 and 17th March 2022.
 Heat Index Analysis (Feels like temperature)	Surat experienced 2 days of caution (27°C to 31°C) heat index, 96 days of extreme caution (32°C to 40°C) heat index, 674 days of danger (41°C to 54°C) heat index, and 189 days of extreme (more than 54°C) danger heat index.	Climate Adaptive and Gender Integrated Heat Wave Action Plan of Surat City, 2023 and Demonstration packet: City Heat Resilience Toolkit for Surat City, 2021
 Heat Wave	The number of heat wave events is expected to increase by 5 to 30 events by 2070 (as per RCP 2.6, RCP 4.5 and RCP 8.5 scenarios).	Analysis based on SAPCC Gujarat 2021.
 Rainfall	annual average precipitation of 2000mm to 2500mm, with the monsoon season contributing 1000-1500mm of this rainfall. In recent years, there has been a positive trend in monsoon rainfall, with an increase of 100mm observed. Additionally, the frequency of extreme rainfall events has risen to 4-5 occurrences.	Analysis based on SAPCC Gujarat 2021.

Table 13. Climate trends for Surat, Gujarat

Risk and Vulnerability Profile

Vulnerability Variable		Risk and Vulnerability Matrix	
		Urban Heat Risk	
		Exposure data	Source and Methodology
Socio economic aspects	Vulnerable population	36,167 deaths were reported over 961 summer days (2001–2012), with a mean daily mortality of 37.6±9.4. All-cause mortality rose 11% when temperatures exceeded 40°C. Daily deaths increased by 9% (3 deaths) at 'Danger' Heat Index levels and 18% (6 deaths) at 'Extreme Danger' levels, peaking on the second day of extreme heat.	Demonstration packet: City Heat Resilience Toolkit for Surat City 2021
	Population by age	7,36,286 children population	Primary Census Abstract (PCA), 2011
	Population by gender	19,97,863 women population	Primary Census Abstract (PCA), 2012
	Population by education		
	Population by income needs	As per SMC, there are 224 slum households. People vulnerable to extreme temperatures are those who have to remain outdoors for work all day long and have limited options to protect themselves, for example, street vendors, beggars, shopkeepers, traffic police, and auto-rickshaw drivers.	Demonstration packet: City Heat Resilience Toolkit for Surat City 2021

Table 14. Risk and Vulnerability matrix for Surat City

Urban Flood risk	
Exposure data	**Source and Methodology**
7,36,286 children population	Primary Census Abstract (PCA), 2011
19,97,863 women population	Primary Census Abstract (PCA), 2012
68% of surveyed schools, located in flood-prone north and west zones, faced significant impacts: 30% reported complete furniture damage, 20% partial damage. Other issues included lack of safe drinking water, wiring problems, loss of books, and disrupted communication and transportation.	Based on survey of 56 schools in " Vulnerability of Surat, Gujarat to Flooding from Tapi River: A Climate Change Impact Assessment " (Integrated Research and Action for Development)
As per SMC there are 333 slum Households. Approx. 70% of the households reported that the water level inside the house was more than 50 cm. Entry of water in the house caused damage to the wall, floors and household items. After the water recedes, the people have to incur expenditure in repairing the damaged houses. People also reported an unusual increase in their medical expenses because of spurt in diseases like fever, chicken guinea, etc. Sanitation was the pressing concern.	Based on survey of 56 slum households in " Vulnerability of Surat, Gujarat to Flooding from Tapi River: A Climate Change Impact Assessment " (Integrated Research and Action for Development)

Vulnerability Variable		Risk and Vulnerability Matrix	
		Urban Heat Risk	
		Exposure data	Source and Methodology
Socio economic aspects	Population with poor workplace condition	The surveyed sample spend most days in direct sun exposure of 4 to 6 hours and 7 to 9 hours, respectively. 52% of the respondents have a monthly productivity loss accounting for about 2000 INR, with another 48% registering a loss close to 500 INR monthly during the extreme summer heat. Over 22 % of the respondents also had to be hospitalised due to excess heat. About 50 % of people reported the loss of income due to heat-associated illness and leaves, with wage or salary loss between 1-999 to above 3000, with maximum loss recorded within 1000-1999 INR per month.	Based on surveyed sample of 60 households in " Climate Adaptive and Gender Integrated Heat Wave Action Plan of Surat City, 2022 "
	Vulnerable areas and wards	Road Dust: Core and densely populated areas – Chowk, Muglisara, Rander, Udhana, Katargam, Adajan, Athwa Gate, Piplod, Varachha, and Limbayat. Industries: Udhana, Pandesara, Ved Road, Bhestan, Sachin, Katargam, Unn, Adajan, Bhimrad, Sarsana, and Amroli-Utran. Construction: Pal, Adajan, Katargam, Piplod, Vesu, Rander, Tunki, Palsana, and Pandesara.	WRI India (2020). Hot Spots Identification and Micro Action Plan for Surat City. Prepared as part of the Surat Clean Air Action Plan (SCAP) Project
Solid Waste	Vulnerable areas	Waste Burning: TPS - 4, Ashvanikumar Navagam, TPS - 8 Umarwada, Fulpada, Kapadra, Dindoli (52), Bhestan, Pandesara, Udhana, Bamroli, Dindoli part (81), Bamroli (Part). Some wards have Industrial areas such as Bhestan, Pandesara, Udhana, Ashvanikumar Navagam, Kapadra which seek special focus since highest burning incidences were observed in these industrial areas.	WRI India (2020). Hot Spots Identification and Micro Action Plan for Surat City. Prepared as part of the Surat Clean Air Action Plan (SCAP) Project

Risk and Vulnerability Matrix	
Urban Flood risk	
Exposure data	**Source and Methodology**
70 percent small scale industries, scattered across four most vulnerable zones identified, namely East zone, North zone, South-East zone and South zone. Impact of the flood of 2006 was limited not only to production disruption, but it also caused an epidemic. Spread of epidemic was reported by 17 percent of the industries surveyed, in the post flood scenario. Post-flood disruption in transportation and communication also caused losses for the enterprises located in the flood affected areas. Losses due to transportation and communication disruption were reported by 53 percent of the enterprises covered in the survey.	Based on survey of 30 industries in " Vulnerability of Surat, Gujarat to Flooding from Tapi River: A Climate Change Impact Assessment " (Integrated Research and Action for Development)
Since the altitude of Surat is less than 13 m above mean sea level, even with a sea level rise of 1 m, the area under high tide zone particularly western parts of the city which are less than 10 m above mean sea level may be highly impacted.	Surat development plan 2035
11.4% (28 out of 245) of the total WDS 65 are impacted due to urban flooding.	

Vulnerability Variable		Risk and Vulnerability Matrix	
		Urban Heat Risk	
		Exposure data	Source and Methodology
	Public Transport	All wards in the south and south west zones shall be given priority as areas of concern for heat risk.	Hotspot Identification and Micro Action Plan for Surat (WRI India, SCAP Project).
	Health: Hospitals at risk	NA	
	Public Housing Sites (BSUP)		
Housing	Slum Settlements		
	Manufacturing		

Risk and Vulnerability Matrix	
Urban Flood risk	
Exposure data	**Source and Methodology**
0.2 million slum population (23% of total slum population) and about 14,000 vendors (22% of total vendors)	
11 hospitals were located in the area submerged up to 1 m, 11 were located in the area submerged up to 1 to 2 m and 28 were located in the area submerged by more than 2 m.	Based on a survey of 50 hospitals[1].
43% of households were affected in the past 5 years, with 15.6% impacted last year. Water logging averaged 0.3–0.5 m for 1–2 days. 10.2% reported housing damage, incurring an average cost of INR 1,857. Two work and school days were lost on average, with 2.3% of both factory workers and labourers impacted.	From a sample of 208 households, 61.5% were from public housing (mainly BSUP) and 38.5% from slum settlements [2].
85% of households were affected over 5 years, with 75% impacted last year. Water logging averaged 0.4–0.7 m for 1–2 days, affecting 5% of factory workers and 7.5% of labourers.	
During the 2006 floods, 5.56% of respondents faced very high business impacts, 77.78% high impact, 13.89% moderate, and 2.77% low impact. Labour shortages affected 82.64%, transportation 1.39%, energy 5.56%, machinery repair 1.39%, and raw material access 0.69%.	Based on surveys and shared learning with 145 textile businesses and 19 weaving unit owners[3].

1 *Vulnerability of Surat, Gujarat to Flooding from Tapi River: A Climate Change Impact Assessment (IRADe).*

2 *Mahadevia et al. (2018). Affordable Housing as Flood Resilient for Low-Income Households: Case of Ahmedabad and Surat.*

3 *Bahinipati et al. (2017). Flood-Induced Loss in Surat's Textile Industry. Env. Urban. Asia, 8(2), 170–187.*

Power Loom Workers in Surat

Migrants from Odisha, displaced by climate stress and declining agricultural income, now work in Surat's power loom industry. They endure long hours for minimal wages and live in substandard housing, leaving them highly vulnerable to contagious diseases and vector-borne illnesses, especially during floods and heat waves.

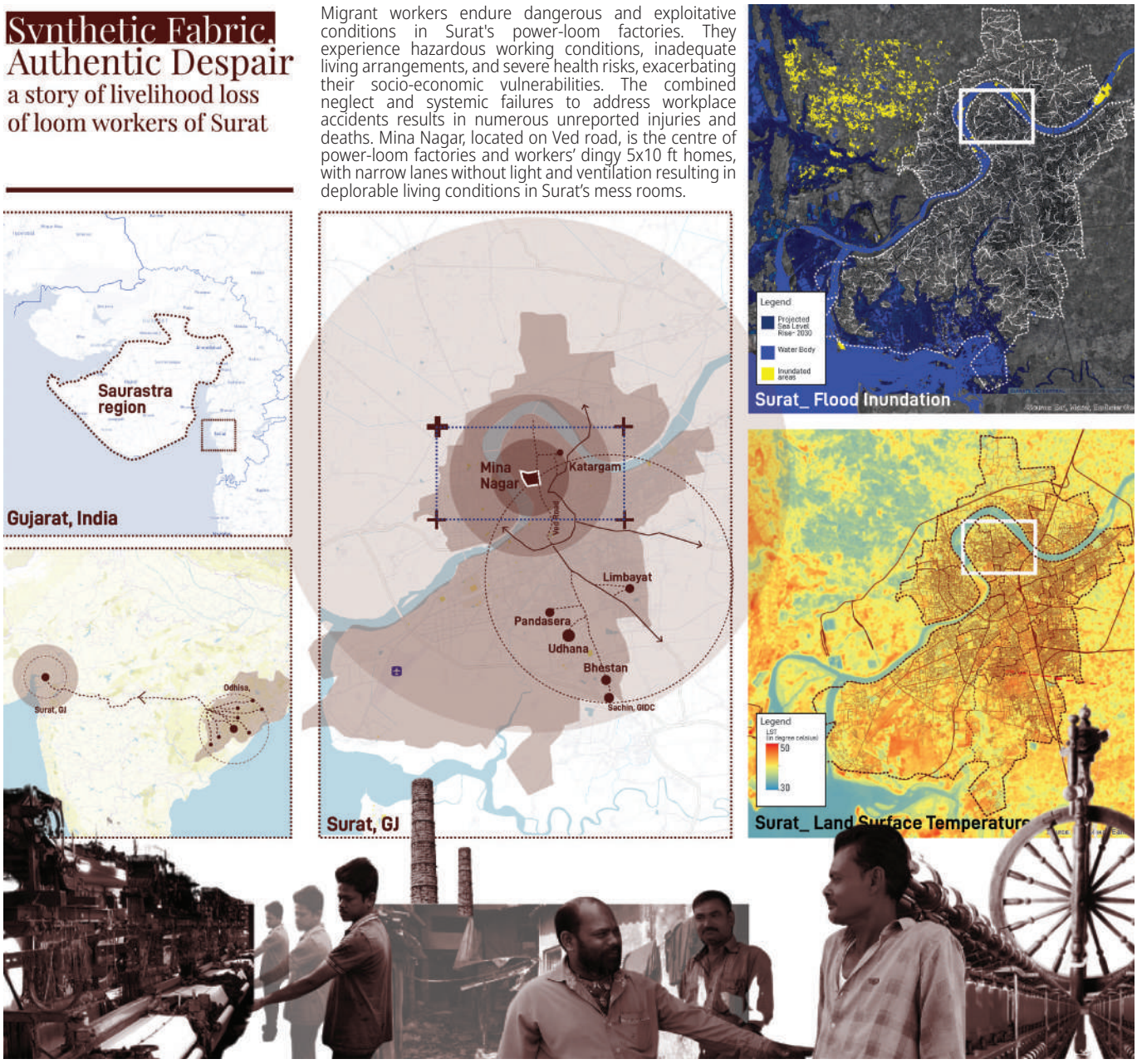


Fig 11. Community stories and their livelihood linkages to loss and damage in Surat.

Climate change exacerbates the vulnerabilities of these already struggling communities. Unpredictable and extreme weather patterns, including severe rainfall, urban flooding, and rising temperatures (up to 42 degrees), have led to significant disruptions to their work and living conditions. Flooding, high temperatures and erratic rainfall are the climatic factors that not only reduce productivity but also increase financial instability, pushing many of these people further into poverty.

The impact of climate change, coupled with economic pressures from industrial competitors, threatens the lives and livelihoods of the people and communities who depend on them.



Data Sources:Flood inundation- Copernicus Global Land Cover Digital Surface Model Collection 3 on Google Earth Engine
Land Surface Temperature- Landsat 8 on USGS explorer
Mapping and spatial climate assessment: ICLEI South Asia
Story and images: PARI (People's Archive of Rural India) Network

Cyclones

Cyclones are not known to be common in Surat, with two events reported from the Gulf of Khambhat in the last 140 years, most recently in 1976 (ACCCRN, 2010). A cyclone in 1782 had damaged many old and new buildings at Burhanpuri gate, causing at least 2000 deaths, and cyclones in 1800 & 1872 had relatively less impact on Surat.

Flooding

In the past century, Surat has witnessed 23 floods, including highly destructive ones in 1968, 2006 and 2013 (Gujarat SAPCC 2021). Since 1869 to 1884, the city flooded every 2.5 years on average (SCRS, 2011), while its occurrence was noted to be once in every 4 years on average during 1949 - 1979. Due to its physical proximity to the Arabian sea and estuary of Tapi river, the coastal city of Surat is prone to risk of flooding from heavy precipitation in the river catchment area, as well as from high tides downstream (Bhat et al., 2013). River Tapi passes through Surat via Ukai dam constructed in 1972, and anthropogenic changes in river hydrology (such as loss of floodplains) have increased silt deposition or reduced water percolation, further increasing flood risk (SCRS, 2011). The city's gross daily water supply depends majorly (90%) on Tapi River, which also provides water for drinking and industrial purposes to Hazira industrial area. Conflicting objectives of Ukai dam in terms of irrigation, power generation and partial flood control cause dam managers to prioritise water storage for forthcoming seasons due to unpredictability of monsoon (SCRS, 2011). In unexpected cases of heavy rainfall towards the end of monsoon, high tides may prevent outflow of flood discharge, resulting in higher flood levels and increasing damages (SCRS, 2011).

Past impacts

In the past century, Surat has witnessed 23 floods, including highly destructive ones in 1968, 2006 and 2013 (Gujarat SAPCC 2021). From 1869 to 1884, the city flooded every 2.5 years on average (SCRS, 2011), while its occurrence was noted to be once in every 4 years on average during 1949 - 1979. In 1968, a total area of 1360 sq. km was flooded resulting in major loss and damage to life and property. In the 1998 flood, areas of Rander, Katargam and Umra in the city were worst affected.

Ukai floods: Flood events caused due to water discharge from the Ukai dam (SCRS 2011). The floods of 1998, 2004 and 2006 may be attributed to emergency discharges from Ukai dam (SCRS 2011). In 2006, nearly 75% of the city was inundated due to floods, with at least 43% of people not having received any warning (Patel & Bhagat, 2019).

Khadi floods: Flood events caused by the overflowing of streams/tidal creeks passing through the city. Usually more frequent but less damaging in nature, although with rising sea levels and increased population growth, 'khadi floods' pose a significant risk to sections of the population living on stream banks. In 2020, heavy precipitation in catchment areas of Mithi Khadi led to flooding of sewage-filled creeks, causing inundation of approx. 6000 households, evacuation of 750 people and rescue of 190 people, severely affecting areas of Limbayat and Parvat Patiya.

Current status and projected risk

A recent study identified 8 wards under high to very high socio-economic vulnerability (Jibhakate et al., 2023). Socio-economic vulnerability maps were used to identify susceptibility to flood hazard and inform planning of flood mitigation strategies. Another study noted higher resilience in formal settlements associated with a higher

level of education, with >70% informal settlers lacking awareness of flooding impacts and coping / precautionary measures (Jamshed et al., 2023). Floods, water logging and inundation are known to be recurrent in the rainy season in a few low-lying areas such as Navasari Bazar, Khapatia Chakla, Panini Bhit, Vada Chauhta areas, southern side of Kamrej (SUDA 2017). Post 2006 floods, areas of Rander, Jahangirpura, Mora Bhagal, Adajan and Palanpur Patia in the West Zone and slum areas in the South-East zone faced major losses (Acharya et al., 2006).

As part of the ACCCRN Phase-II study, a vulnerability assessment was carried out across 929 households in 110 informal settlements along tidal creeks. The indicators included education level, social networks, income stability, physical infrastructure, water scarcity, and access to lifeline services (ACCCRN, 2010). The study classified households according to an index based on flood-related damage, inundation depth and flood duration, and a total of 71,000 households were found to be vulnerable to 'Khadi flooding' along with 450,000 households vulnerable to 'Ukai flooding'. Most slums and low-income settlements were found to be in proximity to flood risk zones, along with many higher-income households (ACCCRN, 2010).

Climate modelling under IPCC A2 and B2 scenarios predicted an increase in total annual precipitation by 250-500 mm in Gujarat, with monsoons in Surat dominated by heavy spells of rain interspersed with longer dry spells (Bhat et al., 2013). Due to changing climatic trends, water yield of Tapi river basin is predicted to increase, in turn increasing flooding risk (SRCS, 2011). According to a flood risk assessment conducted by integrating flood hazard and socioeconomic vulnerability, 8 wards were found to be highly vulnerable to flooding with wards adjoining river and creek at highest flood risk (Jibhakate et al., 2023). Flood risk maps were developed, highlighting north and west zones as the worst affected by floods (Jibhakate et al., 2023; Parikh et al., 2017).

As per a survey conducted in 2013-14 under Rajiv Awas Yojana (RAY), 36% of slums i.e. 144 slums were found to be located along the major roads or the Tapi river, and 19% i.e. 75 slums were found to be located in the Khadi region or along the railway (SUDA 2017).

To combat flooding risk, Waghwala & Agnihotri (2019) suggested the provision of detention ponds for storage of diverted flood water at either sides of river Tapi, estimating the decrease of flood depth by 50%.

Impact on transport and mobility

Despite the major street network of Surat with some extent of tree cover, the city lacks a robust network of permeable pavements, vegetated swales and softscapes that promote natural drainage, thereby leading to disturbances in access to transport during floods (Mahadevia et al., 2022). According to a survey on impact of extreme weather events on livelihood, access to modes of transport and its affordability, 54% respondents reported complete loss of mobility (Mahadevia et al., 2022). The introduction of a reliable feeder service and convenient last-mile options, along with green streets, bioswales and permeable pavements were suggested as measures in retaining transit ridership during extreme weather events (Mahadevia et al., 2022).

Sea level rise

During the last century, an increase in sea level by ~0.67 m has been noted along the Gulf of Cambay (Unnikrishnan, 2007). Surat city is among regions vulnerable to submergence

due to sea level rise and flooding by 2050 (Kulp & Strauss, 2019). More than 49% of the city is below 9-m contour and faces high exposure to rising sea levels (Sahu & Mehta, 2024).

In Surat, more than 5,000 households located along tidal creeks are known to be directly at risk from sea level rise, with the relatively less populated Dumas beach zone identified as most vulnerable (ACCCRN, 2010). Many informal settlements & slums are located along the tidal creeks, along the river, between the embankments and other drainage lines. These areas face higher risk of flooding (pluvial, fluvial and tidal). Rising sea levels are likely to impact coastal aquifers and erode parts of Dumas beach (Bhat et al., 2013). During monsoon, high tides cause tidal inundation in slums located along tidal creeks (SCRS, 2011). The highest tide was recorded in 2007, which inundated some coastal areas never having previously been submerged by tides (Bhat et al., 2013). By 2050, approximately 3,677,859 people and infrastructure accounting to approximately $627.112 billion USD may be flooded in Surat due to extreme water levels in a 1 in 100-year return period (Sahu & Mehta, 2024). Moreover, a current lack of precise and long-term sea-level data may lead to underestimated future impacts of sea level rise (Sahu & Mehta, 2024).

Urban expansion has also occurred in the coastal zone and there are currently no land use rules in place to prevent urban growth, especially in terms of real estate, in current and future high-risk zones.

Extreme heat

Since 1990, Surat has witnessed a rise in temperature, humidity and summer heat index, more frequently in the past decade (Desai et al., 2015).

The first study of heat-related mortality on the urban population of Surat city was conducted in 2015, revealing an increase of 11% mortality at temperatures exceeding 40°C, with an 18% increase during extreme danger days of high heat index i.e. high temperature and humidity (Desai et al., 2015). Apart from mortality, extreme heat may impact work performance of the population, industrial economy, cause heat disorders such as muscle cramps and trigger the severity of other illnesses. Such impacts have been found to remain largely unaccounted for.

According to a survey, in the informal settlements of Morarji Vasahat, the Ugat Site & Services Scheme, Kosad Awas, 60% of respondents reported increasing ambient temperature and reported higher temperatures indoors than outdoors (Rangwala et al., 2018). A project by World Resources Institute in partnership with Urban Health and Climate Resilience Centre for Excellence (UHCRCE) and 100 Resilient Cities Network implemented the Urban Community Resilience Assessment (UCRA) tool in 3 communities – Morarji Vasahat, Ugat Site & Services Scheme, Kosad Awas via household surveys and focus group discussions for a total of 513 households. Key findings are -

- Significant gaps in community-level infrastructure (blocked drainage, lacking garbage collection & segregation, crowded and poorly ventilated housing increasing vulnerability to heat, lacking accessibility to shade/green spaces)
- High risk perception – 75% reported severe or recurrent health impacts related to extreme heat and water logging, 63% reported losses in income or livelihoods
- Poor preparedness and emergency response among communities

A Heat Action Plan was prepared in 2023 by the Integrated Research and Action for Development (IRADe) and the Urban Health & Climate Resilience Centre of Excellence (UHCRCE), supported by the Asia-Pacific Network for Global Change Research. The plan identified hotspot zones, including South Zones A & B, East Zone B, North Zone, and South West Zone (Desai et al., 2023).

The satellite imagery used for this analysis was sourced from LANDSAT dataset at 10 AM and so, temperatures could be even higher during peak summer hours and night time (Desai et al., 2023).

A few key findings from vulnerability assessment in 6 informal settlements (Desai et al., 2023):

- Overcrowded housing with poor ventilation, use of heat-trapping housing materials
- 48% respondents use public transport or non-motorized transport, increasing duration of exposure to heat
- 43 % respondents reported heat stroke, 28 % reported heat exhaustion symptoms
- Rise in associated medical expenditure – more than 22% hospitalised

The report highlighted the heightened vulnerability of women, children, and the elderly, especially older women, to extreme heat and emphasized the need for gender-specific adaptations (Desai et al., 2023). Factors like nutrition challenges, dehydration, inadequate water and sanitation, lack of awareness, limited health insurance, and access to medical care further exacerbate risks, particularly in informal settlements. (Desai et al., 2023).

Disease risk

Moderate La Nina has been associated with 21% increased risk of water-borne diseases such as enteric fever in Surat, and the seasonal improvements in water supply and sewage systems, preventive public health measures. The city has an approximately 90 km irrigation canal, adding to the risk of mosquito breeding which is consistently noted to reach peak densities during flood events (SCRS, 2011). Floods and water logging are known to increase the risk of vector-borne diseases. Rising winter temperatures and high humidity may create favourable conditions for breeding and increase risks of malaria, dengue and other vector-borne diseases (Yagnik & Ahluwalia, 2015). Changes in frequency and intensity of extreme heat, floods and droughts are expected to directly affect population health, while indirect impacts would be through changes in the range and intensity of infectious diseases, food and water-borne diseases, respiratory disorders associated with air pollutants and aero-allergens (Ghanekar & Desai, 2019). Health risks identified during and post floods include plague, leptospirosis, malaria, gastrointestinal disorders, etc. The effect of heat stress on morbidity and overall mortality has also been recognized as a public health challenge (Ghanekar & Desai, 2019).

The linkage between climate change, further deterioration in air quality and increasing risk of respiratory diseases due to the presence of high suspended particulate matter was recognized by the Surat government (Surat Resilience Strategy 2011).

Erosion of social cohesion may increase vulnerability

High population growth and immigration of people from different cultures seem to be increasing social and cultural differences and changing the social fabric (Taru Leading Edge-ACCCRN 2011). A need for strengthening of informal social networks is recognized to build resilience among the migrant population, as well as formal housing.

4.2 Economic loss and damage estimate

4.2.1 Risk Assessment

Based on climate trends and projections for Ahmedabad, climate risks were identified and analysed according to the likelihood of occurrence and consequence. Inferences drawn from GIS based spatial analysis and analysis of relevant climate and qualitative information informed the climate risk assessment. Information from the State Disaster Management Plan (Gujarat 2016-17) and District Disaster Management Plan (Ahmedabad 2021) corroborated the results. It was observed that the city of Ahmedabad is vulnerable to extreme heat, urban floods, and air pollution. Indicators used to analyse risks due to extreme heat, urban flood and air pollution are mentioned below. Based on this analysis, the climate fragility of various urban systems was assessed.

For Surat, the collection of data on sea level rise, vulnerable populations, and flood risk zones is necessary, with the municipal corporation expected to play a significant role in providing this data. However, historical evidence accounts that in 2006, Surat faced the most devastating flood since the construction of the Ukai Dam, caused by heavy rainfall over three days. Water began entering low-lying areas of the city around 3 PM on August 7, 2006, and by midnight, the flood had killed 150 people, according to official estimates. Unofficial counts put the death toll at over 500. Apart from that, data on air pollution sources such as road dust, industrial emissions, waste burning, and transportation in Surat has been documented in the "Hot Spots Identification and Micro Action Plan for Surat City." However, further analysis is needed to assess the risks to critical infrastructure, such as businesses, schools, and hospitals, for which Ahmedabad has more complete data through CRCAP, but Surat requires further assistance from its municipal corporation.

4.2.2 Impact Assessment

This segment of the report is set to be thoroughly developed in the upcoming month. At present, the collection of data regarding historical economic losses and damages for Surat and Ahmedabad is still in progress, with public-source data collected, but pending data collection from city partners. Notwithstanding these challenges with tie as we work with city officials, we have made significant strides in establishing a solid foundation for a detailed analysis.

Our team has been diligently working on formulating methodologies for the fair valuation of non-economic loss and damage (NELD), acknowledging the necessity of encompassing the full range of impacts that extend beyond direct economic losses, and are contextual to the cities. Thus far, we have conducted a comprehensive desk review of existing methodologies for NELD assessment, which has yielded valuable insights into the various strategies and challenges inherent in this intricate field.

Moreover, we have devised a comprehensive plan for stakeholder engagement, which will be instrumental in customising our approach to the unique contexts of Surat and Ahmedabad. These engagements aim to assist us in identifying and categorising the diverse types of loss and damage that are particularly pertinent to these cities, including those often neglected in traditional assessments.

After the stakeholder consultations, our attention will turn to the identification and implementation of suitable valuation methods for these non-economic dimensions of loss and damage. This phase is crucial, as it will allow us to incorporate these broader impacts into our overall assessment of economic loss and damage. The insights derived from this process will be essential in ensuring that our final analysis is both thorough and contextually appropriate, ultimately aiding in the development of more effective and equitable disaster risk management strategies for Surat and Ahmedabad.

5 Annexes

Table 15. Data and Source matrix for Surat

Category of Data	Data Metric	Scale of Data	Source of data
Demographic Data	Population	City	"Primary Census Abstract, 2011"
		City	UN - Department of Economic and Social Affairs
Demographic Data	Median Household Income	City	Japan International Cooperation Agency (JICA), & Ministry of Railways, Republic of India. (2015, July). Joint feasibility study for Mumbai-Ahmedabad high speed railway corridor. (Volume 1).
Demographic Data	#Women	City	"Primary Census Abstract, 2011"
Demographic Data	#Children	District	"Primary Census Abstract, 2011"
Demographic Data	#Elderly	Surat Urban area (District level)	"Primary Census Abstract, 2011"
Demographic Data	Population distribution by age	Surat Urban area (District level)	Primary Census Abstract, 2011 (D-1 APPENDIX - 2011 POPULATION CLASSIFIED BY PLACE OF BIRTH, AGE AND SEX)
Demographic Data	Population distribution by income level	City	Surat Municipal Corporation, & Surat Urban Development Authority. (2006). Surat City Development Plan (2006–2012). TARU Leading Edge. (2011). Surat City Resilience Strategy. Surat Municipal Corporation.
Demographic Data	Literacy rate (with age group bifurcation) over the years	City	Surat District Handbook
Demographic Data	Daily wage workers (trend over the years + gender bifurcation)		
Demographic Data	Displacement rates / trends		
Climate Data	Estimated Economic Loss		

Details of Data	Date of last update	Data Aggregation (Total/Average/Median)
"46,45,384"	2011	Total
83,30,528	2024 Projected	Total
Rs 57,000 (Per capita income)	2006	Average
"19,97,863"	2011	Total
736,286	2011	Total
"25-34 years: 1028171 35-59 years: 1217088 60+ years: 229878"	2011	Total
"0-4 years: 420290; 5-9 years: 428972 10-14 years: 415580; 15-24 years: 1066585 25-34 years: 1028171; 35-59 years: 1217088 60+ years: 229878"	2011	Total
"Distribution of Slum HH by income; Income range %Slum HH (2001) <700 6 701-1000 12 1001-2000 36 2001-3000 12 >3000 15"	2012	Total
87.89%	2011	Total

Data and Source matrix for Surat

Category of Data	Data Metric	Scale of Data	Source of data
Climate Data	Estimated Damage by sector (housing, transport, health, water & sanitation, other sectors)		
Climate Data	Projected Climate Data	city	Gujarat State Action Plan on Climate Change 2021
Institutional (State)	State hunger index: pre and post high-impact disasters		
Institutional (State)	Poverty levels:pre and post high-impact disasters		
Institutional (State)	Multi-dimensional poverty index		
Institutional (State)	Population affected by floods		
Health	Child mortality rate (over the years)	City	Surat Municipal Corporation
Health	% of children in the workforce (pre and post high-impact disasters)		
Health	% of population with Access to health services (trend ove the years)		
Health	Heat-related illnesses, number of cases prior to/during/post heatwave, health expenditure during heatwaves		
Health	Population affected by vector-borne diseases (summer, monsoon, winter)	city	Surat Municipal Corporation. (n.d.). Health Department Disease Reports. https://www.suratmunicipal.gov.in/Departments/HealthDepartmentDiseaseReports Surat Municipal Corporation. (n.d.). Vector Borne Diseases Control Annual Report. https://www.suratmunicipal.gov.in/Content/Documents/Departments/VectorBorneDiseasesControl/VBDC_Annual_Report.pdf
Environment	Biodiversity and/or habitat lost post high-impact disasters		
Environment	Loss or shrinkage of water bodies		
Economic	Estimated loss of work hours during floods, heatwaves		

Details of Data	Date of last update	Data Aggregation (Total/Average/Median)
	2021	
17.98%	2011	Total
"For 2018, total no. of > Malaria cases - 4582. > Dengue - 248 > Chikungunya - 43 > Filaria - 29 Monthly data is provided in the report"	"2023 for Malaria related; other vector borne diseases the report data till 2018."	Total

Data and Source matrix for Surat

Category of Data	Data Metric	Scale of Data	Source of data
	Estimated damage to businesses during floods, heatwaves	City	Waghwala, R. K., & Agnihotri, P. G. (2019). Flood risk assessment and resilience strategies for flood risk management: A case study of Surat City. Internationa Journal of Disaster Risk Reduction, 40, 101155. https:/ doi.org/10.1016/j.ijdrr.2019.101155
Economic			Parikh, K., Parikh, J., & Kumar, M. (2017). Vulnerability of Surat, Gujarat to flooding from Tapi River: A climate change impact assessment. Vayu Mandal, 43(2), 123–132. https://imetsociety.org/wp-content/pdf/vayumandal/2017432/2017432_11.pdf
Economic	Loss of livelihoods among displaced population		
Economic	GDP rate	City	Resilient Cities Network. (2017). Surat Resilience Strategy. Retrieved from https://resilientcitiesnetwork org/downloadable_resources/Network/Surat-Resilience-Strategy-English.pdf
Community	Perceptions of tradeoffs among displaced population		
Community	vulnerable groups	City	Surat Municipal Corporation
Community	Risk-prone zones to flood (in case of Ahmedabad and Surat) and sea level rise (only in case of Surat)	City	Surat Urban Development Authority. (2020). Development Plan 2035. Retrieved from https://www. sudaonline.org/development-plans/development-plan-2035/
Community	Heat hotspots, flood risk zones	City	WRI India. (n.d.). Hot Spots Identification and Micro Action Plan for Surat City (Micro-Area Level Plan – Surat). Prepared as part of the SCAP Project. Retrieved from https://www.suratmunicipal.gov. in/Content/Documents/Departments/AQMCell/MicroLevelPlanforSuratCity.pdf?ver=5692
Community	Prominent locations (businesses, schools, hospitals, etc.) to determine risk		

Details of Data	Date of last update	Data Aggregation (Total/Average/Median)
Vulnerability Analysis Summary: - Schools: Among 56 surveyed schools, 68% are located in flood-prone north and west zones. Thirty percent reported total furniture damage, while 20% faced partial damage. Additional damages include unsafe drinking water, wiring issues, loss of books, and disrupted communication and transportation. - Slums: Approximately 70% of households experienced water levels above 50 cm, damaging walls, floors, and belongings. Post-flood expenses included house repairs and increased medical costs due to diseases such as fever and chikungunya. Sanitation was a major concern. - Hospitals: In a sample of 50 hospitals, 11 were submerged up to 1 meter, 11 up to 1-2 meters, and 28 over 2 meters. - Industries: Seventy percent of small-scale industries in East, North, South-East, and South zones were affected. The 2006 flood disrupted production and caused an epidemic, with 17% reporting illness outbreaks. Transportation and communication disruptions affected 53% of surveyed enterprises, leading to losses.	2019	Total
11.50%	2017	NA
Number of slum pockets: 334	2011	Total
Since the altitude of Surat is less than 13 m above mean sea level, even with a sea level rise of one meter, the area under high tide zone particularly western parts of the city which are less than 10 m above mean sea level may be highly impacted.	2017	NA
Road Dust: Core areas with dense populations include Chowk, Muglisara, Rander, Udhana, Katargam, Adajan, Athwa Gate, Piplod, Varachha, and Limbayat. Industries Sector: Udhana, Pandesara, Ved Road, Bhestan, Sachin and Katargaam, Unn, Adajan, Bhimrad and Sarsana along with Amroli-Utran. Waste Burning: Notable hotspots include TPS-4, Ashvanikumar Navagam, TPS-8 Umarwada, Fulpada, Kapadra, and industrial areas like Bhestan, Pandesara, and Udhana. Construction Sector: Pal, Adajan, Kataargam, Piplod and Vesu (area), Rander and Tunki along with Palsana and Pandesara. Transportation Sector: Priority concern areas are wards in the south and southwest zones.	2019	NA

Table 17. Data and Source matrix for Ahmedabad

Category of Data	Data Metric	Scale of Data	Source of datav
Demographic Data	Population	Ward	Planning Department, AMC
Demographic Data	Median Household Income	City	Based on a random sample survey of 300 HHs https://www.mdpi.com/1660-4601/10/6/2515
		City	Japan International Cooperation Agency (JICA). (n.d.). Joint feasibility study for Mumbai-Ahmedabad high-speed railway corridor (Final report, Volume 1). Retrieved from https://www.jica.go.jp/english/our_work/social_environmental/id/asia/south/india/c8h0vm00009v1ylc-att/c8h0vm0000bzv4e5.pdf
Demographic Data	#Women	City	Ahmedabad CRCAP analysis using Ahmedabad Municipal Corporation data
Demographic Data	#Children	City	Ahmedabad Municipal Corporation
Demographic Data	#Elderly	Ahmedabad Urban area (District level)	Primary Census Abstract, 2011 (D-1 APPENDIX - 2011: POPULATION CLASSIFIED BY PLACE OF BIRTH, AGE AND SEX)
Demographic Data	Population distribution by age	Ahmedabad Urban area (District level)	Primary Census Abstract, 2011 (D-1 APPENDIX - 2011: POPULATION CLASSIFIED BY PLACE OF BIRTH, AGE AND SEX)
Demographic Data	Population distribution by income level		
Demographic Data	Literacy rate (with age group bifurcation) over the years	City	Ahmedabad District Handbook
Demographic Data	Daily wage workers (trend over the years + gender bifurcation)		
Demographic Data	Displacement rates / trends		
Climate Data	Estimated Damage by sector (housing, transport, health, water & sanitation, other sectors)		

Details of Data	Date of last update	Data Aggregation (Total/Average/Median)
7,18,17,731	2021	Total
6389 INR per month	2013	Median
Rs 63,000 (Per capita income)	2006	Average
48% of total population	2022	Total
6,21,034	2011	Total
"25-35 years = 1104922 35-59 years= 1765140 60+ years= 480980"	2011	Total
"0-4 years = 476696 5-9 years = 506559 10-14 years = 542816 15-24 years= 1169119 25-35 years = 1104922 35-59 years= 1765140 60+ years= 480980"	2011	Total
88.29%	2011	Total

Data and Source matrix for Ahmedabad

Category of Data	Data Metric	Scale of Data	Source of data
Climate Data	Projected Climate Data	city	Gujarat State Action Plan on Climate Change 2021
Institutional (State)	State hunger index: pre and post high-impact disasters		
Institutional (State)	Poverty levels:pre and post high-impact disasters		
Institutional (State)	Multi-dimensional poverty index		
Institutional (State)	Population affected by floods	City	Ahmedabad CRCAP analysis using Ahmedabad Municipal Corporation data
Health	Child mortality rate (over the years)		*Requested Health Department, AMC to share the data
Health	% of children in the workforce (pre and post high-impact disasters)		
Health	% of population with Access to health services (trend ove the years)	City	"Ahmedabad CRCAP analysis using Ahmedabad Municipal Corporation data *Requested Health Department, AMC to share the updated data"
Health	Heat-related illnesses, number of cases prior to/during/post heatwave, health expenditure during heatwaves	City	"Ahmedabad CRCAP analysis using Ahmedabad Municipal Corporation data; *Requested Health Department, AMC to share the updated data"

Details of Data	Date of last update	Data Aggregation (Total/Average/Median)
"RCP Scenario Projections for Ahmedabad • Ambient temperature is expected to rise from 0.5°C to 3°C in all scenarios (RCP 2.6, RCP 4.5, RCP 8.5) in the near and midterm. • Frequencies of hot days and nights and number of heatwave days are expected to increase in all scenarios. • Average rainfall is expected to increase from 20 mm to 60 mm (RCP 4.5 and RCP 8.5). • Extreme precipitation events are expected to increase by 0 to 0.25 events for RCP 4.5 and RCP 8.5."	2021	
9.5% (Total: 0.7 Million) 55,000 Children, 34,000 Elders, 88,000 Slum dwellers, 5000 Street-side vendors	2021	Total
"Ahmedabad has 2,080 hospitals with a capacity of 34,432 beds (5 beds per 1000 persons). 94.1% of the total population (6.7 million people) can access health care facilities within 1 km, 4.7% (0.3 million people) within 2 km, 1% (75,000 people) within 3 km. 25% of all slum dwellers (0.2 million people) can access government health care facilities within 1 km, 27% within 2 km, and 27% within 3 km"	2022	Total
72.1% of the total population in the city (5.1 million people - 2.4 million females and 2.7 million males)	2021	Total

Data and Source matrix for Ahmedabad

Category of Data	Data Metric	Scale of Data	Source of data
Health	Population affected by vector-borne diseases (summer, monsoon, winter)	Ward	"Health Department, Ahmedabad Municiapal Corporation *Requested Health Department, AMC to share the updated data"
Environment	Biodiversity and/or habitat lost post high-impact disasters		
Environment	Loss or shrinkage of water bodies	City	Citizen Matters. (n.d.). Ahmedabad's vanishing water bodies.
Economic	Estimated loss of work hours during floods, heatwaves		
Economic	Estimated damage to businesses during floods, heatwaves		
Economic	Loss of livelihoods among displaced population		
Economic	GDP rate	City	India Times. (2021). Top 10 richest cities in India 2021. Retrieved from https://www.indiatimes.com/trending/social-relevance/top-10-richest-cities-in-india-2021-552132.html
Community	Perceptions of tradeoffs among displaced population		
Community	vulnerable groups	City	Ahmedabad Municipal Corporation
Community	Risk-prone zones to flood (in case of Ahmedabad and Surat) and sea level rise (only in case of Surat)	Ward	Ahmedabad CRCAP analysis using Ahmedabad Municipal Corporation data
Community	Heat hotspots, flood risk zones	Ward	Ahmedabad CRCAP analysis using Ahmedabad Municipal Corporation data
Community	Prominent locations (businesses, schools, hospitals, etc.) to determine risk	Ward	Ahmedabad CRCAP analysis using Ahmedabad Municipal Corporation data

Details of Data	Date of last update	Data Aggregation (Total/Average/Median)
"Jaundice: 2407 Cholera: 34 Typhoid: 2754 Water Borne diseases: 20734 Air Borne diseases: 62 Vector Borne diseases: 5983 TB: 1185"	2021	Total
water bodies in Ahmedabad have been shrinking at a decadal rate of 1.57 square km because of increase in built-up space as well as pollution and dumping of wastes.	2020	Total
USD 68 billion	2020	
Street Vendors: 62,100, Total Slums: 840,502 (186,778 households in 690 notified slum areas)	2021	Total
Vasna, Saraspur, Jamalpur, Maninagar, Lambha and Vatva wards	2022	Total
"Heat vulnerability: 5.1 million people (2.4 million females, 2.7 million males) are vulnerable, constituting a significant 72.1% of the total population. This vulnerability is aggravated by the presence of 0.4 million children and 0.3 million elders within this group. Heat Hotspots: Wards: Amraiwadi, Bapunagar, Viratnagar, Vasna, India Colony, Chandlodiya, Ranip, Thaltej, Gota, Lambha, Ramol-Hathijan. Industrial areas or estates: Odhav GIDC, Vatva GIDC, Kathwada GIDC, Narol. Landfill site: Gyaspur and Pirana."	2022	Total
For health risk due to air pollution, approximately 16.9% of slum population (0.1 million people) and 18.2% of all vendors (around 11,000 vendors) could be affected.	2022	Total

6 References

1. Ahmedabad Climate Resilient City Action Plan - Towards A Net Zero Future. (2023, July). https://southasia.iclei.org/wp-content/uploads/2024/01/AMC-CRCAP-EXEC-SUMMARY_06JULY2023_compressed.pdf
2. Ahmedabad Municipal Corporation, Natural Resources Defense Council (NRDC), Climate and Development Knowledge Network (CDKN), Indian Institute of Public Health-Gandhinagar, Mount Sinai, University of Washington. (2016, January). City resilience toolkit: Response to deadly heat waves and preparing for rising temperatures in Ahmedabad. https://www.nrdc.org/sites/default/files/ahmedabad-resilience-toolkit.pdf
3. Ahmedabad Municipal Corporation. (2023). Ahmedabad Climate Resilient City Action Plan: Towards a Net Zero Future. Retrieved from https://www.cities-and-regions.org/wp-content/uploads/2023-ahmedabad-climate-resilient-city-action-plan-compressed.pdf
4. Ahmedabad Mirror. (2023). Heat is on. Retrieved from https://www.ahmedabadmirror.com/heat-is-on--419c/81854759.html#googrewarded
5. Arif, M., Sachdeva, S., Mangla, S., & Sahoo, P. K. (2024). India's cultural heritage: Air quality effects amidst COVID-19 lockdown and seasonal variability. Journal of Atmospheric Chemistry, 81(5). https://doi.org/10.1007/s10874-024-09458-x
6. Bahinipati, C. S., Rajasekar, U., Acharya, A., & Patel, M. (2015). Flood-induced economic loss and damage to the textile industry in Surat City, India. International Institute for Environment and Development. https://www.iied.org/sites/default/files/pdfs/migrate/10749IIED.pdf
7. Bharadwaj, R., Chaliha, S., Chinnaswamy, K., Karthikeyan, N., Mitchell, T., & Chakravarti, D. (2024, March). Report: Taxonomy of climate-attributable loss and damage and scalable responses related to DRR, health, and human mobility. IIED. https://www.undp.org/sites/g/files/zskgke326/files/2024-04/Taxonomy%20of%20climate-attributable%20loss%20%26%20damage.pdf
8. Bose, T., Bandyopadhyay, S., & Rawal, D. (2016, October). Impacts of climate variability on urban floods--A case of Ahmedabad. Environment and Urbanization ASIA, 7(2). https://doi.org/10.1177/0975425316655649
9. Centre for Research on the Epidemiology of Disasters (CRED). (n.d.). Economic Impact Variables. EM-DAT Documentation. Retrieved November 5, 2024, from https://doc.emdat.be/docs/data-structure-and-content/impact-variables/economic/
10. Citizen Matters. (n.d.). Ahmedabad's vanishing water bodies. Retrieved from https://citizenmatters.in/ahmedabad-vanishing-water-bodies/#:~:text=The%20study%20has%20pointed%20out,pollution%20and%20dumping%20of%20wastes
11. Desai, V. K., Patel, U., Rathi, S. K., Wagle, S., & Desai, H. S. (2015). International Journal of Environmental Sciences, 5(5), 935-946. Retrieved from https://smartnet.niua.org/sites/default/files/resources/temp_and_humidity.pdf

12. Desai, V., Magotra, R., & Jha, N. (2023). Climate adaptive and gender integrated heat wave action plan of Surat City, India. Integrated Research and Action for Development (IRADe).

13. Down to Earth. (2023, September 1). Number of daily wage workers dying by suicide increased in 2022: NCRB data. Retrieved from https://www.downtoearth.org.in/governance/number-of-daily-wage-workers-dying-by-suicide-increased-in-2022-ncrb-data-93185

14. Down to Earth. (2023, October 10). Karnataka has highest suicide-related economic burden in country: Report. Retrieved from https://www.downtoearth.org.in/health/karnataka-has-highest-suicide-related-economic-burden-in-country-report

15. Doherty, F., & Rao, S. (2023, August 29). Extreme weather events linked to increased child marriage. PreventionWeb. https://www.preventionweb.net/news/extreme-weather-events-linked-increased-child-marriage

16. Dorkenoo, K., Scown, M., & Boyd, E. (2022). A critical review of disproportionality in loss and damage from climate change. Wiley Interdisciplinary Reviews: Climate Change, 13(4), e770. https://doi.org/10.1002/wcc.770

17. Dumka, R., Rakesh, & Donupudi, S. (2021). Bopal, Vatva sinking along with groundwater levels in Ahmedabad. https://www.researchgate.net/publication/356833741_Bopal_Vatva_sinking_along_with_groundwater_levels_in_Ahmedabad

18. Economic Commission for Latin America and the Caribbean (ECLAC). (1972). Damage and Loss Assessment (DaLA). Retrieved from https://www.openknowledge.worldbank.org/entities/publication

19. Government of Gujarat. (2014). Narmada Master Plan. Update Report. https://gwilws.gujarat.gov.in/web/public/content/cms.portal.document/2276/document/Narmada%20Master%20Plan%20Aug%202014.pdf

20. Government of Gujarat. (2014). Gujarat State Action Plan on Climate Change. Climate Change Department. Retrieved from https://ccd.gujarat.gov.in/Images/Gujarat-State-Action-Plan-on-Climate-Change.pdf

21. Gujarat Institute of Disaster Management. (2023). Report on Extreme Heat Exposure and Actions for Gujarat. Retrieved from https://gidm.gujarat.gov.in/sites/default/files/Report-on-Extreme-Heat-Exposure-and-Actions-for-Gujarat-jun-2023.pdf

22. Government of Kerala. (2018). Post Disaster Needs Assessment: Floods and Landslides – August 2018. Kerala State Disaster Management Authority. Retrieved from https://sdma.kerala.gov.in/wp-content/uploads/2019/03/PDNA-report-FINAL-FEB-2019_compressed.pdf

23. Global Facility for Disaster Reduction and Recovery (GFDRR). (2018). Post-Disaster Needs Assessments: Guidelines Volume (2013) & Disaster Recovery Framework Guide (2018). World Bank. Retrieved from https://www.gfdrr.org/en/publication/post-disaster-needs-assessments-guidelines-volume-2013

24. Government of Odisha. (2019). Cyclone Fani 2019 DLNA Report. Odisha State Disaster Management Authority. Retrieved from https://www.osdma.org/publication/cyclone-fani-2019-dlna-report/

25. Gujarat State Disaster Management Authority. (2021). District Disaster Management Plan Year-2024-25. http://www.gsdma.org/uploads/Assets/ddmp2024/ahmedabad-ddmp-20240620202403533029O.pdf

26. Gujarat Labour Commissionerate. (2023, March 27). Minimum wage rates for 46 scheduled employments. Government of Gujarat. Retrieved from https://col.gujarat.gov.in/Portal/Document/3_1405_1_998_3_minimum_wages_46_Schedule_Employment_27.03.2023__1_.pdf

27. Gujarat Institute of Disaster Management. (2020). Frequency of cyclones affecting Gujarat state; Role of mangroves and shelterbelt in cyclone risk mitigation. Gujarat Institute of Disaster Management. https://gidm.gujarat.gov.in/sites/default/files/educate_your_self_document/Report%20on%20Frequency%20of%20Cyclones%20Affecting%20Gujarat%20State%20%26%20Role%20of%20Mangroves%20%26%20Shelterbelt.pdf

28. Government of Tamil Nadu. (2021). Gist of Fifteenth Finance Commission Main Report Along with Action Taken Report. Finance Department, Government of Tamil Nadu. Retrieved from https://tnbudget.tn.gov.in/tnweb_files/CFC/15th_FinanceCom_ENG_2021.pdf

29. Ghanekar, A., Jariwala, P., Selvakumar, S., & Desai, V. (2015). Proceedings of the Tenth Annual International Conference on Public Policy and Management, IIM Bangalore, August 3-5, 2015.

30. Hess, J. J., Saha, S., Luber, G., Conlon, K., Uejio, C., & Hayden, M. (2018). Building resilience to climate change: Pilot evaluation of the impact of India's first heat action plan on all-cause mortality. Journal of Environmental and Public Health, 2018, Article ID 7973519. https://doi.org/10.1155/2018/7973519

31. Indian Express. (2017, July 27). Gujarat floods: Submerged Sabarmati Riverfront throws up snakes and many questions. The Indian Express. https://indianexpress.com/article/india/gujarat-floods-submerged-sabarmati-riverfront-throws-up-snakes-and-many-questions-4775653/

32. Jamshed, A., Patel, C., Puriya, A., ... Saad, U. (2023). Flood resilience assessment from the perspective of urban (in)formality in Surat, India: Implications for sustainable development. Natural Hazards. Springer.

33. Jibhakate, S. M., Timbadiya, P. V., & Patel, P. L. (2023). Multiparameter flood hazard, socioeconomic vulnerability, and flood risk assessment for densely populated coastal city. Journal of Environmental Management, 344.

34. Jibhakate, S. M., Timbadiya, P. V., & Patel, P. L. (2023). Computation of socio-economic vulnerability for densely populated Surat city, India. In P.V. Timbadiya, P. L. Patel, V. P. Singh, & V. L. Manekar (Eds.), Flood forecasting and hydraulic structures (pp. 143-153). Springer. https://doi.org/10.1007/978-981-99-1890-4_11

35. Kulp, S. A., & Strauss, B. H. (2019). New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding.

36. Knowlton, K., Kulkarni, S. P., Azhar, G. S., Mavalankar, D., Jaiswal, A., Connolly, M., Nori-Sarma, A., Rajiva, A., Dutta, P., Deol, B., Sanchez, L., Khosla, R., Webster, P. J., Toma, V. E., Sheffield, P., Hess, J. J., & Group, C. S. (2014). Development and implementation of South Asia's first heat-health action plan

in Ahmedabad (Gujarat, India). International Journal of Environmental Research and Public Health, 11(4), 3473-3492. https://doi.org/10.3390/ijerph110403473

37. Mahadevia, D., Lathia, S., & Dubey, A. (2022). Public transport access during extreme weather events in urban India. Policy Brief 5, Optimism Project (India), Ahmedabad University.
38. Mahadevia et al. (2018). Affordable Housing as Flood Resilient for Low-Income Households: Case of Ahmedabad and Surat.
39. Magotra, R., Tyagi, A., & Sharma, Y. (2023). Assessment of urban vulnerability to climate hazards of selected Indian cities. Preprints, 2023051886. https://doi.org/10.20944/preprints202305.1886.v1
40. Murray, C. J. L., Aravkin, A. Y., Zheng, P., Abbafati, C., Abbas, K. M., Abbasi-Kangevari, M., ... & Lim, S. S. (2022). Global burden of 87 risk factors in 204 countries and territories, 1990–2020: a systematic analysis for the Global Burden of Disease Study 2020. The Lancet, 400(10352), 1223-1259. https://doi.org/10.1016/S0140-6736(22)01540-9
41. National Centre for Disease Control. (2023). National Programme on Climate Change and Human Health: Annual Report 2022-2023. Ministry of Health and Family Welfare, Government of India. Retrieved from https://npcchh.inroad.in/WriteReadData/RTF1984/1681445514.pdf
42. National Disaster Management Authority. (n.d.). XVth Finance Commission Recommendations for Disaster Risk Management. Retrieved from https://ndma.gov.in/sites/default/files/PDF/Reports/XV-FC-Recommendations-FA-NDMA.pdf
43. Natural Resources Defense Council. (2016). City resilience toolkit: Response to deadly heat waves and preparing for rising temperatures. https://www.nrdc.org/sites/default/files/ahmedabad-resilience-toolkit.pdf
44. National Institute of Disaster Management. (2019). Handbook: Post Disaster Needs Assessment India. Ministry of Home Affairs, Government of India. Retrieved from https://nidm.gov.in/PDF/pubs/handbook_pdna.pdf
45. National Institute of Urban Affairs. (2017). Children-focused vulnerability assessment and city resilience action strategy: Udaipur. ClimateSmart Cities. Retrieved November 5, 2024, from https://niua.in/csc/assets/pdf/urban-planning/Children-focused-vulnerability-assessment-and-city-resilience-action-strategy-Udaipur.pdf
46. NITI Aayog. (2023). National Multidimensional Poverty Index: A Progress Review 2023. Government of India. https://www.niti.gov.in/sites/default/files/2023-07/National-Multidimentional-Poverty-Index-2023.pdf
47. Patel, K., & Bose, T. (2023). Urban flood vulnerability assessment for Ahmedabad city. Paper presented at the International Land Use Symposium.
48. Patel, K. A., & Bhagat, S. S. (2019). An overview of flood resilience: A case of Surat city. The 6th Conference on Innovative Trends in Science, Engineering and Management. Institution of Engineers, Chandigarh, India. pp. 273-280. Retrieved from http://proceeding.conferenceworld.in/ICITSEM-19%20Jan/vDFfubRgC4041.pdf
49. Parikh, K., Parikh, J., & Kumar, M. (2017). Vulnerability of Surat, Gujarat to flooding from Tapi River: A climate change impact assessment. Vayu Mandal, 43(2), 123-132.

50. Sahu, R. T., & Mehta, D. J. (2024). Impact of coastal inundation due to rise in sea level: A case study of Surat City, India. Water Practice and Technology, 19(5), 1753. https://doi.org/10.2166/wpt.2024.116

51. Surat Municipal Corporation. (2021). District Disaster Management Plan: Surat Municipal Corporation. Gujarat State Disaster Management Authority. Retrieved from http://www.gsdma.org/uploads/Assets/ddmp2021/DDMP-Surat-MC.pdf

52. TARU Leading Edge. (2011). Surat City Resilience Strategy. Surat Municipal Corporation. Retrieved from https://www.acccrn.org/sites/default/files/publication/attach/surat_cityresiliencestrategy_taru-smc.compressed.pdf

53. The Indian Express. (2024, May 23). Heatwave continues; red alert in Ahmedabad, Gandhinagar. https://indianexpress.com/article/cities/ahmedabad/gujarat-heatwave-red-alert-ahmedabad-gandhinagar-9348224/

54. Times of India. (2023, June 28). Floods in Ahmedabad. https://timesofindia.indiatimes.com/calamities/floods-inahmedabad/articleshow/101329964.cms

55. Taru Leading Edge-ACCCRN. (2011). Surat City Resilience Strategy.

56. Unnikrishnan. (2007). Observed sea level rise in the North Indian Ocean coasts in the past century. Physical Science, 91-92.

57. United Nations Development Programme (UNDP). (2008). Post Disaster Needs Assessment (PDNA). Retrieved from https://www.undp.org/publications/post-disaster-needs-assessment

58. Vasudha Foundation. (2022). Climate Change and Environment Action Plan of Ahmedabad District. https://shaktifoundation.in/wp-content/uploads/2022/11/Full-Action-Plan-Ahmedabad.pdf

59. Vulnerability of Surat, Gujarat to Flooding from Tapi River: A Climate Change Impact Assessment (IRADe).

60. Watts, N., Adger, W. N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W., ... & Costello, A. (2015). Health and climate change: policy responses to protect public health. The Lancet, 386(10006), 1861-1914. https://doi.org/10.1016/S0140-6736(15)60854-6

61. World Bank. (2013). Damage, loss and needs assessment: Guidance notes. Retrieved from https://documents1.worldbank.org/curated/en/617521468335985769/pdf/880860v10WP0Bo0PUBLIC00TTL0Vol10WEB.pdf

62. WIN Foundation. (n.d.). Ahmedabad water context. Urban Waters Ahmedabad. Retrieved November 5, 2024, from https://sites.google.com/winfoundations.org/urban-waters-ahmedabad/ahmedabad-water-context

63. World Resources Institute India. (2020). Hot Spots Identification and Micro Action Plan for Surat City (Micro-Area Level Plan – Surat). Prepared as part of the Surat Clean Air Action Plan (SCAP) Project

64. Yadav, S., K, A. K., Cunningham, S. A., Bhandari, P., Mishra, U. S., Aditi, A., & Yadav, R. (2023). Changing pattern of suicide deaths in India. The Lancet Regional Health - Southeast Asia, 16. https://doi.org/10.1016/j.lansea.2023.100265

65. Yagnik, K., & Ahluwalia, I. J. (2015). Improving Surat's flood resilience. Urban Solutions, 7, 44-49.

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